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Study of Top Dying of Sundri (*Heritiera fomes*) and its Management in the Sundarbans

Volume I: Main Report

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EXECUTIVE SUMMARY

1. Introduction

Sundri (*Heritiera fomes*) has been suffering from a top dying disease syndrome in the Sundarbans. In general, top dying sundri trees have a dead and truncated top, accompanied with the death of twigs and branches to a varying degree, leaving a variable extent of healthy canopy. The disease syndrome is quite extensive in the Sundarbans and is considered to be the most serious of all diseases/ disorders of trees in Bangladesh. It is generally believed to be the result of a complex interactions of abiotic and biotic factors. A study to find out the cause(s) of top dying of sundri was undertaken with effect from July 2001 under the financial support from Global Environmental Facility fund through the Sundarban Biodiversity Conservation Project (SBCP) of the Forest Department under the Ministry of Environment and Forests.

2. Methodology

The study was mainly concentrated in 36 sample plots, each 400 sq m, laid down at 12 landings in compartment no. 2, 11, 19 (having two landings), 20, 22, 26, 33, 36 (having two landings), 37 and 40. Stratified random sampling method was used for selecting the 36 sample plots. There were nine sample plots for each of none (i.e. little or no top dying), slight, moderate and severe top dying of sundri classes. Sub-plots were established within each sample plot for study of pneumatophores, regeneration and collection of soil samples for physico-chemical analysis each of the four trips in early October 2001, late January 2002, June 2002 and January 2003. The study included ecological, pathological and edaphic aspects of top dying of sundri primarily in order to find out the cause of top dying of sundri in the Sundarbans. As a part of the study an **In depth literature study on the sundri (*Heritiera fomes*) top dying in the Sundarbans** was carried out to provide critical review of knowledge and understanding of top dying of sundri prior to the initiation of the present study. An Inception Report on the subject contained the detailed methodology followed in the study and also a full description of the project (Rahman *et al,* 2002a and 2002b).

3.0 Results

3.1: Ecological Aspects

3.1.1: Number and length of pneumatophores and top dying of sundri

The data on number of pneumatophores that were collected in October 2001, January 2002, June 2002 and January 2003 from the sample plots reveal that mean of 44.14, 43.09, 19.48 and 26.47 number of pneumatophores per sq meter of the sub-plot of none, slight, moderate and severe top dying sample plots respectively. The first two values were significantly higher (P= 0.05) than the last two values. That means the number of pneumatophores per sq meter area of no top dying and slight top dying sample plots were consistently higher than moderate and severe top dying sample plots. Besides per cent top dying of sundri trees and number of pneumatophores show a significant negative correlation (P = 0.01). Mean length of pneumatophores did not, however, show any significant difference among the four top dying severity classes. Hence the conclusion that reduction in the number of pneumatophores per unit area is directly associated with the severity of top dying of sundri is a reasonably acceptable.

3.1.2 : Number of lenticels on pneumatophores and top dying of sundri

Lenticels are small pores on the breathing roots i.e. pneumatophores through which sundri roots get required supply of air for necessary respiration in the root tissues to ensure normal growth and development of the tree species. This is also true for many other mangrove species. The lowest mean number of 2.17 and 0.67 lenticels on per sq. cm area of the collar region were found to be present in case of pneumatophores observed in severely top dying sample plots as compared to 2.42 and 1.28 number of lenticels on per sq cm at collar of pneumatophore of no top dying sample plots of sundri as observed in January 2002 and June 2002. The difference in both the cases were significant (P =0.05). Besides there occurred significant negative correlation between the number of lenticels and per cent top dying of sundri trees. Correlation analysis also revealed that the occurrence of significantly negative correlation (P = 0.01) between the number of lenticels on the pneumatophores and severity top dying of sundri trees.

3.1.3 : Sedimentation and burial of pneumatophores and top dying of sundri

The extent of sedimentation/erosion was studied by establishing sediment gauges. The data of sedimentation/subsidence of soil between January 2002 and January 2003 157 sediment gauges (36 from none, 42 from slight, 36 from moderate and 43 from severe top dying sample plots) revealed a significant (P=0.01) difference in the mean values from the four top dying severity classes of the sample plots i.e. none having –1.06 cm, slight -1.59 cm, moderate having 2.69 cm and severe 1.90 cm. The first two means did not significantly differ from each other while the last two means also did not differ significantly from each other, but the latter means were significantly higher than the first two means. Thus sedimentation in the moderate and severe top dying sample plots was found to be associated with the severity of top dying of sundri trees.

3.1.4: Geomorphological characteristics of the sample plots and top dying of sundri

Study of the geomorphological characteristics of the 36 sample plots and top dying of sundri revealed that the concentration of severely top dying sample plots occurred on the levee and backswamp and are absent on the shoulder. It may be noted that there is poor aeration on the levee because of higher sedimentation and because of water logging on the backswamp areas. For these reasons sundri experiences great stress both on levee and backswamp areas. This suggests an association between sundri top dying and the availability of oxygen at the root zone of sundri.

3.2 Edaphic factors and top dying of sundri

Soil samples were collected from 36 sample plots having four top dying severity (i.e none, slight, moderate and severe) from 12 landings in 10 compartments in the Sundarbans during October 2001, January 2002, June 2002 and January 2003. In all twelve parameters were studied from the soil samples. These included Electrical Conductivity (EC), Sodium (Na), Calcium (Ca), Magnesium (Mg), total available Nitrogen (N), Potassium (K), Phosphorus (P), Manganese (Mn), Zinc (Zn), clay, silt and sand.

Analysis of variance of each of the soil parameters obtained from sample plots falling in no top dying (i.e. none), slight, moderate and severe top dying of sundri were carried out. Significant (P=0.05) variations were found in exist in case of the mean Ca (Calcium), Mg (Magnesium), Mn (Manganese), Zn (Zinc) and sand content from the sample plots falling in four top dying severity classes. Trend analysis of the occurrence of Ca, Mg, Mn and Zn in none, slight, moderate and severe top dying sample plots reveal that:

- Calcium showed the same trend of occurrence among the soil samples from none, slight, moderate and severe top dying sample plots in soil samples collected in October 2001 and January 2002. The lowest level of Calcium (6.19 meq/100g) was found in sample plots having no top dying (i.e. none) sample plots. Increasingly higher levels of Calcium were found to occur in soils from slight top dying sample plots (7.47 meq/100g), severe top dying sample plots (10.31 meq/100g) and moderate top dying sample plots ((13.67 meq/100g) in soil samples collected in October 2001. A similar trend was found in case of Calcium level in soils collected in January 2002. So the trend of increasingly higher level of Calcium in higher severity of top dying particularly moderate top dying sample plots indicate an association of Calcium toxicity and occurrence and severity of top dying of sundri.
- A highly significant (P=0.001) negative correlation coefficient (r = -0.872, with 35 df) was found to exist between levels of manganese in soil sample collected in October 2001 from 0-30 cm soil depths and per cent top dying of sundri from 36 sample plots of four top dying severity classes. Analysis of this trend of this association by drawing a linear regression line clearly suggests that a deficiency of Manganese is associated with the development of top dying of sundri. The highest mean value of manganese was found in case of none (37.59μg/g) and progressively lower values in case of slight (32.68μg/g), moderate (30.34 μg/g) and severe (28.80 μg/g) top dying of sundri sample plots. The difference was significant (P =0.05).
- Mean values of zinc in soil collected in October 2001 from none (19.78μg/g) and slight (21.80 μg/g) top dying sample plots were significantly higher (P=0.05) that that from moderate (13.60 μg/g) and severe (15.74 μg/g) top dying of sundri sample plots.
- The levels of sand per cent in soil depth of 0-10 cm (D1 depth) collected in January 2002 showed significant (P=0.05) negative correlation (r = -0. 3260800, with 35 df) with per cent top dying data of sundri trees from 36 sample plots. This clearly suggests that as sand content in soil depth of 0-10 cm decrease top dying per cent increase. Thus level of sand content is associated with the development of top dying of sundri.

3.2.1 Soil salinity and top dying of sundri

Soil salinity has been measured in terms of the levels of Sodium (Na) and Electrical Conductivity (EC) from soil samples collected from 36 sample plots fallings in four top dying severity classes in October 2001 and January 2002. Analysis of both Na and EC data revealed only insignificant Correlation Coefficient (r = 0.080322 and r = 0.020602 for EC of October 2001 and January 2002 respectively) while Correlation Coefficient for Na and per cent top dying of sundri were r = 0.060001 and r = 0.014066 for October 2001 and January 2002 respectively. Variance analysis revealed no significant difference in the mean values of EC and Na from soil samples collected from four top dying severity classes (i.e. none, slight, moderate and severe) of sundri as F-values obtained were 2.37, 0.28, 0.36 and 0.38 respectively with 3, 68 df in each case. It is thus evident that soil salinity and four top dying severity classes are not correlated.

3.2.2 Distribution of four mangrove species in relation to three salinity zonation in the Sundarbans

The data of the distribution of sundri seedlings, saplings, poles and trees per hectare in the three salinity zones revealed significantly (P = 0.001) higher number of 32413 of seedlings, 3205 saplings, 1390 poles and 165 trees per hectare in the fresh water zone (FWZ) as compared to 15985 of seedlings, 1933 saplings, 1219 poles and 99 trees per hectare in moderately saline water zone (MSWZ), and the MSWZ had significantly (P=0.001) higher number as compared to that of 1714 seedlings, 439 saplings, 423 poles and 5 trees per hectare saline water zone (SWZ) compartments. **Thus it is very clear that distribution of the number of sundri seedlings, saplings, poles and trees are distinctively governed by the salinity of the areas.**

3.3 Pathological factors

3.3.1: Stages of symptom development of top dying of sundri

The early stages of the development of top dying condition is seen as yellowing of leaves on some of the twigs. Such twigs then continue to dry out and die. Examination of dying twigs and small branches by cutting through the dying portion reveal the presence of clear transition of progressive invasion characteristic of some causal organism. Besides, dying small twigs are eaten up by insects at places which injuries the tender bark. Death of such twigs and branches gradually reduces the photosynthetic potentials of such affected trees and they became progressively bare. Progressive death of the major branches are followed by the breakage of such dead branches and main stem giving a truncated appearance which is characteristics of top dying of sundri.

3.3.2: Extent of damage of crown of top dying sundri

The status of crown damage and its progressive change over time were studied by careful observation of sundri trees in 36 sample plots at 12 landings in 10 compartments through observation in October 2001, January 2002 and June 2002. The observations included state of health of individual sundri tree whether it belonged to healthy category or G2 type (i.e. only twigs dying or dead), G3 type (i.e. main branches dying or dead but less than 50% of the crown affected), G4 type (i.e. main branches dying or dead but more than 50% of the crown dying or dead), state of health of main leader (i.e., leading branch), state of health of twigs, presence and level of gall cankers, loranthus (i.e angiospermic parasite) and epiphytes. A comparison of the data collected in October 2001 and that of January 2003 per sample plot of 400 sp m revealed the following:

- Mean number of healthy sundri trees per sample plot changed from 8.22 to 0.33;
- Mean number of sundri trees with few twigs affected changed per sample plot changed from 10.66 to 19.25;
- Mean number of G2 type sundri trees per sample plot changed from 4.63 to 5.08;
- Mean number of G3 type sundri trees per sample plot changed from 3.78 to 10.25;
- Mean number of G4 type sundri trees per sample plot changed from 2.56 to 4.00;
- Mean number of sundri trees with dead main leader per sample plot changed from 5.88 to 7.50;

These reveal that over one year and four months period of observation substantial change in top dying symptom expression occurred.

3.3.3: Association of sapwood rot and insect damage

This was studied by splitting 24 top dying affected sundri stems. Each log was sawn into a number of sub-samples and then examining each sub-samples for the presence of sapwood rot and of any insect damage as evident by the presence of tunnels. Then correlation coefficient (r) was found out between per cent sub-samples having sapwood rot and per cent sub-samples having insect tunnels. There exists a highly significant ($P = 0.001$) correlation coefficient ($r = 0.651$, with 23 degrees of freedom) between per cent of sub-samples having sapwood rot and per cent of sub-samples having insect damage. This suggested a strong association between sapwood rot and insect damage in top dying affected sundri trees.

3.3.4: Isolation of causal pathogen from top dying sundri wood

Isolations of fungi were done from dying and healthy wood tissues of sundri twigs, branches and stem wood collected in July 2001, January 2002 and June 2002 following standard procedures. Ten different fungal isolates and bacteria were isolated. Out of these fungal isolate T60 was isolated from 22.73% inocula of dying twig, 23.49% inocula from dying branch and 56.75% inocula from dying stem wood of top dying sundri as compared to only 0.91%, 3.75 % and 3.77% from healthy twig, branch and stem wood collected in July 2001. Thus isolation of isolate T60 was significantly ($P=0.05$) higher from dying tissue as compared to healthy tissue of sundri wood. Isolation of fungal isolate T60 at a highly significantly ($P = 0.01$) higher per cent (i.e.56.75%) from dying stem wood tissues as compared to that from branch (23.49%) and twig (22.73%) wood tissues is probably because of the large size of the stem wood which retained food for fungus longer while small wood of branch and twigs were quickly decayed and become exhausted as food for the invading fungus which then died because of starvation. In all, healthy sapwood tissues yielded only 3.13% of isolate T60 as against 39.54 % from dying sapwood tissues. This very strongly suggests that isolate T60 is associated with the death of sapwood of sundri. **The isolate -T60 is *Fomes badius*.**

Isolation of fungi and bacteria from sundri dying twigs collected at the early stage of symptoms expression as collected in June 2002 yield fungal isolate- A most dominantly from the tissues of dying bark and wood of sundri. This was significantly ($P = 0.05$) higher than other types of fungi and also bacteria. This has been identified as *Philophora* sp. Hence isolate-A is considered as the causal organism for the death of small twigs in the initial stage of twigs dieback of sundri.

3.4 Factors aggravating the severity of top dying of sundri

3.4.1: Correlation between per cent top dying of sundri and loranthus infestation

Data of per cent top dying of sundri trees from 1203 TSPs of 55 compartments showed highly significant (P=0.001) positive correlation (r = 0.412946, with 54 df) with per cent loranthus infestation. This convincingly suggests that with the increase in infestation by the loranthus per cent top dying of sundri also increase and vice versa. The regression equation is Y=2.48956 + 0.887051X, where per cent top dying of sundri trees is in Y axis and per cent sundri trees infested by loranthus on the X axis.

3.4.2: Forest types having no association with the severity of top dying of sundri

Forest types and per cent top dying data of 200 TSPs revealed an insignificant association as we had a correlation coefficient r = -0.06881 with 199 df. Hence there is no association of forest types and per cent top dying of sundri.

3.4.3 : Low canopy closure aggravating the severity of top dying of sundri

Three-canopy closures per cent were recognized in FRMP Forest Inventory. These were canopy closure equal to or more than 70 per cent (i.e. 1), canopy closures of equal to or greater than 30 per cent but less than 70 per cent (i.e. 2) and canopy closures of equal to or greater than 10 per cent but less than 30 per cent (i.e. 3). Canopy closure and per cent top dying of sundri data from 200 TSPs showed a highly significant (P= 0.001) F value of 14.57 with 199 and 2 df and a highly significant (P=0.001) Correlation Coefficient r = 0.344616, with 199 df. Hence a close association exists between canopy closure and per cent top dying of sundri trees. It is therefore suggested that creation of too open a canopy artificially or naturally may lead to greater development of top dying of sundri in the Sundarbans.

3.4.4: Prevalence of more top dying of sundri in higher d.b.h. classes

Data of diameter at breast height (d.b.h) in cm data and per cent top dying of 1625 sundri trees collected from the Sundarbans during the present study showed a significant (P= 0.01) positive Correlation Coefficient (r=0.275, with 1624 degrees of freedom). This means there is higher prevalence of top dying on sundri trees of higher dbh classes.

3.4.5: Insect damage aggravating sapwood rot and top dying of sundri

This was studied by splitting 24 top dying affected sundri main stems. Each log was sawn into a number of sub-samples and then examining each sub-samples for the presence of sapwood rot and of any insect damage as evident by the presence of tunnels. Then correlation coefficient (r) was found out (r = 0.651, with 23 degrees of freedom) between per cent sub-samples having sapwood rot and per cent sub-samples having insect tunnels. This correlation is highly significant (P = 0.001). This suggested a strong association between sapwood rot and insect damage in top dying affected sundri trees. Therefore, it is suggested that once top dying has affected /set death of main stem of sundri sapwood damage increases insect damage and vice versa. However, which of these two commences first is not yet convincingly clear. Since insect damage occurs in the form of tunnels in deeper wood tissues, while sapwood rot occurs in the sap wood which is in the outer sapwood zone, it is most likely that sapwood rot occurs first and is followed by entry of insect.

3.5 Occurrence and severity of top dying of sundri in 55 compartments in the Sundarbans

This was studied by analysis of the data of top dying of sundri in 1203 Temporary Sample Plots (TSP) fallings in 55 compartments in the Sundarbans. The data were generated during FRMP Forest Inventory of the Sundarbans during 1996 and 1997. In each of the 55 compartments varying number of TSPs were laid down during the inventory. Out of 1203 TSPs sundri were found to occur in 830 TSPs. Based on per cent of TSPs showing top dying of sundri the **relative widespreadness of top dying in a particular compartment** was determined. However, for this consideration compartment numbers 46, 41, 42, 47, 48, 49, 50, 51, 52, 53, 54 and 55 have been excluded as the total number of sundri trees present in all the TSPs falling in each of these compartments were very small. In the next step the total number of sundri trees falling in the TSPs of a particular compartment and the actual number of sundri trees showing top dying symptoms were considered to express **per cent of sundri trees exhibiting top dying**. In the third stage **Ranking Index of top dying of sundri was determined by multiplying the relative widespreadness by per cent of sundri trees exhibiting top dying.** Compartment number 37 was found to have the highest ranking index (i.e., being the worst affected by top dying of sundri). This is followed by compartment numbers 42, 33, 40, 19, 36, 41, 18, 45, 34, 22, 8, 20, 5, 31, 38, 25, 29, 32, 13, 26, 43, 28, 27, 17, 44, 10,30, 24, 23, 4, 9, 16, 35, 2, 3, 14, 39, 1, 11, 21, 6, 7, 12, and 15. However, compartment nos. 41 had only 46 sundri trees in 13 TSPs and compartment 42 had only a 36 sundri trees in 8 TSPs. So although compartment 41 and 42 had obtained ranked position of 7 and 2 respectively should be excluded from any further consideration of severity of top dying.

3.6: Regeneration and recruitment

3.6.1 Status of seedlings, saplings, poles and trees of major tree species in the Sundarbans

The status of regeneration in the whole of the Sundarbans has been assessed from the data of 1203 TSP generated during 1996 and 1997 during FRMP Forest Inventory of the Sundarbans. Mean number of seedlings, saplings, poles and trees per ha were determined for 30 tree species. On an average there were 33895 seedlings, 7116 saplings, 3224 poles and 141 trees per ha of all the 30 species taken collectively in the whole of the Sundarbans. Sundri, gewa, goran, amur, passur, baen, shingra, dhundhul, keora and kankra constituted 97.33 % of the seedlings, 98.69% of saplings, 99.44 % of poles and 99.72% of tree populations in the Sundarbans in 1996-1997. For the whole Sundarbans sundri commanded 18615 seedlings, 2045 saplings, 1068 poles and 100 trees per ha on an average. Gewa had 5501 seedlings, 1398 saplings, 1379 poles and 19 trees per ha. Goran had 5599 seedlings, 3157 saplings, 500 poles and 0.13 trees per ha. Amur had 598 seedlings, 214 saplings, 61 poles and 0.23 trees per ha. Passur had 87 seedlings, 22 saplings, 14 poles and 11 trees per ha. Baen had 194 seedlings, 29 saplings, 5 poles and 4 trees per ha. Shingra had 1835 seedlings, 52 saplings, 112 poles and 0.02 trees per ha. Dhundhul had 19 seedlings, 5 saplings, 0 poles and 0.64 trees per ha. Keora had 0 seedlings, 22 saplings, 5 poles and 2 trees per ha and Kankra had 554 seedlings, 83 saplings, 30 poles and 3 trees per ha on an average for the whole of the Sundarbans. All other species had 2.67% of seedlings, 1.31 % of saplings, 0.56% of poles and 0.28% of trees in the Sundarbans. Thus we find that sundri constituted 54.92% seedlings, 28.74 saplings, 33.13% poles and 70.92% of the tree populations in the Sundarbans.

Gewa constituted 16.23% seedlings, 19.64% saplings, 44.76% poles and 13.77% of the tree populations. Goran constituted 16.52% seedlings, 44.36% saplings, 15.52% poles and 0.09% of the tree populations. Amur constituted 1.76% seedlings, 3.01% saplings, 1.90% poles and 0.16% of the tree populations. Passur constituted 0.26% seedlings, 0.30% saplings, 0.43% poles and 7.93% of the tree populations. Baen constituted 0.57% seedlings, 0.41% saplings, 0.16% poles and 3.04% of the tree populations. Shingra constituted 5.41% seedlings, 0.73% saplings, 3.46% poles and 0.01% of the tree populations. Dhundhul constituted 0.03% seedlings, 0.04% saplings, 0% poles and 0.45% of the tree populations. Keora constituted 0% seedlings, 0.31% saplings, 0.14% poles and 1.68% of the tree populations. Kankra constituted 1.63% seedlings, 1.16% saplings, 0.44% poles and 1.87% of the tree populations These data clearly reveal the single dominance of sundri in the Sundarbans.

3.6.2: Impact of top dying of sundri on regeneration

In regeneration studies were carried out in 180 regeneration sub-plots, each 4 sq m, in no top dying (i.e. none), slight, moderate and severe top dying of sundri. Equal number of sub-plots were from each of the four top dying severity classes from 36 sample plots. Species encountered were sundri, gewa, goran, amur, singra, baen, passur and kankra. Sundri R1 type regeneration were the highest in all cases and significantly ($P = 0.05$) higher than all the remaining types of regeneration of all other species. It was found that within each type of regeneration (i.e. R1, R2 and R3) of sundri there is in general a trend of higher regeneration in the more top dying severity classes (i.e. from none, slight, moderate and finally to severe). This is particularly evident in case of R2 type regeneration in case of sundri . This finding support the idea that opening created in the ground level because of removal of canopy by top dying allows more sun light in the forest floor which has imparted a positive impact on the growth of young seedlings (R1 type) of sundri and this promoted more recruitment of R2 type sundri regeneration. **This finding convincingly suggests that removal of top dying affected sundri tree through a salvage felling is not going to affect the status of regeneration and recruitment of sundri seedlings in the top dying affected areas of the Sundarbans. This has undoubtedly a very important bearing in the management of the top dying affected sundri trees in the Sundarbans by the Forest Department.**

3.6.3: Impact of salvage felling on recruitment of saplings in 3 top dying harvested and 4 unharvested compartments

In order to determine the impact of salvage felling of top dying sundri status of regeneration, particularly saplings from compartment nos. 32, 36 and 38 were compared with that of compartment nos. 16, 31, 35 and 41. The data have been derived from the TSP Database generated during FRMP Forest Inventory of the Sundarbans during 1996 and 1997 so that status of regeneration 3 - 4 years after top dying harvest could be obtained from these three compartments. So far as the comparison of relative dominance of all available species sundri saplings both from harvested and unharvested compartments were significantly ($P=0.01$) higher than mean number of saplings of the remaining eight species (i.e. gewa, goran, passur, kankra, baen, singra, khalisha and amur). The highest mean regeneration of 2.65 sundri saplings were obtained per Temporary Sample Plot (TSP) in an area of 62.82 m^2 from the unharvested compartments and mean of 2.33 number of sundri saplings per TSP from harvested compartment nos. 32., 36 and 38. The difference was, however, insignificant.

3.6.4 Comparison of sundri seedlings, saplings and poles in 1996-97 and 2003

A comparison of the level of sundri seedlings, saplings and poles per ha compartment numbers 2,11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans during January 2003 and that of 1996-97 was made. It was found that sundri had significantly higher number of 32194.44 seedlings per ha in January 2003 as compared to 18302.95 seedlings in 1996 – 1997 and had significantly higher no. of 2847.22 poles per ha as compared to 1201.41 poles in 1996-97. But in case of saplings there were 1847.22 in 2003 as compared to 2308.92 saplings in 1996-97, the difference was, however, insignificant. **These reveal that there have occurred significant ($P = 0.05$) increase in the number of**

sundri seedlings and poles in 2003 over that of 1996-1997, but the difference in case of saplings is insignificant. It is suggested that the increase might have resulted because of the impact of moratorium imposed in the Sundarbans.

3.7 Findings about the causes of top dying of sundri

- Soil salinity plays a vital role and governs the distribution of sundri in the Sundarbans.
- Burial of pneumatophores, production of reduced number of pneumatophores and lenticels on the pneumatophores create condition of reduced soil aeration affecting normal metabolism in the root system and thereby predispose sundri trees to stressed condition which results in the initiation of twig deaths. This is considered as the primary cause of top dying of sundri in the Sundarbans.
- Deficiency of micronutrients (eg. Manganese and Zinc) and presence of higher levels of Calcium in the soil are associated with top dying of sundri.
- Greater opening in the canopy of sundri trees, loranthus (angiospermic parasite) infestations, and sundri trees of higher diameter at breast height (dbh) classes are associated with severity of top dying of sundri.
- Once top dying starts a number of fungi degrade wood of branches and main stem of sundri trees resulting in increasing top dying. Degrade due to top dying of sundri has been estimated to be 42.18 ± 4.69 per cent. The fungi include *Phialophora* sp with twig death, *Botryosphaeria ribis* with gall canker, *Ganoderma lucidum* with root rot and *Fomes badius* and a number of other basidiomycetes with wood decay.
- There exists a strong association between sapwood rot and insect damage in top dying affected sundri trees.

3.8 Salvage felling as a management tool for top dying sundri

3.8.1 Salvage felling of top dying sundri trees is recommended for the following reasons:

- Removal of top dying sundri trees are necessary to reduce further build up of top dying of sundri and progressive deterioration of the health of the Sundarbans.
- Impact of salvage felling on regeneration and recruitment of sundri has been found to be insignificant.
- Top dying sundri trees suffer from further degrade induced by wood decay Basidiomycetous fungi and also insects, and cause degrade of estimated 42.18 ± 4.69 per cent. This is a heavy economic loss in forestry terms where millions of cubic meter of timbers are involved. Therefore, MOEF should seriously consider reintroduction of a well planned and rigorously monitored salvage felling in more severely top dying affected compartments in the Sundarbans.

3.8.2 Top dying sundri trees recommended to be salvage felled:

- Sundri trees having 50% or more canopy damaged by top dying should only be included for salvage felling.
- All dead and decaying trees should be removed from the forest floor, if economically feasible, to reduce the build up of wood decay fungi and thereby reduce the extent of degrade due to top dying.
- Loranthus infested branches should be removed, during salvage felling, from other sundri trees as that will reduce the severity of top dying.

3.9 Suggestions for further studies

- Direct measurement of the status of soil aeration should be carried out using Redox Potential Meter (an equipment using which one can measure the level of air in soil directly) in areas of no top dying, slight, moderate and severe top dying of sundri to confirm the role of reduced soil aeration on the development of top dying of sundri in the Sundarbans.
- Factors that promote lower pneumatophore production and lenticels development by severe top dying affected sundri in comparison to that of healthy sundri should be studied. Depth and duration of flooding, rate of sedimentation may be interesting factors in this respect.
- Effect of removal of various levels (25%, 50% and 75%) of pneumatophores from around healthy sundri trees in sample plots selected from eastern and central parts of the Sundarbans and their effect on development of top dying should be studied.
- Effect of higher Calcium level and lower Manganese and Zinc levels on the development of top dying of sundri should be studied in simulated experiments.
- The labeled sundri trees in 36 sample plots established during the Study of Top Dying of Sundri Project should be further observed at yearly intervals for at least 2 years beginning from January 2004 to record the progressive changes of top dying symptom development and compared with the data of January 2002 generated by the present project. This will enable to find out precisely the time required from the early stage to more than 50% of the crown damage by top dying of sundri. Such knowledge would be useful for deciding about sundri trees to be covered under salvage felling and trees to be retained.

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1.0 INTRODUCTION

1.1 Purpose

The primary purpose of this Draft Final Report is to present the activities so far carried out and the findings of the Sundri Top-dying Project to Forest Department and Technical Assistance Group (TAG) of Sundarban Biodiversity Conservation Project (SBCP). It is intended that all concerned will examine the findings to develop precise ideas about our understanding of the cause(s) of top dying of sundri so that suitable management strategy could be developed for long term management of sundri in the Sundarbans by the Forest Department.

1.2 The Project:

Sundarbans, the largest single tract of mangrove forest in the world, covers an area of 571500 ha and lies in the south west corner of Bangladesh. Sundri (*Heritiera fomes*) is the most valuable and dominant tree species in the forest and represents 64% of the total standing volume. Sundri has been subjected to a disease syndrome called top dying. In general, top dying sundri trees have a dead and truncated top accompanied with the death of twigs and branches to a varying degree leaving a variable extent of healthy canopy.

A detailed study had been undertaken with effect from July 2001 on ecological, pathological and edaphic/hydrological aspects of top dying of sundri primarily in order to find out the cause. Rahman *et al* (2002) submitted an Inception Report in January 2002 to the TAG, which contains a detailed description of the project.

2.0 OBJECTIVES OF THE PROJECT

2.1: General Goal: To know the actual cause(s) and develop appropriate management strategy for top dying of sundri in the Sundarbans.

2.2: Specific Objectives

2.2.1: Ecological aspects

- To determine relationship between environmental factors (geomorphology, rate of sedimentation, smothering of pneumatophores and level of salinity) and development of top dying of sundri.
- To determine relationship between damage to the tree (by natural and anthropogenic causes) and development of top dying of sundri.
- To determine impact of salvage and sanitation felling of sundri on vegetation structure in the Sundarbans
- To determine the relationship between top dying of sundri and age, density and associated tree crops.

2.2.2: Pathological aspects

- To find out the causal agent of top dying of sundri.
- To determine the infection biology of the causal factor (pathogen) for top dying of sundri.
- To find out the biotic and abiotic factors responsible for aggravating the top dying of sundri.
- To find out ways how the knowledge of the causal pathogen and factors aggravating the disease can be used to develop appropriate management strategy for top dying affected sundri in the Sundarbans.

2.2.3 Edaphic aspects

- To determine physico-chemical properties of selected top dying affected and healthy sundri areas in order to find out whether there exists any relationship between site condition (including soil properties and nutrient regime) and the development of top dying of sundri.

3.0 REVEIEW OF LITERATURE

3.1 Introduction

The Sundarbans covering an area of 571500 ha is the largest single-tract of mangrove forest in the world. It is located in the estuary of the river Ganges in the south west corner of Bangladesh. The land supports good productive and protective forests. In the Sundarbans sundri (*Heritiera fomes*) is by far the most important and commercially valuable tree species. The species commands its single dominance in 52.7% forest area and codominance in 14.8% of the forest representing about 64% of the total standing volume in the Sundarbans.

Sundri has been subjected to a disease syndrome called top dying. Chaffey *et al.* (1985) noted that 18% of the sundri of 5-cm dbh class and above were affected by the problem in the Sundarbans. Sattar (1977), Shafi (1982), Chowdhury (1984), Chaffey *et al.* (1985) and Rahman (1990) reported quantitative estimates about the extent of damage due to top dying of sundri. Based on the survey data provided by Chaffey *et al.* (1985) it was estimated by Rahman (1990) that during 1983-84 in the Sundarbans there were 45.2 million sundri trees affected by top dying. Out of this 25.02 million trees occupying 25446 ha had developed moderate top dying (less than 50% of the crown dead) and 20.18 million trees covering 19848 ha were severely affected (more than 50% of the crown dead). Out of the 45.02 million sundri trees affected by top dying 81%, 14%, 4% and 1% occurred in the 5, 10, 15 and 20 cm d.b.h. classes respectively. It was estimated that 42.07% ± 7.08% (at $P = 0.05$) wood loss due to top dying of sundri in compartment nos. 32, 36, 37, 38 and 39. This is considered to be a very heavy economic loss. The Forest Department recognizes top dying of sundri as the key management concern of the Sundarbans (Rahman, 1995).

Therefore, in the present study an attempt has been made to review top dying related studies/literatures and data generated by a number of workers have been critically analyzed to find out the latest state of knowledge about the causal factor(s) of top dying of sundri. Thus knowledge gap has been determined and suggestions have been made for necessary further studies to determine more precisely the cause of top dying of sundri in order to be able to come up with recommendations for efficient management of sundri top dying problem in the Sundarbans.

3.2. Methodology

3.2.1 Sources of Literature Consulted:

- Books on mangrove, particularly those on Sundarbans
- Tree CD ROM (prepared by Commonwealth Agricultural Bureaux, Oxford, U.K. and Silver Platter Information Limited, USA) containing abstracts of about 1500 forestry and related journals published throughout the world and covering the period 1939 to October 2001.
- Documents of ODA Inventory of the Sundarbans reserved forest.
- Documents of FAO/UNDP Projects BGD/84/056: Integrated Resource Development of the Sundarbans Reserved Forest.
- Documents of Forestry Resources Management Project
- Mangrove Bibliography prepared by UNICEF and covering the period 1600 to 1975 (UNICEF, 1976).
- Bibliography on Tropical Coastal Ecosystems prepared by Mangrove Management Group based at Vrue Universiteit Brussel, Belgium (Farid Dahdouh-Guebas,2000).
- Plant Diseases of India: A source book (Mukerji and Bashin, 1986)
- Published information on Mangrove Ecology, particularly those related to edaphic factors.
- Published and unpublished materials from personal collections.
- Personal contacts.

3.2.2 Approach for Consulting the Literatures:

Published literatures/documents on top dying of sundri were consulted and extracts of relevant portions were prepared. For this purpose libraries consulted included that of Bangladesh Forest Research Institute, Chittagong; Forest Department HQs at Bano Bhaban, Mohakhali in Dhaka; Bangladesh Agricultural Research Council in Dhaka, Bangladesh National Scientific and Technical Documentation Centre in Dhaka and Khulna University. Besides, literatures related to top dying of sundri in personal collections were consulted. Tree CD ROM for the period 1939 to 2001were scanned for literature on sundri (*Heritiera fomes*) top dying, and also on mangrove ecology in general with particular reference to the role of edaphic factors on the development of top dying, abstracts and related citations were printed out and then carefully examined for any information on top dying of sundri, and then extracts of relevant portions were prepared.

The extracts were then arranged in chronological sequence to prepare an up to date account and understanding of the suggested causal factors of top dying of sundri in the Sundarbans. A summary of the probable causes suggested by various authors was then prepared. Then the strengths and weaknesses of each of the suggested probable causes of top dying of sundri was critically analyzed in the light of available information.

The edaphic data generated by Chaffey *et al.* (1985), Mujibur Rahman (1995), Bhuiyan (1995) and Karim (1995) were critically analyzed to find out any possible association/relationship of such factors/parameters with the occurrence and severity of top dying of sundri in the Sundarbans.

Besides, reports on hydrology prepared during the FAO/UNDP Project: BGD/84/056: Integrated Resource Development of the Sundarbans Reserved Forest and more recent documents prepared by the Surface Water Modeling Centre were consulted and found no information directly related to top dying of sundri. Therefore, such reports have not been quoted.

3.3 Findings from the review of literatures

3.3.1: Summary of Literature Review

Top dying of sundri is a complex disease syndrome that has caused an extensive damage to the crop in the Sundarbans. Of the affected trees, wood loss has been estimated to be 42. 42.07% ± 7.08% (at $P = 0.05$) of the total wood produced up to top inner bark diameter of 10 cm. This is considered to be a very heavy economic loss. The Forest Department recognizes top dying of sundri as the key management concern in the Sundarbans.

Chronological accounts of the information related to top dying of sundri for the period 1933 to October 2001 has been prepared. It is evident from the Annexures that various workers have suggested probable causes of top dying of sundri. These include 1) Reduced soil aeration, 2) Increased soil salinity and change in some of the chemical properties of soil, 3) Wind damage in the crown, 4) Canker and stag-headed condition, 5) Root rot caused by *Ganoderma lucidum,* 6) Sapwood decay by one or more fungus/fungi resulting girdle and dieback, 7) Pathogenic bacterial (*Arthobacter nicotianae & Pseudomonas sp.*) infection, 8) Loranthus (*Dendrophthoe falcata*) attack and/or 9) Change in hydrological condition (**Table 1**).

Table 1: Suggested causes of top dying sundri in the Sundarbans as per various investigators.

SL. No.	Suggested probable causes of top dying of sundri	References
1.	Reduced soil aeration	Sobhan (1973); Sattar (1977); Karim (1988); Habib (1990); Rahman (1990); Anon (1995)
2.	Increased soil salinity and chemical properties of soil	Sattar (1977); Chaffey *et al.* (1985); Hassan (1988); Karim (1988); Ciesla (1994); Anon. (1995); Griffin (1995); Rahman and Hoque (2001)
3.	Wind damage in the crown	Ahmed (1957); Atiqullah (1973); Sattar (1977); Chowdhury (1984); Ciesla (1994); Anon. (1995)
4.	Canker and stag-headed condition	Curtis (1933); Atiqullah (1973); Gibson (1975); Rahman *et al.* (1983); Chowdhury (1984); Anon. (1995); Rahman (1995)
5.	Root rot caused by *Ganoderma lucidum*	Rahman (1995)
6.	Sapwood decay by fungus/fungi resulting girdle and dieback	Rahman (1995)
7.	Pathogenic bacterial (*Arthobacter nicotianae & Pseudomonas sp.*) infection	Hartung *et al.* (1998)
8	Loranthus (*Dendrophthoe falcata*)	Atiqullah (1973), Chowdhury (1984), Rahman (1995)
9.	Change in hydrological condition	Sattar (1977); Shafi (1982), Imam (1982), Chaffey *et al.* (1985), Jemenz and Lugo (1985), Karim (1988), Grepin (1995), Ciesla (1994); Anon. (1995)

3.3.2: Discussion on the Suggested Probable Causes of Top Dying of Sundri

3.3.2.1: Reduced soil aeration and development of top dying of sundri: Sobhan (1973), Sattar (1977), Islam (1982), Shafi (1982), Chowdhury (1984), Chaffey *et al.* (1985), Hassan (1987), Karim (1988), Habib (1990), and Rahman *et al.* (1990) reported various aspects of edaphic factors in relation to sundri top dying (STD). Shafi (1982) and Chowdhury (1984) very vaguely mentioned that edaphic changes in the Sundarbans might have contributed towards the development of STD. Other authors dealt with the problem more specifically highlighting three main issues - soil aeration, soil salinity and chemical properties of soil. The roles of reduced soil aeration in relation to the development of top dying of sundri are discussed below:

Soil aeration: Long period of oxygen deficiency in soil may cause temporary change in the metabolic activity or permanent damage to mangroves (Waisel 1972). It may also cause absorption of certain chemicals (e.g., iron) in toxic concentrations by plants (Hogarth 1999) and reduced availability of others (Hutchings and Saenger 1987). Lugo and Snedaker (1975) also opined that soil anoxia could cause massive mortality of mangroves.

Troup (1921), Curtis (1933) and Das and Siddiqi (1985) mentioned that sundri prefers site of intermediate elevation that is less frequently inundated and is well drained. This indicate that sundri could be sensitive to the deficiency of oxygen in the soil.

Sobhan (1973) observed that sand component of healthy sundri areas were much higher than that in STD areas. This reflects that STD might be related with soil anoxia. Sattar (1977), Habib (1990), and Rahman (1995) observed association between STD and higher sedimentation. In explaining the impact of higher sedimentation it is important to note that in mangrove habitat the top 10-cm of the substrate remains well oxygenated. Nutrients are also available to mangroves only in this zone. Shamsul Huda (pers. com.) also reported that STD is more prominent in low-lying areas of the Sundarbans. These areas are poorly drained and remain flooded for prolonged period. Thus, Shamsul Huda's observation also indicates a relationship between STD and deficiency of soil oxygen.

Massive mortality of sundri in localized area occurs when sundri pneumatophores become buried because of heavy siltation. Mangrove swampy soil has very little air passage. For that to provide the required supply of air for normal metabolic activities in the roots, oxygen is supplied to the roots through lenticels of the pneumatophores. This is a well-known biological process. In sites with heavy siltation pneumatophores become almost or totally buried. That greatly reduces oxygen supply to the roots, then roots start dying and to loss their ability for normal absorption and uptake of water and nutrients for the shoots. In such a situation shoot starts functioning abnormally in absence of adequate manufacture of photosynthetic products. Such trees first fail to support adequate growth of the foliage, which then becomes smaller, deformed and bronze in color. Because of the change of site condition such trees suffer massive mortality in localized areas. Such sites with massive death of sundri have been seen to occur on the north bank of Tapamari khal (Compartment 39), Jaliakhal bank and north of Gewakhali Copue Office (Compartment 20); adjacent to Sarbotkhali (north of Compartment 32 and southern area of Compartment 33); east of Sibsa Petrol Camp (Compartment 34), at Sheker Tek just at the approach of Sheker Tek ruins in Compartment 39; at the bank of Jafa khal between Jafa and Chamta in Compartment 38 (Rahman, 1995). **Thus it is evident that there is apparently a relationship between the STD and soil anoxia.**

To study the relationship between the availability of soil oxygen and STD, as a direct approach, the availability of soil oxygen could be measured with a soil oxygen meter (Redox Potential Meter) in areas of the Sundarbans affected by the various degrees of STD. As an alternative approach, responses produced by sundri to soil anoxia could also be measured. In a sedimentary environment, to cope with the soil anoxia mangroves produced adventitious lateral roots close the surface, put on secondary growth on pneumatophores, produce feeding roots from pneumatophore, produce large number of pneumatophores and increased number of lenticels (Hogarth 1999). It may, however, be mentioned here that use of Redox Potential Meter is a direct and much more appropriate way of measuring the level of oxygen in the soil near the root environment.

As the **Sundarban Biodiversity Conservation Project** has not yet been able to provide a Redox Potential Meter for this study, the above alternative approach for this study has been adopted. It has been planned to measure the rate of sedimentation, number of pneumatophores per unit area, length of pneumatophores and the number of lenticels per unit area of pneumatophores.

The conventional technique for measuring the rate of sedimentation is – mark a site, put a thin layer of brick dust at regular intervals of time, finally take a core sample of the soil and measure the intervals between the layers of brick dusts and the surface. This technique does not seem suitable for the Sundarbans as trampling by animals could disarray the layers of sediment. On the other hand fencing of the area might affect the tidal pattern, increase sedimentation and is also very expensive.

- In this study it has been planned to study the rate of sedimentation by fixing siltation gauge. As per the project proposal the siltation gauges will be measured at four months interval during the study period to determine the rate of sedimentation.

In the present study it is also planned to uproot several pneumatophores to measure total, above and below ground length. However, this would be an inappropriate indicator of the rate of sedimentation. It is already discussed that in sedimentary environment mangroves produce sets of lateral roots (from which pneumatophores arise) close to the surface abandoning the lower ones. By digging out a pneumatophore it is not possible to ensure the set of lateral roots from which the pneumatophores have arisen. Thus total length of the pneumatophore do not indicate the rate of sedimentation. In this context, determining the density of pneumatophore and lenticels on the pneumatophore are practicable approaches to study the relationship between soil anoxia and STD.

In badly drained depressions, the number of pneumatophores, lenticels, and above ground height of pneumatophores are good indicators of anoxic environmental conditions. However, a direct approach would be to experimentally drain a few STD affected depressions and observe the area for some years. Tenure of this project is perhaps very short to carry out this study. **Therefore it is recommended that Forest Department try it on a number of sites in the Sundarbans.**

3.2.2.2: Soil salinity, chemical properties of soil and development of top dying of sundri
Sobhan (1973), Sattar (1977), Islam (1982), Shafi (1982), Chowdhury (1984), Chaffey *et al.* (1985), Hassan (1987), Sheil and Ross (personal communication), Habib (1990), Karim (1988) and Mujibur Rahman (1995) studied various aspects of edaphic factors in relation to STD. Shafi (1982) and Chowdhury (1984) very vaguely mentioned that edaphic changes in the Sundarbans might have contributed towards the development of STD. Other authors dealt with the problem more specifically highlighting three main issues in all– soil aeration, soil salinity and chemical properties of soil. The roles of soil aeration have already been discussed. Hence the roles of soil salinity and chemical properties of soil in relation to the development of top dying of sundri are discussed below:

Soil salinity and chemical properties of soil: The chemical properties of the Sundarbans soil, in relation to the STD were studied by Sobhan (1973), Islam (1982), Chaffey *et al.* (1985), Hassan (1987), Sheil and Ross (1987) Karim (1988), Bhuiyan (1995) and Mujibur Rahman (1995). Most of the studies emphasized on the level of soil salinity.

Lugo and Snedaker (1975) and Lugo *et al.* (1981) reported that any drastic reduction in the intensity and/or frequency of runoff and flushing within a mangrove stand generally leads to changes in the structure, vigor and mortality pattern of the stand. Diversion of terrestrial runoff, reduction in river discharge, changes in tidal regimes, and decreased rainfall are the primary factors that cause changes in such edaphic characteristics as salinity, fertility, degree of anoxia, and so on.

International Engineering Co. Inc. (1977) mentioned that occurrence of sundri is directly related to the amount of fresh water i.e., the level of salinity. Sattar (1977) suggested increased salinity as a potential reason for STD.

Chaffey *et al.* (1985) collected soil samples from 20 sites covering no top dying, moderate top dying, severe top dying and extreme top dying areas from 10 compartments (i.e. compartment nos. 1, 3, 13, 16, 22, 32, 33, 35, 36 and 38) in the Sundarbans. The 8 sites in no top dying of sundri areas included site numbers 1, 2, 3, 4, 5, 6, 19 and 20 and fell in the compartment nos. 1, 3, 13, 16 and 22; the 3 sites in moderate top dying areas were site nos. 7, 13 and 14 and fell in compartment nos. 33, 35 and 38; the 5 sites having severe top dying areas were site nos. 9, 10, 11, 12 and 18 and fell in compartments 32, 33, 36 and 38; and 4 sites having extreme top dying of sundri were site nos. 8, 15, 16 and 17 and fell in the compartments 33 and 38. The soil samples were collected from surface to 5 cm, 5 to 35 cm, 35 to 65 cm and 65 to 100 cm depths and were analyzed for electrical conductivity (EC), soluble and exchangeable sodium (Na) and the sodium absorption ratio (SAR).

The values of EC, Na and SAR were taken together as a measure of soil salinity. It was mentioned that the results of soil analysis strongly indicated a relationship between the presence of top dying and the concentration of sodium in the soil profile. Soil salinity was higher on sites affected by top dying than in unaffected sites. From this it was suggested that the increase in soil salinity is an important factor on the onset of the top dying. It was concluded that the environment in most of the areas of Sundarbans is not conducive for the growth and survivability of sundri (Chaffey *et al.* 1985). It may be noted that all the unaffected sites taken by Chaffey *et al* (1985) were in the eastern part of the Sundarbans. **Karim (1988) and BFRI soil salinity data as provided by Bhuiyan (1995) very clearly suggest that salinity in the eastern part is the lowest and that in the western part is the highest while intermediate salinity values are in the central part of the Sundarbans.**

Chaffey *et al.* (1985) did not provide any detailed analysis of the data. Therefore, Rahman and Hoque (2001) critically analyzed the data. No significant variations have been obtained in case of EC levels in soils collected at 5, 35, 65 and 100 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. Similarly, no significant variations have been obtained in case of Sodium levels in soils collected at 35 and 100 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. Similarly, no significant variations have been obtained in case of Sodium Absorption Ratio levels in soils collected at 35 and 100 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans.

In the levels of Sodium and Sodium Absorption Ratio significant variations ($P = 0.05$) have been obtained in case of soils collected at 5 cm and 65 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. Further analysis of the mean data by using Duncan's Multiple Range Tests (Duncan, 1955) reveal that in both the cases of sodium and SAR in mean levels, there were no significant variations between the levels obtained from no top dying areas and in soils from extreme top dying areas. Similarly, there were no significant variation in the levels of Sodium and SAR in soils from areas of moderate and severe top dying areas, but the levels of sodium and SAR in soils of areas having severe and moderate top dying were significantly higher ($P = 0.05$) as compared to that of no top dying areas and areas having extreme top dying areas. This is shown in **Table 2** (Rahman and Hoque, 2001).

Table 2: Summary of Duncan's Multiple Range Test (Duncan, 1955) of the mean values of different parameters from the analysis of soil samples collected from the compartments falling in no top dying compartments (i.e. none), moderately top dying compartments (i.e. moderate), severe top dying compartments (i.e. severe) and extreme top dying compartments (i.e. extreme) in the Sundarbans by Chaffey *et al.* (1985) as analyzed by Rahman and Hoque (2001).

Parameter	Mean values with mention of the zone (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters				Comment on the result obtained after Duncan's multiple range test of the means following the method of Duncan (1955)
Sodium (5 cm depth)	2.64 (N)	3.58 (E)	6.88 (S)	7.30 (M)	In the level of sodium there was no significant difference between soil from no top dying sites and sites having extreme top dying of sundri. Sodium levels from sites with moderate and severe top dying were significantly higher (P =0.05) than no top dying and extreme top dying areas.
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Sodium (65 cm depth)	6.40 (N)	9.25 (E)	13.62 (S)	16.30 (M)	In the level of sodium there was no significant difference between soil from no top dying sites and sites having extreme top dying of sundri. Sodium levels from sites with moderate and severe top dying were significantly higher (P =0.05) than no top dying and extreme top dying areas. But there was no significant difference in sodium between severe and extreme top dying sites.
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SAR (5 cm depth)	9.25 (N)	15.63 (E)	21.53 (M)	22.10 (S)	In the level of sodium absorption ratio there was no significant difference between soil from no top dying sites and sites having extreme top dying of sundri. Sodium levels from sites with moderate and severe top dying were significantly higher (P =0.05) than no top dying and extreme top dying areas. But there was no significant difference in sodium absorption ratio between severe and extreme top dying sites.
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SAR (65 cm depth)	19.39 (N)	23.88 (E)	33.50 (S)	35.60 (M)	In the level of sodium absorption ratio there was no significant difference between soil from no top dying sites and sites having extreme top dying of sundri. Sodium levels from sites with moderate and severe top dying were significantly higher (P =0.05) than no top dying and extreme top dying areas. But there was no significant difference in sodium absorption ratio between severe and extreme top dying sites.
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Notes: N = None i.e. soil from 8 compartments having no top dying of sundri; M = Moderate i.e. soil from 3 compartments having moderate top dying of sundri; S = Severe i.e. soil from 5 compartments having severe top dying of sundri; E = Extreme i.e. soil from 4 compartments having extreme top dying of sundri; Sodium (5 cm depth) = Means level of Sodium obtained from all the soil samples collected from surface to 5 cm depth from the respective compartments having N, M, S and E top dying; Sodium (65 cm depth) = Means level of Sodium obtained from all the soil samples collected from 35 to 65 cm depth from the respective compartments having N, M, S and E top dying ; SAR (5 cm depth) = Means Sodium Absorption Ratio obtained from all the soil samples collected from surface to 5 cm depth from the respective compartments having N, M, S and E top dying ; SAR (65 cm depth) = Means Sodium Absorption Ratio obtained from all the soil samples collected from 35 cm to 65 cm depth from the respective compartments having N, M, S and E top dying ; -------- = Means underscored by dotted line (s) are not significantly different.

When one compares the levels of EC, Sodium and SAR from soils collected at 5, 35, 65 and 100 cm depths from the four top dying areas (i.e. no top dying, moderate, severe and extreme top dying) pooled together, no significant variations were obtained between 5 and 35 cm depths, between 35 and 65 cm depths and also between 65 and 100 cm depths but the levels of EC, sodium and SAR obtained from soils at 65 and 100 cm depths were significantly higher (P = 0.05) than that at 5 cm depths.

The insignificant variations obtained in sodium and SAR from areas having no top dying and extreme top dying areas indicate that levels of sodium and SAR are unlikely to be the initiating cause of top dying of sundri in the Sundarbans. It should also be mentioned here that all the eight sites of no top dying of sundri areas from which Chaffey *et al.* (1985) collected soil samples were from the eastern part of the Sundarbans lying between the rivers Baleswar River and Passur River while the top dying affected areas were from the north central part of the Sundarbans lying around the Sibsa river. Karim (1988) by comparing salinity as measured by sodium chloride level of eastern, central and western Sundarbans has shown that mean salinity from these three zones were 6.29, 8.03 and 12.98 ppt respectively. **Soil salinity data generated at monthly intervals during May 1991 to January 1994 from four stations of Bangladesh Forest Research Institute (BFRI) at Bogi in compartment no. 1, Chandpai in compartment no. 28, Kassiabad in compartment no. 36 and Burigoalini in compartment no.46 reveal that mean monthly soil salinity were 3168.44, 4590.15, 6126.67 and 6579.79 micro mhos respectively (vide Table.9).** It is thus evident that the salinity in the eastern zone of the Sundarbans is distinctly lower than that in the central part and western zones of the Sundarbans. **It is therefore suggested that the low salinity of no top dying sites and relatively high salinity from top dying sites of Chaffey *et al* (1985) have been due to location of sites in eastern and central zones of the Sundarbans respectively.** Thus the higher sodium absorption ratio (SAR) and electrical conductivity (EC) obtained by Chaffey *et al.* (1985) is to be expected.

Chaffey *et al.* (1985) observed that generally soil salinity in STD affected areas were higher. However, Chaffey *et al.* (1985), Hassan (1987) did not find any consistent relationship between STD and higher salinity. Rahman and Hoque (2001) also did not find any significant difference in salinity (EC) in severe, moderate and slightly STD affected areas. Analyzing Sobhan's (1973) data an association between higher clay content in the soil and STD also indicate that STD is not related with higher soil salinity as Mc Millan (1975) observed that the effect of salt on mangrove reduces as the clay content in the soil increases.

Mujibur Rahman (1995) collected soil samples from 20 sites of 17 compartments of the Sundarbans including 4 sites from no top dying areas in compartment nos. 6, 12A and 24, six sites from moderate top dying areas in compartment nos.14, 15, 27, 35 and 36; 5 sites from severe top dying areas in compartment nos. 8, 17, 45, 53 and 54; and 5 sites from extreme top dying of sundri areas in compartment nos. 10, 18, 20 and 36. The soil samples were collected from two depths: surface to 30 cm and 60-90 cm. Each of the soil samples was analyzed for pH, electrical conductivity, levels of sodium, magnesium, potassium, chlorine, sodium/calcium ratio, organic matter, nitrogen in the form of ammonium, phosphorus, sulphur, sulphate, copper, iron and manganese. The data were not properly analyzed and commented upon by Mujibur Rahman (1995). Therefore Rahman and Hoque (2001) critically analyzed the data and found that except in case of calcium, there was no significant variation in the levels of any of these soil parameters from surface to 30 cm and 60 to 90 cm depths of soil. Analysis of variance with the data revealed significant variance in case of data from surface to 30 cm soil depth among the four top dying categories (i.e. none, moderate, severe and extreme top dying) in case of electrical conductivity, chlorine, sodium/calcium ratio, levels of sodium, potassium and calcium. Further analysis of the data using DMRT (Duncan, 1955) revealed that there is a more or less similar trend of occurrence of electrical conductivity (EC), levels of chlorine, sodium/calcium ratio and levels of sodium in the soils of surface to 30 cm depths collected from no top dying, moderately top dying, severely top dying and extremely top dying compartments in the Sundarbans **(Table 3)**.

Table 3: Summary of Duncan's Multiple Range Tests of the mean values of different parameters from analysis of soil samples collected from compartments having no top dying (N), moderate (M), severe (S) and extreme (E) top dying of sundri in the Sundarbans by Mujibur Rahman (1995) with comments on the results.

Parameter	Mean values with mention of the status of top dying (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters				Comment on the results obtained after Duncan's Multiple range test of the means following the method of Duncan (1955)
EC (S)	3.18(N)	5.18(M)	5.96 (S)	7.66(E)	Electrical Conductivity (EC) was the lowest I the sites having no top dying and the highest in case of sites having extreme top dying. EC of severe and extreme top dying sites were significantly higher (P=0.05) than no top dying and moderate top dying sites. Underscored means were not significantly different.
Cl (S)	29.58(N)	52.12(M)	63.90(S)	73.50(E)	Chlorine (Cl) content of soils from severe and extreme top dying sites were significantly higher (P = 0.05) than that of sites having moderate and no top dying. Underscored means were not significantly different.
Na/Ca (S)	0.50(N)	0.65(M)	0.99(E)	1.15(S)	Ratio of Sodium and Calcium (Na/Ca) was the lowest *in* the sites having no top dying and the highest in case of sites having severe top dying. Na/Ca of severe and extreme top dying sites were significantly higher (P=0.05) than no top dying and moderate top dying sites.. Underscored means were not significantly different.
Na (S)	5.30(N)	6.88(M)	8.44(E)	8.90(S)	Sodium (Na) content of soils from severe and extreme top dying sites were significantly higher (P = 0.05) than that of sites having moderate and no top dying. Underscored means were not significantly different.
K (S)	0.46(N)	0.57(M)	0.74(E)	1.10(S)	Potassium (K) from severe top dying sites were significantly higher (P=0.05) than sites having moderate, extreme and no top dying. Underscored means were not significantly different.
Ca (S)	7.64(S)	10.58)E)	10.60(N)	11.02(M)	Calcium (ca) content of soil from sites having extreme, moderate and no top dying were significantly higher (P=0.05) than sites having severe top dying in S soil depth (i.e. surface to 30 cm depth). Underscored means were not significantly different
Ca (SS)	7.50(S)	8.80(E)	10.20(M)	10.38(N)	Calcium (ca) content of soil from sites having no top dying were significantly higher (P=0.05) than sites having severe, extreme and moderate top dying in SS soil depth **(i.e. from 30 to 60 cm depth)**. Underscored means were not significantly different

Notes: In case of the levels of sulphur, iron, manganese, available phosphorus, magnesium, copper, pH, NH4-N, SO4 and organic matter no significant difference in the mean value of each of these was obtained from the soil samples of the four top dying categories (i.e. none = no top dying; moderate, severe and extreme top dying of sundri) as is evident from the insignificant F-ratio in case of data from soil samples from both S (i.e. surface to 30 cm depth) and SS (60-90 cm depth) level of soils from the 17 compartments in the Sundarbans.

Except in case of SS level of Calcium, there were no significant difference in the status of the 17 nutrients obtained from S and SS levels of soil depths from the four top dying categories (i.e. none = no top dying; moderate, severe and extreme top dying of sundri).

In four cases the lowest values were in case of soil from no top dying areas and were insignificantly different from moderately top dying soils. In all these cases severely and extremely top dying soils contained significantly higher levels of these soil parameters as compared to those from no to dying and moderately top dying soils. That means the values were lowest in no top dying areas and highest in either extremely top dying areas or severely tops dying areas. In all cases the highest values were significantly higher than the corresponding value from no top dying areas. But in case of calcium (Ca) there does not exist any such trend as is evident by the fact that calcium level in soil depth from surface to 30 cm calcium level from no top dying area was second highest while calcium from soil depth of 60-90 cm depth was the highest from no top dying compartments. It is thus evident that most likely calcium level has nothing to do with the severity of top tying of sundri (Rahman and Hoque, 2001).

Bhuiyan (1995) collected soil samples from 6 sites of no top dying, 4 sites from moderate top dying, and 10 sites of severe top dying and 6 sites of extreme top dying of sundri in the Sundarbans. The samples were analyzed for electrical conductivity (EC), hydrogen ion concentration (pH), organic matter (OM), nitrogen (N), phosphorus (P), sulphur (S), sulphate (SO4), calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), chlorine (Cl), bicarbonate (HCO3), carbonate (CO3), cation exchange capacity (CEC), sand, silt and clay content. Bhuiyan (1995) did not provide any analysis of the data generated, but simply tabulated the data. Therefore all the data have been critically analyzed. Significant variance among samples from no top dying, moderate, severe and extreme top dying of sundri have been obtained in case of EC, N, Mg, Mn, Zn, and Cl only. Further analysis of these parameters by DMRT (Duncan, 1955) have been done and summarized in **Table 4.**

Table 4: Summary of Duncan's Multiple Range Tests of the mean values of different parameters from analysis of soil samples collected from compartments having no top dying (N), moderate (M), severe (S) and extreme (E) top dying of sundri in the Sundarbans by Bhuiyan (1995) as analyzed by Rahman and Hoque (2001).

Parameter	Mean values with mention of the status of top dying (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters				Comment on the results obtained after Duncan's Multiple range test of the means following the method of Duncan (1955)
EC (0-30 cm)	1.7 (N)	2.14 (M)	2.98(S)	4.40(E)	Electrical conductivity (EC) of soil in 0-30 cm depth in severe and extreme top dying areas were significantly higher (P = 0.05) than that in no top dying and moderate top dying areas.

EC (30-60 cm)	2.04 (N)	2.66 (M)	3.15 (S)	4.23 (E)	Electrical conductivity (EC) of soil in 30-60 cm depth in severe and extreme top dying areas were significantly higher (P = 0.05) than that in no top dying and moderate top dying areas.

EC (60-100 cm)	2.39 (N)	3.10 (M)	3.59 (S)	4.25 (E)	Electrical conductivity (EC) of soil in 60-100 cm depth in moderate, severe and extreme top dying areas were significantly higher (P = 0.05) than that in no top dying areas. The difference between moderate and severe top dying area soils was insignificant. Similarly, insignificant difference existed between severe and extreme top dying areas.

N (0-30 cm)	22.50 (S)	23.50 (N)	33.25 (M)	33.50 (E)	Nitrogen (N) level in soil of 0-30 cm depth in areas of severe and no top dying areas did not differ significantly. Similarly, Nitrogen (N) level in areas of moderate and extreme top dying areas did not differ, although both the latter two values were significantly higher (P =0.05) than that in soils of severe and no top dying areas.
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N (30-60 cm)	18.00 (S)	18.67(N)	28.83 (E)	29.25 (M)	Nitrogen (N) level in soil of 30-60 cm depth in areas of severe and no top dying areas did not differ significantly. Similarly, Nitrogen (N) level in areas of moderate and extreme top dying areas did not differ, although both the latter two values were significantly higher (P =0.05) than that in soils of severe and no top dying areas.
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Mg (0-30 cm)	4.55 (N)	6.55 (M)	6.70(S)	7.62(E)	Magnesium (Mg) levels in 0-30 cm depth soils from moderate, severe and extreme top dying areas were significantly higher (P =0.05) than that in soils from no top dying areas, but the difference among the former three were insignificant.
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Mg (30-60 cm)	4.27 (N)	6.13 (M)	6.05(S)	7.83(E)	Magnesium (Mg) levels in 30-60 cm depth soils from moderate, severe and extreme top dying areas were significantly higher (P =0.05) than that in soils from no top dying areas, but the difference among the former three were insignificant.
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Mg (60-100 cm)	4.18 (N)	6.20 (M)	6.24(S)	7.93(E)	Magnesium (Mg) levels in 60-100 cm depth soils from moderate, severe and extreme top dying areas were significantly higher (P =0.05) than that in soils from no top dying areas, but the difference between the moderate and severe top dying area soils in respect of Mg were insignificant.
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Mn (0-30 cm)	36.33 (N)	45.83 (S)	48.36(E)	145.75(M)	Manganese (Mn) levels in 0-30 cm depth soils from areas of moderate top dying areas were significantly higher (P =0.05) than areas of no top dying areas, in severe and extreme top dying areas, but the difference among the latter three were insignificant.
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Mn (30-60 cm)	37.83 (E)	71.50 (N)	72.91(S)	1124.50(M)	Manganese (Mn) levels in 30-60 cm depth soils from areas of moderate top dying areas were significantly higher (P =0.05) than areas of extreme top dying, no top dying and severe top dying areas, but the difference among the latter three were insignificant.
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Mn (60-100 cm)	44.00 (E)	61.83 (N)	79.55(S)	139.25(M)	Manganese (Mn) levels in 60-100 cm depth soils in areas of moderate top dying areas were significantly higher (P =0.05) than areas of extreme top dying, no top dying and severe top dying areas, but the difference among the latter three were insignificant.
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Zn (0-30 cm)	3.42 (E)	3.98 (S)	6.13(M)	6.15(N)	Zinc (Zn) levels in 0-30 cm depth soil from areas of moderate and no top dying areas were significantly higher (P= 0.05) than that from areas of extreme and severe top dying. areas, but there being only insignificant difference between the latter two. The difference in Zn levels in areas of severe, moderate and no top dying areas were only insignificant.
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Zn (30-60 cm)	3.62 (S)	3.75 (E)	6.53(M)	7.58(N)	Zinc (Zn) levels in 30-60 cm depth soil from areas of no top dying areas were significantly higher (P=0.05) than that from severe, extreme and moderate top dying areas, but there being only insignificant difference among the former three. The difference in Mn levels in areas of moderate and no top dying areas were only insignificant.
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Zn (60-100 cm)	3.48(S)	4.33 (E)	6.63(M)	6.93(N)	Zinc (Zn) levels in 60-100 cm depth soil from areas of moderate and no top dying areas were significantly higher (P=0.05) than severe and extreme top dying areas than that from severe and extreme top dying areas, but there being only insignificant difference between the former two. The difference in Mn levels in areas of extreme, moderate and no top dying areas were only insignificant. than severe and extreme top dying areas.
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Cl (0 -30 cm)	19.7(M)	24.17 (N)	27.90(S)	40.50(E)	Chlorine (Cl) levels in 0-30 cm depth soil from areas of extreme top dying areas were significantly higher (P=0.05) than that from moderate, no top dying and severe top dying areas, but there being only insignificant difference among the former three. The difference in Cl levels in areas of severe and extreme top dying areas were only insignificant.
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Cl (60-100 cm)	31.50(M)	33.13 (N)	34.45(S)	55.26(E)	Chlorine (Cl) levels in 60-100 cm depth soil from areas of extreme top dying areas were significantly higher (P=0.05) than that from moderate, no top dying and severe top dying areas, but there being only insignificant difference among the former three.
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Note:	Means underscored by the same dotted line are not significantly different.				

The pattern of the mean values in case of EC and Mg from all the three soil depths and Zn from surface to 30 cm soil depth show consistent association with top dying of sundri. Similarly, the data of Zn level indicate that deficiency of zinc (Zn) might be associated with top dying of sundri.

Karim (1988) concluded that salinity may not be the direct cause that results top dying condition rather sundri may become vulnerable to other factors which directly cause top dying of sundri within the prevailing salinity range where top dying occurs. Chaffey *et al.* (1985) inferred that increase in soil salinity is an important factor on the onset of top dying.

A comparative presentation of the findings of soil salinity and soil chemical properties of Sundarbans soils by Bhuiyan (1995), Mujibur Rahman (1995) and Chaffey *et al.* (1985) is shown in **Table 5.**

Table-5: Comparative presentation of the findings of soil analysis in relation of top dying of Sundri by Bhuiyan (1995), Mujibur Rahman (1995) and Chaffey *et al.* (1985).

Author »	Bhuiyan (1995)								Mujibur Rahman (1995)				Chaffey *et al.* (1985)							
Soil depth (in cm) »	0-30 cm (D1)		30-60 cm (D2)		60-100 cm (D3)		D1,D2, D3		0-30 cm		60-90 cm		0-5 cm		5-35 cm		35-65 cm		65-100 cm	
Soil parameters	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant	Significant	Insignificant
Electrical conductivity	✓		✓		✓			✓	✓			✓		✓		✓		✓		✓
pH		✓		✓				✓		✓		✓	-	-	-	-	-	-	-	-
OM%		✓		✓	✓		✓	✓		✓		✓	-	-	-	-	-	-	-	-
Nitrogen	✓		✓				✓			✓		✓	-	-	-	-	-	-	-	-
Phosphorus		✓		✓				✓		✓		✓	-	-	-	-	-	-	-	-
Sulphur		✓		✓				✓		✓		✓	-	-	-	-	-	-	-	-
Sulphate		✓		✓	✓			✓		✓		✓	-	-	-	-	-	-	-	-
Calcium		✓		✓				✓	✓		✓		-	-	-	-	-	-	-	-
Magnesium	✓		✓		✓			✓		✓		✓	-	-	-	-	-	-	-	-
Potassium		✓		✓				✓	✓			✓	-	-	-	-	-	-	-	-
Sodium		✓		✓		✓		✓	✓			✓	✓			✓	✓			✓
SAR	-	-	-	-	-	-	-	-	-	-	-	-	✓			✓	✓			✓
Sodium/ Calcium	-	-	-	-	-	-	-	-	✓		-	-	-	-	-	-	-	-	-	-
Iron		✓		✓			✓			✓		✓	-	-	-	-	-	-	-	-
Manganese	✓		✓		✓			✓		✓		✓	-	-	-	-	-	-	-	-
Zinc	✓		✓		✓			✓	-	-	-	-	-	-	-	-	-	-	-	-
Copper		✓		✓				✓		✓			-	-	-	-	-	-	-	-
Boron		✓		✓				✓	-	-	-	-	-	-	-	-	-	-	-	-
Chlorine	✓			✓			✓		✓				-	-	-	-	-	-	-	-
Bicarbonate		✓		✓				✓	-	-	-	-	-	-	-	-	-	-	-	-
Carbonate		✓		✓				✓	-	-	-	-	-	-	-	-	-	-	-	-
Sand				✓					-	-	-	-	-	-	-	-	-	-	-	-
Silt				✓					-	-	-	-	-	-	-	-	-	-	-	-
Clay				✓					-	-	-	-	-	-	-	-	-	-	-	-
CEC		✓		✓				✓	-	-	-	-	-	-	-	-	-	-	-	-
Notes:	**- = Indicates no data was available; Of the significant parameters further analysis of the data in case of Bhuiyan (1995), Mujibur Rahman (1995) and Chaffey *et al.* (1985) are provided in Tables 2, 3 and 4.; SAR = Sodium Absorption Ratio; CEC = Cation Exchange Capacity.**																			

It is evident from **Table 5** that for the same parameter (eg. EC, N etc.) significant variation has been obtained in the data of Bhuiyan (1995) for all the three soil depths while significant variation has been obtained by Mujibur Rahman (1995) for 0-30 cm depth only but insignificant variation obtained for 60-90 cm soil depth; at the same time Chaffey *et al.* (1985) obtained insignificant variation for all the four soil depths (0-5 cm, 5-35 cm, 35-65 cm and 65-100 cm) for EC values. Such variability might have arisen because of the variable time of the year when soil samples were collected by these authors. It may be noted that the date of collection of soil samples is obtained only in case of Bhuiyan (1995), but not for others. Therefore, these data can not really be compared. Furthermore, a significant variance automatically does not mean that lowest or highest value of a particular parameter in question is from areas of no top dying of sundri, but simply refers to that among the four mean values of that particular parameter there exists significant variation. Therefore, further analysis by DMRT (Duncan, 1955) reveal the actual situation in variability. This can be seen from Tables 2, 3 and 4.

A careful look into **Table 5** in association with the Tables 2, 3, and 4 reveal that electrical conductivity, levels of sodium, sodium/calcium ratio, magnesium, chlorine and zinc, particularly in the region of 0-30 cm soil depth have shown some relevance to top dying of sundri. Zinc deficiency showed close association with top dying as in evident from the data in Tables 2 and 4. A thorough search of literature on zinc deficiency reveal that widespread, patchy occurrence of dieback of radiata pine (*Pinus radiata*) was identified with natural zinc deficiency in plantations in South Australia (Boardman and McGuire, 1990). Hassan (1999) noted that zinc content in the estuarine floodplain soils is low or marginal and is less than 1 ppm.

Therefore, soil sampling at regular intervals from selected sites in the Sundarbans exhibiting no top dying, moderate, severe and extreme top dying of sundri should be carried out round the year, preferably for two years, to sort out once for all, the possible role of such parameters in relation to top dying of sundri.

Many authors (e.g. Waisel 1972, Ball and Pidsley 1995) described salinity as the specific dominant factor controlling distribution, growth, and dominance of mangrove species, their ability to reproduce and persist. Hutchings and Saenger (1987), Siddiqi *et al.* (1989) mentioned that high salinity causes mortality of mangroves. However, Clarke and Hannon (1970), Ukpong (1992) and Elster *et al.* (1999) differ with Hutchings and Saenger (1987) and Siddiqi *et al.* (1989) and claim that higher salinity do not cause mass mortality in mangroves rather reduces their growth. Hogarth (1999) recently declined to recognize salinity as the key factor in mangrove zonation.

From the above discussion, it is evident that scientist are divided regarding the role soil salinity in mangrove ecosystem as they are divided about the relationship between STD and salinity. From the discussion above it appears that STD is not related with higher soil salinity. However, despite this confusion we believe that still it is important to try to find any relationship between soil salinity and STD.

It could be argued that the impact of salinity could be significantly different without itself being significantly different. It is well known that different mangrove species has different range of tolerance to salt. Within this tolerance limit a significant variation in the salinity may not produce a significant impact. However, smaller (insignificant) changes beyond this limit are likely to produce significant impact by compounding. **At the present state of knowledge the salt tolerance of sundri is not known except that most authors identified sundri as fresh water species and Karim (1988) and Alam (2001) mentioned that the salt tolerance range of sundri is very limited. Thus, it is important to study salt tolerance of sundri and study the relationship between STD and salinity. For these both field and laboratory data should be collected. This has been duly incorporated in the present study.**

3.3.2.3: Wind damage in the crown and development of top dying of sundri

Observations of Anon (1973), Ahmed (1957) Chowdhury (1968), Sattar (1977), Atiquilah (1973), Chowdhury (1984) Ciesla (1994) and Anon (1995) indicate the relevance between sundri top dying (STD) and wind damage to the forest.

Atiqullah (1973) and Gibson (1975) reported prevalence of STD on the canal bank. Atiqullah (1973), Gibson (1975) and Chowdhury (1984) reported prevalence of STD in older trees. Chowdhury (1984) also mentioned about the damage to the root system caused by cyclones. Here this is to be noted that trees on the riverbank, particularly of big rivers, and older trees are more exposed to wind. The authors, who mentioned about old trees, must have inferred this on the basis of visual observation – height or diameter of trees. In addition, Ahmed (1957) noted that the production of greater opening in the canopy (through heavy thinning and logging) induce development of epicormic branches and render sundri vulnerable to wind damage. As noted by Chowdhury (1968) and Sattar (1977) such damages to the crown of sundri could provide passage to the rot fungi. Hoque (unpublished data) observed girdling on branches of sundri on riverbank produced by regular wind. Such injuries, in addition to causing death of damaged branches, might also enhance attack by fungi.

Rahman (1995) after examining permanent sample plot (PSP) records in the Sundarbans found that out of 17027 sundri trees in total in the PSPs 2.5% were cyclone damaged, 0.6% uprooted by cyclone, 1.3% top broken, 1.9% top dead and 0.9% trees were completely dead. These statistics indicate the severity of cyclone damage in the Sundarbans.

Here this is to be noted that since the inception of management of the Sundarbans, for economic reasons the exploitable diameter of sundri has been reduced from time to time **(Table 1)**. This implies that during felling operations more and more trees are harvested per unit area, i.e., greater openings were developed in the canopy and trees were rendered more vulnerable to wind damage. With this official felling if unofficial felling which amounts to 70% of the Annual Allowable Cut (ACC) is added, the vulnerability of the Sundarbans becomes obvious.
From the discussion above, it appears that there might be some relevance between STD and wind damage to sundri. In such a situation STD could be minimized by devising suitable management technique – increasing the exploitable diameter or reducing the felling cycle which would reduce the volume of timber harvest per unit area in each operation.

Gibson (1975) suggested that repeated cyclone may cause cryptic root damage resulting in the mortality of roots of sundri which might give to reduced flow of water and nutrient in the crown ultimately resulting in the development of top dying condition. Karim (1995) recorded that cyclones affected Sundarbans during May 1833, June 1842, October 1848. May 1852, October 1864, November 1867, May and June 1869, September, 1872, October 1895, November 1901, October 1909, May 1917, September 1919, May 1960, October 1967, October 1969, October 1970, November 1971, December 1973, August 1974, May 1975, May 1977, September & October, 1978 and November 1988. Rahman (1990) examined the state of health of 5 healthy and 8 dying sundri trees at Sutarkhali in the Sundarbans and found only insignificantly higher proportion of dead roots in dying trees as compared to healthy sundri.

To investigate the relationship between STD and wind damage the best way would be to mark some wind-damaged trees (generally after a cyclone) and observe them over a long period of time and this is beyond the tenure of the current project However, limitation of this process is that tree climbing is a cumbersome job and often it is difficult to identify a damage particularly if the STD is in advance stage. The observation on direct wind damage and its effect on subsequent development of top dying of sundri do not rationally fall within the purview of short-term scientific investigation. Since wind throw creates opening in the canopy closure and greater opening in the canopy has been reported to lead to the development of epicormic branching and adventitious crown which render sundri more vulnerable to cyclone damage (Ahmed, 1957; and Balmforth, 1985). **Therefore, it is suggested that canopy closure and its association with top dying, if any should be studied.**

3.3.2.4: Formation of canker/stag headed condition and development of top dying of sundri

Curtis (1933) recorded that sundri appears to be liable to and become unsound (i.e. develop cankers or become stag headed) during the period of its most vigorous growth. This is evident from the proportion of unsound trees in the enumeration results, which were 16.5% for the first quality sundri of 36-38 cm diameter, and 13.4% for the second quality sundri of 28-cm diameter. The average height of the first quality forest is probably 17-18 m. The average diameter upto, which an average sundri tree of this height growth remains sound and healthy, is estimated to be 33 cm, corresponding to an age of 131.5 years. This diameter may be termed as the biologically mature diameter. Sundri trees beyond this size are very liable to develop cankers or become stag-headed. Similarly the corresponding mature diameter of average second quality sundri is estimated to be around 25 cm.

Atiqullah (1973) from field observation in the Sundarbans noted that cankers are more common on top dying sundri trees.

Gibson (1975) reported that top dying of sundri has become increasingly serious, particularly in the northeastern region of the Sundarbans. He noted that top dying sundri generally occurred in the older trees but prevailed at all ages beyond the sapling stage. The disease was the most severe in trees growing on banks of channels. Cankering and gummosis of top dying trees were observed. He recommended that all trees showing early signs of top dying should be felled as a sanitary measure to ensure maximum use of the diseased crop before it is destroyed by insects and rot fungi.

Rahman *et al.* (1983) reported that *Botryosphaeria ribis* was consistently isolated from sundri gall cankers. Pathogenicity tests have shown that the fungus can cause canker on artificial inoculation. It was, therefore, suggested that the fungus is the cause of development of canker and death of sundri twigs in a proportion of sundri trees. The death of twigs gradually reduces the photosynthetic surface on the crown of sundri, which reduces the growth of such affected trees. In this connection it may be mentioned here that Kristic (1964) reported that covered perennial canker and generalized bark necrosis have been found to induce mass killing in forestry stands and plantations. It may, however, be mentioned here that only a proportion of the dying twigs reveal the presence/ and association of canker, while large proportion of dying twigs do not exhibit any gall canker. **It is therefore, suggested that along with the study of the stages of symptom expression, the extent of association of cankers with twig die back of sundri should be studied**. This has been planned in the present programme of study. The presence of canker and its intensity of occurrence on all the sundri trees in the sample plots are being observed at three monthly intervals.

Chowdhury (1984) expressed the opinion that among others canker formation is a cause of top dying of sundri.

Anon (1995) reviewing the works of Rahman (1995) and Ciesla (1994) considered among others the occurrence of a gall canker caused by the fungus *Botryospharia ribis* as a cause of top dying of sundri.

Rahman (1995) noted that cracked perennial gall cankers are often seen associated with dead branches of sundri. During the development of cankers small swellings appear at different locations of young twigs, branchlets, branches. Those gradually enlarge and number of vertical fissures and cracks develop on bark ultimately forming a mass of irregular and rough surfaced bark in the affected area. In some cases the wood is also exposed. In case of an advanced canker, death of sapwood and bark, either in full or in part may occur. When death of sapwood and bark occur due to girdling, the twigs dry up and die. Thus death of small twigs and branches may die due to the occurrence of gall cankers, but trees are also seen where only small twigs and branches die yet there are no gall cankers. It is not known when the initial stages of death of twigs and small branches start. Rahman (1995) noted that between October to December 1994 dead twigs and branches were observed on many hundreds of trees but in no case were dying branches seen. **Further observation from January onward is needed to detect the early stage of symptom expression of dying twigs and small branches.** This has been addressed in the present plan of observation of all the sundri trees in each of the 36 sample plots at three monthly intervals for two years. This is provided in **Data sheet no.12.**

3.3.2.5: Root rot caused by *Ganoderma lucidum* and development of top dying of sundri

Damage in the root systems may result in top dying in the crown of trees (Browne, 1968). Pathogenic root rot has been suggested to cause top dying of sundri (Singh, pers. Communication). Rahman (1995) reported a root rot and resultant dieback of sundri from the Sundarbans. The problem has been seen to occur in the west bank of Bhola river in compartment 2 at Dhanchabari area, on the banks of Kalidah khal off Kotka river in Compartment 6, on the west bank of Pathuria river by the side of Marabhola Coupe office where quite a large number of sundri trees were seen to be affected by root rot resulting in dieback. Characteristic symptoms are that the leaves become gradually discoloured, pale and light yellow, then yellow and finally fall off the tree. Examinations of such trees reveal the presence of root and collar rot, which girdle and actually cause death of such trees. A basidiomycetous fungus has been consistently isolated from such trees. The fungus has been identified a s *Ganoderma lucidum* (Rahman, 1995). The same fungus has been attributed to case similar root rot resulting in the death of pyinkado (*Xylia dolabriformis*) at Lawchara (Rahman, 1989). Sharma and Florence (1996) reported the results of a survey conducted in *Acacia aulacocarpa, A. crassicarpa, A. mangium* and *A. auriculiformis* trial plots and plantations established between 1985 to 1995 in the states of Kerala, Tamil Nadu, Karnataka and West Bengal, revealed that in *Acacia mangium* root rot caused by *Ganoderma sp.* caused extensive mortality. Vember and Reddy (1956) reported root rot of coconut and arecanut palms caused by *Ganoderma lucidum* in Nicobar Islands, while Saksena and Vyas (1964) recorded a root and wood rot of Tamarindus at Sagar in Maddhya Prasesh in India caused by *G. lucidum*. Thind *et al.* (1960) recorded a trunk rot at the base of Quercus sp. tree in Uttar Pradesh in India caused by *G. lucidum*. **It may, however, be mentioned here that only a small proportion of the top dying trees results from root rot. Therefore, no further study is suggested.**

3.3.2.6: Sapwood decay and development of top dying of sundri

Rahman (1995) reported that top dying sundri trees have dead and truncated tops with accompanied death of twigs and branches to a varying degree leaving a variable extent of healthy canopy. A proportion of sundri trees is seen to be dead from top to bottom. Such trees seldom have any live branches. Examination of such dead trees reveal that the bark dies first and is followed by the deterioration of the sapwood and heartwood being already dead. Occasionally both sap rot and heart rot may occur simultaneously. In still other cases even in the absence of any sap rot, death and decay of heartwood by a white rot fungus (*Fomes badius*) occur. In that generally rot destroys the heart wood of the trees, while sapwood remains still healthy, such damage does not cause death of trees, but it weakens the mechanical support of such trees and thereby renders these trees to be more prone to wind damage. Sapwood rot may initiate at near the stem collar, in the mid stem zone or even on the top and then progress both up and down. Dead main stem and branches are consequently broken off by strong wind, resulting in most cases a bare stem. It is very convincingly clear that this type of damage is caused by one or more sapwood decay fungi (Rahman, 1995). Rahman (1995) studied the nature and extent of sap wood rot and its occurrence through careful observation and laboratory examination of top dying affected sundri stems. For that individual sample was sawn longitudinally, the cut surface was cleaned with sandpaper and then closer observation of the distribution of sapwood rot, heart rot and insect damage, if any. In all 52 top dying affected sundri stem samples were examined. These included 5, 14, 15 and 18 samples of A, B, C and D type respectively. The specifications of these four sample types are provided below:

- A: Top portion of top broken sundri with no clear sign of decay further down the stem having crown with profuse normal foliage.
- B: Top broken, some proportion of decay progressing, crown with profuse normal foliage.
- C: Top dead, gradually progressing downwards, foliage to some extent present.
- D: Top dead and broken, little or no crown left, stand severely top dying affected.

In general 93.5% of all the samples showed the presence of sap wood rot and was highly significantly (P =0.01) higher than that of heart rot (50.4%) and significantly higher (P =0.05) than insect tunnels (78% of the samples), while the percent occurrence of insect tunnel in samples was significantly higher (P =0.05) than that of heart rot samples. In case of the mean extent of damage (as % of total length of stem samples) sapwood rot was significantly higher (P =0.05) than heart rot and highly significantly higher (P =0.01) than insect tunnel damage. These results reveal that the occurrence of sapwood rot and its extent was the most dominant in all the four types of samples examined. The death of sapwood and bark was highly correlated. That meant the death of bark was always linked up with the death of sapwood and vice versa. Since heartwood has lower moisture content as compared to sapwood, so heart rot fungi are unlikely to attack sapwood. Moreover, heartwood is deadwood so its rot can never lead to the death of sapwood, bark and foliage in the crown. Insect tunnels were seen scattered either in the sapwood or in the heartwood or in both. More commonly, insect tunnels were associated with rotted sapwood. Therefore, it is suggested that the death of the stem of sundri is connected with the death of sapwood because of the rot of sapwood caused by one or more fungi. But the causal fungi could not be isolated and identified by Rahman (1995). **Therefore, it is suggested that sapwood decay fungi be isolated in pure culture and identified, and their role in the development of top dying is clarified.** In the present programme of study this aspect has been incorporated and the methodology has been clearly spelled out.

3.3.2.7: Pathogenic bacterial infection and development of top dying of sundri

Hartung *et al.* (1998) have reported their findings about the putative biotic disease agents of top dying of sundri in the Sundarbans. For the study the authors collected 20 samples of wood, bark and leaves from compartment nos. 19, 22, 26, 32, and 39 in January 1997. Out of these samples 16 samples were from sundri, while four samples were from unaffected other tree species (2 being from gewa (*Excoecaria agallocha*), 1 from passur (*Xylocarpus mekongensis*), and 1 from goran (*Ceriops decandra*). The sundri samples comprised of 3 from unaffected tree, 2 from pneumatophores, 1 from affected dead standing tree, 2 from dead top of affected tree, 2 from top dying affected felled tree and 1 from seedling in extracted area. The samples were used for isolation of bacteria. Eight types of bacterial colonies were obtained. The colour of bacterial colonies were white, yellow, red, white-yellow, yellow-white, yellow-brown, gray white, shiny white, etc. There was no yield of bacterial colonies from wood tissues taken from unaffected sundri trees (3 samples). Affected dead standing sundri (2 samples), 4 unaffected wood samples of other tree species (2 from gewa, 1 form passur and 1 from goran). Out of the 6 to 8 types of bacterial colonies of two isolates have been identified as *Arthrobacter nicotianae* and *Pseudomonas* sp. due to their sequence homologies in a PCR assay. Both the species of bacteria were isolated from samples of severely top dying affected living sundri trees. The species showed phytopathogenic ability in a bioassay where 3-4 weeks old tomato plants (*Lycopersicon esculentum* MILL. cv. Rutgers) were used as indicator plants. The authors concluded a close association of phytopathogenic bacteria with the top dying disease of sundri (Hartung *et al.* 1998).

A thorough search of literature does not reveal any association of *A. nicotianane* with any other tree disease problem anywhere in the world. Moreover, the data presented do not provide enough evidence of consistent association of *Pseudomonas* sp. with top dying of sundri. *Pseudomonas sp.* has been reported to be associated with a heartwood of white birch in north east China (Chao and Tsai (1958); leaf spot of *Ailanthus triphysa* (Sharma *et al.*, 1987) and partial dieback of *Albizia falcataria* (Sharma and Sankaran, 1987) in Kerala in India. Rahman *et al.* (1997) has reported *Pseudomonas solanacearum* as the causal agent of wilt of teak (*Tectona grandis*) seedlings in a number of nurseries in Cox's Bazar Forest Division in Bangladesh. But no record of these bacteria has been found in the literature on sundri or on any other tree species in the mangrove from anywhere else in the world. **Clearly further data/evidences are needed on bacterial association of top dying of sundri. Therefore, it has been planned to carry out further studies of bacterial association and sundri top dying in the Sundarbans.** This has been covered in the suggested programme of study.

3.3.2.8. Loranthus attack and development of top dying of sundri

Loranthus attack has been suggested as a possible cause of top dying of sundri by a number of authors including Atiqullah (1973), Chowdhury (1984) and Rahman (1995). In general angiospermic parasites (i.e. mistletoes) belonging to the family Loranthaceae can initiate parasitic infestation, cause girdling at the point of attack and can result in the death of the affected branch further up the point of attack. In Bangladesh mistletoe is popularly known as Loranthus. One member of loranthus, *Dendrophthoe falcata* is commonly seen on sundri in the Sundarbans. This is particularly common at Sheker Tek khal area where a limited survey revealed that 34% of the sundri trees are infested by *D. falcata*. This parasite is quite common on sundri on the banks of Kalidah khal, Sundra khal, Kotka khal and Marabhola khal *D.falcata* and other loranthus are known to attack many tree species including *Mangifera indica, Tectona grandis*, cotton plant, while *Scurulla gracilifolia* has been known to cause quite extensive damage on *Gmelina arborea* in the hill forests of Bangladesh (Rahman and Alam, 1994). **But the incidence of *D. falcata* on sundri is not sufficiently abundant or consistent to suggest that they be of a primary consideration as a cause of the top dying of sundri.** Yet, collection of further data about the intensity of occurrence of *D. falcata* has been made to record the infestation of loranthus on each of the sundri trees in all the 36 sample plots laid out in 12 compartments in the Sundarbans without any additional cost involvement.

3.3.2.9: Changes in hydrological condition and development of top dying of sundri

Tidal inundation is not a direct physiological requirement for mangroves but plays important role in the functioning of mangrove (Hutchings and Saenger 1987). It contributes in the dispersal of propagules, brings nutrient in the ecosystem, reduces the concentration of salt and removes toxic materials affects height of the ground water table, drainage and aeration of substrate (Hogarth 1999 and Waisel 1972). Prevailing wind and elevation influence tidal inundation itself (Hutchings and Saenger, 1987).

International Engineering Company Inc. (1980) from study of the water resources of the south western region of Bangladesh stressed the importance of fresh water and alluvium in maintaining soil fertility in the Sundarbans and maintained that the occurrence of sundri is directly related to the amount of fresh water. Reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses.

Sattar (1977) on the basis of an enumeration of top dying affected sundri suggested that mortality of sundri is possibly due to heavy siltation, increase in salinity, reduced flooding by fresh water, alteration in the frequency and duration of inundation of forest floor in the Sundarbans.

Lugo and Snedaker (1975) and Lugo *et al.* (1981) reported that any drastic reduction in the intensity and/or frequency of runoff and flushing within a mangrove stand generally leads to changes in the structure, vigor and mortality patterns of the stand. Diversion of terrestrial runoff, reduction in river discharge, changes in tidal regimes and decreased rainfall are the primary factors that cause changes in such edaphic characteristics as salinity, fertility, degree of anoxia, and so on. For example, reductions in runoff and flushing change the concentration of toxic sulfides and decrease the availability of nutrients in the mangrove soil (Carter, 1973). Reductions in freshwater input allow the concentration of salts in the soil and promote hypersalinity in arid or seasonal climates (Clintron *et al.* 1978). Finally, reductions in flooding promote the oxidation of reduced compounds in the soil and this results in a rapid lowering of pH (Hesse, 1961, Thornton and Giglioli, 1965). Massive tree moralities have been associated with one or several of these factors (Bacon, 1970, Augustinus, 1978). However, *Chaffey et al. (1985)* from chemical analysis of 20 soil samples collected from varying regimes of top dying sundri noted that there is no occurrence of acid sulphate at level which is toxic to plants in the Sundarbans. The soil data generated by Bhuiyan (1995) and Mujibur Rahman (1995) show that there is only insignificant variation in the pH values from soil samples from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans **(Table 5).These suggest that neither formation of acid sulphate or change in pH value of soil is associated with top dying of sundri.**

Shafi (1982) compared the regeneration status of sundri of 1950-60 with those of 1977-80 at Bogi, Chandpai, Kassiabad and Burigoalini. Mean regeneration at Bogi varied from 519 to 691 per ha during 1977-80 compared to 637 per ha in 1959-60. Regeneration of sundri at Chandpai during 1977-80 was drastically low (43 per ha) compared to 822 per ha in 1959-60. Although Forestal (1960) recorded 250 sundri seedlings at Kassiabad and 450 per ha at Burigoalini but Shafi (1982) made no record on regeneration of sundri during 1977-80 in these areas. It was concluded that decrease in fresh water flow in the Sundarbans in dry season due to diversion of the Ganges water at Farakka as well as increased use of ground water for agricultural and industrial uses has caused adverse edaphic changes which resulted in deterioration of the condition of the forests leading to the extensive mortality of sundri especially of young age classes as well as affecting regeneration.

Imam (1982) noted that a system analysis and simulated studies on the ecology of mangrove forests in Florida, USA, have shown that terrestrial water plays a vital role in the development of mangrove biomass, which in turn reflects the gross photosynthesis. It has been construed that both mangrove zonation and vigor are functions of nutrient availability rather than salinity alone

Chaffey *et al. (1985)* noted that Baleshwar and Passur rivers and their distributries have direct link with the Ganges and thus to an uninterrupted supply of fresh water. The Sibsha River and all other rivers to the west of it receive fresh water only from localized catchments lying between the Ganges and the northern edge of the Sundarbans. These rivers are therefore the more susceptible to dry season reduction in stream flow and to tidal intrusions of salt water. It may, however, be noted that more severely affected top dying areas are located in the fresh water and moderately saline water zones.

Jemenz and Lugo (1985) reviewed 28 worldwide reports of massive mangrove tree moralities that occur in response to rapid environmental change and affect all size classes. Massive mortality occurs in addition to normal tree mortality. Diseases and other biotic factors do not appear to be the primary causes of massive mangrove moralities. Instead these factors appear to attack forests weakened by changes in the physical environment. Mangrove environments are dynamical and cyclical and mangrove associations adapt to such environment by both growing and dying fast.

Grepin (1995) suggested that any apparent equilibrium might be fragile, particularly for tall trees in areas where salinity is high. In these circumstances, when trees reach a particular age, it could be that amount of energy required to pump sap to the top of a tree is unable to compensate for osmotic pressure and is not sufficient to pump fresh water out of the ground to the top of the tree, thus creating a damaging level of physiological stress and top dying may ensue or indeed death of the whole tree. Anon (1995) mention that this theory by Grepin would accord with Curtis (1933) who found that sundri trees appeared to show signs of senescence and dieback at the peak of their growth. In this connection it may be mentioned here that transport of nutrient and water to tree crown from root is mostly due to Cohesion-Tension where tension is created due to the transpiration loss of water vapour through the stomata and cohesive force is because of hydrogen bonding of water molecules. These are very well established physiological facts. It is also known that osmotic pressure can account for upward transport of water against atmospheric pressure only for a short distance. **It is thus suggested that the idea of inadequate osmotic pressure to pump fresh water to the crown of tall trees is not theoretically acceptable although it has been suggested by Grepin (1995) and advocated by Anon (1995).**

Karim (1988) through studies on the distribution of sundri in the Sundarbans and through simulation studies (Zashim and Karim, 1992) have suggested some of the probable causes of the decline of sundri in the Sundarbans. The suggested causes include: a) Sundri attains dominance in the latter stage of succession and prefers basin type physiography representing relatively older deltaic formation; b) sundri has a critical level of tidal flooding, above or below which sundri rarely occurs; c) sundri has a critical level of salinity above which its growth is stunted and seedlings also die out; d) unlike other mangrove plants, potassium concentration in the leaves of sundri is higher than sodium This selective ion absorption is an extra-energy requiring process, which can only be maintained in presence of smooth oxygen uptake mechanism. Karim (1988) maintained that areas with excessive sediment deposit might also raise the land elevation that causes reduction of frequency of tidal flooding. Sudden change in flooding regime may thus produce a physiological stress condition for the growth of the mature sundri. It may, however, be noted that Karim (1988) has not provided any evidence or data on the suggested critical level of flooding and salinity. No other available literature does provide any data on these aspects.

From the above presentation on the hydrological conditions a number of features appears to be of importance in relation to sundri top dying which are given below:

- **Mangrove environment receives nutrients from terrestrial fresh water flush and with sea water along with about 40% nutrient from recycling of litter.**
- **Mangrove zonation and vigor are functions of nutrient availability and species interaction rather than salinity.**
- **Reduction of fresh water flush through the Sundarbans has occurred because of upstream diversion of water. This has been coupled with reduced supply of nutrient load to the forest floor.**
- **Reduced flush of fresh water has resulted in increased intrusion of more saline seawater raising salinity, which has affected nutrient uptake to sundri trees.**
- **Baleshwar and Passur rivers and their distributries have direct link with the Ganges and thus to an uninterrupted supply of fresh water. The Sibsha River and all other rivers to the west of it receive fresh water only from localized catchments lying between the Ganges and the northern edge of the Sundarbans. These rivers are therefore the**

more susceptible to dry season reduction in stream flow and to tidal intrusions of salt water.

- **Change in the depth and duration of tidal flooding has occurred in the Sundarbans.**
- **Massive mangrove tree mortality occurs in response to rapid environmental change.**

It order to assess what is known about the above the following discussion /analysis is presented:

Reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses (IECO, 1977, 1980; Shahidullah, 1980; Hannan, 1981; Shafi, 1982; Chowdhury, 1984).

Reduction of the nutrient supply has resulted due to the reduction of fresh water supply in the Sundarbans (Snedaker *et al.*, 1977; Imam, 1982; Chowdhury, 1984).

Reduction in fresh water flush has also been associated with increase in salinity in the Sundarbans (Hannan, 1981; Shahidullah, 1980; Hassan, 1988). The increase in salinity has exerted an increased osmotic stress on the root systems and thereby reduced the availability and uptake of water and nutrients by sundri. This in turn has resulted in reduced growth of sundri in the more saline water areas. The occurrence of the tallest sundri trees are found in the least saline north-eastern and north central Sundarbans, and the most dwarf sundri trees occur in the most saline south-western areas of the Sundarbans support the above statements.

Mujibur Rahman (1995) collected soil samples from a number of compartments from the eastern , central and western parts of the Sundarbans. Compartment numbers 4, 5, 7, 14, 21, 25, 26, 29 and 31 represented eastern parts, 19, 33, 35, 36, 43 and 44 represented central parts and 46, 47, 51A, 52 and 53 represented western parts of the Sundarbans. The soil samples were collected from three depths from surface to 30 cm, 31-60 cm and 61- 100-cm depths and then homogenized to get one sample. All the soil samples were analyzed for pH, electrical conductivity (EC), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), organic matter percent (OM%), available phosphorus (P), sulphur (S), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn) carbonic acid (HCO3) and sulphate (SO4). The summary of the mean values is provided in **Table 6.**

Table 6: Mean levels of 16 soil parameters present in soil samples collected from 9 compartments of eastern zone, 6 compartments of central zone and 5 compartments of western zone of the Sundarbans (from Mujibur Rahman, 1995).

Name	Mean levels of different nutrients present in soil samples collected from compartments falling in		
	Eastern zone	Central zone	Western zone
pH	7.55	6.85	7.76
Electrical conductivity (ds/m)	4.06	8.52	9.43
Sodium (meq/100g)	9.73	20.75	9.38
Calcium (meq/100g)	9.09	7.89	7.68
Magnesium (meq/100g)	8.96	16.08	6.81
Potassium (meq/100g)	0.30	0.65	1.39
Organic matter (per cent)	1.69	2.49	1.54
NH4-N (µg/g)	164.11	91.03	55.94
Phosphorus (µg/g)	10.44	6.23	19.80
Sulphur (µg/g)	332.56	451.07	341.00
Copper	5.87	6.09	20.60
Iron	261.41	306.87	281.92

Manganese	281.33	233.38	255.20
Zinc	2.30	3.25	1.58
Carbonic acid	1.25	1.42	1.89
Sulphate	17.74	24.97	18.81

Analysis of variance with the data in **Table 6** reveals that significant variance have been obtained in case of data from the three zones (i.e. eastern, central and western zones) in case of pH, electrical conductivity, levels of sodium, magnesium, potassium, chlorine, nitrogen in the form of ammonium, phosphorus, copper, and sulphate) as in evident in **Table 7**. But in case of calcium, **organic matter percent, iron, manganese, zinc and carbonic acid** there were no significant variations in soils from the compartments of eastern, central and western zones as insignificant F-ratios were obtained in all these and are therefore excluded from **Table 7.**

Table 7: Summary of Duncan's Multiple Range Tests of the mean values of different parameters from analysis of soil samples collected from compartments falling in eastern, central and western zones in the Sundarbans by Mujibur Rahman (1995) and analyzed by Rahman and Hoque (2001).

Parameter	**Mean values with mention of the zone (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters**			**Comment on the result obtained after Duncan's multiple range test of the means following the method of Duncan (1955)**
pH	7.76 (W)	7.55 (E)	6.85 (C)	Soil pH was significantly higher (P=0.05) in western and eastern compartments as compared to central compartments, but there was no difference between the former two.
	------------	------------		
EC	9.43 (W)	8.52 (C)	4.06 (E)	Electrical conductivity was significantly higher (P=0.05) in western and central compartments as compared to eastern compartments, but there was no difference between the former two.
	------------	------------		
Na	20.75 (C)	9.73 (E)	9.38 ((W)	Sodium content was significantly higher (P=0.05) in central compartments as compared to eastern and western compartments, but there was no difference between the latter two.
		------------	------------	
Mg	16.08 (C)	8.96 (E)	6.81 (W)	Magnesium content was significantly higher (P=0.05) in central compartments as compared to eastern and western compartments, but there was no significant difference between the latter two.
		------------	------------	
K	1.39 (W)	0.65 (C)	0.30 (E)	Potassium values from all the three areas (from eastern, central and western compartments) differed highly significantly (P=0.01).
Cl	87.82 (C)	84.80 (W)	40.96 (E)	Chlorine level was significantly higher (P=0.01) in western and central compartments as compared to eastern compartments, but there was no difference between the former two.
	------------	------------		
NH_4- N	164.11 (E)	91.03 (C)	55.94 (W)	Ammonia as a source of nitrogen was significantly higher (P=0.05) in eastern compartments as compared to central and western compartments, but there was no difference between the latter two.
		------------	------------	
Avail. P	19.80 (W)	10.44 (E)	6.23 (C)	Available phosphorus values from all the three areas (from eastern, central and western compartments) differed highly significantly (P=0.01).
Cu	20.60 (W)	6.09 ©	5.87 (E)	Copper was significantly higher (P=0.05) in western compartments as compared to central and eastern compartments, but there was no difference in the latter two.
		------------	------------	
SO_4	24.97 (C)	18.81 (W)	17.74 (E)	Sulphate was significantly higher (P=0.05) in central compartments as compared to western and eastern compartments, but there was no difference in the latter two.
		------------	------------	

Notes:	Means underscored by ------------ line are not significantly different. W = Western compartments included compartment numbers 46, 47, 51A, 52 and 53; C = Central compartments included compartment numbers 19, 332, 35, 36,43 and 44; E = Eastern compartments included compartment numbers 4, 5, 7, 14, 21, 25, 26, 29 and 31. One plot was taken from each of the compartments mentioned above where from soil samples were collected from three depths (0-30 cm; 31-60 cm and 61-100 cm from each site and then homogenized to get one sample. pH = Negative logarithm of hydrogen ion concentration; EC= electrical conductivity; Na = Sodium; Mg = Magnesium; K= Potassium; OM% = organic matter percent; NH_4- N = nitrogen present in the form of Ammonia; Avail P= Available Phosphorus; S= Sulphur; Cu = Copper; Fe = Iron; Mn = Manganese; Zn = Zinc; HCO_3 = carbonic acid; SO_4 = Sulphate.

It is evident from **Table 7** that highest of the ranked values were obtained from the western zone in case of pH, EC, K, avail. P and Cu but there were no significant difference between levels of pH, Na, Mg, and SO_4 between the western and the eastern zones. In the central zone Sodium, Mg and SO_4 were significantly higher than eastern and western zones. Nitrogen in the form of NH_4 was the highest in the eastern zone and was significantly higher than the central and western zones. In case of potassium (K) and phosphorus (P) were significantly higher in the soil of the western zone as compared to the eastern and central zones. It is suggested that presence of the highest level of nitrogen in the form of NH_4 and the lowest EC, low salinity (as indicated by the presence of low Sodium) in the eastern zone may be primarily responsible for the more pronounced growth of healthy sundri in the eastern zone while the highest Sodium (i.e. the highest salinity in the central zone might have predisposed the sundri trees in the zone to higher osmotic stress and thereby to more adverse top dying situation in the Sundarbans. **Very clearly further insight is needed to understand the mechanisms how these various levels of soil nutrients affect growth of sundri and predispose the severity of top dying of sundri.**

Karim (1988) collected soil samples from 11 compartments of the Sundarbans of which four (compartment nos. 3, 6, 24 and 25) were from the eastern part of the Sundarbans, four (compartment nos. 20, 32, 38 and 40) were from the central part and three (compartment nos. 47, 50B and 54) from the western part of the Sundarbans. From each of the compartment soil sample were collected from three transects, thus 33 soil samples were obtained. Each of these soil samples were analyzed for the level of sodium chloride (NaCl), ratio of sodium and calcium (Na/Ca), cation exchange capacity (CEC), organic matter (OM) and hydrogen ion concentration (pH). The mean values are presented in **Table 8**.

Table 8: Summary of mean values of sodium chloride (NaCl), sodium/calcium ratio (Na/Ca), cation exchange capacity (CEC), organic matter (% of oven dry soil) and hydrogen ion concentration (pH) from 11 sites representing eastern, central and western zones of the Sundarbans (after Karim, 1988).

Soil sampling site and Compartment No.	Mean values of three soil samples from each site				
	NaCl (in ppt)	Na/Ca ratio	CEC (in meq/100g soil)	OM (%) (in oven dry soil)	pH
B1 (Dangsagar) Compt. 25	4.5	0.54	15.53	8.17	6.90
B2 (Sarankhola) Compt. 24	5.2	0.60	18.83	6.23	7.17
B3 (Supoti) Compt. 3	6.2	0.76	23.57	6.77	7.27
B4 (Kachikhali) Compt. 6	9.3	0.92	16.90	6.23	7.57
B5 (Kalabogi) Compt. 32	7.0	0.66	22.00	8.00	7.20
B6 (Kalirkhal) Compt. 38	6.1	0.85	22.93	7.43	7.23
B7 (Hilsamari) Compt. 20	8.4	0.92	21.00	6.63	7.60
B8 (Nilkamal) Compt. 44	10.6	1.3	15.20	6.00	7.47
B9 (Kadamtala) Compt. 47	14.1	2.30	21.90	9.30	6.47
B10 (Kukumari) Compt.50B	13.2	1.96	18.90	5.87	7.67

B11 (Chanbaria) Compt. 54	11.7	1.33	12.43	7.33	7.70
Eastern zone compartments (25, 24, 3 and 6)	6.29	0.70	18.71	6.85	7.23
Central zone compartments (32, 38, 20 and 44)	8.03	0.92	20.28	7.02	7.38
Western zone compartments (47, 50B and 54)	12.98	1.87	17.74	7.50	7.28
Notes: NaCl = Sodium chloride; Na = Sodium, Ca = Calcium, CEC = Cation exchange capacity; OM = organic matter, pH = Logarithm of the reciprocal of hydrogen ion concentration.					

Variance analysis of the data in **Table 8** reveal that in case of CEC and OM% there is only insignificant variations among the 11 sample means, but in case of NaCl, Na/Ca ratio and pH there exist significant (P =0.05) variations. When mean values for the eastern, central and western compartments are pooled together and compared variations were only insignificant in case of pH, CEC and OM%, but significant (P=0.05) variations existed in case of NaCl and Na/Ca ratio. Sodium chloride level was the lowest (6.29 ppt) in the eastern zone, the highest (12.98 ppt) in the western zone, the value in the central zone was intermediate (8.03 ppt). There was no significant variation in NaCl values of the eastern and central zone, but the value from the western zone was very highly significantly higher (P= 0.001) that those from the central and eastern zone. The same was true in case of Na/Ca ratio.

Monthly Soil salinity data of four stations in the Sundarbans of Bangladesh Forest Research Institute (BFRI) at Bogi (Compt. 1), Chandpai (Compt.28), Kassiabad (Compt. 36) and Burigoalini (Compt.46) for the period May 1991 to January, 1994 were examined. For each station soil samples for 0-1 cm, 0-25 cm, 25-50 cm soil depths were collected and analyzed for soil salinity. The summarized data are presented in Table **9.**

Table 9: Soil salinity values at three soil depths at four stations of Bangladesh Forest Research Institute (BFRI) in the Sundarbans during May 1991 to February 1994.

A) Comparison of soil salinity at three soil depths of four stations of BFRI of which Bogi and Chandpai are in the eastern part and Kassiabad and Burigoalini are in the western part of the Sundarbans (three vertical columns present data against three soil depths).					
Station name and compartment	No. of months data	Mean monthly soil salinity in micro mhos at 3 soil depths (in cm)			
		0-1 cm	0-25 cm	25-50cm	
Bogi (Compt.1)	33	3194.70	3185.61	3125.00	NS
Chandpai (Compt.28)	22	4586.36	4602.27	4581.82	NS
Kassiabad (Compt.36)	30	6156.67	6140.00	6083.33	NS
Burigoalini (Compt.46)	33	6633.33	6583.33	6522.73	NS
Note: NS = The soil salinity values from three soil depths of each of the four sites did not differ significantly i.e. was not significant.					

B) Comparison of soil salinity at three soil depths of four stations of BFRI of which Bogi and Chandpai are in the eastern part and Kassiabad and Burigoalini are in the western part of the Sundarbans (three vertical columns present data against four stations).					
Soil depth in cm	Mean monthly soil salinity in micro mhos				
	Bogi	Chandpai	Kassiabad	Burigoalini	
0 to 1 cm	3194.70	4586.36	6156.67	6633.33	***
0 to 25 cm	3185.61	4602.27	6140.00	6583.33	***
25 to 50 cm	3125.00	4581.82	6083.33	6522.73	***
Mean:	3168.44	4590.15	6126.67	6579.79	

Notes: **** = Soil salinity values of Bogi, Chandpai and Kassiabad at all the three depths differed from each other very highly significantly (at P 0.001).
Soil salinity values at Burigoalini were the highest at all the three soil depths and were significantly higher (at P= 0.05) than that at Kassiabad and very highly significantly higher (at P= 0.001) than that at Bogi and Chandpai.

Thus by examining the data presented in the Tables 6, 7, 8 and 9 the following points are clear:

- **Soil salinity in the western zone is highly significantly higher (P =0.001) than the eastern zone of the Sundarbans.**
- **Soil salinity at Bogi, Chandpai, Kassiabad and Burigoalini differ highly significantly from one another, being the lowest at Bogi and the highest at Burigoalini.**
- **There is no significant variation in soil salinity at 0-1 cm, 0-25 cm and 25-50 cm soil depths in the eastern and western zones of the Sundarbans.**
- **Nitrogen nutrition in the eastern zone is 2.9 times higher than the western zone and 1.9 times higher than that in the central zone.**
- **Potassium level is the highest in the western zone and the lowest in the eastern zone, being intermediate in the central zone.**
- **Phosphorus level is the highest in the western zone and the lowest in the central zone, being intermediate in the eastern zone.**
- **In case of cation exchange capacity, pH, calcium, organic matter percent, iron, manganese, zinc and carbonic acid there is no significant variation among the eastern, central and western zones.**
- **There is no information about the depth and duration of flooding at various locations of the Sundarbans in relation to top dying of sundri.**

In the dynamic geomorphological setting of the deltaic mangrove habitat of the Sundarbans, many authors (e.g., Lugo and Snedaker 1975) mentioned that changes in the tidal regime could be related with the STD. In this case the observation of Huda (pers. com.) is particularly important. As it has already been mentioned that to examine this, few depression with STD should be experimentally drained by digging canals. This is beyond the scope and resource limit of the present project. It is suggested that the Forest Department might be able to test this strategy in a number of sites in the Sundarbans.

Mangrove ecosystems are open and heavily dependent on external sources for the supply of nutrients (Ball 1988). Hogarth (1999) observed that most of the nutrients available to mangroves are terrestrial in origin. These nutrients deposit in the mangrove habitat in the form of sediment. The rate of sedimentation depends on the velocity of water current, sediment load in rivers and size of the sediment particles (FA0 1994), and frequency and depth of inundation. The rate of sedimentation plays an important role in nutrient cycling in mangrove ecosystem (Waisel 1972) and the growth and development of mangroves. In areas where the rate of sedimentation is low, as in the western part of the Sundarbans, the growth of plants are also slow and might also cause disappearance of mangroves (Hogarth 1999).

However, excess sedimentation is proved to be harmful for mangroves. In mangrove habitat the availability of nutrient and oxygen varies with the depth of substrate – nutrients only in the top 10-cm of the substrate are available to plants and the availability of oxygen decreases with the increase in depth. In sedimentary/depository environment, the nutrient rich layer of substrate (top 10 cm) continuously moves upward and mangrove response to it by repeatedly producing feeder roots in this layer abandoning the deeper roots. Similarly, in such environment the availability of oxygen to the root layer decreases with sedimentation. Mangroves respond to it by producing new set of cable roots, large number of pneumatophores (Hogarth 1999), secondary growth of pneumatophores (Chapman 1976) and increased number of lenticels on pneumatophores, stem, and aerial roots (Hogarth 1999). However, with very heavy sedimentation, plants may not be able to cope with and face the consequences.

Lugo and Snedaker (1974) suggested that gross primary productivity of mangrove increases with the availability of fresh water. The fresh water input to the estuary is associated with physical, chemical, geological and biological melange for the fauna and flora of the estuary/coastal zone. This input tends to enrich the sites (Snedaker *et al.* (1977)

3.4: Chronological listing of relevant studies conducted, main findings and recommendations on top dying of sundri in the Sundarbans

During 1916 death of sundri trees in small groups near water channels in the Sundarbans were observed by scientists of Dehra Dun Forest Research Institute and was considered to be due to root rot (Singh, pers. comm.).

Troup (1921) noted that sundri trees growing in depressions tend to deteriorate rapidly and die off. Severe damage is caused periodically by cyclones, which uproot the trees, break the tops off, or tear off the branches. The severe cyclone of 1909 caused immense damage to sundri.

Curtis (1933) found that sundri attains 0.004 cubic meter per year growth between the ages 141-148. It attains 36-37 cm in diameter at maturity. A second quality sundri tree attains its maximum average timber increment of 0.002 cubic meter per year at the age of 147 years when it reaches 28 cm in diameter. Unfortunately, comparatively few trees appear to survive to these ages in their respective site qualities. Sundri appears to be liable to become unsound (i.e. develop cankers or become stag headed) during period of its most vigorous growth. This is evident from the proportion of unsound trees in the enumeration results, which are 16.5% for the first quality sundri of 36-38 cm diameter, and 13.4% for the second quality of 28-cm diameter. The average height of the first quality forest is probably 17-18 m. The average diameter upto, which an average sundri tree of this height growth remains sound and healthy, is estimated to be 33 cm, corresponding to an age of 131.5 years. This diameter may be termed as the mature diameter. Sundri trees beyond this size are very liable to develop cankers or become stag-headed. Similarly the corresponding mature diameter of average second quality sundri is estimated to be around 25 cm.

Ahmed (1957) reported that in the compartments 30, 31 and 32 on an average the number of sundri in diameter class 7.5 cm and above were 266 and 233 per hectare. He also recorded the number of sundri seedlings and saplings upto 8-cm in diameter in the compartments 3, 15, 19, 29, 37, 50 and 51 in randomly selected sample plots. The average number of sundri within the diameter limit was 837 per hectare. He recorded 13-17% unsound (top dying) sundri trees were in the Sundarbans. He noted that production of greater opening in the canopy (through heavy thinning or logging) induce development of epicormic branches and render *H. fomes* vulnerable to cyclonic damage. This may indicate association between top dying of *H. fomes* and wind damage.

Forestal (1960) recorded top dying of sundri in the Sundarbans.

Chowdhury (1968) noted cyclone torn crown of *H. fomes* and opined that it could provide passage to rot fungi.

Rahman and Zethner (1971) recorded two major heart rot fungi (e.g. *Fomes conchatus and F.*

rimosus) and seven common heart rot fungi (*Fomes badius, Hymenochaete tabacina, Schizophyllum commune, Hypoxylon sp.,Poria spp., Trametes spp.*) on sundri.

Sobhan (1973) compared the chemical and physical properties of triplicate soil samples collected from severely affected top dying and healthy sundri area in the Sundarbans. The results showed that there was little difference in chemical properties of the two regions and the sand component of the healthy sundri areas was much higher than in top dying areas.

Atiqullah (1973), the then Director Bangladesh Forest Research Institute (BFRI), who with a team of seven members intensively visited different areas of the Sundarbans, visited top dying sundri and noted that top dying of sundri is more in the a) northern compartments, b) on river banks, c) on old aged trees, and may be due to d) the attack of loranthus and e) cankers are more common on top dying sundri.

Chowdhury (1973) observed plenty of *Chrysocroa sp.* (Coleoptera: Buprestidae) beetle in the twig crotches of dead and dying sundri trees n the compartment nos. 29 and 30 at Marapassur and adjacent areas. The role of Chrysocroa sp. in the initiation of top dying of sundri was subsequently studied and reported by Chowdhury and Baksha (1983).

Lugo and Snedaker (1974) suggested that gross primary productivity of mangrove increases with the availability of fresh water. The fresh water input to the estuary is associated with physical, chemical, geological and biological melange for the fauna and flora of the estuary/coastal zone. This input tends to enrich the sites.

Gibson (1975) reported that top dying of sundri has become increasingly serious, particularly in the northeastern region of the Sundarbans. He noted that top dying generally occurred in the older trees but it also prevailed at all ages beyond the sapling stage. The disease was most severe in trees growing on banks of channels. Cankering and gummosis of top dying trees were observed. He recommended that all trees showing early signs of top dying should be felled as a sanitary measure to ensure maximum use of the diseased crop before it is destroyed by insects and rot fungi.

Lugo and Snedaker (1975) and Lugo *et al* (1981) reported that any drastic reduction in the intensity and/or frequency of runoff and flushing within a mangrove stand generally leads to changes in the structure, vigor and mortality patterns of the stand. Diversion of terrestrial runoff, reduction in river discharge, changes in tidal regimes and decreased rainfall are the primary factors that cause changes in such edaphic characteristics as salinity, fertility, degree of anoxia, and so on. For example, reductions in runoff and flushing change the concentration of toxic sulfides and decrease the availability of nutrients in the mangrove soil (Carter, 1973). Reductions in freshwater input allow the concentration of salts in the soil and promote hypersalinity in arid or seasonal climates (Clintron *et al* 1978). Finally, reductions in flooding promote the oxidation of reduced compounds in the soil and this results in a rapid lowering of pH (Hesse, 1961, Thornton and Giglioli, 1965). Massive tree moralities have been associated .with one or several of these factors (Bacon, 1970, Augustinus, 1978). However, *Chaffey et al. (1985)* noted that there is no occurrence of acid sulphate, which is toxic to plants, in the Sundarbans.

Sattar (1977) on the basis of an enumeration of top dying affected sundri suggested that mortality of sundri is possibly due to heavy siltation, increase in salinity, reduced flooding by fresh water, alteration in the frequency and duration of inundation of forest floor in the

Sundarbans. Sattar (1977) noted that occasionally tops and branches of sundri are broken by cyclones. Heart rot fungi then cause further damage.

Reduced nutrient supply has resulted from the reduction of fresh water supply in the Sundarbans (Snedaker, 1977).

International Engineering Company Inc. (1980) from study of the water resources of the south western region of Bangladesh stressed the importance of fresh water and alluvium in maintaining soil fertility in the Sundarbans and maintained that the occurrence of sundri is directly related to the amount of fresh water.

Shahidullah (1980) recorded that reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses.

Hannan (1981) noted that reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses.

Hassan (1981) reported that reduction the fresh water flush through the Sundarbans has also been associated with increase in salinity.

Islam (1982) noted that lime is a normal component of the Himalayan alluvium and is expected to alleviate adverse effect of soluble sodium.

Imam (1982) noted that a system analysis and simulated studies on the ecology of mangrove forests in Florida, USA, have shown that terrestrial water plays a vital role in the development of mangrove biomass, which in turn reflects the gross photosynthesis. It has been construed that both mangrove zonation and vigor are functions of nutrient availability rather than salinity alone.

Shafi (1982) compared the regeneration status of sundri of 1950-60 with those of 1977-80 at Bogi, Chandpai, Kassiabad and Burigoalini. Mean regeneration at Bogi varied from 519 to 691 per ha during 1977-80 compared to 637 per ha in 1959-60. Regeneration of sundri at Chandpai during 1977-80 was drastically low (43 per ha) compared to 822 per ha in 1959-60. Although Forestal (1960) recorded 250 sundri seedlings at Kassiabad and 450 per ha at Burigoalini but no record on Shafi (1982) made regeneration of sundri during 1977-80 in these areas. It was concluded that decrease in fresh water flow in the Sundarbans in dry season due to diversion of the Ganges water at Farakka as well as increased use of ground water for agricultural and industrial uses has caused adverse edaphic changes which resulted in deterioration of the condition of the forests leading to the extensive mortality of sundri especially of young age classes as well as affecting regeneration.

Imam (1982) noted that a system analysis and simulated studies on the ecology of mangrove forests in Florida, USA, have shown that terrestrial water plays a vital role in the development of mangrove biomass, which in turn reflects the gross photosynthesis. It has been construed that both mangrove zonation and vigor are functions of nutrient availability rather than salinity alone. He inferred that reduced nutrient supply has resulted from the reduction of fresh water supply in the Sundarbans.

Rahman *et al* (1983) reported that *Botryosphaeria ribis* was consistently isolated from sundri gall cankers. Pathogenicity tests have shown that the fungus can cause canker on artificial inoculation. It was, therefore, suggested that the fungus is the cause of development of canker and death of sundri twigs in a proportion of sundri trees. The death of twigs gradually reduces the photosynthetic surface on the crown of sundri, which reduces the growth of such affected trees. In this connection it may be mentioned here that Kristic (1964) reported that covered perennial canker and generalized bark necrosis have been found to induce mass killing in forestry stands and plantations.

Chowdhury and Baksha (1983) studied the role of *Chrysocroa SP* beetle in the initiation of top dying of sundri. For the study three top dying and one healthy sundri trees were selected at random in compartment nos. 1, 32 and 46 representing fresh water, moderately saline water and saline water zones in the Sundarbans. All the 12 trees were felled and splited thoroughly from top to bottom. The positions of the dead branches, larval tunnels and heart rots were recorded in relation to the position on the stem of each tree. There were in all 19 dead branches of which the relative positions of 15 branches were from the sites of the larval tunnels and heart rots. Heart rot was observed in 11 out of 12 trees, while larval tunnels were observed 8 trees out of 12 trees. It became obvious that larval tunnels and/or heart rots did not have any contiguity with the dead branches. Even the tissues at the base of the branches were found to be healthy and the entrance holes of the larval tunnels were healed up. They observed that *Chrysocroa sp.* (Coleoptera: Buprestidae) did not have any role in the initiation of top dying of sundri in the Sundarbans.

Chowdhury (1984) expressed the importance of fresh water flush in the Sundarbans and maintained that the causes of top dying of sundri may include a) mechanical damage to root system caused by successive cyclones; b) old age of sundri; c) changes in edaphic conditions; d) loranthus attack; e) canker formation. Reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses. He noted that reduced flush of fresh water cause thinner and shorter growth of sundri.

Snedaker (1984) noted that in general salinity is a controlling factor in the floristic ecology of the Sundarbans.

Christensen (1984) stated that salinity may not were a direct cause of top dying of sundri but is an indicator of many geochemical processes that have an impact on living organisms (e.g. by affecting nutrient availability).

Chowdhury (1984) reported that reduced nutrient supply has resulted from the reduction of fresh water supply in the Sundarbans.

Chaffey *et al.* (1985) collected soil samples from 20 sites covering no top dying, moderate top dying, severe top dying and extreme top dying from 10 compartments (i.e. compartment nos. 1, 3, 13, 16, 22, 32, 33, 35, 36 and 38) in the Sundarbans. The 8 sites in no top dying of sundri areas were in the compartment nos. 1, 3, 13, 16 and 22; the 3 sites in moderate top dying areas were in compartment nos. 33, 35 and 38; the 5 sites having severe top dying of sundri were in compartments 32, 33, 36 and 38; and 4 sites having extreme top dying of sundri fell in the compartments 33 and 38. The samples were analyzed for electrical conductivity (EC), soluble and exchangeable sodium (Na) and the sodium absorption ratio (SAR).

The values of EC, Na and SAR were taken together as a measure of soil salinity. They found no evidence of acid sulphate was found which adversely affect plant growth. It was mentioned that the results of soil analysis strongly indicated a relationship between the presence of top dying and the concentration of sodium in the soil profile. Soil salinity was higher on sites affected by top dying than on unaffected sites. This suggests the increase in soil salinity is an important factor on the onset of the top dying. It was concluded that the environment in most of the areas of Sundarbans is not conducive for the growth and survivability of sundri.

Chaffey *et al.* (1985) which mainly occur in 20 compartments (viz. 6, 14, 17, 18,21, 23, 25, 26, 28, 31, 32, 33, 35, 38, 39, 40, 42, 45,46 & 47) out of 55 compartments of the Sundarbans.

Chaffey *et al. (1985)* noted that Baleshwar and Passur rivers and their distributries have direct link with the Ganges and thus to an uninterrupted supply of fresh water. The Sibsha River and all other rivers to the west of it receive fresh water only from localized catchments lying between the Ganges and the northern edge of the Sundarbans. These rivers are therefore the more susceptible to dry season reduction in stream flow and to tidal intrusions of salt water. It may, however, be noted that more severely affected top dying areas are located in the fresh water and moderately saline water zones. This observation contradicts with the inference drawn by *Chaffey et al. (1985)* that salinity is a factor in the presence or absence of sundri top dying.

Chaffey *et al. (1985)* inferred that increase in soil salinity is an important factor on the onset of top dying. They mentioned about an association between higher soil salinity and top dying of *H. fomes* but without consistent correlation.

Balmforth (1985) published the results of a descriptive sampling with reference to top dying of sundri at Chandpai and Kalabogi areas. He noted that the incidence of epicormic branching and formation of adventitious crowns in the older mature stands was found to be high at Chandpai, while it was hardly seen in the younger or immature stands at Kalabogi.

Jemenz and Lugo (1985) reviewed 28 worldwide reports of massive mangrove tree, moralities that occur in response to rapid environmental change and affect all size classes. Massive mortality occurs in addition to normal tree mortality. Diseases and other biotic factors do not appear to be primary causes of massive mangrove moralities. Instead these factors appear to attack forests weakened by changes in the physical environment. Mangrove environments are dynamical and cyclical and mangrove associations adapt to such environment by both growing and dying fast.

Bangash and Gardiner (1985) reported that boron deficiency is known to cause large-scale dieback in forest. But levels of boron found in soil analysis by *Chaffey et al. (1985)* are not correlated with top dying of sundri.

Hassan (1987) provided data on soil salinity of a number of sites in the Sundarbans. He also studied the effect of salinity on sundri seedlings in a simulated experiment conducted at BFRI campus. The data on salinity were compared with those of Chaffey *et al.* (1985). It was observed that the top dying did not show any consistent relationship with salinity. Moreover, regeneration and survival of sundri seedlings did not show any change due to water salinity variation between the range 1000 to 49 000 micro mhos under the experimental conditions.

Sheil and Ross (1987, pers. communication) at Cambridge studied Na+ and K+ levels in sundri tissues and found that a) the Na+/K+ ratios in the tissues of healthy sundri trees appear to be related to the salinity of their local environment; b) the average percentage of Na+ and K+ was not significantly different in healthy and top dying sundri trees; c) though some form of link was indicated between top dying and ionic balance in sundri tissues, it was not possible to resolve the causal factor and its effect. They, however, concluded that these observations are compatible with a pathogenic cause as suggested by Rahman *et al* (1983).

Habib (1988) studied in compartment 33 the lengths of pneumatophore above and below soil level in top dying and healthy sundri areas and reported that there is a correlation between burial of pneumatophores and occurrence of top dying of sundri. He observed that the under ground part of pneumatophores of top dying *H. fomes* trees were longer than those of healthy trees and it was reverse for above ground part. This indicates that top dying of *H. fomes* could be associated with higher sedimentation rates.

Karim (1988) through studies on the distribution of sundri in the Sundarbans and through simulation studies (Zashim and Karim, 1992) have suggested some of the probable causes of the decline of sundri in the Sundarbans. The suggested causes include: a) Sundri attains dominance in the latter stage of succession and prefers basin type physiography representing relatively older deltaic formation; b) sundri has a critical level of tidal flooding, above or below which sundri rarely occurs; c) sundri has a critical level of salinity above which its growth is stunted and seedlings also die out; d) unlike other mangrove plants, potassium concentration in the leaves of sundri is higher than sodium This selective ion absorption is an extra-energy requiring process, which can only be maintained in presence of smooth oxygen uptake mechanism. Karim (1988) concluded that salinity may not be the direct cause that results top dying condition rather sundri may become vulnerable to other factors which directly cause top dying of sundri within the prevailing salinity range where top dying occurs. It is maintained that areas with excessive sediment deposit may also raise the land elevation that causes reduction of frequency of tidal flooding. Sudden change in flooding regime may thus produce a physiological stress condition for the growth of the mature sundri. Moreover, sudden deposit of fresh coarse sediment may change the constituent of the nutrient pool in the root system. Sundri having preferred optimum condition in the latter stage of succession may suffer due to the changed nutrient pool. This change of status of the substrate due to the change in the geomorphological feature is an irreversible phenomenon in the context of present ecological features of the Sundarbans.

Rahman *et al.* (1990) recorded the presentation in a national seminar on top dying of sundri (*Heritiera fomes*) trees in the Sundarbans which was held on August 11, 1988 at Bangladesh Agricultural Research Council in Dhaka. It was revealed in the discussion of the seminar that studies so far conducted on top dying of sundri are fragmentary in nature and limited in scope. Hardly any study has been made on ecological and physiological factors. A number of factors rather than a single factor may be responsible for the top dying of sundri. Solutions are; therefore, not likely to be found in simplistic single factor studies. A multidisciplinary study within a system framework has been advocated. Field observations revealed that incidence of top dying of sundri is more pronounced in places where more siltation has occurred. The length of pneumatophores above soil, in more silted up areas where sundri is dying is predominant, is comparatively less than in areas of reduced siltation where sundri is dying is predominant, is comparatively less than in areas of reduced siltation where sundri is healthy. This suggests that under heavily silted up conditions, area of pneumatophores with functional lenticells be reduced which results in reduced root respiration and affect the physiological processes. Therefore, change of the condition is the likely primary cause of top dying of sundri. A detailed study should be taken up on a priority basis to determine the effect of change of site condition and the role of pneumatophores on the top dying of sundri. The seminar recommended a number of studies and advocated salvage felling for better recovery and use of top dying affected trees (Rahman *et al.* 1990).

Rahman (1990), based on the survey data provided by *Chaffey et al. (1985)*, determined over 45.2 million sundri trees that have been affected by top dying in the Sundarbans. Out of this 25.02 million trees occupying 25446 ha had developed moderate top dying (less than 50% of the crown dead) and 20.18 million trees covering 19,848 ha were severely affected (more than 50% of the crown dead).

Rahman (1990) based on a critical review of available information listed the following as the possible causes of top dying of sundri: a) increase in salinity due to reduction of the flow of fresh water through the Sundarbans, b) alteration in the depth and duration of flooding, c) formation of pathogenic gall canker on sundri branches, d) cryptic root damage due to repeated cyclones, e) epicormic branching following cyclone damage on the crown, f) increased siltation, g) loranthus infestation, h) insect damage, i) old age, j) deficiency of micronutrient.

Ciesla (1994) noted that biotic factors such as weak pathogenic fungi, bark beetles, wood boring insects which are capable of overcoming trees weakened by predisposing and inciting factors and eventually kill the trees. The suggested predisposing, inciting and contributing factors are provided below:

Predisposing factors	Inciting factors	Contributing factors
• Relative low tolerance to salinity.	Frequent storms and tidal surges resulting in defoliation of sundri by high winds, deposition of marine sediments and mechanical injury to standing trees.	Invasion of wounds by decay fungi and the gall canker fungus *Botryosphaeria ribis* Wood boring insect e.g. *Chrysocroa sp.*

Rahman (1995) in BGD/84/056 detected and diagnosed two conditions which may have been previously been confused with top dying of sundri. One is the occurrence of localized areas of massive dieback and mortality of sundri due to siltation of the pneumatophores. The second disorder is infection of roots by the fungus Ganoderma lucidum which causes death of trees in small groups. Such sites with massive death of sundri have been seen to occur on the north bank of Tapamari khal (Compartment 39), at Jaliakhal bank and north of Gewakhali Copue Office (Compartment 20); adjacent to Sarbotkhali (north of Compartment 32 and southern area of Compartment 33); east of Sibsa Petrol Camp (Compartment 34), at Sheker Tek just at the approach of Sheker Tek ruins in Compartment 39; at the bank of Jafa khal between Jafa and Chamta (in Compartment 38). Root rot and resultant dieback of sundri have been found on the west bank of Bhola river in compartment 2 in Dhanchabari area, on the bank of Kalidah khal off Kotka river in compartment 6, on the bank of Pathuria river by the side of Marabhola coupe office. Characteristic symptoms are that the leaves become gradually discoloured, pale and light yellow, then yellow and finally fall off the tree. Examinations of such trees reveal the presence of root and root collar rot, which girdle and actually cause death of such trees. A basidiomycetous fungus, *Ganoderma lucidum* has been found to be the cause of such root rot of sundri. Top dieback of sundri is clearly the most serious disease problem affecting the forests of the Sundarbans.

Rahman (1995) suggested that totally dead but standing sundri with very little branches left on the stem, result from one or more sap wood decay fungi which attack healthy trees through injured or dead broken branch stub, and then kill the bark and sapwood, cause partial or complete girdling and thus result in the death of such trees because of interruption of the flow of water and nutrients from roots to the shoots and of prepared food materials from shoots for use in the roots. Sapwood rot mav initiate at near the stem collar; in mid stem zone or even on the top and then progress both up and down. Dead main stem and supported branches are consequently broken off by strong wind, resulting in most cases a bare stem. It is very convincingly clear that this type of damage is caused by one or more sapwood decay fungi. Therefore, it is imperative that further study about the causal factor of sap wood decay and development of top dying of sundri is likely to provide information which will be useful for development of suitable management strategies for sustainable management of sundri in the Sundarbans.

Rahman (1995) on the basis of data generated on wood deterioration associated with top dying of sundri for the compartments 32, 36, 37, 38 and 39 estimated that 42.07% ± 7.08% (at P= 0.05) of sundri total wood was found deteriorated. This is considered to a very heavy economic loss. The Forest Department recognizes top dying of sundri as the key management concern of the Sundarbans.

Rahman (1995) reported that in a number of sites where excessive siltation has buried all or a portion of the pneumatophores, sundri in particular and other tree species in general have been seen to produce leaves of very diminished size, light bronze in colour, having a general pale appearance. Such trees can add very little new growth. Quite often such branches are seen to die and ultimately most of the affected trees die or show rapid death from the top downwards. Such trees with massive death of sundri have been seen to occur on the north bank of Tapamari khal (Compartment 39), at Jaliakhal bank and north of Gewakhali Copue Office (Compartment 20); adjacent to Sarbotkhali (north of Compartment 32 and southern area of Compartment 33); east of Sibsa Petrol Cam (Compartment 34), at Sheker Tek just at the approach of Sheker Tek ruins in Compartment 39; at the bank of Jafa khal between Jafa and Chamta (in Compartment 38).

Rahman (1995) reported that scattered top dead and truncated trees with varying degrees of healthy crown on partly living main stem are typical of top dying sundri. In such trees scattered twigs and branches may die because of a fungal gall canker causes by *Botryosphaeria ribis* or without it. In the latter case some other still unknown biotic (fungal/bacterial) or abiotic factors may be responsible for death of twigs and branches. Main stem may be broken by cyclone, which is secondarily invaded by one or more sap wood decay fungi causing progressively downward death of the stem and thereby of the associated branches as well. Cyclones or strong wind may easily break off such portion of the affected main stem. This results in a truncated condition. However, stems with or without sapwood decay, may also be invaded by one or more heart rot fungi (as for instance *Fomes badius*, and beetle (eg. *Chrysocroa sp.*) which cause tunneling either in healthy or dead sapwood or heartwood. Insect tunneling is of very limited occurrence and causes the least damage. Sapwood decay is the main cause of downward and progressive death of the main stem.

Rahman (1995) found that group dying of sundri is due to a root rot caused by *Ganoderma lucidum*, which attacks and causes rot of major roots as well as collar of healthy trees. A white rot of bark and sapwood develops in such cases. This results in the destruction of passage of water and mineral nutrients from roots to the shoots while loss of water from leaves to the atmosphere continues due to transpiration resulting from the exposure of the tree crown to solar heat. In such situation the foliage first turn pale green, light yellow, yellow and finally fall off the trees, leaving bare leafless trees. The branches than gradually dry up and ultimately breaks off the tree because of establishment of secondary decay fungi and /or strong wind (Rahman, 1995). The increase in salinity has exerted an increased osmotic stress on the roots and thereby reduced the availability and uptake of water and nutrients by sundri. This in turn has resulted in reduced growth of sundri in the more saline areas. The occurrence of the tallest sundri trees are found in the least saline north east and north central Sundarbans, and the most dwarf sundri trees occur in the most saline south western areas of the Sundarbans support the above statements.

Rahman (1995) on the basis of much better understanding of the problem of top dying of sundri then ever before, suggested that the cause of top dying of sundri in the Sundarbans is a complex phenomenon regarding which previously suggested hypothesis (Rahman, 1990) was revised. The revised hypothesis id provided below:

a) Reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses (IECO, 1977, 1980; Shahidullah, 1980; Hannan, 1981; Shafi, 1982; Chowdhury, 1984).

b) Reduced nutrient supply has resulted from the reduction of fresh water supply in the Sundarbans (Senedaker, 1984; Imam, 1982; Chowdhury, 1984).

c) Reduction in the fresh water flush has also been associated with increase in salinity (Hannan, 1981; Shahidullah, 1980; Hassan, 1988). The increase in salinity has exerted an increased osmotic stress on the roots and thereby reduced the availability and uptake of water and nutrients by sundri. This in turn has resulted in reduced growth of sundri in the more saline areas. The occurrence of the tallest sundri trees are found in the least and moderately saline north east and north central Sundarbans, and the most dwarf sundri trees occur in the most saline south western areas of the Sundarbans support the above statements.

d) Top dying is still considered to be the major disease problem affecting the health of sundri in the Sundarbans. Previously all of the dying and dead sundri trees were considered to be top dying. However, study by Rahman (1995) revealed that there is a number of often-independent diseases and disorders, which can lead to the death of sundri in the Sundarbans. These include:

i) Scattered top dead and truncated trees with varying degrees of healthy crown on partly living main stem are typical of top dying sundri. In such trees scattered twigs and branches may die because of a fungal gall canker causes by *Botryosphaeria ribis* or without it. In the latter case some other still unknown biotic (fungal/bacterial) or abiotic factors may be responsible for death of twigs and branches. Main stem may be broken by cyclone, which is secondarily invaded by one or more sap wood decay fungi causing progressively downward death of the stem and thereby of the associated branches. Cyclones or strong wind may easily break off such portion of the affected main stem. This results in a truncated condition. However, stems with or without sapwood decay, may also be invaded by one or more heart rot fungi (as for instance *Fomes badius*, and beetle (eg. *Chrysocroa sp.*) which cause tunneling either in healthy or dead sap wood or heart wood. Insect tunneling is of very limited occurrence and causes the least damage. Sapwood decay is the main cause of downward and progressive death of the main stem.

ii) Totally dead but standing sundri with very little branches left on the stem, result from one or more sap wood decay fungi which attack healthy trees through injured or broken branch stub, and then kill the bark and sapwood, cause partial or complete girdling and thus result in the death of such trees because of interruption of the flow of water and nutrients from roots to the shoots and of prepared food materials from shoots for use in the roots. Sapwood rot may initiate at near the stem collar, in the mid stem zone or even on the top and then progress both up and down. Dead main stem and supported branches are consequently broken off by strong wind, resulting in most cases a bare stem. It is very convincingly clear that this type of damage is caused by one or more sapwood decay fungi.

iii) Group dying of sundri is due to a root rot caused by *Ganoderma lucidum*, which attacks and causes rot of major roots as well as collar of healthy trees. A white rot of bark and sapwood develops in such cases. This results in the destruction of passage of water and mineral nutrients from roots to the shoots while loss of water from leaves to the atmosphere continues due to transpiration resulting from the exposure of the tree crown to solar heat. In such situation the foliage first turn pale green, light yellow, yellow and finally fall off the trees, leaving bare leafless trees. The branches than gradually dry up and ultimately break off the tree because of establishment of secondary decay fungi and /or strong wind.

iv) Massive mortality of sundri in localized area occurs when sundri pneumatophores become buried because of heavy siltation. Mangrove swampy soil has very little air passage. For that to provide the required supply of air for normal metabolic activities of the root, oxygen is supplied to the roots through lenticels of the pneumatophores. This is a well-known biological process. In sites with heavy siltation pneumatophores become almost or totally buried. That drastically cuts off oxygen supply to the roots, when roots start dying and start to loss their ability for normal absorption and uptake of water and nutrient for the shoots. In such a situation shoot start function abnormally in absence of adequate manufacture of photosynthetic products. Such trees first fail to support adequate growth of the foliage, which then becomes smaller, deformed and bronze in color. Because of the change of site condition such trees suffer massive mortality in localized areas.

Anon (1995) reviewing the works of Rahman (1995), Chowdhury (1995) and Ciesla (1994) considered the following factors in relationship to top dying of sundri:

- Reduction of fresh water supply due to upstream diversion of water resulting in increased salinity and reduced flow of nutrients.
- The moratoriums on tree felling between 1972 and 1976.
- Occurrence of a gall canker caused by the fungus *Botryospharia ribis.*
- Infestation by a wood boring beetle, *Chrysocroa sp.* (Coleoptera: Buprestidae)
- Tree damage resulting from cyclones.
- Variation in the depth and frequency of flooding.
- Siltation
- Normal senescence as part of the phenological cycle.

Chowdhury (1995) after carrying out Entomological studies in the Sundarbans did not reveal any causal relationship between sundri top dying and insects in the Sundarbans. Insect attacks, in most cases, were found to be of a secondary nature affecting diseased and wakened trees and hastening their death and decay. Severe infection of sundri, gewa, baen and passur by molluscan borers was detected. An intensive search for the extent of damage on submerged wooden structures and live trees is deemed necessary. Severe insect depredation calling for preventive or control measures was not detected. He maintained that maintenance of biodiversity is expected to keep the population of injurious species within acceptable limits.

Anon (1995) recorded that sundri is able to grow in saline areas but the full development of the species is only found in areas where freshwater flushing occurs as remarked upon by Curtis (1933) and further substantiated by Chaffey *et al.* (1985) and Grepin (1995). It can be observed that the status of sundri top dying and data on electrical conductivity (EC) of the Sundarbans soil that no top dying was found in the areas where the EC was 1.00 to 2.00 mmhos/cm, but moderate to extreme top dying was found in areas where the EC was above 3.00 micro mhos/cm. Anon (1995) also noted that Bhuiyan (1995) found that moderate to severe top dying in areas where soil salinity was relatively high and areas of lower salinity where there was evidently no top dying. Anon (1995) inferred that therefore, it could be argued that EC measurements of soil salinity, Bhuiyan (1995) data suggest a possible role link in the intensity and possibly rate of top dying of sundri but not necessarily a direct cause.

Grepin (1995) suggested that any apparent equilibrium might be fragile, particularly for tall trees in areas where salinity is high. In these circumstances, when trees reach a particular age, it could be that amount of energy required to pump sap to the top of a tree is unable to compensate for osmotic pressure and is not sufficient to pump fresh water out of the ground to the top of the tree, thus creating a damaging level of physiological stress and top dying may ensue or indeed death of the whole tree. Anon (1995) mention that this theory by Grepin would accord with Curtis (1933) who found that sundri trees appeared to show signs of senescence and dieback at the peak of their growth and earlier than might be expected under less saline conditions.

Canonizado and Hossain (1998) estimated the extent of top dying damage of sundri in all the compartment of the Sundarbans falling in various forest types viz. sundri, sundri-gewa, gewa-sundri, sundri-others. The data were analyzed by Rahman and Hoque (2001) and no significant difference in the occurrence of sundri top dying in any of sundri, sundri-gewa and gewa-sundri forest types was found to occur in the Sundarbans.

Revilla *et al* (1998) provided data for comparison of the % number of sundri trees showing top dying in sundri, sundri/gewa, gewa/sundri and sundri/others forest types in the plots of fresh water zone (FWZ) and moderately salt water zone (MSZ) in the Sundarbans. Rahman and Hoque (2001) after critical analysis of the data of Revilla *et al* (1998) did not find any significant difference in the occurrence of top dying in sundri, sundri/gewa, gewa/sundri and sundri/others forest types. Therefore, there is no further need to study the association of forest types with top dying of sundri.

Hartung *et al.* (1998) have reported their findings about the putative biotic disease agents of top dying of sundri in the Sundarbans. For the study the authors collected 20 samples of wood, bark and leaves from compartment nos. 19, 22, 26, 32, and 39 in January 1997. Out of these samples 16 samples were from sundri, while four samples were from unaffected other tree species (2 being from gewa (*Excoecaria agallocha*), 1 from passur (*Xylocarpus mekongensis*), and 1 from goran (*Ceriops decandra*). The sundri samples comprised of 3 from unaffected tree, 2 from pneumatophores, 1 from affected dead standing tree, 2 from dead top of affected tree, 2 from top dying affected felled tree and 1 from seedling in extracted area. The samples were used for isolation of bacteria. Eight types of bacterial colonies were obtained. The colour of bacterial colonies were white, yellow, red, white-yellow, yellow-white, yellow-brown, gray white, shiny white, etc. There was no yield of bacterial colonies from wood tissues taken from unaffected sundri trees (3 samples). Affected dead standing sundri (2 samples), 4 unaffected wood samples of other tree species (2 from gewa, 1 form passur and 1 from goran). Out of the 6 to 8 types of bacterial colonies of two isolates have been identified as *Arthrobacter micotianae* and *Pseudomonas* sp. Due to their sequence homologies in a PCR assay. Both the species of bacteria were isolated from samples of severely top dying affected living sundri trees. The species showed phytopathogenic ability in a bioassay where 3-4 weeks old tomato plants (*Lycopersicon esculentum* MILL. cv. Rutgers) were used as indicator plants. The authors concluded a close association of phytopathogenic bacteria with the top dying disease of sundri (Hartung *et al.* 1998). A thorough search of literature does not reveal any association of *A. nicotianane* with any other tree disease problem anywhere in the world. Moreover, the data presented do not provide enough evidence of consistent association of *Pseudomonas* sp. with top dying of sundri wood. Clearly further data/evidences are needed on bacterial association of top dying of sundri

Rahman and Hoque (2001) found that the data generated on stand density of sundri have shown an insignificant but negative correlation ($r = 0.430$, $df = 23$) between top dying and number of sundri. This indicates that the disease might have decreased with increasing stocking.

Rahman and Hoque (2001) found that correlation analyses of diameter at breast height (dbh) and per cent top dying of sundri with data of 781 sundri trees (Appendix 2) provide a correlation efficient of $r=0.265666$ with 780 df. This is significant at $p = 0.01$. Data in Table 5 reveal that trees of higher dbh classes have been more attacked by top dying as compared to those of lower dbh classes. It is considered to be an important finding which has direct bearing on the management of top dying sundri trees in the Sundarbans.

Oxygen deficient substrate, due to regular tidal inundation, is characteristic feature of mangrove habitat. Degree of this anoxic condition varies depending on the texture of the substrate, frequency and duration of tidal inundation. Thus, soil anoxia varies form place to place. Mangrove plants respond to this variable soil condition by producing pneumatophores. However, this involves physiological cost on the part of the tree. Quite rationally mangroves produce greater number of pneumatophores in areas where the deficiency of soil oxygen is greater. Thus, in absence of a Redox Potential Meter, in this study, the number of pneumatophores has been used as an indicator of soil anoxia. The significant variation ($F = 13.73$; df. 9, 24, $p = 0.001$) in the number of pneumatophores per sq. m. among the sample compartments indicates the variability of soil anoxia in the Sundarbans (Rahman and Hoque, 2001).

Comparison of the number of pneumatophores per unit area and number of lenticels per sq. cm on the pneumatophore with the severity of the top dying of sundri produced only a very weak but negative relationship ($r = -0.249$, $t = -0.727$; $r = 0.225$, $t = 0.653$, $df = 8$). These indicate that despite variation of the anoxic condition in the substrate, it may not be responsible for the development of top-dying disease of sundri. Definitely further study is needed to firmly establish the role of anoxia of soil with the onset and severity of top dying of sundri (Rahman and Hoque, 2001).

In this study it is observed that the length of pneumatophores varied significantly among the sample compartments (F = 4.67, df. 9, 16, p = 0.01) However, comparison of the length of pneumatophore with the severity (%) of top dying of sundri, exhibited no significant correlation between them (r = 0.545, t= 1.839, df = 8). This indicates that the depth of inundation and rate of sedimentation have little impact on the development of top dying of sundri. (Rahman and Hoque, 2001).

Rahman and Hoque (2001) observed that the length of pneumatophores varied significantly among the sample compartments (F=4.67,df. 9, 16, p<0.05). However comparison of the length of pneumatophore with the severity per cent of top dying of sundri, exhibited only a weak correlation between them(r =0.545,t=1.839, df =9). This indicates that the depth of inundation and rate of sedimentation have little impact of the development of top dying of sundri.

Rahman and Hoque (2001) through critical analysis of the soil data generated by Mujibur Rahman (1995) found significant variance in case of data from surface to 30 cm soil depth among the four top dying categories (i.e. none, moderate, severe and extreme top dying) in case of electrical conductivity, chlorine, sodium/calcium ratio, levels of sodium, potassium, and calcium. But in case of pH, levels of magnesium, organic matter percent, nitrogen in the form of ammonium, phosphorus, sulphur, sulphate, copper, iron and manganese there were no significant variations in soils from the compartments having the four top dying categories as insignificant F-ratios were obtained in all these cases.

In case of soils collected from 60-90 cm depths from the compartments having the four top dying categories no significant variation was obtained in case of pH, electrical conductivity, levels of sodium, magnesium, potassium, chlorine, sodium/ calcium ratio, organic matter percent, nitrogen in the form of ammonium, phosphorus, sulphur, sulphate, copper, iron and manganese. Only in case of calcium content significant variation was obtained among the soils samples collected from the four top dying categories at 60 to 90 cm depths. A comparison of the pooled data from the two soil depths (i.e. surface to 30 cm; and 60-90 cm) in case of pH, electrical conductivity, levels of sodium, magnesium, potassium, chlorine, sodium/calcium ratio, calcium, organic matter percent, nitrogen in the form of ammonium, phosphorus, sulphur, sulphate, copper, iron and manganese did not reveal the presence of any significant variation in any of these soil parameters. This clearly indicates that there is no significant variation in the distribution of the levels of any of these soil parameters at soil depth surface to 30 cm and 60-90 cm in the Sundarbans (Rahman and Hoque, 2001).

Rahman and Hoque (2001) found a more or less similar trend of occurrence of electrical conductivity (EC), levels of chlorine, sodium/calcium ratio, levels of sodium in the soils from no top dying, moderately top dying, severely top dying and extremely top dying compartments in the Sundarbans. In these four cases the lowest values were in case of soil from no top dying areas and were insignificantly different from moderately top dying soils. In all these cases severely and extremely top dying soils contained significantly higher levels of these soil parameters as compared to those from no to dying and moderately top dying soils. That means the values were lowest in the no top dying areas and highest in either extremely top dying areas or severely tops dying areas. In all cases the highest values were significantly higher than the corresponding value from no top dying areas. But in case of calcium (Ca) there does not exists any such trend as is evident by the fact that calcium level in soil depth of surface to 30 cm from no top dying areas was second highest while calcium from soil depth of 60-90 cm depth was the highest from no top dying compartments. It is thus evident that calcium level has nothing to do with the severity of top tying of sundri.

Rahman and Hoque (2001) found that the highest of the ranked values were obtained from the western zone in case of pH, EC, K, avail. P and Cu but there were no significant difference between levels of pH, Na, Mg, and SO_4 between the western and the eastern zones. In the central zone Sodium, Mg and SO_4 were significantly higher than eastern and western zones. Nitrogen in the form of NH_4 was the highest in the eastern zone and was significantly higher than the central and western zones. In case of potassium (K) and phosphorus were significantly higher in the soil of the western zone as compared to the eastern and central zones. It is suggested that presence of the highest level of nitrogen in the form of NH_4 and the lowest EC, low salinity (as indicated by the presence of low Sodium) in the eastern zone may be primarily responsible for the more pronounced growth of healthy sundri in the eastern zone while the highest Sodium (i.e. the highest salinity in the central zone might have predisposed the sundri trees in the zone to higher osmotic stress and thereby to more adverse top dying situation in the Sundarbans. Very clearly further insight is needed to understand the mechanisms how these various levels of soil nutrients affect growth of sundri and predispose the severity of top dying of sundri.

Rahman and Hoque (2001) from critical analysis of data generated by Chaffey *et al* (1985) found no significant variations have been obtained in case of EC levels in soils collected at 5, 35, 65 and 100 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. Similarly, no significant variations have been obtained in case of Sodium levels in soils collected at 35 and 100 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. Exactly similarly, no significant variations have been obtained in case of Sodium Absorption Ratio (SAR) levels in soils collected at 35 and 100 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. In the levels of Sodium and Sodium Absorption Ratio significant variations ($P = 0.05$) have been obtained in case of soils collected at 5 cm and 65 cm depths from no top dying, moderate, severe and extreme top dying of sundri areas in the Sundarbans. Further analysis of the mean data by using Duncan's Multiple Range Tests revealed that in both the cases of sodium and SAR in mean levels, there were no significant variations between the levels obtained from no top dying areas and in soils from extreme top dying areas. Similarly, there were no significant variation in the levels of Sodium and SAR from soils from areas of moderate and severe top dying areas, but the levels of sodium and SAR in soils of areas having severe and moderate top dying were significantly higher ($P = 0.05$) as compared to that of no top dying areas and areas having extreme top dying areas. When one compares the levels of EC, Sodium and SAR from soils collected at 5, 35, 65 and 100 cm depths from the four top dying areas (i.e. no top dying, moderate, severe and extreme top dying) were pooled together and compared, no significant variations ere obtained between 5 and 35 cm depths, between 35 and 65 cm depths and also between 65 and 100 cm depths but the levels of EC, sodium and SAR obtained from soils at 65 and 100 cm depths were significantly higher ($P = 0.05$) than that at 5 cm depths.

The insignificant variations obtained in sodium and SAR from areas having no top dying and extreme top dying areas indicate that levels of sodium and SAR are unlikely to be the initiating cause of top dying of sundri in the Sundarbans (Rahman and Hoque, 2001).

3.5 Conclusions and Recommendations

3.5.1: New insights in the possible causes of top dying of sundri

Based on the analysis on each of the probable causes as provided in Section 3.2 it is evident that a number of the suggested causes of top dying are not supported by adequate and necessary data. This is true in case of reduced soil aeration, wind damage in the crown, sapwood decay by fungus/fungi and loranthus attack in the crown. But the discussion on reduced soil aeration strongly suggests it to be one of the major causes of top dying. Similarly sapwood decay, following wind damage in the crown or without it, is also considered to be a very probable cause of top dying. **Loranthus attack though can lead to death of twigs/branches but are of so infrequent occurrence that it should not be attributed to be any major cause of top dying. Furthermore, gall canker caused by *Botryosphaeria ribis* though can causes death of the affected twigs/branches and *Ganoderma* root rot are rather of rare occurrence in consideration of the extensive occurrence of sundri top dying, so these do not need to be further followed up.**

Soil salinity has shown variable relation with top dying. Chaffey *et al.* (1985) measured soil salinity in term of EC, Sodium and Sodium Absorption Ratio. They found significant variation in case of sodium and SAR at 5 cm and 65 depths among soil samples from no top dying, moderate top dying, severe top dying and extreme top dying area soils. But there was no significant difference between no top dying and extreme top dying area soils, which were significantly lower than moderate and severe top dying area soil. **This does not suggest that an increase in soil salinity is associated with top dying of sundri.** Bhuiyan (1995) found significant variations in Electrical Conductivity (EC) and Chlorine contents but insignificant variations in Sodium contents among soil samples from no top dying, moderate, severe and extreme top dying area soils. The EC values from severe and extreme top dying soils were always significantly higher than that from no top dying area soils. The data of Mujibur Rahman (1995) suggest that EC, Na, Na/Ca and Cl contents from severe and extreme top dying area soils were significantly higher than from no top dying area soils (**Table 5**). These suggest that the data of Bhuiyan (1995) and Mujibur Rahman (1995) more or less support each other, but the data of Chaffey *et al* (1985) differ from the former two authors' data. There were no significant variations among salinity values of soil samples collected from 0-30 cm, 30- 60 cm and 60-100 cm depths by Bhuiyan (1995), 0-30 cm and 60-90 cm soil depths by Mujibur Rahman (1995), 0-5cm, 5-35 cm, 35-65cm and 65-100 cm soil depths by Chaffey *et al* (1985) and 0-1 cm, 0-25 cm and 25-50 cm soil depths in BFRI's monthly soil salinity data from the period May 1991 to Jan 1994 from four field stations at Bogi, Chandpai, Kassiabad and Burigoalini in the Sundarbans (Rahman, 2001, unpublished data). **It is therefore suggested that this variability in soil salinity data may be because of variable time and place of collection of soil samples. In all cases data are available from soil samples collected from a place only once. In the Sundarbans increased soil salinity plays a vital role in affecting nutrient availability and uptake, it is considered worth to follow up soil salinity studies from specified places (i.e. sample plots) over longer time at regular intervals and try to correlate that with the intensity of top dying of sundri. It may be noted here that future salinity studies should be limited to top 30 cm of soil.**

Out of the twenty five soil parameters for which soil samples collected from no top dying, moderate top dying, severe top dying and extreme top dying area were analyzed, no significant variations among the four top dying areas have been found in case of pH, OM, P, S, SO4, Ca, K, Na, Fe, Cu, B, CO3, bicarbonate, sand, silt and clay in the data by Bhuiyan (1995). In the data generated by Mujibur Rahman (1995) among these parameters significant variations among the four top dying soils were obtained in case of Ca, K, Na, Na/Ca levels, while Chaffey *et al* (1985) obtained significant variations in case of Na levels. The data generated by Bhuiyan (1995) reveal significant variations in case of EC, N, Mg, Mn and Zn, while data by Mujibur Rahman (1995) show significant variations in case of EC, Ca, K, Na, Na/Ca and Cl, but the data of Chaffey *et al.* (1985) provide significant variation in case of Na and SAR among soil samples collected from no top dying, moderate top dying, severe top dying and extreme top dying area soils. In all cases higher levels of all these soil parameters were found in severe and extreme top dying areas, but in case of zinc a deficiency has been found to be associated with moderate, severe and extreme top dying conditions (**Table 5**). It may be noted here that the available zinc content in the estuarine floodplain soil is low or marginal and is less than 1 ppm **(Hassan, 1999). It is therefore, recommended that further studies on soil parameters in relation to top dying of sundri should investigate the role of EC, Na, Na/Ca, Cl, N, Ca, K, Mg, Mn, Zn and Ca. Besides studies should also be made on the sand, silt and clay content of soils because these have direct relevance to soil aeration and that the data of Sobhan (1973) were only from three replicate soil samples and that the data of Bhuiyan (195) were inadequate to make any comparison of the sand, silt and clay percent from no top dying, moderate top dying, severe top dying and extreme top dying area soils.**

The hypothesis put forward by Rahman (1990) and modified by Rahman (1995) concerning top dying of sundri has been included in Section 4.2 under Annex. 1. The hypothesis needs to be tested but available knowledge is not enough to verify this hypothesis. That reduced flush of fresh water through the Sundarbans has occurred and has been accompanied by an increase in salinity (Senedaker, 1977; IECO, 1980; Shahidullah, 1980; Hannan, 1981; Shafi, 1982; Chowdhury, 1984; Imam, 1982; Chowdhury, 1984). Chaffey *et al. (1985)* noted that Baleshwar and Passur rivers and their distributries have direct link with the Ganges and thus to an uninterrupted supply of fresh water. The Sibsha River and all other rivers to the west of it receive fresh water only from localized catchments lying between the Ganges and the northern edge of the Sundarbans. These rivers are therefore the more susceptible to dry season reduction in stream flow and to tidal intrusions of salt water. In this connection it may be noted that monthly soil salinity data generated by BFRI from Bogi and Chandpai (from eastern part of the Sundarbans) and Kassiabad and Burigoalini (from the western part of the forest) as summarized in **Table 9** and the salinity data of Karim (1988) as presented in **Table 8** from the eastern zone, central zone and western zone of the Sundarbans clearly reveal that soil salinity in west is just double of that in the eastern part of the Sundarbans (vide Tables 8 and 9). Thus the fact that reduced flow of fresh water has been coupled with increased soil salinity in the Sundarbans is amply established.

The other aspect is that reduced fresh water flush is likely to be coupled with a reduced supply of nutrients to the forest floor. In this aspect data generated by Mujibur Rahman (1995) (**vide Table 7**) reveal that the level of nitrogen in the eastern part of the Sundarbans is about three times that n the western part, but phosphorus is about half and potassium only one fourth in the east as compared that in the west. EC in the east is only half that of the west, while in CEC there is no significant difference. Chen and Twilley (1999) reported from Florida estuary that concentrations of nitrogen (N) and phosphorus (P) are more closely related to patterns of forest development, with higher soil fertility indicated by higher concentrations of extractable ammonium, total soil P, and available P, along with higher ammonium production. Siddiqi (2001) recorded that organic carbon and nitrogen in the topsoil at 15 cm depth were 0.62% and 0.05% respectively on dry weight basis. In the eastern part of the Sundarbans, where the rivers supply fresh silt every year, topsoil is soft and fertile. In the western Sundarbans where there is little fresh supply of silt, even the surface soil has settled down to a hard mass, and the ground is much less suitable for fast tree growth. It is thus evident that the eastern part of the Sundarbans is much more fertile than the western part of the forest. It is also known that salinity affects nutrient availability as Christensen (1984) stated that salinity may not be a direct cause of top dying of sundri but is an indicator of many geochemical processes that have an impact on living organisms (e.g. by affecting nutrient availability) **It is thus suggested that further study should explain how different salinity affect nutrient availability to plants. Therefore, soil and plant analysis of the already mentioned nutrients from areas of no top dying, sight, moderate, severe and extreme top dying sundri areas should be investigated to determine whether there exists any correlation between soil salinity and occurrence and severity of top dying of sundri in the Sundarbans. Hence the present programme of study should include soil and plant analysis studies to determine the level of various nutrients and then try to determine the correlation between salinity values and the levels of severity of top dying (no top dying, moderate, sever and extreme top dying of sundri).**

The data generated by Canonizado and Hossain (1998) on the extent of top dying damage in all the compartments where sundri occur did not show any significant difference in the extent of occurrence top dying of sundri in any of sundri, sundri-gewa and gewa-sundri forest types as found by Rahman and Hoque (2001). **Therefore, there is no need to select sample plots in all the forest types where sundri occur as proposed in plan of study of the present proposal.**

4.0 DETAILED APPROACH AND METHODOLOGY

The study was mainly concentrated in 36 sample plots, each 400 sq m, laid down at 12 landings in compartment no. 2, 11, 19 (having two landings), 20, 22, 26, 33, 36 (having two landings), 37 and 40. Stratified random sampling method was used for selecting the 36 sample plots. There were nine sample plots for each of none (i.e. little or no top dying), slight, moderate and severe top dying of sundri classes. Sub-plots were established within each sample plot for study of pneumatophores, regeneration and collection of soil samples for physico-chemical analysis each of the four trips in early October 2001, late January 2002, June 2002 and January 2003. The study included ecological, pathological and edaphic aspects of top dying of sundri primarily in order to find out the cause of top dying of sundri in the Sundarbans. As a part of the study an **In depth literature study on the sundri (*Heritiera fomes*) top dying in the Sundarbans** was carried out to provide critical review of knowledge and understanding of top dying of sundri prior to the initiation of the present study. An Inception Report on the subject contained the detailed methodology followed in the study and also a full description of the project (Rahman *et al.* 2002a and 2002b).

4.1 Ecological Aspects

4.1.1 Pneumatophore smothering by sediments and development of top dying of sundri: Data available on top dying affected compartments were identified and then classified into severe, moderate, slight and no top dying classes. Then 3 compartments have been selected from each of the four top dying severity categories. Thus a total of 12 landings in 10 compartments were selected. In each of the selected compartments, one point was selected randomly, and from that point three lines were established at 120° angles. Then on each line at 100 m from the center point, one 0.02 ha main sample plot (20m x 10 m) was selected. Thus in 12 landings (3 in each of severe, moderate, slight top dying and healthy sundri area having no top dying) 12 clusters of 3 sample plots totaling 36 in all were selected for the study. For each of the cluster of the sample plots, trees at landing on the riverbank, access to the center of the selected grid, center of the grid, access to the sample plots, and border of the sample plots were marked with paint. For each compartment a sketch map was be prepared showing landing, bearing and length of access to the center of the selected grid, bearing of the access from the center to the sample plots. From each sample plot data were collected.

In each sample plot five sub-plots of 2 m x 2 m were selected systematically. The sample plot was divided into 4 quadrants. One sub-plot was taken from the centre of the plot and 4 sub-plots were taken from the center of each of the four quadrants. In each sub-plot the number of pneumatophores of sundri were counted and the height of each pneumatophore above the soil level were measured to the nearest millimeter. From each sub-plot three 3 pneumatophores were collected for counting the number of lenticells. The number of lenticells on 1 sq. cm area on each of three pneumatophores and at collar, middle and top of the pneumatophore in each sub-plot was counted with the help of a hand lens.

For measuring siltation rate 5 poles, one at the centre of each of the 4 quadrants and one at the centre of the plot were fixed in each of the 36 main plots. The rate of siltation were measured at approximately 4 monthly intervals by measuring the height of the pole form the sediment surface to the nearest millimeter at every observation. The difference between two observations would be the thickness of silt/sand deposited in the time elapsed between two observations.

4.1.2 Impact of salinity on the development of top dying of sundri: Soil salinity were determined in 5 sub-plots (4m x 4 m) of each of 36 sample plots (each 0.02 ha) falling in 12 landings of four top dying severity classes. This was repeated at 4-monthly intervals. Thus salinity data were collected from 5 (sub-plots) x 3 (sample plots) x 3 (compartments) x 4 (severity classes). This allowed testing whether there exists any correlation between soil salinity and occurrence and severity of top dying of sundri.

For this soil samples were collected from two depths (0-10 cm and 10-30 cm). The soil salinity was determined for each sample. Thus five salinity data were obtained for top and bottom soil samples from each of the 36 sample plots covering severe, moderate, slight top dying and no top dying areas. Then variance analysis were carried out to detect whether there existed significant variation in level of soil salinity in four top dying categories. This was followed by DMRT test or t-test to locate main sources of variability & thus to ensure whether soil salinity has a significant association with top dying level. The data thus obtained were used to examine whether there exist any relationship between different levels of soil salinity at two levels and severity levels of top dying of sundri in the Sundarbans.

4.1.3 Relationship between soil aeration and development of top dying of sundri: To study the relationship between the availability of soil oxygen and sundri top dying, as a direct approach, the availability of soil oxygen could be measured with a Soil Oxygen Meter (Redox Potential Meter) in areas of the Sundarbans affected by various degrees of top dying. The present budget of the project did not have any provision to buy Redox Potential Meter. As an alternative approach, responses produced by plant to soil anoxia could be measured. In a sedimentary environment, to cope with the soil anoxia mangroves produce adventitious lateral roots close to the surface, put on secondary growth on pneumatophore, produce feeding roots from pneumatophores, produce large number of pneumatophores and increased number of lenticels (Hogarth, 1999).

As the Sundarban Biodiversity Conservation Project could not provide a Redox Potential Meter for the study, that alternative approach for this study, though of much less precision, has been adopted. Hence the rate of sedimentation, number of pneumatophores per unit area, length of pneumatophores and the number of lenticels per unit area of pneumatophores were measured. The rate of sedimentation was studied by fixing siltation gauges.

4.1.4 Relationship between age/diameter of tree and the incidence of top dying of sundri: In sundri growth ring counting is not a very definite way for the determination of age of a tree. Therefore diameter measurement of sundri trees was considered as an alternative to age class. In each of the main sample plot (0.02 ha) diameter at breast height (d.b.h.) of all sundri trees up to 5 cm d.b.h. were measured. The extent of top dying damage to each tree was estimated as per the classification used by Chaffey *et. al.*, (1985). Then a correlation between the occurrence of top dying and diameter classes of sundri trees was determined.

4.1.5 Relationship between density of the crop and incidence of top dying of sundri: In the sample plots, the number of stems of sundri and all other tree species was counted. Observation of Anon (1973), Ahmed (1957) Chowdhury (1968), Sattar (1977), Atiqullah (1973), Chowdhury (1984) Ciesla (1994), and Anon (1995) indicate the relevance between sundri top dying (STD) and wind damage to the forest.

Anon (1973) noted the prevalence of sundri top dying after the catastrophic cyclone of 1970. Atiqullah (1973) and Gibson (1975) reported prevalence of sundri top dying on the canal bank. Atiqullah (1973), Gibson (1975) and Chowdhury (1984) reported prevalence of sundri top dying in older trees. Chowdhury (1984) also mentioned about the damage to the root system caused by cyclones. Here this is to be noted that trees on the riverbank, particularly of big rivers, and older trees are more exposed to wind.

To investigate the relationship between STD and wind damage the best way would be to mark some wind-damaged trees (generally after a cyclone) and observe them over a long period of time. However, limitation of this process is that tree climbing is a cumbersome job and often it is difficult to identify a damage particularly if the sundri top dying is in advance stage. The observation on direct wind damage and its effect on subsequent development of top dying of sundri does not rationally fall within the purview of short term scientific investigation. Since wind throw creates opening in the canopy closure and greater opening in the canopy has been reported to lead to the development of epicormic branching and adventitious crown which render sundri more vulnerable to cyclone damage (Ahmed, 1957; and Balmforth, 1985). Therefore, canopy closure and its association with top dying was studied.

The percentage of canopy closure in each sample plot was measured using Crown Densiometer. Canopy closure per cent was determined in 36 sample plots (3 plots in each compartment X 3 compartments in each top dying severity types X 4 top dying severity types). Per cent of sundri trees affected by top dying in each of 36 samples was found out. Besides, data from the Temporary Sample Plots (TSPs) generated under Forest Resources Management Project during 1996-97 were also used to determine whether there exists an the association between canopy closure per cent and per cent top dying of sundri trees. In case of significant correlation linear regression was determined.

4.2 Pathological aspects

4.2.1 Stages of symptom development of top dying of sundri: Precise description of symptoms of any plant/tree disease is important for further study leading to disease control/prevention. The same is true in case of top dying of sundri as well. To identify the very early stages of symptom expression, in 4 compartments of severe, moderate, slight top dying of sundri and compartment with no top dying, all the sundri trees were observed. Subsequently, each tree was observed at 4-monthly intervals to observe and record progressive changes and also of new symptom expression, if any. From such information, it was attempted to identify the first symptom expression and its progressive changes over time.

4.2.2 Isolation of fungi /bacteria from top dying sundri and their identification: For the isolation of fungi from top dying sundri / sapwood decayed sundri stem samples the experimental design was completely randomized design (CRD) where selection of compartments, top dying (sapwood decayed) sundri trees, selection of affected samples and then taking inocula pieces from the samples were on CRD basis. Equal number of inocula pieces were taken from the healthy portions of each of the samples and treated in the same way as that of the top dying (sapwood decayed) of sundri samples for the isolation of fungi and this acted as the controls.

From each sample three 1-cm thick disc was cut from three places using a circular saw. Thus 45 discs will be obtained. From each disc fungi were be isolated following standard procedure as detailed by Booth (1971) and Rahman (1999) on 2% Malt extract agar, 2% malt extract agar modified for basidiomycetes and on other suitable culture media. Similarly bacteria were also be isolated.

Isolation of fungi was made on 2% Malt extract agar medium. After following the standard practices for isolation of fungi under aseptic condition (Rahman, 1982; 1999; Booth, 1971) the inoculated agar plates were incubated at constant 30^0 C in an incubator for about a week. During the period the petridishes were observed periodically for any fungal growth. When fungal growth were seen to develop from the inoculated sundri inocula, then on all the petri-dishes one type of fungal colony were given a particular number or code and then the dominance of each type of fungus from both the sapwood decayed inocula and also from the control inocula were determined and expressed in per cent to find out the relative dominance of the more common and dominant fungi.

4.3 Edaphic Aspects

4.3.1 Study of physico-chemical properties of soils collected from areas having different levels of top dying of sundri: Soil samples were collected for physico-chemical studies from each of the 36 sample plots which were selected on the basis of severity of top dying from each of severe, moderate, slight top dying and no top dying area. From each sample plot three soil samples were collected from three sites (one from the center of the sample plot and two from two points half way through from the center to the sides) with the help of a soil auger. Each soil sample included soil from two depths Thus from each of 36 sample plots, 3 top and 3 bottom soil samples were collected, properly labeled and brought to the laboratory. After air-drying and grinding, the 3 soil samples from the top layer of each sample plot were thoroughly mixed to get one composite soil sample. Similarly, a composite soil sample from bottom layer were prepared. Thus from each of the 36 sample plots one soil sample form each of top and bottom layer were obtained. Such samples were kept in labeled polyethylene bags and were used for physico-chemical analysis. Each of the 36 x 2 = 72 soil samples were analyzed for nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sodium (Na), chlorine (Cl) electrical conductivity (EC), manganese (Mn), zinc (Zn), sand, silt and clay contents using standard methods for physico-chemical analysis of soil (Black, 1965 and Hesse,1994). The analyses were carried out at Soil Resources Development Institute (SRDI) Laboratory in Khulna on payment of usual cost. Thus various physico-chemical properties of 18 soil samples (3 compartments x 3 sample plots from each compartment x 2 soil depths) from each of the four top dying severity class areas (i.e. severe, moderate and slight top dying and no top dying areas) were obtained. The 18 sample form each of the four top dying severity classes included 9 samples from each of top soil samples (soil surface to 30 cm during first trip and 0-10 cm during second trip), and bottom soil samples(60-90 cm during the first trip and 10 cm to 30 cm during the second trip) . Such soil data were analyzed through variance analysis by using a programme of the SAS system and also of the Microsoft Excel programme , Duncan's Multiple Range Test (Duncan, 1955) and to find out whether any particular soil parameter had any association with the occurrence and severity of top dying by way of determination of correlation coefficient by using a programme of Minitab. In case of significant correlation linear regression analysis were carried out by using a programme of the Minitab.

Soil nutrient contents of soil samples from top and bottom layers from severe, moderate and slight top dying and no top dying were compared by variance analysis followed by Duncan's multiple range test (Duncan, 1955).

4.3.2 Nutrient status in soil and uptake by sundri trees: From each of the 36 sample plots (0.2 ha) three top dying and three healthy sundri trees were selected from any point nearest to the three sites form which soil samples were collected. Then from each tree healthy leaves and small twigs, weighing about 1 kg were collected and labeled. Then the leaf samples of three healthy trees were mixed to get one composite sample. Similarly the leaf samples from three top dying trees were mixed to get one top dying tree leaf sample. It may be noted that the top dying trees were selected in such a way that it represented the category of top dying of the sample plot (i.e. slight, moderate or severe top dying tree). It means that from a slight top dying sample plot top dying trees were selected in such a way that they had slight top dying. Similarly moderate top dying and severe top dying trees were selected from moderate top dying and severe top dying sample plots. Thus out of the 36 top dying leaf samples, there were 9 samples from trees of each of slight, moderate and severe top dying condition. In the laboratory, the leaf samples were first washed in running water to clean, then dried in shade and then about 500 gm leaves from each sample were air dried and then grinded in a Grinder. After grinding the each leaf sample was thoroughly mixed, kept in airtight container and properly labeled. Similarly, three leaf samples from top dying sundri trees from each plot were similarly mixed to get one sample. Thus in all 36 leaf samples 9 from each of healthy, slight, moderate and severe top dying sundri trees. Then nutrient content of each of 36 leaf samples were sent for analysis in Atomic Absorption Spectrophotometer for selected nutrients only at the Institute of Nuclear Science and Technology of Atomic Energy Commission at Shavar in Dhaka, where from we could not get the analysis done. Then Department of Soil, Water and Environment, Dhaka University, did the job for us on payment.

A comparison of the status of nutrients in leaves of sundri trees attacked by severe, moderate, slight top dying and healthy sundri are to be made. Furthermore, comparison of the particular nutrient status of the corresponding soil samples will be made to determine whether availability of nutrient in the soil and uptake of nutrient to the leaves had any correlations or not. For that variance analysis will follow Duncan's Multiple Range Test (DMRT) to locate source of significant variation. In variance analysis, if any particular parameter shows significant result, then attempt will be made to find out the correlation coefficient of that particular parameter in both soil and plant samples as well as with that of the level of top dying of sundri.

4.4 Additional studies undertaken

4.4.1 Mapping of the distribution of top dying sundri in the Sundarbans

For this study data generated from 1190 Temporary Sample Plots (TSPs) by Forest Resource Management Project during 1996-97 and stored in the TSP database have been used to determine the widespreadness of sundri top dying in the TSPs of each of the 55 compartments and then severity of top dying ranking index have been calculated for each of the 55 compartments. In this way a clear picture about the distribution of sundri top dying in the whole Sundarbans has been obtained. This information shall be used to prepare top dying distribution map.

4.4.2 Status of regeneration of tree species in the Sundarbans

This was done by extracting the data of regeneration of all the tree species from the 1203 Temporary Sample Plots (TSPs) generated during FRMP Forest Inventory of the Sundarbans in 1996 and 1997. A programme using the Structured Query Language (SQL) was used to extract the regeneration data from the TSP database.

4.4.3 Regeneration studies in different sundri top dying affected areas to find out the impact of salvage and sanitation felling on regeneration and forest structure

In each of the 36 sample plots first 3 and latter 5 sub-plots of 2 m x 2 m were established one in the center of the sample plot and four in the centre of the four quadrants. In each of the regeneration sub-plots (2m x 2m), the regeneration of all tree species were counted and measured up to 1.3 m height. Regeneration sub-classes as followed by Chaffey *et al.* (1985) were followed. Then a comparison in the level of regeneration of sundri and other species were made among the plots in severe, moderate, slight top dying and no top dying areas to identify and establish whether there exists any impact of top dying on regeneration and recruitment in the Sundarbans.

Besides data on saplings of all species were taken from the TSPs database for all the TSPs falling in compartment numbers 32, 36 and 38 from which top dying sundri were harvested during 1990- 92. Then the data on saplings of all species in all the TSPs of compartments numbers 16, 31, 35 and 41 were taken from the TSPs database. The latter compartments were selected in such a way that these were neighbouring to the above mentioned top dying harvested compartments but from these compartments no top dying sundri have been harvested. Then the level of regeneration of different species were compared to find out the impact of top dying harvest on subsequent recruitment of sundri and others species in the Sundarbans.

4.5 Data analysis

Normality of data was tested and when necessary the required transformation of data were done. Data analysis was mainly limited to the determination of means, confidence intervals at 95% probability level, determining the correlation co-efficient and in case of significant correlation by developing regression plots to draw the line of best fit and obtained regression equation, variance analysis to compare the existing variability among data sets to find out the level of significance of variability, if any, and in case of significant variance Duncan's multiple range test has been used to determine the relative significance of the ranked means. Computer software such as Microsoft Excel, Minitab, the SAS System and SPSS were mainly used for data analysis.

5.0 RESULTS

5.1 Ecological Aspects

5.1.1: Data on number and length of pneumatophores and lenticels on pneumatophores: Data on the density of pneumatophore (number per sq. m.), length of the pneumatophore (in cm) above soil level were collected in October 2001, January 2002 and June 2002, while number of lenticels at collar, middle and top portion of pneumatophore were collected in January and June 2002. The detailed data collected from five sub-plots from each of 36 sample plots, 9 from each of none (i.e. no top dying), slight, moderate and severe top dying of sundri, on the number of pneumatophores and also on the length of each of the pneumatophores encountered in the sub-plots during October 2001 have been provided in **Appendix 1 and 2**. The data on the mean number of pneumatophores, mean length of pneumatophores from 1 sq. meter area of the five sub-plots from each of 36 sample plots and the mean number of lenticels from 1 cm^2 area from near the bottom, middle and top of five pneumatophores randomly collected from the vicinity of each sub-plot collected in January 2002 have been provided in **Appendix 3.**

Data on number of pneumatophores collected from 1 sq. m area of the sub-plots and the data on the mean number of lenticels from 1 cm^2 area from near the bottom, middle and top of five pneumatophores randomly collected from the vicinity of each sub-plot collected in June 2002 are presented in **Appendix 4.** Data on length of pneumatophores collected from the sub-plots collected in June 2002 are presented in **Appendix 5.**

Data on number and length of pneumatophores collected from the sub-plots in January 2003 are presented in **Appendix 6** while data on the mean number of lenticels from 1 cm^2 area from near the bottom, middle and top of five pneumatophores randomly collected from the vicinity of each sub-plot in June 2002 are presented in **Appendix 7.**

Using a programme of Minitab Release 11.2 32 Bit calculations of means and confidence intervals were done. Analysis of variance of data collected were carried out by using a programme of the SAS System and also that of Microsoft Excel 1997.

The data on number of pneumatophores and length of pneumatophores (in cm) recorded from five sub-sample plots falling in each sample plot from four category (viz. severe, moderate, slight and none) of top dying of sundri severity from 12 landings in 10 compartments in October 2001 have been processed and summarized in **Table 10**. Similarly the data on number of pneumatophores and length of pneumatophores recorded from five 1 sq m subplots from each of the 36 sample plots in January 2002, June 2002 and January 2003 have been summarized in **Tables 11, 12** and **13** respectively. The data of number of lenticells recorded from 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-sample plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none (i.e. no top dying of sundri) from 36 sample plots in January 2002, Jume 2002 and January 2003 have been summarized in **Tables 14, 15 and 16** respectively.

Table 10: Summarized data on the mean number and length (in cm) of pneumatophores recorded from five sub-sample plots falling in each sample plot from four category (viz. severe, moderate, slight and none) of top dying of sundri severity at 12 landings in 10 compartments in October 2001 from the Sundarbans.

Top dying severity category	No. of compartments	No. of sample plots and (subplots)	Total No. of pneumatophores	Pneumatophore Number			Pneumatophore length		
				Mean	Standard Error	Confidence Interval (at P = 0.05)	Mean	Standard Error	Confidence Interval (at P = 0.05)
None	3	9 (45)	2014	39.20	5.69	27.73 – 50.67	16.09	0.19	15.71 – 16.46
Slight	3	9 (45)	1828	36.55	5.09	26.26 – 46.84	17.08	0.27	16.56 – 17.60
Moderate	3	9 (45)	1244	15.33	2.51	10.20 – 20.47	13.25	0.21	12.84 – 13.67
Severe	3	9 (45)	1703	14.97	2.35	10.19 – 19.76	17.55	0.24	17.08 – 18.01

Table 11: Summarized data on the mean number and length (in cm) of pneumatophores recorded from five sub-plots falling in each sample plot from four category (viz. severe, moderate, slight and none) of top dying of sundri severity at 12 landings in 10 compartments in January 2002 from the Sundarbans.

Top dying severity category	No. of compartments	No. of sample plots and (subplots)	Total No. of pneumatophores	Pneumatophore Number			Pneumatophore length		
				Mean	Standard Error	Confidence Interval (at P = 0.05)	Mean	Standard Error	Confidence Interval (at P = 0.05)
None	3	9 (45)	1263	28.07	1.98	24.07 – 32.06	19.35	0.96	17.41 – 21.28
Slight	3	9 (45)	1224	27.20	1.73	23.71 – 30.69	17.11	0.84	15.43 – 18.80
Moderate	3	9 (45)	903	20.07	1.71	16.61 – 23.52	13.79	0.79	12.09 – 15.40
Severe	3	9 (45)	830	16.68	0.98	14.60 – 18.66	16.68	0.98	14.69 – 18.66

Table 12: Summarized data on the mean number and length (in cm) of pneumatophores recorded from five sub-plots falling in each sample plot from four category (viz. severe, moderate, slight and none) of top dying of sundri severity at 12 landings in 10 compartments in June 2002 from the Sundarbans.

Top dying severity category	No. of compartments	No. of sample plots and (subplots)	Total No. of pneumatophores	Pneumatophore Number			Pneumatophore length		
				Mean	Standard Error	Confidence Interval (at P = 0.05)	Mean	Standard Error	Confidence Interval (at P = 0.05)
None	3	9 (45)	1263	39.20	5.69	27.73 – 50.67	15.94	1.69	12.05 – 19.84
Slight	3	9 (45)	1224	36.55	5.09	26.26 – 46.84	13.18	1.13	10.52 – 15.84
Moderate	3	9 (45)	903	15.33	2.51	10.20 – 20.47	14.09	2.11	8.68 – 19.51
Severe	3	9 (45)	830	14.97	2.35	10.19 – 19.76	18.84	1.70	14.67 – 23.00

Table 13: Summarized data on the mean number and length (in cm) of pneumatophores recorded from five sub-plots falling in each sample plot from four category (viz. severe, moderate, slight and none) of top dying of sundri severity at 12 landings in 10 compartments in January 2003 from the Sundarbans.

Top dying severity category	No. of compartments	No. of sample plots and (subplots)	Total No. of pneumatophores	Pneumatophore Number			Pneumatophore length		
				Mean	Standard Error	Confidence Interval (at P = 0.05)	Mean	Standard Error	Confidence Interval (at P = 0.05)
None	3	9 (37)	1854	49.70	7.12	35.29 – 64.10	18.60	1.01	16.56 – 20.65
Slight	3	9 (35)	1688	47.65	9.32	28.76 – 66.54	16.96	0.93	15.08 – 18.84
Moderate	3	9 (29)	508	17.57	1.37	14.77 – 20.37	15.93	1.05	13.79 – 18.08
Severe	3	9 (29)	811	27.98	4.58	18.63 – 37.32	18.13	1.08	15.92 – 20.34

Table 14: Summarized data on the mean number of lenticels in 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-sample plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e no top dying of sundri) at12 landings in 10 compartments in January 2002 from the Sundarbans

Top dying severity category	No. of compartments	No. of sample plots	No. of sub-sample plots	Mean with standard error in parenthesis	Mean with standard error in parenthesis	Mean with standard error in parenthesis	Confidence Interval at P = 0.05	Confidence Interval at P = 0.05	Confidence Interval at P = 0.05
				Bottom	Middle	Top	Bottom	Middle	Top
None	3	9	45	2.43 (0.102)	2.21 (0.092)	2.08 (0.134)	1.80 –2.35	2.02 – 2.39	2.08 – 2.35
Slight	3	9	45	2.46 (0.1.35)	1.99 (0.107)	2.20 (0.146)	2.19 – 2.74	1.78 – 2.21	1.90 – 2.49
Moderate	3	9	45	2.91 (0.110)	2.79 (0.137)	2.32 (0.107)	2.68 – 3.13	2.51 – 3.07	2.11 – 2.54
Severe	3	9	45	2.17 (0.104)	1.89 (0.114)	2.00 (0.136)	1.96 – 2.38	1.67 – 2.13	1.73 – 2.27

Table 15: Summarized data on the mean number of lenticels in 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-sample plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e. no top dying of sundri) at12 landings in 10 compartments in June 2002 from the Sundarbans.

Top dying severity category	No. of compartments	No. of sample plots	No. of sub-sample plots	Mean with standard error in parenthesis	Mean with standard error in parenthesis	Mean with standard error in parenthesis	Confidence Interval at P = 0.05	Confidence Interval at P = 0.05	Confidence Interval at P = 0.05
				Bottom	Middle	Top	Bottom	Middle	Top
None	3	9	45	1.282 (0.163)	1.111 (0.139)	1.571 (0.166)	0.94 - 1.62	0.82 - 1.40	1.22 - 1.92
Slight	3	9	45	1.240 (0.100)	1.239 (0.134)	1.595 (0.171)	1.03 - 1.45	0.96 - 1.52	1.24 - 1.95
Moderate	3	9	45	0.947 (0.120)	1.111 (0.082)	1.306 (0.152)	0.69 - 1.20	0.94 - 1.28	0.99 - 1.63
Severe	3	9	45	0.672 (0.065)	0.768 (0.092)	1.250 (0.172)	0.54 - 0.81	0.58 - 0.96	0.89 - 1.61

Table 16: Summarized data on the mean number of lenticels in 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-sample plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e. no top dying of sundri) at12 landings in 10 compartments in January 2003 from the Sundarbans.

Top dying severity category	No. of compartments	No. of sample plots	No. of sub-sample plots	Mean with standard error in parenthesis	Mean with standard error in parenthesis	Mean with standard error in parenthesis	Confidence Interval at P = 0.05	Confidence Interval at P = 0.05	Confidence Interval at P = 0.05
				Bottom	Middle	Top	Bottom	Middle	Top
None	3	9	45	0.7368 (0.0413)	0.4991 (0.0368)	1.3615 (0.0782)	0.655-0.819	0.426-0.572	1.207-1.516
Slight	3	9	45	0.7808 (0.0381)	0.5486 (0.0279)	1.3496 (0.0704)	0.705-0.856	0.494-0.604	1.210-1.489
Moderate	3	9	45	0.7613 (0.0394)	0.5856 (0.0351)	1.293 (0.107)	0.683-0.839	0.516-0.655	1.081-1.505
Severe	3	9	45	0.7632 (0.0478)	0.5740 (0.0346)	1.548 (0.112)	0.669-0.858	0.506-0.643	1.327-1.770

Data of sedimentation (i.e. sediment deposition and erosion) around 157 sediment gauges established in 36 sample plots at 12 landings in 10 compartments falling in severe, moderate, slight and none (i.e. no) top dying of sundri as recorded in January 2002 and January 2003 in the Sundarbans have been provided in **Appendix 8.**

Analysis of variance of the data on number of pneumatophores collected in October 2001 (vide Appendix 1) is provided in **Appendix 9**. Analysis of variance of the data length of pneumatophores collected in October 2001 (vide Appendix 2) is provided in **Appendix 10**., Analysis of variance of the data on number of pneumatophores, and length of pneumatophores and number of lenticels from 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e. no top dying of sundri) classes from 36 sample plots in January 2002 (vide Appendix 3) is provided in **Appendix 11**. Analysis of variance of the data on number and length of pneumatophores collected in January 2002 (vide Appendix 4 and 5) are provided in **Appendix 12 and 13** respectively. Analysis of variance of the data on number of lenticels from 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e. no top dying of sundri) classes from 36 sample plots in June 2002 (vide Appendix 4) is provided in **Appendix 14**. Analysis of variance of the data on number of pneumatophores, and length of pneumatophores collected in January 2003 (vide Appendix 6) is provided in **Appendix 15**. Analysis of variance of the data on number of lenticels from 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e. no top dying of sundri) classes from 36 sample plots in January 2003 (vide Appendix 7) is provided in **Appendix 16.**

Comparison of the results of variance analysis of the data of pneumatophore numbers collected in October 2001, January 2002, June 2002 and January 2003 reveal that there exist significant difference among the mean number of pneumatophores from the sample plots of the four top dying severity classes (i.e. none, slight, moderate and severe) as are shown by significant variances expressed in terms of F-value which have been summarized in **Table 17.**

Table 17: Summary to compare the results of variance analysis of the data on the number of pneumatophores recorded from the sub-plots in October 2001, January 2002, June 2002 and January 2003 from the 36 sample plots in the Sundarbans.

Data collected in	Total No. of data of sub-plots	Top dying severity classes *	Degrees of freedom	Calculated F-value	Probability	Difference among the mean values
October 2001	162	4	3, 161	11.81	0.0001	Very highly significant
January 2002	177	4	3, 176	8.18	0.0001	Very highly significant
June 2002	147	4	3, 146	8.06	0.0001	Very highly significant
January 2003	160	4	3, 156	4.31	0.0060	Highly significant
Note:	* = Four top dying severity classes are none, slight, moderate and severe.					

Comparison of the results of variance analysis of the data of length of pneumatophores collected in October 2001, January 2002, June 2002 and January 2003 reveal that there exist significant difference among the mean length of pneumatophores from the sample plots of the four top dying severity classes (i.e. none, slight, moderate and severe) as are shown by significant variances expressed in terms of F-value which have been summarized in **Table 18.**

Table 18: Summary to compare the results of variance analysis of the data on the length of pneumatophores recorded from the sub-plots in October 2001, January 2002, June 2002 and January 2003 from the 36 sample plots in the Sundarbans.

Data collected in	Total No. of data	Top dying severity classes	Degrees of freedom	Calculated F-value	Probability	Difference among the mean values
October 2001	6789	4	3, 6785	56.74	3.24E-36	Very highly significant
January 2002	180 *	4	3, 176	6.45	0.000362	Very highly significant
June 2002	3226	4	3, 3222	36.91	1.89E-23	Very highly significant
January 2003	3720	4	3, 3716	7.69	4.06E-05	Very highly significant
Note: * = Data were 180 mean values from 180 sub-plots; Four top dying severity classes were none, slight, moderate and severe.						

Comparison of the results of variance analysis of the data on the number of lenticels collected in January 2002, June 2002 and January 2003 from sample plots of none, slight, moderate and severe top dying of sundri reveal that there exist significant difference among the mean values from the sample plots of the four top dying severity classes as are shown by significant variances expressed in terms of F-value which have been summarized in **Table 19**.

Table 19: Summary to compare the results of variance analysis of the data on the number of lenticels recorded from 1 cm^2 area from near bottom, middle and top of five pneumatophores collected from each of five sub-plots falling in each sample plot from four category of top dying severity (viz. severe, moderate, slight and none i.e. no top dying of sundri) classes from 12 compartments in January 2002 , June 2002 and January 2003 from the Sundarbans.

Data collected in	Total No. of data	No. of top dying severity class	Parameter	Degrees of freedom	Calculated F-value	Probability	Difference among the mean values
January 2002	150	4	No. of lenticels at the collar	3, 146	7.47	0.0001	Very highly significant
January 2002	150	4	No. of lenticels at the middle	3, 146	1.08	0.3605	Insignificant
January 2002	150	4	No. of lenticels at the top	3, 146	0.71	0.5484	Insignificant
June 2002	80	4	No. of lenticels at the collar	3, 76	5.87	0.0012	Highly significant
June 2002	80	4	No. of lenticels at the middle	3, 76	3.51	0.0356	Significant
June 2002	80	4	No. of lenticels at the top	3, 76	1.33	0.3353	Insignificant
January 2003	505	4	No. of lenticels at the collar	3, 501	0.20	0.8986	Insignificant
January 2003	505	4	No. of lenticels at the middle	3, 501	1.31	0.2690	Insignificant
January 2003	505	4	No. of lenticels at the top	3, 501	1.35	0.2559	Insignificant

The significant difference among the mean values of the number of pneumatophores from the four top dying severity classes (i.e. none, slight, moderate and severe) as are evident from **Table 17.**

The above comparison in Tables 17, 18 and 19 however, do not reveal the extent and trend of the differences among the mean values. Therefore, further analysis of the data were carried out by using Duncan's Multiple Range Tests (Duncan, 1955). These in respect of number of pneumatophores data are provided in **Tables 20, 21** and **22**; for length of pneumatophores data in **Tables 23, 24** and **25**; and in respect of the number of lenticels in **Tables 26, 27** and **28.**

Table 20: Comparison of the ranked mean number of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in October 2001 in the Sundarbans.

Moderate	Severe	None	Slight
28.79	43.19	48.45	62.48
	--------------------	--------------------	

Notes: Means underscored by the same dotted line are not significantly different. Number of pneumatophores in slight top dying sample plots are significantly higher (P = 0.05) than that in none (i.e. no top dying), severe and moderate top dying sample plots.

Table 21: Comparison of the ranked mean number of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in January 2002 in the Sundarbans.

Severe	Moderate	Slight	None
18.44	20.07	27.20	28.047
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Notes: Means underscored by the same dotted line are not significantly different. Number of pneumatophores in slight top dying sample plots and no top dying sample plots (i.e. none) are significantly higher (P = 0.05) than that of severe and moderate top dying sample plots.

Table 22: Comparison of the ranked mean number of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in June 2002 in the Sundarbans.

Severe	Moderate	Slight	None
14.97	15.33	36.55	39.20
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Notes: Means underscored by the same dotted line are not significantly different. Number of pneumatophores in slight top dying sample plots and no top dying sample plots (i.e. none) are highly significantly higher (P = 0.001) than that of severe and moderate top dying sample plots.

It is thus seen from the data of mean number of pneumatophores and the trend of their distribution among no top dying sample plots (i.e. none) and slight top dying sample plots have been significantly higher than those from moderate and severe top dying sample plots. This has been true in case of data from January 2002 and June 2002. In case of data from October 2001 the trend is more or less the same in that in the none and slight top dying sample plots there is higher number of pneumatophores as compared to moderate and severe top dying sample plots. It is therefore, suggested that significantly higher number of pneumatophores arising from the cable roots of the sundri trees having no top dying and only slight top dying strongly advocate higher degree of aeration in the root system of healthy trees. Absence of such a situation is associated with moderate and severe top dying condition of sundri.

The significant difference among the mean values of the length of pneumatophores from the four top dying severity classes (i.e. none, slight, moderate and severe) are evident from **Table 18**. This, however, does not reveal the extent and trend of the differences among the mean length of pneumatophores from sample having none, slight, moderate and severe top dying of sundri

Therefore, further analysis of the data were carried out by using Duncan's Multiple Range Tests (Duncan, 1955). These are provided in **Tables 23, 24, 25** and **26**.

Table 23: Comparison of the ranked mean length (in cm) of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in October 2001 in the Sundarbans.

Moderate	None	Slight	Severe
13.25	16.09	17.08	17.55
		--------------------	--------------------

Notes: Means underscored by the same dotted line are not significantly different. Length of pneumatophores in slight top dying sample plots and severe top dying sample plots are significantly higher (P = 0.05) than that of none and moderate top dying sample plots.

Table 24: Comparison of the ranked mean length (in cm) of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in January 2002 in the Sundarbans.

Moderate	Severe	Slight	None
13.79	16.68	17.11	19.34
	--------------------	--------------------	
		--------------------	--------------------

Notes: Means underscored by the same dotted line are not significantly different. Length of pneumatophores in the none (i.e. no top dying sample plots) are significantly (P = 0.05) higher than that from severe and moderate top dying sample plots.

Table 25: Comparison of the ranked mean length (in cm) of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in June 2002 in the Sundarbans.

Slight	None	Moderate	Severe
14.16	14.90	14.91	18.52
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Notes: Means underscored by the same dotted line are not significantly different. Length of pneumatophores in the severe is significantly (P = 0.05) higher than that of the remaining three categories.

Table 26: Comparison of the ranked mean length (in cm) of pneumatophores of sundri per square meter area of the sub-plots of the 36 sample plots of four top dying severity categories of none, slight, moderate and severe as recorded in January 2003 in the Sundarbans.

Moderate	Slight	Severe	None
15.85	16.80	18.18	18.47
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Note: Mean underscored by the same dotted line are not significantly different.

It is found from Tables 14 to 17 that no distinctly clear trend is found in case of the length of pneumatophores from the sample plots of four top dying severity categories (i,e, none, slight, moderate and severe). Data collected in October 2001, June 2002 showed

significantly higher length of pneumatophore from severe top dying sample plots as compared to no top dying sample plots (i.e. none). January 2003 showed no significant difference in mean length of pneumatophores from the four top dying severity categories sample plots. It may be pertinently mentioned here that none and slight top dying sample plots had significantly and substantially higher number of pneumatophores as compared to moderate and severe top dying sample plots (vide Tables 12 and 13). Therefore it is suggested that to meet the demand of aeration in the root system the moderate and severe top dying trees with a smaller number of pneumatophores tend to increase the length of the pneumatophores. This gets the support from a rational sense of judgement in case of a mangrove environment.

The significant difference among the mean values of the number of lenticels at near the collar region of the pneumatophores from the four top dying severity classes (i.e. none, slight, moderate and severe) have been obtained from the data collected in January 2002 and also in June 2002. In case of the number of lenticels from near the middle of pneumatophores significant difference has been obtained in data collected in June 2002 but there was no significant difference in the data collected in January 2002 from the middle of the pneumatophores. There was no significant difference in the number of lenticels from near the top of the pneumatophores in the data collected in January 2002 and June 2002. Therefore, further analysis of the data of number of lenticels at near the collar from both the observations in January and June 2002 and that from the middle of pneumatophores from June 2002 observation were carried out by using Duncan's Multiple Range Tests (Duncan, 1955). These are provided in Tables 18, 19 and 20 respectively.

Table 27: Comparison of the ranked mean number of lenticells on per sq. cm area at collar region of pneumatophores of sundri in the sub-plots of four top dying severity categories of none, slight, moderate and severe as observed in January 2002 in the Sundarbans

Severe	None	Slight	Moderate
2.17	2.43	2.46	2.91
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Notes: Means underscored by the same dotted line are not significantly different. Number of lenticels in per sq. cm area at collar region of pneumatophores of moderate top dying sub-plots are highly significantly (P = 0.01) higher than that of none, slight and severe top dying sub-plots.

Table 28: Comparison of the ranked mean number of lenticells on per sq. cm area at collar region of pneumatophores of sundri in the sub-plots of four top dying severity categories of none, slight, moderate and severe as observed in June 2002 in the Sundarbans

Severe	Moderate	Slight	None
0.67	0.95	1.24	1.28
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	----------	----------	
		----------	----------

Notes: Means underscored by the same dotted line are not significantly different. Number of lenticels in per sq. cm area at collar region of pneumatophores of no top dying (i.e. none) sample plots are highly significantly (P = 0.01) higher than that of severe top dying sample plots but significantly (P = 0.05) higher than that from moderate top dying sample plots.

Table 29: Comparison of the ranked mean number of lenticells on per sq. cm area at middle region of pneumatophores of sundri in the sub-plots of four top dying severity categories of none, slight, moderate and severe as observed in January 2003 in the Sundarbans

Severe	Moderate	None	Slight
0.75	1.11	1.15	1.24
	------------------------	------------------------	------------------------

Notes: Means underscored by the same dotted line are not significantly different. Number of lenticels in per sq. cm area at middle region of pneumatophores of no top dying (i.e. none) and moderate top dying sample plots are significantly (P = 0.05) higher than that of severe top dying sample plots but slight top dying sample plots had highly significantly (P = 0.01) higher than that from severe top dying sample plots.

It is evident from **Tables 27, 28** and **29** that the lowest mean number of lenticels per sq. cm area of the collar region were found to be present in case of pneumatophores observed in severely top dying sample plots in January 2002, June 2002 and January 2003. But in case of data collected in January 2002 the mean number of lenticels per sq. cm area of collar region of pneumatophores from moderate top dying sample plots had the highest mean no. of lenticels which was significantly higher ($P = 0.05$) than that from the collar region of pneumatophores from severe, none and slight top dying sample plots. There was, however, no significant difference in the mean number of lenticels found to occur at the collar region of pneumatophores of none, slight and severe top dying sample plots. **Presence of the lowest number of lenticels per sq. cm area at the collar region of the pneumatophores of severely top dying affected sample plots strongly suggests that reduced supply of oxygen to the root system is very likely to be responsible for the development of top dying of sundri in the Sundarbans. This gets further support from the fact that significantly higher number of pneumatophores arising from the cable roots of the sundri trees having no top dying and only slight top dying strongly advocate higher degree of aeration in the root system of healthy trees.**

5.1.2: Association of the number of pneumatophores per unit area and number of lenticels on the pneumatophores and four severity classes of top dying of sundri trees

Therefore, in a further attempt the correlation of the four top dying severity classes (i.e. none, slight, moderate and severe) and data of the number of pneumatophores collected from 180 sub-plots in January 2002 was determined. The correlation coefficient $r = -0.332$, with 179 df was found to exist. Similarly, the correlation coefficient $r = -0.350$, with 149 df was found to occur between the data of number of pneumatophores from the sub-plots as observed in June, 2002 and the four top dying severity classes. Both these values of correlation coefficient are highly significant at $P = <0.01$. In both cases the value of Correlation Coefficients are negative which suggest that as the values of the four top dying severity classes (i.e. 1 = None, 2 = slight, 3 = moderate and 4 = severe top dying of sundri) increases the mean number of pneumatophore from 1 sq. meter area of the sub-plot decreases. Besides, the number of lenticels recorded from the collar, middle and near top of the pneumatophores in June 2002 all had a significant association with the four top dying severity classes as already mentioned as we obtained Correlation Coefficient $r = 0-0.418$, -0.242 and -0.189 (each with df =149) respectively. However, the number of lenticels recorded from the collar region of pneumatophore recorded in January 2002 had only an insignificant association with the four top dying severity classes as we had a

Correlation Coefficient, r = -0.083, with 179 df., although this had a significant variance. To further test the nature of this association and in cases where we had a significant correlation coefficient, linear regression analysis and drawing the line of best fit with the data of mean number of pneumatophores recorded from the sub-plots of all the sample plots recorded in January and June 2002, and that of the number of lenticels recorded from the collar, middle and top region of pneumatophore in June were attempted by using a programme of Linear Regression of Minitab for Windows Release 11.2 32 bit. These have been provided in Figs.1, 2, 3, 4 and 5 respectively.

Fig. 1: Relationship between the number of sundri pneumatophore and per cent top dying of sundri trees in 180 sub-plots of 36 sample plots observed in January 2002 in the Sundarbans.

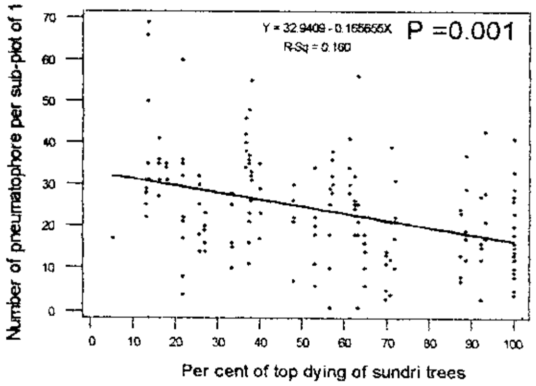


Fig. 2: Relationship between the number of pneumatophore and per cent top dying of sundri trees in 150 sub-plots of 36 sample plots observed in June 2002 in the Sundarbans.

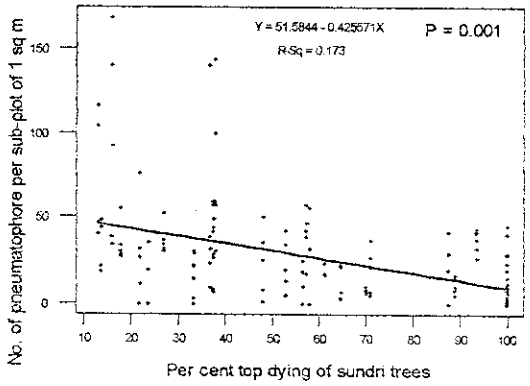


Fig. 3: Relationship between the number of lenticels at near collar of pneumatophore and per cent top dying of sundri trees based on data of 150 sub-plots from 36 sample plots as collected in June 2002 in the Sundarbans.

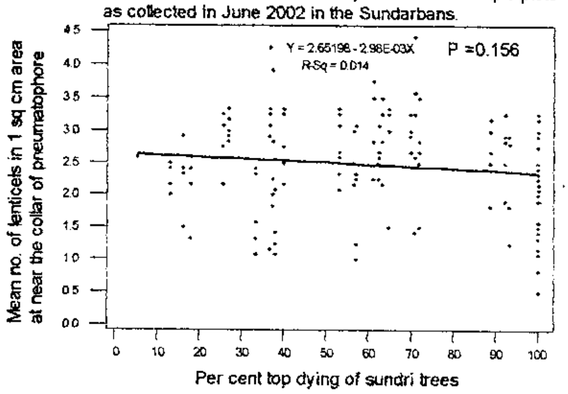


Fig. 4: Relationship between the number of lenticels at near the middle of pneumatophore and per cent top dying of sundri trees based on data of 150 sub-plots from 36 sample plots as collected in June 2002 in the Sundarbans.

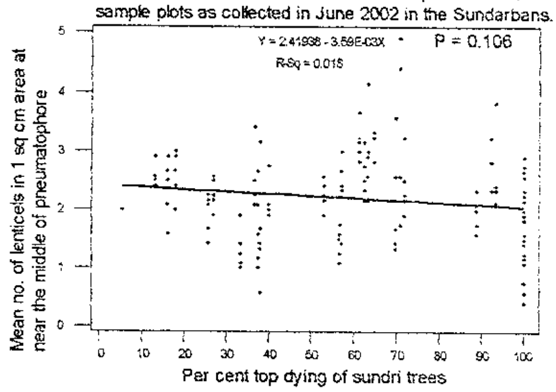


Fig. 5: Relationship between the number of lenticels at near the top of pneumatophore and per cent top dying of sundri trees based on data of 150 sub-plots from 36 sample plots as collected in June 2002 from the Sundarbans.

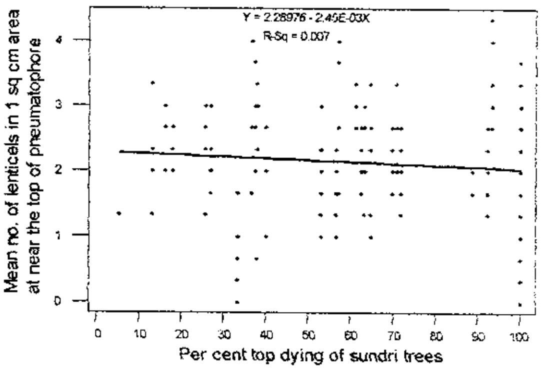


Fig. 6: Showing distribution of residuals of data of pneumatophores from four top dying severity classes observed in January 2002 in 180 sub-plots in the Sundarbans.

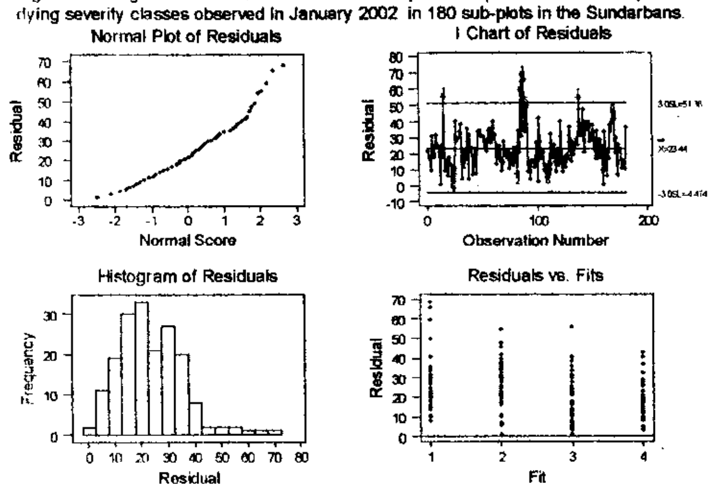


Fig. 7: Showing distribution of residuals of data of number of pneumatophores from four top dying severity classes observed in June 2002 in 150 sub-plots in the Sundarbans

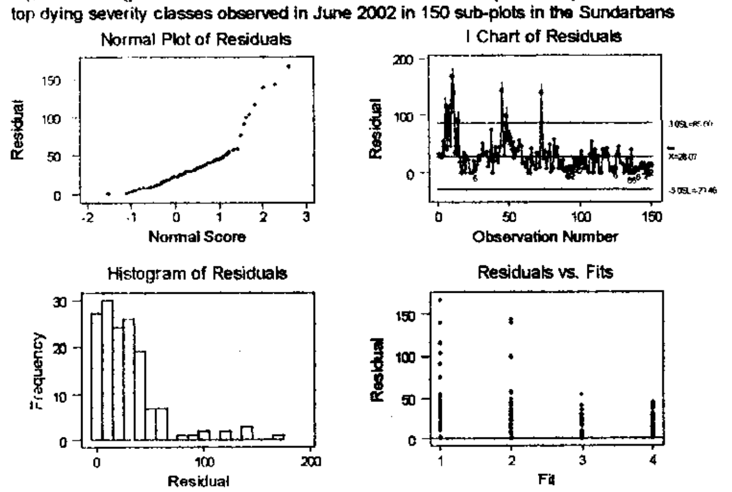


Fig. 8: Showing distribution of residuals of data of lenticels at collar of pneumatophores from four top dying severity classes observed in June 2002 in the Sundarbans

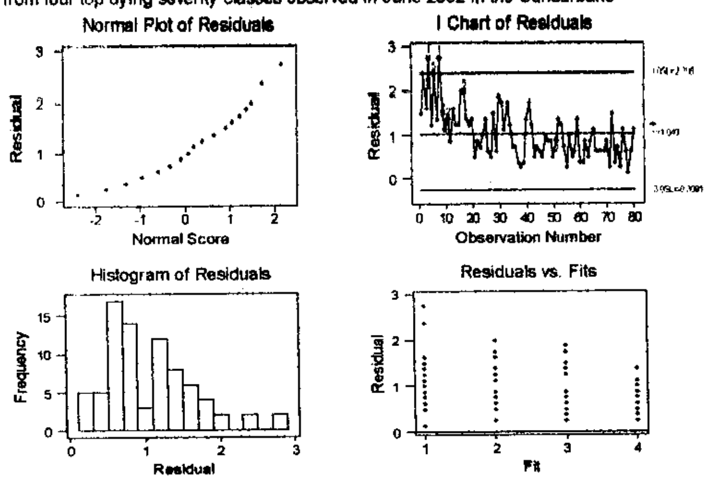


Fig 9: Showing distribution of residuals of data of lenticels at middle of pneumatophores from four top dying severity classes observed in June 2002 in the Sundarbans

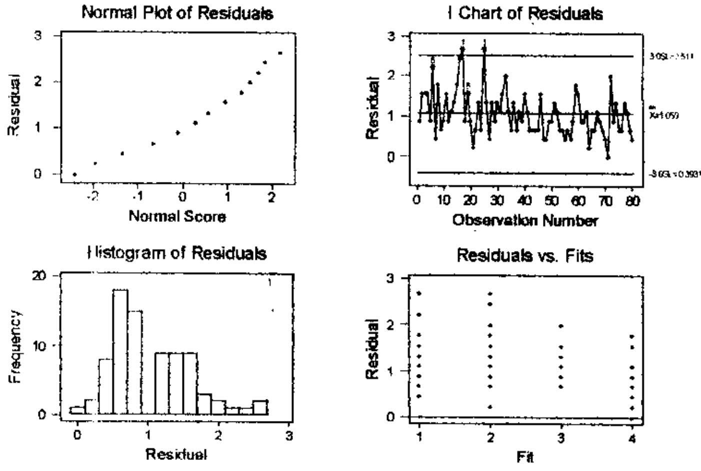
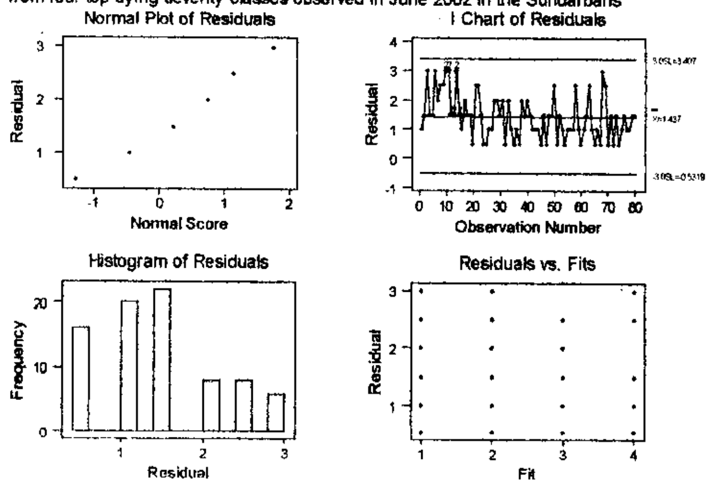


Fig. 10: Showing distribution of residuals of data of lenticels at top of pneumatophores from four top dying severity classes observed in June 2002 in the Sundarbans



Both Figs. 1 and 2 clearly reveal that with the increase in the severity of top dying of sundri the mean number of pneumatophores from unit area of the sub-plots decrease substantially. The regression equations for data of pneumatophore number (in Y axis) and four top dying severity classes (in X axis) from January and June 2002 are as follows:

1) Y =30.1946 – 2.80816 X, with R Sq. = 0.087 .... Data collected in January 2002
2) Y = 49.9275 – 9.23695 X, with R Sq. = 0.122 .... Data collected in June 2002

In the next step the residuals from the above two regressions were plotted in Figs. 6 and Fig. 7. In case of data collected in January 2002 showed a very regular pattern as is evident from the pattern of the histogram of residuals which has shown a more or less normal distribution with very small deviation. Moreover, most of the residuals are distributed within the confidence limits of the residuals (vide Fig. 6). In case of data collected in June 2002 showed broadly a similar pattern as is evident from the distribution of residuals mostly within the confidence limit but there were some observations whose residuals had more divergent distribution (vide Fig. 7). On overall judgement the data on the number of pneumatophores are quite well acceptable. **Hence the conclusion that reduction in the number of pneumatophores per unit area is directly associated with the severity of top dying of sundri is a reasonably acceptable conclusion.**

Variance analysis showed a significant variance of the number of lenticels at near the collar of the pneumatophores in case of data collected in January and June 2002, but number of lenticels at near the middle of the pneumatophore showed a significant variance in case of data collected in June 2002 only. Therefore, regression analysis of these three sets of data with the top dying per cent data of the 36 sample plots were carried out and regression equations were arrived at (vide Figs. 2, 4, and 5). The regression equations from data of number of lenticels at near collar of pneumatophore (in Y axis) and four top dying severity classes (in X axis) from January and June 2002 and that of lenticels from near the middle of pneumatophore in case of data from June 2002 are as follows:

3) Y = 1.56554 –0.212099 X, with R Sq. = 0.175 for collar lenticels data collected in June 2002
4) Y = 1.34451 – 0.11599 X, with R Sq. = 0.058 for middle lenticels data collected in June 2002
5) Y = 1.74414 – 0.124525 X, with R. Sq. = 0.036 for top lenticels data collected in June 2002

Fig. 3 shows that there is a trend of the occurrence of reduced number of lenticels at the collar region of pneumatophores from none through to slight, moderate and severe top dying of sundri trees. This is also evident in case of data of lenticels at the middle of pneumatophores as observed in June 2002 (vide Fig. 4). The trend is also evident in case of number of lenticels at top region of pneumatophores when data were collected in June 2002 (vide Fig. 5). It is suggested that the significant difference in case of number of lenticels at collar, middle and top of pneumatophore obtained from data collected in June 2002 may be because of the fact that during June level of innundation was higher as compared to that in January 2002 therefore reduction in the number of lenticels at collar became much more pronounced in June as compared to that in January. In simple words, in January because of less innundation there was more stress at collar of pneumatophore so there were more lenticels at collar. In June because of more innundation there were smaller number of lenticels at collar as compared that in January. Because of higher level of innundation the reduction in number of lenticels progressed further up the pneumatophores which resulted in the significant reduction of in the number of lenticels at the middle zone and much less at top portion of pneumatophore in June and this was absent in January because of less pronounced innundation during that time.

The residuals from the regressions 3, 4 and 5 were plotted in Figs. 8, 9 and 10. In case of lenticels data collected from collar in June 2002 showed a very regular pattern as is evident from the pattern of the histogram of residuals which has shown a more or less normal distribution with very small deviation. Moreover, most of the residuals are distributed within the confidence limits of the residuals (vide Fig. 8). In case of lenticels data collected from middle in June 2002 showed broadly a similar pattern as is evident from the distribution of residuals mostly within the confidence limit but there were some observations from none (i.e. no top dying sub-plots) whose residuals had more divergent distribution (vide Fig. 9). In case of data of lenticels from top of pneumatophores collected in June 2002 a more regular pattern of distribution of residuals are seen (vide Fig. 10) .On overall judgement the data on the number of lenticels are quite well acceptable. Hence it is found that the reduced number of lenticels per unit area of pneumatophores at the collar, middle and top of pneumatophores, particularly during the time of higher level of innundation as in June is associated with the severity of top dying of sundri as we had highly significant Correlation Coefficients ($r = -0.350$, with 149 degrees of freedom) and that the trend of occurrence of lenticels on the pneumatophores shows a clear cut pattern of increasingly reduced number of lenticels from none, through to slight, moderate and severe top dying categories (vide Figs. 3, 4 and 5).

Thus we arrive at the conclusions that occurrence of significantly reduced number of pneumatophores and significantly reduced number of lenticels at the collar and middle region of the pneumatophores are associated with progressive severity (i.e. none, slight, moderate and severe) top dying of sundri in the Sundarbans. Hence, among others, these are considered to be the causes of top dying of sundri. However, the cause(s) which promotes the reduced number of pneumatophore development and fewer lenticels production needs to be clarified in further studies. But one thing seems to be very evident that depth and duration of flooding of the pneumatophore are very interesting parameters to be monitored in rather micro scales in future.

5.1. 3 Sedimentation/subsidence and to dying of sundri

The extent of sedimentation/subsidence and/or erosion on was studied by establishing 180 sediment gauges, 5 in each of 36 sample plots in January 2001 . These were sundri poles fixed one in the centre and four in the centre of the four quadrant of each sample plot. After establishing the sediment gauges, the height of each gauge above the soil was measured in January 2002, June 2002 and January 2003. If the height of the sediment gauge above the soil was found to reduce that indicated sedimentation, but if the reading was found to be greater than the first observation that indicated erosion. In the first case the difference between two observations was plus value, while in the latter case the difference was a minus value. Quite a large number of sediment gauges were removed either by wildlife or by human interference. Hence, to compare sedimentation/erosion between January 2002 and January 2003, data were obtained from 157 sediment gauges that are provided in **Appendix 8.** A comparison of the sedimentation/erosion data of 157 gauges (36 from none, 42 from slight, 36 from moderate and 43 from severe top dying sample plots) revealed a significant ($P=0.01$) difference in the mean values from the four top dying severity classes of the sample plots i.e. none having –1.06 cm, slight -1.59 cm, moderate having +2.69 cm and severe +1.90 cm. The first two means did not significantly differ from each other and the last two means also did not differ significantly from each other, but the latter means were significantly higher than the first two means. Thus sedimentation in the moderate and severe top dying sample plots was associated with the severity of top dying while subsidence in the none and slight top dying sample plots had commenced

Table 30: Summary of variance analysis of the data on sedimentation (sediment deposition and erosion) around the base of 157 sediment gauges established in 36 sample plots at 12 landings in 10 compartments falling in severe, moderate, slight and none (i.e. no) top dying of sundri as recorded in January 2002 and January 2003 in the Sundarbans

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	36	-38.2	-1.061111	9.767587		
Slight	42	-66.7	-1.588095	29.83425		
Moderate	36	+96.8	+2.68889	59.93473		
Severe	43	+81.87	+1.90395	75.50049		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit (at P =0.05)
Between Groups	527.959	3	175.9863	3.940105	0.009646	2.663711
Within Groups	6833.806	153	44.6654			
Total	7361.765	156				

Table 31: Comparison of the ranked mean sedimentation (figures with plus sign) and subsidence and/or erosion (figures with minus sign) around the base of 157 sediment gauges established in 36 sample plots at 12 landings in 10 compartments falling in severe, moderate, slight and none (i.e. no top dying) of sundri as recorded between January 2002 and January 2003 in the Sundarbans.

Slight	None	Severe	Moderate
-1.59	-1.06	+ 1.90	+2.69
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Note: Means underscored by the same dotted line are not significantly different. Sedimentation in severe and moderate sample plots were significantly higher (at P= 0.05) as compared to slight and none sample plots.

5.1.4 Geomorphological characteristics of the 36 sample plots in relation to top dying of sundri

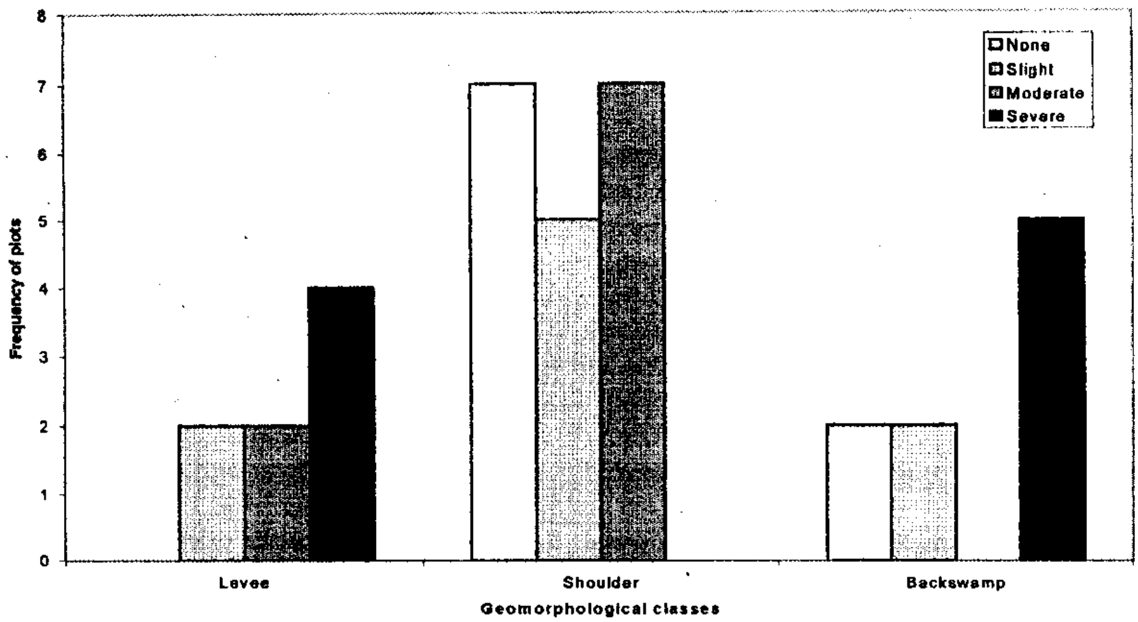
The landscape of the Sundarbans is a complex of islands separated by large or small water bodies. Morphologically each of these islands are like a big saucer with elevated edges, a sloping surface between the edge and bottom of the saucer and the bottom which collects tidal/rain water. In this study the raised edge of the saucer is defined as levee, the sloping area as shoulder and the bottom of the saucer or depression at center of the delta as backswamp. Attributes of these geomorphological settings are:

- Levees are well drained and often densely covered by bushy ground vegetation
- Shoulder- the gently sloping area which is considerably well drained
- Backswamp- drainage is usually very poor; substrate is soft and often saturated with water.

These geomorphological features influence several environmental factors, e.g., soil drainage and aeration, critical to the distribution of mangrove vegetation. Karim (1994) observed that these geomorphic features in the Sundarbans influenced zonation of mangroves.

In this study the geomorphic characteristics of each sample plot, i.e., location of the plot on the saucer - levee, shoulder and backswamp, was meticulously observed. Here this is important to note that sample plots even in the same geomorphological setting were not identical. For example, in compartment 2 though the sample plot on the backswamp was badly drained in comparison to those on levee and shoulder, the substrate in the plot was just moist and it was well drained in comparison to the backswamp in the compartment 37. Later any association between the severity of STD and geomorphological characteristics of the sample posts was tested. The figure below shows the frequency of plots bearing various STD severity classes in relation to geomorphological condition of the site. It clearly indicates the concentration of severely STD affected areas on the levee and backswamp but absence on the shoulder. It reveals

Fig. 10a Frequency of various STD severity classes in three geomorphological conditions



that sundri experiences great stress both on levee and backswamp areas and least stressed on the shoulder. This indicates an association between STD the availability of oxygen at the root zone of sundri and probably no association of STD with the variation in the availability of nutrient or soil salinity even at micro level which are discussed below.

In the sedimentary environment the rate of sedimentation depends upon the depth of the water column above the surface, sediment load in water and the velocity of water current (McConchie, 1991). MacNae (1968) observed the highest rate of sedimentation on the seaward side (towards the direction of incoming water) which makes natural levee on the edge of water bodies or islands, a common feature in mangrove habitat. Again, it is well recognized that only the surface layer of the mangrove sediment (top 10 cm) remain well oxygenated, suitable for root development and nutrient uptake. Thus at places with high sedimentation this useful substrate layer continuously moves upward and the existing roots are buried in the anoxic sediment. Mangroves respond to this by putting secondary growth on the pneumatophore and producing new roots close to the surface (Troll and Dragendorff 1914, Chapman 1976, Huchings and Saenger, 1987). However, if the rate of sedimentation is so high that the adaptations in mangrove (secondary growth on pneumatophore and production of new roots) cannot cope with, mangroves usually suffer. In mangrove plantations in certain areas of high sedimentation

McConchie (1991) reduced growth, mortality and even partial or complete burial of transplanted mangrove seedlings.

Drainage in backswamp, bottom of the saucer, is generally very bad. Substrate in the area remains almost permanently saturated with water. At high tide the area remains deeply flooded for longer time. In such sites substrate presents highly anoxic condition for plants. Mangroves respond to the situation by producing large number of tall pneumatophores, which are likely to remain above the general tidal height. However, the situation could some times be critical to cause stress on the mangrove plants in the area.

From the discussion above, apparently concentrations of severely STD affected areas on the levees and backswamp of mangroves and its absence on the shoulder indicates the association between STD and deficiency of oxygen in the soil.

5.1.5 Data on Regeneration

5.1.5.1 Data of seedlings and saplings of tree species from the 36 sample plots in 10 compartments

Regeneration of all mangrove species seedlings was studied in October 2001 and June 2002 from the 36 sample plots. During October 2001 from each of 36 sample plots three sub-plots, each 2 m x 2 m, were randomly laid out, while during June 2002 this was increased to 5 sub-plots from each sample plots. From each of the selected sub-plots all regeneration were classified into three types: R1 – seedlings less than 1.3 m in height; R2 – seedlings of height 1.3 m or more but less than 2.5 cm in d.b.h.; and R3 – seedlings of height 1.3 m or more and d.b.h. of 2.5 cm or more. From each of the four types of top dying severity classes (i.e. none, slight, moderate and severe), 3 compartments, 9 sample plots and 27 sub-plots were taken during October 2001 observation, but during June 2002 this number was raised to 45 sub-plots from each of four top dying severity classes The data of October 2001 have been provided in **Appendix 17** and those of June 2002 in **Appendix 18,** and have been summarized in **Tables 32** and **33** respectively. Analysis of variance of the data of Appendix 17 and 18 using a programme of the SAS System have been done. The data of regeneration of R1, R2 and R3 types of different mangrove species as recorded in January 2003 from 45 sub-plots (each 4 sq meter) from 9 sample plots from each of severe, moderate, slight and none (i.e. no) top dying of sundri from 12 landings in 10 compartments in the Sundarbans have been provided in **Appendix 19**. **The data of Appendix 19 have been summarized in Table 34**. Analysis of variance of the data of have been done using a programme of the SAS System. The results of analysis of variances as provided in Appendix 19, 20 and 22 for regeneration data of October 2001, June 2002 and January 2003 have been summarized in **Tables 35, 36** and **37** respectively.

Table 32: Summarized data of mean regeneration of types R1, R2 and R3 in an area of 4 square meter of each of 27 sub-plots in 9 sample plots of all mangrove species recorded in each of four top dying severity classes (viz. none, slight, moderate and severe) in October 2001 in the Sundarbans.

Top dying severity class	No. of sample plots	No. of sub-sample plots	Sundri R1	Sundri R2	Sundri R3	Gewa R1	Gewa R2	Gewa R3	Goran R1	Goran R3	Amur R1	Amur R2	Amur R3	Singra R1
None	9	27	15.27	1.50	1.75	9.00	4.50	1.00	1.33	0	2.54	1.67	4.00	4.00
Slight	9	27	19.39	1.00	1.00	2.77	2.00	4.67	2.00	0	2.73	1.50	0	0
Moderate	9	27	16.81	4.00	3.00	6.71	0	9.00	1.00	1.50	2.07	1.00	4.00	0
Severe	9	27	20.78	2.83	5.00	4.71	1.50	4.33	0	0	1.50	1.00	0	0

Notes: Regeneration R1 = Stem less than 1.3 m in height; R2 = Stem of 1.3 m or more in height but d.b.h. less than 2.5 cm; R3 = Stem of 1.3 m or more in height and d.b.h. 2.5 cm or more; Goran R2, Passur R1, Passur R2, Passur R3, Singra R2 and Singra R3 have been excluded from this table as all values were zero.

Table 33: Summarized data of mean regeneration of types R1, R2 and R3 in an area of 4 square meters of each of 45 sub-plots in 9 sample plots of all mangrove species recorded in each of four top dying severity classes (viz. none, slight, moderate and severe) in June 2002 in the Sundarbans.

Top dying severity class	No. of sample plots	No. of sub-sample plots.	Sundri R1	Sundri R2	Sundri R3	Gewa R1	Gewa R2	Gewa R3	Goran R1	Goran R2	Goran R3	Amur R1	Amur R2	Amur R3	Singra R1	Kankra R1	Kankra R2
None	9	45	11.42	0.20	0.11	0.40	0.40	0.11	0.36	0.11	0.18	0.69	0.39	0.07	0.29	0.04	0
Slight	9	45	11.04	0.22	0.18	0.76	0.22	0.13	0	0	0.02	0.51	0.09	0.07	0	0	0.02
Moderate	9	45	19.82	1.38	1.02	0.64	0.56	0.24	0.08	0	0.04	0.20	0.11	0	0	0.02	0
Severe	9	45	13.98	0.62	0.27	0.27	0.60	0.31	0.04	0	0.09	0.38	0.24	0.20	0	0	0

Notes: Regeneration R1 = Stem less than 1.3 m in height; R2 = Stem of 1.3 m or more in height but d.b.h. less than 2.5 cm; R3 = Stem of 1.3 m or more in height and d.b.h. 2.5 cm or more; Singra R2, Singra R3 and Kankra R3 have been excluded from this table as all values were zero.

Table 34: Summarized data of mean regeneration of types R1, R2 and R3 in an area of 4 square meters of each of 45 sub-plots in 9 sample plots of all mangrove species recorded in each of four top dying severity classes (viz. none, slight, moderate and severe) in January 2003 in the Sundarbans.

Top dying severity class	No. of sample plots	No. of sub-sample plots	Sundri R1	Sundri R2	Sundri R3	Gewa R1	Gewa R2	Gewa R3	Goran R1	Goran R3	Amur R1	Amur R2	Amur R3	Singra R1	Kankra R1	Kankra R2
None	9	45	7.02	0.16	0.38	2.20	0	0.42	0.60	1.48	0.29	0.29	0.80	0.02	0.04	0.02
Slight	9	45	11.60	0.33	0.31	0.11	0.07	0.16	0.69	0	1.80	0.13	0.38	0	0.56	0
Moderate	9	45	21.07	1.42	1.56	9.13	0.51	1.33	0.24	0.02	1.49	0.04	0.18	0.16	0	0.02
Severe	9	45	11.82	1.04	2.31	0.82	0.22	0.51	0.02	0	0.64	0.27	0.42	0.13	0	0

Notes: Regeneration R1 = Stem less than 1.3 m in height; R2 = Stem of 1.3 m or more in height but d.b.h. less than 2.5 cm; R3 = Stem of 1.3 m or more in height and d.b.h. 2.5 cm or more; Goran R2, Singra R2, Singra R3 and Kankra R3 have been excluded from this table as all values were zero.

Table 35 : Comparative F-value and level of significance obtained from comparison of the three levels of regeneration of R1, R2 and R3 among 27 sub-plots of each of the four top dying severity classes (viz. none, slight, moderate and severe) as observed in October 2001 at 12 landings in 10 compartments in the Sundarbans.

Species	R1 type regeneration		R2 type regeneration		R3 Regeneration	
	F-value*	Significance	F-value*	Significance	F-value*	Significance
Sundri	1.04	Insignificant	2.34	Insignificant	**1.97**	Insignificant
Gewa	0.08	Insignificant	1.27	Insignificant	0.45	Insignificant
Goran	0.90	Insignificant	-	-	1.83	Insignificant
Amur	0.70	Insignificant	0.20	Insignificant	1.18	Insignificant
Singra	2.41	Significant	-	-	-	-

Note: * refers that all the F-values are with 3 and 103 (residual) degrees of freedom

Table 36: Comparative F-value and level of significance obtained from comparison of the three levels of regeneration of R1, R2 and R3 among 44 sub-plots of each of the four top dying severity classes (viz. none, slight, moderate and severe) as observed in June 2002 at 12 landings in 10 compartments in the Sundarbans.

Species	R1 type regeneration		R2 type regeneration		R3 Regeneration	
	F-value*	Significance	F-value*	Significance	F-value*	Significance
Sundri	1.82	Insignificant	**6.05**	**Significant**	**6.80**	**Significant**
Gewa	0.92	Insignificant	0.77	Insignificant	0.54	Insignificant
Goran	1.61	Insignificant	**3.15**	**Significant**	1.07	Insignificant
Amur	1.56	Insignificant	0.48	Insignificant	1.62	Insignificant
Singra	**7.80**	**Significant**	-	-	1.08	Insignificant
Kankra	0.67	Insignificant	2.06	Insignificant	1.14	Insignificant
Note: * refers that all the F-values are with 3 and 170 (residual) degrees of freedom						

Table 37: Comparative F-value and level of significance obtained from comparison of the three levels of regeneration of R1, R2 and R3 among 45 sub-plots of each of the four top dying severity classes (viz. none, slight, moderate and severe) as observed in January 2003 at 12 landings in 10 compartments in the Sundarbans.

Species	R1 type regeneration		R2 type regeneration		R3 Regeneration	
	F-value*	Significance	F-value*	Significance	F-value*	Significance
Sundri	**4.08**	Significant	**3.49**	**Significant**	**4.15**	**Significant**
Gewa	2.13	Insignificant	2.53	Insignificant	1.77	Insignificant
Goran	**2.97**	**Significant**	-	-	7.23	**Significant**
Amur	2.31	Insignificant	2.23	Insignificant	0.46	Insignificant
Singra	**4.10**	**Significant**	1.35	Insignificant	0.14	Insignificant
Kankra	1.98	Insignificant	-	-	-	Insignificant
Pssur	2.69		-		-	
Note: * refers that all the F-values are with 3 and 176 (residual) degrees of freedom						

It is seen from **Tables 32, 33 and 34** that significant variations in regeneration among the four top dying severity classes (i.e. none, slight, moderate and severe) were found to occur in cases of R1 (i.e. seedling) type regeneration of passur in October 2001, R2 (i.e. saplings) and R3 (i.e. pole) type of sundri, R2 type goran and R1 type of singra in data of June 2002; and R1 type, R2 and R3 type of sundri, R1 and R3 type goran, and R1 type of singra in data of January 2003.

Therefore, to identify the trend of occurrence of regeneration of different species in the four types of top dying severity classes (i.e. none, slight, moderate and severe) further analysis were carried out of the relevant data from the **Appendix 17, 18 and 19** and the results are provided in **Table 38**. These include shingra R1 of data collected in October 2001; sundri R2, sundri R3, goran R2 and shingra R1 of data collected in June 2002; and sundri R1, R2 and R3 , goran R1 and R3, and shingra R1 data collected in January 2003 from 36 sample plots from 10 compartments in the Sundarbans.

Table 38: Summary of Duncan's Multiple Range Tests of the mean values regeneration (R1 = seedlings, R2 = saplings, R3 = poles) from 179 sub-plots (each 4 sq. feet) from 36 sample plots, 9 from each of no top dying (i.e. none), slight, moderate and severe top dying of sundri, in 10 compartments, data collected in January 2003, in the Sundarbans

Parameter					
Shingra R1 (October 2001)	0	0	0	4.00 (N)	Shingra seedlings (i.e. R1) was found to occur only in the no top dying (i.e. none) sample plots and there were no regeneration from the three other types of sample plots. Hence F value was significant.
Sundri R2 (June 2002)	0.20 (N)	0.22 (S)	0.62 (Se)	1.38 (M)	Sundri saplings (i.e. R2) was the highest in the moderate top dying sample plots and was significantly higher (P =0.05) that from none, slight and severe top dying. sample plots. Underscored means were not significantly different.
Sundri R3 (June 2002)	0.11 (N)	0.18 (S)	0.27(Se)	1.02 (M)	Sundri poles (i.e. R3) was the highest in the moderate top dying sample plots and was significantly higher (P =0.05) that from none, slight and severe top dying. sample plots. Underscored means were not significantly different.
Shingra R1 (June 2002)	0 (M)	0 (S)	0 (Se)	0.29 (N)	Shingra seedlings (i.e. R1) was found to occur only in the no top dying (i.e. none) sample plots and there were no regeneration from the three other types of sample plots. Hence F value was significant.
Sundri R1 (January 2003)	7.02 (N)	11.60 (S)	11.82 (Se)	21.07 (M)	Sundri seedlings (i.e. R1) was the highest in the moderate top dying sample plots and was significantly higher (P =0.05) that from none, slight and severe top dying. sample plots. Underscored means were not significantly different.
Sundri R2 (January 2003)	0.16 (N)	0.33 (S)	1.04 (Se)	1.42 (M)	Sundri saplings (i.e. R2) was the highest in the moderate top dying sample plots and was significantly higher (P =0.05) that from none, and slight top dying. sample plots. Underscored means were not significantly different.
Sundri R3 (January 2003)	0.31 (S)	0.38 (N)	1.56 (M)	2.31 (Se)	Sundri poles (i.e. R3) was the highest in the severe top dying sample plots and was significantly higher (P =0.05) that from none, and slight top dying. sample plots. Underscored means were not significantly different.
Goran R1 (January	0.02 (Se)	0.24 (M)	0.60 (N)	0.69 (S)	Goran seedlings (i.e. R1) was the highest in the slight top dying sample plots and was

2003)					significantly higher (P =0.05) that from severe and moderate top dying. sample plots. Underscored means were not significantly different.
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Goran R3 (January 2003)	0 (Se)	0 (S)	0.02 (M)	0.64 (N)	Goran poles (i.e. R3) was the highest in the no t top dying (i.e. none) sample plots and was significantly higher (P =0.05) that from severe, slight and moderate top dying. sample plots. Underscored means were not significantly different.
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Shingra R1 (January 2003)	0 (S)	0.13 (Se)	0.16 (M)	0.80 (N)	Shingra seedlings (i.e. R1) was the highest in the no t top dying (i.e. none) sample plots and was significantly higher (P =0.05) that from severe, slight and moderate top dying. sample plots. Underscored means were not significantly different.
		----------	----------		
Passur R1 (January 2003)	0 (Se)	0.11 (M)	0.56 (S)	0.76 (N)	Passur (i.e. R1) was the highest in the no t top dying (i.e. none) sample plots and was significantly higher (P =0.05) that from severe top dying. sample plots having no regeneration. Underscored means were not significantly different.
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It is evident from Table 38 that sundri of types R2 (i.e. saplings) and R3 (i.e. poles) from none, slight and severe top dying of sundri areas did not differ significantly, whereas both R2 and R3 types were significantly higher in moderate top dying sample plots as compared to the remaining three types i.e. none, slight and severe top dying sample plots. This strongly suggests that level of severity of top dying of sundri did not have any significant impact on regeneration and recruitment to sundri saplings and poles R2 and R3 which are seedlings of height 1.3 m and above but less than 2.5 cm in d.b.h. (R2 type) and 1.3 m in or more in height and d.b.h of 2.5 cm and above (i.e. R3). These are quite stable and going to change to poles and trees in course of time. Furthermore, in case of R1 type (i.e. seedlings) of regeneration of sundri we do not have any significant difference from among the none, slight and severe top dying sample plots, but moderate sample plots had significantly higher number of seedlings as compared to the remaining three types. The significant F value of Shingra was due to presence of seedlings only in the No top dying category during October 2001 and June 2002, but in January 2003 only insignificant occurrence of seedlings were found in severe and moderate top dying sample plots, none had higher no. of seedlings. In case of Goran R1 type highest no. was in slight top dying sample plot and the lowest number in severe top dying sample plots, In case of R3 type Goran significantly higher number was in none sample plots. In case of passur there was no significant difference among moderate, slight and none (i.e. no top dying) sample plots.

In the next step the data of regeneration of all species from each of the four types (i.e. none, slight, moderate and severe) of top dying of sundri sites were compared to find out which species and which type was the most dominant in the compartments under investigations. In that the mean values of the regeneration types of all the species in each of the four types of top dying severity categories (i.e. none, slight, moderate and severe) obtained in October 2001 and June

2002 were compared by using the Duncan's Multiple Range Test (Duncan, 1955). The results are summarized in **Tables 39, 40, 41, 42, 43, 44, 45 and 46.**

Table 39: Comparison of the mean number of regeneration (R1, R2, R3) of five mangrove species from 9 sample plots having no top dying of sundri (i.e. none) as observed in October 2001 in the Sundarbans.

Gewa R3	Goran R1	Sundri R2	Amur R2	Sundri R3	Amur R1	Singra R1	Amur R3	Gewa R2	Gewa R1	Sundri R1
1.0	1.33	1.50	1.67	1.75	2.54	3.00	4.00	4.50	9.00	15.28
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than all the remaining species except Gewa R1 regeneration

Table 40: Comparison of the mean number of regeneration (R1, R2, R3) of four mangrove species from 9 sample plots having slight top dying of sundri as observed in October 2001 in the Sundarbans.

Sundri R2	Sundri R3	Amur R2	Gewa R2	Goran R1	Amur R1	Gewa R1	Gewa R3	Sundri R1
1.00	1.00	1.50	2.00	2.00	2.72	2.76	4.67	19.39
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than regeneration of all the remaining species.

Table 41: Comparison of the mean number of regeneration (R1, R2, R3) of four mangrove species from 9 sample plots having moderate top dying of sundri as observed in October 2001 in the Sundarbans.

Goran R1	Amur R2	Goran R3	Amur R1	Sundri R3	Sundri R2	Amur R3	Gewa R1	Gewa R3	Sundri R1
1.00	1.00	1.50	2.07	3.00	4.00	4.00	6.71	9.00	16.80
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than all the remaining species except Gewa R3 regeneration

Table 42: Comparison of the mean number of regeneration (R1, R2, R3) of three mangrove species from 9 sample plots having severe top dying of sundri as observed in October 2001 in the Sundarbans.

Amur R2	Gewa R2	Amur R1	Sundri R2	Gewa R3	Gewa R1	Sundri R3	Sundri R1
1.00	1.50	1.50	2.83	4.33	4.71	5.00	20.79
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than all the remaining species.

Table 43: Comparison of the mean number of regeneration of types R1, R2 and R3 of all mangrove species in an area of 4 square meters in each of 45 sub-plots in 9 sample plots in no top dying of sundri (i.e. none) locations as observed in June 2002 in the Sundarbans.

Kank ra R1	Amu r R3	Sundr i R3	Gewa R3	Goran R2	Goran R3	Sundr i R2	Singr a R1	Goran R1	Amur R2	Gewa R1	Gewa R2	Amur R1	Sundr i R1
0.04	0.07	0.11	0.11	0.11	0.18	0.20	0.29	0.36	0.39	0.40	0.40	0.69	11.42
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Note: Mean underscored by the same dotted line is not significantly different. Sundri R1 type regeneration is significantly higher than that of all the remaining species.

Table 44: Comparison of the mean number of regeneration of types R1, R2 and R3 of all mangrove species in an area of 4 square meters in each of 45 sub-plots in 9 sample plots in slight top dying of sundri locations as observed in June 2002 in the Sundarbans.

Gora n R3	Kankr a R1	Amur R3	Amur R2	Gewa R3	Sundri R3	Sundri R2	Gewa R2	Amur R1	Gewa R1	Sundri R1
0.02	0.02	0.07	0.09	0.13	0.8	0.22	0.22	0.51	0.76	11.04
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than that of all the remaining species.

Table 45: Comparison of the mean number of regeneration of types R1, R2 and R3 of all mangrove species in an area of 4 square meters in each of 45 sub-plots in 9 sample plots in moderate top dying of sundri locations as observed in June 2002 in the Sundarbans.

Kankr aR1	Goran R3	Goran R1	Amur R2	Amur R1	Gewa R3	Gewa R2	Gewa R1	Sundri R3	Sundri R2	Sundri R1
0.02	0.04	0.09	0.11	0.20	0.24	0.56	0.64	1.02	1.38	19.82
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than that of all the remaining species.

Table 46: Comparison of the mean number of regeneration of types R1, R2 and R3 of all mangrove species in an area of 4 square meters in each of 45 sub-plots in 9 sample plots in severe top dying of sundri locations as observed in June 2002 in the Sundarbans.

Goran R1	Goran R3	Amur R3	Amur R2	Sundri R3	Gewa R1	Gewa R3	Amur R1	Gewa R2	Sundri R2	Sundri R1
0.04	0.09	0.20	0.24	0.27	0.27	0.31	0.38	0.60	0.62	13.98
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Note: Means underscored by the same dotted line are not significantly different. Sundri R1 type regeneration is significantly higher than that of all the remaining species.

It is seen from **Tables 39, 40 and 41** that sundri R1 type regeneration was the highest among the three types i.e. R1, R2 and R3 types of regeneration of all the species under consideration in the 36 sample plots at 12 landings in 10 compartments. Sundri R1 type regeneration was significantly higher than all other species in all the four types of top dying severity classes as observed in June 2002 observation (vide **Tables 34, 35, 36 and 37**). During October observation also sundri R1 type regeneration was the highest but was insignificantly higher than R3 type regeneration of gewa in case of slight and moderate top dying sample plots and in case of R1 type regeneration of gewa . It may be mentioned here that R1 type regeneration is seedlings (i.e. height less than 1.3 m), R2 type regeneration is saplings (height more than 1,3 m but d.b.h. less than 2.5 cm) and R3 type includes the poles having height more than 1.3 m or more and dbh more than 2.5 cm,

These clearly and strongly suggest that level of severity of top dying of sundri did not have any significant impact on the status of regeneration and recruitment of sundri in the 36 sample plots at 12 landings in 10 compartments in the Sundarbans. Pertinently, it may be further mentioned here that the significant difference among the four top dying severity sample plots in case of R2 type regeneration of goran and R1 type regeneration of shingra have resulted because in both the cases regeneration were obtained only from no top dying sample plots (i.e. none), while the mean value for all the remaining three top dying severity categories were zero (vide Table 38).

An examination of the trend of total regeneration (R1, R2 and R3 types collectively) of sundri and gewa along top dying per cent data in the sample plots are shown in Figs. 11 and 12 respectively. It is seen that total regeneration is clearly more in the higher top dying of sundri in case of both the species. An examination of the scale of regeneration along the Y-axis reveals that total regeneration of sundri is much higher as compared to that of gewa. This is likely in the sense that the experimental sample plots were laid mainly in the sundri dominant areas. In the next stage a comparison of the levels of R1, R2 and R3 type of regeneration of sundri and gewa along increasing per cent of top dying of sundri has been made in the Figs 13, 14 and 15 for sundri and Figs. 16, 17 and 18 for gewa. Within each type of regeneration (i.e. R1, R2 and R3) of sundri there is in general a trend of higher regeneration in the higher top dying per cent of sundri. This is particularly evident in case of R2 type regeneration in case of sundri (vide Fig. 14) where significantly higher saplings have been obtained in areas of higher per cent of sundri top dying as is evident from significant (P=0.046) level of probability of regression. This finding support the idea that opening created in the ground level because of removal of canopy by top dying allows more sun light in the forest floor which has imparted a positive impact on the growth of young seedlings (R1 type) of sundri and this promoted more recruitment of R2 type (i.e. saplings) of sundri. **This finding convincingly suggests that removal of top dying affected sundri tree through a salvage felling is not going to affect the status of regeneration and recruitment of sundri seedlings in the top dying affected areas of the Sundarbans. This has undoubtedly a very important bearing in the management of the top dying affected sundri trees in the Sundarbans by the Forest Department.**

Fig.11: Relationship between per cent top dying of sundri and regeneration (R1= seedlings, R2 = saplings and R3 = poles) of sundri based on data of 180 sub-plots from 36 sample plots in 10 compartments in Sundarbans as observed in June 2002.

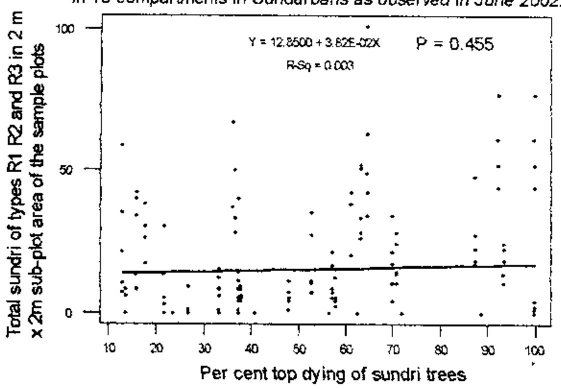


Fig.12: Relationship between per cent top dying of sundri and total regeneration of gewa (R1=seedlings, R2 = saplings and R3 = poles) based on data of 180 sub-plots from 36 sample plots in 10 compartments in the Sundarbans as observed in June 2002.

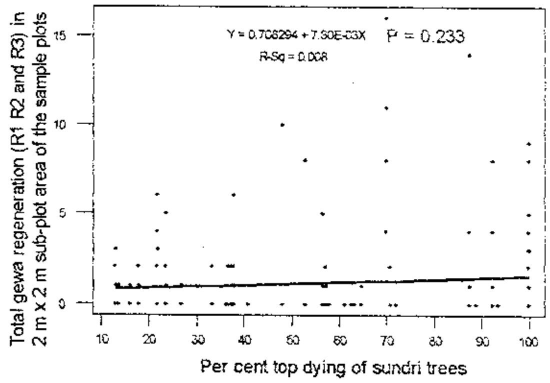


Fig.13: Relationship between per cent top dying of sundri and R1 type (i.e. seedlings) regeneration of sundri based on data of 180 sub-plots in 10 compartments in the Sundarbans as observed in June 2002.

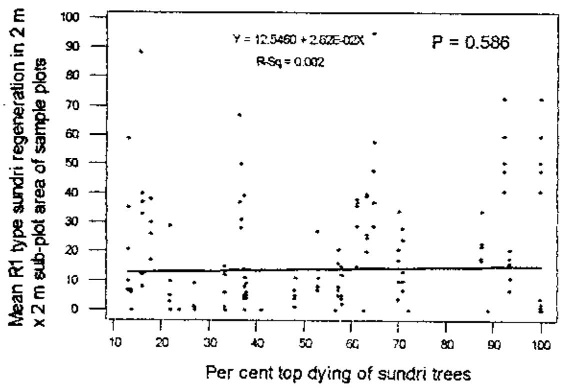


Fig. 14: Relationship between per cent top dying of sundri and R2 type (i.e. saplings) regeneration of sundri based on data of 180 sub-plots in 10 compartments in the Sundarbans as observed in June 2002.

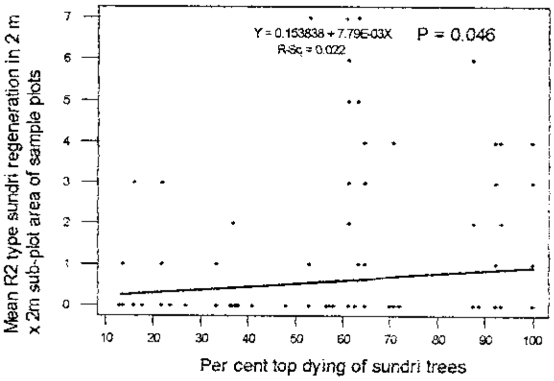


Fig. 15: Relationship between per cent top dying of sundri and R3 type (i.e. poles) of sundri based on data of 180 sub-plots in 10 compartments in the Sundarbans as observed in June 2002.

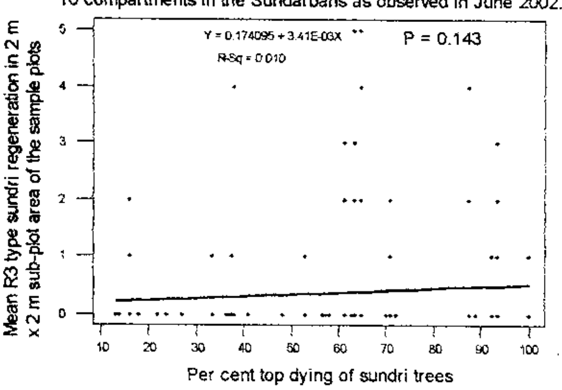


Fig.16: Relationship between per cent top dying of sundri and R1 type (i.e. seedlings) regeneration of gewa based on data of 180 sub-plots in 10 compartments in the Sundarbans as observed in June 2002.

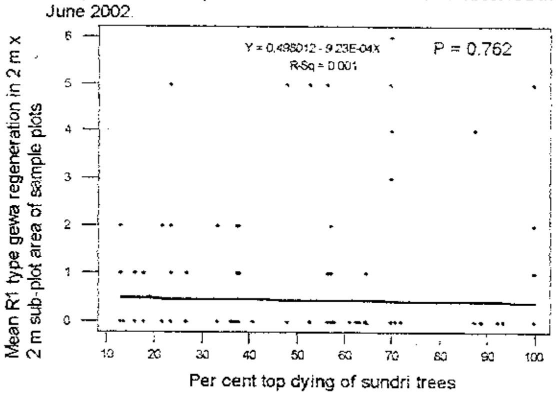


Fig.17: Relationship between per cent top dying of sundri and R2 type (i.e. saplings) regeneration of gewa based on data of 180 sub-plots in 10 compartments in the Sundarbans as observed in June 2002.

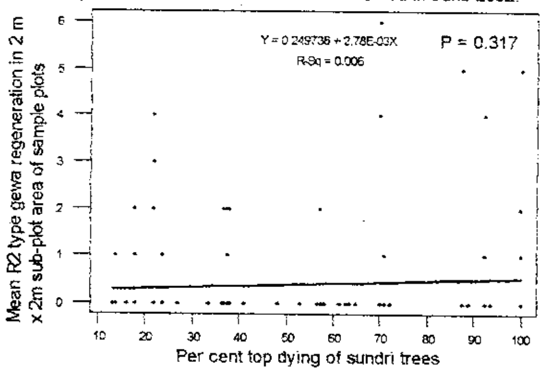
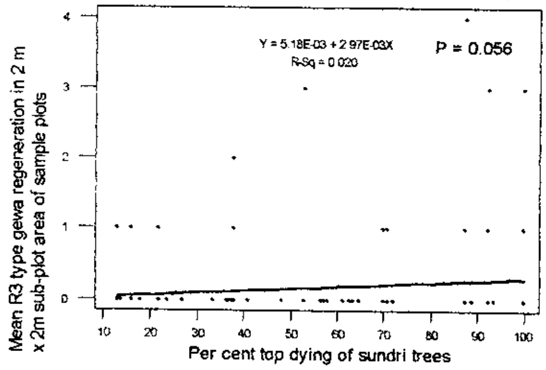


Fig. 18: Relationship between per cent top dying of sundri and R3 type (i.e. poles) of gewa based on data of 180 sub-plots in 10 compartments in the Sundarbans as observed in June 2002.



5.1.5.2 Regeneration and recruitment of major mangrove species as determined from the Temporary Sample Plot (TSP) Data

In 1996 and 1997 during the FRMP Forest Inventory of the Sundarbans 1203 Temporary Sample Plots (TSP) were laid in 55 compartments of the Sundarbans. In that programme along with other data, from each TSP data were collected about seedlings, saplings, poles and trees. Five sub-plots were taken for each of seedlings, saplings, poles and trees. The area of five seedlings sub-plots were 3.14 * (1m)2 * 5 = 15.70 sq.m. Similarly the area of five sapling sub-plots were 3.14 * (2m)2 * 5 = 62.80 sq.m; the area of poles sub-plots inlcudes 3.14 * (5m)2 * 5 = 392.50 sq. m and that of trees sub-plot were 3.14 * (11m) 2* 5 = 1899.70 sq.m. (Mohsinul Alam, personal communication). TSP data were obtained with kind permission from the Project Director, Sundarban Biodiversity Conservation Project. The data were thoroughly scanned, retrieved and analyzed to find out the hard facts contained in the huge data concerning sundri in particular and other species in general. The extent of occurrence and number of seedlings, saplings, poles and trees of different species in the Sundarbans as a whole as determined in the light of the data of the 1203 TSPs are summarized in **Table 47**. Furthermore, the data mean number of sundri seedlings, saplings, poles and trees per TSP falling in each of the 55 compartments and also that converted to per hectare values of seedlings, saplings, poles and trees of sundri per hectare and organized in **Table 48.**

Table 47: Extent of occurrence and number of seedlings, saplings, poles and trees of 30 species per hectare for the whole of the Sundarbans based on data of 1203 Temporary Sample Plots (TSPs) generated during FRMP Forest Inventory in 1996 and 1997.

Species	No. of TSPs in which the species was found	% of TSPs with the species	Mean No. of seedlings per ha	Per cent of total seedlings of all species	Mean No. of saplings per ha	Per cent of total saplings of all species	Mean No. of poles per ha	Per cent of total poles of all species	Mean No. of trees per ha	Per cent of total trees of all species
Amur	493	40.98	597.76	1.76	214.30	3.01	61.31	1.90	0.23	0.16
Babul	4	0.33	0.59	0.00	0.00	0.00	0.57	0.02	0.00	0.00
Baen	61	5.07	194.24	0.57	29.29	0.41	5.22	0.16	4.28	3.04
Ban Jam	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03
Baral	1	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Batla	2	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bhola	38	3.16	29.12	0.09	17.92	0.25	8.73	0.27	0.00	0.00
Bon Lichu	2	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bon Noty	1	0.08	9.76	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Dhundhul	31	2.58	19.36	0.06	4.56	0.06	0.00	0.00	0.64	0.45
Doya	2	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gab	22	1.83	0.00	0.00	1.32	0.02	0.00	0.00	0.00	0.00
Gewa	1168	97.09	5500.58	16.23	1397.91	19.64	1378.68	42.76	19.38	13.77
Golpatta	0	0.00	0.00	0.00	0.00	0.00	1.17	0.04	0.00	0.00
Goran	733	60.93	5598.53	16.52	3156.65	44.36	500.28	15.52	0.13	0.09
Jhana	13	1.08	0.00	0.00	1.86	0.03	0.00	0.00	0.09	0.06
Jhao	3	0.25	184.48	0.54	0.00	0.00	0.58	0.02	0.00	0.00
Jir	18	1.50	0.00	0.00	2.99	0.04	3.51	0.11	0.02	0.01
Kankra	102	8.48	553.59	1.63	82.79	1.16	30.25	0.94	2.63	1.87
Karanja	9	0.75	19.36	0.06	0.00	0.00	4.06	0.13	0.01	0.01
Keora	28	2.33	0.00	0.00	22.23	0.31	4.64	0.14	2.37	1.68
Khalisha	17	1.41	0.00	0.00	11.74	0.16	0.00	0.00	0.02	0.01
Kirpa	22	1.83	0.00	0.00	2.55	0.04	0.00	0.00	0.04	0.03
Misc.	205	17.04	563.19	1.66	50.63	0.71	23.86	0.74	0.11	0.08
Ora	3	0.25	48.48	0.14	0.00	0.00	3.51	0.11	0.02	0.01
Passur	170	14.13	87.36	0.26	21.54	0.30	13.96	0.43	11.16	7.93
Sadda Baen	12	1.00	38.88	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Shingra	183	15.21	1835.34	5.41	51.76	0.73	111.69	3.46	0.02	0.01
Sitka	4	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Sundri	1054	87.61	18614.82	54.92	2044.76	28.73	1068.35	33.13	99.57	70.72
Sundri Lota	14	1.16	0.00	0.00	1.32	0.02	4.06	0.13	0.02	0.01
Total:			33895.44	100.00	7116.12	100.0 0	3224.43	100.0 0	140.7 9	100.00
Notes: Misc. = Miscellaneous include all unidentified species										

Out of 1203 TSPs taken from all over the Sundarbans the most widespread occurrence was that of gewa from 97.09% of TSPs, followed by sundri from 87.61% of TSPs, then goran from 60.93% of TSPs, amur from 40.98% of TSPs, shingra from 15.21% of TSPs, passur from 14.13% of TSPs, kankra from 8.48% of TSPs and then bhola from 3.16% of TSPs. These were followed in decreasing order by other species in very small percentage of occurrences.

In case of per ha seedlings for the whole of the Sundarbans, sundri had the highest number of 18615. In decreasing order of occurrence of the species goran came as second dominant species which had 5599 seedlings per ha. This was followed by gewa having 5501 seedlings, shingra had 1835 seedlings, amur had 598 seedlings, kankra had 554 seedlings, baen had 194 seedlings, babul had 117 seedlings, passur 87 seedlings and this was followed by other species in still lower numbers. It is further noted that of the total seedlings of all species in the Sundarbans 54.92% was of sundri, 16.52% of goran, 16.23% of gewa, 5.41% of shingra, 1.76% of amur, 1.66% of miscellaneous unidentified species, 1.63% of kankra, 0.57% of baen, 0.54% of nunia jhao, 0.26% of passur, 0.14% of ora, 0.11% of sada baen, 0.09% of bhola, 0.06% of each of karanja and dhundhul, 0.03% of bon noty. A number of other species had still of lesser per cent occurrence (vide **Table 47**).

In case of occurrence of saplings per ha the highest number of 3157 was that of goran. This was followed by sundri 2045, gewa 1398, amur 214, kankra 82, shingra 52, baen 29, keora 22, passur 22 and bhola 18. These were followed by other species in still lower numbers. It is further noted that of the total saplings of all species in the Sundarbans 44.36% was of goran, 28.73% of sundri, 19.64% of gewa, 3.01% of amur, 1.16% of kankra, 0.73% of shingra, 0.71% of miscellaneous unidentified species, 0.41% of baen, 0.31% of keora, 0.30% of passur, 0.25% of bhola, 0.16% of khalisha, 0.06% of dhundhul, 0.04 % of each of kirpa and jir, 0.03% of jhana, 0.02% of each of sundri lota and gab. A number of other species had less than 0.02% of occurrence (vie **Table 47**).

So far as number of poles (i.e. above 2.5 cm but less than 15 cm in dbh) per ha is concerned the highest number of 1379 was that of gewa. This was followed by sundri having 1068, goran 500, shingra 112, amur 61, kankra 30, passur 14, bhola 9 poles per ha, other species had still decreasing no. of poles per ha for the whole of the Sundarbans. It is further noted that of the total pole crop of all species in the Sundarbans 44.76% was of gewa, 33.13% of sundri, 15.52% of goran, 3.46% of shingra, 1.90% of amur, 0.94% of kankra, 0.74% of miscellaneous unidentified species, 0.43% of passur, 0.27% of bhola, 0.16% of baen, 0.14% of keora, 0.13% of sundri lota, 0.13% of karanja, 0.11 % of each of jir and ora, 0.04% of golpatta, 0.02% of each of jhao and babul. A number of other species had less than 0.02% of occurrence (vide **Table 47**).

So far as trees (i.e. above 15 cm in dbh) are concerned for the whole of the Sundarbans, the highest per ha was that of sundri which had 100 trees. This was followed in decreasing order of occurrence by gewa which had 19 trees, passur 11, baen 4, kankra 3, keora 2 and dhundhul 1 tree per ha. Other species had less than 1 tree per ha considering the whole of the Sundarbans. It is found that of the total tree populations in the Sundarbans 70.72% was of sundri, 13.77% of gewa, 7.93% of passur, 3.04% of baen, 1.87% of kankra, 1.68 % of keora, 0.45% of dhundhul, 0.16% of amur, 0.09% of goran, 0.08% of miscellaneous unidentified species, 0.06% of jhana, 0.03% of each of kirpa and bon jam, 0.01% of each of sundri lota, karanja, ora, jir, khalisha, shingra, sitka and 0.08% of unidentified miscellaneous species. A number of other species had less than 0.01% of occurrence (vide **Table 47**).

Table 48: Compartmentwise number of sundri seedlings, saplings, poles and trees per Temporary Sample Plot (TSP) and per hectare in 55 compartments in the Sundarbans.

Compt. No.	No. of TSPs	Mean no. of sundri seedlings per TSP of 15.70 sq.m	No. of sundri seedlings per hectare	Mean no. of sundri saplings per TSP of 62.80 sq.m	No. of sundri saplings per hectare	Mean no. of sundri poles per TSP of 392.50 sq.m	No. of sundri poles per hectare	Mean no. of sundri trees per TSP of 1899.70 sq.m	No. of sundri trees per hectare
1	31	37.81	24082.80	19.29	3071.66	53.94	1374.27	29.55	155.55
2	21	54.33	34605.10	20.86	3321.66	77.43	1972.74	31.33	164.92
3	17	45	28662.42	13.53	2154.46	71.82	1829.81	35.65	187.66
4	17	44.06	28063.69	18.71	2979.30	64.82	1651.46	32.76	172.45
5	17	62.53	39828.03	19.53	3109.87	75.24	1916.94	24.29	127.86
6	21	27.19	17318.47	6.57	1046.18	57.81	1472.87	15.52	81.70
7	30	32.17	20490.45	14.07	2240.45	50.1	1276.43	15.77	83.01
8	36	33.19	21140.13	13.94	2219.75	51.94	1323.31	20.42	107.49
9	36	34.03	21675.16	20.64	3286.62	58.97	1502.42	13.22	69.59
10	19	67	42675.16	20.26	3226.11	81.95	2087.90	40.32	212.24
11	15	54.27	34566.88	23.47	3737.26	81.27	2070.57	25.93	136.50
12	19	81.42	51859.87	20.95	3335.99	65.79	1676.18	25.63	134.92
13	19	72.11	45929.94	21.21	3377.39	64.89	1653.25	53.47	281.47
14	13	109.62	69821.66	32.54	5181.53	58.77	1497.32	45.62	240.14
15	15	115.6	73630.57	32.53	5179.94	72.53	1847.90	61.73	324.95
16	20	45.15	28757.96	15.25	2428.34	62.3	1587.26	33.05	173.97
17	24	27.79	17700.64	12.67	2017.52	41.25	1050.96	23.67	124.60
18	37	8.14	5184.71	10.05	1600.32	43.95	1119.75	20.68	108.86
19	22	9.05	5764.33	8.5	1353.50	32.55	829.30	27.91	146.92
20	26	3.69	2350.32	9.62	1531.85	34.85	887.90	32.12	169.08
21	14	109.86	69974.52	38.5	6130.57	59.5	1515.92	45.36	238.77
22	13	58.77	37433.12	26.69	4250.00	45.85	1168.15	53.38	280.99
23	11	43	27388.54	28.09	4472.93	60.18	1533.25	52.91	278.52
24	17	94.18	59987.26	35.88	5713.38	64.35	1639.49	35.59	187.35
25	12	61.42	39121.02	24.08	3834.39	65.92	1679.49	25.83	135.97
26	12	91.58	58331.21	27.26	4340.76	72.17	1838.73	26.08	137.28
27	15	88.67	56477.71	25.27	4023.89	53.8	1370.70	24.2	127.39
28	12	71.58	45592.36	27.67	4406.05	68.58	1747.26	22.08	116.23
29	14	47.71	30388.54	19.43	3093.95	64.14	1634.14	31.36	165.08
30	16	36.5	23248.41	12.67	2017.52	58.06	1479.24	31.25	164.50
31	25	22.8	14522.29	14.03	2234.08	36.12	920.25	23.44	123.39
32	16	49.81	31726.11	36.25	5772.29	50.31	1281.78	18.5	97.38
33	15	25.8	16433.12	19.4	3089.17	46.67	1189.04	35.53	187.03
34	12	25.25	16082.80	15.25	2428.34	36.67	934.27	33.08	174.13
35	20	22.95	14617.83	14.8	2356.69	33.55	854.78	10.3	54.22
36	22	11.14	7095.54	4.64	738.85	33.32	848.92	23.41	123.23
37	16	4.88	3108.28	2.5	398.09	24.13	614.78	21.19	111.54
38	21	6.86	4369.43	4.05	644.90	31.95	814.01	23.9	125.81
39	22	48.5	30891.72	25.68	4089.17	65	1656.05	32.09	168.92
40	12	14.75	9394.90	13.25	2109.87	38.08	970.19	24.67	129.86
41	19	2.95	1878.98	4.53	721.34	29.79	758.98	2.42	12.74
42	20	3.95	2515.92	4.21	670.38	23.55	600.00	1.85	9.74
43	29	6.59	4197.45	7.03	1119.43	42.38	1079.75	6.52	34.32

44	26	13.08	8331.21	6.31	1004.78	41.92	1068.03	8.35	43.95
45	26	25.62	16318.47	10.96	1745.22	37.58	957.45	9.62	50.64
46	29	1.34	853.50	2.52	401.27	28.14	716.94	0.28	1.47
47	29	4.14	2636.94	5.97	950.64	34.76	885.61	0.21	1.11
48	27	0.81	515.92	1.22	194.27	10.52	268.03	0.37	1.95
49	33	0.06	38.22	0.48	76.43	2.64	67.26	0.03	0.16
50	21	0.67	426.75	0.24	38.22	3	76.43	0.14	0.74
51	29	0	0.00	0.14	22.29	1.45	36.94	0.07	0.37
52	33	1.48	942.68	2.03	323.25	13.97	355.92	1.2[illegible]	6.53
53	28	2.93	1866.24	2.11	335.99	11.71	298.34	0.89	4.68
54	39	10	6369.43	7.56	1203.82	31.87	811.97	1.51	7.95
55	43	0.14	89.17	0	0.00	1.86	47.39	0	0.00

Table 48 above provides Compartmentwise number of seedlings, saplings, poles and trees of sundri per Temporary Sample Plots (TSP) and per hectare (ha) for compartment numbers 1to 55 as determined during the FRMP Forest Inventory in 1996 and 1997 in which data were collected from 1203 TSPs. In order to get a clear insight about the distribution and intensity of sundri seedlings, saplings, poles and trees in 55 compartments of the Sundarbans, the data of **Table 48** have been sorted out according to seedlings, saplings, poles and trees and are provided in **Tables 49, 50, 51 and 52 respectively.**

Table:49: Number of sundri seedlings, saplings, poles and trees per Temporary Sample Plots (TSPs) and per hectare in 55 compartments in the Sundarbans arranged according to the number of seedlings per hectare.

Compt. No.	No. of TSPs	Mean no. of sundri seedlings per TSP of 15.70 sq.m	No. of sundri seedlings per hectare	Mean no. of sundri saplings per TSP of 62.80 sq.m	No. of sundri saplings per hectare	Mean no. of sundri poles per TSP of 392.50 sq.m	No. of sundri poles per hectare	Mean no. of sundri trees per TSP of 1899.70 sq.m	No. of sundri trees per hectare
51	29	0	0.00	0.14	22.29	1.45	36.94	0.07	0.37
49	33	0.06	38.22	0.48	76.43	2.64	67.26	0.03	0.16
55	43	0.14	89.17	0	0.00	1.86	47.39	0	0.00
50	21	0.67	426.75	0.24	38.22	3	76.43	0.14	0.74
48	27	0.81	515.92	1.22	194.27	10.52	268.03	0.37	1.95
46	29	1.34	853.50	2.52	401.27	28.14	716.94	0.28	1.47
52	33	1.48	942.68	2.03	323.25	13.97	355.9[illegible]	1.24	6.53
53	28	2.93	1866.24	2.11	335.99	11.71	298.34	0.89	4.68
41	19	2.95	1878.98	4.53	721.34	29.79	758.98	2.42	12.74
20	26	3.69	2350.32	9.62	1531.85	34.85	887.90	32.12	169.08
42	20	3.95	2515.92	4.21	670.38	23.55	600.00	1.85	9.74
47	29	4.14	2636.94	5.97	950.64	34.76	885.61	0.21	1.11
37	16	4.88	3108.28	2.5	398.09	24.13	614.78	21.19	111.54
43	29	6.59	4197.45	7.03	1119.43	42.38	1079.75	6.52	34.32
38	21	6.86	4369.43	4.05	644.90	31.95	814.01	23.9	125.81
18	37	8.14	5184.71	10.05	1600.32	43.95	1119.75	20.68	108.86
19	22	9.05	5764.33	8.5	1353.50	32.55	829.30	27.91	146.92
54	39	10	6369.43	7.56	1203.82	31.87	811.97	1.51	7.95
36	22	11.14	7095.54	4.64	738.85	33.32	848.92	23.41	123.23
44	26	13.08	8331.21	6.31	1004.78	41.92	1068.03	8.[illegible]	43.95

40	12	14.75	9394.90	13.25	2109.87	38.08	970.19	24.67	129.86
31	25	22.8	14522.29	14.03	2234.08	36.12	920.25	23.44	123.39
35	20	22.95	14617.83	14.8	2356.69	33.55	854.78	10.3	54.22
34	12	25.25	16082.80	15.25	2428.34	36.67	934.27	33.08	174.13
45	26	25.62	16318.47	10.96	1745.22	37.58	957.45	9.62	50.64
33	15	25.8	16433.12	19.4	3089.17	46.67	1189.04	35.53	187.03
6	21	27.19	17318.47	6.57	1046.18	57.81	1472.87	15.52	81.70
17	24	27.79	17700.64	12.67	2017.52	41.25	1050.96	23.67	124.60
7	30	32.17	20490.45	14.07	2240.45	50.1	1276.43	15.77	83.01
8	36	33.19	21140.13	13.94	2219.75	51.94	1323.31	20.42	107.49
9	36	34.03	21675.16	20.64	3286.62	58.97	1502.42	13.22	69.59
30	16	36.5	23248.41	12.67	2017.52	58.06	1479.24	31.25	164.50
1	31	37.81	24082.80	19.29	3071.66	53.94	1374.27	29.55	155.55
23	11	43	27388.54	28.09	4472.93	60.18	1533.25	52.91	278.52
4	17	44.06	28063.69	18.71	2979.30	64.82	1651.46	32.76	172.45
3	17	45	28662.42	13.53	2154.46	71.82	1829.81	35.65	187.66
16	20	45.15	28757.96	15.25	2428.34	62.3	1587.26	33.05	173.97
29	14	47.71	30388.54	19.43	3093.95	64.14	1634.14	31.36	165.08
39	22	48.5	30891.72	25.68	4089.17	65	1656.05	32.09	168.92
32	16	49.81	31726.11	36.25	5772.29	50.31	1281.78	18.5	97.38
11	15	54.27	34566.88	23.47	3737.26	81.27	2070.57	25.93	136.50
2	21	54.33	34605.10	20.86	3321.66	77.43	1972.74	31.33	164.92
22	13	58.77	37433.12	26.69	4250.00	45.85	1168.15	53.38	280.99
25	12	61.42	39121.02	24.08	3834.39	65.92	1679.49	25.83	135.97
5	17	62.53	39828.03	19.53	3109.87	75.24	1916.94	24.29	127.86
10	19	67	42675.16	20.26	3226.11	81.95	2087.90	40.32	212.24
28	12	71.58	45592.36	27.67	4406.05	68.58	1747.26	22.08	116.23
13	19	72.11	45929.94	21.21	3377.39	64.89	1653.25	53.47	281.47
12	19	81.42	51859.87	20.95	3335.99	65.79	1676.18	25.63	134.92
27	15	88.67	56477.71	25.27	4023.89	53.8	1370.70	24.2	127.39
26	12	91.58	58331.21	27.26	4340.76	72.17	1838.73	26.08	137.28
24	17	94.18	59987.26	35.88	5713.38	64.35	1639.49	35.59	187.35
14	13	109.62	69821.66	32.54	5181.53	58.77	1497.32	45.62	240.14
21	14	109.86	69974.52	38.5	6130.57	59.5	1515.92	45.36	238.77
15	15	115.6	73630.57	32.53	5179.94	72.53	1847.90	61.73	324.95

Table 50: Number of sundri seedlings, saplings, poles and trees per Temporary Sample Plots (TSPs) and per hectare in 55 compartments in the Sundarbans arranged according to the number of saplings per hectare.

Compt. No.	No. of TSPs	Mean no. of sundri seedlings per TSP of 15.70 sq.m	No. of sundri seedlings per hectare	Mean no. of sundri saplings per TSP of 62.80 sq.m	No. of sundri saplings per hectare	Mean no. of sundri poles per TSP of 392.50 sq.m	No. of sundri poles per hectare	Mean no. of sundri trees per TSP of 1899.70 sq.m	No. of sundri trees per hectare
55	43	0.14	89.17	0	0.00	1.86	47.39	0	0.00
51	29	0	0.00	0.14	22.29	1.45	36.94	0.07	0.37
50	21	0.67	426.75	0.24	38.22	3	76.43	0.14	0.74
49	33	0.06	38.22	0.48	76.43	2.64	67.26	0.03	0.16
48	27	0.81	515.92	1.22	194.27	10.52	268.03	0.37	1.95

52	33	1.48	942.68	2.03	323.25	13.97	355.92	1.24	6.53
53	28	2.93	1866.24	2.11	335.99	11.71	298.34	0.89	4.68
37	16	4.88	3108.28	2.5	398.09	24.13	614.78	21.19	111.54
46	29	1.34	853.50	2.52	401.27	28.14	716.94	0.28	1.47
38	21	6.86	4369.43	4.05	644.90	31.95	814.01	23.9	125.81
42	20	3.95	2515.92	4.21	670.38	23.55	600.00	1.85	9.74
41	19	2.95	1878.98	4.53	721.34	29.79	758.98	2.42	12.74
36	22	11.14	7095.54	4.64	738.85	33.32	848.92	23.41	123.23
47	29	4.14	2636.94	5.97	950.64	34.76	885.61	0.21	1.11
44	26	13.08	8331.21	6.31	1004.78	41.92	1068.03	8.35	43.95
6	21	27.19	17318.47	6.57	1046.18	57.81	1472.87	15.52	81.70
43	29	6.59	4197.45	7.03	1119.43	42.38	1079.75	6.52	34.32
54	39	10	6369.43	7.56	1203.82	31.87	811.97	1.51	7.95
19	22	9.05	5764.33	8.5	1353.50	32.55	829.30	27.91	146.92
20	26	3.69	2350.32	9.62	1531.85	34.85	887.90	32.12	169.08
18	37	8.14	5184.71	10.05	1600.32	43.95	1119.75	20.68	108.86
45	26	25.62	16318.47	10.96	1745.22	37.58	957.45	9.62	50.64
17	24	27.79	17700.64	12.67	2017.52	41.25	1050.96	23.67	124.60
30	16	36.5	23248.41	12.67	2017.52	58.06	1479.24	31.25	164.50
40	12	14.75	9394.90	13.25	2109.87	38.08	970.19	24.67	129.86
3	17	45	28662.42	13.53	2154.46	71.82	1829.81	35.65	187.66
8	36	33.19	21140.13	13.94	2219.75	51.94	1323.31	20.42	107.49
31	25	22.8	14522.29	14.03	2234.08	36.12	920.25	23.44	123.39
7	30	32.17	20490.45	14.07	2240.45	50.1	1276.43	15.77	83.01
35	20	22.95	14617.83	14.8	2356.69	33.55	854.78	10.3	54.22
16	20	45.15	28757.96	15.25	2428.34	62.3	1587.26	33.05	173.97
34	12	25.25	16082.80	15.25	2428.34	36.67	934.27	33.08	174.13
4	17	44.06	28063.69	18.71	2979.30	64.82	1651.46	32.76	172.45
1	31	37.81	24082.80	19.29	3071.66	53.94	1374.27	29.55	155.55
33	15	25.8	16433.12	19.4	3089.17	46.67	1189.04	35.53	187.03
29	14	47.71	30388.54	19.43	3093.95	64.14	1634.14	31.36	165.08
5	17	62.53	39828.03	19.53	3109.87	75.24	1916.94	24.29	127.86
10	19	67	42675.16	20.26	3226.11	81.95	2087.90	40.32	212.24
9	36	34.03	21675.16	20.64	3286.62	58.97	1502.42	13.22	69.59
2	21	54.33	34605.10	20.86	3321.66	77.43	1972.74	31.33	164.92
12	19	81.42	51859.87	20.95	3335.99	65.79	1676.18	25.63	134.92
13	19	72.11	45929.94	21.21	3377.39	64.89	1653.25	53.47	281.47
11	15	54.27	34566.88	23.47	3737.26	81.27	2070.57	25.93	136.50
25	12	61.42	39121.02	24.08	3834.39	65.92	1679.49	25.83	135.97
27	15	88.67	56477.71	25.27	4023.89	53.8	1370.70	24.2	127.39
39	22	48.5	30891.72	25.68	4089.17	65	1656.05	32.09	168.92
22	13	58.77	37433.12	26.69	4250.00	45.85	1168.15	53.38	280.99
26	12	91.58	58331.21	27.26	4340.76	72.17	1838.73	26.08	137.28
28	12	71.58	45592.36	27.67	4406.05	68.58	1747.26	22.08	116.23
23	11	43	27388.54	28.09	4472.93	60.18	1533.25	52.91	278.52
15	15	115.6	73630.57	32.53	5179.94	72.53	1847.90	61.73	324.95
14	13	109.62	69821.66	32.54	5181.53	58.77	1497.32	45.62	240.14
24	17	94.18	59987.26	35.88	5713.38	64.35	1639.49	35.59	187.35
32	16	49.81	31726.11	36.25	5772.29	50.31	1281.78	18.5	97.38
21	14	109.86	69974.52	38.5	6130.57	59.5	1515.92	45.3[illegible]	238.77

Table 51: Number of sundri seedlings, saplings, poles and trees per Temporary Sample Plots (TSPs) and per hectare in 55 compartments in the Sundarbans arranged according to the number of poles per hectare.

Compt. No.	No. of TSPs	Mean no. of sundri seedlings per TSP of 15.70 sq.m	No. of sundri seedlings per hectare	Mean no. of sundri saplings per TSP of 62.80 sq.m	No. of sundri saplings per hectare	Mean no. of sundri poles per TSP of 392.50 sq.m	No. of sundri poles per hectare	Mean no. of sundri trees per TSP of 1899.70 sq.m	No. of sundri trees per hectare
51	29	0	0.00	0.14	22.29	1.45	36.94	0.07	0.37
55	43	0.14	89.17	0	0.00	1.86	47.39	0	0.00
49	33	0.06	38.22	0.48	76.43	2.64	67.26	0.03	0.16
50	21	0.67	426.75	0.24	38.22	3	76.43	0.14	0.74
48	27	0.81	515.92	1.22	194.27	10.52	268.03	0.37	1.95
53	28	2.93	1866.24	2.11	335.99	11.71	298.34	0.89	4.68
52	33	1.48	942.68	2.03	323.25	13.97	355.92	1.24	6.53
42	20	3.95	2515.92	4.21	670.38	23.55	600.00	1.85	9.74
37	16	4.88	3108.28	2.5	398.09	24.13	614.78	21.19	111.54
46	29	1.34	853.50	2.52	401.27	28.14	716.94	0.28	1.47
41	19	2.95	1878.98	4.53	721.34	29.79	758.98	2.42	12.74
54	39	10	6369.43	7.56	1203.82	31.87	811.97	1.51	7.95
38	21	6.86	4369.43	4.05	644.90	31.95	814.01	23.9	125.81
19	22	9.05	5764.33	8.5	1353.50	32.55	829.30	27.91	146.92
36	22	11.14	7095.54	4.64	738.85	33.32	848.92	23.41	123.23
35	20	22.95	14617.83	14.8	2356.69	33.55	854.78	10.3	54.22
47	29	4.14	2636.94	5.97	950.64	34.76	885.61	0.21	1.11
20	26	3.69	2350.32	9.62	1531.85	34.85	887.90	32.12	169.08
31	25	22.8	14522.29	14.03	2234.08	36.12	920.25	23.44	123.39
34	12	25.25	16082.80	15.25	2428.34	36.67	934.27	33.08	174.13
45	26	25.62	16318.47	10.96	1745.22	37.58	957.45	9.62	50.64
40	12	14.75	9394.90	13.25	2109.87	38.08	970.19	24.67	129.86
17	24	27.79	17700.64	12.67	2017.52	41.25	1050.96	23.67	124.60
44	26	13.08	8331.21	6.31	1004.78	41.92	1068.03	8.35	43.95
43	29	6.59	4197.45	7.03	1119.43	42.38	1079.75	6.52	34.32
18	37	8.14	5184.71	10.05	1600.32	43.95	1119.75	20.68	108.86
22	13	58.77	37433.12	26.69	4250.00	45.85	1168.15	53.38	280.99
33	15	25.8	16433.12	19.4	3089.17	46.67	1189.04	35.53	187.03
7	30	32.17	20490.45	14.07	2240.45	50.1	1276.43	15.77	83.01
32	16	49.81	31726.11	36.25	5772.29	50.31	1281.78	18.5	97.38
8	36	33.19	21140.13	13.94	2219.75	51.94	1323.31	20.42	107.49
27	15	88.67	56477.71	25.27	4023.89	53.8	1370.70	24.2	127.39
1	31	37.81	24082.80	19.29	3071.66	53.94	1374.27	29.55	155.55
6	21	27.19	17318.47	6.57	1046.18	57.81	1472.87	15.52	81.70
30	16	36.5	23248.41	12.67	2017.52	58.06	1479.24	31.25	164.50
14	13	109.62	69821.66	32.54	5181.53	58.77	1497.32	45.62	240.14
9	36	34.03	21675.16	20.64	3286.62	58.97	1502.42	13.22	69.59
21	14	109.86	69974.52	38.5	6130.57	59.5	1515.92	45.36	238.77
23	11	43	27388.54	28.09	4472.93	60.18	1533.25	52.91	278.52
16	20	45.15	28757.96	15.25	2428.34	62.3	1587.26	33.05	173.97
29	14	47.71	30388.54	19.43	3093.95	64.14	1634.14	31.36	165.08
24	17	94.18	59987.26	35.88	5713.38	64.35	1639.49	35.59	187.35

4	17	44.06	28063.69	18.71	2979.30	64.82	1651.46	32.76	172.45
13	19	72.11	45929.94	21.21	3377.39	64.89	1653.25	53.47	281.47
39	22	48.5	30891.72	25.68	4089.17	65	1656.05	32.09	168.92
12	19	81.42	51859.87	20.95	3335.99	65.79	1676.18	25.63	134.92
25	12	61.42	39121.02	24.08	3834.39	65.92	1679.49	25.83	135.97
28	12	71.58	45592.36	27.67	4406.05	68.58	1747.26	22.08	116.23
3	17	45	28662.42	13.53	2154.46	71.82	1829.81	35.65	187.66
26	12	91.58	58331.21	27.26	4340.76	72.17	1838.73	26.08	137.28
15	15	115.6	73630.57	32.53	5179.94	72.53	1847.90	61.73	324.95
5	17	62.53	39828.03	19.53	3109.87	75.24	1916.94	24.29	127.86
2	21	54.33	34605.10	20.86	3321.66	77.43	1972.74	31.33	164.92
11	15	54.27	34566.88	23.47	3737.26	81.27	2070.57	25.93	136.50
10	19	67	42675.16	20.26	3226.11	81.95	2087.90	40.32	212.24

Table 52: Number of sundri seedlings, saplings, poles and trees per Temporary Sample Plots TSPs) and per hectare in 55 compartments in the Sundarbans arranged according to the number of trees.

Compt. No.	No. of TSPs	Mean no. of sundri seedlings per TSP of 15.70 sq.m	No. of sundri seedlings per hectare	Mean no. of sundri saplings per TSP of 62.80 sq.m	No. of sundri saplings per hectare	Mean no. of sundri poles per TSP of 392.50 sq.m	No. of sundri poles per hectare	Mean no. of sundri trees per TSP of 1899.70 sq.m	No. of sundri trees per hectare
55	43	0.14	89.17	0	0.00	1.86	47.39	0	0.00
49	33	0.06	38.22	0.48	76.43	2.64	67.26	0.03	0.16
51	29	0	0.00	0.14	22.29	1.45	36.94	0.07	0.37
50	21	0.67	426.75	0.24	38.22	3	76.43	0.14	0.74
47	29	4.14	2636.94	5.97	950.64	34.76	885.61	0.21	1.11
46	29	1.34	853.50	2.52	401.27	28.14	716.94	0.28	1.47
48	27	0.81	515.92	1.22	194.27	10.52	268.03	0.37	1.95
53	28	2.93	1866.24	2.11	335.99	11.71	298.34	0.89	4.68
52	33	1.48	942.68	2.03	323.25	13.97	355.92	1.24	6.53
54	39	10	6369.43	7.56	1203.82	31.87	811.97	1.51	7.95
42	20	3.95	2515.92	4.21	670.38	23.55	600.00	1.85	9.74
41	19	2.95	1878.98	4.53	721.34	29.79	758.98	2.42	12.74
43	29	6.59	4197.45	7.03	1119.43	42.38	1079.75	6.52	34.32
44	26	13.08	8331.21	6.31	1004.78	41.92	1068.03	8.35	43.95
45	26	25.62	16318.47	10.96	1745.22	37.58	957.45	9.62	50.64
35	20	22.95	14617.83	14.8	2356.69	33.55	854.78	10.3	54.22
9	36	34.03	21675.16	20.64	3286.62	58.97	1502.42	13.22	69.59
6	21	27.19	17318.47	6.57	1046.18	57.81	1472.87	15.52	81.70
7	30	32.17	20490.45	14.07	2240.45	50.1	1276.43	15.77	83.01
32	16	49.81	31726.11	36.25	5772.29	50.31	1281.78	18.5	97.38
8	36	33.19	21140.13	13.94	2219.75	51.94	1323.31	20.42	107.49
18	37	8.14	5184.71	10.05	1600.32	43.95	1119.75	20.68	108.86
37	16	4.88	3108.28	2.5	398.09	24.13	614.78	21.19	111.54
28	12	71.58	45592.36	27.67	4406.05	68.58	1747.26	22.08	116.23
36	22	11.14	7095.54	4.64	738.85	33.32	848.92	23.41	123.23
31	25	22.8	14522.29	14.03	2234.08	36.12	920.25	23.44	123.39
17	24	27.79	17700.64	12.67	2017.52	41.25	1050.96	23.67	124.60

38	21	6.86	4369.43	4.05	644.90	31.95	814.01	23.9	125.81
27	15	88.67	56477.71	25.27	4023.89	53.8	1370.70	24.2	127.39
5	17	62.53	39828.03	19.53	3109.87	75.24	1916.94	24.29	127.86
40	12	14.75	9394.90	13.25	2109.87	38.08	970.19	24.67	129.86
12	19	81.42	51859.87	20.95	3335.99	65.79	1676.18	25.63	134.92
25	12	61.42	39121.02	24.08	3834.39	65.92	1679.49	25.83	135.97
11	15	54.27	34566.88	23.47	3737.26	81.27	2070.57	25.93	136.50
26	12	91.58	58331.21	27.26	4340.76	72.17	1838.73	26.08	137.28
19	22	9.05	5764.33	8.5	1353.50	32.55	829.30	27.91	146.92
1	31	37.81	24082.80	19.29	3071.66	53.94	1374.27	29.55	155.55
30	16	36.5	23248.41	12.67	2017.52	58.06	1479.24	31.25	164.50
2	21	54.33	34605.10	20.86	3321.66	77.43	1972.74	31.33	164.92
29	14	47.71	30388.54	19.43	3093.95	64.14	1634.14	31.36	165.08
39	22	48.5	30891.72	25.68	4089.17	65	1656.05	32.09	168.92
20	26	3.69	2350.32	9.62	1531.85	34.85	887.90	32.12	169.08
4	17	44.06	28063.69	18.71	2979.30	64.82	1651.46	32.76	172.45
16	20	45.15	28757.96	15.25	2428.34	62.3	1587.26	33.05	173.97
34	12	25.25	16082.80	15.25	2428.34	36.67	934.27	33.08	174.13
33	15	25.8	16433.12	19.4	3089.17	46.67	1189.04	35.53	187.03
24	17	94.18	59987.26	35.88	5713.38	64.35	1639.49	35.59	187.35
3	17	45	28662.42	13.53	2154.46	71.82	1829.81	35.65	187.66
10	19	67	42675.16	20.26	3226.11	81.95	2087.90	40.32	212.24
21	14	109.86	69974.52	38.5	6130.57	59.5	1515.92	45.36	238.77
14	13	109.62	69821.66	32.54	5181.53	58.77	1497.32	45.62	240.14
23	11	43	27388.54	28.09	4472.93	60.18	1533.25	52.91	278.52
22	13	58.77	37433.12	26.69	4250.00	45.85	1168.15	53.38	280.99
13	19	72.11	45929.94	21.21	3377.39	64.89	1653.25	53.47	281.47
15	15	115.6	73630.57	32.53	5179.94	72.53	1847.90	61.73	324.95

It is seen from **Table 49** that the highest concentration of sundri seedlings of above 50,000 to less than 74000 per ha were found to occur in compartment nos. 12, 27, 26, 24, 14, 21 and 15. In compartments 29, 39, 32, 11, 2, 22, 25, 5, 10, 28 and 13 the number of sundri seedlings per ha varied from above 30,000 but less than 50,000. Above 20,000 but less than 30,000 sundri seedlings per ha were found to occur in compartment nos. 7, 8, 9, 30, 1, 23, 4, 3 and 16. In compartments 31, 35, 34, 45, 33, 6 and 17 the number of sundri seedlings ranged from above 14,000 but less than 20,000. In compartments 18, 19, 54, 36, 44 and 40 the number of sundri seedlings per ha varied from above 5,000 but less than 14,000. Similarly, in compartment nos. 53, 41, 20, 42, 47, 37, 43 and 38 no. of sundri seedlings per ha ranged from above 1,000 but less than 5,000, but in compartments 50, 48, 46 and 52 the no. of sundri seedlings were more than 400 but less than 1,000. In compartments 49 and 55 the no. of sundri seedlings per ha were less than 100. In compartment 51 no sundri seedlings were found to occur in 29 TSPs.

A careful look at **Table 50** reveals that the highest mean no. of saplings per ha of 6131 was obtained in compartment no. 21 and in compartment 55 no sundri sapling was found in 43 TSPs which fell in compartment 55. Above 5,000 but less than 6,000 saplings per ha were obtained in compartments 15, 14, 24 and 32. In compartments 27, 39, 22, 26, 28 and 23 no. of sundri saplings were above 4,000 but less than 5,000. More than 3,000 but less than 4,000 sundri saplings per ha were found to occur in compartments 1, 33, 29, 5, 10, 9, 2, 12, 13, 11 and 25. More than 2,000 but less than 3,000 sundri saplings per ha were prevalent in compartments 17, 30, 40, 3, 8, 31, 7, 35, 16, 34 and 4. Compartment nos. 44, 6, 43, 54, 19, 20, 18 and 45 had sundri saplings above 1,000 but less than 2,000 per ha. In compartment nos. 38, 42, 41, 36 and 47 sundri saplings per ha were above 500 but less than 1,000, while in compartment nos. 52, 53, 37 and 46 sundri saplings per ha were more than 300 but less than 500. In compartments 51, 50, 49 and 48 saplings per ha were less than 200.

In case of sundri poles (vide **Table 51**) having dbh more than 2.5 cm but less than 15 cm the highest no. of 2088 per ha was obtained in case of compartment no. 10 whereas the lowest of 37 poles per ha were obtained in case of compartment 51. More than 1500 but less than 2,000 sundri poles per ha were obtained in case of compartment nos. 9, 21, 23, 16, 29, 24, 4, 13, 39, 12, 25, 28, 3, 26, 15, 5 and 2. In compartment nos. 17, 44, 43, 18, 22, 33, 7, 32, 8, 27, 1, 6, 30 and 14 the no. of sundri poles per ha were more than 1,000 but less than 1,500. More than 500 but less than 1,000 sundri poles per ha were found to occur in compartment nos. 42, 37, 46, 41, 54, 38, 19, 36, 35, 47, 20, 31, 34, 45 and 40. In compartment nos. 48, 53 and 52 the no. of sundri poles per ha were 268, 298 and 356 respectively but in compartment nos. 51, 55, 49 and 50 less than 100 sundri poles per ha were found to occur.

In case of sundri trees (vide **Table 51**) having 15 cm or more in dbh the highest no. of 325 trees per ha was obtained in case of compartment no. 15. More than 200 but less than 300 sundri trees per ha were found to occur in compartment nos. 10, 21, 14, 23, 22 and 13. In compartment nos. 11, 30, 2, 229, 39, 20, 4, 16, 34,33, 24 and 3 the number of sundri trees per ha varied from more than 150 but less than 200. More than 100 but less than 150 sundri trees per ha were obtained in case of compartment nos. 8, 18, 37, 28, 36, 31, 17, 38, 27, 5, 40, 12, 25, 11, 26 and 19. More than 50 but less than 100 sundri trees per ha were obtained in compartment nos. 45, 35, 9, 6,, 7 and 32. There were only 44, 34, 13, 10, 8, 7, 5, 2, 2, 1, 1, 0.4, 0.02 sundri trees per ha in compartment nos. 44, 43, 41,42, 54, 52, 53, 48, 46, 47, 50, 51 and 49 respectively. No sundri tree was found in 43 TSPs of compartment no. 55 in the Sundarbans.

The distribution of sundri seedlings, saplings, poles and trees per ha in the compartments of the Sundarbans has been provided in **Map 2.**

5.1.5.3 Comparison of the Status of Regeneration of Major Mangrove Species in 1996-1997 and 2003 from Data of Ten Compartments

In **Appendix 20** data of 1203 Temporary Sample Plots in respect of seedlings, saplings and poles and trees of sundri, gewa, goran and amur for all the 55 compartments of the Sundarbans are presented as these four species represented 89.43% seedlings, 95.74% saplings, 95.31% of poles and 84.74% of trees of all species in the Sundarbans (vide **Table 47**). **Appendix 19** provides data of seedlings, saplings and poles of major mangrove species encountered in 180 sub-plots from 36 sample plots falling in compartment numbers 2, 11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans which were collected during the present sundri top dying study in January 2003. From these two Appendices data of seedlings, saplings and poles of sundri, gewa, goran and amur were separated out . These included regeneration data of 180 sub-plots of sundri top dying (STD) study in January 2003 and 174 Temporary Sample Plot (TSP) data from the same 10 compartments. Then the data of sundri seedlings obtained from the present study (denoted as STD data of 2003) and that from the TSP data denoted as (TSP data of 1996-97) were organized in two side by side columns and by using a programme of Microsoft Excel 1997 variance analysis were carried out to compare the mean values and to find out whether there existed any significant difference or not. In this way the two sets of data in respect of seedlings, saplings, poles of sundri, gewa, goran and amur were compared through analysis of variance and summarized in **Table 53.**

Table 53: Comparison of the mean values of the data of seedlings, saplings and poles of sundri, gewa, goran and amur per ha from in and around (a) 180 sample plots in January 2003 during study of top dying of sundri (i.e. STD data) with (b) data found to occur in and around 174 Temporary Sample Plots (TSP data) during FRMP Forest Inventory in 1996 and 1997 in compartment numbers 2,11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans.

Parameter	Mean of STD data of January 2003	Mean of TSP data of 1996-1997	F value	Probability level of difference of the two means	Significance of difference of the means
Sundri seedlings	32194.44	18302.95	10.68699	P = 0.001192	Significant
Sundri saplings	1847.22	2308.92	0.98707	P = 0.321143	Insignificant
Sundri poles	2847.22	1201.41	6.98239	P = 0.008599	Significant
Gewa seedlings	7666.67	3682.55	1.15539	P = 0.283160	Insignificant
Gewa saplings	500.00	841.94	2.79252	P = 0.095594	Insignificant
Gewa poles	1513.89	1159.97	0.51065	P = 0.475330	Insignificant
Goran seedlings	972.22	1402.01	1.47007	P = 0.226148	Insignificant
Goran saplings	0	855.66	32.40264	P = 2.64E-08	Significant
Goran poles	416.67	82.44	4.409963	P = 0.036441	Significant
Amur seedlings	3371.69	849.26	33.5229	P = 1.56E-08	Significant
Amur saplings	458.33	374.30	0.598245	P = 0.439768	Insignificant
Amur poles	791.67	98.10	11.77421	P = 0.000672	Significant

Table 53 clearly reveals that sundri had significantly higher number of 32194.44 seedlings per ha in January 2003 as compared to 18302.95 seedlings in 1996 - 1997 in the compartment numbers 2,11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans . Similarly in 2003 sundri had significantly higher no. of 2847.22 poles per ha as compared to 1201.41 poles in 1996-97. In case of goran poles, amur seedlings and amur poles substantial and significant increases were found to occur in 2003 as compared to that of 1996 -97 as we found 416.67 goran poles per ha in 2003 as against 82.44 in 1996-97, 3371.69 amur seedlings in 2003 as against 849.26 amur seedlings in 1996-97 and 791.67 amur poles in 2003 as against 98.10 poles in 1996-97.

It is also seen from Table 53 that higher number of gewa seedlings and poles, amur saplings were found to occur in 2003 as compared to 1996-97 but the difference between the mean pairs were insignificant. Similarly, in case of sundri saplings, gewa saplings and goran seedlings were found to occur in 1996-97 as compared to those found in January 2003, but in all cases the differences were only insignificant.

The mean values and the confidence intervals at 95% point (at P =0.05 level of probability) taking into considerations the existing variability among the 180 subplot and 174 TSPs are provided in **Table 54** to get a easily look into the means and their range of variability in the population in the Sundarbans.

Map No. 2: Map of the Sundarbans Reserved Forest Showing Distribution and Intensity of Sundri Seedlings, Saplings, Poles and Trees as determined from the TSP Database Generated by FRMP Forest Inventory During 1996 and 1997.

Scale = 1 : 3.50.000

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Table 54 : Calculation of mean and confidence intervals at 95% point (at P = 0.05) of the data of regeneration and recruitment (i.e. data of seedlings, saplings and poles) of sundri, gewa, goran and amur per hectare (a) based on data of 180 sub-plots from 36 sample plots established during sundri top dying study in compartment nos. 2, 11, 19, 20, 22, 26, 33, 36, 37 and 40 and collected in January 2003 (eg. Sseedl/ha) and (b) of 174 Temporary Sample Plots (TSP) data (eg.SundSeed) from the same compartments and collected during FRMP Forest Inventory during 1996 and 1997 from the Sundarbans.

Confidence Intervals

Variable	N	Mean	StDev	SE Mean	95.0 % CI
Sseedl/h	180	32194	50150	3738	(24818, 39571)
SundSeed	174	18303	25521	1935	(14484, 22122)
Ssapl/ha	180	1847	5457	407	(1045, 2650)
SundSap	174	2309	2841	215	(1884, 2734)
Spole/ha	180	2847	8174	609	(1645, 4049)
SundPole	174	1201.4	839.5	63.6	(1075.8, 1327.0)
Gseed/ha	180	7667	47994	3577	(608, 14726)
GewaSeed	174	3683	9476	718	(2265, 5100)
Gsapl/ha	180	500	2428	181	(143, 857)
GewaSapl	174	841.9	1199.6	90.9	(662.4, 1021.4)
Gpole/ha	180	1514	6454	481	(565, 2463)
GewaPole	174	1160.0	1028.5	78.0	(1006.1, 1313.9)
Goseed/h	180	972	3075	229	(520, 1424)
GoranSee	174	1402	3583	272	(866, 1938)
GoSap/ha	180	0.00	0.00	0.00	(0.00, 0.00)
GoranSap	174	856	2017	153	(554, 1157)
Gopole/h	180	417	2089	156	(109, 724)
GoranPol	174	82.4	210.2	15.9	(51.0, 113.9)
Amseed/h	180	3363	5513	411	(2552, 4174)
AmurSeed	174	849	1700	129	(595, 1104)
Amsap/ha	180	458.3	1307.3	97.4	(266.0, 650.6)
AmurSapl	174	374.3	597.2	45.3	(284.9, 463.7)
Ampole/h	180	792	2662	198	(400, 1183)
AmurPole	174	98.1	150.0	11.4	(75.7, 120.6)

Notes:a) Sseedl/h = sundri seedlings from STD data; Ssapl/ha = sundri saplings from STD data; Spole/ha = sundri poles from STD data; Gseed/ha = gewa seedlings from STD data; Gsapl/ha = Gewa saplings from STD data, Gpole/ha = gewa poles from STD data; Goseed/ha = goran seedlings from STD data; Gosap/ha =goran saplings from STD data; Gopole =goran pole from STD data; Amseed/h = amur seedlings from STD data; Amsap/ha = amur saplings from STD data; Ampole/h = amur pole from STD data;
b) Sundseed = sundri seedlings from TSP data; Sundsap = sundri saplings from TSP data; Sundpole = sundri poles from TSP data; Gewaseed = gewa seedlings from TSP data; Gewasapl = gewa saplings from TSP data, GewaPole = gewa poles from TSP data;GoranSee= goran seedlings from TSP data;GoranSap=goran saplings from TSP data, GoranPol =goran pole from TSP data; AmurSeed = amur seedlings from TSP data; AmurSapl = amur saplings from TSP data; AmurPole = amur pole from TSP data.

Since the above findings are from data of 180 sub-plots in January 2003 and 174 TSPs in 1996-97 from compartments nos. 2, 11, 19, 20, 22, 26, 33, 36, 37 and 40 it is considered safely that this represents the general conditions of regeneration and recruitment in the Sundarbans. The overall status of regeneration and recruitment of a number of major species for the whole of the Sundarbans as determined from data of 1203 TSP from 55 compartments is provided in **Table 55.**

Table 55: Per cent distribution of seedlings, sapling, poles and trees of a number mangrove species in the Sundarbans as found from the TSP data generated in 1996 and 1997.

Species	Per cent of total seedlings of all species	Per cent of total saplings of all species	Per cent of total poles of all species	Per cent of total trees of all species
Sundri	54.92	28.73	33.13	70.72
Gewa	16.23	19.64	44.76	13.77
Goran	16.52	44.36	15.52	0.09
Amur	1.76	3.01	1.90	0.16
Passur	0.26	0.30	0.43	7.93
Baen	0.57	0.41	0.16	3.04
Shingra	5.41	0.73	3.46	0.01
Dhundul	0.03	0.04	0.00	0.45
Keora	0.00	0.31	0.14	1.68
Kankra	1.63	1.16	0.44	1.87
Other species	2.67	1.31	0.56	0.28
Total:	**100.00**	**100.00**	**100.00**	**100.00**

It is thus seen that as sundri is the most dominant tree occupying 70.72% of all trees in the Sundarbans and it represents 33.13% of all poles (dbh 2.5 or more but less than 15 cm dbh), 28.73% of all saplings (height equal to or more than 1.5 m but dbh less than 2.5 cm) and 54.92% of the seedlings (height equal to less than 1.5 m) present in the Sundarbans. The second dominant tree species is gewa which is represents 13.77% trees, 44.76 % poles, 19.64% saplings and 16.23% seedlings in Sundarbans. In consideration of tree passur is third dominant having 7.93% trees, but in consideration of poles, saplings and seedlings goran is in reality third dominant which has 0.09% trees, 15.52% poles, 44.36% saplings and 16.52% seedlings in the Sundarbans. Amur has 0.16% tree, 1.90% poles, 3.01% saplings and 1.76 % seedlings. Bean has 3.04% trees, 0.16% poles, 0.41% saplings and 0.57% seedlings. The occurrence of kankra is also noticeable as it has 1.87% trees, 0.44% poles, 1.16% saplings and 1.63% seedlings in the forest. Shingra has 0.01% tree, 3.46% poles, 0.73% saplings and 5.41% seedlings. dhundul has 0.45% trees,0.04% saplings and 0.03% seedlings. Keora has 1.68% trees, 0.14% poles and 0.31% saplings in the Sundarbans (**Table 55**).

5.1.5.4 Distribution of four mangrove species in three salinity zones

It is established fact that reduction of fresh water flow through the Sundarbans has resulted in the increase of salinity in the Sundarbans. Therefore, it was considered to examine the effect of salinity on the distribution of sundri in particular and a few other mangrove species in the Sundarbans. The whole of the Sundarbans is divided into three salinity zones: Fresh Water Zone (FWZ), Moderately Saline water Zone (MSWZ) and Saline Water Zone (SWZ). From Map No. 1 the 55 compartments were divided into three salinity zones. In doing so compartments that falls in more than one salinity zones have been shown only in one of the zones to avoid repetition. Thus compartment nos. 1, 2, 3, 11, 12, 13, 14, 15, 16, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38 and 40 fall in FWZ, compartment nos. 4, 5, 6, 7, 8, 9, 10, 11, 17, 18, 19, 20, 41, 42, 44 and 45 fall in MSWZ, and compartment nos. 43, 46, 47, 48, 49, 50, 51, 52, 53, 54 and 55 fall in SWZ. This information of three salinity zones were incorporated in the data provided in **Appendix 20** which contain data of 1203 Temporary Sample Plots (TSP) converted to per hectare values for each of seedlings, saplings, poles and trees of sundri, gewa, goran and amur from 55 compartments in the Sundarbans. Then the 1203 data were sorted out into FWZ, MSWZ and SWZ by using Microsoft Word and copied to Microsoft Excel where the data of each category (i.e. seedling, sapling, pole and tree) of each species under three salinity zones (i.e. FWZ, MSWZ and SWZ). Thus data of 466 TSP fell under FWZ, 375 TSP under MSWZ and 340 TSP under SWZ. Then variance analysis were carried out of each category having data from three salinity zones. The variance analysis thus conducted has been provided in **Appendix 21** and the results are summarized in **Table 56** for easy and quick comparison of the effect of the salinity on the distribution of the seedlings, saplings, poles and trees of sundri, gewa goran and amur in the Sundarbans.

Table 56: Distribution of the seedlings, saplings, poles and trees of each of sundri, gewa, goran and amur in Fresh Water Zone (FWZ), Moderately Saline Water Zone (MSWZ) and Saline Water Zone (SWZ) in the Sundarbans.

Parameters	FWZ	MSWZ	SWZ	F values	Probability	Significance of the difference of the three means
Sundri seedlings	32413.15	15984.71	1714.13	177.6053	3.79E-68	Significant
Sundri saplings	3205.22	1932.91	439.30	159.1594	6.54E-62	Significant
Sundri poles	1390.23	1219.26	422.71	158.3549	1.23E-61	Significant
Sundri trees	165.25	99.34	5.33	282.596	5.7E-101	Significant
Gewa seedlings	5244.53	5583.02	5384.04	0.155877	0.855682	Insignificant
Gewa saplings	860.76	1673.46	1795.62	33.18584	9.53E-15	Significant
Gewa poles	1021.68	1600.34	1618.43	44.48847	2.36E-19	Significant
Gewa trees	17.77	18.05	22.57	3.468357	0.031487	Significant
Goran seedlings	882.97	6721.02	10994.75	132.66	1.1E-52	Significant
Goran saplings	454.42	1673.46	6289.34	378.39	1.3E-127	Significant
Goran poles	51.01	455.07	1191.68	234.18	2.41E-86	Significant
Goran trees	0.08	0.21	0.11	1.337696	0.262848	Insignificant
Amur seedlings	958.15	482.38	119.90	29.66337	2.7E-13	Significant
Amur saplings	369.39	145.65	53.39	57.91557	1.02E-24	Significant
Amur poles	95.68	47.76	24.95	41.7698	2.98E-18	Significant
Amur trees	0.45	0.10	0.09	3.374433	0.034569	Significant
Note: Degree of freedom for each of the F values is 2 and 1178.						

It is seen from **Table 56** that in case of seedlings, saplings, poles and trees sundri had significantly higher number in the FWZ compartments as compared to MSWZ, and the latter had significantly higher number as compared to SWZ compartments. This explicitly and vividly makes it clear that salinity has a very pronounced effect on the physiology of sundri and hence salinity affects the distribution and also of growth of sundri in the Sundarbans. It may be mentioned here that in the north eastern compartments (i.e. FWZ) best growth of sundri trees are found to occur, whereas in the southwestern compartments (i.e. SWZ) very reduced growth of sundri is seen. This behaviour of sundri is directly linked up with the prevailing salinity of the areas under consideration.

In case of gewa seedlings there were only insignificant variations of the mean number of gewa seedlings from the three salinity zones which is evident from the insignificant F-value. In case of gewa saplings and poles significantly (P =0.05) higher numbers were obtained from moderately saline water zone and saline water zone as compared to fresh water zone. In case of gewa trees significantly (P 0.05) higher number of trees were present in saline water zone as compared to moderately saline water zone and fresh water zone, there being no significant difference in no. of trees from FWZ and MSWZ.

In case of goran very distinct effect of salinity on the abundance and distribution of the species is seen. In the SWZ significantly (P =0.05) higher number of seedlings, saplings and poles of goran were found to occur as compared to MSWZ, the latter in turn had significantly (P= 0.05) higher number of seedlings, saplings and poles of goran as compared to FWZ. The mean no. of goran trees (i.e. above 15 cm dbh) were very few indeed and the difference in the mean from the three salinity zones were only insignificant.

The behaviour of amur was just reserve to that of goran. That mean amur had significantly (P= 0.05) higher number of seedlings, saplings, poles and trees in the FWZ as compared to MSWZ, and the latter in turn had significantly (P = 0.05) higher number of seedlings, saplings and poles and trees as compared to SWZ (vide **Table 56** and **Appendix 21**).

5.1.5.5 Distribution of sundri seedlings, saplings, poles and trees in three salinity zones

In order to examine the effect of salinity prevailing on the distribution of seedlings, saplings , poles and trees of sundri the per hectare data of sundri from 55 compartments (vide **Table 51)** have been classified into three salinity zones: fresh water zone (FWZ), moderately saline water zone (MSWZ) and saline water zone (SWZ) and then sorted out and presented in **Table 57**.

Table 57: Number of sundri seedlings, saplings, poles and trees per Temporary Sample Plots (TSPs) and per hectare in 55 compartments in the Sundarbans arranged according to the number of seedlings per hectare.

Compt. No.	Salinity Zones	No. of sundri seedlings per hectare	No. of sundri saplings per hectare	No. of sundri poles per hectare	No. of sundri trees per hectare
1	FWZ	24082.80	3071.66	1374.27	155.55
2	FWZ	34605.10	3321.66	1972.74	164.92
3	FWZ	28662.42	2154.46	1829.81	187.66
12	FWZ	51859.87	3335.99	1676.18	134.92
13	FWZ	45929.94	3377.39	1653.25	281.47
14	FWZ	69821.66	5181.53	1497.32	240.14
15	FWZ	73630.57	5179.94	1847.90	324.95
16	FWZ	28757.96	2428.34	1587.26	173.97
21	FWZ	69974.52	6130.57	1515.92	238.77
22	FWZ	37433.12	4250.00	1168.15	280.99
23	FWZ	27388.54	4472.93	1533.25	278.52
24	FWZ	59987.26	5713.38	1639.49	187.35
25	FWZ	39121.02	3834.39	1679.49	135.97
26	FWZ	58331.21	4340.76	1838.73	137.28
27	FWZ	56477.71	4023.89	1370.70	127.39
28	FWZ	45592.36	4406.05	1747.26	116.23

29	FWZ	30388.54	3093.95	1634.14	165.08
30	FWZ	23248.41	2017.52	1479.24	164.50
31	FWZ	14522.29	2234.08	920.25	123.39
32	FWZ	31726.11	5772.29	1281.78	97.38
33	FWZ	16433.12	3089.17	1189.04	187.03
34	FWZ	16082.80	2428.34	934.27	174.13
35	FWZ	14617.83	2356.69	854.78	54.22
36	FWZ	7095.54	738.85	848.92	123.23
37	FWZ	3108.28	398.09	614.78	111.54
38	FWZ	4369.43	644.90	814.01	125.81
39	FWZ	30891.72	4089.17	1656.05	168.92
40	FWZ	9394.90	2109.87	970.19	129.86
4	MSWZ	28063.69	2979.30	1651.46	172.45
5	MSWZ	39828.03	3109.87	1916.94	127.86
6	MSWZ	17318.47	1046.18	1472.87	81.70
7	MSWZ	20490.45	2240.45	1276.43	83.01
8	MSWZ	21140.13	2219.75	1323.31	107.49
9	MSWZ	21675.16	3286.62	1502.42	69.59
10	MSWZ	42675.16	3226.11	2087.90	212.24
11	MSWZ	34566.88	3737.26	2070.57	136.50
17	MSWZ	17700.64	2017.52	1050.96	124.60
18	MSWZ	5184.71	1600.32	1119.75	108.85
19	MSWZ	5764.33	1353.50	829.30	146.92
20	MSWZ	2350.32	1531.85	887.90	169.08
41	MSWZ	1878.98	721.34	758.98	12.74
42	MSWZ	2515.92	670.38	600.00	9.74
44	MSWZ	8331.21	1004.78	1068.03	43.95
45	MSWZ	16318.47	1745.22	957.45	50.64
43	SWZ	4197.45	1119.43	1079.75	34.32
46	SWZ	853.50	401.27	716.94	1.47
47	SWZ	2636.94	950.64	885.61	1.11
48	SWZ	515.92	194.27	268.03	1.95
49	SWZ	38.22	76.43	67.26	0.16
50	SWZ	426.75	38.22	76.43	0.74
51	SWZ	0.00	22.29	36.94	0.37
52	SWZ	942.68	323.25	355.92	6.53
53	SWZ	1866.24	335.99	298.34	4.68
54	SWZ	6369.43	1203.82	811.97	7.95
55	SWZ	89.17	0.00	47.39	0.00

Analysis of variance of the were then carried out of the data of number of sundri seedlings, saplings, poles and trees by the three salinity zones (FWZ, MSWZ and SWZ). The results are provided in Tables 58, 59, 60 and 61 for sundri seedlings, saplings, poles and trees respectively.

Table 58: Analysis of variance of the data of mean number of sundri seedlings per hectare in 55 compartments falling in three salinity zones (i.e. none, slight, moderate and severe) in the Sundarbans.

SUMMARY						Seedling
Groups	*Count*	*Sum*	*Average*	*Variance*		
FWZ	28	953535	34054.82	4.24E+08		
MSWZ	17	285802.6	17862.66	1.76E+08		
SWZ	10	17936.3	1630.57	4145290		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.87E+09	2	4.43E+09	16.31509	3.17E-06	3.175145
Within Groups	1.41E+10	52	2.72E+08			
Total	2.3E+10	54				

Table 59: Analysis of variance of the data of mean number of sundri saplings per hectare in 55 compartments falling in three salinity zones (i.e. none, slight, moderate and severe) in the Sundarbans.

SUMMARY						Sapling
Groups	*Count*	*Sum*	*Average*	*Variance*		
FWZ	28	94195.86	3364.14	2334112		
MSWZ	17	32490.45	2030.65	974927.2		
SWZ	10	4665.61	466.56	205907.6		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	65535431	2	32767715	21.0213	2.2E-07	3.178798
Within Groups	79498096	51	1558786			
Total	1.45E+08	53				

Table 60: Analysis of variance of the data of mean number of sundri poles per hectare in 55 compartments falling in three salinity zones (i.e. none, slight, moderate and severe) in the Sundarbans.

SUMMARY						poles
Groups	*Count*	*Sum*	*Average*	*Variance*		
FWZ	28	39129.17	1397.47	141148.7		
MSWZ	17	21654.02	1273.77	204201.2		
SWZ	10	3564.83	356.48	109811.5		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8249941	2	4124971	26.59114	1.11E-08	3.17514
Within Groups	8066539	52	155125.7			
Total	16316480	54				

Table 61: Analysis of variance of the data of mean number of sundri trees per hectare in 55 compartments falling in three salinity zones (i.e. none, slight, moderate and severe) in the Sundarbans.

SUMMARY						Trees
Groups	*Count*	*Sum*	*Average*	*Variance*		
FWZ	28	4791.17	171.11	4057.661		
MSWZ	17	1657.37	103.59	3356.689		
SWZ	10	59.28	5.93	106.9002		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	207572.5	2	103786.2	32.9031	6.65E-10	3.178798
Within Groups	160869.3	51	3154.3			
Total	368441.8	53				

Tables 58, 59, 60 and 61 show a highly significant (P = 0.001) difference among the mean values of sundri seedlings, saplings, poles and trees from compartment nos. falling in FWZ, MSWZ and SWZ as are evident from F values of 16.31, 21.02, 26.59 and 32.90 in case of seedlings, saplings, poles and trees respectively each having 2 and 52 df. Hence DMRT (Duncan, 1955) tests were then done to find the trend of the means no. of sundri seedlings, saplings, poles and trees from FWZ, MSWZ and SWZ. The results are provided in Tables 62, 63, 64 and 65.

Table 62: Comparison of the mean number of sundri seedlings per hectare in 55 compartments fallings in fresh water zone (FWZ), moderately saline water zone (MSWZ), saline water zone (SWZ) in the Sundarbans.

SWZ	**MSWZ**	**FWZ**
1630.57	17862.66	34054.82
Note: The three mean no. of seedlings differ from each other highly significantly (P =0.01)		

Table 63: Comparison of the mean number of sundri saplings per hectare in 55 compartments fallings in fresh water zone (FWZ), moderately saline water zone (MSWZ), saline water zone (SWZ) in the Sundarbans.

SWZ	**MSWZ**	**FWZ**
466.56	2030.65	3364.14
Note: The three mean no. of saplings differ from each other highly significantly (P =0.01)		

Table 64: Comparison of the mean number of sundri poles per hectare in 55 compartments fallings in fresh water zone (FWZ), moderately saline water zone (MSWZ), saline water zone (SWZ) in the Sundarbans.

SWZ	**MSWZ**	**FWZ**
356.48	1273.77	1397.47
Notes: No. of sundri poles in MSWZ and FWZ are highly significantly higher than that of SWZ, but there is no significant difference between the mean no. of sundri poles from FWZ and MSWZ.		

Table 65: Comparison of the mean number of sundri trees per hectare in 55 compartments fallings in fresh water zone (FWZ), moderately saline water zone (MSWZ), saline water zone (SWZ) in the Sundarbans

SWZ	MSWZ	FWZ
5.93	103.59	171.11
Note: The three mean no. of trees differ from each other highly significantly (P =0.01)		

Tables 62, 63, 64 and 65 reveal that in case of Moderately Saline Water Zone (MSWZ) compartments had highly significantly (P =0.01) higher number of sundri seedlings, saplings, poles and trees as compared to Saline Water Zone (SWZ). Similarly Fresh Water Zone compartments had highly significantly (P = 0.01) higher number of sundri seedlings, saplings and trees as compared to that of Moderately Saline Water Zone compartments. In case of sundri poles, however, there was no significant difference between the mean number of poles from MSWZ and FWZ compartments. **Thus it is very clear that distribution of the number of sundri seedlings, saplings, poles and trees are distinctively governed by the salinity of the areas of the compartments.**

In **Table 49** only mean values of sundri seedlings, saplings , poles and trees per ha have been provided for each of 55 compartments. But these data do not reveal the real dispersion of each of seedlings, saplings, poles and trees in each of the 55 compartments. Hence to get a more realistic view of dispersion of the population parameters confidence intervals of each of sundri seedlings, saplings, poles and trees data of all the TSPs of each of 55 compartments were arranged according to seedlings, sapling, poles and trees and then by using a programme of the Minitab Release 11.2 32 Bit, mean, standard deviation, standard error of mean, and confidence intervals (at P= 0.05) were calculated. These are provided in **Appendix 22, 23, 24 and 25** for sundri seedlings, saplings, poles and trees respectively. From these four Appendix a summary table has been prepared and based on the mean value within each of seedlings, saplings, poles and trees mean data have been sorted out from the smallest to the largest value. Thus in this table against each mean value of each of 55 compartments in respect of seedlings, saplings, poles and trees the confidence intervals (i.e. the limits of the population mean within each compartment) gives a value which has a precision level of 95% i.e. the value is 95% true to the population value really occurring in the forest at the time of carrying out the FRMP Forest Inventory in 1996 and 1997. To state in a simple language say for example in case of compartment 15 the number of sundri seedlings per ha varies from 51, 244 to 78,692 with a mean value of 64,968. This is true in 95% of the cases in the compartment 15. **Thus this knowledge of the occurrence of sundri seedlings, saplings, poles and trees per ha for each of 55 compartments in the Sundarbans is of great value from a management point of view.**

5.1.5.6 Regeneration and recruitment of sundri in compartments alongside ship/steamer routes and in compartments away from such routes and thereby to examine the effect of oil pollution on regeneration and recruitment of mangrove species in the Sundarbans

During presentation of the Mid term report at Bano Bhaban auditorium concerns were expressed about any possible impact of oil spills from ships coming from the Bay of Bengal to Mongla Port and also from India via Koikhali through the Sundarbans to Mongla Port. In order to examine any possible effect on regeneration of sundri and gewa, the routes of ships were identified on the map of the Sundarbans in consultation with officers of the Coast Guards and Mongla Port authority. It was thus found that the compartments falling on the sides of the ships routes (**CFSSR**) include compartment nos. 8, 9, 10, 15, 16, 17, 18, 21, 22, 26, 28, 28, 29, 30, 31, 35, 36, 37, 39, 40, 41, 45, 46, 49, 50 and 51. The compartments that are away from the ship routes (**CAFSR**) include compartment nos. 7, 11, 12, 13, 14, 19, 20, 24, 25, 32, 33, 34, 38, 42, 43, 47, and 48. This information of the compartments were incorporated in the data provided in **Appendix 20** which contain data of 1203 Temporary Sample Plots (TSP) converted to per hectare values for each of seedlings, saplings, poles and trees of sundri, gewa, goran and amur from 55 compartments in the Sundarbans. Then the 1203 data were sorted out into CFSSR and CAFSR by using Microsoft Word and copied to Microsoft Excel where the data of each category (i.e. seedling, sapling and pole) of each species under CFSSR and CAFSR. Thus data of 541 TSP fell under CFSSR, 343 TSP fell under CAFSR. Then variance analysis were carried out of each category having data from CFSSR and CAFSR. The variance analysis thus conducted and the results are summarized in **Table 66** for easy and quick comparison of the effect of any possible oil spills on the seedlings, saplings and poles of sundri and gewa in the Sundarbans.

Table 66: Distribution of the seedlings, saplings and poles of each of sundri and gewa per hectare from in and around 541 Temporary Sample Plots (TSPs) from 25 compartments which are by the sides of ship/steamer routes (CFSSR) from Bay of Bengal to Mongla and from India via Koikhali through the Sundarbans to Mongla Port and from in and around 343 TSPs from 18 compartments which are away from ship/steamer routes (CAFSR).

Parameters	CFSSR	CAFSR	F values	Probability	Significance of the difference of the two means
Sundri seedlings	19135.36	19439.72	0.04440?	0.833135	Insignificant
Sundri saplings	2110.09	2180.66	0.265859	0.606204	Insignificant
Sundri poles	1066.30	1085.40	0.160344	0.688900	Insignificant
Gewa seedlings	6367.07	4245.05	11.31658	0.000801	Significant
Gewa saplings	1484.04	1213.99	4.775316	0.029133	Significant
Gewa poles	1399.34	1352.48	0.645708	0.421786	Insignificant

Table 66 reveals that there in case of sundri seedlings, saplings and poles there were only insignificant F values for seedlings saplings and poles of sundri. This suggests that any possible oil spills did not have any adverse effect, if any, on regeneration and recruitment of sundri. In case of gewa significantly higher regeneration of seedlings and saplings were obtained in case of compartment falling on the sides of ship routes. So there was also no adverse effect on regeneration and recruitment of gewa.

5.1.5.7 Data of saplings of tree species from top dying sundri harvested and unharvested compartments

Extraction of top dying affected sundri trees was started in 1990. Since then top dying extractions have been done in the following compartments in the schedule given in **Table 67**.

Table 67: Information on the harvest of top dying sundri (from Gani and Hossen, 2002)

Compartment Number	Area in ha	Year of start of harvest	Year of completion of harvest	No. of trees marked for harvesting	Trees removed /ha	Tim (in m^3)	Firewood harvested (in m^3)
36	7160	1990-91	1991-92	69570	10	6962	9663
37	5776	1990-91	1990-91	58981	10	6811	10653
32	5523	1991-92	1991-92	70905	13	15668	15608
38	6331	1992-93	1992-93	148408	23	7473	11397
20	7847	1992-93	1995-96	332248	42	19860	26884
39	6150	1992-93	1995-96	246742	40	24770	28487
26	3824	1995-96	1999-00	50758	13	7941	8902
19	7764	1996-97	2000-01	252613	33	11098	15502

Hence considering the year of start of extraction and year of completion of top dying of sundri harvest, compartment numbers 32, 36 and 38 were selected to examine the status of regeneration particularly of saplings in the Temporary Sample Plots (TSPs) laid down in these compartments during FRMP Forest Inventory of the Sundarbans during 1996 and 1997 so that status of regeneration after 3- 4 years after top dying harvest could be obtained from these three compartments. To compare the level of saplings of compartment nos. 32, 36 and 38, neighbouring compartments from which top dying sundri were not harvested before 1996 and 1997, the years of FRMP Inventory, compartment nos. 31, 35, 41 and 16 were selected. Then for each of the compartment nos. 32, 36, 38, 41, 16, 31 and 35, the TSP nos. which fell in these compartments were found out from the TSP Database. There were 16, 22, 21, 19, 20, 25 and 20 nos. of TSPs in compartment numbers 32, 36, 38, 41, 16, 31 and 35 respectively. Thereafter, for each of these 143 TSPs saplings of all the tree species were retrieved from the TSP Database using a Structured Query Language (SQL) programme. The detailed data of the distribution of the saplings of different species in each of these 143 TSPs sorted out according to compartments are provided in **Appendix 26**. The data have been further processed and summarized in **Table 68.**

Table 68: Summarized data on the mean number of saplings of nine tree species in Temporary Sample Plots (TSPs) of three compartments harvested for top dying affected sundri during 1990-92 and four neighbouring compartments where top dying sundri have not been harvested in the Sundarbans.

Status of compartment	Compt. No.	No. of TSPs	Amur (201)	Baen (203)	Gewa (215)	Goran (216)	Kankra (219)	Khalisha (222)	Passur (224)	Shingra (226)	Sundri (228)
Harvested	32	16	0.81	0	1	0	0.13	0	0	0	4.19
Harvested	36	22	1.27	0	1.27	0.14	0.14	0.14	0.14	0.14	1.36
Harvested	38	21	1.33	0	1.71	0.9	0	0	0	0	1.43
		Mean	1.14	0.00	1.33	0.35	0.09	0.05	0.05	0.05	2.33
Unharvested	41	19	0.42	0.05	1.05	2.32	0	0	0	0	0.68
Unharvested	16	20	0.85	0	2.25	1.25	0.05	0	0.05	0.1	3.75

Unharvested	31	23	0.32	0.2	1.64	0	1	0	0.16	0.2	2.8
Unharvested	35	22	1.25	0	1.05	0	0.2	0	0.1	0	3.35
		Mean	0.71	0.06	1.49	0.89	0.31	0.00	0.08	0.08	2.65
	Grand mean		0.89	0.03	1.42	0.66	0.22	0.02	0.06	0.06	2.51

Analysis of variance of the data of 143 TSPs (vide **Appendix 26**) from seven compartments were carried out using a programme of the SAS System. The results of variance analysis of the data of regeneration of saplings from 60 TSPs from three top dying harvested compartments and 83 TSPs from four unharvested compartments are summarized in the **Table 69**.

Table 69: Summary of findings from variance analysis of the data of mean no. of saplings from 60 TSPs from harvested compartments (i.e. 32, 36 and 38) and 83 TSPs from unharvested compartments 16, 31, 35 and 41 for each of amur, baen, gewa, goran, kankra, khalisha, passur, singra and sundri recorded during 1996 and 1997 in the Sundarbans.

Species	Degrees of freedom	Calculated F value	Probability	Tabulated F-value	Significance
Amur	1 & 141	**6.09**	**0.0148**	**3.91**	**Significant**
Baen	1 & 141	3.29	0.0717	3.91	Insignificant
Gewa	1 & 141	0.39	0.5344	3.91	Insignificant
Goran	1 & 141	3.29	0.0338	3.91	Insignificant
Kankra	1 & 141	**6.49**	**0.0119**	**3.91**	**Significant**
Khalisha	1 & 141	2.61	0.1087	3.91	Insignificant
Passur	1 & 141	0.39	0.5339	3.91	Insignificant
Singra	1 & 141	0.46	0.4997	3.91	Insignificant
Sundri	1 & 141	2.47	0.0927	3.91	Insignificant

Table 69 reveals that there is significant variation in the mean number of saplings from harvested and unharvested TSPs in case of amur and kankra. The differences are, however, insignificant in case of baen, gewa, goran, khalisha, passur, singra and sundri. Therefore, further analysis of the data of amur and kankra were carried out to find out the trend of the significant variation and are provided in **Table 70** and **71** for amur and kankra respectively.

Table 70: Summary of variance analysis of the data of regeneration of saplings of Amur obtained from 1996 and 1997 FRMP Forest Inventory of the Sundarbans from 60 Temporary Sample Plots (TSPs) from compartment nos. 32, 36 and 38 harvested in 1990-92 and 83 TSPs from unharvested compartment nos. 16, 31, 35 and 41.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Harvested	60	69	1.169492	1.488019		
Unharvested	83	58	0.690476	1.180149		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7.952325	1	7.952325	6.085386	0.014829	3.908255
Within Groups	184.2575	141	1.306791			
Total	192.2098	142				

95

Table 71: Summary of variance analysis of the data of regeneration of saplings of Kankra obtained from 1996 and 1997 FRMP Forest Inventory of the Sundarbans from 60 Temporary Sample Plots (TSPs) from compartment nos. 32, 36 and 38 harvested in 1990-92 and 83 TSPs from unharvested compartment nos. 16, 31, 35 and 41.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Harvested	60	5	0.083333	0.111582		
Unharvested	83	30	0.361446	0.599471		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.693607	1	2.693607	6.813757	0.010023	3.908255
Within Groups	55.73996	141	0.395319			
Total	58.43357	142				

It is seen from Table 70 that in case of amur a mean of 1.17 saplings per 62.82 m^2 area of each TSP for sapling regeneration was obtained from harvested compartments and was significantly higher (P = 0.05) than that from the unharvested compartments which had a mean number of 0.69 sapling of amur per TSP. The situation was just the reverse in case of Kankra where significantly higher mean number of sapling of 0.36 was obtained from unharvested compartments as compared to that from harvested compartments of 0.08. The trend of the two major species sundri and gewa are seen from **Tables 72** and **73**.

It is seen from Table 72 that in case of sundri a mean of 2.67 number of saplings were obtained from an area of 62.82 m^2 of each TSP for saplings regeneration from unharvested compartments against 2.17 number of saplings per TSP from harvested compartments. However, the difference between these two mean number of saplings was insignificant as is evident from an F value of 2.68 with 1 and 141 df (vide Table 72).

Similarly, although a higher number of sapling regeneration of gewa from unharvested compartment as compared to harvested compartment was obtained, but the difference was insignificant (vide Table 73).

Table 72: Summary of variance analysis of the data of regeneration of saplings of Sundri obtained from 1996 and 1997 FRMP Forest Inventory of the Sundarbans from 60 Temporary Sample Plots (TSPs) from compartment nos. 32, 36 and 38 harvested in 1990-92 and 83 TSPs from unharvested compartment nos. 16, 31, 35 and 41.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Harvested	60	130	2.166667	3.463277		
Unharvested	83	222	2.674699	3.270937		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8.988261	1	8.988261	2.681926	0.103723	3.908255
Within Groups	472.5502	141	3.35142			
Total	481.5385	142				

Table 73: Summary of variance analysis of the data of regeneration of saplings of Gewa obtained from 1996 and 1997 FRMP Forest Inventory of the Sundarbans from 60 Temporary Sample Plots (TSPs) from compartment nos. 32, 36 and 38 harvested in 1990-92 and 83 TSPs from unharvested compartment nos. 16, 31, 35 and 41.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Harvested	60	82	1.366667	1.693785		
Unharvested	83	125	1.506024	2.521305		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.676322	1	0.676322	0.310947	0.577984	3.908255
Within Groups	306.6803	141	2.175038			
Total	307.3566	142				

To find out the relative dominance of all the nine species from harvested and unharvested compartments further analysis of all the data of sapling regeneration was made. For that the mean number of saplings of each of sundri, gewa, amur, goran, kankra, singra, baen, passur and khalisha from 63 TSPs from harvested compartments (i.e. 32, 36 and 38) and 80 TSPs from the four unharvested compartments (i.e. 16, 31, 35 and 41) were analyzed. This is provided in **Table 74.**

Table 74: Summary of variance analysis of the data of regeneration of saplings of amur, baen, gewa, goran, kankra, khalisha, passur, singra and sundri obtained from 1996 and 1997 FRMP Forest Inventory of the Sundarbans from 60 Temporary Sample Plots (TSPs) from compartment nos. 32, 36 and 38 harvested in 1990-92 and 83 TSPs from unharvested compartment nos. 16, 31, 35 and 41.

SUMMARY						
Groups	No. of TSPs	Sum	Average	Variance		
Amur (Harvested)	59	69	1.169492	1.488019		
Amur (Unharvested)	84	58	0.690476	1.180149		
Baen (Harvested)	59	0	0	0		
Baen (Unharvested)	84	6	0.071429	0.091222		
Gewa (Harvested)	60	82	1.366667	1.693785		
Gewa (Unharvested)	83	125	1.506024	2.521305		
Goran (Harvested)	60	25	0.416667	0.95904		
Goran (Unharvested)	83	66	0.795181	1.945342		
Kankra (Harvested)	60	5	0.083333	0.111582		
Kankra (Unharvested)	83	30	0.361446	0.599471		
Khalisha (Harvested)	60	3	0.05	0.082203		
Khalisha (Unharvested)	83	0	0	0		
Passur (Harvested)	60	3	0.05	0.082203		
Passur (Unharvested)	83	7	0.084337	0.102557		
Singra (Harvested)	60	3	0.05	0.082203		
Singra (Unharvested)	83	7	0.084337	0.078166		
Sundri (Harvested)	60	130	2.166667	3.463277		
Sundri (Unharvested)	83	222	2.674699	3.270937		
ANOVA						

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	823.1721	17	48.42189	48.29743	2.3E-124	1.630823
Within Groups	1272.27	1269	1.002577			
Total	2095.442	1286				

Table 75: Comparison of mean number of saplings amur, baen, gewa, goran, kankra, khalisha, passur, singra and sundri obtained from 1996 and 1997 FRMP Forest Inventory of the Sundarbans from 60 Temporary Sample Plots (TSPs) from compartment nos. 32, 36 and 38 harvested in 1990-92 and 83 TSPs from unharvested compartment nos. 16, 31, 35 and 41.

BH	KhU	KhH	PH	SiH	BU	KH	PU	SiU	KU	GoH	AU	GoU	AH	GH	GU	SH	SU
0	0	0.05	0.05	0.05	0.07	0.08	0.08	0.08	0.36	0.42	0.69	0.80	1.17	1.37	1.51	2.17	2.67
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Notes: BH = Baen from harvested compartments i.e. Baen (Harvested), KhU = Khalisha (Unharvested), KhH = Khalisha (Harvested), PH = Passur (Harvested), SiH = Singra (Harvested), BU = Baen (Unharvested), KH = Kankra (Harvested), PU = Passur (Unharvested), SiU = Singra (Unharvested), KU = Kankra (Unharvested), GoH = Goran (Harvested), AU = Amur (Unharvested), GoU = Goran (Unharvested), AH - Amur (Harvested), GH = Gewa (Harvested), GU = Gewa (Unharvested), SH = Sundri (Harvested), SU = Sundri (Unharvested); Means underscored by the same dotted line are not significantly different.

It is seen from Table 75 that sundri had the highest mean regeneration of 2.67 saplings per Temporary Sample Plot (TSP) in an area of 62.82 m^2 from the unharvested compartments nos. 16, 31, 35 and 41 and mean of 2.17 number of sundri saplings regeneration from harvested compartment nos. 32, 36 and 38. The difference was, however, insignificant. The level of sundri regeneration of saplings both from harvested and unharvested compartments were highly significantly (P= 0.01) higher than the mean number of saplings of all the remaining species such as gewa, amur, goran, kankra, khalisha, singra, passur and baen.

Next to sundri were regeneration of saplings of gewa from unharvested (1.51 nos.) and harvested (1.37 nos.) compartments and amur saplings (1.17 nos.) from harvested compartments, but these three did not differ significantly. However, mean number of saplings of gewa from harvested and unharvested compartments and amur from harvested compartments were significantly (P= 0.05) higher than sapling regeneration of the remaining species (i.e. goran, kankra, singra, passur, khalisha and baen) from both harvested and unharvested compartments.

Saplings of kankra and amur from unharvested compartments and goran from harvested compartments did not differ significantly. Furthermore, mean number of saplings of baen, khalisha, kankra, passur and singra from unharvested compartments and those of goran, khalisha, kankra, passur and singra from harvested compartments did not differ significantly.

5.1.6 : Association of diameter at breast height (dbh) and per cent top dying of sundri trees

In case of plantation age of a particular tree is known from the record of plantation year. But in a natural forest there is no way to know the age of a particular tree. Hence in order to study the relationship between age and top dying of sundri, diameter at breast height (d.b.h.) was considered as an effective indicator for age. Hence data on dbh (in cm) and per cent top dying of individual sundri trees were collected from 1625 trees from sixteen compartments. These data for dbh and per cent top dying of sundri are summarized and present in **Tables 76** and **77** respectively.

Table 76: Calculation of mean, standard error (SE) of mean, t-value, probability level and confidence intervals (at P=0.05) with the data of diameter at breast height (dbh) of 1625 sundri trees recorded from 16 compartments in the Sundarbans.

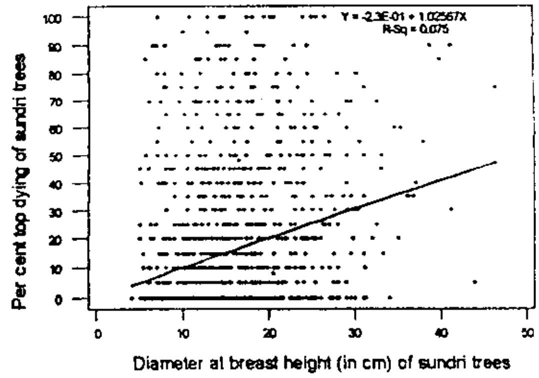
Compartment Number	No. of sundri trees	Mean dbh (in cm)	SE of mean	T- value*	Probability level	Confidence Intervals at P = 0.05
2	292	13.79	0.319	43.19	0.0000	13.159-14.416
5	110	10.22	0.466	21.93	0.0000	09.298-11.146
11	74	14.47	0.409	35.38	0.0000	13.654-15.284
14	115	13.48	0.616	21.90	0.0000	12.260-14.700
19	123	15.26	0.293	52.05	0.0000	14.682-15.843
20	60	15.46	0.448	34.52	0.0000	14.564-16.356
22	53	24.10	0.942	25.59	0.0000	22.213-25.994
26	66	15.74	0.666	23.65	0.0000	14.410-17.069
28	58	17.66	0.448	12.09	0.0000	14.740-20.590
31	61	9.42	0.710	21.04	0.0000	08.523-10.313
33	116	17.73	0.362	24.97	0.0000	16.321-19.134
34	124	11.08	0.389	30.60	0.0000	10.362-11.796
36	182	14.87	0.814	38.20	0.0000	14.102-15.638
37	32	26.24	0.576	32.23	0.0000	24.580-27.901
39	97	13.40	0.585	23.27	0.0000	12.261-14.547
40	62	15.24	1.010	26.04	0.0000	14.073-16.414
Note: * = Test of mu = 0.000 vs mu not = 0.000						

Table 77: Calculation of mean, standard error (SE) of mean, t-value, probability level and confidence intervals (at P=0.05) with the data of per cent top dying of 1625 sundri trees recorded from 16 compartments in the Sundarbans.

Compartment Number	No. of sundri trees	Mean % top dying	SE of mean	T-value*	Probability level	Confidence Intervals at P = 0.05
2	292	8.07	1.010	7.96	0.0000	06.07-10.06
5	110	2.18	0.531	4.11	0.0001	01.13-3.234
11	74	8.72	1.510	5.76	0.0000	05.70-11.73
14	115	8.22	1.810	4.53	0.0000	04.63-11.81
19	123	16.26	2.150	7.57	0.0000	12.01-20.51
20	60	6.33	1.600	3.96	0.0002	03.14-09.53
22	53	28.49	3.600	7.91	0.0000	21.26-35.72
26	66	12.42	2.560	4.85	0.0000	07.31-17.54
28	58	24.48	3.930	6.23	0.0000	16.61-32.35
31	61	38.85	4.120	9.43	0.0000	30.61-47.10
33	116	37.03	3.310	11.19	0.0000	30.47-43.58
34	124	4.64	1.140	4.07	0.0001	02.38-06.89
36	182	17.19	1.590	10.80	0.0000	14.05-20.33
37	32	42.34	4.660	9.10	0.0000	32.85-51.84
39	97	12.58	2.070	6.08	0.0000	08.47-16.68
40	62	11.05	2.800	3.95	0.0002	05.45-16.65
Note: * = Test of mu = 0.000 vs mu not = 0.000						

Correlation Coefficient (r) between the dbh data and per cent top dying data of 1625 sundri trees were calculated by using a programme of the Minitab and it was found to be r = 0.275, with 1624 degrees of freedom. This is significant at P= 0.01. That means there is a highly significant correlation between dbh and per cent top dying of sundri. Hence to determine the trend of this association a linear regression equation was developed and the line of best fit was drawn by using a programme of the Minitab and is provided in **Fig. 19**. It is seen from Fig 19 that there is a clear positive linear relationship between dbh and per cent top dying. That is as the dbh increases per cent top dying also increases. The regression equation is Y= -2.3E-01 + 1.02567 X, where per cent top dying is in the Y-axis and dbh (in cm) in the X-axis.

Fig. 19: Relationship between diameter at breast height (dbh) in cm and per cent top dying of 1625 sundri trees recorded from 16 compartments in the Sundarbans.



5.1.7: Association of forest types and canopy closures with per cent top dying of sundri trees based on data of Temporary Sample Plots

Out 1190 TSPs laid down during 1996-1997 in the Sundarbans sundri trees were present in 830 TSPs out of which top dying of sundri were found to occur in 200 TSPs in 41 compartments. In each TSP top dying sundri trees were expressed as per cent of total sundri of that particular TSP. From the TSP data information on forest types and canopy closure per cent of these 200 TSPs were also be retrieved. In all data were available about ten forest types and three canopy closure types which are as follows:

a) Forest types :

1. Sundri
2. Sundri Gewa
3. Sundri others
4. Gewa/Gewa Mathal
5. Gewa Goran
6. Gewa Sundri
7. Goran
8. Goran Gewa
9. Passur Kankra/Passur Kankra Baen/Baen
10. Keora

b) Canopy closure types:

1. > = 70% (i.e. greater than or equal to 70%)
2. < 70% >=30% (i.e. less than 70% but greater than or equal to 30%)
3. < 30% >=10% (i.e. less than 30% but greater than or equal to 10%)

In order to determine whether there existed any association between a) the forest types of these 200 TSPs and per cent top dying of sundri , and b) canopy closure of the 200 TSPs and per cent top dying of sundri correlation coefficients were determined by using a programme in Microsoft Excel 1997. The correlation coefficient $r = -0.06881$ and 0.344616, both with 199 degrees of freedom, were obtained in case of forest types and canopy closure respectively. This shows that in case of forest types and per cent top dying of sundri there is only insignificant association. The data on top dying of sundri in the ten forest types are summarized in **Table 78.**

Table 78: Summary of data of the Temporary Sample Plots (TSPs) in the ten forest types in which sundri top dying were observed in the Sundarbans.

	Forest type	No. of TSP	No. of TSP showing top dying of sundri	Per cent of TSPs showing top dying	Total sundri trees	No. of sundri trees showing top dying	Per cent of sundri trees showing top dying
1	Sundri	219	75	34.25	8303	877	10.56
2	Sundri Gewa	281	81	28.82	7515	832	11.07
3	Sundri Others	25	5	20.00	486	64	13.16
4	Gewa/Gewa Mathal	29	6	20.69	553	44	7.96
5	Gewa Goran	27	2	7.41	177	17	9.60
6	Gewa Sundri	143	31	21.68	3926	346	8.81
7	Goran	2	0	0	3	0	0

8	Goran Gewa	22	0	0	88	0	0
9	Passur Kankra/Passur Kankra Baen/Baen	5	0	0	32	0	0
10	Keora	4	0	0	38	0	0
		724	200		21121	2180	10.32

The mean per cent top dying in the ten forest types was 10.32 per cent of sundri trees (Table 78). The mean per cent sundri top dying as observed in the six forest types did not show any significant variation as is indicated by an insignificant F value of 0.374295 with 199 degrees of freedom from analysis of variance (vide **Table 79**). This is also very clearly evident from Fig. 20.

Table 79: Summary of analysis of variance of the data on man per cent top dying of sundri in 200 TSPs of ten forest types in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Sundri	75	792.31	10.56413	119.6886		
Sundri Gewa	81	896.88	11.07259	100.1686		
Sundri others	5	65.18	13.036	140.7479		
Gewa/Gewa Mathal	6	47.54	7.923333	35.75323		
Gewa Goran	2	19.17	9.585	16.99445		
Gewa sundri	31	273.475	8.821774	60.91222		
Goran	0	0				
Goran-Gewa	0	0				
Passur Kankra/Passur Kankra Baen/Baen	0	0				
Keora	0	0				
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	187.693	9	20.85	0.20	0.865909	2.260649
Within Groups	19456.56	190	102.40			
Total	19644.26	199				

Analysis of variance of the data on per cent top dying in 200 TSPs having three canopy closure types have been carried out and provided in **Table 80**. which shows that per cent sundri top dying in the three canopy closure types varied highly significantly (P= 0.001) as is evident from an F value of 14.57 with 199 and 2 df. This reveals that there is highly significant difference in the mean per cent of top dying in the three-canopy closure types 1, 2 and 3 (**Table 80**). Further analysis of these three mean values of per cent top dying of sundri by using Duncan's multiple range test (Duncan, 1955) as provided in **Table 81**.

Table 80: Summary of analysis of variance of per cent top dying of sundri data of 202 Temporary Sample Plots (TSPs) falling in canopy closure types 1, 2 and 3 in 41 compartments in the Sundarbans.

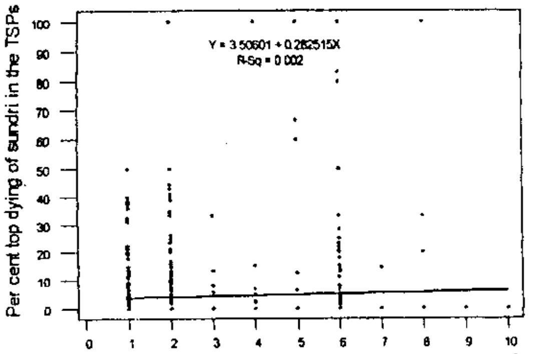
SUMMARY						
Groups	Count	Sum	Average	Variance		
Canopy closure type 1	131	1024.38	7.819695	54.44591		
Canopy closure type 2	65	983.495	15.13069	135.6334		
Canopy closure type 3	6	96.32	16.05333	288.2457		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2518.563	2	1259.282	14.56982	1.24E-06	3.041286
Within Groups	17199.73	199	86.43081			
Total	19718.29	201				

Table 81: Comparison of the mean per cent top dying of sundri in canopy closure types 1, 2 and 3 in 202 Temporary Sample Plots (TSPs) in 41 compartments in the Sundarbans.

Canopy closure type 1	Canopy closure type 2	Canopy closure type 3
7.82	15.13	16.05
	------------------------------------	------------------------------------
Note: Means under scored the same dotted line are not significantly different, but both these means are highly significantly higher (P = 0.001) than that of canopy closure type 1.		

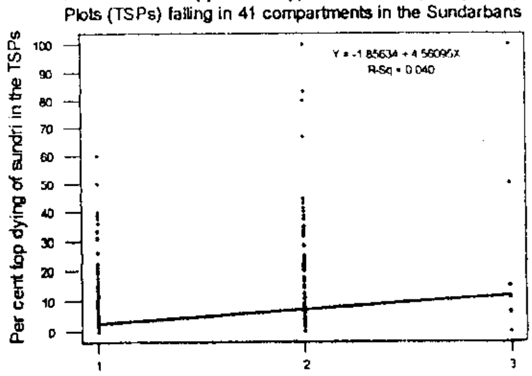
Table 81 reveals that per cent top dying of sundri was the highest (16.08%) in case of canopy closure type 3 (i.e. canopy closure of equal to or greater than 10% but less than 30% in the TSPs), which was followed by 15.13% in canopy closure type 2 (i.e. canopy closure of equal to or greater than 30% but less than 70% in the TSPs), while the lowest per cent top dying of sundri (7.82%) was found to occur in canopy closure type 1 (i.e. canopy closure of equal to or greater than 70%). Per cent top dying of sundri in canopy closure types 3 and 2 were highly significantly (P = 0.001) higher than that of canopy closure type 1, but there was only insignificant difference in per cent top dying of sundri in canopy closure types 2 and 3. Besides, there is a highly significant (P = 0.001) association between canopy closure and per cent top dying in 200 TSPs as in shown by a correlation coefficient r = 0.344616 with 199 degrees of freedom. Hence a linear regression analysis followed by drawing the line of best fit of the data of per cent top dying of sundri and per cent canopy closure of 200 TSPs are provided in Fig. 21.

Fig. 20: Pattern of distribution of per cent top dying of sundri in the ten forest types of 780 Temporary Sample Plots (TSPs) falling in 41 compartments in the Sundarbans



Ten forest types of 780 TSPs (1= Sundri, 2=Sundri Gewa, 3 = Sundri others, 4 = Gewa/Gewa Mathal, 6= Gewa Sundri, 7 = Goran, 8 = Goran Gewa, 9 = Passur Kankra/Passur Kankra Baen/Baen, 10 = Keora) in the Sundarbans

Fig. 21: Pattern of distribution of per cent top dying of sundri in the three canopy closure types of 780 Temporary Sample Plots (TSPs) falling in 41 compartments in the Sundarbans



Three canopy closures (1 = equal to or above 70%, 2 = equal to or more than 30% but less than 70%, 3 = equal to more than 10% but less than 30%) in the TSPs having sundri trees

The finding that significantly higher per cent of top dying of sundri is present in forest areas having canopy closures of equal to or greater than 10 per cent but less than 70 per cent (i.e. canopy closure types 2 and 3) clearly suggests that an open canopy is more prune to greater top dying development. This evidently suggests that creation of too open a canopy artificially may lead to greater development of top dying of sundri in the Sundarbans. This finding has an important bearing in the management of top dying of sundri in the Sundarbans.

5.2 Pathological Aspects

5.2.1 Stages of development of symptoms of top dying of sundri

A general view of healthy sundri stand in Sundarbans is very unique (Fig. 22). Sundri top dying affected areas provides a very unsightly and gloomy picture of such a beautiful forest (Fig. 23). In some of cases of extreme top dying the situation is simply alarming indeed. There most of the sundri trees are seen to be leafless and with truncated main stems and major branches (Fig. 24). The early stages of the development of top dying condition is seen as yellowing of leaves on some of the twigs as has been observed in June 2002 (Fig. 25). As the yellowing continues the affected leaves finally fall-off the twigs. Such twigs then continue to dry out and die. Examination of dying twigs and small branches by cutting through the dying portion reveal the presence of clear transition of progressive invasion (Fig. 26). This very clearly suggests that certain causal organism is responsible for such progressive death of tissues. Besides, dying small twigs have been seen to be eaten up by insects at places which injuries the tender bark (Fig. 27). But no insect have been found in situ .Careful observation of sundri trees in top dying areas reveal the presence of leafless bare and dead twigs (Fig. 28). With the passage of time, death of twigs is further followed by death of the corresponding branches, which bear such twigs. Death of such twigs and branches gradually reduces the photosynthetic potentials of such affected trees when such trees became progressively bare (Fig. 29). Progressive death of the major branches are followed by the breakage of such dead twigs and branches (Fig. 30) and when this phenomenon continues the main stem is also affected by top dying and became truncated because of wood decay and strong wind/ storms actions (Fig. 31). Quite often top dying affected sundri are further infested by different epiphytes including lichens. With the death of the main stem and major branches top dying affected sundri trees are seen to have only small proportion of green leaves and in some situation most part of the main stem become progressively dead and bare (Figs. 32 and 33). In some situations where enhanced siltation and burial of most part of the pneumatophores are seen to occur, the leaves on the remaining crown became light bronze colored as compared to the normal green colour of sundri leaves on the healthy trees (Fig. 34). At times, loranthus (*Dendrophthoe falcata*) infestation is seen to kill and replace sundri branches (Fig. 35). Dead tops of top dying affected sundri when observed carefully reveal wood pickers hole, insect tunnels, white rotted wood (Figs. 36).

Fig. 22. A general view of the Sundarbans showing dominantly sundri (*Heritiera fomes*) trees

Fig. 23. A general view of the Sundarbans showing many top dying affected sundri trees.

Fig. 24. A general view of the Sundarbans showing a badly affected top dying site of sundri.

Fig.25.A top dying affected sundri tree showing early yellowing of leaves in twigs in June 2002

Fig.26: One healthy (left) and two dying twigs of sundri cut through transition zone showing advancing invasion zone by certain pathogen.

Fig.27: A portion of sundri twig showing damage by insect eating up of tender bark at a number of places.

Fig. 28. Two top dying affected sundri trees showing early yellowing and death of twigs in the crown.

Fig. 29. Two top dying affected sundri trees showing progressively more death of twigs and branches.

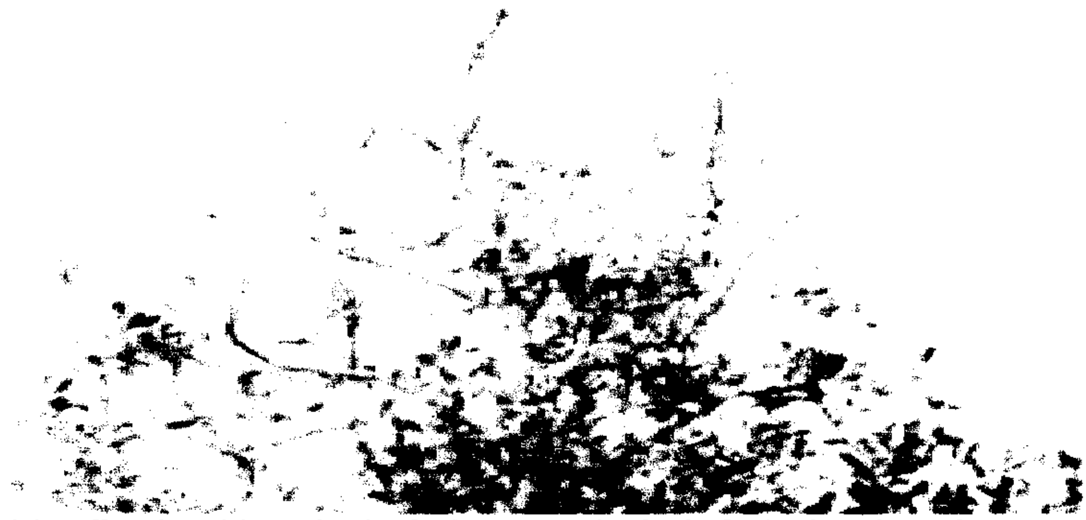


Fig. 30. A top dying affected sundri tree showing further progressive death of twigs, branches and stems,

Fig. 31:A top dying affected sundri tree showing dead top and very reduced crown.

Fig. 32:A top dying affected sundri tree showing death of most of the main branches which have been truncated.

Fig.33:A number of top dying affected sundri trees showing dead truncated tops and almost bare main stem of two trees.

Fig. 34. A top dying affected sundri tree in a heavily silted up site showing bronze coloured leaves in the remaining crown.

Fig. 35. A sundri tree showing loranthus (*Dendrophthoe falcata*) infestation on the crown.

Fig. 36. Dead tops of top dying sundri trees showing fungal decay and insect damage on the main stem.

5.2.2 Occurrence sapwood rot, heart rot and insect damage in top dying sundri

Occurrences sapwood rot, heart rot and insect damage in top dying sundri wood were studied from 24 top dying affected sundri logs collected in January 2002 from compartment nos. 11, 19, 20, 33 and 36 in the Sundarbans. This included dying and some healthy portions of the top portion of the stem individual sundri tree. The collected samples were sawn longitudinally into 5 to 20 sub-samples depending on the size of the sample. Then each of the sub-samples was observed for the area of heart wood, length, width and depth of the wood (heartwood and sapwood), and area of heart wood affected by decay, conditions of the sap wood and the area of the affected sapwood were determined. Presence of insect damage as evident by tunnel, if any, was also recorded. These data of a total of 24 logs and 199 sub-samples have been provided in **Appendix 27** and summarized in **Table 82.**

Table 82: Summarized data on the occurrence of sap wood rot, heart wood rot and insect damage (i.e. tunnels) in 24 top dying affected sundri top logs collected from compartment nos. 11, 19, 20, 33 and 36 in January 2002 from the Sundarbans.

Log Number	No. of sub-samples examined	No. of sub-sample showing heart rot	Per cent of sub-samples showing heart wood rot	Volume of heart wood (in cm^3)	Volume of affected heart wood (in cm^3)	Per cent of heart wood affected	No. of sub-sample showing sapwood rot	Per cent of sub-samples showing sap wood rot	Volume sap wood affected	No. of sub-samples showing dead bark	No. of sub-samples showing insect damage	Per cent of sub-samples showing insect damage (i.e. tunnel)
1	6	3	50.00	1144.22	21.57	2.15	0	0	177.55	3	3	50.00
2	8	6	75.00	581.78	93.9	15.61	0	0	0.31	3	3	37.50
3	6	1	16.67	863	57.73	8.88	2	33.33	88.93	0	3	50.00
4	5	1	20.00	863	57.73	8.88	4	80.00	88.93	4	5	100.00
5	10	2	20.00	680.1	23.82	2.43	10	100.00	190.93	6	10	100.00
6	8	1	12.50	681.33	1.06	0.15	7	87.50	183.81	0	6	75.00
7	8	1	12.50	845.59	2.34	0	2	25.00	0	0	1	12.50
8	10	3	30.00	962.88	5.47	0.58	0	0.00	0	0	4	40.00
9	10	6	60.00	342.48	37.48	11.07	6	60.00	10.69	0	6	60.00
10	8	1	12.50	283.34	2.25	0.58	4	50.00	41.17	1	4	50.00
11	8	7	87.50	584.69	110.66	22.3	0	0.00	6.83	0	6	75.00
12	5	1	20.00	640.24	3.6	0.72	0	0.00	0	0	0	0.00
13	7	4	57.14	366.14	20.44	4.97	1	14.29	0.1	0	5	71.43
14	6	3	50.00	529.96	29.98	6.7	6	100.00	11.76	5	6	100.00
15	7	4	57.14	1376.16	119.82	14.93	1	14.29	33.25	1	7	100.00
16	7	3	42.86	346.94	51.24	13.89	4	57.14	53.53	3	7	100.00
17	8	3	37.50	313.48	2.45	0.66	4	50.00	3.3	0	4	50.00
18	5	4	80.00	836.33	44.1	4.69	3	60.00	3.21	0	4	80.00
19	6	5	83.33	528.33	115.29	28.49	2	33.33	34.15	0	4	66.67
20	20	14	70.00	579.56	55.48	11.42	9	45.00	0	0	6	30.00
21	10	1	10.00	542.51	3.38	0.68	9	90.00	207.27	0	9	90.00
22	11	2	18.18	461.39	18.2	3.18	6	54.55	208.79	0	11	100.00
23	9	5	55.56	584.81	33.92	5.2	7	77.78	137	0	9	100.00
24	11	0	0	380.52	0		0	0.00	0	0	0	0.00

Analysis of variance of the data of per cent sub-samples affected by heart rot, sapwood rot and insect as have been provided in **Table 83,** while ANOVA of the volume of wood affected by heart rot and sapwood rot has been provided in **Table 84**. **Table 83** shows a significant variance of 4.014 (with 69 and 2 df). A further comparison of the mean per cent data reveal that 64.09 per cent of the sub-samples were found to be attacked by insect which was significantly higher (P =0.05) than those of mean per sub-samples affected by heart rot (40.77 %) and sapwood rot (43.01%), there being no significant variation between the latter two values.

Analysis of variance of the data of volume of wood affected by heart rot and sapwood rot in the sub-samples shows an insignificant F value of 3.21 (with 43 and 1 df) which suggests that there was only insignificant variation in the volume of wood affected by these two types of damage (vide **Table 83**).

Table 83: Summary of variance analysis of per cent sub-sample showing heart wood rot, sap wood rot and insect damage of the data of 24 top dying affected sundri logs collected in January 2002 from the Sundarbans.

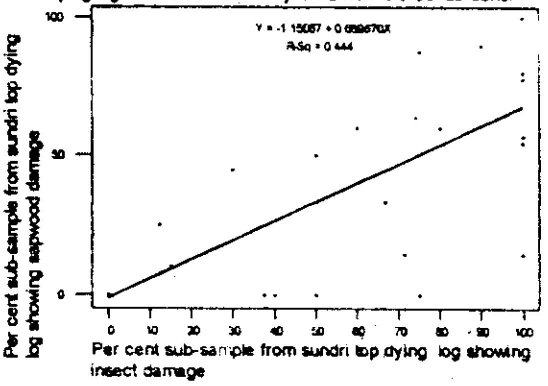
SUMMARY						
Groups	Count	Sum	Average	Variance		
% sub-samples affected by heart rot	24	978.38	40.77	712.08		
% sub-samples affected by sapwood rot	24	1032.21	43.01	1197.08		
% sub-samples affected by insect	24	1538.1	64.09	1060.29		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7945.96	2	3972.98	4.014	0.022	3.130
Within Groups	68297.4	69	989.82			
Total	76243.3	71				

Table 84: Summary of variance analysis of the data on volume of rot affected heart wood and sap wood in the 24 top dying affected sundri logs collected in January 2002 from the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Volume of affected heart wood	24	911.91	37.99625	1464.52		
Volume of affected sapwood	21	1481.51	70.5481	6276.981		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11867.77	1	11867.77	3.205017	0.080455	4.06704
Within Groups	159223.6	43	3702.874			
Total	171091.4	44				

In the next stage relationship between the per cent of sub-samples from sundri top dying affected stem segments having sapwood rot and per cent of sub-samples having insect damage was determined by the way of calculating the Correlation Coefficient r (Pearson) which was found to be 0.651 with 23 df. This is highly significant at P = 0.001. Per cent sub-samples having heart rot and per cent of sub-samples having insect damage showed an insignificant. Correlation Coefficient r (Pearson) of 0.191 with 23 df. This suggested a strong correlation between sapwood rot and insect damage in top dying affected sundri trees. Hence a Regression analysis of the data of per cent sub-samples having sapwood rot and per cent sub-samples having insect damage was carried out and the results are provided in Fig. 37. This shows that there exists a strong association between sapwood rot and insect damage. The regression equation being Y = 1.29619 +0.691304X, with R Sq. = 0.423, where sapwood rot is on the Y-axis and insect damage is on the X-axis of the Fig. Therefore, it is suggested that once top dying has affected /set death of main stem of sundri sapwood damage increases insect damage and vice versa. But which of these two commences first is not yet convincingly clear but since insect damage occurs in the form of tunnels in deeper wood tissues, while sapwood rot occurs in the sap wood which is in the outer zone it is suggested that sapwood rot occurs first and followed by entry of insect. There is a need to clarify this further.

Fig. 37: Relationship between the occurrence of sapwood decay in sundri log affected by top dying and the presence of insect damage based on data of 199 sundri sub-samples from 24 top dying logs collected in January 2002 from the Sundarbens.



5.2.3 Isolation of fungi from healthy and dying stems, branches and twigs of sundri collected in July 2001

During July 2001 top dying affected sundri specimens of dying and healthy main stems, branches and twigs were collected from compartment nos. 14, 28, 33, 34 and 39. In all from all these compartments specimens were collected from 21 dying and 23 healthy stem piece.. 11 dying branches and 16 healthy branches, and 11 dying twigs and 11 healthy twigs. These were brought to the laboratory and isolations were made from top dying affected and healthy sapwood tissues. Isolations were made in 2% Malt Agar medium following usual phytopathological methods (Booth, 1971; Rahman, 2002). Isolation included plating of 1065 small inocula pieces (each about 1 mm^3) which consisted of 535 pieces taken from top dying affected sapwood and another 530 pieces from healthy sapwood from stems, branches and twigs. The results is isolation have been summarized in **Table 85**.

Table 85: Summarized results of isolation of fungal isolates from sapwood tissues of dying and healthy stems, branches and twigs of sundri collected from compartment nos. 14, 19, 20, 36 and 37 in the Sundarbans.

Source of inocula	Sample Number	No. of inocula plated	No of inocula yielding fungi	Per cent of inocula yielding fungal isolate no. T60	Per cent of inocula yielding fungal isolate no. T61	Per cent of inocula yielding fungal isolate no. T62	Per cent of inocula yielding fungal isolate no. T63	Per cent of inocula yielding fungal isolate no. T64	Per cent of inocula yielding fungal isolate no. T65	Per cent of inocula yielding fungal isolate no. T66	Per cent of inocula yielding fungal isolate no. T67	Per cent of inocula yielding fungal isolate no. T68	Per cent of inocula yielding fungal isolate no. T69	Per cent of inocula yielding fungal isolate no. T70
Dying stem	21	275	179	56.75	5.79	0.00	0.00	0.00	0.00	1.43	0.00	0.00	0.48	0.00
Healthy stem	23	255	38	3.77	1.16	4.35	0	0	0	2.03	0	0	0	0.87
Dying branch	11	145	88	23.49	9.24	4.55	9.09	6.36	0	0.61	6.06	2.73	0	0
Healthy branch	16	160	49	3.75	0.63	20.00	2.50	1.88	0	12.5	0	0	0	0.63
Dying twig	11	115	48	22.73	4.85	1.21	0	3.64	0	0	0	7.27	0	0
Healthy twig	11	115	9	[illegible].91	0.00	4.55	0	0	0.91	0.91	0	0.61	0	0

In the analysis of variance an attempt has been made to compare the variability of per cent isolation of 11 fungal isolates (T60, T61, T62, T63, T64, T65, T66, T67, T68, T69, T70 obtained from top dying affected sapwood tissues from stem, branches and twigs and also those obtained from healthy sapwood tissues from stems, branches and twigs. The results of analysis of variance with the per cent isolation data of 11 fungal isolates reveal that only insignificant F values in cases of all ten fungal isolates T61, T62, T63, T64, T65, T66, T67, T68, T69 and T70. This very clearly suggests that there were no significant variations in the per cent isolation of each of these 10 fungal isolates from the six types of sundri sapwood tissues which included dying stems, healthy stems, dying branches , healthy branch, dying twigs and healthy twigs. In case of isolate T60 highly significant ($P= 0.001$) F-value of 12.66 (with 87 and 5 df) clearly reveals that there occurred significant difference in the per cent isolation of fungal isolate T60 from the above mentioned six types of sap wood tissues of sundri. Therefore, further analysis of the data of isolation of only isolate T60 from the six types of sapwood tissues (dying stems, healthy stems, dying branch, healthy branches, dying twigs and healthy twigs) was done using a programme of Microsoft Excel 1997. The result of this analysis of variance is provided in **Table 86.**

Table 86: Summary of analysis of variance of the per cent isolation data of fungal isolate T60 from dying and healthy sapwood tissues of stems, branches and twigs of sundri collected from the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Top dying stem	21	1191.67	56.74619	1723.427		
Healthy stem	23	86.67	3.768261	205.377		
Top dying branch	11	258.34	23.48545	1304.715		
Healthy branch	16	60	3.75	158.3333		
Top dying twig	11	250	22.72727	441.8182		
Healthy twig	11	10	0.909091	9.090909		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	42865.15	5	8573.03	12.65917	3.03E-09	2.319275
Within Groups	58918.06	87	677.2191			
Total	101783.2	92				

A further comparison of the mean per cent isolate of isolate T60 from sap wood tissues of the six types of samples were carried out (**Table 87**) by Duncan's Multiple Range Test (Duncan, 1955).

Table 87: Comparison of the mean per cent isolation of fungal isolate T60 from healthy and dying sapwood from stems, branches and twigs of sundri from the Sundarbans.

Healthy twig	Healthy branch	Healthy stem	Top dying twig	Top dying branch	Top dying stem
0.91	3.75	3.77	22.73	23.49	56.75
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Note: Means under scored by the same dotted line are not significantly different.

Table 87 reveals that isolations of isolate T60 from the three types of healthy sapwood tissues were very small (0.91% to 3.77%) as compared to 22.73 % lowest isolation of isolate T60 from dying twig, 23.49 % from dying branch and 56.75% from dying stem tissues. Isolation of isolate T60 from even at the lowest level was significantly (P =0.05) higher than those from healthy twig, branch and stem of sundri. A higher recovery of isolate T60 from dying stem is probably because of the large size of the stem wood for which the affected wood tissues were not exhausted, but in case of small wood of twigs and branches may be easily decayed by the fungus and then the fungus may die because of starvation. In all healthy sapwood tissues yielded only 3.13% of isolate T60 as against 39.54 % from dying sapwood tissues. This very strongly suggests that isolate T60 is associated with the death of sapwood of sundri.

5.2.4: Isolation of fungi from top dying sundri stem wood collected in January 2002

Isolation of fungi was carried out from 12 top dying affected sundri logs collected from compartment nos. 11, 19, 20, 33 and 36 in January 2002 from the Sundarbans. Each log included dying and partly healthy portion of the main stem. In the laboratory each log was sawn longitudinally into a number sub-samples. Then 3-5 sub-samples were selected from each of the 12 logs for isolation of fungi. Then from each sub-sample a number of small sections were selected for isolation on 2% Malt Agar medium. The details of the method of isolation have been described in Rahman *et al.* (2001). Each of the selected sections were first surface sterilized and then cut into small inocula pieces aseptically and plated onto 2% Malt Agar medium, incubated in an Incubator at 25 ± 2 ^{0}C . After 5 days of incubation the plates were observed for any fungal colony from the incubated inocula pieces. Observations were repeated upto 15 days of incubation . Same type of fungal colony was given the same isolate number. Thus primarily five fungal isolates (F1, F2, F3, F5 and F6) were obtained from the incubation of the plates. A number of other fungi were also obtained in very small proportions of samples. These have been lumped as 'others' for the purpose of comparison. The results of isolation of fungi from the 12 top dying sundri logs samples collected in January 2002 are provided in **Appendix 28.** The data have been summarized in **Tables 88** and **89.** Analysis of variance of the per cent isolation data (vide Table 70) is provided in **Table 90 .**

Table 88: Summary of isolation of fungi on 2% Malt Agar medium from top dying affected 12 sundri stem collected in January 2002 from the Sundarbans

Log No.	No. of sample	No. of inocula plated	Colour of wood from which inocula were taken	No. of inocula yielding fungus	Per cent inocula yielding fungus	Per cent yield of fungal isolate numbers					
						F1	F2	F3	F5	F6	Others
1	5	60	A, B, RB, W	59	98.33	35.16	19.17	30.00	15.00	0	0
2	5	90	A, B, W	49	54.44	24.44	11.11	12.22	6.67	0	0
3	5	90	A, B, RB, W	48	53.33	33.33	3.33	11.11	5.56	0	0
4	5	90	B, RB, W	61	67.78	31.01	22.33	10.00	0	0	4.44
5	5	60	A, B, RB, W	37	61.67	50.00	0	0	0	11.67	0
6	5	60	A, B, RB, W	33	55.00	18.75	0	16.67	9.58	0	10.00
7	5	60	RB, W	35	58.33	39.16	4.17	6.67	0	8.33	0
8	5	60	A, RB, W	40	66.67	25.01	33.33	8.33	0	0	0
9	3	30	A, RB, W	10	33.33	0	0	33.33	0	0	0
10	3	30	A, RB, W	26	86.67	67.67	8.33	6.67	0	4.00	0
11	3	30	A, RB	15	50.00	0	33.33	6.67	10.00	0	0
12	3	30	RB	13	43.33	33.33	10.00	0	0	0	0

Notes: A = Ash, B = Brick, RB = Rosy Buff, W = Whitish

Table 89: Summary of isolation of fungi on 2% Malt Agar medium from top dying affected 12 sundri stem collected in January 2002 from the Sundarbans arranged according to colour of inocula.

Colour of inocula	No. of log sample	Total No. of inocula plated	No. of inocula yielded fungi	Percent inocula yielding fungi	Per cent isolation of fungal isolates				
					F1	F2	F3	F5	F6
Ash	7	80	57	68.75	12.5	3.75	22.50	30.00	0
Brick	7	180	91	50.56	6.25	14.36	22.22	0	7.73
Rosy Buff	12	230	146	63.48	37.18	20.22	3.91	2.17	0
Whitish	10	200	142	71.00	35.00	20.00	10.00	0	6.00

Table 90: Summary of analysis of variance of the per cent isolation data from 12 top dying affected sundri logs collected from the Sundarbans in January 2001.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Fungus F1	12	357.86	29.82167	357.7048		
Fungus F2	12	145.1	12.09167	150.4267		
Fungus F3	12	141.67	11.80583	108.351		
Fungus F5	12	46.81	3.900833	28.14372		
Fungus F6	12	24	2	15.7798		
Fungus others	12	14.44	1.203333	9.303406		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	6948.033	5	1389.607	12.44964	1.61E-08	2.353808
Within Groups	7366.804	66	111.6182			
Total	14314.84	71				

Table 90 reveals that a highly significant (P= 0.001) F value of 12.45 with 66 and 5 df which indicates a significant variation in the mean per cent isolation of six types of fungi from wood samples having four coloured inocula viz. ash, brick, rosy buff and whitish. Further analysis of the mean per cent isolation of six types of fungal isolates by DMRT (Duncan, 1955) reveals that F1 isolate was obtained at the highest level of 29.82 per cent which was highly significantly higher (P = 0.001) than all the remaining isolates. The second dominant isolate F2 was obtained at 12.09 per cent of inocula, which did not differ significantly from isolate F3 obtained from 11.81 per cent of inocula. Recovery of the remaining isolates (F5, F6 and others) was at a very low level.

Classification of the sundri inocula pieces by colour (viz. ash, brick, rosy buff and whitish) and summarizing the isolation data were carried out and provided in Table 90. It is seen from Table 90 that the most dominant isolation of isolate F1 comes from rosy buff and whitish coloured inocula, while ash and brick coloured inocula yielded only a small proportion of isolate F1. Variance analysis of the data of isolation of fungi from four coloured inocula reveals that 37.18 and 35.00 per cent of isolation of isolate F1 was obtained from rosy buff and whitish coloured inocula pieces, while ash and brick coloured inocula yielded 12.5 and 6.25 per cent of isolate F1. But ash coloured inocula yielded 22.50 per cent of isolate F3 and 30.00 per cent of isolate F5. However, in the overall considerations yield of F5 was only 3.90 per cent and that of F3 was only 11.80 per cent, F2 12.09 per cent, F6 only 2.00 per cent and other isolates 1.20 per cent, as compared to 29.82 per cent F1. Hence F2, F3, F5, F6 and other isolates are not considered to be of any real significance, but F1 fungus is considered to be very probable fungus responsible for rot of sapwood of sundri.

5.2.5 Isolation of fungi from twigs of top dying sundri collected in June 2002

During fieldwork for the third time in June 2002 early dying symptoms of twigs of sundri were observed in Compartment 26. Hence such dying and healthy twigs were collected from the field. Then in the laboratory the dying shoots were examined carefully. Cutting through freshly collected dying twigs revealed the presence of progressive fungal invasion as was evident by the presence of transition zone characteristic of fungal invasion (Fig. 26). It was found that the bark of the twigs was eaten up in patches by certain insects (Fig. 27). No presence of insect was found, but there was no doubt the damage was caused by insect because of the characteristic nature of the damage. Then from the bark and wood tissues of such dying twigs and also from healthy twigs fungi and bacteria were isolated following standard method. The details of isolation data is provided in **Appendix 29.** The isolation data have been processed and summarized in **Table 91**.

Table 91: Summarized data of isolation fungi and bacteria from bark and wood of top dying and healthy sundri twigs collected from compartment 26 in June 2002 from the Sundarbans.

Source of inocula	No. of inocula plated	No. of inocula yielding fungal isolates	No. of inocula yielding bacteria	Mean per cent isolation of bacteria	Mean per cent isolation of fungal isolate A	Mean per cent isolation of fungal isolate B	Mean per cent isolation of fungal isolate C	Mean per cent isolation of fungal isolate D	Mean per cent isolation of fungal isolate others
Dying bark	228	180	53	24.00	51.07	2.80	1.20	22.06	0.80
Dying wood	210	180	30	18.19	50.14	2.92	0.56	18.75	8.19
Healthy bark	100	6	74	74.00	0	0	0	0	0
Healthy wood	110	4	96	78.18	0	0	0	0	0

Analysis of variance was carried out with the data of per cent isolation of bacteria (all types), fungal isolates A, B, C, D and isolate others from bark and wood of top dying affected and healthy sundri twigs were carried out. The results of analysis of variance showed that in case of isolation from bark and wood of top dying and healthy sundri twigs significant variance have been obtained in case of isolation of bacteria (all types), fungal isolate A and isolates others as are seen from F values of 13.42 (with 65 and 3 df) in case of bacteria which is significant at P = 0.001, F value of 9.19 (with 65 and 3 df) in case of isolate A being significant at P = 0.001, and F value of 3.10 (with 64 and 3 df) in case of isolate others being significant at P = 0.05. In case of isolation of fungal isolates B, C and D only insignificant difference occur from isolation of bark and wood of dying and healthy sundri twigs. Hence no further analysis of the data of isolation in case of these three isolates (B, C and D) were carried out. It is very evident that these three isolates have no role in the development of twig dieback or mortality of sundri.

Significant F values in case of per cent isolation of bacteria, isolate A and isolate Others indicate that there is significant variation among the per cent isolate of each of these three from dying bark,, dying wood, healthy bark and healthy wood of sundri twigs used for isolation of bacteria and fungi. To locate precisely the reason for significant F values in case of per cent isolation of bacteria, isolate A and isolate others further variance analysis of the data of per cent isolation of these three were carried out by using a programme of Microsoft Excel 1997. The results of these analysis are provided in **Tables 92, 93** and **94** respectively. Furthermore, a comparison of per cent isolation of bacteria, isolate A and isolate others from all the four types of tissues (i.e. dying bark, dying wood, healthy bark and healthy wood) were carried out and is provided in **Table 95**.

Table 92: Analysis of variance of the data of isolation bacteria (all types) isolated from bark and wood of top dying affected and healthy sundri twigs collected from compartment 26 in the Sundarbans in June 2002. .

SUMMARY						
Groups	Count	Sum	Average	Variance		
Dying bark	25	600	24	785.1982		
Dying wood	24	436.67	18.19458	908.193		
Healthy bark	10	740	74	1071.111		
Healthy wood	11	860	78.18182	1056.364		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	45026.7	3	15008.9	16.52719	4.08E-08	2.743711
Within Groups	59936.83	66	908.1338			
Total	104963.5	69				

Results of analysis of variance of the data of isolation of bacteria from four types of tissues reveal that healthy bark and wood tissues of sundri twigs supported distinctly higher per cent of bacteria as compared to that from dying twig, but there is no significant difference in the isolation of bacteria from bark and wood of either dying twigs and that from healthy twigs (Table 92). This suggests that bacteria isolated from dying twigs is not related or associated with the death of the sundri twigs.

Table 93: Analysis of variance of the data of isolation of fungal isolate A from bark and wood of top dying affected and healthy sundri twigs collected from compartment 26 in the Sundarbans in June 2002.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Dying bark	25	1276.67	51.0668	1658.993		
Dying wood	24	1203.33	50.13875	1954.097		
Healthy bark	10	0	0	0		
Healthy wood	11	0	0	0		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	37666.06	3	12555.35	9.776458	2.02E-05	2.743711
Within Groups	84760.06	66	1284.243			
Total	122426.1	69				

Results of analysis of variance of the data of isolation of fungal isolate A from four types of tissues (i.e. dying bark, dying wood, healthy bark, healthy wood) reveal that top dying bark and wood tissues of sundri twigs supported distinctly a very high per cent of isolate A. Isolate A was not at all isolated from bark and wood of healthy twigs (Table 93). This suggests very convincingly that isolate A is associated with the death of the sundri twigs.

Table 94: Analysis of variance of the data of isolation of fungal isolate others from bark and wood of top dying affected and healthy sundri twigs collected from compartment 26 in the Sundarbans in June 2002.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Dying bark	25	20	0.8	8.590742		
Dying wood	24	196.67	8.194583	282.1147		
Healthy bark	10	80	8	128.8889		
Healthy wood	11	0	0	0		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1010.299	3	336.7663	2.829675	0.045084	2.743711
Within Groups	7854.816	66	119.0124			
Total	8865.115	69				

Results of analysis of variance of the data of isolation of fungal isolate others from four types of tissues reveal that top dying bark and wood tissues of sundri twigs supported a very low per cent of isolate others (Table 94). This very convincingly supports that isolate others are not associated with the death of the sundri twigs.

Table 95 : Analysis of variance of the data of isolation bacteria (all types), fungal isolate A and isolate others from bark and wood of top dying affected and healthy sundri twigs collected from compartment 26 in the Sundarbans in June 2002.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Bacteria	70	2636.67	37.66671	1521.211		
Isolate A	70	2480	35.42857	1774.292		
Isolate others	70	296.67	4.238143	128.4799		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	48890.84	2	24445.42	21.41841	3.51E-09	3.039503
Within Groups	236254.8	207	1141.327			
Total	285145.6	209				

A general comparison of isolation of bacteria (all types) , fungal isolate A and others from the bark of dying twigs and bark of healthy twigs, wood of dying twigs and wood of healthy twigs of sundri collected from compartment 26 in June 2002 has been made as provided in Table 95. This clearly shows that in the per cent isolation of bacteria (37.67%) and isolate A (35.43%) collectively from all the four types of tissues (bark and wood of dying and healthy twigs) there is no significant difference, but both these were highly significantly higher than that of isolate others (4.24%). It may, however, be noted here that high per cent of isolation of bacteria from healthy bark (74.00%) and wood tissues (78.18%) of sundri twigs resulted this overall higher per cent of isolation of bacteria but isolate A was not at all isolated from healthy bark and wood tissues. Therefore, in consideration of dying bark and dying wood tissues of sundri there is the most dominant role of isolate A, but bacteria do not seem to have any role in that respect (vide **Table 92**). So bacterial isolates were not considered for further study.

5.2.6 Data on progressive changes in crown damage of top dying of sundri based on observations in October 2001, January 2002 and January 2003

Data on per cent crown affected, number of main branches affected by top dying of sundri as observed at the time of first laying out of 36 sample plots in the Sundarbans in October 2001 and at the time of second observation in January 2002 were collected for all the sundri trees in the sample plots falling in four top dying severity categories (viz. none, slight, moderate and severe) and provided in **Appendix 30**. Analysis of variance was carried out to compare none (i.e. top dying sample plots), slight, moderate and severe top dying sample plots by using the SAS System programme. The results reveal that highly significant (P=0.0001) F values of 66.03 and 71.98 (each with 704 and 3 degrees of freedom) obtained in case of per cent crown affected in case of none, slight, moderate and severe top dying sample plots at the time of laying out of the sample plots in October 2001 and that during the second observation in January 2002 respectively. These indicate a significant variation in per cent crown affected among the four top dying categories. The extent and source of significant variability in the per cent crown affected among the four types of top dying sundri trees (i.e. none, moderate, slight and severe categories) as observed in October 2001 and January 2002 are further tested and presented in **Tables 96** and **97.**

Table 96: Summary of variance analysis of the data on the per cent crown affected by top dying of 708 sundri trees of 36 sample plots falling in four top dying severity classes (viz. moderate, none, severe and slight) as observed in October 2001 at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Moderate	186	3490	18.76344	500.6248		
None	194	1020	5.257732	171.954		
Severe	122	4300	35.2459	600.7655		
Slight	206	1891	9.17961	290.5762		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	78312.74	3	26104.25	71.05324	2.9E-40	2.617519
Within Groups	258644.6	704	367.39			
Total	336957.3	707				

Table 97 : Summary of variance analysis of the data on the per cent crown affected by top dying of 708 sundri trees of 36 sample plots falling in four top dying severity classes (viz. moderate, none, severe and slight) as observed in January 2002 at 12 landings in 10 compartments in the Sundarbans

SUMMARY						
Groups	Count	Sum	Average	Variance		
Moderate	186	3750	20.16129	609.163		
None	194	1235	6.365979	208.0985		
Severe	122	4468	36.62295	708.4517		
Slight	206	1960	9.514563	273.9553		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	82446.88	3	27482.29	65.39977	1.6E-37	2.617483
Within Groups	295837.5	704	420.22			
Total	378284.4	707				

Table 98 shows the comparison of the ranked mean per cent crown affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) in 10 compartments in the Sundarbans as observed in October 2001.

Table 98: Comparison of the ranked mean per cent crown affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) at 12 landings in 10 compartments in the Sundarbans as observed in October 2001.

None	Slight	Moderate	Severe
5.26	9.09	18.76	35.25
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Notes: Means underscored by the same dotted line are not significantly different. Mean per cent of both moderate and severe are significantly higher (P = 0.05) than mean values from none and slight top dying severity categories.

It is seen from Table 98 that on an average the per cent crown affected were 5.26, 9.18, 18.76 and 35.25 in none, slight, moderate and severe top dying sample plots respectively. There was no significant variation in per cent crown affected in no top dying (i.e. none) and slight top dying sample plots, but mean per cent crown affected in moderate and severe top dying sample plots were highly significantly higher (P = 0.001) than those of none and slight top dying sample plots.

Table 99 shows the comparison of the ranked mean per cent crown affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) in 10 compartments in the Sundarbans as observed in January 2002.

Table 99: Comparison of the ranked mean per cent crown affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) at 12 landings in 10 compartments in the Sundarbans as observed in January 2002.

None	Slight	Moderate	Severe
6.36	9.33	20.16	36.62
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Notes: Means underscored by the same dotted line are not significantly different. Mean per cent of both moderate and severe are significantly higher (P = 0.05) than mean values from none and slight top dying severity categories.

It is seen from Table 99 that on an average the per cent crown affected were 6.36, 9.33, 20.16 and 36.62 in none, slight, moderate and severe top dying sample plots respectively. There was no significant variation in per cent crown affected in no top dying and slight top dying sample plots, but mean per cent crown affected in moderate and severe top dying sample plots were highly significantly higher (P = 0.001) than those of none and slight top dying sample plots.

Highly significant (P=0.0001) F values of 18.29 and 79.90 (each with 704 and 3 degrees of freedom) were obtained in case of number of main branches affected in case of none, slight, moderate and severe top dying sample plots at the time of laying out of the sample plots in October 2001 and that during the second observation in January 2002 respectively. These indicate a significant variation in the number of main branches affected among the four top dying categories. The extent and source of significant variability in the number of main branches affected among the four types of top dying sundri trees (i.e. none, moderate, slight and severe categories) as observed in October 2001 and January 2002 are further tested and presented in **Tables 100 and 101.**

Table 100: Summary of variance analysis of the data on the number of main branches affected by top dying of 708 sundri trees of 36 sample plots falling in four top dying severity classes (viz. moderate, none, severe and slight) as observed in October 2001 at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Moderate	186	87	0.467742	0.434089		
None	194	19	0.097938	0.109529		
Severe	122	166	1.360656	1.670505		
Slight	206	54	0.262135	0.335475		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	133.0449	3	44.3483	83.55086	1.64E-46	2.617483
Within Groups	373.6911	704	0.5308			
Total	506.736	707				

Table 101: Summary of variance analysis of the data on the number of main branches affected by top dying of 708 sundri trees of 36 sample plots falling in four top dying severity classes (viz. moderate, none, severe and slight) as observed in January 2002 at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Moderate	18[illegible]	141	0.758065	1.297908		
None	194	110	0.56701	0.909994		
Severe	122	168	1.377049	1.575667		
Slight	206	129	0.626214	0.833548		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	65535	3	21845	234.69058	0.0001	2.22681
Within Groups	65535	704	93.08			
Total	837.6315	707				

It is seen from **Table 101** that on an average the number of main branches affected were 0.09, 0.25, 0.47 and 1.36 per tree in October 2001 in none, slight, moderate and severe top dying sample plots respectively. There was no significant variation in the number of main branches attacked in no top dying (i.e. none) and slight top dying sample plots, but mean number of main branches affected in moderate and severe top dying sample plots were highly significantly higher (P = 0.001) than those of none and slight top dying sample plots.

Table 102: Comparison of the ranked mean number of main branches affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) in 12 compartments in the Sundarbans as observed in October 2001.

None	Slight	Moderate	Severe
0.09	0.25	0.47	1.36
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Notes: Means underscored by the same dotted line are not significantly different. Mean values from both moderate and severe top dying categories are significantly (P =0.05) higher than that from none and slight top dying categories.

It is seen from **Table 102** that on an average the number of main branches affected per tree were 0.57, 0.62, 0.67 and 1.38 in none, slight, moderate and severe top dying sample plots respectively as observed in January 2002. There was no significant variation in mean number of main branches in no top dying (i.e. none), slight, moderate and severe top dying sample plots, but mean number of main branches affected in moderate and severe top dying sample plots (Table 85).

Table 103: Comparison of the ranked mean number of main branches affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) at 12 landings in 10 compartments in the Sundarbans as observed in January 2002.

None	Slight	Moderate	Severe
0.57	0.62	0.76	1.38
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Notes: Means underscored by the same dotted line are not significantly different.

Highly significant (P=0.0001) F values of 62.19 and 62.17 (each with 704 and 3 degrees of freedom) were obtained in case of per cent of main stem affected in case of none, slight, moderate and severe top dying sample plots at the time of laying out of the sample plots in October 2001 and that during the second observation in January 2002 respectively. These indicate a significant variation in the per cent of main stem affected among the four top dying categories. The extent and source of significant variability in the per cent of main stem affected among the four types of top dying sundri trees (i.e. none, moderate, slight and severe categories) as observed in October 2001 and January 2002 are further tested and presented in **Tables 104 and 105.**

Table 104: Summary of variance analysis of the data on the per cent of main stem affected by top dying of 708 sundri trees of 36 sample plots falling in four top dying severity classes (viz. moderate, none, severe and slight) as observed in October 2001 at 12 landings in 10 compartments in the Sundarbans

SUMMARY						
Groups	Count	Sum	Average	Variance		
Moderate	186	1775	9.543011	347.763		
None	194	539	2.778351	119.3962		
Severe	122	3270	26.80328	675.2337		
Slight	206	690	3.34951	140.9712		
ANOVA						

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	52998.11	3	17666.04	62.6833	4.42E-36	2.617497
Within Groups	198404.9	704	281.83			
Total	251403	707				

Table 105: Summary of variance analysis of the data on the per cent of main stem affected by top dying of 708 sundri trees of 36 sample plots falling in four top dying severity classes (viz. moderate, none, severe and slight) as observed in January 2002 at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
Moderate	186	2410	12.95699	453.3711		
None	194	632	3.257732	163.0317		
Severe	122	3530	28.93443	571.1692		
Slight	206	1060	5.14563	183.2513		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	58966.05	3	19655.35	62.1788	7.66E-36	2.617483
Within Groups	222749.8	704	316.41			
Total	281715.8	707				

It is seen from Table 106 that on an average the per cent of main stem affected were 2.78, 3.30, 9.54 and 26.80 per tree in October 2001 in none, slight, moderate and severe top dying sample plots respectively. There was no significant variation in per cent main stem affected in no top dying (i.e. none) and slight top dying sample plots, but mean per cent main stem affected in moderate and severe top dying sample plots were highly significantly higher (P = 0.001) than those of none and slight top dying sample plots (**Table 106**).

Table 106: Comparison of the ranked mean per cent of main stem affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) in 12 compartments in the Sundarbans as observed in October 2001.

None	Slight	Moderate	Severe
2.78	3.30	9.54	26.80
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Notes: Means underscored by the same dotted line are not significantly different. Means of moderate and severe are significantly different from each other and both are significantly higher than those of none and slight top dying sample plots.

It is seen from **Table 107** that on an average the per cent of main stem affected were 3.26, 5.05, 12.96 and 28.93 per tree in January 2002 in none, slight, moderate and severe top dying sample plots respectively. There was no significant variation in per cent main stem affected in no top dying (i.e. none) and slight top dying sample plots, but mean per cent main stem affected in moderate and severe top dying sample plots were highly significantly (P = 0.001) higher than those of none and slight top dying sample plots.

Table 108: Comparison of the ranked mean per cent of main stem affected on 708 sundri trees in 36 sample plots falling in four types of severity classes of top dying (i.e. none, slight, moderate and severe) at 12 landings in 10 compartments in the Sundarbans as observed in January 2002.

None	Slight	Moderate	Severe
3.26	5.05	12.96	28.93
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Notes: Means underscored by the same dotted line are not significantly different. Means of moderate and severe are significantly different from each other and both are significantly higher than those of none and slight top dying sample plots.			

Variance in case of number of main branches affected at the time of laying out of the sample plots in October 2001 has been 18.28 and that with the data of the second observation in January 2002 has been found to be 79.90 (both with 704 and 3 df). These indicate that during the time lapse between laying out of the sample plots and the second observation further deterioration of top dying condition affected the main branches. A comparison of the mean number of main branches affected by top dying in case of none, slight, moderate and severe top dying of sundri were 0.57, 0.39, 0.76 and 1.38 respectively.

However, per cent of main stem affected by top dying of sundri remained more or less constant as is evident by almost equal variances of 62.19 and 62.17, both with 704 and 3 df, during the first observation and the second observation in October 2001 and January 2002 respectively. The mean per cent of main stem affected by top dying in the four top dying categories (i.e. none, slight, moderate and severe) were 0.42, 2.78, 9.54 and 26.80 respectively.

Sample plot-wise summarized data on total sundri, five health categories of sundri (i.e. healthy, G2, G3, G4 and dead), state of health of leading shoots (i.e. leaders), twigs, extent of presence of gall cankers and epiphytes as observed in 36 sample plots during the first and second observations in October 2001, January 2002 and January 2003 are provided in **Tables 109, 110** and **111** respectively.

Table 109:Sample plot wise summarized data collected in October 2001 on total sundri trees, five health categories of top dying severity, state of health of leader, twigs, extent of presence of gall cankers and epiphyte.

Top dying severity class	Compartment	Plot	Tsundri	TotalH	TotalG2	TotalG3	TotalG4	Totaldad	Maindd	Mainlh	TwigNA	TwigFA	TwigMA	DyingTP	DyingTNP	CankerPF	CankerPM	CankerNP	LoranP	LoranNP	EpiphyeP	EpiphyNP
			d	e	f	g	h		i	j	k	l	m	n	o	p	q	r	s	t		
None	20	2	19	12	5	1	1	0	2	17	11	8	0	0	19	15	4	0	3	16	1	18
None	20	3	25	19	5	1	0	0	1	24	19	6	0	0	25	19	6	0	0	25	0	25
None	36A	1	23	18	1	4	0	0	0	6	7	6	0	0	6	10	3	0	1	10	1	10
None	19B	3	12	8	2	0	0	0	10	2	8	4	0	0	12	12	0	0	1	11	2	10
None	19B	1	17	13	1	3	0	0	2	15	8	9	0	0	17	17	0	0	0	17	0	17
None	40	3	22	22	7	5	3	0	0	22	0	22	0	0	22	19	3	0	1	21	1	21
Slight	11	1	29	22	7	0	0	0	4	25	16	13	0	0	29	28	1	0	3	26	25	4
Slight	11	2	25	18	6	0	1	0	4	21	14	11	0	0	25	17	8	0	1	24	16	9
Slight	19A	3	22	13	3	5	1	0	6	16	13	9	0	0	22	22	0	0	1	21	4	18

Slight	19B	2	23	10	5	4	3	1	7	16	9	14	0	0	23	21	2	0	3	20	4	19
Slight	20	1	16	9	6	2	0	0	2	14	8	8	0	0	16	15	1	0	0	16	3	13
Slight	26	2	25	9	16	1	0	0	0	0	0	0	0	0	0	23	6	0	3	22	11	14
Slight	36A	3	25	11	5	6	2	0	6	19	0	25	0	0	25	21	3	1	2	22	7	0
Slight	40	2	24	16	3	3	2	0	4	20	0	24	0	0	24	18.	6	0	16	8	19	8
Moderate	19A	1	25	7	7	5	6	0	14	11	0	25	0	0	25	21	4	0	0	25	0	0
Moderate	19A	2	24	12	7	5	0	0	3	21	2	22	0	0	24	23	1	0	9	15	18	6
Moderate	22	3	19	7	6	4	2	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
Moderate	26	1	17	7	7	2	1	0	3	0	0	3	0	0	3	15	1	0	5			
Moderate	26	3	24	3	10	7	4	0	11	13	0	0	0	0	24	19	5	0	0	24	0	0
Moderate	33	1	18	7	5	3	3	0	0	7	0	3	5	2	14	0	0	0	0	0	0	0
Moderate	36A	2	19	8	7	2	2	0	8	11	0	19	0	0	19	16	3	0	2	17	5	14
Moderate	33	2	24	7	5	7	5	8	5	5	11	11	3	1	12	11	3	0	0	0	0	0
Moderate	40	1	16	2	6	3	5	0	9	7	0	16	0	0	16	9	4	3	2	14	1	15
Severe	22	1	21	1	2	7	11	0	17	4	0	0	0	0	0	19	2	0	11	10	11	10
Severe	22	2	13	0	0	0	0	0	9	3	0	0	0	0	0	13	0	0	4	0	10	0
Severe	33	3	15	1	1	5	8	10	1	1	3	11	0	0	0	11	0	3	0	11	1	7
Severe	36B	1	13	0	4	5	4	0	9	4	0	13	0	0	13	12	1	0	0	11	0	11
Severe	36B	2	16	0	4	10	1	0	12	4	0	16	0	0	16	15	1	0	0	16	2	14
Severe	36B	3	12	0	0	5	7	0	12	0	0	11	1	0	12	11	1	0	0	12	5	7
Severe	37	1	13	0	1	7	5	0	12	1	0	13	0	0	13	13	0	0	1	12	10	3
Severe	37	2	9	1	3	3	2	0	6	3	0	9	0	0	9	8	1	0	1	8	2	7
Severe	37	3	10	0	1	6	3	0	9	1	0	10	0	0	10	7	3	0	2	8	9	1

Notes: Sclass = Top dying severity class, Compt = Compartment Number, Plot = Sample plot number, Tsundri = Total no. of sundri trees, TotalH = Total no. of healthy sundri trees , TotalG2 = Total no. of sundri trees with only twigs affected, TotalG3 = Total no. of sundri trees having main branches affected by top dying but less than 50% of the crown affected, TotalG4 = Total no. of sundri trees having main branches affected by top dying but more than 50% of the crown affected; Totaldad = Total no. of sundri trees dead, Mainld = Main leader dead, Mainlh = Main leader healthy, TwigNA = Twigs not affected, TwigFA = Few twigs affected by dieback, TwigMA = Many twigs affected by dieback, DyingTP = Dying twig present, DyingTNP = Dying twig not present, CankerPF = Few cankers present, CankerPM = Many cankers present, CankerNP = Canker not present, LoranP = Loranthus present, LoranNP = Loranthus not present, EpiphytP = Epiphyte present, EpiphytNP = Epiphyte not present.

Table 110: Sample plot wise summarized data collected in January 2002 on total sundri trees, four health category of top dying severity, state of health of leader, twigs, extent of presence of gall cankers and epiphyte.

Top dying severity class	Compartment	Plot	Totsundi	Healthy	G2	G3	G4	LeaderH	LeaderD	TwigH	TwigFD	TwigMD	TwigFY	TwigFNDY	GallcanF	GallcanM	GallcanN	LoranP	LoranNP	Epiphyte
None	40	3	22	19	3	0	0	0	22	19	3	0	0	22	0	0	22	1	21	2
None	36A	1	23	18	1	4	0	4	19	18	5	0	0	18	0	0	23	0	23	1
None	19B	1	17	13	1	3	0	4	13	10	7	0	0	17	0	0	17	0	17	0
None	19B	3	12	8	1	1	2	3	9	6	6	0	0	12	0	0	12	1	11	2
None	20	2	18	12	5	1	0	1	17	10	8	0	0	18	1	0	17	0	18	0
None	20	3	26	19	6	1	0	1	25	19	7	0	0	26	0	0	26	0	26	2
None	2	1	28	23	4	0	1	1	27	23	5	0	0	28	0	0	28	0	28	4
None	2	2	23	20	3	0	0	0	23	20	3	0	0	23	0	0	23	0	23	2
None	2	3	25	21	3	1	0	1	24	20	4	0	0	25	0	0	25	0	25	6
Slight	40	2	24	15	6	3	0	3	21	16	8	0	0	24	1	0	23	0	15	23
Slight	36A	3	25	13	11	1	0	1	24	11	14	0	0	25	0	0	25	0	25	4
Slight	19A	3	22	13	4	3	2	5	17	12	10	0	0	22	0	0	22	0	22	5
Slight	19B	2	23	10	4	5	4	9	14	11	12	0	0	23	0	0	23	0	23	2
Slight	20	1	17	8	6	3	0	3	14	8	9	0	0	17	0	0	17	0	17	5

Slight	11	1	29	18	11	0	0	0	29	18	11	0	0	29	0	0	29	0	29	22
Slight	11	2	24	15	9	0	0	0	24	15	9	0	0	24	0	1	23	0	24	17
Slight	11	3	21	9	10	2	0	2	19	9	12	0	0	21	0	0	21	0	21	20
Slight	26	2	30	19	10	1	0	1	29	19	11	0	0	30	4	2	24	0	30	12
Moderate	33	1	18	7	5	3	3	6	12	7	11	0	0	18	1	2	15	0	18	0
Moderate	33	2	24	7	5	7	5	12	12	7	14	3	0	24	4	1	19	0	24	4
Moderate	40	1	16	2	6	3	5	8	8	1	15	0	0	16	8	0	8	2	14	5
Moderate	36A	2	19	8	7	2	2	4	15	9	10	0	0	19	0	0	19	0	19	9
Moderate	19A	1	25	7	7	5	6	11	14	6	19	0	0	25	0	0	25	1	24	0
Moderate	19A	2	24	9	7	7	1	8	16	9	15	0	1	24	0	0	24	0	24	13
Moderate	26	1	17	6	9	2	0	2	15	6	11	0	0	17	2	0	15	0	17	6
Moderate	26	3	20	6	6	7	1	8	12	6	14	0	0	20	0	0	20		18	0
Moderate	22	3	19	7	6	4	2	6	13	7	12	0	0	19	1	2	16	0	19	13
Severe	33	3	15	1	2	7	5	12	3	1	14	0	0	15	2	0	13	1	14	2
Severe	37	1	13	0	1	7	5	12	1	1	12	0	0	13	0	0	13	0	13	6
Severe	37	2	9	1	3	3	2	5	4	1	8	0	0	9	0	0	9	0	13	7
Severe	37	3	10	0	1	6	3	9	1	0	10	0	0	10	0	0	10	0	10	9
Severe	36B	1	13	0	4	5	4	9	4	0	13	0	0	13	0	0	13	0	13	4
Severe	36B	2	16	0	6	8	2	10	6	0	15	1	0	16	0	0	16	0	16	1
Severe	36B	3	12	0	1	5	6	11	1	0	12	0	0	12	2	0	10	0	12	5
Severe	22	1	21	0	3	6	12	18	3	0	21	0	0	21	5	0	16	2	19	12
Severe	22	2	13	1	3	3	6	9	4	1	12	0	0	13	3	1	9	1	12	12

Notes: Compt = Compartment ;Totsundi = total no. of sundri trees; Healthy = No. of healthy sundri trees; G2 = No. of sundri trees where only twigs are affected; G3= No. of sundri trees having less than 50% of the crown affected including main branches; G3= No. of sundri trees having more than 50% of the crown affected including main branches; LeaderH = Leader of the tree healthy; LeaderD = Leader of the tree dead; TwigH = Twigs healthy; TwigFD = Few of the twigs dead; TwigMD = Many of the twigs dead; TwigFDY= Twigs freshly dying; TwigNFDY = Twigs not freshly dying; GallcanF = Gall canker only few; GallcanM = Gallcanker many; GallcanN = Gall canker not present; LoranP = Loranthus present; LoranNP = Loranthus not present; Epiphyte = Epiphyte present No.; Compt 19A = First landing in compartment 19, 19B= Second landing in compartment 19; Compt 36A = First landing in compartment 36, 36B= Second landing in compartment

Table 111:Sample plot wise summarized data collected in January 2003 on total sundri trees, five health categories of top dying severity, state of health of leader, twigs and extent of presence of gall cankers.

Top dying severity class	Compartment	Plot	Tsundri	Total H	Total G 2	Total G 3	Total G 4	Mainl d	Mainl h	Twig NA	TwigFA	Twig MA	Dying TP	Dying TNP	Canker PF	Canker PM	Canker NP	LoranP	Loran NP
Moderate	19A	1	25	1	3	8	13	16	9	1	24	0	0	25	8	0	17	0	25
Moderate	19A	2	24	1	5	12	6	7	17	1	22	0	0	24	17	2	5	0	24
Moderate	22	3	19	0	6	8	5	8	11	0	19	0	0	19	13	4	2	0	19
Moderate	26	1	17	0	3	11	3	5	12	0	17	0	0	17	8	7	2	4	13
Moderate	26	3	24	1	1	10	8	13	7	0	20	0	0	20	13	0	7	6	14
Moderate	33	1	18	0	0	10	5	14	1	3	12	0	0	15	12	2	1	3	12
Moderate	33	2	24	0	3	13	4	17	7	0	21	3	0	24	7	4	7	4	20
Moderate	36A	2	19	1	2	12	4	6	13	1	18	0	0	19	15	0	4	1	18
Moderate	40	1	16	0	1	5	9	12	3	0	15	0	0	15	11	1	3	1	14
None	2	1	22	2	18	9	1	1	27	2	26	0	0	28	8	0	20	0	28
None	2	2	22	1	17	4	0	1	21	1	21	0	0	22	5	1	16	0	22
None	2	3	23	0	16	4	3	3	20	0	23	0	0	23	7	0	16	0	23
None	19B	3	12	0	3	7	2	5	7	0	12	0	0	12	3	1	8	1	11
None	19B	1	17	0	5	6	6	9	8	0	17	0	0	17	6	0	11	0	17

None	20	2	19	0	3	14	2	2	17	0	19	0	0	19	7	4	8	0	19
None	20	3	25	0	17	8	0	3	22	0	25	0	0	25	7	3	15	0	25
None	36A	1	23	1	6	15	1	4	19	0	23	0	0	23	18	0	5	0	23
None	40	3	22	0	6	17	0	1	22	0	23	0	0	23	19	1	3	1	22
Severe	22	1	21	0	1	7	14	19	3	0	22	0	0	22	7	13	2	2	20
Severe	22	2	13	0	0	6	7	11	2	0	13	0	0	13	6	7	0	1	12
Severe	33	3	15	0	0	17	1	10	8	0	17	0	0	18	8	3	7	1	17
Severe	36B	1	13	0	1	5	4	7	3	0	10	0	0	10	4	0	6	0	10
Severe	36B	2	16	0	0	17	1	10	8	0	18	0	0	18	9	1	8	0	18
Severe	36B	3	12	0	0	7	6	13	0	0	13	0	0	13	4	2	7	1	12
Severe	37	1	13	0	0	4	9	13	0	0	13	0	0	13	7	0	6	2	11
Severe	37	2	9	0	0	5	4	8	1	0	9	0	0	9	4	1	4	0	9
Severe	37	3	10	0	0	4	6	10	0	0	10	0	0	10	6	0	4	2	8
Slight	11	1	29	1	11	15	2	2	27	1	28	0	0	29	4	0	25	0	29
Slight	11	2	25	0	11	10	3	2	22	0	24	0	0	24	7	1	16	0	27
Slight	11	3	29	1	11	7	1	1	19	0	20	0	0	20	6	0	14	0	20
Slight	19A	3	22	0	7	13	3	8	15	0	23	0	0	23	12	1	10	1	22
Slight	19B	2	23	2	3	13	5	12	11	2	21	0	0	23	11	1	11	0	23
Slight	20	1	16	0	2	13	2	4	13	0	17	0	0	17	6	3	8	2	15
Slight	26	2	25	0	6	24	0	1	29	0	30	0	0	30	11	15	4	4	26
Slight	36A	3	25	0	8	17	0	4	21	0	25	0	0	25	16	0	8	1	24
Slight	40	2	24	0	7	12	4	8	15	0	23	0	0	23	20	1	2	2	21

Notes: Sclass = Top dying severity class, Compt = Compartment Number, Plot = Sample plot number, Tsundri = Total no. of sundri trees, TotalH = Total no. of healthy sundri trees , TotalG2 = Total no. of sundri trees with only twigs affected, TotalG3 = Total no. of sundri trees having main branches affected by top dying but less than 50% of the crown affected, TotalG4 = Total no. of sundri trees having main branches affected by top dying but more than 50% of the crown affected; Totaldad = Total no. of sundri trees dead, Mainld = Main leader dead, Mainlh = Main leader healthy, TwigNA = Twigs not affected, TwigFA = Few twigs affected by dieback, TwigMA = Many twigs affected by dieback, DyingTP = Dying twig present, DyingTNP = Dying twig not present, CankerPF = Few cankers present, CankerPM = Many cankers present, CankerNP = Canker not present, LoranP = Loranthus present, LoranNP = Loranthus not present.

Analysis of variances of the data of Tables 109, 110 and 111 were carried out. It was found that there are no significant variations among the sample plots of the four top dying severity categories (i.e. none, slight, moderate and severe) in respect of few twig affected, many twig affected, many cankers, loranthus and epiphytes, as are indicated by insignificant F-values of 0.54, 0.77, 0.79, 1.77, 0.65 and 2.64 (each with 27 and 3 df) respectively in case of data from the first observation. In case of the data of second observation there are no significant difference in case of twigs many affected, dying twigs present, few gall cankers present, and loranthus infestation present among the four top dying severity classes as are indicated by insignificant F-values of 0.80, 1.00, 1.57, and 1.46 (with 3, 32 df). These suggest that none of these are associated with the severity of development of top dying of sundri.

In case of the total number of sundri trees having only twigs affected (i.e. G2 category of top dying), main branches affected but less than 50 per cent of crown affected by top dying (i.e. G3 category), main branches affected but more than 50 per cent of crown affected (i.e. G4 category), sundri having main leader dead, sundri having main leader healthy, and sundri with twig not affected by top dying (die back) there are significant variations among the sample plots of the four top dying severity categories (i.e. none, slight, moderate and severe) as indicated by significant F-values of 6.52 (with 26 and 3 df), 3.71 , 4.91, 4.09 and 8.55 (each with 27 and 3 df) and 6.29 (with 28 and 3 df) respectively in case of first observation. Similarly in case of data from second observation significant F-values were obtained. Comparative figures of the F-values on the above parameters in case of data collected during the first trip in October 2001 and second observations in January 2003 are provided in **Table 112**.

Table 112: Comparison of the mean values of sundri trees under different parameters observed in October 2001 and January 2003 from 36 sample plots falling in 10 compartments in the Sundarbans.

Sl. No	Mean number of sundri trees per sample plot of 400 sq m area having	October 2001	January 2003	F- value	Level of probability
d	Sundri tree	19.22	19.75	0.16982	0.681607
e	Healthy sundri	8.22	0.33	46.92932***	2.99E-09
f	G2 type sundri trees	4.63	5.08	0.174731	0.677298
g	G3 type sundri trees	3.78	10.25	46.87082***	3.04E-09
h	G4 type sundri trees	2.56	4.00	3.566252	0.063361
i	Sundri trees with main leader dead	5.88	7.50	1.868098	0.176331
j	Sundri trees with main leader healthy	10.00	12.22	1.194053	0.278486
k	Trees with healthy twigs	4.03	0.33	14.46570***	0.000314
l	Trees with few twigs affected	10.66	19.25	29.68251***	8.11E-07
m	Trees with many twigs affected	0.28	0.08	1.06257	0.306393
n	Dying twigs present	0.09	0	2.082587	0.153717
o	Dying twigs not present	14.85	19.72	7.531081**	0.007803
p	Few canker present	15.00	9.22	18.90659***	4.86E-05
q	Many cankers present	2.28	2.19	0.014936	0.903103
r	Cankers not present	0.22	8.11	56.57633***	1.9E-10
s	Loranthus present	2.25	1.11	3.062522	0.084765
t	Loranthus not present	14.25	18.69	7.056908*	0.009923
	Notes: ** = Significant at P= 0.01; *** = Significant at P =0.001				

Table 112 reveals that in case of G2, G3, G4 type top dying sundri, sundri trees having dead main leader, sundri trees with few twigs affected substantial increase took place between October 2001 and January 2003. Among these increase in case of G3, sundri trees with few twigs affected the difference in the mean values of October 2001 and January 2003 were highly significant, but in the other cases although increase over time took place but the difference was not statistically significant. A careful look into the Table 112 reveals that a good number of healthy sundri (i..e. having no dead or dying twigs) lost the same status and changed to G2 type (i.e. sundri trees having dead or dying twigs) as we find that G3 (i.e. main branches dying or dead, less than 50% of the crown affected by top dying) type sundri changed from 3.78 to 10.25 mean number per sample plot. At the same time some of the G3 type changed to G4 (i.e. main branches dying or dead, more than 50% of the crown affected by top dying) type as we find that G4 type sundri changed from 2.56 to 4.00 per sample plot on an average of the 36 sample plots over a period of one year and four months time (i.e. October 2001 to January 2003) over which the observations were undertaken. These have been summarized and presented in Fig. 38. These data , however, do not clearly reveal the time required for a G2 type sundri to change to G3 type sundri and then G4 type sundri. Hence, further observation of the labeled sundri trees in the 36 sample plots at yearly intervals for two more years should be undertaken.

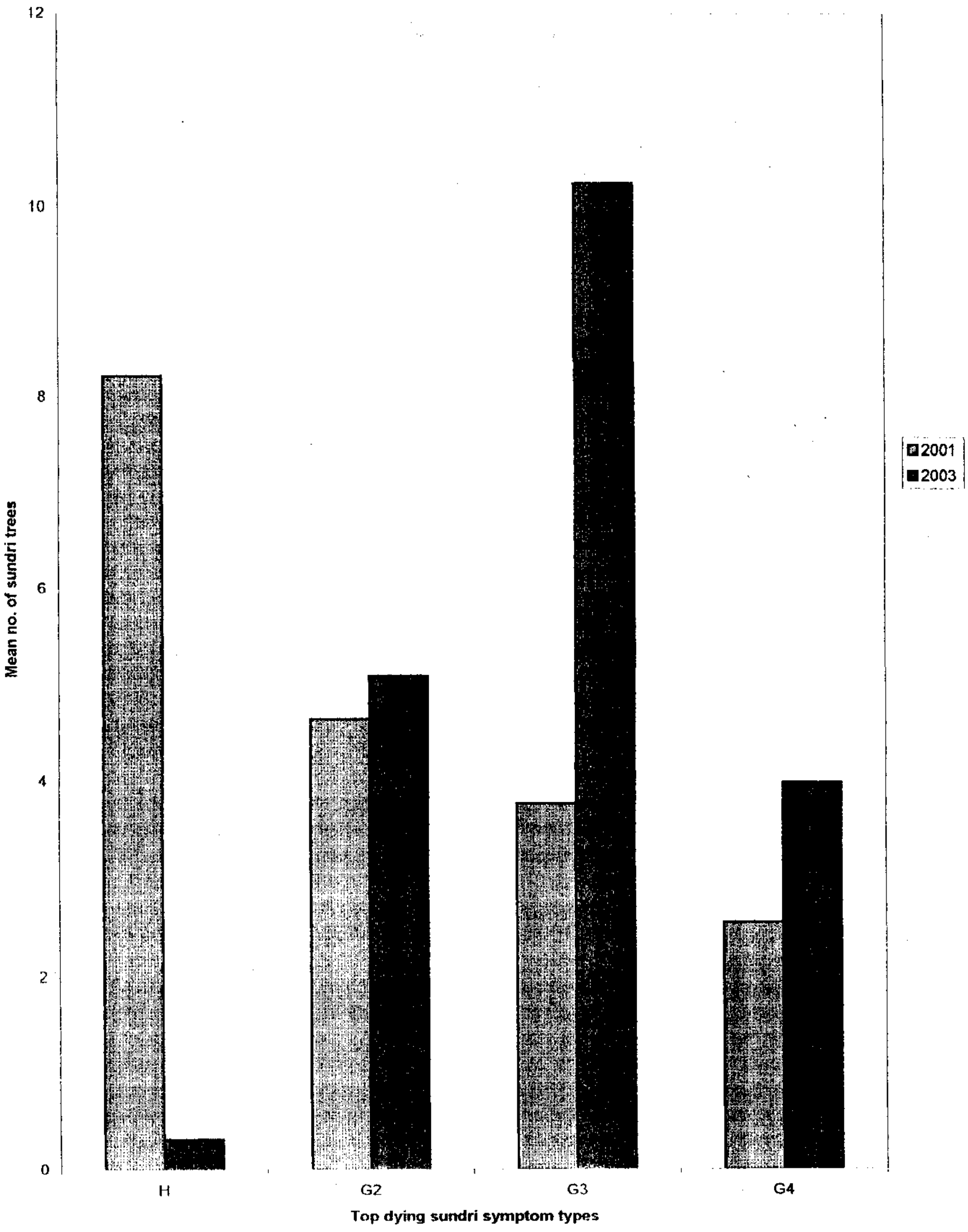


Fig. 38: Pattern of change of top dying symptom types (H = healthy , G2= only twigs affected, G3 = main branches dying or dead, less than 50% of the crown affected; G4 = main branches dying or dead, more than of the crown affected) over the period October 2001 to January 2003 as mean of 36 sample plots each being of 400 sq m area.

5.2.7 Examination and analysis of data of Temporary Sample Plots (TSPs)

5.2.7.1 Prevalence of infestation of by insects, rattans, climbers and loranthus and top dying of sundri in the Sundarbans

The status of top dying of sundri has been studied from the data of Temporary Sample Plots (TSPs) maintained in the database of SBCP at Boyra, Khulna. The data on TSP and Permanent Sample Plots (PSPs) were obtained from the database at the consent of the Project Director, SBCP. We express our gratitude for the support.

In the TSP database there are data collected during 1996-1997 by the personnel of Forest Resources Management Project of the Forest Department.

In all there are records of data of 1190 TSPs. From each TSP, data on sundri trees were retrieved. The data included distribution of sundri trees in seven infestation categories viz. healthy sundri, sundri infested by insects, rattans, slightly infested by climbers, heavily infested by climbers, infested by loranthus and sundri affected by top dying (dieback). In each of the 1190 TSPs data on total number of sundri trees and number of sundri trees falling in each of the seven infestation categories were recorded on a designed proforma. Against each TSP, compartment number, forest type and canopy closure percentage were also noted in the proforma. Structured Query Language (SQL) programme was used in retrieving the required data on infestation categories. At any one time data of only one TSP could be retrieved. That means the process involved 1190 retrievals of data from 1190 TSPs on infestation categories. Once data retrieval was complete, then the data of all TSPs falling in a particular compartment number out of 55 compartments in the Sundarbans were placed side by side. Thus the data on sundri falling in seven infestation categories were finalized and presented in **Appendix 31**. Using Microsoft Excel Programme the sub-totals of each of 55 compartments were obtained. All the data on sundri falling in seven infestation categories were summarized. The data on number of sundri trees in seven infestation categories from 1190 TSPs are summarized in **Table 113** and the same expressed as per cent of total number of sundri in a particular compartment in **Table 114**. The per cent distribution of healthy sundri trees and sundri trees infested by insects, rattans, climbers, loranthus and affected by top dying for the whole Sundarbans are provided in **Figs. 39** and **40**.

Fig. 39: Per cent distribution of healthy sundri trees and sundri trees infested by insects, rattans, climbers, loranthus and top dying as determined from the data of 1190 Temporary Sample Plots (TSPs)of FRMP Forest Inventory (1996-97) in Sundarbans.

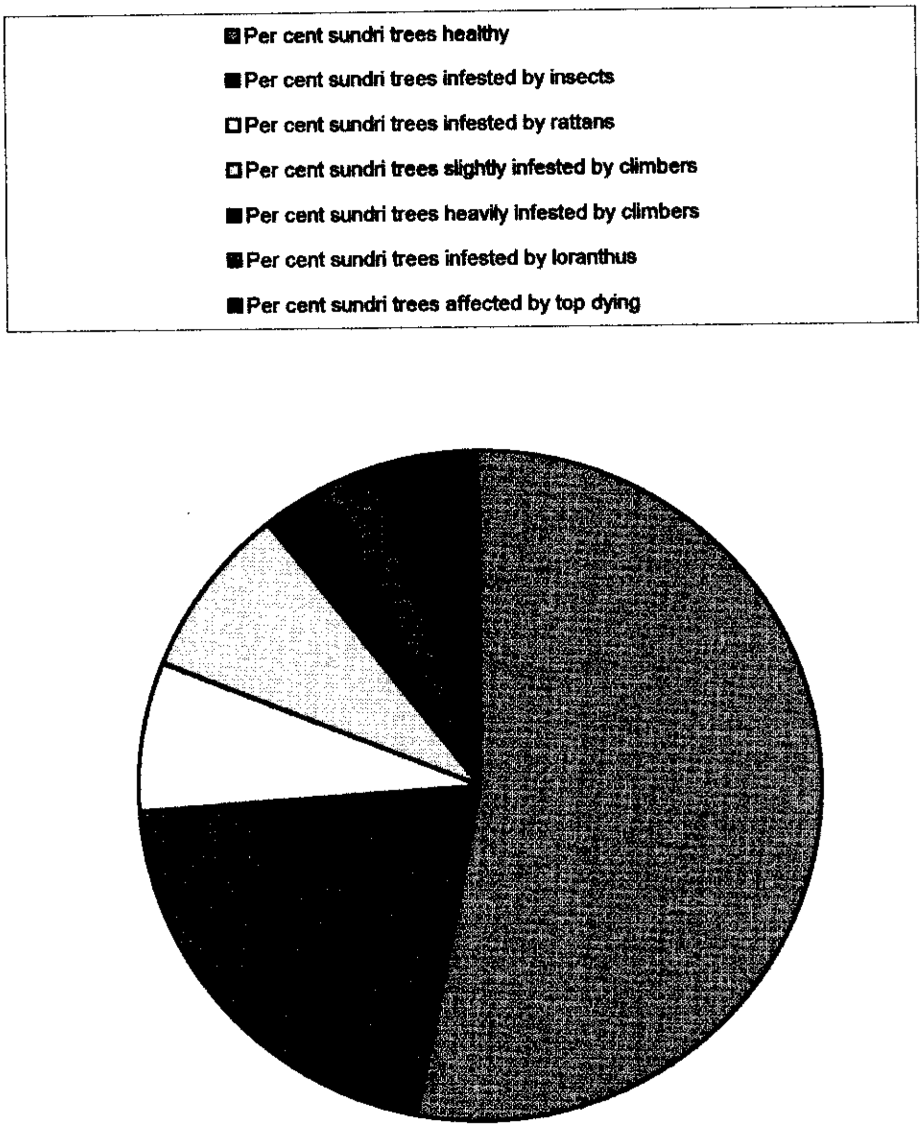


Fig. 40:Occurrence of healthy sundri trees and sundri trees infested by insects, rattans, climbers, loranthus and top dying from data of 1190 Temporary Sample Plots of 55 compartments collecetd by FRMP Forest Inventory in 1996-97 from the Sundarbans.

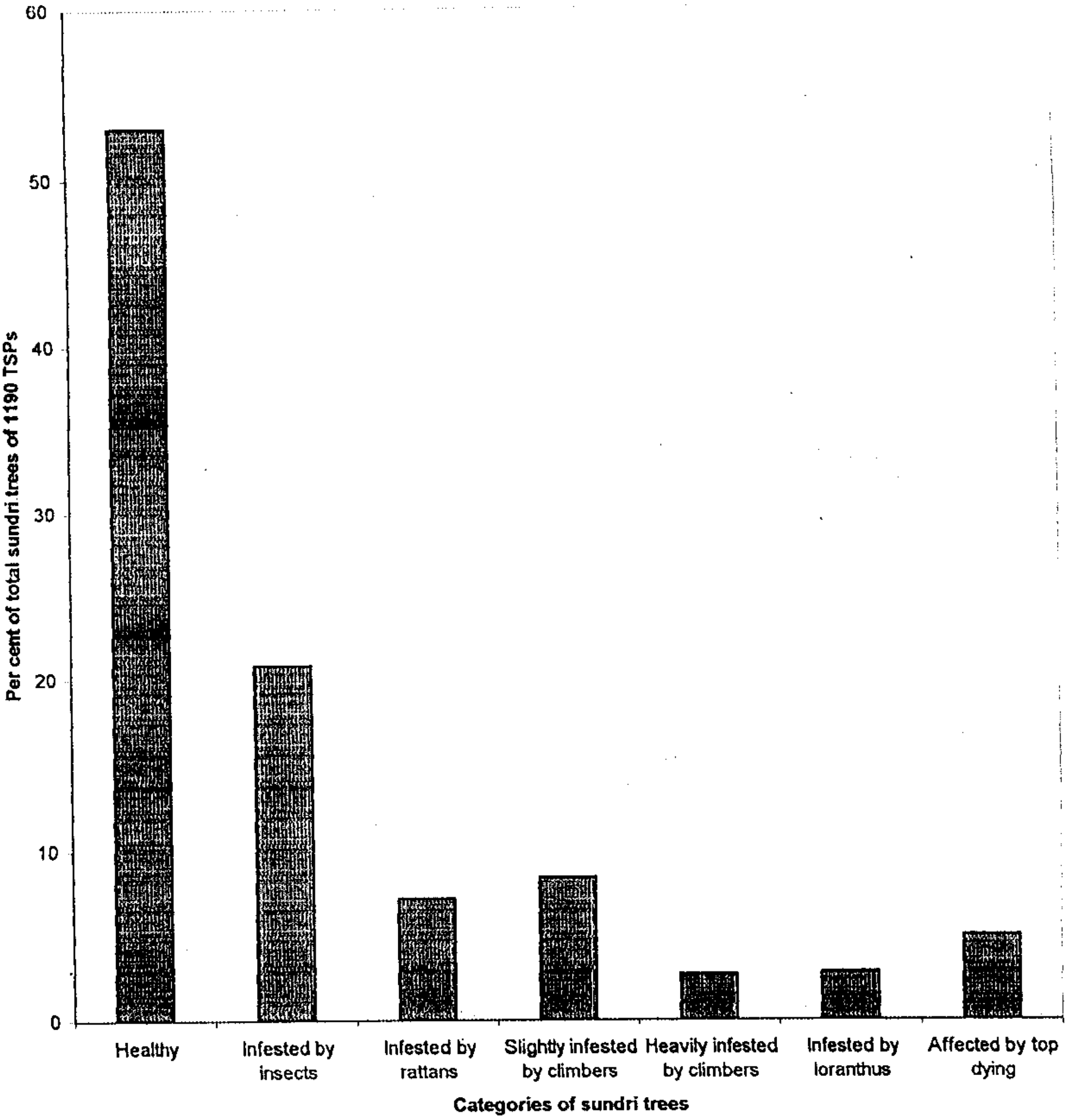


Table 113: Total number of sundri trees in seven infestation categories (i.e. healthy, infested by insects, infested by rattans, slightly infested by climbers, heavily infested by climbers, infested by loranthus and affected by top dying (as recorded in 1190 Temporary Sample Plots) and sorted out in 55 compartments in the Sundarbans.

Compart-ment Number	Total Number of temporary sample plots	Total number of sundri trees	No. of healthy sundri trees	No. of sundri trees infested by insect	No. of sundri trees infested by rattans	No. of sundri trees slightly infested by climbers	No. of sundri trees heavily infested by climbers	No. of sundri trees infested by loranthus	No. of sundri trees exhibiting top dying (dieback)
1	30	915	489	281	82	33	13	12	5
2	20	618	345	177	48	33	4	6	5
3	17	606	208	216	44	91	36	7	4
4	17	540	180	217	42	60	35	0	6
5	17	412	102	171	37	59	37	3	3
6	21	326	121	85	42	58	15	3	2
7	30	473	176	175	32	59	28	0	3
8	36	734	498	89	12	22	4	72	37
9	36	480	352	37	16	38	5	26	6
10	19	767	491	83	26	138	10	8	11
11	15	389	171	129	36	35	14	1	3
12	19	483	298	80	25	52	23	5	0
13	19	1016	750	99	68	70	5	7	17
14	12	542	320	67	42	61	30	19	3
15	15	926	468	191	110	140	15	2	0
16	20	661	260	120	53	157	39	26	6
17	23	577	299	93	27	78	20	47	13
18	37	769	486	154	27	13	4	19	66
19	21	586	364	51	11	18	10	80	52
20	26	835	403	198	127	44	19	12	32
21	14	634	360	125	45	67	33	2	2
22	13	695	294	144	98	105	15	12	27
23	11	582	419	82	29	34	6	6	6
24	17	605	420	62	51	43	13	8	8
25	11	296	178	52	25	23	1	8	9
26	12	313	158	95	25	23	2	2	8
27	15	369	212	92	32	15	3	4	11
28	12	265	114	91	23	16	8	6	7
29	14	455	226	116	61	23	14	4	11
30	16	499	194	162	48	58	21	7	9
31	24	559	284	147	35	50	7	9	27
32	16	295	110	115	19	18	15	4	14
33	15	541	222	94	32	60	29	30	74
34	12	397	177	67	18	54	31	22	28
35	20	205	59	77	12	36	9	9	3
36	21	476	199	88	40	46	11	33	60
37	16	336	201	21	13	9	7	24	61
38	20	501	305	66	45	25	18	25	17
39	20	637	337	123	42	80	33	16	6
40	13	295	160	38	11	21	6	22	37

41	19	46	27	4	1	1	2	4	7
42	20	36	18	8	1	0	1	0	8
43	28	189	72	74	23	5	3	3	9
44	25	213	88	90	25	2	2	0	6
45	26	284	180	23	5	10	1	33	32
46	29	11	7	0	0	0	0	1	3
47	29	6	1	5	0	0	0	0	0
48	27	10	9	1	0	0	0	0	0
49	33	1	1	0	0	0	0	0	0
50	21	3	2	0	0	0	0	0	1
51	28	2	0	0	1	1	0	0	0
52	33	37	34	2	0	0	0	1	0
53	28	23	4	5	4	4	2	1	3
54	40	59	42	11	2	2	0	0	2
55	42	4	4	0	0	0	0	0	0
Total	1190	22534	11899	4793	1673	2090	659	651	770

Table 114: Total number of sundri trees and their per cent distribution in seven infestation categories (i.e. healthy, infested by insects, infested by rattans, slightly infested by climbers, heavily infested by climbers, infested by loranthus and affected by top dying) as recorded in 1190 Temporary Sample Plots and sorted out in 55 compartments in the Sundarbans.

Compart-ment Number	Total Number of temporary sample plots	Total number of sundri trees	Per cent of healthy sundri trees	Per cent of sundri trees infested by insects	Per cent of sundri trees infested by rattans	Per cent of sundri trees slightly infested by climbers	Per cent of sundri trees heavily infested by climbers	Per cent of sundri trees infested by loranthus	Per cent of sundri trees exhibiting top dying (dieback)
1	30	915	53.44	30.71	8.96	3.61	1.42	1.31	0.55
2	20	618	55.83	28.64	7.77	5.34	0.65	0.97	0.81
3	17	606	34.32	35.64	7.26	15.02	5.94	1.16	0.66
4	17	540	33.33	40.19	7.78	11.11	6.48	0.00	1.11
5	17	412	24.76	41.50	8.98	14.32	8.98	0.73	0.73
6	21	326	37.12	26.07	12.88	17.79	4.60	0.92	0.61
7	30	473	37.21	37.00	6.77	12.47	5.92	0.00	0.63
8	36	734	67.85	12.13	1.63	3.00	0.54	9.81	5.04
9	36	480	73.33	7.71	3.33	7.92	1.04	5.42	1.25
10	19	767	64.02	10.82	3.39	17.99	1.30	1.04	1.43
11	15	389	43.96	33.16	9.25	9.00	3.60	0.26	0.77
12	19	483	61.70	16.56	5.18	10.77	4.76	1.04	0.00
13	19	1016	73.82	9.74	6.69	6.89	0.49	0.69	1.67
14	12	542	59.04	12.36	7.75	11.25	5.54	3.51	0.55
15	15	926	50.54	20.63	11.88	15.12	1.62	0.22	0.00
16	20	661	39.33	18.15	8.02	23.75	5.90	3.93	0.91
17	23	577	51.82	16.12	4.68	13.52	3.47	8.15	2.25
18	37	769	63.20	20.03	3.51	1.69	0.52	2.47	8.58
19	21	586	62.12	8.70	1.88	3.07	1.71	13.65	8.87
20	26	835	48.26	23.71	15.21	5.27	2.28	1.44	3.83
21	14	634	56.78	19.72	7.10	10.57	5.21	0.32	0.32
22	13	695	42.30	20.72	14.10	15.11	2.16	1.73	3.88
23	11	582	71.99	14.09	4.98	5.84	1.03	1.03	1.03
24	17	605	69.42	10.25	8.43	7.11	2.15	1.32	1.32

25	11	296	60.14	17.57	8.45	7.77	0.34	2.70	3.04
26	12	313	50.48	30.35	7.99	7.35	0.64	0.64	2.56
27	15	369	57.45	24.93	8.67	4.07	0.81	1.08	2.98
28	12	265	43.02	34.34	8.68	6.04	3.02	2.26	2.64
29	14	455	49.67	25.49	13.41	5.05	3.08	0.88	2.42
30	16	499	38.88	32.46	9.62	11.62	4.21	1.40	1.80
31	24	559	50.81	26.30	6.26	8.94	1.25	1.61	4.83
32	16	295	37.29	38.98	6.44	6.10	5.08	1.36	4.75
33	15	541	41.04	17.38	5.91	11.09	5.36	5.55	13.68
34	12	397	44.58	16.88	4.53	13.60	7.81	5.54	7.05
35	20	205	28.78	37.56	5.85	17.56	4.39	4.39	1.46
36	21	476	41.81	18.49	8.40	9.66	2.31	6.93	12.61
37	16	336	59.82	6.25	3.87	2.68	2.08	7.14	18.15
38	20	501	60.88	13.17	8.98	4.99	3.59	4.99	3.39
39	20	637	52.90	19.31	6.59	12.56	5.18	2.51	0.94
40	13	295	54.24	12.88	3.73	7.12	2.03	7.46	12.54
41	19	46	58.70	8.70	2.17	2.17	4.35	8.70	15.22
42	20	36	50.00	22.22	2.78	0.00	2.78	0.00	22.22
43	28	189	38.10	39.15	12.17	2.65	1.59	1.59	4.76
44	25	213	41.31	42.25	11.74	0.94	0.94	0.00	2.82
45	26	284	63.38	8.10	1.76	3.52	0.35	11.62	11.27
46	29	11	63.64	0.00	0.00	0.00	0.00	9.09	27.27
47	29	6	16.67	83.33	0.00	0.00	0.00	0.00	0.00
48	27	10	90.00	10.00	0.00	0.00	0.00	0.00	0.00
49	33	1	100.00	0.00	0.00	0.00	0.00	0.00	0.00
50	21	3	66.67	0.00	0.00	0.00	0.00	0.00	33.33
51	28	2	0.00	0.00	50.00	50.00	0.00	0.00	0.00
52	33	37	91.89	5.41	0.00	0.00	0.00	2.70	0.00
53	28	23	17.39	21.74	17.39	17.39	8.70	4.35	13.04
54	40	59	71.19	18.64	3.39	3.39	0.00	0.00	3.39
55	42	4	100.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean per cent:			53.02	20.84	7.20	8.43	2.68	2.83	5.00

In order to easily find out within each of the seven infestation categories in which compartment the highest infestation occurred the per cent occurrence data of each of the seven infestation categories were sorted out in descending order and then the corresponding compartment number has been provided in parenthesis. In this way data have been sorted out for 1) per cent healthy sundri trees, 2) per cent sundri trees having insect damage 3) per cent sundri trees with rattans infestation, 4) per cent sundri trees having slight infestation by climbers, 5) per cent sundri trees having heavy infestation by climbers, 6) per cent sundri trees having loranthus infestation, and 7) per cent sundri trees having top dying damage. These are provided in **Table 115.**

Table 115: Per cent distribution of sundri trees in seven infestation categories (i.e. healthy, infested by insects, infested by rattans, slightly infested by climbers, heavily infested by climbers, infested by loranthus and affected by top dying) and sorted out in descending order having compartment number in parenthesis as recorded from 1190 Temporary Sample Plots in 1996 and 1997 from 55 compartments in the Sundarbans.

% healthy sundri trees	% sundri trees with insect damage	% sundri trees with rattans infestation	% sundri trees with slight infestation by climbers	% sundri trees with heavy infestation by climbers	% sundri trees with loranthus infestation	% sundri trees having top dying damage
100.00 (49)	83.33 (47)	50 (51)	23.75 (16)	8.98 (5)	13.65 (19)	33.33 (50)
100.00 (55)	42.25 (44)	17.39 (53)	17.99 (10)	8.7 (53)	11.62 (45)	27.27 (46)
91.89 (52)	41.5 (5)	15.21 (20)	17.79 (6)	7.81 (34)	9.81 (8)	22.22 (42)
90.00 (48)	40.19 (4)	14.1 (22)	17.56 (35)	6.48 (4)	9.09 (46)	18.15 (37)
73.82 (13)	39.15 (43)	13.41 (29)	17.39 (53)	5.94 (3)	8.7 (41)	15.22 (41)
73.33 (9)	38.98 (32)	12.88 (6)	15.12 (15)	5.92 (7)	8.15 (17)	13.68 (33)
71.99 (23)	37.56 (35)	12.17 (43)	15.11(22)	5.9 (16)	7.46 (40)	13.04 (53)
71.19 (54)	37.00 (7)	11.88 (43)	15.02 (3)	5.54 (14)	7.14 (37)	12.61 (36)
69.42 (24)	35.64 (3)	11.74 (44)	14.32 (5)	5.36 (33)	6.93 (36)	12.54 (40)
67.85 (8)	34.34 (28)	9.62 (30)	13.60 (34)	5.21 (21)	5.55 (33)	11.27 (45)
66.67 (50)	33.16 (11)	9.25 (11)	13.52 (17)	5.18 (39)	5.54 (34)	8.87 (19)
64.02 910)	32.46 (30)	8.98 (38)	12.56 (39)	5.08 (32)	5.42 (9)	8.58 (18)
63.64 (46)	30.71(1)	8.98 (5)	12.47 (7)	4.76 (12)	4.99 (38)	7.05 (34)
63.38 (45)	30.35 (26)	8.96 (1)	11.62 (30)	4.60 (6)	4.39 (35)	5.04 (8)
63.20 (18)	28.64 (2)	8.68 (28)	11.25 (14)	4.39 (35)	4.35 (53)	4.83 (31)
62.12 (19)	26.3 (31)	8.67 (27)	11.11 (4)	4.35 (41)	3.93 (16)	4.76 (43)
61.70 (12)	26.07(6)	8.45 (25)	11.09 (33)	4.21 (30)	3.51 (14)	4.75 (32)
60.88 (38)	25.49 (29)	8.43 (24)	10.77 (12)	3.6 (11)	2.7 (25)	3.88 (22)
60.14 (25)	24.93 (27)	8.4 (36)	10.57 (21)	3.59 (38)	2.7 (52)	3.83 (20)
59.82 (37)	23.71(20)	8.02 (16)	9.66 (36)	3.47 (17)	2.51 (39)	3.39 (38)
59.04 (14)	22.22 (42)	7.99 (26)	9.00 (11)	3.08 (29)	2.47 (18)	3.39 (54)
58.70 (41)	21.74 (53)	7.78 (4)	8.94 (31)	3.02 (28)	2.26 (28)	3.04 (25)
57.45 (27)	20.72 (22)	7.77 (2)	7.92 (9)	2.78 (42)	1.73 (22)	2.98 (27)
56.78 (21)	20.63 (15)	7.75 (14)	7.77 (25)	2.31 (36)	1.61 (31)	2.82 (44)
55.83 (2)	20.03 (18)	7.26 (3)	7.35 (26)	2.28 (20)	1.59 (43)	2.64 (28)
54.24 (40)	19.72 (21)	7.1 (21)	7.12 (40)	2.16 (22)	1.44 (20)	2.56 (26)
53.44 (1)	19.31(39)	6.77 (7)	7.11 (24)	2.15 (24)	1.4 (30)	2.42 (29)
52.90 (39)	18.64 (54)	6.69 (13)	6.89 (13)	2.08 (37)	1.36 (32)	2.25 (17)
51.82 (17)	18.49 (36)	6.59 (39)	6.10 (32)	2.03 (40)	1.32 (24)	1.8 (30)
50.81 (31)	18.15 (16)	6.44 (32)	6.04 (28)	1.71 (19)	1.31 (1)	1.67 (13)
50.54 (15)	17.57 (25)	6.26 (31)	50 (51)	1.62 (15)	1.16 (3)	1.46 (35)
50.48 (26)	17.38 (33)	5.91(33)	5.84 (23)	1.59 (43)	1.08 (27)	1.43 (10)
50.00 (42)	16.88 (34)	5.85 (35)	5.34 (2)	1.42 (1)	1.04 (12)	1.32 (24)
49.67 (29)	16.56 (12)	5.18 (12)	5.27 (20)	1.3 (10)	1.04 (10)	1.25 (9)
48.26 (20)	16.12 (17)	4.98 (23)	5.05 (29)	1.25 (31)	1.03 (23)	1.11 (4)
44.58 (34)	14.09 (23)	4.68 (17)	4.99 (38)	1.04 (9)	0.97 (2)	1.03 (23)
43.96 (11)	13.17 (38)	4.53 (34)	4.07 (27)	1.03 (23)	0.92 (6)	0.94 (39)
43.02 (28)	12.88 (40)	3.87 (37)	3.61 (1)	0.94 (44)	0.88 (29)	0.91 (16)

42.30 (22)	12.36 (14)	3.73 (40)	3.52 (45)	0.81 (27)	0.73 (5)	0.81 (2)
41.81 (36)	12.13 (8)	3.51 (18)	3.39 (54)	0.65 (2)	0.69 (13)	0.77 (11)
41.31 (44)	10.82 (10)	3.39 (10)	3.07 (19)	0.64 (26)	0.64 (26)	0.73 (5)
41.04 (33)	10.25 (24)	3.39 (54)	3.00 (8)	0.54 (8)	0.32 (21)	0.66 (3)
39.33 (16)	10 (48)	3.33 (9)	2.68 (37)	0.52 (18)	0.26 (11)	0.63 (7)
38.88 (30)	9.74 (13)	2.78 (42)	2.65 (43)	0.49 (13)	0.22 (15)	0.61 (6)
38.10 (43)	8.70 (19)	2.17 (41)	2.17 (41)	0.35 (45)	0 (4)	0.55 (14)
37.29 (32)	8.70 (41)	1.88 (19)	1.69 (18)	0.34 (25)	0 (7)	0.55 91)
37.21 (7)	8.10 (45)	1.76 (45)	0.94 (44)	0 (54)	0 (42)	0 32 (21)
37.12 (6)	7.71(9)	1.63 (8)	0 (55)	0 (48)	0 (44)	0 (52)
34.32 (3)	6.25 (37)	0 (48)	0 (52)	0 (52)	0 (54)	0 (12)
33.33 (4)	5.41(52)	0 (52)	0 (50)	0 (49)	0 (48)	0 (15)
28.78 (35)	0 (49)	0 (49)	0 (49)	0 (50)	0 (49)	0 (48)
24.76 (5)	0 (50)	0 (50)	0 (48)	0 (55)	0 (50)	0 (49)
17.39 (53)	0 (51)	0 (55)	0 (47)	0 (46)	0 (55)	0 (55)
16.67 (47)	0 (55)	0 (46)	0 (46)	0 (47)	0 (47)	0 (47)
0.00 (51)	0 (46)	0 (47)	0 (42)	0 (51)	0 (51)	0 (51)

From Table 115 it is very convincingly clear that :

a) The 55 compartments in a descending order of **occurrence of healthy sundri trees** are as follows: compartment 49 (having 100% healthy sundri trees) and this followed by 55, 52, 48, 13, 9, 23, 54, 24, 8, 50, 10, 46, 45, 18, 19, 12, 38, 25, 37, 14, 41, 27, 21, 2, 40, 1, 39, 17, 31, 15, 26, 42, 29, 20, 34, 11, 28, 22, 36, 44, 33, 16, 30, 43, 32, 7, 6, 3, 4, 35, 5, 53 and 47 (having the lowest of 16.67 per cent) healthy sundri trees. Compartment 51 had no sundri trees in the studied TSPs.

b) The 55 compartments in a descending order of **occurrence of insect damage on sundri trees** are as follows: compartment 47 having the highest of 83.33% sundri with insect damage, followed by 44, 5, 4, 43, 32, 35, 7, 3, 28, 11, 30, 1, 26, 2, 31, 6, 29, 27, 20, 42, 53, 22. 15, 18, 21, 39, 54, 36, 16, 25, 33, 34, 12, 17, 23, 38, 40, 14, 8, 10, 24, 48, 13, 19, 41, 45, 9, 37, 52 (having 5.41 % sundri with insect damage). Compartment nos. 49, 50, 51, 55 and 46 had no insect damage at all.

c) The 55 compartments in a descending order of **occurrence of rattans infestation on sundri trees** are as follows: compartment 51 having the highest of 50.00% sundri with rattans infestation, followed by 53, 20, 22, 29, 6, 43, 44, 30, 11, 38, 5, 1, 28, 27, 25, 24, 36, 16, 26, 4, 2, 14, 3, 21, 7, 13, 39, 32, 31, 33, 35, 12, 23, 17. 34, 37, 40, 18, 10, 54, 9, 42, 41, 19, 45. and 8 (having 1.63 % sundri with rattans damage). Compartment nos 48, 52, 49, 50, 55, 46, and 47 had no rattans infestation at all.

d) The 55 compartments in a descending order of **occurrence of slight infestation by climbers on sundri trees** are as follows: compartment 16 having the highest of 23.75% sundri with climbers infestation, followed by 10, 6, 35, 53, 15, 22, 3, 5, 34, 17, 39, 7, 30, 14, 4, 33, 12, 21, 36, 11, 31, 9, 25, 26, 40, 24, 13, 32, 28, 51, 23, 2, 20, 29, 38, 27, 1, 45, 54, 19, 8, 37, 43, 41, 18 and 44 (having 0.94 % sundri with slight climbers damage). Compartment nos. 55, 52, 50, 49, 48, 47, 46, and 42 had no climbers infestation at all.

e) The 55 compartments in a descending order of **occurrence of heavy infestation by climbers on sundri trees** are as follows: compartment 5 having the highest of 8.98% sundri with climbers infestation, followed by 53, 34, 4, 3, 7, 16, 14, 33, 21, 39, 32, 12, 6, 35, 41, 30, 11, 38, 17, 29, 28, 42, 36, 20, 22, 24, 37, 40, 19, 15, 43, 1, 10, 31, 9, 23, 44, 27, 2, 26, 8, 18, 13, 45 and 25 (having 0.34 % sundri with heavy climbers damage). Compartment nos. 54, 48, 52, 49, 50, 55, 46, 47 and 51 had no heavy climbers infestation at all.

f) The 55 compartments in a descending order of **occurrence of loranthus infestation on sundri trees** are as follows: compartment 19 having the highest of 13.65% sundri with loranthus infestation, followed by 45, 8, 46, 41, 17, 40, 37, 36, 33, 34, 9, 38, 35, 53, 16, 14, 25, 52, 39, 18, 28, 22, 31, 43, 20, 30, 32, 24, 1, 3, 27, 12, 10, 23, 2, 6, 29, 5, 13, 26, 21, 11 and 15 (having 0.22 % sundri with loranthus infestations). Compartment nos. 4, 7, 42, 44, 54, 48, 49, 50, 55, 47 and 51 had no loranthus infestation at all. It may be noted that the loranthus was *Dendrophthoe falcata*.

g) The 55 compartments in a descending order of **occurrence of top dying of sundri trees** are as follows: compartment 50 having the highest of 33.33% sundri with top dying damage, followed by 46, 42, 37, 41, 33, 53, 36, 40, 45, 19, 18, 34, 8, 31, 43, 32, 22, 20, 38, 54, 25, 27, 44, 28, 26, 29, 17, 30, 13, 35, 10, 24, 9, 4, 23, 39, 16, 2, 11, 5, 3, 7,6, 14, ..., and 21 (having 0.32 % sundri top dying). Compartment nos.52, 12, 15, 48, 49, 55, 47 and 51 had no top dying of sundri at all.

5.2.7.2 : Association of infestation of sundri by insects, rattans, climbers, loranthus and per cent top dying of sundri

Based on the data provided in Table 113 association of per cent top dying of sundri with per cent insect infestations, per cent rattans, per cent slight infestation with climbers, per cent heavy infestation with climbers, per cent loranthus infestation have been determined by way of calculation of correlation co-efficient (r). Moreover, association of the data of per cent top dying of 202 Temporary Sample Plots with that of six forest types and three canopy closures have been calculated. All these correlation coefficients have been calculated by using a programme of Microsoft Excel 1997. The summary of these findings is provided in **Table 116**.

Table 116: Correlation coefficient (r) between 1) per cent sundri top dying and per cent insect infestation, (2) per cent sundri top dying and per cent rattans infestation, (3) per cent sundri top dying and per cent slight infestation by climbers , (4) per cent sundri top dying and per cent heavy infestation by climbers and (5) per cent sundri top dying and per cent loranthus infestation data of 830 Temporary Sample Plots (TSPs) sorted out into that of 55 compartments and (6) per cent sundri top dying and canopy closure per cent of 202 TSPs, and (7) percent sundri top dying and forest types of 202 TSPs in 55 compartments in the Sundarbans.

Serial No.	Per cent of top dying of sundri trees in the TSP	Per cent insect infestation of sundri trees	Per cent rattans infestation of sundri trees	Per cent slight infestation of sundri trees with climbers	Per cent heavy infestation of sundri trees with climbers	Per cent loranthus infestation of sundri trees	Canopy closure	Forest type	Degrees of freedom	Calculated Correlation Coefficient (i.e. r value)	Tabulated Correlation Coefficient	Significance of the association (Significant/ Insignificant)	Levels of significance of the association at the probability level (P= 0.0 5 / P= 0.01/ P= 0.001)
1	✔	✔							54	-0.32455	0.266	Significant negative correlation	P< 0.001
2	✔		✔						54	-0.24069	0.266	Insignificant	
3	✔			✔					54	-0.29577	0.266	Significant negative correlation	P =0.001
4	✔				✔				54	-0.09007	0.266	Insignificant	
5	✔					✔			54	0.412946	0.266	Highly Significant positive correlation	P =0.001
6	✔						✔		201	0.344616	0.195	Highly significant positive correlation	P =0.001
7	✔							✔	201	-0.06881	0.195	Insignificant	

From Table 116 it is seen that per cent top dying of sundri data showed highly significant positive correlation with per cent loranthus infestation as well as that with per cent canopy closure. These indicate that with the increase in infestation by loranthus, per cent top dying of sundri also increase and vice versa (Fig. 41). Similarly, canopy closure had a highly significant association with per cent top dying of sundri. A significant positive correlation of canopy closure with per cent top dying of sundri indicates that per cent top dying of sundri increased with the decrease of canopy closure per cent.

Furthermore, per cent top dying of sundri had only insignificant association with per cent rattans infestations and forest types, and showed significant but negative correlation with per cent insect infestation (Fig. 41) and slight infestation by climbers. This suggests that with the increase in insect infestation top dying per cent decreased (Fig. 42).

Fig. 40: Relationship between per cent sundri trees infested by loranthus (i.e. mistletoes) and per cent sundri trees affected by top dying based on data of 1180 Temporary Sample Plots (TSPs) falling in 55 compartments in the Sundarbans

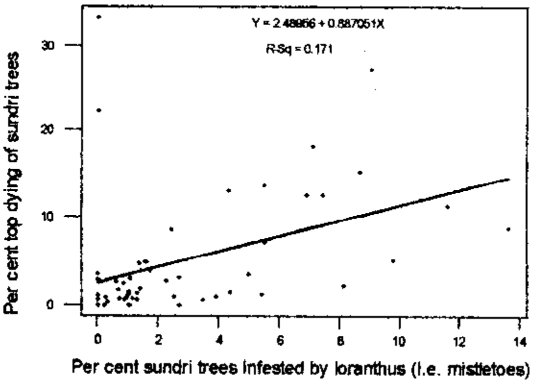


Fig.41: Relationship between per cent sundri infested by insects and per cent sundri affected by top dying based on data of 1190 Temporary Sample Plots (TSPs) falling in 55 compartments in the Sundarbans

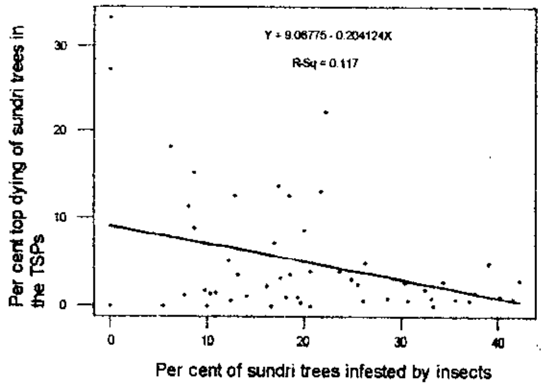
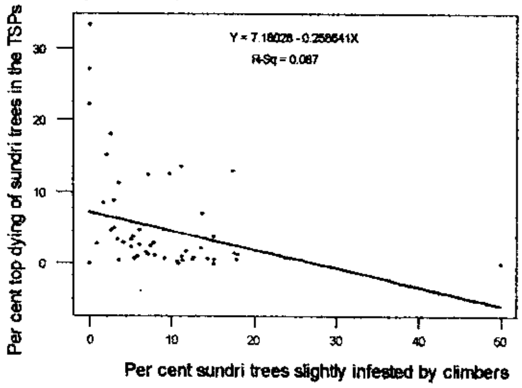


Fig. 42: Relationship between per cent of sundri trees slightly infested by climbers and per cent of sundri trees affected by top dying based on data of 1180 Temporary Sample Plots (TSPs) falling in 55 compartments in the Sundarbans



5.3 EDAPHIC ASPECTS

5.3.1 Data of soil samples collected in October 2001, January and June 2002 and January 2003

The soil samples collected as per schedule mentioned in the methodology were analyzed in respect of electrical conductivity (EC), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), total available nitrogen (N), phosphorus (P), manganese (Mn) and zinc (Zn) in Soil Resources Development Regional Laboratory, Daulatpur, Khulna on payment of usual charges. The detailed of the soil data of October 2001, January 2002, June 2002 and January 2003 are provided in **Appendix 32, 33, 34 and 35** and summarized in Tables 117, 118, 119 and 120 respectively.

Table 117: Summary of analysis of 71 soil samples collected at two soil depths from 36 sample plots during the first field trip (3.10.2001 to 13.10.2001) in the Sundarbans.

Top dying severity category	No. of compart ments	No. of sample plots	Soil depths (in cm)	EC	Na	Ca	Mg	K	Total N	P	Mn	Zn
				(dS/m)		(meq/100g)			%		µg/gm	
None	6	9	0-30	11.26	1.65	6.23	8.51	1.70	0.10	12.40	28.38	1.03
None	5	9	60-90	10.65	1.66	6.30	8.46	1.67	0.09	11.73	27.91	1.00
Slight	6	9	0-30	10.70	1.59	6.71	8.32	1.64	0.10	12.08	28.56	1.03
Slight	6	9	60-90	10.85	1.60	6.76	8.35	1.64	0.10	12.00	28.30	1.00
Moderate	6	9	0-30	10.36	1.48	7.31	8.07	1.59	0.10	11.62	28.93	0.95
Moderate	6	9	60-90	11.18	1.56	7.85	8.26	1.63	0.10	12.41	28.59	0.97
Severe	4	9	0-30	10.65	1.66	6.30	8.46	1.67	0.09	11.73	27.91	1.00
Severe	4	9	60-90	11.15	1.63	6.59	8.35	1.61	0.09	11.99	27.84	1.03
Notes:	EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total nitrogen ; P = Phosphorus; Mn = Manganese; Zn = Zinc;											

Table 118: Summary of analysis of 72 soil samples collected at two soil depths from 36 sample plots during the second field trip (21.1.2002 to 31.1.2002) in the Sundarbans.

Top dying severity category	No. of com part ments	No. of sample plots	Soil depth in cm	EC	Na	Ca	Mg	K	Total N	P	Mn	Zn	Clay	Silt	Sand
				(dS/m)		(meq/100g)			%		µg/gm		%	%	%
None	6	9	0-10	14.86	19.61	6.83	9.77	1.23	0.10	11.47	40.78	2.63	32.94	61.99	5.07
None	5	9	10-30	14.58	19.05	6.69	9.68	1.24	0.10	10.83	42.67	2.57	33.22	61.57	5.22
Slight	6	9	0-10	14.31	18.59	7.16	9.50	1.19	0.10	11.10	40.81	2.68	32.45	62.70	4.85
Slight	6	9	10-30	14.35	18.70	7.29	9.53	1.20	0.11	11.29	40.96	2.62	32.49	62.60	4.91
Moderate	6	9	0-10	14.00	18.45	7.64	9.35	1.17	0.09	10.80	39.85	2.43	32.23	63.21	4.56
Moderate	6	9	10-30	14.63	19.20	8.35	9.52	1.19	0.09	11.72	40.27	2.47	32.41	62.79	4.80
Severe	4	9	0-10	14.04	18.62	6.96	9.51	1.23	0.09	10.62	41.75	2.73	32.88	61.90	5.21
Severe	4	9	10-30	13.84	18.34	7.14	9.39	1.22	0.08	11.15	41.14	2.55	32.83	62.28	4.89
Notes:	EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available nitrogen ; P = Phosphorus; Mn = Manganese; Zn = Zinc;														

Table 119: Summary of analyses of 62 soil samples collected during the third field trip in June 2002 from 0-10 cm soil depth from 36 sample plots at 12 landings in 10 compartments in the Sundarbans.

Sclass	No. of Plots	EC	Na	Ca	Mg	K	N	P	Mn	Zn	S	B	Clay	Silt	Sand
		(dS/m)	(meq/100g)				%	µg/gm					%	%	%
None	9	17.86	4.71	12.26	8.29	1.41	0.09	8.77	8.89	1.15	202.2	3.12	46.99	43.61	9.40
Slight	9	19.90	5.02	8.39	8.81	1.50	0.09	8.11	8.67	1.14	293.1	3.84	47.92	40.98	11.09
Moderate	9	18.88	4.94	6.98	8.95	1.54	6.11	9.28	8.10	1.38	249.6	3.88	50.64	40.40	1.38
Severe	9	18.13	5.10	8.81	8.68	1.39	0.10	9.25	7.25	1.06	240.8	3.12	47.56	43.50	8.94
Notes:	EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available nitrogen ; P = Phosphorus; Mn = Manganese; Zn = Zinc; S= Sulphur; B = Boron														

Table 120: Summary of analyses of 62 soil samples collected during the fourth field trip in January 2003 from 0-10 cm soil depth from 36 sample plots at 12 landings in 10 compartments the Sundarbans.

Top dying severity	No. of sample plots	Calcium	Magnesium	Nitrogen	Sulphur	Manganese	Zinc
		meq/100g	meq/100g	%	µg/gm	µg/gm	µg/gm
None	9	8.75	7.83	0.1300	208.54	7.57	0.72
Slight	9	9.89	7.75	0.1100	196.37	8.61	0.62
Moderate	9	16.47	7.17	0.1000	221.71	8.79	0.64
Severe	9	12.22	7.56	0.1100	229.10	9.77	0.77
OSP Healthy	5	11.05	6.95	0.0792	222.04	7.18	0.58
Notes:	meq/100g = milliequivalent per 100 gm of soil; µg/gm = micro gram per gram of soil ; OSP Healthy = Out side the experimental 36 sample plots from compartment nos. 54, 44 and 8 from healthy sundri areas.						

A comparison of the mean of each of the none soil parameters from soil samples collected in October 2001 (i.e. first trip) and in January 2002 (second trip) is provided in **Table 121**. The extent of change of nine soil parameters, which took place by January 2002 over that of October 2001, was determined as per cent change in two soil depths at each of the four top dying severity classes (i.e. none, slight, moderate and severe) were obtained for each of the nine soil parameters. These data are provided in **Table 122.**

Table 121: Comparison of the soil parameters of soils collected during the first trip in October 2001 and that during the second trip in January 2002 in the Sundarbans.

Top dying severity category	Soil collected during	EC	Na	Ca	Mg	K	Total available N	P	Mn	Zn	Clay	Silt	Sand
		(dS/m)	(meq/100g)				%	(meq/100g)			%	%	%
None	First trip	12.15	8.40	7.00	8.83	1.46	0.10	11.55	33.41	1.62	-	-	-
None	Second trip	14.16	18.63	7.45	9.44	1.19	0.10	10.96	40.44	2.51	32.45	62.8	4.75
Slight	First trip	97.47	8.40	7.29	8.86	1.45	0.10	11.60	33.36	1.61	-	-	-
Slight	Second trip	14.56	19.18	6.96	9.65	1.22	0.10	11.24	40.97	2.62	32.83	62.16	5.01
Moderate	First trip	11.93	7.34	7.11	8.73	1.48	0.10	11.61	32.75	1.52	-	-	-
Moderate	Second trip	13.93	18.46	7.16	9.41	1.18	0.09	10.7	40.84	2.64	32.5	62.79	4.7
Severe	First trip	10.65	1.56	9.94	8.85	1.59	0.11	12.90	28.25	0.89	-	-	-
Severe	Second trip	14.47	19.01	7.77	9.53	1.2	0.10	11.41	40.71	2.54	32.56	62.56	4.88

Notes: First trip was undertaken during 3.10.2001 to 13.10.2001 October 2001; Second trip was undertaken during 21.1.2002 to 31.1.2002; - = no determination of clay, silt and sand was made with soil samples of the first trip. EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total nitrogen ; P = Phosphorus; Mn = Manganese; Zn = Zinc;

Table 122: Per cent change in the levels of nine nutrients in January 2002 over that in October 2001 in 36 sample plots 9 falling in each of none, slight, moderate and severe top dying of sundri in the Sundarbans.

Severity	EC	Na	Ca	Mg	K	N	P	Mn	Zn
None	131.97	1188.48	109.63	114.81	72.35	100.00	92.50	143.69	255.34
None	136.90	1147.59	106.19	114.42	74.25	111.11	92.33	152.88	257.00
Slight	133.74	1169.18	106.71	114.18	72.56	100.00	91.89	142.89	260.19
Slight	132.26	1168.75	107.84	114.13	73.17	110.00	94.08	144.73	262.00
Moderate	135.14	1246.62	104.51	115.86	73.58	90.00	92.94	137.75	255.79
Moderate	130.86	1230.77	106.37	115.25	73.01	90.00	94.44	140.85	254.64
Severe	131.83	1121.69	110.48	112.41	73.65	100.00	90.54	149.59	273.00
Severe	124.13	1125.15	108.35	112.46	75.78	88.89	92.99	147.77	247.57

Analyses of trend of change of each of the nine soil parameters (i.e. K, P, Mn, Ca, Mg, EC, Mn, Zn and Na) have been done. The ranked mean data have been tested through DMRT (Duncan, 1955) and summarized in **Table 123**.

Table 123: Comparison of the per cent change of nine soil nutrient in January 2002 over that in October 2001 in 36 sample plots in the Sundarbans.

K	P	Mn	Ca	Mg	EC	Mn	Zn	Na
73.55	92.71	98.75	107.51	114.19	132.10	145.02	258.19	1174.78
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		------	------	------				
					------	------		

Notes: Means underscored by the same dotted line are not significantly different.; EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available Nitrogen ; P = Phosphorus; Mn = Manganese; Zn = Zinc

It can be seen from Table 123 that the highest increase (over the level of October 2001), took place in case of Sodium (Na) in which case 1174.78 per cent increase occurred. Second highest increase of 258.19% occurred in case of zinc. This was followed by 145.02% increase of manganese, 132.10% of Electrical Conductivity and 114.19% of Magnesium, 107.51% of Calcium. Manganese decreased to 98.75%, Phosphorus to 92.71% and Potassium to 72.55% with reference to the level of October 2001.

5.3.2 Correlation of 12 soil parameters with per cent top dying of sundri trees

Correlation between electrical conductivity at field capacity and per cent sundri trees affected by top dying were not significant for any of the four top dying category with respect to any soil depth or any period of data collection except for the slight category at soil depth of 10-30 cm during January 2002 where a significant negative correlation (*P*= 0.035) existed between electrical conductivity and per cent top dying affected trees (**Table 124**).

Table 124: Correlation coefficients between Electrical Conductivity (EC, dsm/m2) of soil samples collected from sites of four different severity classes of top dying of sundri and percent sundri trees affected by top dying. Figures in bold are levels of probabilities at which correlation is significant and x means insignificant correlation.

Soil sample identity	Severity class			
	None	Slight	Moderate	Severe
October 2001, 0-10 cm depth	0.206	-0.067	0.271	-0.189
	x	x	x	x
October 2001, 10-30 cm depth	0.183	-0.366	0.173	-0.0127
	x	x	x	x
January 2002, 0-10 cm depth	0.145	-0.365	0.159	-0.017
	x	x	x	x
January 2002, 10-30 cm depth	0.029	-0.431	0.305	-0.026
	x	**0.035**	x	x

In most cases, correlation between various soil parameters and per cent sundri trees affected by top dying were not significant for any top dying category with respect to any soil depth or any period of data collection. However, for data collected during October 2001 with respect to both the soil depths Calcium content in no top dying (i.e. none) category had a significant positive (*P*=0.0001) correlation (r = 0.8943) with per cent top dying affected sundri trees. Magnesium content in the moderate top dying category had a significant (*P*=0.01, 0.027 negative correlation (r = -0.80 and – 0.073) for soil depths of 0-30 cm and 60-90 cm and with per cent top dying of sundri trees in the sample plots (**Table 125**).

Table 125: Correlation coefficients between soil parameters of soil samples collected in October 2001 **from sites of four different severity classes of top dying of sundri and percent sundri trees affected by top dying. Figures in bold are levels of probabilities at which correlation is significant and x means insignificant correlation.**

Soil depth (cm)	Severity class	Soil chemical element								
		EC	Na	Ca	Mg	K	Total N	P	Mn	Zn
		dS/m	(meq/100g)			%	µg/gm		µg/gm	µg/gm
0-10	None	-0.189	-0.18	0.8943	-0.21	-0.117	-0.22	-0.118	-0.085	-0.161
		x	x	**0.0001**	x	x	x	x	x	x
	Slight	0.432	0.031	0.1195	0.008	0.135	-0.39	0.1619	-0.447	0.364
		x	x	x	x	x	x	x	x	x
	Moderate	0.421	-0.14	0.188	-0.8	-0.479	-0.07	0.1327	-0.564	-0.096
		x	x	x	**0.01**	x	x	x	x	x
	Severe	-0.236	-0.08	-0.098	-0.37	-0.155	-0.22	-0.366	-0.643	0.197
		x	x	x	x	x	x	x	x	x
10-30	None	-0.189	-0.18	0.8943	-0.21	-0.117	-0.22	-0.118	-0.085	-0.161
		x	x	**0.0001**	x	x	x	x	x	x
	Slight	0.242	0.218	-0.397	-0.37	-0.215	-0.55	-0.211	-0.378	-0.090
		x	x	x	x	x	x	x	x	x
	Moderate	0.172	-0.07	0.1821	-0.73	-0.423	-0.09	0.5217	-0.621	0.016
		x	x	x	**0.027**	x	x	x	x	x
	Severe	-0.236	-0.08	-0.098	-0.37	-0.155	-0.22	-0.366	-0.643	0.197
		x	x	x	x	x	x	x	x	x

Notes: EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available Nitrogen; P = Phosphorus; Mn = Manganese; Zn = Zinc ; dS/m = deci Siemen per meter; meq/100g = milliequivalent per 100 gm of soil; % = percentage; µg/gm = micro gram per gram of soil.

Interestingly, however, Ca content in the none category of the soil samples collected during January 2002 at soil depth 10-30 cm was negatively (P= 0.016) correlated (r = -0.765) with percent top dying affected sundri trees. For soil samples collected during the same period, P and Zn contents in the soil of the moderate category at soil depth 10-30 cm were found to have significant (P= 0.034 for P and P= 0.023 for Zn) positive correlation (r = 0.7047 for Phosphorus and r = 0.739 for Zinc) with per cent top dying of sundri trees in the sample plots. A highly significant (P= 0.0001) negative correlation (r = -0.872) occurred between Manganese content and percent top dying of sundri trees in the sample plots (**Table 126**).

Table 126: Correlation coefficients between soil parameters of soil samples collected in January 2002 from sites of four different severity classes of top dying of sundri and percent sundri trees affected by top dying. Figures in bold are levels of probabilities at which correlation significant and x means insignificant correlation.

Soil depth (cm)	Severity class	Soil chemical element											
		EC	Na	Ca	Mg	K	Total N	P	Mn	Zn	Clay	Silt	Sand
		dS/m	(meq/100g)				%	µg/gm			%		
0-10	None	0.611	0.466	-0.604	0.516	0.611	0.331	0.222	0.401	0.647	0.407	-0.476	0.636
		x	x	x	x	x	x	x	x	x	x	x	x
	Slight	0.136	0.1	-0.264	-0.08	0.303	-0.6	-0.072	0.16	0.090	-0.054	-0.002	0.146
		x	x	x	x	x	x	x	x	x	x	x	x
	Moderate	0.247	0.114	0.037	-0.52	-0.235	-0.51	-0.46	-0.533	0.550	-0.629	0.556	0.187
		x	x	x	x	x	x	x	x	x	x	x	x
	Severe	0.198	0.237	-0.28	-0.18	0.145	0.233	-0.299	-0.289	0.230	0.059	-0.025	-0.156
		x	x	x	x	x	x	x	x	x	x	x	x
10-30	None	0.415	0.559	-0.765	0.182	0.57	0.513	-0.115	0.262	0.257	0.343	-0.436	0.573
		x	x	**0.016**	x	x	x	x	x	x	x	x	x
	Slight	-0.203	-0.37	-0.358	-0.32	0.13	-0.5	-0.144	-0.03	0.036	-0.044	-0.020	0.144
		x	x	x	x	x	x	x	x	x	x	x	x
	Moderate	0.255	0.191	-0.084	-0.49	-0.199	-0.58	0.704	-0.872	0.739	-0.628	0.576	-0.152
		x	x	x	x	x	x	**0.034**	**0.0001**	**0.023**	x	x	x
	Severe	-0.117	0.259	-0.3	-0.33	0.195	0.337	0.239	-0.094	0.037	0.083	-0.009	-0.486
		x	x	x	x	x	x	x	x	x	x	x	x

Notes: EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available Nitrogen; P = Phosphorus; Mn = Manganese; Zn = Zinc ; dS/m = deci Siemen per meter; meq/100g = milliequivalent per 100 gm of soil; % = per cent; µg/gm = micro gram per gram of soil

Correlation analysis of the levels of each of the nine parameters from soil data obtained from analysis of soil samples collected in October 2001 (vide Table 117) and those of 12 soil parameters from two soil depths from soil samples collected in January 2002 (vide Table 118) were then tested. It may be mentioned here that the two soil depths for October 2001 soil collection were 0-30 cm and 60-90 cm , but for January 2002 collection the soil depths were 0-10 cm and 10-30 cm. The soil parameters in case of October 2001 were EC, Na, Ca, Mg, K, N, P, Mn and Zn but that in case of January 2002 in addition to these 9, there were clay, silt and sand contents as well. The top dying per cent of each of the 36 sample plots were determined by examining all the sundri trees for top dying in each of the sample plots and then expressing as per cent of total sundri of a particular sample plot Correlation coefficients (r-values) were determined by using a programme of Minitab and were also rechecked by using another programme of Microsoft Excel.

The summarized data of correlation coefficients for the two soil depths for nine soil parameters from October 2001 and for 12 soil parameters from soils of January 2002 have been presented in **Table 127.**

Table 127: Summary of calculation of Correlation Coefficients (r) between (a) each of soil parameters from 36 soil samples each collected at two depths during October 2001 and January 2002 and (b) per cent top dying of sundri prevailing in 36 sample plots in the Sundarbans.

Soil parameters	Correlation Coefficient (r) of nine soil parameters from two soil depths of 36 soil samples collected during 3.10.2001 to 13.10.2001 and per cent top dying of sundri trees in 36 sample plots					Correlation Coefficient (r) of twelve soil parameters from two soil depths of 36 soil samples collected during January 2002 and per cent top dying of sundri trees in 36 sample plots			
		Soil from 0-30 cm depth	Soil from 60-90 cm depth	df	Significance	Soil from 0-10 cm depth	Soil from 10-30 cm depth	Df	Significance
EC	r =	0.080322	-0.16971	35	Insig.	0.020602	0.06590022	35	Insig.
Na	r =	0.060001	0.001778	35	Insig.	0.014066	-8.90479E-05	35	Insig.
Ca	r =	0.246066	0.254266	35	Insig.	0.253869	0.220311014	35	Insig.
Mg	r =	0.006538	0.07747	35	Insig.	-0.22592	-0.158545774	35	Insig.
K	r =	0.102427	0.07838	35	Insig.	0.066285	0.088632096	35	Insig.
N	r =	0.050229	0.227914	35	Insig.	0.204713	0.035225000	35	Insig.
P	r =	0.162129	0.098335	35	Insig.	0.029088	0.187875645	35	Insig.
Mn	r =	**-0.41475***	**-0.3682***	**35**	**Sig.**	0.083566	-0.088573022	35	Insig.
Zn	r =	-0.17346	-0.31992	35	Insig.	0.08837	0.084304478	35	Insig.
Clay	r =					-0.17717	-0.204868793	35	Insig.
Silt	r =					0.092361	0.189923169	35	Insig.
Sand	r =					**-0.326080**	-0.010449354	35	**Sig.**

Notes: * = Significant at a probability label of 5% i.e. P = 0.05; Insig. = Insignificant; Sig. = Significant, which means that there is significant variation in a particular soil parameters (e.g. Mn) from the four top dying severity classes i.e. none (i.e. no op dying), slight, moderate and severe top dying of sundri. ; EC = Electrical Conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available Nitrogen; P = Phosphorus; Mn = Manganese; Zn = Zinc;

Table 127 reveals that the levels of Manganese in the soil collected in October 2001 from both soil depths (0-30 cm =D1 depth and 60-90 cm = D2 depth) showed significant negative correlation with per cent top dying of sundri trees in the 36 sample plots. This clearly suggests that a deficiency of Manganese is associated with the development of top dying of sundri. However, Manganese levels in soils samples collected in January 2002 showed only insignificant correlation with per cent top dying data of 36 sample plots. This is because of the fact that Manganese levels had under gone 145.02 per cent increase in January 2002 over that of October 2001 as is evident from Table 123. The levels of sand per cent in soil depth of 0-10 cm (D1 depth) collected in January 2002 showed significant negative correlation (r = -0. 3260800, with 35 df) with per cent top dying data from 36 sample plots (vide Table 127).

This clearly suggests that as sand content in soil depth of 0-10 cm decrease top dying per cent increase. Thus reduced level of sand content is associated with the development of top dying of sundri. Therefore examination of the trend of occurrence of Manganese from D1 and D2 depths of October 2001 and sand from D1 depth of January 2002 in the sample plots having none, slight, moderate and severe top dying of sundri were further examined by way of drawing regression line of best fit and calculating the regression equation using a programme of Minitab. These are shown in Figs. 43 and 44 for Manganese from depth D1 and D2 and in Fig. 45 for sand from D1 depth respectively.

Fig. 43: Relationship between per cent top dying of sundri trees and levels of Manganese at 0-30 cm (i.e. D1) depth of soils colleceted in October 2001 from 36 sample plots in 12 landings in 10 compartments in the Sundarbans.

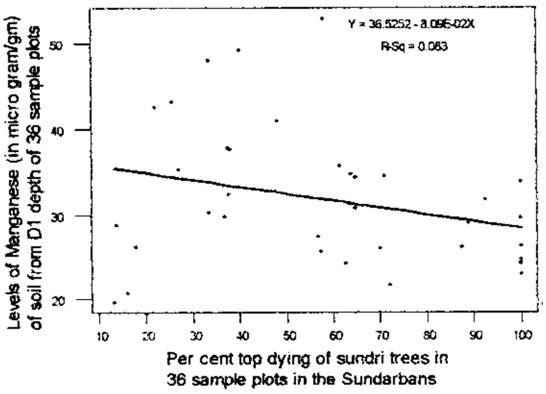


Fig. 44: Relationship between per cent top dying of sundri trees and levels of Manganese at 60-90 cm (i.e. D2) depth of soils colleceted in October 2001 from 36 sample plots at 12landings in 10 compartments in the Sundarbans.

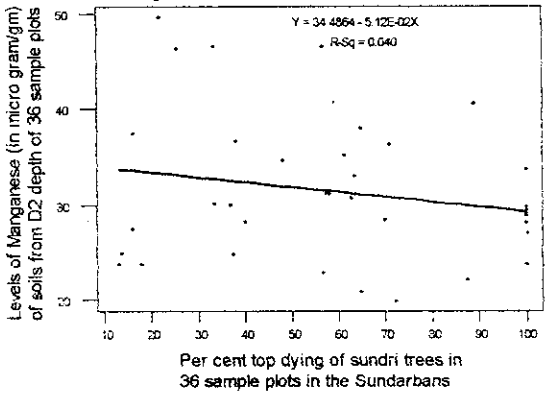
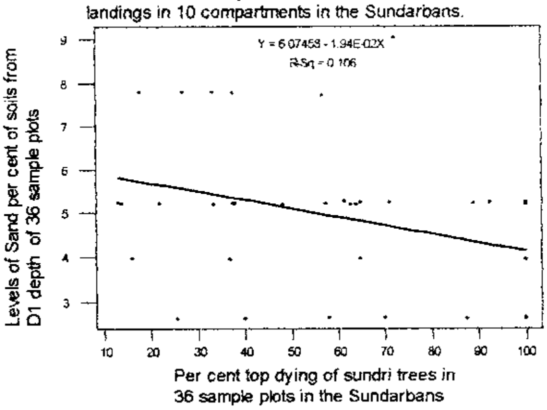


Fig. 45: Relationship between per cent top dying of sundri trees and levels of sand at 0-10 cm (i.e. D1) depth of soils collected in January 2002 from 36 sample plots at 12 landings in 10 compartments in the Sundarbans.



In case of soil samples collected in June 2002, P, S, Br and Mn contents in the soil of the none category at soil depth 0-10 cm were found to have significant (P= 0.001 for P and S) and P= 0.01 for Mn and B) positive correlation (r = 0.739 for Phosphorus, r = 0.558 for S, r = 0.457 for B and r = 0.497 for Mn, and r = 0.350 for clay) with per cent top dying of sundri trees in the sample plots. Similarly, in case of slightly top dying sample plots Ca, S, Zn and sand content of soil showed significant (P= 0.05) correlation (r = 0.450 for Ca, r = -0.33389 for Mg, r = -0.580 for S, r = -0.517 for Zn and r = 0.355 for sand) with per cent top dying of sundri trees in the sample plots. In case of severe top dying sample plots Na, K, S and silt content of soil showed significant (P= 0.05) correlation (r = 0.350 for Na, r = 0.432 for K, r = 0.412 for S, r = -0.387 for silt content of soil) with per cent top dying of sundri trees in the sample plots. This is shown in **Table 128.** Summary of calculation of Correlation Coefficients (r) between (a) each of 14 soil parameters from 36 soil samples collected at 0-10 cm depths in June 2002 and January 2003 and (b) per cent top dying of sundri prevailing in 36 sample plots in the Sundarbans have been provided in **Table 129.**

Table 128: Correlation coefficients between soil parameters of soil samples collected in June 2002 from sites of four different severity classes of top dying of sundri and percent sundri trees affected by top dying. Figures in bold are levels of probabilities at which correlation is significant and x means insignificant correlation.

Sclass	EC	Na	Ca	Mg	K	N	P	S	B	Mn	Zn	Sand	Silt	Clay
	dS/m	meq/ 100g	meq/ 100g	meq/ 100g	meq/ 100g	%	µg/gm	µg/gm	µg/gm	µg/gm	µg/gm	%	%	%
None	0.406	0.263	0.036	0.338	0.247	0.316	0.739	0.558	0.457	0.497	-0.166	-0.342	-0.197	0.350
	P=0.05	x	**x**	x	x	x	**P=0.001**	**P=0.001**	**P=0.01**	**P=0.01**	x	x	x	P=0.05
	-0.271	-0.232	0.450	-0.389	-0.346	0.132	-0.048	-0.580	-0.255	-0.072	-0.517	0.355	0.042	-0.335
Slight	x	x	**P=0.01**	P=0.05	x	x	x	**P=0.01**	x	x	**P=0.01**	**P=0.05**	x	x
Moder	-0.724	-0.257	-0.127	-0.329	-0.112	-0.145	0.052	-0.135	-0.347	0.032	0.057	-0.260	0.194	0.167
ate		x	x	**x**	x	x	x	x	x	x	x	x	x	x
	0.170	0.350	0.036	0.225	0.432	-0.009	0.213	0.412	0.265	0.250	-0.202	0.146	-0.387	0.229
Severe	x	**P=0.05**	x	x	P=0.01	x	x	**P=0.01**	x	x	x	x	**P=0.05**	x

Notes: EC = Electrical conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available Nitrogen; P = Phosphorus; S= Sulphur; B= Boron; Mn = Manganese; Zn= Zinc ;dS/m = deci Siemen per meter; meq/100g = milliequivalent per 100 gm of soil; % = percentage; µg/gm = micro gram per gram of soil,

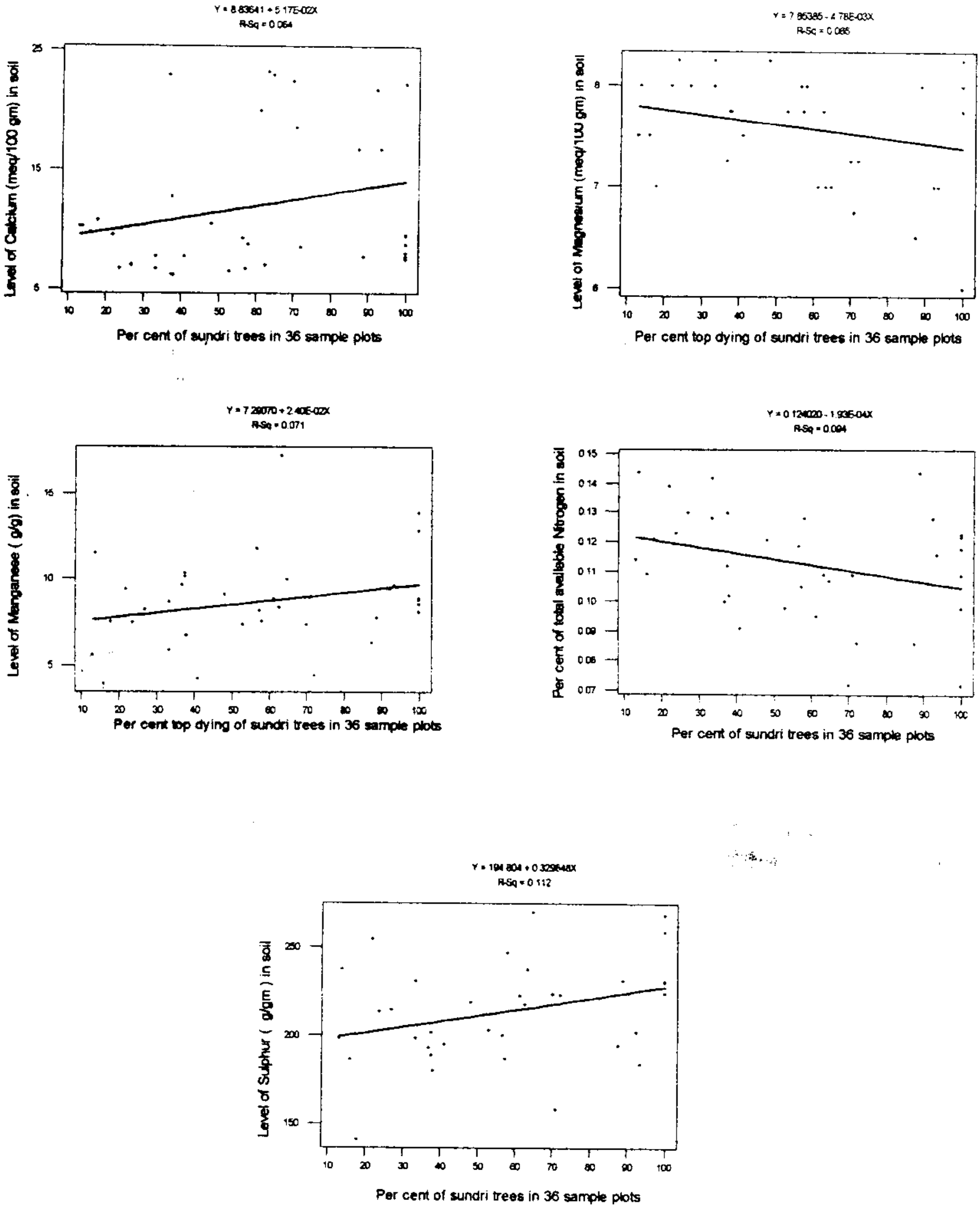
Table 129: Summary of calculation of Correlation Coefficients (r) between (a) each of 14 soil parameters from 36 soil samples collected at 0-10 cm depths in June 2002 and January 2003 and (b) per cent top dying of sundri prevailing in 36 sample plots in the Sundarbans.

Soil parameters	Soil sample collected in June 2002				Soil sample collected in January 2003			
	CC	Calculated value of CC	df	Significance of CC	CC	Calculated value of CC	df	Significance
EC	r =	-0.065	70	Insignificant	-	-	-	-
Na	r =	0.095	70	Insignificant	-	-	-	-
Ca	r =	-0.218	70	Insignificant	r =	0.253	70	Significant
Mg	r =	0.103	70	Insignificant	r =	-0.254	70	Significant
K	r =	-0.002	70	Insignificant	r =	-	-	-
N	r =	0.022	70	Insignificant	r =	-0.307	70	Significant
P	r =	0.154	70	Insignificant		-	-	-
Mn	r =	-0.204	70	Insignificant	r =	0.267	70	Significant
Zn	r =	-0.074	70	Insignificant	r =	0.100	70	Insignificant
S	r =	0.076	70	Insignificant	r =	0.334	70	Significant
Br	r =	-0.011	70	Insignificant	-	-	-	-
Clay	r =	0.034	70	Insignificant	-	-	-	-
Silt	r =	0.016	70	Insignificant	-	-	-	-
Sand	r =	-0.051	70	Insignificant	-	-	-	-

Notes: Significant means that there is significant variation in the mean value of a particular soil parameters (e.g. Mn) from the four top dying severity classes i.e. none (i.e. no op dying), slight, moderate and severe top dying of sundri. ; EC = Electrical Conductivity; Na = Sodium; Ca = Calcium; Mg = Magnesium; K = Potassium; N = Total available Nitrogen; P = Phosphorus; Mn = Manganese; Zn = Zinc; S = Sulphur; Br = Boron; CC = Correlation Coefficient (Pearson's); - = no data.

Table 129 reveals significant correlation coefficient between levels of Ca, Mg, Mn, N and S with per cent top dying of sundri trees. But in case of January 2002 data, significant correlation coefficients were obtained only in case of sand per cent and per cent top dying of sundri, while in case of October 2001 data significant negative correlation coefficient was obtained in case of Mn only (vide Table 105). Therefore, examination of the trend of occurrence of Ca, Mg, Mn, N and S from January 2003 soil data were further examined by way of drawing regression line of best fit and calculation of the regression equation by using a programme of the Minitab Release 11.2 32 Bit. These are shown in **Fig. 46.**

Fig. 46. Relationship between per cent top dying of sundri trees and levels of Calcium, Magnesium, Manganese, Nitrogen and Sulphur in soil samples at 0-10 cm depth collected in January 2003 from 36 sample plots at 12 landings in 10 compartments in the Sundarbans.



5.3.3 Analysis of variance of soil data from four top dying severity classes

The summarized data of all the soil parameters (vide Tables 117 and 118) were obtained from 72 soil samples consisting of 9 samples from each of none, slight, moderate and severe top dying samples plots from each of two soil depths. That means we had 18 number of data from two soil depths for each of nine soil parameters of October 2001 and 12 soil parameters of January 2002 from none (i.e. no top dying), slight, moderate and severe top dying of sundri from the Sundarbans. The two soil depths for October 2001 soil samples were 0-30 cm and 60-90 cm while that for January 2002 soil samples were 0-10 cm and 10-30 cm. The 72 values for of each of the soil parameters included 36 samples from each of two soil depths. Hence variance analysis for each of nine parameters from October 2001 soil samples and 12 soil parameters for January 2002 soil samples were carried out to compare the variability of each parameter from the two soil depths. The results of variance analysis for October 2001 and January 2002 soil samples have been summarized in **Tables 130** and **131** respectively.

Table 130: Comparison of nine soil parameters at two soil depths from 36 soil samples collected from 36 sample plots collected in October 2001, nine from each of none, slight, moderate and severe top dying of sundri in the Sundarbans.

Soil parameters	No. of soil samples from each soil depths	Mean values at two soil depths		F value	df	Difference being	
		0-30 cm	60-90 cm			Significant	Insignificant
EC (in dS/m)	36	9.78	11.78	4.233325	1, 69	✔	
Na (in meq/100g)	36	1.53	1.49	0.084459	1, 69		✔
Ca (in meq/100g)	36	9.56	8.84	0.274657	1, 69		✔
Mg (in meq/100g)	36	8.06	8.30	0.418869	1, 69		✔
K (in meq/100g)	36	1.39	1.54	1.884472	1, 69		✔
N (in per cent)	36	0.102	0.100	0.049675	1, 69		✔
P (in µg/gm)	36	12.30	11.75	0.322173	1, 69		✔
Mn (in µg/gm)	36	33.18	32.18	0.166304	1, 69		✔
Zn (in µg/gm)	36	0.998	0.999	0.000116	1, 69		✔

Table 131: Comparison of nine soil parameters at two soil depths from 36 soil samples collected from 36 sample plots collected in January 2002, nine from each of none, slight, moderate and severe top dying of sundri in the Sundarbans.

Soil parameters	No. of soil samples from each soil depths	Mean values at two soil depths		F value	df	Difference being	
		0-10 cm	10-30 cm			Significant	Insignificant
EC (in dS/m)	36	15.55	14.07	3.51	1, 70		✔
Na (in meq/100g)	36	17.20	18.37	0.92	1, 70		✔
Ca (in meq/100g)	36	10.67	8.15	2.49	1, 70		✔
Mg (in meq/100g)	36	9.99	9.93	0.01	1, 70		✔
K (in meq/100g)	36	1.08	1.14	0.42	1, 70		✔
N (in per cent)	36	0.12	0.10	0.76	1, 70		✔
P (in µg/gm)	36	13.49	11.14	2.73	1, 70		✔
Mn (in µg/gm)	36	44.95	41.35	1.13	1, 70		✔
Zn (in µg/gm)	36	1.98	2.01	0.01	1, 70		✔

Table 130 reveals that mean electrical conductivity (EC) value of 11.78 (dS/m) from soil depth 60-90 cm showed significant variation from that of 9.78 (dS/m) from 0-30 cm as is evident from F value of 4.23 (with 1, and 69 df). The mean values of remaining soil parameters i.e. Na, Ca, Mg, K, N, P, Mn and Zn from 0- 30 cm and 60-90 cm did not show any significant variations as are indicated by only insignificant F-values for all these parameters (vide Table 130). Since, there was no significant difference in mean values of these soil parameters, except EC, from two soil depths in January 2002 soil samples were collected from upto 30 cm (i.e. 0-10 cm and 10-30 cm). Table 131 reveals that when a particular soil parameter are compared there is no significant difference in mean values of any of the twelve soil parameters from the soil samples collected at two soil depths during the second trip in January 2002.

In the soil data for each of the parameters there were 18 data from each of the four top dying severity categories (i.e. none, slight, moderate and severe). Hence in the next step for each of the soil parameters (nine for the first trip and twelve for the second trip) from the four top dying severity categories were compared by analysis of variance using a programme of the SAS System. The results of the analysis of soil parameters from the soil samples of the first trip in October 2001 and second trip in January 2002 have been summarized in **Tables 132 and 133.**

Table 132: Summary of variance analysis showing F-value, degree of freedom (df), level of probability, significance of the probability of variations and mean values of nine soil parameters from each of four top dying severity classes from 71 soil samples collected in October 2001 from 36 sample plots at 12 landings in 10 compartments in the Sundarbans.

Soil parameters	Mean value from four top dying severity classes				F-value	df	Probability	Significance	
	None	Slight	Moderate	Severe				Significant	Insignificant
EC (in dS/m)	10.96	10.78	10.77	10.90	2.37	3, 67	P = 0.0783		✓
Na (in meq/100g)	1.66	1.60	1.52	1.65	0.36	3, 67	P = 0.7792		✓
Ca (in meq/100g)	8.19	7.54	12.49	8.56	4.00	3, 67	P = 0.0111	✓	
Mg (in meq/100g)	8.23	8.13	7.39	9.12	2.92	3, 67	P = 0.0402	✓	✓
K (in meq/100g)	1.69	1.64	1.61	1.64	1.02	3, 67	P = 0.3881		✓
N (in per cent)	0.10	0.10	0.10	0.09	1.81	3, 67	P = 0.1541		✓
P (in µg/gm)	12.07	12.04	12.02	11.86	0.51	3, 67	P = 0.6747		✓
Mn (in µg/gm)	37.59	32.68	30.34	28.80	3.49	3, 67	P = 0.0204	✓	
Zn (in µg/gm)	19.78	21.80	13.60	15.74	5.33	3, 67	P = 0.0024	✓	

Table 133: Summary of variance analysis showing F-value, degree of freedom (df), level of probability, significance of the probability of variations and mean values of nine soil parameters from each of four top dying severity classes from 72 soil samples collected in January 2002 from 36 sample plots at 12 landings in 10 compartments in the Sundarbans.

Soil parameters	Mean value from four top dying severity classes				F-value	df	Probability	Significance	
	None	Slight	Moderate	Severe				Significant	Insignificant
EC (in dS/m)	14.72	14.33	14.32	13.94	0.28	3, 68	P = 0.8422		✔
Na (in meq/100g)	19.33	18.65	18.83	18.48	0.38	3, 68	P = 0.7672		✔
Ca (in meq/100g)	6.19	7.47	13.67	10.31	4.96	3, 68	P = 0.0036	✔	
Mg (in meq/100g)	11.94	9.50	8.25	10.14	3.85	3, 68	P = 0.0132	✔	✔
K (in meq/100g)	1.24	1.20	1.18	1.23	1.46	3, 68	P = 0.2325		✔
N (in per cent)	0.10	0.11	0.09	0.09	1.18	3, 68	P = 0.3252		✔
P (in µg/gm)	11.15	11.20	11.26	10.89	0.90	3, 68	P = 0.4474		✔
Mn (in µg/gm)	41.75	40.89	40.06	41.45	1.44	3, 68	P = 0.2376		✔
Zn (in µg/gm)	25.74	52.16	29.46	36.12	3.86	3, 68	P = 0.0131	✔	
Clay (%)	33.08	32.47	32.32	32.86	2.11	3, 68	P = 0.1066		✔
Silt (%)	61.78	62.65	63.00	62.09	2.33	3, 68	P = 0.0825		✔
Sand (%)	5.15	4.88	4.68	5.05	0.27	3, 68	P = 0.2664		✔

It is seen from Table 132 that significant variations were found in case of Ca, Mg, Mn and Zn among the sample plots of the four top dying severity categories (i.e. none, slight, moderate and severe) in soil samples collected in October 2001. But in case of data from soils collected in January 2002, significant variations in the levels of Calcium, Magnesium and Zinc occurred among the sample plots falling in none, slight, moderate and severe top dying categories (Table 133). Therefore, further analysis of all data of these four parameters of October 2001 and of three parameters of January 2002 were carried out and presented in **Tables 134, 135, 136, 137, 138, 139 and 140** respectively.

Table 134: Comparison of Calcium levels of 71 soil samples collected during October 2001 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	147.4	8.188889	21.00987		
Slight	18	135.75	7.541667	41.50919		
Moderate	18	224.85	12.49167	40.27743		
Severe	17	145.6	8.564706	21.67118		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	269.7936	3	89.93122	2.877072	0.042465	2.741572
Within Groups	2094.279	67	31.2579			
Total	2364.073	70				

Table 135 : Comparison of Magnesium levels of 71 soils samples collected during October 2001 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	146.25	8.125	2.469191		
Slight	18	146.25	8.125	1.190662		
Moderate	18	133	7.388889	0.842222		
Severe	17	155.1	9.123529	4.295349		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	26.50808	3	8.836026	4.075521	0.01015	2.741572
Within Groups	145.2609	67	2.168073			
Total	171.7689	70				

Table 136 : Comparison of Manganese levels of 71 soil samples collected during October 2001 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	676.66	37.59222	248.2369		
Slight	18	588.32	32.68444	43.57038		
Moderate	18	546.06	30.33667	32.11211		
Severe	17	489.6	28.8	40.4598		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	783.6728	3	261.2243	2.844014	0.04419	2.741572
Within Groups	6153.987	67	91.85055			
Total	6937.66	70				

Table 137: Comparison of Zinc levels of 71 soil samples collected during October 2001 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	19.78	1.098889	0.133105		
Slight	18	21.8	1.211111	0.403634		
Moderate	18	13.6	0.755556	0.018238		
Severe	17	15.74	0.925882	0.065638		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.147098	3	0.715699	4.573459	0.005657	2.741572
Within Groups	10.48481	67	0.15649			
Total	12.63191	70				

Table 138: Comparison of Calcium levels of 72 soil samples collected during January 2002 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	111.5	6.194444	5.827614		
Slight	18	134.5	7.472222	33.80801		
Moderate	18	246	13.66667	53.26471		
Severe	18	185.5	10.30556	66.94526		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	594.2882	3	198.0961	4.957186	0.003593	2.739498
Within Groups	2717.375	68	39.9614			
Total	3311.663	71				

Table 139: Comparison of Magnesium levels of soils collected during January 2002 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	215	11.94444	22.64379		
Slight	18	171	9.5	2.029412		
Moderate	18	148.5	8.25	3.242647		
Severe	18	182.5	10.13889	16.37663		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	127.9028	3	42.63426	3.850248	0.013186	2.739498
Within Groups	752.9722	68	11.07312			
Total	880.875	71				

Table 140 : Comparison of Zinc levels of soils collected during January 2002 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	Count	Sum	Average	Variance		
None	18	25.74	1.43	0.255165		
Slight	18	52.16	2.897778	4.195054		
Moderate	18	29.46	1.636667	0.536388		
Severe	18	36.12	2.006667	2.8576		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	22.72953	3	7.576511	3.863494	0.01298	2.739498
Within Groups	133.3515	68	1.961052			
Total	156.081	71				

Duncan's Multiple Range Tests (Duncan, 1955) were then carried out locate the mean values responsible for significant difference in case of Ca, Mg, Mn and Zn of October 2001 from soil samples having none, slight, moderate and severe top dying of sundri, from nine sample plots of each of the four categories of top dying, in the Sundarbans are provided in **Table 141**. Similarly, comparison of the mean values of Ca, Mg and Zn of January 2002 obtained from soil samples having none, slight, moderate and severe top dying of sundri, from nine sample plots of each of the four categories of top dying, in the Sundarbans are provided in **Table 142**.

Table 141: Summary of Duncan's Multiple Range Tests of the mean values (in meq/100 gm) of Calcium, Magnesium, Manganese and Zinc from analysis of soil samples collected in October 2001 from 36 sample plots, nine falling in each of no top dying i.e. none (N), slight (S), moderate (M) and severe (Se) top dying of sundri in the Sundarbans

Parameter	Mean values with mention of the status of top dying (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters				Comment on the results obtained after Duncan's Multiple range test of the means following the method of Duncan (1955)
Calcium	6.72(N)	7.54(S)	9.94 (Se)	12.49(M)	Calcium (Ca) was the lowest in the no top dying sample plots (i.e. None) and the highest in case of sites having moderate top dying. Calcium of moderate top dying sample plots was significantly higher (P=0.05) than none, slight and severe top dying sample plots. Underscored means were not significantly different.
Magnesium	7.39(M)	8.13(S)	8.36(N)	8.85(Se)	Magnesium (Mg) content of soils from Severe top dying sample plots was significantly higher (P = 0.05) than that of sample plots having moderate, slight and no top dying (none) sample plots. Underscored means were not significantly different.
Manganese	28.25(Se)	31.45(M)	32.68(S)	38.69(N)	Manganese was the lowest in the sample plots having severe top dying and the highest in case of sample plots having no top dying (i.e. none) of sundri. No top dying sample plots had significantly higher (P = 0.05) level of manganese as compared to all the remaining sites. Underscored means were not significantly different.
Zinc (Zn)	0.76(M)	0.89(Se)	1.20(S)	1.44(N)	Zinc (Zn) content of soils from slight and none top dying sample plots were significantly higher (P = 0.05) than that of moderate and severe top dying sites. Underscored means were not significantly different.

Table 142: Summary of Duncan's Multiple Range Tests of the mean values (in meq/100 gm) of Calcium, Magnesium and Zinc from analysis of soil samples collected in January 2002 from 36 sample plots, nine falling in each of no top dying i.e. none (N), slight (S), moderate (M) and severe (Se) top dying of sundri in the Sundarbans.

Parameter	Mean values with mention of the status of top dying (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters				Comment on the results obtained after Duncan's Multiple range test of the means following the method of Duncan (1955)
Calcium	6.19(N)	7.47(S)	10.31(Se)	13.67(M)	Calcium (Ca) was the lowest in the no top dying sample plots (i.e. None) and the highest in case of sites having moderate top dying. Calcium of moderate top dying sample plots was significantly higher (P=0.05) than none, slight and severe top dying sample plots. Underscored means were not significantly different.
Magnesium	8.25(M)	9.50(S)	10.14(Se)	11.94(N)	Magnesium (Mg) content of soils from no top dying (i.e. none) sample plots was significantly higher (P = 0.05) than that of sample plots having moderate, slight and severe top dying sample plots. Underscored means were not significantly different.
Zinc	1.43(N)	1.64(M)	2.01(Se)	2.89(S)	Zinc (Zn) contents of soils from severe and slight top dying sample plots were significantly higher (P = 0.05) than that of no top dying (i.e. none) and moderate top dying sites. Underscored means were not significantly different.

Table 138 reveals that moderate top dying of sundri sample plots had significantly (P=0.01) higher levels of Calcium as compared to no top dying and slight top dying sample plots. There were no significant variations in Calcium contents from severe and moderate top dying sample plots of sundri in the Sundarbans. This finding was based on Calcium data obtained from analysis of soil samples collected in October 2001. Exactly the same pattern was obtained from Calcium data obtained from soil samples collected in January 2002 (vide Table 142).

There were no significant variations in the Magnesium contents in soils of moderate, slight and none (i.e. no top dying) sample plots, and also among slight, none and severe top dying sample plots. Although severe top dying sample plots had significantly higher (P=0.05) levels of Magnesium as compared to moderate top dying sample plots, but clearly there is no systematic pattern (vide Table 139). This was also by and large true in case of Magnesium data generated from soil samples collected in January 2002. In case of January 2002 data the highest Mg level was obtained from no top dying sample plots (vide Table 142), while in case of Mg data from October 2001 soil samples the highest level was obtained from severe top dying sample plots (Table 144). The trend of Mg level in moderate and slight top dying sample plots was, however, the same in the data of both October 2001 and January 2002 (Table 141). Thus it is suggested that neither deficiency nor toxicity of Magnesium may be responsible for top dying of sundri in the Sundarbans.

Table 140 reveals that in October 2001 soil data from no top dying (i.e. none) sample plots had significantly higher (P=0.01) levels of Manganese (Mn) as compared to severe top dying sample plots and significantly higher (P= 0.05) levels of Mn as compared to moderate top dying sample plots. There were no significant variations in case of severe, moderate and slight top dying sample plots and between slight and no top dying sample plots (Table 141). The data clearly reveal that a consistent pattern of occurrence of Mn has been obtained from the soils in which the highest level of Mn was obtained from the soil of no top dying sample plots, while progressively decreasing levels of Mn were obtained from soils of slight, moderate and severe top dying sample plots (Table 136 and 141). This clearly suggests that a deficiency of Mn is most likely associated with the development of top dying of sundri in the Sundarbans. Manganese data generated from soil samples collected in January 2002 did not show any significant difference in the mean value of Manganese from the sample plots from none, slight, moderate and severe top dying of sundri as we found an insignificant F-value of 1.44 with 3 and 68 degrees of freedom. Thus the findings on Mn from data generated from soils collected in October 2001 is not supported from the data on Mn from soil collected in January 2002. It is suggested that because of 145.02 per cent increase in the level of Manganese in soil collected in January 2002 over the level of October 2001 (vide Table 122) is primarily responsible for the deviation in the results of Manganese from soils collected in January 2002.

Table 137 reveals that Zinc (Zn) deficiency is most likely associated with the development of top dying of sundri. None (i.e. no top dying) sample plots had the highest levels of Zn while moderate top dying sample plots had the lowest Zn levels. There were no significant variations in case of none and slight; and moderate and severe top dying sample plots. Thus, like Mn, Zn deficiency is also most likely responsible for the development of top dying of sundri (Table 137 and 141). However, data of Zinc level in soils collected in January 2002 soils from no top dying (i.e. none) sample plots had the lowest zinc level and the highest in case of severe top dying sample plots (Table 140). It is suggested that because of 258.19 per cent increase in the level of Zinc in soil collected in January 2002 over the level of October 2001 (vide Table 123) in primarily responsible for the deviation in the results of Zinc from soils collected in January 2002.

During the third field trip in June 2002 in all 66 soil sample were collected from two soil depths 0-10 cm and 20-30 cm. from the sample plots. These soil samples were analyzed for Electrical Conductivity (EC), Sodium (Na), Calcium (Ca), Magnesium (Mg), Potassium (K), total Nitrogen (N), Phosphorus (P), Sulphur (S), Boron (B), Manganese (MN) and Zinc (Zn), % sand, % silt and % clay. In the next step for each of the 14 soil parameters of June 2002 from the four top dying severity categories were compared by analysis of variance using a programme of the SAS System. The results of the analysis of soil data of June 2002 have been summarized in **Table 143**

Table 143 : Summary of variance analysis showing F-value, degree of freedom (df), level of probability, significance of the probability of variations and mean values of 14 soil parameters from each of four top dying severity classes from 66 soil samples collected in June 2002 from 36 sample plots at 12 landings in 10 compartments in the Sundarbans.

Soil parameters	Mean value from four top dying severity classes				F-value	df	Probability	Significance	
	None	Slight	Moderate	Severe				Significant	Insignificant
EC (in dS/m)	17.86	19.90	18.88	18.13	0.47	3, 62	0.7074		✓
Na(in meq/100g)	4.71	5.02	4.94	5.10	0.31	3, 62	0.8194		✓
Ca(in meq/100g)	12.26	8.39	6.98	8.81	3.91	3, 62	0.0369	✓	
Mg(in eq/100g)	8.29	8.81	8.95	8.68	0.76	3, 62	0.5224		✓
K (in meq/100g)	1.41	1.50	1.54	1.39	0.23	3, 62	0.8754		✓
N (in per cent)	0.09	0.09	6.11	0.10	1.28	3, 62	0.2888		✓
P (in µg/gm)	8.77	8.11	9.28	9.25	0.35	3, 62	0.7898		✓
S (in µg/gm)	202.23	293.07	249.62	240.79	3.46	3, 62	0.0207	✓	
Br (in µg/gm)	3.12	3.84	3.88	3.12	1.67	3, 62	0.1840		✓
Mn (in µg/gm)	8.89	8.67	8.10	7.25	1.28	3, 62	0.2889		✓
Zn (in µg/gm)	1.15	1.14	1.38	1.06	1.43	3, 62	0.2427		✓
Clay (%)	46.99	47.92	50.64	47.56	2.03	3, 62	0.1190		✓
Silt (%)	43.61	40.98	40.40	43.50	2.08	3, 62	0.1128		✓
Sand (%)	9.40	11.09	8.96	8.94	0.73	3, 62	0.5413		✓

Since Calcium levels in soil samples from none, slight, moderate and severe top dying sample plots showed significant F-value of 3.91 with 3 and 62 df (P =0.05) while sulphur levels in the soil samples showed significant F-value of 3.46 with 3 and 62 df (P = 0.05), further analysis of the data were done. These are provided in **Tables 144, 145, 146 and 147.**

Table 144: Analysis of variance of the data of Calcium levels from 66 soil samples collected in June 2002 from 36 sample plots, nine from each of none, slight, moderate and severe top dying of sundri at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
None	18	220.75	12.26389	31.26818		
Slight	16	134.3	8.39375	25.93896		
Moderate	14	97.75	6.982143	13.42754		
Severe	18	158.5	8.805556	13.54085		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	250.7844	3	83.59481	3.910438	0.012687	2.752969
Within Groups	1325.396	62	21.37735			
Total	1576.18	65				

Table 145: Comparison of the four levels of Calcium in soil samples collected in June 2002 from **66 soil samples collected from none, slight, moderate and severe top dying sundri affected** sample plots in the Sundarbans.

Moderate	Slight	Severe	None
6.98	8.39	8.81	12.26
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Note: No top dying i.e. none sample plots had significantly higher levels of Calcium as compared to slight, moderate and severe top dying sample plots. There was no significant variations in mean values of Calcium from slight, moderate and severe top dying sample plots in June 2002.			

Table 145 reveals that calcium level in none (i.e. no top dying sample plots) had significantly (P =0.05) higher level as compared to slight, moderate and severe top dying sample plots, but there existed only insignificant variation among slight, moderate and severe top dying sample plots. Therefore clear trend of calcium deficiency and occurrence of top dying of sundri existed during June 2002.

Table 146: Analysis of variance of the data of Sulphur levels from 66 soil samples collected in June 2002 from 36 sample plots, nine from each of none, slight, moderate and severe top dying of sundri at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
None	18	3640.07	202.2261	3315.38		
Slight	16	4689.14	293.0713	10983.2		
Moderate	14	3494.65	249.6179	6124.146		
Severe	18	4334.27	240.7928	7083.847		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	70521.44	3	23507.15	3.460638	0.021542	2.752969
Within Groups	421148.7	62	6792.721			
Total	491670.1	65				

Table 147: Comparison of the four levels of Sulphur in soil samples collected in June 2002 from 66 soil samples from none, slight, moderate and severe top dying sundri affected sample plots in the Sundarbans.

None	Severe	Moderate	Slight
202.23	240.79	249.62	293.07
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Notes: Means underscored by the same dotted line are not significantly different.			

Table 147 reveals that sulphur level in slight top dying sample plots had significantly (P =0.05) higher level as compared to none (i.e. no top dying) sample plots, but there existed only insignificant variation among slight, moderate and severe top dying sample plots. Similarly for none, moderate and severe top dying sample plots. Therefore no clear trend of sulphur toxicity and occurrence of top dying of sundri exists.

During the fourth trip in January 2003 76 soil samples were collected but analyses were done for 36 soil samples from 36 sample plots and five from healthy sundri stands in high saline areas of compartment 8, 44 and 54. These five samples have been designated as Extra samples. The samples were analyzed for Calcium, Magnesium, Manganese, Zinc, Nitrogen and Sulphur. The soil data for soil samples collected in January 2003 have been summarized in Table 120. The soil data were analyzed for each of the six soil parameters from each of the four top dying severity classes (i.e. none, slight, moderate and severe) and summarized in **Table 148.**

Table 148: Summary of variance analysis showing F-value, degree of freedom (df), level of probability, significance of the probability of variations and mean values of 6 soil parameters from each of four top dying severity classes from 36 soil samples collected in January 2003 at 12 landings in 10 compartments in the Sundarbans.

Soil parameters	Mean value from four top dying severity classes				F-value	df	Probability	Significance	
	None	Slight	Moderate	Severe				Significant	Insignificant
Ca(in meq/100g)	8.75	9.89	16.47	12.22	3.64	3, 32	0.0229	✔	
Mg(in eq/100g)	7.83	7.75	7.17	7.56	3.14	3, 32	0.0389	✔	
N (in per cent)	0.13	0.11	0.10	0.11	4.68	3, 32	0.0080	✔	
S (in µg/gm)	208.54	196.37	221.71	229.10	2.61	3, 32	0.0685		✔
Mn (in µg/gm)	7.57	8.61	8.79	9.77	1.07	3, 32	0.3738		✔
Zn (in µg/gm)	0.72	0.62	0.64	0.77	1.92	3, 32	0.1456		✔

Since significant variations in the mean values existed in case of Ca, Mg and N levels in soils collected in January 2003, further analysis were carried out. These are provided in **Tables 149, 150, 151 and 152.**

Table 149: Comparison of the Calcium levels of 36 soil samples collected in January 2003 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites, at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
None	9	78.75	8.75	2.765625		
Slight	9	89	9.89	29.15799		
Moderate	9	148.25	16.47	44.30382		
Severe	9	110	12.22	38.92882		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	314.625	3	104.875	3.642877	0.022877	2.901118
Within Groups	921.25	32	28.78906			
Total	1235.875	35				

Table 150: Comparison of the Magnesium levels of 36 soil samples collected in January 2003 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites, at 12 landings in 10 compartments in the Sundarbans.

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
None	9	70.5	7.83	0.171875		
Slight	9	69.75	7.75	0.078125		
Moderate	9	64.5	7.17	0.21875		
Severe	9	68	7.56	0.543403		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.380208	3	0.793403	3.135506	0.038937	2.901118
Within Groups	8.097222	32	0.253038			
Total	10.47743	35				

Table 151: Comparison of the Nitrogen levels of 36 soil samples collected in January 2003 from 36 sample plots, nine from each of none, slight, moderate and severe top dying affected sites at 12 landings in 10 compartments in the Sundarbans

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
None	9	1.15	0.12778	0.000151		
Slight	9	0.978	0.10867	0.000161		
Moderate	9	0.904	0.10044	0.000292		
Severe	9	1.03	0.11444	0.000413		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.003571	3	0.00119	4.682895	0.008022	2.901118
Within Groups	0.008134	32	0.000254			
Total	0.011705	35				

Table 152: Summary of Duncan's Multiple Range Tests of the mean values (in meq/100 gm) of Calcium and Magnesium and Nitrogen (in %) from analysis of soil samples collected in January 2003 from 36 sample plots, nine falling in each of no top dying i.e. none (N), slight (S), moderate (M) and severe (Se) top dying of sundri in the Sundarbans.

Parameter	Mean values with mention of the status of top dying (in parenthesis) from where the soil samples were taken. Figures are in the usual unit for all the parameters				Comment on the results obtained after Duncan's Multiple range test of the means following the method of Duncan (1955)
Calcium	8.75(N)	9.89(S)	12.22(Se)	16.47(M)	Calcium (Ca) was the lowest in the no top dying sample plots (i.e. None) and the highest in case of sites having moderate top dying. Calcium of moderate top dying sample plots was significantly higher (P=0.05) than none and slight top dying sample plots. Underscored means were not significantly different.
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			----------	----------	
Magnesium	7.17(M)	7.56(Se)	7.75(S)	7.83(N)	Magnesium (Mg) content of soils from None (i. e. no top dying) and slight top dying sample plots were significantly higher (P = 0.05) than that of sample plots having moderate top dying sample plots. Underscored means were not significantly different.
	----------	----------			
		----------	----------	----------	
Nitrogen	0. 100(M)	0.109(S)	0.114(Se)	0.128(N)	Nitrogen contents was the lowest in the sample plots having moderate top dying and the highest in case of sample plots having no top dying (i.e. none) of sundri. No top dying sample plots had significantly higher (P = 0.05) level of Nitrogen as compared to moderate and slight top dying sites. Underscored means were not significantly different.
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A further comparison of the levels of Calcium, Magnesium and Nitrogen from the soil samples collected in January 2003 from the 36 sample plots having none, slight, moderate and severe top dying from 10 selected compartments were also made with data of these parameters obtained from 5 soil samples collected from five spots having healthy sundri trees in more saline areas of compartments 54, 44 and 8. The samples from these three compartments have been designated as OSP healthy group. The results of the comparison of the ranked mean values of Calcium, Magnesium and Nitrogen from sample plots having none, slight, moderate and severe and also plots of OSP healthy are provided in **Tables 153, 154 and 155**.

Table 153: Comparison of the ranked mean values of Calcium from none, slight, moderate and severe top dying sample plots and also five samples from outside sample plots in high saline areas having very healthy sundri trees in compartments 54, 44 and 8 in the Sundarbans.

None	Slight	OSP Healthy	Severe	Moderate
8.75	9.89	11.05	12.22	16.47
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		----------	----------	----------
Notes: Mean underscored by the same dotted line are not statistically different.				

Table 154: Comparison of the ranked mean values of Magnesium from none, slight, moderate and severe top dying sample plots and also five samples from outside sample plots in high saline areas having very healthy sundri trees in compartments 54, 44 and 8 in the Sundarbans.

OSP Healthy	Moderate	Severe	Slight	None
6.95	7.17	7.56	7.75	7.83
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	----------	----------	----------	----------
Notes: Means underscored by the same dotted line are not significantly different.				

Table 155: Comparison of the ranked mean values of Nitrogen from none, slight, moderate and severe top dying sample plots and also five samples from outside sample plots in high saline areas having very healthy sundri trees in compartments 54, 44 and 8 in the Sundarbans.

OSP Healthy	Moderate	Slight	Severe	None
0.0792	0.1004	0.1087	0.1144	0.1278
	----------	----------	----------	----------
		----------	----------	
Notes: Means underscored by the same dotted line are not significantly different.				

It is found that from Table 153 that soil samples from moderate top dying sample plots had significantly (P =0.05) higher levels of Calcium in soils collected in January 2003 as compared to none and slight top dying sample plots, but there was no significant difference in levels of Calcium in soils from OSP healthy, severe and moderate top dying sample plots.
The level of Magnesium in the soils of the none and slight top dying sample plots had significantly higher (P = 0.05) levels of Magnesium as compared to that from the OSP healthy spots (vide Table 154).

It is very evident from Tables 155 that the level of Nitrogen in the soil samples collected from high saline spots in compartments 54, 44 and 8 was the lowest , while the Nitrogen level in the soils of sample plots having none, slight, moderate and severe top dying of sundri all had significantly (P =0.05) higher level of Nitrogen as compared to OSP healthy sites soil samples. **It is, therefore, suggested that the very low levels of Nitrogen and Magnesium in presence high soil salinity coupled with very little fresh water flush from the uplands in those area are the primary reasons for very stunted growth of sundri in such areas in the south western parts of the Sundarbans.**

5.3.4 Comparison of nutrient elements in Sundarbans soils and sundri leaf samples

In January 2003 while soil samples were collected from top 0-10 cm depth from very close to the tree of different categories (i.e. healthy (H), sundri trees having only dying or dead twigs (G2), sundri trees having dying or dead major branches but less than 50% of the crown affected (G3), sundri trees having dying or dead major branches but more than 50% of the crown affected (G4) leaf samples were also collected from the mid crown zone of each tree. The object was to examine the nutrient status in soil and also in the leaf and to find out whether there exist any correlation or pattern and whether that had any indication or role in the development of top dying.

Each leaf sample and soil sample was given the same sample number. Shortly after collection the leaf samples were spread on labeled polyethylene bag kept opened in the Motor Launch to dry out any moisture. Then after bring them in the laboratory in Khulna University, the leaf samples were dried by exposing at room temperature for about two weeks. Then the leaf samples from 36 trees from 36 sample plots were grinded in a grinder, kept in labeled polyethylene bag. Then one sample from each of the 36 sample plots and 5 samples from outside the sample plots but from healthy sundri areas in compartment 54, 44 and 8 were also included. Each of the 41 leaf samples were then analyzed for Calcium (Ca), magnesium (Mg), Nitrogen (N), Manganese (Mn) and Zinc (Zn) contents in an **Atomic Absorption Spectrophotometer** in the Department of soil, Water and Environment in Dhaka University. The results of analysis of the 41 leaf samples are provided in **Appendix 36.**

The results of soil analysis data have been provided in **Appendix 35**. It can be seen from Appendix 35 that from soil analysis the values of Calcium and Magnesium have been expressed in meq/100 gm of soil (Milli equivalent per 100 gm of soil), Manganese and Zinc as μg/gm (microgram per gram of soil). But in case of leaf analysis Calcium, Magnesium and Nitrogen have been expressed as %, Manganese and Zinc as μg/gm. Thus we can see that the values of soil analysis and leaf analysis were in the same unit in case of Nitrogen, Manganese and Zinc, but different in case of Calcium and Magnesium.

Therefore, to convert meq/100 gm data of Calcium to %, the meq/100 gm values of Calcium were first multiplied by molecular weight of Calcium which is 12 to get values in mg/100 gm, then that value was divided by 1000 to values of Calcium in per cent. Similarly, to convert meq/100 gm data of Magnesium to %, the meq/100 gm values of Magnesium were first multiplied by molecular weight of Magnesium which is 20 to get values in mg/100 gm, then that value was divided by 1000 to values of Magnesium in per cent. It may, however, be mentioned here that meq/100 gm refers to mg of Hydrogen per 100 gm of soil. Thus the values of Ca, Mg, N, Mn and Zn from soil analysis and leaf analysis were brought on uniform values. Incorporating multiplied by molecular weight of Magnesium which is 20 to get values in mg/100 gm, then that value was divided by 1000 to values of Magnesium in per cent. It may, however, be mentioned here that meq/100 gm refers to mg of Hydrogen per 100 gm of soil. Thus the values of Ca, Mg, N, Mn and Zn from soil analysis and leaf analysis were brought on uniform values. Incorporating such conversions, the results of analysis of 41 soil samples and 41 leaf samples collected in January 2003 from 13 compartments in the Sundarbans have been provided in **Appendix 37.**

5.3.4.1 Correlation between levels of Calcium, Magnesium, Nitrogen, Manganese and Zinc from soil and sundri leaf samples in relation to top dying of sundri

In the first place correlation analysis of the levels of Calcium, Magnesium, Nitrogen, Manganese and Zinc from soil and leaf samples were examined. Then correlation of both soil and leaf nutrients from 36 samples plots were carried out with per cent top dying of sundri trees in 36 sample plots. The results of these correlation analyses have been summarized in **Table 156.**

Table 156: Correlation coefficients (r) between levels of Calcium, magnesium, Nitrogen, Manganese and Zinc from soil samples and sundri leaf samples collected in January 2003 and also between nutrient levels and percent sundri trees in 36 sample plots.

Correlation analysis done between		**df**	
Calcium levels from soil and leaf	r = -0.005	40	Insig.
Magnesium levels from soil and leaf	r = -0.337	40	Sig.
Nitrogen levels from soil and leaf	r = 0.064	40	Insig.
Manganese levels from soil and leaf	r = -0.015	40	Insig
Zinc levels from soil and leaf	r = -0.077	40	Insig.
Calcium level from soil and % top dying of sundri trees	r = 0.253	35	Insig.
Calcium level from sundri leaf and % top dying of sundri trees	r = -0.038	35	Insig.
Magnesium level from soil and % top dying of sundri trees	r = -0.254	35	Insig.
Magnesium level from sundri leaf and % top dying of sundri trees	r = 0.207	35	Insig.
Nitrogen level from soil and % top dying of sundri trees	r = -0.307	35	Sig.
Nitrogen level from sundri leaf and % top dying of sundri trees	r = -0.013	35	Insig.
Manganese level from soil and % top dying of sundri trees	r = 0.267	35	Insig.
Manganese level from sundri leaf and % top dying of sundri trees	r = 0.157	35	Insig.
Zinc level from soil and % top dying of sundri trees	r = 0.100	35	Insig.
Zinc level from sundri leaf and % top dying of sundri trees	r = -0.047	35	Insig.
Notes: Sig = Significant at a probability label of 5% i.e. P = 0.05; Insig. = Insignificant ; df = degrees of freedom			

Table 156 reveals that only significant correlation existed between Manganese levels from soil and sundri leaf samples, and also between nitrogen levels from soil and per cent top dying of sundri trees in the sample plots. In all other cases only insignificant correlation existed.

In the next step the ratio between Calcium, Magnesium, Nitrogen, Manganese and Zinc in sundri leaf and that present in soil were calculated from the data provided in **Appendix 37** and summarized in **Table 157.**

Table 157: Mean values of Calcium, Magnesium, Nitrogen, Manganese and Zinc in soil and sundri leaf collected in January 2003 from 36 sample plots from 10 compartments and five healthy sundri areas from compartment nos. 54, 44 and 8 and the ratio between individual levels in leaf and soil.

Parameters	Mean value	Ratio between level in leaf and in soil	
Calcium level from soil (in %)	0.234756	3.65	
Calcium level from sundri leaf (in %)	0.856220		
Magnesium level from soil (in %)	0.09	60.51	
Magnesium level from sundri leaf (in %)	5.446024		
Nitrogen level from soil (in %)	0.108732	10.13	
Nitrogen level from sundri leaf (in %)	1.101951		
Manganese level from soil (in %)	0.00851	82.83	
Manganese level from sundri leaf (in %)	0.704888		
Zinc level from soil (in %)	0.000676	340.90	
Zinc level from sundri leaf (in %)	0.230448		

Table 157 shows that the levels of Calcium, Magnesium, Nitrogen, Managese and Zinc were higher in leaf as compared to the corresponding level in soil. The level of Calcium in sundri leaf sample was 3.65 times higher than that in the soil. Similarly, level of Magnesium, Nitrogen, Manganese and Zinc were 60.51, 10.13, 82.83 and 340.90 times higher than the levels of Magnesium, Nitrogen, Manganese and Zinc present in the soil respectively.

5.3.4.2 Analysis of variance of levels of Calcium, Magnesium, Nitrogen, Manganese and Zinc from soil and sundri leaf samples in rerlation to top dying of sundri

The mean values of each of Calcium, Magnesium, Nitrogen, Manganese and Zinc levels in each from soil and sundri leaf samples from the four top dying severity classes (i.e. none, slight, moderate and severe) and also from five samples from outside sample plots in areas of high salinity in compartment nos. 54, 44 and 8 and their comparison by way of analysis of variance **have been** summarized in **Table 158**, while the detailed results of analysis are provided in **Appendix 38.**

Table 158: Summary of variance analysis showing mean, F-value, level of probability, significance of the probability of variations of five parameters from both soil and leaf from each of four top dying severity classes (none, slight, moderate and severe) and from healthy sundri areas outside sample plots (HSAOSP) from 41 soil samples and sundri leaf samples collected in January 2003 from 36 sample plots at 12 landings in 10 compartments and also from compartment nos. 8, 44 and 54 (for HSAOSP) in the Sundarbans.

Soil parameters	Mean value from four top dying severity classes				HSAOSP	F value	Probability	Significance	
	None	Slight	Moderate	Severe				Significant	Insignificant
Soil Calcium %	0.1750	0.1978	0.3294	0.2444	0.2210	2.67	0.0475	✔	
Leaf Calcium %	0.9237	0.9180	0.8298	0.9046	0.5842	1.32	0.2815		✔
Soil Mg %	0.0940	0.0930	0.0860	0.0907	0.0834	3.68	0.0129	✔	
Leaf Mg %	0.3270	0.3156	0.3289	0.3690	0.2866	1.97	0.1196		✔
Soil Nitrogen %	0.1278	0.1087	0.1004	0.1144	0.0792	8.49	0.0001	✔	
Leaf Nitrogen %	1.0767	1.1600	1.1089	1.1222	0.9940	0.68	0.6117		✔
Soil Manganese %	0.0076	0.0086	0.0088	0.0098	0.0072	1.18	.0.3365		✔
Leaf Mn %	0.6567	0.8382	0.4523	1.1300	0.2409	1.97	0.1200		✔
Soil Zinc %	0.0007	0.0006	0.0006	0.0008	0.0006	2.10	0.1010		✔
Leaf Zinc %	0.2971	0.1635	0.1987	0.2376	0.2754	1.09	0.3741		✔
Notes: Mg = Magnesium, Mn = Manganese									

Table 158 shows that in case of the soil Managanese and Zinc, and levels of Calcium, Magnesium, Nitrogen, Manganese and Zinc from 41 sundri leaf samples occurrence of only insignificant F values in all cases clearly indicate that the mean values from none, slight, moderate, severe and HSAOSP of each of the five nutrient elements do differ only insignificantly. This suggests that from sundri trees used and accumulated more or less the same amount of each of Calcium, Magnesium, Nitrogen, Managanese and Zinc in the leaf from areas of none, slight, moderate, severe sundri top dying and also from areas of healthy sundri areas of high soil salinity in compartmentss 8, 44 and 54 (HSAOSP). Table 155 shows that significant variation in the mean values of Calcium, Magnesium and Nitrogen from 41 soil samples (i.e. 36 samples from 36 sample plots and 5 soil samples from outside the sample plots but from healthy sundri areas of high saline areas in compartments 54, 44 and 8) exist among the mean values from none, slight, moderate, severe and HSAOSP as are indicated by significant F values. Therefore, further analysis of the ranked mean values of Calcium, Magnesium and Manganese from soil samples from areas of none, slight, moderate, severe and HSAOSP were made to find out the trend of the occurrence and for their mutual comparison. This is summarized in Table 159.

Table 159: Summary of Duncan's Multiple Range Tests of the mean values (in %) of Calcium, Magnesium , Nitrogen, Manganese and Zinc from analysis of soil samples collected in January 2003 from 36 sample plots, nine falling in each of no top dying i.e. none (N), slight (S), moderate (M) and severe (Se) top dying of sundri and five from healthy sundri areas from outside the sample plots (HSAOSP) in high saline areas of compartment nos. 8, 44 and 54 in the Sundarbans.

Parameter	Mean values in per cent				
Calcium	0.175 (N)	0.197778 (S)	0.221 (H)	0.24444 (Se)	0.329444 (M)
			------------	------------	------------
Magnesium	0.0834 (H)	0.086 (M)	0.090667 (Se)	0.093 (S)	0.094 (N)
			------------	------------	------------
Nitrogen	0.0792 (H)	0.100444 (M)	0.108667 (S)	0.114444 (Se)	0.127778 (N)
		------------	------------	------------	
				------------	------------

Notes: N = None, S = Slight, M = Moderate and Se = Severe top dying sample plots. H = healthy sundri areas from outside sample plots from high saline areas of compartments 6, 44 and 54.; Means underscored by the same dotted line are not significantly different.

Table 159 reveals that the level of Calcium in soil in January 2003 in severe and moderate top dying sample plots and also in healthy sundri areas in high saline compartments did not differ significantly. These were significantly higher than Calcium level from areas of slight top dying sample plots and the latter was in turn significantly higher than no top dying sample plots (i.e. none). In case of Magnesium severe, slight and none sample plots did not differ significantly, but these were significantly higher than moderate top dying sample plots, and the latter in turn was significantly higher than in healthy sundri areas in high saline compartments. In case of Nitrogen levels only insignificant differ occurred among the levels of Nitrogen from severe and none, and among slight, moderate and severe top dying sample plots. The levels of nitrogen from none, slight, moderate and severe top dying sample plots were all significantly higher than the level of nitrogen in areas of high saline compartments nos. 8, 44 and 54. It is thus evident that the low levels of Nitrogen in high saline areas of compartment nos. 8, 44 and 54 coupled with the known impact of high salinity in affecting nutrient uptake (Chhabra, 1988; Rowell, 1988; Hayward, 1956) are the primary reasons for reduced growth of sundri in the south western areas of the Sundarbans in the saline water zone.

Salinity affect nutrient availability by modifying the retention, fixation and transformation of the nutrients in soils; interfering with the uptake and/or absorption of nutrients by roots due to ionic competition; reduced root growth; and disturbing metabolism of nutrient within the plants mainly due to water stress and thus reducing their effectiveness (Chhabra, 1988).

Rowell (1988) reported that the status of nitrogen in saline soil is around 0.01 per cent. Nitrogen becomes limiting fertility in saline soil. pH is generally 6.0 to 8.4 and at such high pH phosphate, iron, zinc and manganese become unavailable and soil surface become water unstable, thus bringing about conditions of water permeability and poor aeration results.

It is commonly accepted that soil solutions with high salt concentrations cause growth retardation in most plants (Hayward, 1956).

5.3.4.3 Summarized soil and sundri leaf nutrient data in relation to top dying of sundri

The summarized data of soil and sundri leaf samples collected from 36 sample plots are provided in **Table 160** for easy comparison and comprehension.

Table 160: Summarized soil and sundri leaf nutrient data generated in relation top dying of sundri in the Sundarbans during the present study.

A) Soil from Sundarbans		None	Slight	Moderate	Severe	F-value	df	
Sodium (meq/100 gm)	October 2001	1.66	1.60	1.52	1.65	0.36	3, 67	Insig.
	January 2002	19.33	18.65	18.83	18.48	0.38	3, 68	Insig.
	June 2002	4.71	5.02	4.94	5.10	0.31	3, 62	Insig.
Electrical Conductivity (dS/m)	October 2001	10.96	10.78	10.77	10.90	2.37	3, 67	Insig.
	January 2002	14.72	14.33	14.32	13.94	0.28	3, 68	Insig.
	June 2002	17.86	19.90	18.88	18.13	0.47	3, 62	Insig.
Calcium (meq/100 gm)	October 2001	8.19	7.54	12.49	8.56	4.00	3, 67	* *
	January 2002	6.19	7.47	13.67	10.31	3.85	3, 68	* *
	June 2002	12.26	8.39	6.98	8.81	3.91	3, 62	*
	January 2003	8.75	9.89	16.47	12.22	3.64	3, 32	*
Magnesium (meq/100 gm)	October 2001	8.23	8.13	7.39	9.12	2.92	3, 67	*
	January 2002	11.94	9.50	8.25	10.14	3.85	3, 68	*
	June 2002	8.29	8.81	8.95	8.68	0.76	3, 62	Insig.
	January 2003	7.83	7.75	7.17	7.56	3.14	3, 32	*
Nitrogen (%)	October 2001	0.10	0.10	0.10	0.09	0.51	3, 67	Insig.
	January 2002	0.10	0.11	0.09	0.09	1.18	3, 68	Insig.
	June 2002	0.09	0.09	0.11	0.10	1.28	3, 62	Insig.
	January 2003	0.13	0.11	0.10	0.11	4.68	3, 32	* *
Potassium (meq/100 gm)	October 2001	1.69	1.64	1.61	1.64	1.02	3, 67	Insig.
	January 2002	1.24	1.20	1.18	1.23	1.46	3, 68	Insig.
	June 2002	1.41	1.50	1.54	1.39	0.23	3, 62	Insig.
Phosphorus (µg/gm)	October 2001	12.07	12.04	12.02	11.86	0.51	3, 67	Insig.
	January 2002	11.15	11.20	11.26	10.89	0.90	3, 68	Insig.
	June 2002	8.77	8.11	9.28	9.25	0.35	3, 62	Insig.
Manganese (µg/gm)	October 2001	37.59	32.68	30.34	28.38	3.49	3, 67	*
	January 2002	41.75	40.89	40.06	41.45	1.44	3, 68	Insig.
	June 2002	8.89	8.67	8.10	7.25	1.28	3, 62	Insig.
	January 2003	7.57	8.61	8.79	9.77	1.07	3, 32	Insig.
Zinc (µg/gm)	October 2001	19.78	21.80	13.60	15.74	5.33	3, 67	*
	January 2002	25.74	52.16	29.46	36.12	3.86	3, 68	*
	June 2002	1.15	1.14	1.38	1.06	1.43	3, 62	Insig.
	January 2003	0.72	0.62	0.64	0.77	1.92	3, 32	Insig.
Sulphur (µg/gm)	June 2002	202.2	293.1	249.6	240.8	3.46	3, 62	*
	January 2003	208.54	196.37	221.71	229.10	2.61	3, 32	Insig.
Boron (µg/gm)	June 2002	3.12	3.84	3.88	3.12	1.67	3, 62	Insig.
Sand (in %)	January 2002	5.15	4.88	4.68	5.05	0.27	3, 68	Insig.
	June 2002	9.40	11.09	1.38	8.94	0.73	3, 62	Insig.
Silt (in %)	January 202	61.78	62.65	63.00	62.09	2.33	3, 68	Insig.
	June 2002	43.61	40.98	40.40	43.50	2.08	3, 62	Insig.
Clay (in %)	January 202	33.08	32.47	32.32	32.86	2.11	3, 68	Insig.
	June 2002	46.99	47.92	50.64	47.56	2.03	3, 62	Insig.
B) Sundri leaf (January 2003)								
	Healthy	None	Slight	Moderate	Severe	F-value		Insig.
Calcium (in %)	0.5842	0.9237	0.9180	0.8298	0.9046	1.32	3, 40	Insig.
Magnesium (in %)	0.2866	0.3270	0.3156	0.3289	0.3690	1.97	3, 40	Insig.
Nitrogen (in %)	0.9940	1.0767	1.1600	1.1089	1.1222	0.68	3, 40	Insig.
Manganese (in %)	0.2409	0.6567	0.8382	0.4523	1.1300	1.97	3, 40	Insig.
Zinc (in %)	0.2754	0.2771	0.1635	0.1987	0.2376	1.09	3, 40	Insig.
C) Soil from the base of tree from which leaf samples were collected (January 2003)								
Calcium (in %)	0.2210	0.1750	0.1978	0.394	0.2444	2.67	3, 40	*
Magnesium (in %)	0.0834	0.0940	0.0930	0.0860	0.0907	3.67	3, 40	* *
Nitrogen (in %)	0.0792	0.1278	0.1087	0.1004	0.1144	8.49	3, 40	* * *
Manganese (in %)	0.0072	0.0076	0.0086	0.0088	0.0098	1.18	3, 40	Insig.
Zinc (in %)	0.0006	0.0007	0.0006	0.0006	0.0008	2.10	3, 40	Insig.

Notes: * = Significant at P = 0.05; * * = Significant at P = 0.01; df = degrees of freedom, Insig. = Insignificant

5.3.5 Trend of occurrence of soil and sundri leaf nutrients in relation to top dying of sundri

Trend of occurrence of soil and sundri leaf nutrients in none, slight, moderate and severe top dying sample plots reveal that:

- Calcium showed the same trend of occurrence among the soil samples from none, slight, moderate and severe top dying sample plots in soil samples collected in October 2001 and January 2002 (**Table 117 and 118**). In both the data the lowest level of Calcium were found in sample plots having no top dying (i.e. none) sample plots while increasingly higher level of Calcium were found to occur in case of slight top dying sample plots and still higher levels in severe top dying sample plots. But the level of Calcium in the moderate sample plots in the data of both October 2001 and January 2002 was the highest. January 2003 data of Calcium from soil also showed the same trend of occurrence in which the lowest mean value was obtained from no top dying sample plots while increasing and significantly ($P = 0.05$ or $P = 0.01$) higher values were obtained from slight, moderate and severe top dying sample plots. June 2002 data did not, however, show a reverse trend (**Table 160**). It is suggested that this is because of seasonal fluctuations. **Since data from soil samples collected in October 2001, January 2002 and January 2003 showed the same trend and in all these cases only the lowest Calcium levels were obtained from no top dying (i.e. none) sample splots reveal that the trend of increasingly higher level of Calcium in higher severity of top dying sample plots indicate an association of Calcium toxicity and occurrence and severity of top dying of sundri.**

- In case of Magnesium significant ($P= 0.05$) variation occurred among none, slight, moderate and severe top dying of sundri sample plots in soil sample collected in October 2001, January 2002 and January 2003, but only in sample collected in June 2002. However, Magnesium do not show any pattern of occurrence among none, slight, moderate and severe top dying sample plots.

- October 2001 data showed a very clear pattern of deficiency of Manganese with the development/occurrence of severity of top dying of sundri as the highest value is found in case of none and progressively lower values in case of slight and moderate top dying sample plots. (vide **Table 141**). In January 2002 data of Manganese this pattern is not consistent. There is hardly any difference in mean values of Mn among the sample plots of none, slight, moderate and severe sundri top dying (**Table 133**). June 2002 data of Mn also did not show any significant variation among the mean values but revealed a clear pattern of the highest level of Mn in sample plots of no top dying (i.e. none) and the lowest level in case of sample plots from the severe top dying sample plots (**Table 143**). In January 2003 data there were also no significant variation among the mean values of Mn from the sample plots of the four top dying severity classes but there was a reverse trend that the lowest value was obtained in case of none and the highest in case of severe top dying sample plots (**Table 148**). Analysis of Mn content in soil and sundri leaf from sample collected in January 2003 revelaed that the level of Mn in sundri leaf was 82.83 times higher than the level of Mn present in soil of 0-10 cm depth (**Table 157**). **All these findings do suggest that Manganese deficiency over certain period of the year (say October and around) may be responsible for creating stress which might lead to the development of top dying of sundri.**

- October 2001 data suggest an association of deficiency of Zinc with the occurrence and severity of top dying of sundri , but this did not hold good in case of data from January 2002 soil samples as in the latter case higher Zinc values were found in case of severe and slight top dying sample plots. Significant (P =0.05) variations among Zinc levels in soil sample from none, slight, moderate and severe top dying of sundri occurred in case of October 2001 **and January 2002**, but only insignificant variation occurred in case of June 2002 and January 2003 soil samples (**Table 160**). It is suggested that over certain period of the year (i.e. around October) Zinc deficiency is associated with the occurrence and severity of top dying of sundri but at other period of the year the deficiency is removed because of influx of more Zinc in the soil (vide Tables 117 and 119).

- The data of the levels of Nitrogen in soil samples of October 2001, January 2002 and June 2002 showed only insignificant variations among the sample plots of none, slight, moderate and severe top dying of sundri, but January 2003 exhibited significantly (P=0.05) higher Nitrogen level in no top dying sample plots as compared to the remain three types of sample plots (Table 160).

- Sulphur data of June 2002 and January 2003 showed lower Sulphur values in no top dying sample plots (i.e. none) and higher sulphur levels in higher top dying sample plots. This suggests Sulphur toxicity and asociation of top dying of sundri. It may be mentioned here that toxicity of acid sulphate in low lying tropical forests is well known (FAO, 1994; Brady, 1999).

- Boron showed only insignificant variation and no clear trend among none, slight, moderate and severe top dying sample plots of sundri.

- Per cent sand, silt and clay content of soil samples from none, slight, moderate and severe top dying showed only insignificant variation and no clear trend. However, the occurrence of higher level of top dying of sundri the 36 sample plots was closely and significantly (P =0.05) associated with lower level of sand which is very clearly evident from the regression plot in Fig. 45 and Table 127. Lower level of sand means higher level of silt and clay, which in turn means less and reduced soil aeration. This finding is consistent with the findings of the association of reduced number of pneumatophores and reduced number of lenticels on pneumatophores and higher levels of top dying of sundri.(vide Figs. 1 to 5) and also that of higher rate of sedimentation (vide section 5.1.3) and incidence of higher severity oc top dying of sundri.

- Status of the studied soil parameters undergone substantial change from October 2001 to January 2002. In case of K, P and Mn there occurred reduction in the occurrence of these three elements in the soil, but in case of the remaining elements there occurred an increase in the level. The per cent increase was the lowest in case of Ca (107.51%) and the highest (1174.78%) in case of Sodium, while Mg (114.19%), EC (132.10%), Mn (145.02%), Zn (258.19%) had moderate per cent increase from October 2001 to January 2002.

- Determination of the levels of Calcium, Magnesium, Nitrogen, Managanese and Zinc from sundri leaf samples from 41 sundri trees and also from 41 soil samples from the base of the corresponding tree revelaed that sundri leaves from no top dying sample plots (i.e. none), slight, moderate and severe top dying of sundri showed more or less the same amount of individul nutrients. Thus the levels of Calcium in sundri leaves from none, slight, moderate and severe top dying of sundri did differ only insignificantly. Similar was the case of Magnesium, Nitrogen, Managanese and Zinc from none, slight, mmoderate and severe top dying sample plots. It is interesting to note that the level of Calcium, Magnesium, Nitrogen, Manganese and Zinc in sundri leaf samples were 3.65, 60.51, 10.13, 82.83 and 340.90 times higher than that present in the soil respectively (Table 157). The level of Magnesium in soil samples and that in sundri leaf samples showed significant (P =0.05) negative correlation (vide Table 156) which suggests that with the increase in soil Magnesium, leaf Magnesium levels decrease and vice versa. Moreover, the levels of Nitrogen in soil did show significant (P=0.05) negative correlation with per cent top dying of sundri in the 36 sample plots (Table 156). This also suggests that as the nitrogen levels in soil increase the per cent top dying in the sample plots decrease and as the Nitrogen levels in soil decrease per cent top dying of sundri increase. Observation in the Sundarbans suggests that more severe top dying occurs in the central parts of the Sundarbans. But examination of the levels of Nitrogen in the soil samples from sample plots of the compartments falling in the central compartments (i.e. compartment nos. 19, 20, 33, 36, 37 and 40) and those sample plots falling in the eastern compartments (i.e. compartment nos. 2, 11, 22 and 26) do not, however, support the above finding as is evident from the levels of Nitrogen obtained in soil sample collected in October 2001, January 2002, June 2002 and January 2003 (vide **Appendix** 39) and **Table 161.**

Table 161: Mean level of Nitrogen in soil samples from the sample plots falling in central compartments (i.e. compartment nos. 19, 20, 33, 36, 37 and 40) and from the sample plots falling in eastern compartments (i.e. compartment nos. 2, 11, 22 and 26) collected four times.

Soil samples collected in	Mean level of Nitrogen (%) in soil samples from central compartments	Mean level of Nitrogen (%) in soil samples from eastern compartments	df	F value
October 2001	0.108957	0.086542	1, 69	10.9200 ***
January 2002	0.109271	0.094542	1, 70	0.45978
June 2002	0.103561	0.094542	1, 63	1.03724
January 2003	0.116375	0.105750	1, 34	2.84267
Note: *** = Significant at P = 0.001; df = degree of freedom				

5.4: Distribution and Intensity of Top Dying of Sundri in 55 Compartments in the Sundarbans

During data collection in 1996-1997 from Temporary Sample Plots (TSPs), data were collected from 1190 TSPs out of which 22530 sundri trees were found to occur in 830 TSPs. Compartmentwise distribution of 830 TSPs providing data on per cent TSPs with top dying of sundri, number of TSPs having varying degree of top dying and per cent of the total sundri trees showing top dying in the Sundarbans have been summarized and presented in **Table 162.**

Table 162: Compartmentwise distribution of 830 Temporary Sample Plots (TSPs) having sundri trees out of 1190 TSPs and providing data on per cent TSPs with top dying of sundri, number of TSPs having varying degree of top dying and per cent of the total sundri trees showing top dying in the Sundarbans as in 1996-1997.

Compartment Number	Total No. of TSP	Number of TSP with top dying of sundri	Per cent of TSP with top dying of sundri	Number of TSP showing varying per cent of sundri top dying									Total number of sundri trees in the TSP	Number of sundri with top dying	Per cent of sundri with top dying
				1-2% sundri with top dying	2-3% sundri with top dying	3-5% sundri with top dying	5-10% sundri with top dying	10-20% sundri with top dying	20-30% sundri with top dying	30-40% sundri with top dying	40-50% sundri with top dying	Above 50% sundri with top dying			
1	30	3	10.00	1	0	1	0	1	0	0	0	0	915	5	0.55
2	20	3	15.00	1	1	0	1	0	0	0	0	0	616	5	0.81
3	17	3	17.65	1	0	1	1	0	0	0	0	0	606	4	0.66
4	14	4	23.53	0	2	1	1	0	0	0	0	0	540	6	1.11
5	14	3	17.65	1	1	1	0	0	0	0	0	0	412	3	7.28
6	15	1	6.67	0	0	0	1	0	0	0	0	0	326	2	0.61
7	25	1	4.00	0	0	0	1	0	0	0	0	0	473	3	0.63
8	28	13	46.43	2	0	2	3	5	1	0	0	0	734	37	5.02
9	27	4	14.82	1	0	1	1	1	0	0	0	0	480	6	1.25
10	19	6	31.88	1	2	0	2	1	0	0	0	0	767	11	1.43
11	14	1	7.14	1	0	0	0	0	0	0	0	0	389	3	0.77
12	19	0	0	0	0	0	0	0	0	0	0	0	483	0	0
13	19	10	52.63	3	3	2	2	0	0	0	0	0	1016	17	1.67
14	12	2	16.67	1	0	1	0	0	0	1	0	0	542	3	0.55
15	15	0	0	0	0	0	0	0	0	0	0	0	926	0	0
16	20	4	20.00	1	1	1	1	0	0	0	0	0	661	6	0.91
17	18	4	22.22	0	0	1	1	2	0	0	0	0	577	13	2.25
18	28	15	53.57	0	1	1	4	4	4	0	1	0	769	66	8.58
19	19	12	63.16	0	1	1	2	4	2	1	0	1	586	52	8.87
20	25	14	56.00	1	3	2	4	3	1	0	0	0	835	32	3.83
21	14	2	14.29	2	0	0	0	0	0	0	0	0	634	2	0.32
22	13	8	61.54	0	1	4	1	2	0	0	0	0	695	27	3.88
23	11	4	36.36	2	1	1	0	0	0	0	0	0	582	6	1.03
24	17	5	29.41	1	2	1	1	0	0	0	0	0	605	8	1.32
25	11	4	36.36	0	0	2	0	2	0	0	0	0	296	9	3.04
26	12	4	33.33	0	0	1	2	1	0	0	0	0	313	8	2.56
27	15	3	20.00	0	0	1	0	1	1	0	0	0	369	11	2.98
28	12	3	25.00	1	0	1	0	1	0	0	0	0	265	7	2.64
29	14	6	42.86	0	1	4	0	1	0	0	0	0	455	11	2.42
30	16	4	25.00	0	1	0	2	0	0	1	0	0	499	9	1.80
31	24	6	25.00	0	0	1	1	2	1	1	0	0	559	27	4.83
32	16	3	18.75	0	0	1	1	0	0	1	0	0	295	14	4.75
33	15	9	60.00	0	0	0	3	2	1	3	0	0	541	74	13.68
34	11	5	45.46	0	0	1	1	2	0	1	0	0	397	28	7.05
35	20	2	10.00	0	0	1	0	1	0	0	0	0	205	3	1.46
36	21	9	42.86	0	0	1	1	3	1	2	1	0	476	60	12.61

37	16	10	62.50	0	0	1	1	3	2	1	2	0	336	61	18.15
38	**20**	**7**	**35.00**	**0**	**2**	**2**	**2**	1	0	0	0	0	**501**	17	3.39
39	21	2	9.52	0	0	0	0	2	0	0	0	0	637	6	0.94
40	12	6	50.00	0	0	0	2	0	3	1	0	0	295	37	12.54
41	13	3	23.00	0	0	0	0	0	0	2	1	0	46	8	22.22
42	8	3	50.00	0	0	0	0	0	0	2	0	1	36	8	22.22
43	19	3	15.79	0	1	1	0	0	0	0	0	0	189	9	4.76
44	17	3	17	0	0	0	1	1	1	0	0	0	213	6	2.82
45	19	7	36.84	1	0	0	1	1	2	1	1	0	284	32	11.27
46	7	0	0	0	0	0	0	0	0	0	0	0	11	3	27.27
47	5	0	0	0	0	0	0	0	0	0	0	0	6	0	0
48	1	0	0	0	0	0	0	0	0	0	0	0	10	0	0
49	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
50	2	0	0	0	0	0	0	0	0	0	0	0	3	1	0
51	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0
52	10	0	0	0	0	0	0	0	0	0	0	0	37	0	0
53	8	0	0	0	0	0	0	0	0	0	0	0	23	3	0
54	9	0	0	0	0	0	0	0	0	0	0	0	59	2	0
55	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Total	830	224	-	22	24	40	45	47	20	18	6	2	22532	771	-

It can be seen from Table 162 that out of 493, 926, 6, 10, 1, 3, 2, 37, 23, 59 and 4 sundri trees falling in 19, 15, 5, 1, 1, 2, 1, 10, 8, 9 and 1 TSPs in compartment nos. 12, 15, 47, 48, 49, 50, 51, 52, 53, 54 and 55 respectively no top dying of sundri were recorded. In the remaining 47 compartments varying percentage of top dying of sundri were recorded. Based on the severity of top dying of sundri the TSPs were classified into nine categories and provided in **Table 163**

Table 163 : Distribution of Temporary Sample Plots (TSPs) having different levels of top dying of sundri trees in 47 compartments in the Sundarbans.

SL. No	Level of top dying of sundri	No. of TSPs showing specified level of sundri top dying
1	TSPs having 1 to less than 2 per cent of sundri trees with top dying	22
2	**TSPs having 2 to less than 3 per cent of sundri trees with top dying**	**24**
3	TSPs having 3 to less than 5 per cent of sundri trees with top dying	40
4	TSPs having 5 to less than 10 per cent of sundri trees with top dying	45
5	TSPs having 10 to less than 20 per cent of sundri trees with top dying	47
6	TSPs having 20 to less than 30 per cent of sundri trees with top dying	20
7	TSPs having 30 to less than 40 per cent of sundri trees with top dying	18
8	TSPs having 40 to less than 50 per cent of sundri trees with top dying	6
9	TSPs having above 50 per cent of sundri trees with top dying	2

It is seen from **Table 163** that varying numbers of TSPs were selected from different compartments out of which in varying numbers top dying of sundri were recorded. Hence for comparing the relative widespreadness of top dying of sundri, per cent of TSPs showing top dying have been calculated. This reveals that in compartment No. 19 top dying of sundri was the most widespread during 1996-1997 i.e. the time of recording the data of top dying as in that compartment out of a total of 19 TSPs top dying was recorded in 12 TSPs i.e. 63.16 per cent of TSPs of the compartment. In the same way in decreasing order of widespreadness of top dying of sundri next to compartment 19 fall compartment nos. 37 having 62.50 % TSPs with top dying of sundri, 22 with 61.54%, 33 (60.00%), 20 (56.00%), 18 (53.57%), 13 (52.62%), 40 (50.00%), 42 (50.00%), 8 (46.43%), 34 (45.46%), 36 (42.86%), 29 (42.86%), 45 (36.84%), 38 (35.00%), 26 (33.33%), 10 (31.58%), 24 (29.41%), 28 (25.00%), 30 (25.00%), 31 (25.00%), 4 (23.53%), 41 (23.08%), 17 (22.22%), 16 (20.00%), 27 (20.00%), 32 (18.75%), 3 (17.65%), 5 (17.65%),44 (17.00%),14 (16.67%), 43 (15.79%), 2 (15.00%), 9 (14.82%), 21 (14.29%), 1 (10.00%),35 (10.00%), 39 (9.52%), 11 (7.14%), 6 (6.67%) and 7 (4.00%) (vide **Table 164**).

Table 164; Descending order of per cent of Temporary Sample Plot (TSP) showing top dying with corresponding data on per cent of sundri trees with top dying in 55 compartments in the Sundarbans as in 1996-1997.

Compartment Number	Total No. of TSP	Number of TSP with top dying of sundri	Per cent of TSP with top dying of sundri	Total number of sundri trees in the TSP	Number of sundri with top dying	Per cent of sundri with top dying
19	19	12	63.16	586	52	8.87
37	16	10	62.50	336	61	18.15
22	13	8	61.54	695	27	3.88
33	15	9	60.00	541	74	13.68
20	25	14	56.00	835	32	3.83
18	28	15	53.57	769	66	8.58
13	19	10	52.63	1016	17	1.67
40	12	6	50.00	295	37	12.54
42	8	4	50.00	36	8	22.22
8	28	13	46.43	734	37	5.02
34	11	5	45.46	397	28	7.05
29	14	6	42.86	455	11	2.42
36	21	9	42.86	476	60	12.61
45	19	7	36.84	284	32	11.27
23	11	4	36.36	582	6	1.03
25	11	4	36.36	296	9	3.04
38	20	7	35.00	501	17	3.39
26	12	4	33.33	313	8	2.56
10	19	6	31.88	767	11	1.43
24	17	5	29.41	605	8	1.32
28	12	3	25.00	265	7	2.64
30	16	4	25.00	499	9	1.80
31	24	6	25.00	559	27	4.83
4	14	4	23.53	540	6	1.11
41	13	3	23.00	46	8	22.22
17	18	4	22.22	577	13	2.25
16	20	4	20.00	661	6	0.91
27	15	3	20.00	369	11	2.98
32	16	3	18.75	295	14	4.75
3	17	3	17.65	606	4	0.66
5	14	3	17.65	412	3	7.28
44	17	3	17.00	213	6	2.82
14	12	2	16.67	542	3	0.55
43	19	3	15.79	189	9	4.76

2	20	3	15.00	616	5	0.81
9	27	4	14.82	480	6	1.25
21	14	2	14.29	634	2	0.32
1	30	3	10.00	915	5	0.55
35	20	2	10.00	205	3	1.46
39	21	2	9.52	637	6	0.94
11	14	1	7.14	389	3	0.77
6	15	1	6.67	326	2	0.61
7	25	1	4.00	473	3	0.63
12	19	0	0	483	0	0
15	15	0	0	926	0	0
46	7	0	0	11	3	27.27
47	5	0	0	6	0	0
48	1	0	0	10	0	0
49	1	0	0	1	0	0
50	2	0	0	3	1	0
51	1	0	0	2	0	0
52	10	0	0	37	0	0
53	8	0	0	23	3	0
54	9	0	0	59	2	0
55	1	0	0	4	0.	0

Thus the ranking of the 55 compartments of the Sundarbans in decreasing order of widespreadness of top dying of sundri in the TSPs are as follows: 19, 37, 22, 33, 20, 18, 13, 40, 42, 8, 34, 36, 29, 45 23, 25, 38, 26, 10, 24, 28, 30, 31, 4, 41, 17, 16, 27, 32, 3, 5, 44, 14, 43, 2, 9, 21, 1, 35, 39, 11, 6 and 7.

In consideration of the total number of sundri trees falling in the TSPs of a particular compartment the actual number of sundri trees showing top dying symptoms were considered in the next step to express per cent of sundri trees exhibiting top dying. For this consideration compartment numbers 46, 41, 42, 47, 48, 49, 50, 51, 52, 53, 54 and 55 have been excluded as the total number of sundri trees present in all the TSPs falling the compartments were very small. Among the remaining compartments in consideration of the per cent of sundri top dying compartment no. 37 had the highest occurrence of 18.15% of top dying of sundri trees. Following compartment 37, in decreasing order of occurrence of top dying in the compartment numbers 33 (having 13.68% of sundri with top dying), 36 (12.61%), 40 (12.54%), 45 (11.27%), 19 (8.87%), 18 (8.58%), 5 (7.28%), 34 (7.05%), 8 (5.02%), 31 (4.83%), 43 (4.76%), 32 (4.75%), 22 (3.88%), 20 (3.83%), 38 (3.39%), 25 (304%), 27 (2.98%), 44 (2.82%), 28 2.64(%), 26 (2.56%), 29 (2.42%), 17 (2.25%), 30 (1.80%), 13 (1.67%), 35 (1.46%), 10 (1.43%), 24 (1.32%), 9 (1.25%), 4 (1.11%), 23 (1.03%), 39 (0.94%), 16 (0.91%), 2 (0.81%), 11 (0.77%), 3 (0.66%), 7 (0.63%), 6 (0.61%), 1 (0.55%), 14 (0.55%) and 21 (0.32%) (vide **Table 165**).

Thus the ranking of 55 compartments according to decreasing order of occurrence of top dying of sundri trees falling in the TSPs of each compartment in the Sundarbans are as follows: 37, 33, 36, 40, 45, 19, 18, 5, 34, 8, 31, 43, 32, 22, 20, 38, 25, 27, 44, 28, 26, 29, 17, 30, 13, 35, 10, 24, 9, 4, 23, 39, 16, 2, 11, 3, 7, 6, 1, 14 and 21.

Table 165: Descending order of per cent of sundri trees showing top dying with corresponding data on per cent of Temporary Sample Plot (TSP) affected by top dying in 55 compartments in the Sundarbans as in 1996-1997.

Compartment Number	Total No. of TSP	Number of TSP with top dying of sundri	Per cent of TSP with top dying of sundri	Total number of sundri trees in the TSP	Number of sundri with top dying	Per cent of sundri trees with top dying
46	7	0	0	11	3	27.27
41	·13	3	23.00	46	8	22.22
42	8	4	50.00	36	8	22.22
37	16	10	62.50	336	61	18.15
33	15	9	60.00	541	74	13.68
36	21	9	42.86	476	60	12.61
40	12	6	50.00	295	37	12.54
45	19	7	36.84	284	32	11.27
19	19	12	63.16	586	52	8.87
18	28	15	53.57	769	66	8.58
5	14	3	17.65	412	3	7.28
34	11	5	45.46	397	28	7.05
8	28	13	46.43	734	37	5.02
31	24	6	25.00	559	27	4.83
43	19	3	15.79	189	9	4.76
32	16	3	18.75	295	14	4.75
22	13	8	61.54	695	27	3.88
20	25	14	56.00	835	32	3.83
38	20	7	35.00	501	17	3.39
25	11	4	36.36	296	9	3.04
27	15	3	20.00	369	11	2. 98
44	17	3	17.00	213	6	2.82
28	12	3	25.00	265	7	2.64
26	12	4	33.33	313	8	2.56
29	14	6	42.86	455	11	2.42
17	18	4	22.22	577	13	2.25
30	16	4	25.00	499	9	1.80
13	19	10	52.63	1016	17	1.67
35	20	2	10.00	205	3	1.46
10	19	6	31.88	767	11	1.43
24	17	5	29.41	605	8	1.32
9	27	4	14.82	480	6	1.25
4	14	4	23.53	540	6	1.11
23	11	4	36.36	582	6	1.03
39	21	2	9.52	637	6	0.94
16	20	4	20.00	661	6	0.91
2	20	3	15.00	616	5	0.81
11	14	1	7.14	389	3	0.77
3	17	3	17.65	606	4	0.66
7	25	1	4.00	473	3	0.63
6	15	1	6.67	326	2	0.61
1	30	3	10.00	915	5	0.55
14	12	2	16.67	542	3	0.55
21	14	2	14.29	634	2	0.32

12	19	0	0	483	0	0
15	15	0	0	926	0	0
47	5	0	0	6	0	0
48	1	0	0	10	0	0
49	1	0	0	1	0	0
50	2	0	0	3	1	0
51	1	0	0	2	0	0
52	10	0	0	37	0	0
53	8	0	0	23	3	0
54	9	0	0	59	2	0
55	1	0	0	4	0.	0

It is thus seen that the 55 compartments varied in respect of per cent of TSPs showing top dying (i.e. in widespreadness of top dying in the compartment) and also in case of per cent sundri trees affected by top dying (i.e. in severity of top dying). Therefore, in the next step the Relative Ranking Index of top dying of sundri of the 55 compartments was determined. For that purpose, the per cent of TSPs of a particular compartment showing top dying of sundri was multiplied by the per cent of sundri trees of that particular compartment showing top dying. Then based on the determined Ranking Index the 55 compartments were arranged in decreasing order of seriousness of top dying of sundri. The findings thus arrived at about the severity of top dying of sundri trees in the Sundarbans are provided in **Table 166.**

Table 166: Determination of the relative severity of top dying of sundri in 55 compartments based on the data of 830 Temporary Sample Plots (TSP) in which sundri trees were found to be present out of 1203 TSPs during the FRMP Forest Inventory of the Sundarbans in 1996 and 1997.

Comp. No.	Total No. of TSP	No. of TSP with top dying sundri	Per cent of TSP with top dying of sundri	Total number of sundri trees in the TSPs	Number of sundri with top dying	Per cent of sundri with top dying	Top dying ranking index (Columns D x G)	Ranked position (as per column H)
A	B	C	**D**	E	F	**G**	**H**	**I**
37	16	10	62.50	339	61	17.99	1124.63	1
33	15	9	60.00	533	74	13.88	833.02	2
40	12	6	50.00	296	37	12.50	625.00	3
36	22	9	40.91	515	60	11.65	476.61	4
19	22	12	54.55	614	52	8.47	461.95	5
42	20	4	20.00	37	8	21.62	432.43	6
18	37	15	40.54	765	66	8.63	349.76	7
45	26	7	26.92	250	32	12.80	344.62	8
34	12	5	41.67	397	28	7.05	293.87	9
41	19	3	15.79	46	8	17.39	274.60	10
22	13	8	61.54	694	27	3.89	239.41	11
20	26	14	53.85	835	32	3.83	206.36	12
8	36	13	36.11	735	37	5.03	181.78	13
38	21	7	33.33	502	17	3.39	112.88	14
31	25	6	24.00	586	27	4.61	110.58	15
29	14	6	42.86	439	11	2.51	107.39	16
25	12	4	33.33	310	9	2.90	96.77	17
32	16	3	18.75	296	14	4.73	88.68	18
13	19	10	52.63	1016	17	1.67	88.06	19

26	12	4	33.33	313	8	2.56	85.20	20
28	12	3	25.00	265	7	2.64	66.04	21
27	15	3	20.00	363	11	3.03	60.61	22
43	29	3	10.34	189	9	4.76	49.26	23
10	19	6	31.58	766	11	1.44	45.35	24
30	16	4	25.00	500	9	1.80	45.00	25
24	17	5	29.41	605	8	1.32	38.89	26
17	24	4	16.67	568	13	2.29	38.15	27
23	11	4	36.36	582	6	1.03	37.49	28
44	26	3	11.54	217	6	2.76	31.90	29
4	17	4	23.53	557	6	1.08	25.35	30
16	20	4	20.00	661	6	0.91	18.15	31
35	20	2	10.00	206	3	1.46	14.56	32
9	36	4	11.11	476	6	1.26	14.01	33
5	17	3	17.65	413	3	0.73	12.82	34
3	17	3	17.65	606	4	0.66	11.65	35
2	21	3	14.29	658	5	0.76	10.86	36
14	13	2	15.38	593	3	0.51	7.78	37
39	22	2	9.09	706	6	0.85	7.73	38
1	31	3	9.68	916	5	0.55	5.28	39
11	15	1	6.67	389	3	0.77	5.14	40
21	14	2	14.29	635	2	0.31	4.50	41
6	21	1	4.76	326	2	0.61	2.92	42
7	30	1	3.33	473	3	0.63	2.11	43
12	19	0	0.00	487	0	0.00	0.00	44
15	15	0	0.00	926	0	0.00	0.00	45
46	29	**0**	0.00	8	**0**	0.00	0.00	46
47	29	0	0.00	6	0	0.00	0.00	47
48	27	0	0.00	10	0	0.00	0.00	48
49	33	0	0.00	1	0	0.00	0.00	49
50	21	**0**	0.00	3	**0**	0.00	0.00	50
51	29	0	0.00	2	0	0.00	0.00	51
52	33	0	0.00	41	0	0.00	0.00	52
53	28	**0**	0.00	25	**0**	0.00	0.00	53
54	39	**0**	0.00	59	**0**	0.00	0.00	54
55	43	0	0.00	0	0	0.00	0.00	55
Total:	1203	220		22756	762			

It is evident from **Table 166** that on the basis of the calculated Relative Ranking Index of top dying of sundri compartment number 37 is ranked as the worst affected by top dying of sundri. This is followed by compartment numbers 42, 33, 40, 19, 36, 41, 18, 45, 34, 22, 8, 20, 5, 31, 38, 25, 29, 32, 13, 26 (Fig. 47), 43, 28, 27, 17, 44, 10,30, 24, 23, 4, 9, 16, 35, 2, 3, 14, 39, 1, 11, 21, 6, 7, 12, and 15 (Fig. 48). However, compartment nos. 41 had only 46 sundri trees in 13 TSPs and 42 had only a 36 sundri trees in 8 TSPs (vide Table 165). So although compartment 41 and 42 had obtained ranked position of 7 and 2 respectively should be excluded from any further consideration of severity of top dying.

FRMP Forest Inventory of the Sundarbans conducted during 1996 and 1997 generated data of 1203 Temporary Sample Plots TSP). From that data total number of sundri trees in each was found out and then per cent top dying of sundri was also found out for each compartment. Then based on the top dying per cent wise data of 1203 TSP and using the GPS location of each of the

TSPs a Map of the Sundarbans Reserved Forest showing distribution and intensity of top dying sundri trees has been prepared with the data processed by Top dying of sundri study team and with technical help and support of Mr. Md. Mohsinul Alam, ACF, Unit Head and Shaik Mahmud Sazzad, ISO of the Database Unit of Sundarban Biodiversity Conservation Project. In the map seven types of symbols have been used to identify a particular TSP which include >=70 %, <70>=40 %, <40>=10 %, <10%, 0% top dying of sundri and no sundri trees (Fig. 49). It is hoped that the map would provide a very convenient way to find out the occurrence and intensity of top dying of sundri of any particular compartment for management decision.

It may be pertinently mentioned here that the knowledge of distribution and intensity of top dying of thus generated can be very effectively used for management decision about top dying of sundri. It may be recollected that we have already generated precise knowledge about the extent and distribution of per hectare sundri seedlings, sapling, poles and trees in each of the 55 compartments and their confidence limit at 95% point. The same has been arranged in descending order for each of seedlings, saplings, poles and trees of sundri (vide. Table 57). From that we can know in which compartment we have satisfactory population of sundri seedlings, saplings, poles and trees and in which we do not have them in adequate quantity. We have also found out that canopy closure of Temporary Sample Plots in the 55 compartments in the Sundarbans has shown to hold a positive and significant correlation with the occurrence of top dying of sundri. In that in forest areas where canopy closure is 70% or more the occurrence of per cent top dying of sundri there is significantly less than that of areas where the canopy closure is more than 30% but less than 70%, the latter again showed lesser per cent top dying of sundri as compared to areas having canopy closure of more than 10 per cent but less than 30 per cent (vide Table 81 and Fig. 21). These suggest that for the management of top dying sundri through salvage felling we have to bear in mind that we have to avoid too much opening of canopy because with the creation of more opening in canopy the extent of wind/cyclone damage will be increasingly more. It is only natural that with the increase of cyclone damage on sundri further invasion by wood decay fungi and insects are likely to increase which will result in increased progressive loss through decay and degrade of timber in top dying sundri trees. Rahman (2003) has reported that an analysis of the data obtained from the Forest Department's Top Dying Felling and Marking Registers for 25 sundri trees from each of the compartment nos. 32, 34, 37, 38 and 39 revealed that on an average 57.43 ± 6.40 per cent (at P =0.05) of the total volume of sundri wood could be recovered as saw log. Wood deterioration from these compartments due to top dying has been estimated to be 42.18 ± 6.40 per cent (at P=0.05) of the total volume of wood produced up to a top inner bark diameter of 10 cm. This is considered to be a very heavy economic loss in forestry term. Therefore, it is suggested that the only rational way of salvaging the loss and avoiding further increase and degrade of the sundri wood resources in the Sundarbans salvage felling should be reintroduced. Adequate careful planning and monitoring of the salvage felling operations must be judiciously undertaken. In doing so the knowledge generated from the present study in respect of per cent top dying of sundri and level of regeneration should be taken into cognizance for any salvage felling operation in any particular area of the Sundarbans. In fine, it is mentioned very clearly that to save the progressive deteriorating conditions of the forest and to avoid unnecessary wood loss from decay and degrade reintroduction of salvage felling of top dying of sundri trees in the Sundarbans is recommended.

Fig. 48: Ranking index of severity of top dying of sundri trees in 22 compartments in the Sundarbans

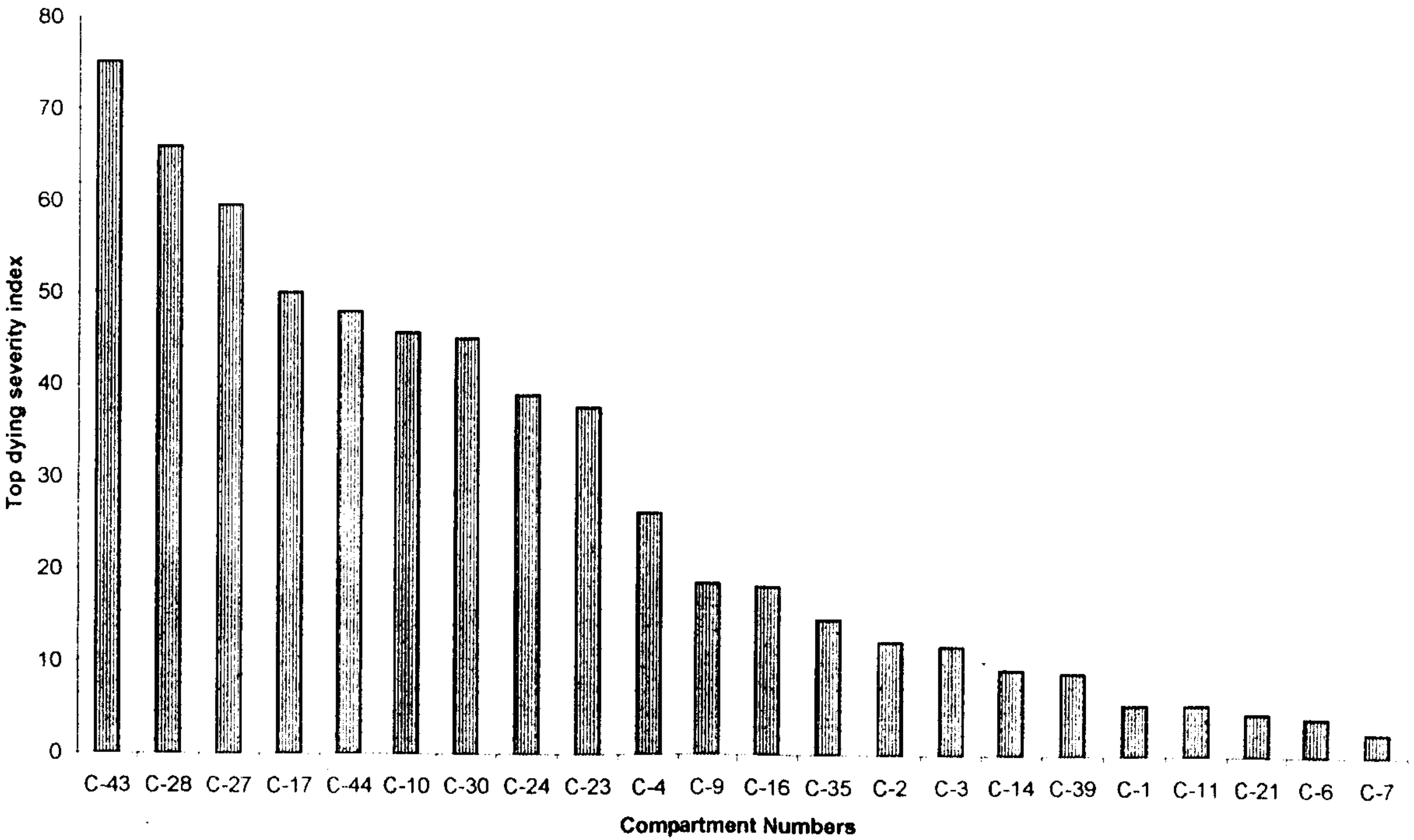
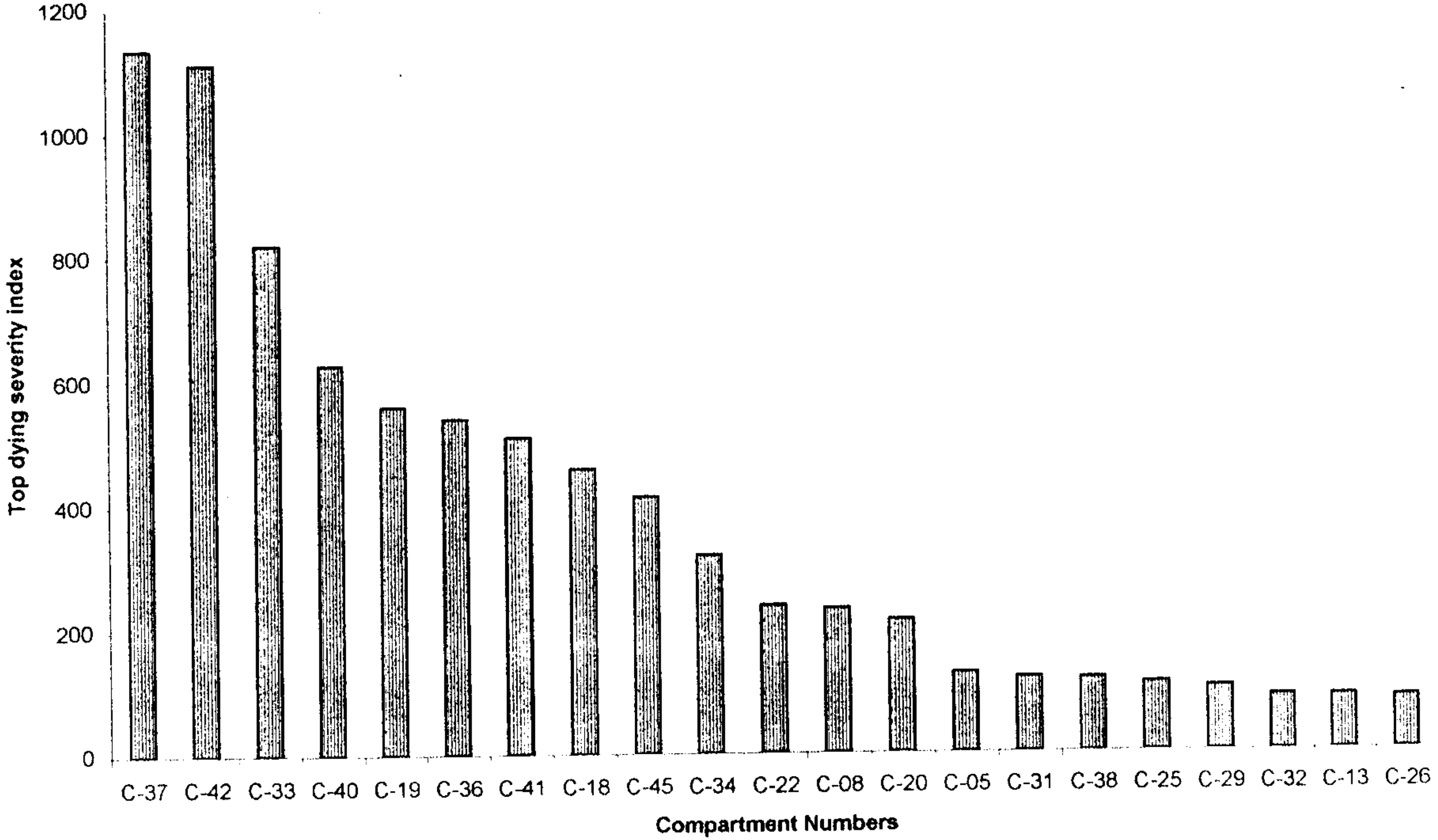


Fig. 47 Ranking index of severity of top dying of sundri trees in 21 compartments in the Sundarbans



6.0 DISCUSSIONS

Pneumatophore data were collected from five sub-plots from each of 36 sample plots during three observations in October 2001, January 2002 and June 2002. The 36 sample plots included 9 sample plots from each of no top dying (i.e. none), slight, moderate and severe top dying of sundri. The data of pneumatophore number when pooled together from three observations yield mean number of 38.57, 38.32, 21.39 and 24.95 per sq meter of none, slight, moderate and severe top dying sample plots respectively. The first two values were significantly higher (P= 0.05) than the last two values. That means the number of pneumatophores per sq. meter area of the sub-plot of no top dying and slight top dying sample plots were consistently higher than moderate and severe top dying sample plots. When the four top dying severity classes were designated as 1= none, 2 = slight, 3 = moderate and 4 = severe and correlation analysis were carried out with the number of pneumatophores recorded from the sub-plots of the four top dying severity classes, then significant (P = 0.01) negative correlation were obtained with the data of January 2002 and June 2002. Thus it is evident that reduction in the number of pneumatophores per unit area of the sub-plots is directly associated with the severity of top dying of sundri. This suggests that reduced number of pneumatophores is associated with the severity of top dying of sundri. Hogarth (1999), however, reported that as the mangrove substrate becomes increasingly anaerobic the number of pneumatophore increases. It is suggested that for moderately and severely top dying affected sundri trees suffer from drastic reduction of the crown because of mortality of twigs, branches and main stem. Such trees had limited ability to allocate more energy to produce higher number of pneumatophores as compared to no top dying and slight top dying sundri trees.

The data on the height/length of the pneumatophores from the four top dying severity classes did not show significant variation. From the survey and field experience it is observed that top dying of sundri is most prevalent on levees along the watercourses and also in the back-swamps. On the levees due to higher sedimentation and lower subsidence of sediment (due to more frequent flooding or proximity to the permanent water source) pneumatophores get continuously buried in sediment and they struggle to remain above the surface by putting on secondary growth. As a result on levees pneumatophores appears to be short. On the contrary, in the back-swamp the rate of sedimentation remains low but the rate of subsidence remains high due to absence of tidal inundation in dry months. In wet months, due to higher tidal inundation and prolonged flooding, trees equally suffer from the anaerobic condition in the substrate including the tidal water. Plants respond to this situation by putting on higher secondary growth on pneumatophores (Hutchings and Saenger, 1987). Consequently in such areas the height of the pneumatophores above the soil surface is of greater. When these data were processed against four sundri top dying severity classes, the difference among the mean values were low. As a result analysis of variance (ANOVA) on the data of height of pneumatophore might have produced insignificant variation.

Lenticels are small pores on the breathing roots i.e. pneumatophores through which sundri roots get required supply of air for necessary respiration in the root tissues to ensure normal growth and development of the tree species. This is also true for many other mangrove species. The data on the number of lenticels were collected from three pneumatophores from each of 45 sub-plots from nine sample plots from each of no top dying (i.e. none), slight, moderate and severe top dying of sundri. Numbers of lenticels were counted from 1 sq. cm area from near top, middle and collar of each of three pneumatophores from 180 sub-plots of 36 sample plots. Analysis of the data revealed significant difference among the mean values from the sample plots of the four top dying severity classes. The significant difference among the mean values of the number of lenticels at near the collar region of the pneumatophores from the four top dying severity classes (i.e. none, slight, moderate and severe) have been obtained from the data collected in January 2002 and also in June 2002. In case of the number of lenticels from near the middle and top of pneumatophores significant difference have been obtained in data collected in June 2002 but there were no significant differences in the data of collected in January 2002 from the middle and top of the pneumatophores.

The lowest mean number of 2.17 and 0.67 lenticels on per sq. cm area of the collar region were found to be present in case of pneumatophores observed in severely top dying sample plots as compared to 2.42 and 1.28 number of lenticels on per sq cm at collar of pneumatophore of no top dying sample plots of sundri as observed in January 2002 and June 2002. Correlation analysis of the data of number of lenticels recorded from near collar, middle and top of the pneumatophores in June 2002 and four top dying severity classes (i.e 1 = none, 2 = slight, 3 = moderate and 4 = severe) revealed significant negative correlation (Correlation Coefficient r = 0-0.418, - 0.242 and - 0.189 each with df =149 respectively). However, the number of lenticels recorded from the collar region of pneumatophore in January 2002 had only an insignificant association with the four top dying severity classes as we had a Correlation Coefficient, r = -0.083 with 179 df., although this had a significant variance.

Presence of the lowest number of lenticels per sq. cm area at the collar region of the pneumatophores of severely top dying affected sample plots strongly suggests that reduced supply of oxygen to the root system is very likely to be responsible for the development of top dying of sundri in the Sundarbans.

Hogarth (1999) has observed that aeration at the collar region of the pneumatophore is a critical factor and mangroves responded to the anaerobiosis in the substrate by producing more lenticels.

The findings stated above, indicating a strong relationship between sundri top dying and soil aeration, is the out put of indirect approach of the problem. At this state it is important that direct measurement of soil oxygen is undertaken with the help of a Redox potential meter fitted with a platinum probe. As Hogarth (1999) observed a variation in the proportion of aerenchymatous tissue in the mangrove roots in substrate with varied level of soil anoxia, anatomical investigation of sundri roots collected from areas of different degrees of sundri top dying should also be undertaken.

The reduced number of lenticels per unit area of pneumatophores at the collar, middle and top of pneumatophores, particularly during the time of higher level of innundation as in June 2002 is associated with the severity of top dying of sundri as we had highly significant Correlation Coefficients (r = -0.350, with 149 degrees of freedom). Besides the trend of occurrence of lenticels on the pneumatophores shows a clear cut pattern of increasingly reduced number of lenticels from none, through to slight, moderate and severe top dying categories (vide Figs. 3, 4 and 5).

Thus we arrive at the conclusions that occurrence of significantly reduced number of pneumatophores and significantly reduced number of lenticels at the collar and middle region of the pneumatophores are associated with progressive severity (i.e. none, slight, moderate and severe) of top dying of sundri in the Sundarbans. Hence, among others, these are considered to be the causes of top dying of sundri. However, the cause(s) which promotes the reduced number of pneumatophore development and poor number of lenticels production needs to be clarified in further studies. But one thing seems to be very evident that depth and duration of flooding of the pneumatophore are very interesting parameters to be monitored in rather micro scale in future studies.

Soil physicist generally consider that if the soil volume occupied by air is reduced below 10-12%, most plants are likely to suffer. Higher plants are adversely affected in three ways by conditions of poor aeration: a) the growth of the plant, particularly the roots, is curtailed; b) the absorption of nutrients and water is decreased; and c) the formation of certain organic compounds toxic to plant growth is favoured. Oxygen deficiency is known to curtail the absorption by plants of both nutrients and water. This is because low oxygen levels constrain root respiration, a process that provides the energy for nutrient and water absorption. It is ironic that an over supply of water in the soil can reduce the amount of water absorbed by plants. Different plants species vary in their ability to tolerate poor aeration. It is known that red pine can tolerate restricted drainage during its early development, but poor growth or even death occur on the same site at later stages (Brady, 1990).

In the present study regeneration data were generated from five sub-plots, each of 4 sq. m , from each of 36 sample plots in October 2001 and in June 2002. Within each type of regeneration (i.e. R1= stem less than 1.3 m in height; R2 = stem of 1,3 m or more in height but d.b.h. less than 2.5 cm, and R3 = stem of 1.3 m or more in height and d.b.h. 2.5 cm or more) of sundri there is in general a trend of higher regeneration in the more top dying severity classes (i.e. from none, slight, moderate and finally to severe). This is particularly evident in case of R2 type regeneration of sundri. This finding support the idea that opening created in the ground level because of removal of canopy by top dying allows more sun light in the forest floor which has imparted a positive impact on the growth of young seedlings (R1 type) of sundri and this promoted more recruitment of R2 type sundri regeneration.

Contrary to the present finding Gani and Hossen (2002) reported that due to top dying sundri harvest there is a change in the composition of the seedlings and saplings where the commercially important sundri is gradually being replaced by less important species of gewa and other mangrove species. Moreover, the recruitment of seedlings to saplings is also reduced to a significant extent.

In order to determine the impact of salvage felling of top dying sundri status of regeneration, particularly saplings from compartment nos. 32, 36 and 38 were compared with that of compartment nos. 16, 31, 35 and 41. In compartment nos. 32, 36 and 38 top dying sundri were extracted during 1990-92, while from compartment numbers 16, 31, 35 and 41 no top dying sundri trees were extracted before 1996-97. The last mentioned four compartments are neighbouring to the first mentioned three compartments. Data of saplings are considered for comparison as saplings are considered to have attained recruitment and will grow to pole stage and mature tree crops in course of time. Sapling data used have been from the TSP Database generated during FRMP Forest Inventory of the Sundarbans during 1996 and 1997 so that status of regeneration 3- 4 years after top dying harvest in the compartment 32, 36 and 38 during 1990-92 could be obtained from these three compartments.

Comparisons were made by the way of variance analysis of the number of saplings of sundri, gewa, passur, baen, kankra, goran, amur, singra and khalisha obtained from 60 Temporary Sample Plots (TSPs) from harvested compartments and 83 TSPs from unharvested compartments. There were no significant difference in the mean number saplings in TSPs from harvested compartments and unharvested compartments in respect of sundri, gewa, baen, goran, passur, singra and khalisha as in all cases we obtained insignificant variance (vide. Table 69). Significant variance was obtained only in case of amur and kankra. In case of amur harvested compartments had significantly higher mean number of 1.17 saplings per TSP of 62.82 sq m as compared to 0.69 saplings in unharvested compartments. But in case of kankra from unharvested compartments a mean of 0.36 saplings was obtained as compared to 0.08 sapling from harvested compartments were obtained. So far as the comparison of relative dominance of the nine species are concerned sundri saplings both from harvested and unharvested compartments were significantly (P=0.01) higher than mean number of saplings of the remaining eight species (i.e. gewa, goran, passur, kankra, baen, singra, khalisha and amur). This is evident from Table 75.

It is thus found that sundri had the highest mean regeneration of 2.67 saplings per Temporary Sample Plot (TSP) in an area of 62.82 m^2 from the unharvested compartments nos. 16, 31, 35 and 41 and mean of 2.17 number of sundri saplings per TSP from harvested compartment nos. 32, 36 and 38. The difference was, however, insignificant. This finding has important bearing on the management of top dying of sundri trees through salvage felling.

Next to sundri were saplings of gewa from unharvested (1.51 nos.) and harvested (1.37 nos.) compartments and amur saplings (1.17 nos.) from harvested compartments, but these three did not differ significantly. However, mean number of saplings of gewa from harvested and unharvested compartments and amur from harvested compartments were significantly (P= 0.05) higher than sapling regeneration of the remaining species (i.e. goran, kankra, singra, passur, khalisha and baen) from both harvested and unharvested compartments.

Hence the present findings firmly differ from that of Gani and Hossen (2002). Thus the present findings convincingly suggest that removal of top dying affected sundri tree through a salvage felling is not going to affect the status of regeneration and recruitment of sundri seedlings in the top dying affected areas of the Sundarbans. This has undoubtedly a very important bearing in the management of the top dying affected sundri trees in the Sundarbans by the Forest Department.

To determine whether there exists any association between age/size of sundri trees with per cent top dying Correlation Coefficient (r) was calculated between diameter at breast height (d.b.h) in cm data and per cent top dying data of 1625 sundri trees collected from the Sundarbans. Correlation coefficient was found to be r = 0.275, with 1624 degrees of freedom. This is significant at P= 0.01. That means there is a highly significant positive correlation between dbh and per cent top dying of sundri. Hence using a programme of the Minitab that is provided in Fig. 19 developed a linear regression equation. This reveals that there is a clear positive linear relationship between dbh and per cent top dying. That is as the dbh increases per cent top dying also increases. The regression equation is Y= -2.3E-01 + 1.02567 X, where Y axis represents per cent top dying and X axis represents d.b.h. in cm. In this connection it may be mentioned here that Gibson (1975) reported that top dying of sundri generally occurred in the older trees but it also prevailed at all ages beyond the sapling stage. The present study has amply demonstrated that there is a clear linear relationship between dbh and per cent top dying of sundri. It may , however, be noted that at some sites even younger trees may be badly damaged by top dying as is evident from Fig. 24.

Three canopy closures per cent were recognized in FRMP Forest Inventory. These are canopy closure 1= canopy closure equal to or more than 70 per cent, 2 = canopy closures of equal to or greater than 30 per cent but less than 70 per cent and 3 = canopy closures of equal to or greater than 10 per cent but less than 30 per cent. Canopy closure and per cent top dying of sundri data from 200 TSPs showed a highly significant (P= 0.001) F value of 14.57 with 199 and 2 df and a

Correlation Coefficient r = 0.344616, with 199 df. This is significant at P = 0.01. Trend of this association is shown in Fig. 21. This also suggests a close association of canopy closure and per cent top dying of sundri trees. Thus it is suggested that an open canopy is more prune to top dying development. Hence it is evident that creation of too open a canopy artificially or naturally may lead to greater development of top dying of sundri in the Sundarbans. This finding has an important bearing in the management of top dying of sundri in the Sundarbans.

The early stages of the development of top dying condition are seen as yellowing of leaves on some of the twigs. This has been observed in June 2002 at Harbaria in compartment 26 in the Sundarbans. As the yellowing continues the affected leaves finally fall-off the twigs. Such twigs then continue to dry out and die. Examination of dying twigs and small branches by cutting through the dying portion reveal the presence of clear transition of progressive invasion characteristic of some causal organism (Fig.26). Besides, dying small twigs was seen eaten up by insects at places which injuries the tender bark. But no insects have been found in situ. Hence careful observation of top dying affected sites at monthly intervals on ward from April through to June 2003 should be carried out in order to locate the very early symptoms of top dying and to detect the insect which eats up the tender twigs.

Association of sapwood rot and insect damage has been established. There exists a highly significant (P = 0.001) correlation coefficient (r = 0.651, with 23 degrees of freedom) between per cent of sub-samples having sapwood rot and per cent of sub-samples having insect damage. This suggested a strong association between sapwood rot and insect damage in top dying affected sundri trees. Regression equation for the association of per cent sub-samples having sapwood rot and per cent sub-samples having insect damage is Y = 1.29619 +0.691304X, with R Sq. = 0.423, where per cent sapwood rot is in Y axis and per cent insect damage on the X axis (vide Fig. 37). Therefore, it is suggested that once top dying has caused death of sundri sapwood, insect damage increases and vice versa. However, which of these two commences first is not yet convincingly clear. Since insect damage occurs in the form of tunnels in deeper wood tissues, while sapwood rot occurs in the peripheral sap wood, it is most likely that sapwood rot occurs first and is followed by entry of insect. There is a need to clarify this in further study.

Per cent top dying of sundri data from the TSPs of 55 compartments showed highly significant (P =0.001) positive correlation (r = 0.412946, with 54 df) with per cent loranthus infestation. This convincingly suggests that with the increase in infestation by loranthus, per cent top dying of sundri also increase and vice versa (Fig. 40). It may, however, be mentioned that loranthus (*Dendrophthoe falcata*) is an angiospermic parasite (Rahman and Alam, 1994). It can infect healthy trees and also dies with the death of infected twigs/branches. Hence it is unlikely that loranthus infection could occur upon death of sundri twigs/branches. Therefore, it is concluded that loranthus infestation is also a cause of mortality of sundri twigs/branches.

In the present study of the 12 soil parameters studied in relation to four top dying severity classes (i.e. no top dying (i.e. none), slight, moderate and severe top dying of sundri. Calcium, Magnesium, Manganese and Zinc showed significant variance (vide Table 132).

Manganese in the soil collected in October 2001 from both soil depths (0-30 cm =D1 depth and 60-90 cm = D2 depth) showed significant negative correlation with per cent top dying of sundri trees in the 36 sample plots (Table 126). This clearly suggests that a deficiency of Manganese is associated with the development of top dying of sundri. However, Manganese levels in soils samples collected in January 2002 showed only insignificant correlation with per cent top dying data of 36 sample plots. This is because of the fact that Manganese levels had under gone 145.02 per cent increase in January 2002 over that of October 2001 as is evident from Table 122.

October 2001 data suggest an association of deficiency of Zinc with the occurrence and severity of top dying of sundri (Table 141), but this did not hold good in case of data from January 2002 soil samples as in the latter case higher Zinc values were found in case of severe and slight top dying sample plots Table 142). It is suggested that over certain period of the year (i.e. around October) Zinc deficiency is associated with the occurrence and severity of top dying of sundri (Table 141) but at other period of the year the deficiency is removed because of influx/availability of more Zinc in the soil (vide Table 143).

Calcium showed the same trend of occurrence among the soil samples from none, slight, moderate and severe top dying sample plots in soil samples collected in October 2001 and January 2002 (Table160). In both the data the lowest level of Calcium were found in sample plots having no top dying (i.e. none) sample plots while increasingly higher level of Calcium were found to occur in case of slight top dying sample plots and still higher levels in severe top dying sample plots. But the levels of Calcium in the moderate top dying of sundri sample plots in the data of both October 2001 and January 2002 were the highest. So the trend of increasingly higher level of Calcium in higher severity of top dying particularly moderate top dying sample plots indicate an association of Calcium toxicity and occurrence and severity of top dying of sundri.

Magnesium do not show any clear pattern of occurrence among none, slight, moderate and severe top dying sample plots as the mean values of none and severe top dying sample plots do not differ significantly in the soil samples of October 2001 and January 2002 (Table 160). This suggests that there is unlikely any association of Magnesium with the development/occurrence of top dying of sundri. So Magnesium do not deserve any further consideration in relation to top dying.

The levels of sand per cent in soil depth of 0-10 cm (D1 depth) collected in January 2002 showed significant negative correlation ($r = -0.3260800$, with 35 df) with per cent top dying of sundri data from 36 sample plots (vide Table 127). This clearly suggests that as sand content in soil depth of 0-10 cm decrease top dying per cent increase. Thus the levels of sand content in soil is associated with the development of top dying of sundri.

Soils having lower sand content and higher per cent of clay and silt are more compact soil. The negative effects of soil compaction are not all owing to poor aeration. Soil layers can become so dense as to impede the growth of roots even if an adequate oxygen supply is available. This has been demonstrated in case of cotton (Brady 1990).

Zinc deficiency is widespread throughout the world causing economic losses on a number of crops. Zn moves very slowly in soil (Swietlik, 2002). Fe, Mn and Zn deficiencies are known to affect the chlorophyll content whereas Fe deficiency caused a larger reduction of total chlorophyll content than Mg and Zn deficiencies in tropical fruit crops (Balakrishnan *et al*, 2000). High levels of zinc is known to reduce concentrations of iron (Fe) and calcium (Ca) in shoot dry matter to levels considered deficient for the growth of *Eucalyptus maculata* and *E.urophylla* in Brazil. There is strong relationship between dry matter reduction and induced F deficiency in plants (Soares *et al.* 2001). Deficiencies of Zn, Mn have been reported to reduce photosynthetic rate, internal CO_2 concentration, stomatal conductance, transpiration rate, chlorophyll formation, protein, ascorbic acid and carotenoid contents in Mulbery in India

(Singhal *et a.* 1999). In the northern region of Coahuliaa, Mexico there are deficiencies of micronutrients mainly of Zn, Mn and Cu. These deficiencies are caused by alkaline pH and high Calcium carbonate concentrations (Medina *et al*, 1999). The Gangetic sediments contain varable quantity of calcite. High content of total zinc (>100 ppm), manganese (>370 ppm), copper (>50 ppm) and cobalt (>33 ppm) in the estuarine floodplain soil is due to their high silt and clay content. The available zinc (> 1.0 ppm), manganese (> 2.0 ppm) and copper (>1.0 ppm) contents are marginal while the cobalt content (>1.3 ppm) is adequate in mangrove soil (Hassan, 1999).

Of the seven elements known to be essential for plant growth, eight are required in such small quantities that they are called micronutrients or trace elements. These are iron, manganese, zinc, copper, boron, molybdenum, cobalt and chlorine. Nicholas and Egan (1975) and Stevenson (1986) have provided detailed review on micronutrients. Mengel and Kirkby (1982) and Marschner (1986) have reviewed roles of individual micronutrients. The known roles of Zn and Mn are provided in the following from Brady (1990).

Micronutrient	Functions in higher plants
Zinc	Present in several dehydrogenase, proteinase, and peptidase enzymes; promotes growth hormones and starch formation; promotes seed maturation and production.
Manganese	Activates decarboxylase, dehydrogenase, and oxidase enzymes; important on photosynthesis, nitrogen metabolism, and nitrogen assimilation.

Zinc plays a role in protein synthesis, in the formation of some growth hormones and in the reproductive process of certain plants. Manganese seems to be essential for for photosynthesis, respiration and nitrogen metabolism. Chlorine is known to influence photosynthesis, and root growth also suffers if it is absent (Brady, 1990).

Some enzymatic and biochemical reactions requiring a given micronutrients may be poisoned by the presence of a second trace element in toxic quantities. Examples include the following Brady 1990) :

1. Iron deficiency is encouraged by an excess of zinc, manganese, copper or molybdenum.
2. Excess phosphate may encourage a deficiency of zinc, iron, or copper but enhance the absorption of molybdenum.
3. Heavy nitrogen fertilization intensifies copper and zinc deficiencies.
4. Excess sodium or potassium may adversely affect manganese uptake.
5. Excess iron, copper, or zinc may reduce the absorption of manganese.
6. High Calcium levels in soil solutions may reduce potassium uptake by the plant

Salinity is defined as the total amount of solid material (in grams) contained in one kilogram of water when all the carbonates has been converted to oxide, bromine and iodine replaced by chloride and all organic matter completely oxidized (Verma and Agarwall, 1995). In other words, salinity refers to the number of grams of dissolved salts in 1000g of sea water with chloride concentration used as an index. Values are usually expressed in parts per thousand (ppt) and range from 33 to 38 ppt in the open sea water (Tomlinson, 1986).

Quite often salinity has been attributed as the cause of top dying of sundri in the Sundarbans (Chaffey *et al.* 1985). But the present findings (vide Tables 56) do strongly support the fact that salinity governs the distribution and intensity of occurrence of sundri in different parts of the Sundarbans. However, we have found only insignificant correlation between EC and Na levels and per cent occurrence of top dying of sundri in the Sundarbans. Moreover, we have found only insignificant variance in case of EC and Na levels from sample plots having no top dying, slight, moderate and severe top dying of sundri in the Sundarbans. It is suggested that salinity can affect growth of plants in various ways. This is evident from the findings of various workers as provided below:

Waisel (1972) recorded that salinity conditions affect plant growth in a variety of ways i.e. a) inducing poor physical conditions of soil, b) decreasing water uptake, c) causing toxic accumulation of sodium and chloride, and d) reducing nutrient availability. Metabolism of carbohydrates in plants is affected by a general increase in salinity, as well as types of ion present.

Greenway (1968) records that the rate of plant growth under saline conditions is affected by the concentrations of salt inside the cells. .

Salinity affect nutrient availability by modifying the retention, fixation and transformation of the nutrients in soils; interfering with the uptake and/or absorption of nutrients by roots due to ionic competition; reduced root growth; and disturbing metabolism of nutrient within the plants mainly due to water stress and thus reducing their effectiveness (Chhabra, 1988).

Rowell (1988) reported that the status of nitrogen in saline soil is around 0.01 per cent. Nitrogen becomes limiting fertility in saline soil. pH is generally 6.0 to 8.4 in the Sundarbans and at such high pH phosphate, iron, zinc and manganese become unavailable and soil surface become water unstable, thus bringing about conditions of water permeability and poor aeration results.

It is commonly accepted that soil solutions with high salt concentrations cause growth retardation in most plants (Hayward, 1956).

The presence of salts in the soils can influence soil water uptake. Osmotic potential (ψ_o) effects in the soil solution tend to reduce the range of available moisture in such soils by increasing the amount of water left in the soil at the time of the plants wilt permanently (wilting coefficients). For soils high in salts, the total moisture stress will include the metric potential as well as the osmotic potential of the soil solution (Brady 1999).

Plants growing under saline condition must maintain a high concentration of osmotically active substrate in order to compete successfully with water retaining capacity of the surrounding medium. Under such condition when the osmotic potential of the solution around the plant roots increase, the OP (osmotic pressure) of the plant tissue increases proportionally. The water potential of plant cells is determined by two components (Adam, 1990):
Ψi (Cell water potential) = Ψp (turgor pressure potential) + $\Psi \pi$ (Cell osmotic potential)

Turgor pressure is responsible for the maintenance of tissue rigidity and is also vital in sustaining growth (Hsiao, 1973). If plants are to grow, it is essential that turgidity be maintained. halophytes might, therefore, be defined as plants which attain internal water potentials sufficiently below that of external saline soil solution to generate pressure permitting growth without suffering metabolic impairment (Adam, 1990).

Soil salinity is a consequence of the interaction of frequency of tidal inundation, evaporation and rainfall (Clarke, 1969). Soil salinity is regulated by a number of factors including tidal inundation, soil type and topography, depth of impervious subsoils, amount and seasonability of rainfall, fresh water discharge of rivers, run on from adjacent terrestrial areas, runoff and evaporation (Hutchings and Saenger, 1987). However, in tidally inundated situation evaporative losses and the frequency of flooding are the major factors determining soil salinity (Oliver, 1982).

Reduction of fresh water discharge through the Sundarbans has occurred as a result of upstream diversion of water at Farakka Barrage and increased use of ground water for agricultural and industrial uses (IECO, 1980; Shahidullah, 1980; Hannan, 1981; Shafi, 1982; Chowdhury, 1984). Reduced nutrient supply has resulted from the reduction of fresh water supply in the Sundarbans (Senedaker, 1984; Imam, 1982; Chowdhury, 1984).

Reduction in the fresh water flush has also been associated with increase in salinity (Hannan, 1981; Shahidullah, 1980; Hassan, 1988). The increase in salinity has exerted an increased osmotic stress on the roots and thereby reduced the availability and uptake of water and nutrients by sundri. This in turn has resulted in reduced growth of sundri in the more saline areas. The occurrence of the tallest sundri trees are found in the least and moderately saline north east and north central Sundarbans, and the most dwarf sundri trees occur in the most saline south western areas of the Sundarbans support the above statements (Rahman, 1995).

Soil salinity has been measured in terms of the levels of Sodium (Na) and Electrical Conductivity (EC) from soil samples collected from 36 sample plots fallings in four top dying severity classes in October 2001 and January 2002. Analysis of both Na and EC data revealed only insignificant Correlation Coefficient ($r = 0.080322$ and $r = 0.020602$ for EC of October 2001 and January 2002 respectively) while Correlation Coefficient for Na and per cent top dying of sundri were $r = 0.060001$ and $r = 0.014066$ for October 2001 and January 2002 respectively. Variance analysis revealed no significant difference in the mean values of EC and Na from soil samples collected from four top dying severity classes (i.e. none, slight, moderate and severe) of sundri as F-values obtained were 2.37, 0.28, 0.36 and 0.38 respectively with 3, 68 df in each case. It is thus evident that soil salinity and four top dying severity classes are not correlated.

The data of the distribution of sundri seedlings, saplings, poles and trees per hectare in the three salinity zones revealed significantly ($P = 0.001$) higher number of 32413 of seedlings, 3205 saplings, 1390 poles and 165 trees per hectare in the fresh water zone (FWZ) as compared to 15985 of seedlings, 1933 saplings, 1219 poles and 99 trees per hectare in moderately saline water zone (MSWZ), and the MSWZ had significantly ($P=0.001$) higher number as compared to that of 1714 seedlings, 439 saplings, 423 poles and 5 trees per hectare saline water zone (SWZ) compartments. **Thus it is very clear that distribution of the number of sundri seedlings, saplings, poles and trees are distinctively governed by the salinity of the areas.**

The intensity of occurrence of sundri and its distribution in the Sundarbans have been shown to be profoundly influenced by the salinity of the prevailing environment (vide Table 56). Salinity is also known to affect availability and uptake of soil nutrients by the plants. Hence it is suggested that increased soil salinity has resulted in physiological stress on sundri in the Sundarbans as a whole. **Thus increased soil salinity is considered as a general predisposing factor towards top dying of sundri in the Sundarbans.**

Burial of pneumatophores because of increased sedimentation, production of smaller number of pneumatophores and lenticels on the pneumatophores create conditions of reduced supply of air to the root mass which would have naturally affected the metabolism in the root system, causing mortality of roots and affecting absorption and uptake of water and nutrients supply to the crown of sundri trees. These result in the initiation of discolouration of the leaves and mortality of twigs.

Once mortality of twigs and gradual thinning out of the canopy results the overall photosynthetic potential of such trees drop down. So reduced supply of carbohydrate in the root system results in the production of fewer numbers of pneumatophores. This gets the support from the fact that moderate and severe top dying sundri sample plots had significantly smaller number of pneumatophores (vide Tables 21 and 22). These are considered as the primary cause of top dying of sundri. Once mortality of twigs and smaller branches occur wood a number of decay fungi (e.g. *Fomes badius, F. conchatus* and *F. rimosus, Hymenochaete tabacina, Schizophyllum commune, Hypoxylon sp., Poria spp., Trametes spp*, etc and insect (e.g. *Chrysocroa sp.*) take over and cause further progressive death and results in progressive degrade of the major branches and stem. Rahman (1995) determined that the extent of degrade due to top dying of sundri to be 42.18± 4.69 (at P= 0.05) and is provided in Table 167.

Table 167: Percent wood loss due to top dying of sundri in the compartment nos. 32, 36, 37, 38 and 39 in the Sundarbans (from Rahman 1995).

Compartment No.	No. of trees assessed	Estimated total wood (from 25 trees) to top 10 cm under bark (in m^3)	Usable wood actually obtained (in m^3)	Wood loss due to buck cut and undercut (in m^3)	Wood loss due to top dying (in m^3)	Percent Sound wood	Percent wood loss due to top dying
32	25	6.025	2.905	0.489	2.631	54.33	43.67
36	25	8.675	3.587	0.798	4.290	50.05	49.45
37	25	5.875	3.651	0.349	1.875	68.09	31.91
38	25	6.025	2.905	0.489	2.631	56.33	43.67
39	25	5.820	2.945	0.451	2.424	58.35	41.65
Total →	125	32.420	15.993	2.576	13.851	57.28	42.72
Mean ± t.se (P=0.05) →		6.484 ± 1.171	3.200± 0.369	0.515 ±0.160	2.77±0.86	57.43±6.40	42.18±4.69
Notes:	Data for compartment No. 39 were taken from Larsen (1993); Data for Compartment Nos. 32, 36, 37 and 38 on usable wood were taken from the Sundarbans Forest Division's Top Dying Felling and Marking Registers; and those of estimated total wood volume were calculated from dbh data by using Volume Regression for sundri provided in Fig. No. 6 by Chaffey *et al*, (1985).						

The findings of the present study do strongly suggest that deficiency of micronutrients (eg. Mn and Zn) over some months of the year and occurrence of higher level of Calcium play definite role in the development of top dying of sundri. Further study in simulated experiments should elucidate and establish the specific roles of these nutrients.

Status of seedlings, saplings, poles and trees of major tree species in the Sundarbans

The status of regeneration in the whole of the Sundarbans has been assessed from the data of 1203 TSP generated during 1996 and 1997 during FRMP Forest Inventory of the Sundarbans. Mean number of seedlings, saplings, poles and trees per ha were determined for 30 tree species. On an average there were 33895 seedlings, 7116 saplings, 3224 poles and 141 trees per ha of all the 30 species taken collectively in the whole of the Sundarbans. Sundri, gewa, goran, amur, passur, baen, shingra, dhundhul, keora and kankra constituted 97.33 % of the seedlings, 98.69% of saplings, 99.44 % of poles and 99.72% of tree populations in the Sundarbans in 1996-1997.

For the whole Sundarbans sundri commanded 18615 seedlings, 2045 saplings, 1068 poles and 100 trees per ha on an average. Gewa had 5501 seedlings, 1398 saplings, 1379 poles and 19 trees per ha. Goran had 5599 seedlings, 3157 saplings, 500 poles and 0.13 trees per ha. Amur had 598 seedlings, 214 saplings, 61 poles and 0.23 trees per ha. Passur had 87 seedlings, 22 saplings, 14 poles and 11 trees per ha. Baen had 194 seedlings, 29 saplings, 5 poles and 4 trees per ha. Shingra had 1835 seedlings, 52 saplings, 112 poles and 0.02 trees per ha. Dhundhul had 19 seedlings, 5 saplings, 0 poles and 0.64 trees per ha. Keora had 0 seedlings, 22 saplings, 5 poles and 2 trees per ha and Kankra had 554 seedlings, 83 saplings, 30 poles and 3 trees per ha on an average for the whole of the Sundarbans. All other species had 2.67% of seedlings, 1.31 % of saplings, 0.56% of poles and 0.28% of trees in the Sundarbans. Thus we find that sundri constituted 54.92% seedlings, 28.74 saplings, 33.13% poles and 70.92% of the tree populations in the Sundarbans.

Gewa constituted 16.23% seedlings, 19.64% saplings, 44.76% poles and 13.77% of the tree populations. Goran constituted 16.52% seedlings, 44.36% saplings, 15.52% poles and 0.09% of the tree populations. Amur constituted 1.76% seedlings, 3.01% saplings, 1.90% poles and 0.16% of the tree populations. Passur constituted 0.26% seedlings, 0.30% saplings, 0.43% poles and 7.93% of the tree populations. Baen constituted 0.57% seedlings, 0.41% saplings, 0.16% poles and 3.04% of the tree populations. Shingra constituted 5.41% seedlings, 0.73% saplings, 3.46% poles and 0.01% of the tree populations. Dhundhul constituted 0.03% seedlings, 0.04% saplings, 0% poles and 0.45% of the tree populations. Keora constituted 0% seedlings, 0.31% saplings, 0.14% poles and 1.68% of the tree populations. Kankra constituted 1.63% seedlings, 1.16% saplings, 0.44% poles and 1.87% of the tree populations These data clearly reveal the single dominance of sundri in the Sundarbans.

Impact of top dying of sundri on regeneration

In regeneration studies were carried out in 180 regeneration sub-plots, each 4 sq m, in no top dying (i.e. none), slight, moderate and severe top dying of sundri. Equal number of sub-plots were from each of the four top dying severity classes from 36 sample plots. Species encountered were sundri, gewa, goran, amur, singra, baen, passur and kankra. Sundri R1 type regeneration were the highest in all cases and significantly ($P = 0.05$) higher than all the remaining types of regeneration of all other species. It was found that within each type of regeneration (i.e. R1, R2 and R3) of sundri there is in general a trend of higher regeneration in the more top dying severity classes (i.e. from none, slight, moderate and finally to severe). This is particularly evident in case of R2 type regeneration in case of sundri . This finding support the idea that opening created in the ground level because of removal of canopy by top dying allows more sun light in the forest floor which has imparted a positive impact on the growth of young seedlings (R1 type) of sundri and this promoted more recruitment of R2 type sundri regeneration. **This finding convincingly suggests that removal of top dying affected sundri tree through a salvage felling is not going to affect the status of regeneration and recruitment of sundri seedlings in the top dying affected areas of the Sundarbans. This has undoubtedly a very important bearing in the management of the top dying affected sundri trees in the Sundarbans by the Forest Department.**

Impact of salvage felling on recruitment of saplings in 3 top dying harvested and 4 unharvested compartments

In order to determine the impact of salvage felling of top dying sundri status of regeneration, particularly saplings from compartment nos. 32, 36 and 38 were compared with that of compartment nos. 16, 31, 35 and 41. The data have been derived from the TSP Database generated during FRMP Forest Inventory of the Sundarbans during 1996 and 1997 so that status of regeneration 3 - 4 years after top dying harvest could be obtained from these three compartments. So far as the comparison of relative dominance of all available species sundri saplings both from harvested and unharvested compartments were significantly (P=0.01) higher than mean number of saplings of the remaining eight species (i.e. gewa, goran, passur, kankra, baen, singra, khalisha and amur). The highest mean regeneration of 2.65 sundri saplings were obtained per Temporary Sample Plot (TSP) in an area of 62.82 m^2 from the unharvested compartments and mean of 2.33 number of sundri saplings per TSP from harvested compartment nos. 32., 36 and 38. The difference was, however, insignificant.

Comparison of sundri seedlings, saplings and poles in 1996-97 and 2003

A comparison of the level of sundri seedlings, saplings and poles per ha compartment numbers 2,11, 19, 20, 22, 26, 33, 36, 37 and 40 in the Sundarbans during January 2003 and that of 1996-97 was made. It was found that sundri had significantly higher number of 32194.44 seedlings per ha in January 2003 as compared to 18302.95 seedlings in 1996 – 1997 and had significantly higher no. of 2847.22 poles per ha as compared to 1201.41 poles in 1996-97. But in case of saplings there were 1847.22 in 2003 as compared to 2308.92 saplings in 1996-97, the difference was, however, insignificant. **These reveal that there have occurred significant (P =0.05) increase in the number of sundri seedlings and poles in 2003 over that of 1996-1997, but the difference in case of saplings is insignificant. It is suggested that the increase might have resulted because of the impact of moratorium imposed in the Sundarbans.**

Findings about the causes of top dying of sundri

- Soil salinity plays a vital role and governs the distribution of sundri in the Sundarbans.
- Burial of pneumatophores, production of reduced number of pneumatophores and lenticels on the pneumatophores create condition of reduced soil aeration affecting normal metabolism in the root system and thereby predispose sundri trees to stressed condition which results in the initiation of twig deaths. This is considered as the primary cause of top dying of sundri in the Sundarbans.
- Deficiency of micronutrients (eg. Manganese and Zinc) and presence of higher levels of Calcium in the soil are associated with top dying of sundri.
- Greater opening in the canopy of sundri trees, loranthus (angiospermic parasite) infestations, and sundri trees of higher diameter at breast height (dbh) classes are associated with severity of top dying of sundri.
- Once top dying starts a number of fungi degrade wood of branches and main stem of sundri trees resulting in increasing top dying. Degrade due to top dying of sundri has been estimated to be 42.18 ± 4.69 per cent. The fungi include *Phialophora* sp with twig death, *Botryosphaeria ribis* with gall canker, *Ganoderma lucidum* with root rot and *Fomes badius* and a number of other basidiomycetes with wood decay.
- There exists a strong association between sapwood rot and insect damage in top dying affected sundri trees.

Salvage felling of top dying sundri trees is recommended for the following reasons:

- Removal of top dying sundri trees is necessary to reduce further build up of top dying of sundri and progressive deterioration of the health of the Sundarbans.
- Impact of salvage felling on regeneration and recruitment of sundri has been found to be insignificant.
- Top dying sundri trees suffer from further degrade induced by wood decay Basidiomycetous fungi and also insects, and cause degrade of estimated 42.18 ± 4.69 per cent. This is a heavy economic loss in forestry terms where millions of cubic meters of timbers are involved.

Therefore, MOEF should seriously consider reintroduction of a well planned and rigorously monitored salvage felling in more severely top dying affected compartments in the Sundarbans.

Top dying sundri trees to be salvage felled

- Sundri trees having 50% or more canopy damaged by top dying should only be included for salvage felling.
- All dead and decaying trees should be removed from the forest floor, if economically feasible, to reduce the build up of wood decay fungi and thereby reduce the extent of degrade due to top dying.
- Loranthus infested branches should be removed, during salvage felling, from other sundri trees as that will reduce the severity of top dying.

Suggestions for further studies

- Direct measurement of the status of soil aeration should be carried out using Redox Potential Meter (an equipment using which one can measure the level of air in soil directly) in areas of no top dying, slight, moderate and severe top dying of sundri to confirm the role of reduced soil aeration on the development of top dying of sundri in the Sundarbans.
- Factors that promote lower pneumatophore production and lenticels development by severe top dying affected sundri in comparison to that of healthy sundri should be studied. Depth and duration of flooding, rate of sedimentation may be interesting factors in this respect.
- Effect of removal of various levels (25%, 50% and 75%) of pneumatophores from around healthy sundri trees in sample plots selected from eastern and central parts of the Sundarbans and their effect on development of top dying should be studied.
- Effect of higher Calcium level and lower Manganese and Zinc levels on the development of top dying of sundri should be studied in simulated experiments.
- The labeled sundri trees in 36 sample plots established during the Study of Top Dying of Sundri Project should be further observed at yearly intervals for at least 2 years beginning from January 2004 to record the progressive changes of top dying symptom development and compared with the data of January 2002 generated by the present project. This will enable to find out precisely the time required from the early stage to more than 50% of the crown damage by top dying of sundri. Such knowledge would be useful for deciding about sundri trees to be covered under salvage felling and trees to be retained.

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