Khulna University
Life Science School
Forestry and Wood Technology Discipline

Author(s): Nourin Ahosan Habib

Title: Effect of Salinity on germination of *Prosopiia juliflora* (Swartz) DC

Supervisor(s): A. K. Fazlul Hoque, Professor, Forestry and Wood Technology Discipline, Khulna University

Programme: Bachelor of Science in Forestry

This thesis has been scanned with the technical support from the Food and Agriculture Organization of the United Nations and financial support from the UN-REDD Bangladesh National Programme and is made available through the Bangladesh Forest Information System (BFIS).

BFIS is the national information system of the Bangladesh Forest Department under the Ministry of Environment, Forest and Climate Change. The terms and conditions of BFIS are available at http://bfis.bforest.gov.bd/bfis/terms-conditions/. By using BFIS, you indicate that you accept these terms of use and that you agree to abide by them. The BFIS e-Library provides an electronic archive of university thesis and supports students seeking to access digital copies for their own research. Any use of materials including any form of data extraction or data mining, reproduction should make reference to this document. Publisher contact information may be obtained at http://ku.ac.bd/copyright/.

BFIS's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission you may use content in the BFIS archive only for your personal, non-commercial use. Any correspondence concerning BFIS should be sent to bfis.rims.fd@gmail.com.

EFFECT OF SALINITY ON GERMINATION OF *Prosopis juliflora* (Swartz) DC.

NOURIN AHOSAN HABIB

FORESTRY AND WOOD TECHNOLOGY DISCIPLINE
KHULNA UNIVERSITY
KHULNA

2014

EFFECT OF SALINITY ON GERMINATION OF

Prosopis juliflora (Swartz). DC.

COURE TITLE# PROJECT THESIS

COURSE NO. # FWT- 4114

This Project Thesis has been prepared and submitted to Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, for the partial fulfillment of 4 years professional B.Sc. (Hons.) degree in Forestry.

FORESTRY AND WOOD TECHNOLOGY DISCIPLINE

LIFE SCIENCE SCHOOL

KHULNA UNIVERSITY

KHULNA – 9208

BANGLADESH.

2014

SEMINAR LIBRARY
Forestry & Wood Technology Discipline
KHULNA UNIVERSITY.
Accn. No. 04040661
Copy ...
Date ... 11-03-2015

Dedicated To...

My Beloved Parents and

Younger Brother

ABSTRACT

Recently *P. juliflora*, a shrub or small tree, was discovered on the coastal embankments at Munshiganj, Satkhira. This native of Central America and the Caribbeans has been introduced in Africa, Asia and Australia for its hardiness in adverse environment and multiple uses. However, IUCN recognizes it as one of the few worst invasive species in the world. In India, the species has invaded even in mangrove forests. Reportedly, the species seriously affects local biodiversity, and human and animal health. Thus, this species is possessing a great concern.

Despite that *P. juliflora* might use various vectors for migration, seeing the older individuals, it is assumed that the species might have migrated to the coast of Bangladesh from South India with the tidal flow in the Bay of Bengal. Thus, to investigate the potential of tidal current as a vector, the impact of salinity on seed and seed germination was investigated. For this, freshly collected seeds were sown in petridishes moistened with 0, 5, 10, 15, 20, 25 and 30 ppt salt solutions. Again, seeds were stored in 0, 5, 10, 15, 20, 25 and 30 ppt salt solutions for 7 and 14 days and then sown in respective salinities as mentioned above. The study revealed that salinity, excepting up to 15 ppt, has significant negative impact on seed germination ($P < 0.05$). Seeds stored for 7 days exhibited high germination success. However, it was significantly low ($P < 0.05$) with seeds stored for longer period. This reflects that *P. juliflora* seeds when exposed to saline water for prolonged time loss viability. This study concludes that migration of *P. juliflora* from South India to Bangladesh through the Bay of Bengal is unlikely. Such migration could be possible only during cyclone or tidal surge in the bay. Further study into other potential vectors and adaptation of *P. juliflora* in the coast of Bangladesh is recommended.

ACKNOWLEDGEMENT

I would first like to thank Almighty Allah for the strength that he has given me to complete this dissertation.

I wish to express my indebtedness to everyone who contributed to the success of this work. My gratitude goes to my supervisor, Prof. A. K. Fazlul Hoque, Forestry and Wood Technology Discipline, Khulna University, Khulna for his untiring support and scholarly guidance throughout the course of this dissertation. I would also like to show my appreciation to Forestry and Wood Technology Discipline, Khulna University, Khulna for the support they have provided to scholarly shape my thinking towards the achievement of this degree.

I appreciate the support of Md. Sharif Hasan Limon, Assistant Professor, Forestry and Wood Technology Discipline, Khulna University, Khulna for necessary guidelines and encouragement during the research. Thanks to the people who sacrificed their time by helping me in seed collection and staff of Nursery, Forestry and Wood Technology Discipline, Khulna University, Khulna for their cooperation to complete this research successfully.

I owe my gratitude to all of my friends for their motivation while in pursuit of this degree.

Nourin Ahosan Habib

APPROVAL

Project Thesis submitted to the Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, for the partial fulfillment of 4 years professional B.Sc. (Hons.) degree in Forestry. I have approved the style and format of the project thesis.

03/02/2015

(A. K. Fazlul Hoque)

Professor

Forestry and Wood Technology Discipline

Khulna University

Khulna - 9208.

DECLARATION

I, Nourin Ahosan Habib, declare that this thesis is submitted for the B.Sc. (Honors) degree in Forestry at Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, is my own original work and have not previously been submitted or it has not been accepted to any other institution.

I give my consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, for the title and summary to be made available for other organizations.

Nourin Ahosan Habib
23.02.2015

Nourin Ahosan Habib

Roll No. 100502

Forestry and Wood Technology Discipline

Khulna University

Khulna - 9208.

CONTENTS

SUBJECT	Page No.
DEDICATION	I
ABSTRACT	II
ACKNOWLEDGEMENT	III
APPROVAL	IV
DECLARATION	V
LIST OF TABLES	VIII
LIST OF FIGURES	IX
CHAPTER ONE: INTRODUCTION	**1-2**
1.1 Background of the Study	1
1.2 Objectives of the Study	2
CHAPTER TWO: LITERATURE REVIEW	**3-21**
PART 1: *Prosopis*- An Overview	**3-19**
2.1 Genus *Prosopis*	3
2.2 *Prosopis juliflora*	3
2.2.1 Taxonomic Tree of *Prosopis juliflora*	4
2.2.2 Synonymy	4
2.2.3 Vernacular Names	5
2.2.4 Distribution of *P. juliflora*	5
2.2.5 Description of the Species	7
2.2.6 Ecology of *P. juliflora*	9
2.2.7 Seed Dispersal of *P. juliflora*	13
2.2.8 Uses of *P. juliflora*	14
2.2.9 Impact of *P. juliflora*	18
PART 2: Salinity	**19-21**
2.3 Salinity is a Constraint	19
2.3.1 Factors Affecting Salinity	20
2.3.2 Salinity Status of Coastal Areas near Sunderbans	20
2.3.3 Impacts of Salinity on *P. juliflora*	21
CHAPTER THREE: MATERIALS AND METHODS	**22-24**
3.1 Materials	22
3.2 Seed Collection	22
3.3 Preparation of Salt Solution	23
3.4 Germination Test	23
3.5 Data Collection and Statistical Analysis	24

CHAPTER FOUR: RESULTS AND DISCUSSIONS **25-28**
4.1 Results 25
4.1.1 Effect of Salinity on the Germination of *Prosopis juliflora* 25
4.1.2 Germination of *P. juliflora* seed stored in different salinities and sown in respective salt solutions 26
4.2 Discussion 28

CHAPTER FIVE: CONCLUSION **29**

REFERENCES **A-F**

LIST OF FIGURES

SUBJECT	Page No.
Figure 2.1: Distribution of *P. juliflora* in World Map	6
Figure 2.2: Mature tree (left) and Medium Sized tree of *P. juliflora*	7
Figure 2.3: Leaves and Flowers of *P. juliflora*	8
Figure 2.4: Fruit pods of *P. juliflora*	8
Figure 3.1: Prepared petridishes for the experiment	24
Figure 4.1: Figure 4.1: Effect of Salinity on the Germination of *Prosopis juliflora*	25
Figure 4.2: Effect of Storage in Respective Saline Water on the Germinated Seed	27

LIST OF TABLES

SUBJECT **Page No.**

Table 2.1. List of the countries where from *P. juliflora* is reported 6

Table 4.1: Fisher Pairwise Comparisons for Salinity Effect on Germinated Seed (No Storage) 26

Table 4.2: Analysis of Variance (ANOVA) 27

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Prosopis juliflora (Sw.) DC. has recently been discovered in the south western coast of Bangladesh in close proximity to the Sundarbuns. The species was imported by Bangladesh Forest Research Institute (the then Pakistan Forest Research Institute) sometime in early 1960s to try its prospect in the drier areas of Bangladesh. Fate of those plants are not known. However, the source of recently discovered *P.juliflora* seems to be different and not yet known. Here the species being supported by favorable soil and climate, local communities, relevant government and non-government institutions, is spreading quickly. In recent years, some *P. juliflora* have been planted on the coastal embankments at Munshiganj, Satkhira. Some people are also planting the species on the edge of their farmland.

P. juliflora is native to Central America, northern part of South America and the Caribbeans. This fast growing species has drawn attention of planters and foresters for its ability to grow in the most adverse environmental conditions where other species will not do, and for its multiple uses (Vimal and Tyagi, 1986; Pasiecznik *et al.,* 2001 and 2004; Mwangi and Swallow, 2008). In last 200 years, *P. juliflora* has been widely introduced in the arid and semi-arid regions of Africa, Asia and Australasia. However, once the species is introduced at a place, because of its high ecological amplitude, reproductive capacity, mobility and prolonged longevity of seed, allelopathy to other species but absence of auto-inhibition *P. juliflora* becomes invasive. In almost everywhere beyond its home range, the species has become invasive. IUCN includes the species in the list of hundred most invasive species in the world (Lowe *et al.,* 2000). Pastoralists in Africa call it a "devil tree" and in India, the species is considered as curse.

In Bangladesh, invasion of *P. juliflora* in the southwestern part should be of great concern for its proximity to the mangrove forest, which provide livelihood to about a million people. On the east coast of South India the species has posed a serious threat to the mangroves (e.g., in Mothupet Mangrove forest *P. julifora* is replacing mangroves (Hoque 2014, pers. com.).

Migration and germination are the key points to determine invasiveness of a species (Ferreras *et al.*, 2014). So, thee invasiveness of *P. juliflora* in our coastal region depends on its successful migration across the Bay of Bengal and efficacy of germination in the coastal sediment. From the east coast of India *P. juliflora* seeds may be transported to Bangladesh by southwesterly current in the Bay of Bengal during the monsoon, or during cyclone events. Thus, to control the spread of the species in Bangladesh, it is important to investigate the ability of *P. juliflora* seeds to travel across the Bay of Bengal withstanding the saline water and again to germinate in the saline coastal substrate. Therefore, to find the invasiveness of *P. juliflora* in our coastal region this study was undertaken with the following objectives.

1.2 Objectives of the Study

- To review the available literature on *Prosopis juliflora* and its interaction with saline environment.
- To find out the fate of *P. juliflora* seeds *in saline water.*
- To assess the effect of salinity on the germination of *P. juliflora* seeds.

CHAPTER TWO

LITERATURE REVIEW

In literature review, objectives were to have the broader idea about *Prosopis juliflora* and understand the salinity condition in the coastal areas of Bangladesh and particularly the effect of salinity on *P. juliflora*. Thus, this chapter includes three sections each with several subsections.

2.1 Genus *Prosopis*

Prosopis is the genus of trees and shrubs in the Mimosoideae sub-family of Leguminosae family. They are native to arid and semi-arid regions of the Americas, Africa and Asia that are mostly thorny and having thick pods (from yellow and long to black and short), which never split naturally, either on the tree or once fallen. *Prosopis* has 44 species and numerous varieties. Of the species 40 are native to the Americas, three to Asia and one to Africa. These species are divided into five distinct sections (Burkart, 1976) within which species can interbreed and lead to hybrid population creation. These hybrids can be described as new varieties or forms or even new species in many cases.

2.2 *Prosopis juliflora*

Prosopis juliflora (Sw.) DC. is a thorny shrub or small tree with a wide and flat-topped crown. The name '*Prosopis*' has been derived from the Greek word 'pros' meaning 'towards', and 'Opis', after the wife of Saturn, the Greek goddess of abundance and agriculture. '*juliflora*', comes from julus, meaning 'whip-like', mentioning the long inflorescences for bearing flower (Perry, 1998). According to Burkart (1976), *P. juliflora* has been placed under section Algarobia.

2.2.1 Taxonomic Tree of *Prosopis juliflora*

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Fabales

Family: Fabaceae

Subfamily: Mimosoideae

Genus: *Prosopis*

Species: *Prosopis juliflora*

Source: http://www.cabi.org/isc/datasheet/43942

2.2.2 Synonymy

P. juliflora had many synonyms before 1788. The old name *Mimosa juliflora* became both *Algarobia juliflora* (Sw.) Benth. ex Heynh. and *Neltuma juliflora* (Sw.) Raf. during the last two centuries until the both genera were placed under genus *Prosopis*. Many synonyms, mentioned below, indicate its wide distribution, diversity and great impact on human.

Other Scientific Names

- *Acacia cumanensis* (H. & B. ex. Willd.)
- *Acacia juliflora* (Sw.) Willd.
- *Acacia salinarum* (Vahl) DC.
- *Algarobia juliflora* (Sw.) Benth. ex Heynh
- *Desmanthus salinarum* (Vahl) Steud.
- *Mimosa juliflora* Sw.
- *Mimosa salinarum* Vahl
- *Neltuma bakeri* Britton & Rose
- *Neltuma juliflora* (Sw.) Raf.

- *Neltuma ocidentalis* Britton & Rose
- *Neltuma pallescens* Britton & Rose
- *Prosopis alpataco* R.A.Philippi
- *Prosopis articulata* (S.Watson)
- *Prosopis bracteolata* DC.
- *Prosopis cumanensis* (H. & B. ex. Willd.) H.B.K.
- *Prosopis dominguensis* DC.
- *Prosopis dulcis* var. domingensis (DC.) Benth.
- *Prosopis flexuosa* DC
- *Prosopis glandulosa* Torrey
- *Prosopis horrida* Kunth
- *Prosopis inermis* H.B.K.
- *Prosopis juliflora* var. inermis (H.B.K.) Burkart
- *Prosopis velutina* Wooton
- *Prosopis vidaliana* A. Naves

2.2.3 Vernacular Names

'Mesquite' is the most common English name for *P. juliflora.* Some common names are:

- English: Algaroba Bean, Mexican Thorn, Prosopis, Ironwood.
- India: Angrezi Bavaliya, Belari Jali, Ganda Babul, Ganda-Babool, Gando Baval, Vilayati Babool, Vilayati Babul, Vilayati Khejra, Vilayati Kikar.
- Bangladesh: Bilati Babla, Guiya Babla, Nona Babla.

2.2.4 Distribution of *P. juliflora*

P. juliflora is a mainly tropical species native to Mexico, Central and northern South America. For its tolerance to adverse environmental conditions and multiple uses, the species has been widely planted in arid and semi-arid parts of Asia, Africa and Australia. The table below presents distribution of *P. juliflora*, however the species may even be more widespread.

Table 2.1. List of the countries where from *P. juliflora* is reported

Continent	Countries
Asia	Bahrain, Bangladesh, Brunei Darussalam, Cambodia, India, Indonesia, Iran, Iraq, Israel, Jordan, Kuwait, Myanmar, Oman, Pakistan, Philippines, Qatar, Saudi Arabia, Sri Lanka, Thailand, United Arab Emirates, Vietnam, Yemen.
Africa	Algeria, Botswana, Burkina Faso, Cape Verde, Chad, Djibouti, Egypt, Eritrea, Ethiopia, Gambia, Ghana, Guinea-Bissau, Kenya, Liberia, Libya, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Senegal, Somalia, South Africa, Sudan, Tanzania, Tunisia, Western Sahara, Zimbabwe.
North America	Bermuda, Mexico, USA, Hawaii.
Central America and Caribbean	Antigua and Barbuda, Aruba, Bahamas, Barbados, British Virgin Islands, Cayman Islands, Costa Rica, Cuba, Curacao, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Montserrat, Nicaragua, Panama, Puerto Rico, United States Virgin Islands.
South America	Bolivia, Brazil, Colombia, Ecuador, Peru, Venezuela.
Oceania	Australia, Papua New Guinea.

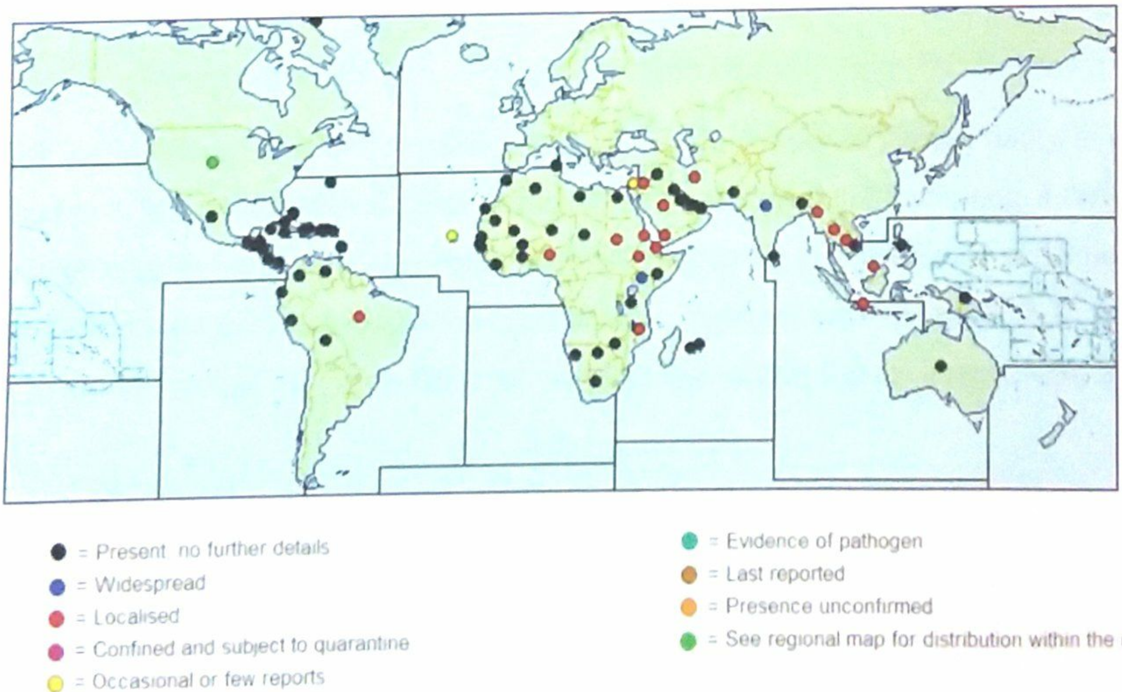

Figure 2.1: Distribution of *P. juliflora* in World Map (Copyright: CABI)

2.2.5 Description of the Species

P. juliflora is shrub or small evergreen tree, 3-12 m tall, with spreading branches. The branches are cylindrical, green, more or less round or flat-topped and containing stubborn, green spins with hard wood. The foliage is glabrous or slightly pubescent or ciliate on the leaflets and spines are axillary, uninodal, divergent, paired, or solitary. Spines are 0.5-5.0 cm long being largest on strong basal shoots. Sometimes they are paired on the same branches, sometimes absent, or not present on all branchlets (CABI, 2005).

Figure 2.2: Mature tree of *P. juliflora* (Copyright: Peter Felker, Colin Hughes)

Leaves are bipinnate, glabrous or pubescent and having 1-3 pairs of pinnae, rarely in 4 pairs measuring 3-11 cm long. Petiole plus rachis (when present) is 0.5-7.5 cm long. Leaflets are elliptic-oblong, glabrous or ciliate, rarely pubescent occurring in generally 11 to 15 pairs per pinna. Leaflets are 6-23 mm long x 1.6-5.5 mm wide. Racemes are cylindrical, 7-15 cm long with puberulent rachis and florets are greenish-white and turning light yellow (CABI, 2005).

Figure 2.3: Leaves and Flowers of *P. juliflora*

Pods are straight with incurved apex, sometimes falcate and colored straw yellow to brown. They are stalked and acuminate, compressed, linear with parallel margins. Pods are 8-29 cm long x 9-17 mm broad x 4-8 mm thick and 2 cm from stipe. Rectangular to sub quadrate endocarp segments present, which are mostly broader than long. The seeds of *P. juliflora* are oval, brown, and transverse (CABI, 2005).

Figure 2.4: Fruit pods of *P. juliflora*

2.2.6 Ecology of *P. juliflora*

P. juliflora has a broad ecological amplitude. It is adapted to a very wide range of soils and site types from sand dunes to cracking clays. It is generally found in areas where water and soil fertility are the principal limiting factor for plant growth. It is able to endure and even thrive on the poorest land, unsuitable for any other tree species. *P. juliflora* can grow and take control in dry or seasonally dry watercourses or depressions, and coastal flats and dunes. However, it is frost sensitive. The optimum temperature for germination of *P. juliflora* seeds is 30-35°C and the germination decreases rapidly at temperatures below 20°C or above 40°C (Pasiecznik *et al.*, 2001).

All *Prosopis* species are able to survive in areas with exceptionally low annual rainfall or very lengthy dry periods but only if the roots are able to tap ground water or another permanent water source within the first few years. Being adapted to arid and semi-arid climates, *P. juliflora* generally germinates and establishes during the brief rainy season and seedlings must be sufficiently well established to survive the first dry season. The existence of two root systems, a deep tap root to reach ground water and a mat of surface lateral roots to make use of infrequent rainfall events. It leads *Prosopis* species firmly in the category of phreatophytes, but they show a variety of mesophytic and xerophytic characteristics depending on water availability. The need for rain or a high water table is reduced in coastal areas, where sufficient atmospheric moisture exists with persistent trade winds or seasonal fog (CABI, 2005).

In *P. juliflora*, the action of the pulvinus (joint like thickening in the leaf base facilitating growth-independent movement) can cause the leaflets to fold and protecting the stomata on the upper leaf surfaces from water loss during high evapotranspiration periods. Leaflets possess specialized adaptations promoting efficient utilization and retention of water such as sunken stomata, more stomata on adaxial than abaxial surfaces, thick and waxy cuticles and the presence of mucilaginous cells. Seasonal variations in *P. juliflora*'s leaf concentration of proline, sugar and protein are presumed a response to drought. In natural stands of *P. juliflora* in Venezuela, osmotic adjustment was observed an increase in leaf concentrations of all measured nutrients in the dry season (CABI, 2005).

P. juliflora exhibits a brief periods of leaf senescence and replenishment (Goel and Behl, 1996). The presence of chlorophyll in the green stems of *P. juliflora* is also a response to drought through leaf shedding during dry periods and maintaining some photosynthetic potential this time (El Fadl, 1997). Diurnal changes affect photosynthetic rate and stomatal conductance and a decrease has found in them during the high temperatures at midday (Sinha *et al.*, 1997).

2.2.6.1 Genetics

Prosopis spp. are generally diploid with a haploid number of n=14 (2n=28). However, *P. juliflora* has at least some tetraploid forms (2n=56) (Hunziker *et al.*, 1975; Solbrig *et al.*, 1977).

2.2.6.2 Physiology and Phenology

The seeds of *P. juliflora* naturally show a high level of dormancy. The hard seed coat must be broken or weakened to allow water absorption by the seed to be germinated. With time seed, dormancy is broken as the seed coat degrades (Pasiecznik and Felker, 1992). Seeds with entire pods or endocarp shells show decreased germination and an allelopathic chemical extract from pod pericarps decreases germination in *P. juliflora* (Warrag, 1994). The dispersal of seed through different animals has positive effects on germination due the removal of the mesocarp or endocarp, or other mechanical or chemical factors. Increasing alkalinity significantly decreases the final germination and germination rate of *P. juliflora* seeds above pH 9.0 (Srinivasu and Toky, 1996).

Prosopis species show high levels of variability in morphological characters due to reproductive self-incompatibility and obligate outcrossing. Continuous differences in climatic conditions i.e. temperature, rainfall and day length, and discrete differences in site conditions i.e. soil type, salinity or depth lead to create varieties of phenological responses. Variations are observed largely in native populations. In invading populations, clinal variations are concealed because of the rapid and widespread dispersal of diverse genetic material by humans and animals over a range of site and climatic conditions (CABI, 2005).

Almost continuous year-round flowering of *P. juliflora* is seen in India and Haiti but a period of maximum fruit production is always present (Goel and Behl, 1995; Timyan, 1996). In parts of India, one or two fruiting periods occur, depending on site and the 'form' of *P. juliflora* present (Luna, 1996).

2.2.6.3 Reproductive Biology

Anthesis is protogynous and occurs simultaneously in all flowers on an inflorescence when the flowers are fully open (Goel and Behl, 1996, Celis, 1995; Burkart, 1976). Flower maturation often initiates at the proximal end while flowers at the distal end are still immature. Assisted by a sugary secretion, pollen falls for fertilization into the stigma through a central depression (Goel and Behl, 1996). Though *Prosopis* species are commonly supposed to be self-incompatible, limited self-compatibility (4%) has been observed in *P. juliflora* (Sareen and Yadav, 1987; Simpson, 1977; Solbrig and Cantino, 1975). The flower of *P. juliflora* is pollinated while the insect eats the protein-carbohydrate exudate released from anther gland (Chaudhry and Vijayaraghavan, 1992). Anther glands also secret a sticky substance to attach the pollen to the body of the insect. This glands may also secret an odorous chemical attractant. Pollination success in *P. juliflora* is always low and it may be due to poor pollen viability, short periods of pollen release or stigma receptivity, lack of synchronization between pollen release and pollen reception, few pollinating insects, flower sterility or high rates of ovary abortion. The pollen viability of *P. juliflora* has been recorded as 79-96% (Goel and Behl, 1995). Though very large numbers of flowers are produced, most of them are not fertile and ovary abortion is high. This leads to very low production of pods compared with the higher flower production per tree.

P. juliflora usually begins to produce flower and fruit after 2-3 years, but this is highly depended upon site conditions. In Sahel 12 months old trees have been observed to flower, whereas on poor exposed sites trees of 15 years or more may not flower (Pasiecznik *et al.*, 2001).

2.2.6.4 Environmental Requirements

Temperature:

Mean minimum temperatures, and the frequency and duration of winter frosts are some of the major limitations to the distribution of the *P. juliflora*. Light frosts cause dieback of the branches, harder frosts cause complete stem mortality, and more severe or longer lasting frosts cause complete death of the plant (Felker *et al.*, 1982). Frost damage is more severe on seedlings and younger trees of *P. juliflora* and trees in the low land areas (Muthana, 1974). Hyde *et al.* (1990) found that *P. juliflora* seedlings were killed by a -2°C frost in Spain, whereas it was noted to suffer frost damage but survive when temperatures fell below 0°C in India (Muthana, 1974). There is also considerable variation in frost tolerance exhibited by different provenances of the species (CABI, 2005).

Optimum temperatures range for the growth of *P. juliflora* is 20-30°C. But it seems that there is no natural upper limit to temperature because introduced *P. juliflora* has found to tolerate daytime shade temperatures of over 50°C and soil temperatures in full sunlight as high as 70°C in Africa and Asia (Pasiecznik *et al.*, 2001).

Rainfall:

P. juliflora thrives in a wide range of rainfall zones, from 100 mm mean annual rainfall or less in dry coastal zones to 1500 mm mean annual rainfall at higher altitudes, and the ability to tolerate very low annual rainfall is well known.

Altitude:

Altitude appears to have a limited effect on distribution. In its native range *P. juliflora* is abundant at altitudes up to 200 m, but the abundance decreases as altitude increases.

Soil:

Soil nutrient status is rarely a limiting factor to distribution. Nitrogen is very rarely limiting, and trees have been noted to fix nitrogen under conditions of high pH, high salinity and high water deficits (Singh, 1996; Felker *et al.*, 1982). Other macronutrients can occasionally be limiting to growth either directly or indirectly. Saline and alkaline soils are often occupied by *P. juliflora* and it is known to tolerate saline sites in its native range such as lowland flats and coastal dunes and in such conditions, it can often dominate (CABI, 2005).

P. juliflora has been successfully raised using saline irrigation water, with an electrical conductivity of 20 dS/m in India and 6-21 dS/m in Pakistan (Singh, 1996; Khan *et al.*, 1986). *P. juliflora* is able to tolerate alkaline soils, with marginal reduction in growth up to pH 9, and will survive and grow in soils of pH 11 (Singh, 1996). However, *Prosopis* spp. appear not to be well suited to acidic soils (Pasiecznik *et al.*, 2001). *P. juliflora* can be found on all soil types from pure sands to heavy clays and stony soils, but deep free-draining soils are preferred. Soil depth is important, with a noted limitation to tree growth occurring where soils are thin, or have a calcareous or iron pan. Above ground growth is stunted due to damage in root system; poor drainage or waterlogging. Poor oxygen content in the soil has the same effect on root system development.

2.2.7 Seed Dispersal of *P. juliflora*

2.2.7.1 Natural Dispersal (Abiotic)

Water is an important dispersal agent in desert ecosystems. Water dispersal ensures widespread dissemination of seed during flooding or other high rainfall events when seedling establishment is favored. *Prosopis* species are often found colonizing ephemeral watercourses and dispersal is aided by water flow in the rainy season, particularly during very wet years (Solbrig and Cantino, 1975). Oceanic dispersal is important for coastal species, and for crossing large bodies of water such as in the Caribbean. Pods and endocarps float and are impervious to water infiltration, protecting the seed from the harmful effects of extended periods in seawater (Pasiecznik *et al.*, 2001).

2.2.7.2 Vector Transmission (Biotic)

Pods have high sugar content and they are low in anti-feedants. Man was a common dispersal agent in historic and prehistoric times. Livestock are now the primary dispersal agents along with a wide variety of wild animals. Birds, bats, reptiles and ants also feed on *Prosopis* fruits and are potential agents of dispersal (CABI, 2005).

Pods are eaten off the tree or off the ground by grazing animal and seeds are deposited in the faeces. Voided seed are given a advantage by being placed in faeces, with their improved water-holding capacity and high levels of nutrients. Livestock tend to spend more time on better pasture or by water sources but voiding of seed in preferential locations is not guaranteed. However, different animals have very different effects on seed survival (CABI, 2005).

2.2.8 Uses of *P. juliflora*

P. juliflora is a valuable multi-purpose tree. The principal uses of *P. juliflora* are wood for fuel, posts, poles and sawn timber, and pods for fodder. There are numerous other tree products including chemical extracts from the wood or pods, honey from the flowers, medicines from various plant parts, exudate gums, fibers, tannins and leaf compost. The tree is also widely planted for soil conservation, in hedgerows, and as an urban and general amenity tree. The general uses of *P. juliflora* are mentioned as follows:

2.2.8.1 Use of *Prosopis juliflora* as Fuel

Although the initial plantations in India were mainly established for the purpose of conservation, *P. juliflora* has become the main source of fuel in rural areas and largely, in urban and semi-urban areas also. Today it fulfils more than 70 percent of the firewood requirements of the rural people in the tropical arid and semi-arid regions of India (Harsh and Tewari, 1998). Biofuels, charcoal, fuelwood, etc. are the fuel products that can be obtained from *P. juliflora*. Charcoal from *P. juliflora* wood is used extensively in the USA as barbecue fuel; about 30% of the charcoal sold for this purpose originates from *P. juliflora* from the Sonora Desert in northern Mexico. In Pakistan, its charcoal has been extensively used in kilns of poultry farms during winter season (CABI, 2005).

2.2.8.2 Use of *Prosopis juliflora* as Food and Fodder

Rich, delicious flour can be made from pulverized pods from which seeds have been removed. Cotyledons and embryos when pulverized yield a flour rich in protein and sugar appropriate for diabetic people. There are reports that *P. juliflora* pods are used in preparing bread, sweets, syrup and coffee. The pods must be processed to improve the flavor. Sugars and sweeteners can be produced from the pods (CABI, 2005).

The use of *P. juliflora* pods as a source of fodder is much popular worldwide. *P. juliflora* foliage is first-quality fodder (Gomes, 1961). For dairy cows, the flour may make up 40-60% of concentrate rations. In South Africa, it is fed unmixed to sheep. Ripe pods contain 12-14% crude protein. The short-fibred parts are also suitable for pigs and poultry.

2.2.8.3 Use of *P. juliflora* as Wood and Pulp Materials

Larger branches and trunks of *P. juliflora* can provide a high quality timber comparable in colour, finish and physical attributes to different Indian commercial hardwoods. Negligible shrinkage (4.17%) is its exceptional property, which is much less than that for oak, maple or walnut trees (14-16%). Because of this quality furniture, items made from *Prosopis* wood develop little or no cracking or warping later (Singh, 2008).

Prosopis species are widely used for making furniture because of their high quality wood. The wood of *P. juliflora* is soluble to varying degrees in water, sodium hydroxide, alcohol and benzene. So, it can be successfully used for pulping to produce writing and printing papers, textile fibers, tyre cord or cellophane. Tests have indicated that writing and printing papers could be produced from *P. juliflora* logs, which have girth of 30 to 50 cm with 50% cellulose and 30 per cent lignin (Madan and Tandon, 1991).

2.2.8.4 Use of *P. juliflora* Biomass

P. juliflora is the most efficient species to convert energy into biomass. It is an excellent candidate for short rotation energy plantations considering its fast growing nature, higher biomass production potential, drought and heat tolerance and excellent coppicing ability. It produces biomass of about 25 to 30 tons/ha/year at 4 to 5 years (Patel, 1986) rotation. It was reported that total biomass from *P. juliflora* ranked first amongst the high biomass producing native trees of arid and semi-arid regions of India. (Singh, 2008).

2.2.8.5 Use of *P. juliflora* Gum

P. juliflora exudes gum from the sapwood. On average, about 40 g of gum is produced from one plant (Tewari et al., 2013). *P. juliflora* gum exudation is increased at higher temperatures and ceased completely at the beginning of the rainy season (Tewari, 1998). The gum forms adhesive mucilage and it can be used as an emulsifying agent with favourable physical and chemical properties. *Prosopis* gum can also be used in confectionery, mending pottery, and as an adulterant and substitute for gum arabic. (Krochmal *et al.,* 1954). It possesses good adhesive strength and can be used as paper adhesive for brown paper and wallpaper (Vimal and Tyagi, 1986).

2.2.8.6 Medicinal Uses

A bark extract obtained from boiling wood chips is used as an antiseptic on wounds, and gum is used to treat eye infections in India (Vimal and Tyagi, 1986). Azam *et al.* (2011) reported presence of antioxidant compound in concentrated form (6-8%) in the heartwood of *P. juliflora.* $C_{15}H_{14}O_6$ ((-)-mesquitol) has been found in *P. juliflora* which is better than familiar antioxidant probucol and α-tocopherol drugs. *Prosopis* wood is reported to have medicinal value against rheumatism and miscarriage. Some of the alkaloids of *Prosopis* species are reported to be antifungal and antibacterial. In Brazil, *P. juliflora* flour is used as an aphrodisiac, syrup as an expectorant and tea infusion against digestive disturbances and skin lesions (Rocha, 1990).

2.2.8.7 Soil Reclamation by *P. juliflora*

P. juliflora litter adds to the humus content of the salt affected soils. The organic acids produced from the decomposed litter react with native calcium carbonate and release calcium to exchange with sodium. Being highly tolerant to soil sodicity, *P. juliflora* roots open up otherwise impermeable sodic soil and thus facilitate entry of water in the deeper layers. The carbon dioxide released by its roots during respiration interacts with water and produces weak carbonic acid.

Such acid facilitate dissolution of precipitated calcium carbonate already present in sodic soils. Thus, it helps in reclamation of the sodic soil. It reclaims the soil to such an extent that agricultural crops can be grown without amendments (Singh, 2008).

2.2.8.8 *P. juliflora* in combating desertification

Desertification is an international problem and *P. juliflora* is solution to this. Shelterbelts of *P. juliflora* and *P. pallida* are planted around fields in many semi-arid regions to reduce wind speed. This reduces wind-induced soil erosion, decreases desiccation by reducing transpiration and consequently increases plant and animal production. In India, shelterbelts of *P. juliflora* were found to have a positive effect in reducing soil erosion compared with other species and control plots. In Sudan, wind speed was reduced by an average of 14% inside *P. juliflora* plantations, and with reductions up to 36% at high winds (El Fadl, 1997).

2.2.9 Impact of *P. juliflora*

There are both positive and negative influences of *P. juliflora* on human, plants and animals including climate and environmental conditions.

2.2.9.1 Economic Impact

P. juliflora are being assumed positive in terms of the benefits from the sale of tree products or negative in terms of the loss in agricultural productivity and other inconveniences. The negative effects, in terms of economic importance, are losses due to the destruction of fishing nets by the thorns, and illness and death of livestock due to eating *P. juliflora* pods. Crop losses, manual eradication costs, the costs for repairing tyres, and doctors' bills for treating thorn wounds, negative effect on water use and tourism can also cause economic damages. Positive benefits included the sale of charcoal, wood and pods (Choge *et al.*, 2002; Maundu *et al.*, 2009).

2.2.9.2 Environmental and Biological Impact

Prosopis are phraetophytic and are known to possess very deep roots, which will use subterranean water when no surface water is available. In India, Cape Verde and elsewhere in the Sahel, farmers blamed *Prosopis* spp. for the lowering of water tables. Positive impacts on the environment include soil stabilization by the roots and reducing soil erosion from windbreaks and within plantations, reduced salinity and alkalinity, and improved soil fertility and soil physical characteristics.

P. juliflora has been renowned as invasive in protected areas in South Asia, notably grasslands in Gujarat, native xerophytic woodlands in Rajasthan and a national park in Sri Lanka. When *P. juliflora* forms dense stands, some plant species are suppressed there. Maundu *et al.* (2009) reported that plant biodiversity was reduced in *P. juliflora* thickets in Kenya. It has also been noted that the numbers and diversity of some mammals increase due to improved cover from predators and hunters. Negative effect of *P. juliflora* has been found on native forage plants. The presence of *P. juliflora* as a readily available source of fuel has drastically reduced the previous over-exploitation and illegal cutting in protected reserves. There are clearly marked local variations due to *P. juliflora* in environmental effects.

2.2.9.3 Social Impact

In the USA, Mexico, Saudi Arabia, Kuwait, United Arab Emirates, India and South Africa the pollen has been identified as a major allergen and *P. juliflora* is described as an 'important source of respiratory allergens in tropical countries'. It has been reported for at least 13 human allergens in the pollen (Killian and McMichael, 2004). It has also close allergenic relationships with animal species and so, planting of *P. juliflora* in urban areas is not recommended.

Weedy invasions can become an obstruction on roads or even block smaller trails completely. An additional and unusual negative social effect was noted by Choge *et al.* (2002) in 12% of respondents in Kenya, who identified *P. juliflora* stands as a 'refuge for thieves', notably livestock poachers and rustlers. Issues related to social impact of this tree arise where invasions are particularly dense, the availability of traditional grass fodder is reduced, and some pastoralists have chosen to move to other areas. In Baringo, Kenya, some local people demanded to be relocated due to the invasion of *P. juliflora.*

2.3 Salinity as a Constraint

Salinity is a major attribute of seawater and undoubtedly has some adverse effects on both plants and animals (Bailey and James 2000). It affects the general health of both mangrove and non-mangrove plants (Hossain *et al.*, 2001). Salt, even at the low concentrations, can limit the functionality of reproductive and vegetative growth of plants by some severe physiological dysfunctions and widespread indirect and direct harmful effects (Shannon *et al.*, 1994).As, plant absorb water through roots salt are found to become progressively concentrated in the root zone but it is very smaller in amount (Kozlowski, 1997). In addition, salinity restricts seed germination, causes alternation of plant morphology and anatomy and often kills non-halophytes. Kozlowski (1997) and Brugnoli and Lauteri (1990) observed that plant anatomy and xylem cells are often altered by salinity and it reduces the photosynthesis rate in both halophytes and non-halophytes.

2.3.1 Factors Affecting Salinity

Salinity in the coastal areas is controlled by the tidal inundation, salinity of tidal waters, fresh water discharge from rivers, rainfall, temperature, wind action, evaporation, humidity, etc. Clarke and Hannon (1970) observed that soil salinity is the consequence of the interaction among frequency of tidal inundation, evaporation and supply of fresh water. Other factors that can affect the soil salinity include soil type and topography, amount and seasonality of rainfall, depth of impervious subsoil, run on from adjacent terrestrial areas, and run off.

Salinity increases due to the increase of temperature, which enhances evaporation. Rainfall decreases the salinity through addition of freshwater in the coastal ecosystem and that makes the site suitable for halophytes. Humidity plays role to influence the evapotranspiration that can control the salt movement in the soil. High salinity is accompanied with high temperature and wind causes salt accumulation at the soil surface. The extent of plant cover also has a significant influence on evaporation loss from the mangrove community (Hutchings and Saenger, 1987).

2.3.2 Salinity condition of Coastal Areas near

The coastal areas of Bangladesh lie in the southern part of the country. The Sundarbuns is the nearest forest that can be associated with and subjected to saline water, and it may be the result of frequent fluctuations of salinity levels. The coastal areas with the mangrove swamp are inundated twice daily and thus tidal inundation regulates the salinity levels of coastal areas. The duration and depth of tidal inundation depend on many factors like the distance from the main rivers and sea including local relief and sediment load in the inundating water (Rahman, 1995).

The salinity of the Sundarbans and its adjacent coastal areas increases from the east to west and north to south, but remains less than 6 dSm^{-1} even in the driest month. Soil salinity in April to May remains 2 and 4.5 $dS\ m^{-1}$ in most part of Sundarbans adjacent coast. Based on the degree of salinity, the area is divided into three saline zones- less saline (salinity<2 $dS\ m^{-1}$), moderately saline (2-4 $dS\ m^{-1}$) and strong saline zones (>4 $dS\ m^{-1}$) (Siddiqi, 2001). The concerned area for this study was under strongly saline zones.

Water salinity along the northeast coast of Bangladesh adjacent to the Sundarbans ranges from 1-9 ppt in the late monsoon of September. This varies from 4-28 ppt during the dry season of May (Siddiqi, 1992).

2.3.3 Impacts of Salinity on *P. juliflora*

Salinity has much less impact on the germination, survival and growth of *P. juliflora. P. juliflora* shows a great tolerance to high salinity and they have been found to grow in the coastal regions. *P. juliflora* seeds showed no effect in final germination with up to 30% added seawater (Khan *et al.,* 1987). *P. juliflora*'s seed germination decreases with the increase in salinity or NaCl concentration. Again, higher salinity shows greater germination rate in regular temperature than in high temperature (Pasiecznik *et al.*, 2004, El-Keblawy and Al-Rawai, 2005, Laxen, 2007, Mwangi and Swallow, 2008, Kaur *et al.* 2012).

CHAPTER THREE

MATERIALS AND METHODS

The effect of salinity on the germination of *Prosopis juliflora* seeds was studied in the Nursery of FWT Discipline, Khulna University, Khulna. The salinity of sea and coastal water is mostly due to the presence of NaCl (Castro and Huber, 2003). Other salts are present in this environment only in trace amount. Therefore, in this study salt represents only NaCl. The materials and methods are described in details as below:

3.1 Materials

The following materials were used to carry out this experiment:

- 10-liter plastic bowl
- Plastic Tub
- Knife and Scissor
- Tap Waters
- Common Salt (NaCl)
- Temperature compensated hand held Salinity Refractometer
- Petri-dishes
- Tissue Paper
- Glass Jars

3.2 Seed Collection

Mature fruits (pods) of *P. juliflora* were collected directly from trees growing on the embankments in Munshiganj, Satkhira in May 2014. Seeds were extracted from the pods using a scissors and a knife. About 2500 seeds were obtained from the fruits collected. Seeds were dried and stored in poly bag for germination test.

3.3 Preparation of Salt Solution

A stock solution of 50 parts per thousand (ppt) salt was prepared by dissolving salt (NaCl) in water and the salinity was checked with a hand held Salinity Refractometer. The Salinity Refractometer was adjusted using distilled water before taking salinity measurements. Using this stock, solutions of different salinities (0, 5, 10, 15, 20, 25, 30 ppt) were prepared using the following formulae:

$$V_1S_1 = V_2S_2$$

Here,

V_1 = Volume of solution in Cubic centimeter

S_1 = Final concentration of solution in ppt

S_2 = Known concentration of stock solution in ppt (50 ppt)

V_2 = Required volume of stock solution

The prepared solution was then justified using the Salinity Refractometer.

3.4 Impact of salinity on seed germination:

The germination study was started on May 21, 2014 following Completely Randomized Design was followed for the germination test. In this experiment, there were seven treatments (0, 5, 10, 15, 20, 25 and 30 ppt salinities) and 3 replications. For each replication 30 seeds were sown. Before sowing seeds, a petridish was filled up to one third of its depth with tissue paper as the substrate. Salt solution was added in the petridish until the tissue papers were completely wet and a thin film of water was visible on the surface. Another tissue paper was placed covering the seeds to moisten seeds from all sides. In this manner, 630 seeds (7 treatments x 3 replication x 30 seeds) were sown 21 petri-dishes.

The level of water in a petridish was marked with a permanent marker. Petridishes were kept open in the air. Every day the water level in petridishes was checked and corrected by adding tap water as it necessitated. Germination was checked daily until there was no fresh germination.

To investigate the longevity of *P. juliflora* seeds in saline waters, seeds were stored in glass jars containing salt solution of 0 to 30 ppt at 5 ppt interval. After 7 days and 14 days of storage, those stored seeds were sown in petridishes in corresponding salinities as described earlier. Salinity in petridishes were also maintained as described above. Data on seed germination were also recorded as described above.

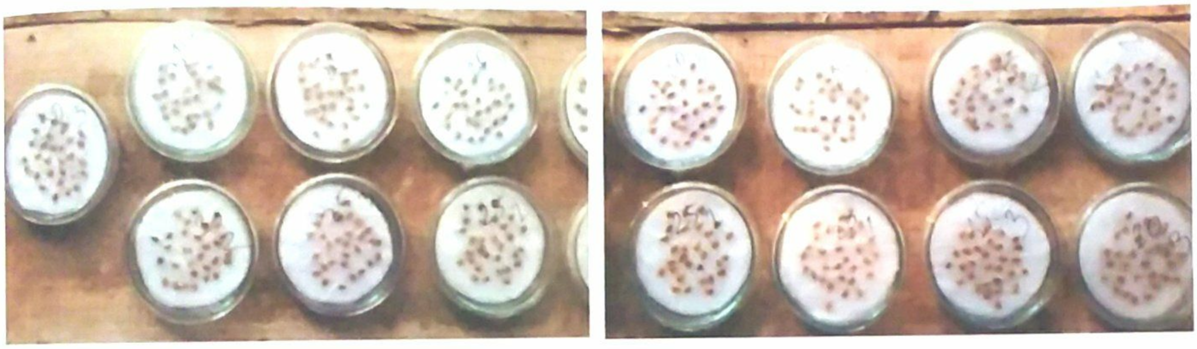

Figure 3.1: Prepared petridishes for the experiment

3.5 Data Collection and Statistical Analysis

Data on seed germination were collected up to July 2, 2014. The data were analyzed using Minitab 17.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results

Effect of salinity on the germination and longivity of *Prosopis juliflora* seeds have been presented in this chapter.

4.1.1 Effect of Salinity on the Germination of *Prosopis juliflora*

Finding of this study regarding the impact of salinity on the germination of *P. juliflora* seeds (freshly collected/not stored) is shown in Figure 4.1. Analysis of variance indicates that salinity has significant negative impact on the germination of *P. juliflora* seeds ($P < 0.05$). The LSD test (Fisher Pairwise Comparisons, Table 4.1) revealed that the germination did not vary significantly within the salinity range 0-15 ppt despite that it was maximum at 15 ppt.

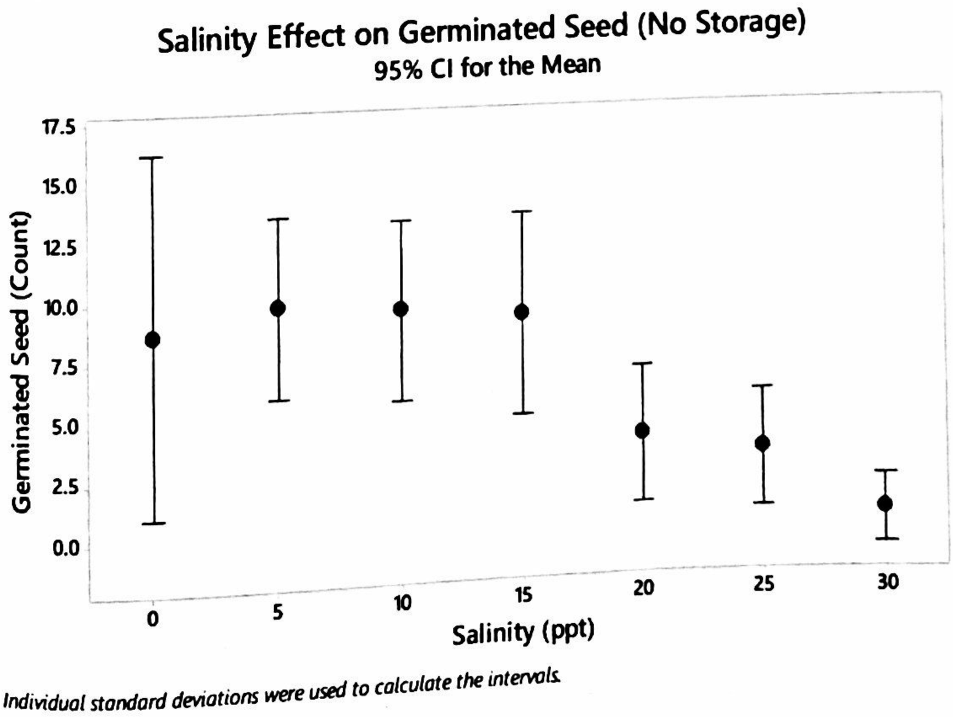

Figure 4.1: Effect of Salinity on the Germination of *Prosopis juliflora*

Table 4.1: Fisher Pairwise Comparisons for Salinity Effect on Germinated Seed (No Storage)

Grouping Information Using the Fisher LSD Method and 95% Confidence

Salinity	N	Mean	Grouping		
5	3	9.667	A		
10	3	9.333	A		
15	3	9	A		
0	3	8.67	A		
20	3	3.667		B	
25	3	3		B	C
30	3	0.333			C

Means that do not share a letter are significantly different.

4.1.2 Germination of *P. juliflora* seed stored in different salinities and sown in respective salt solutions

This study reveals that storage of *P. juliflora* seeds in different concentrations of salt solutions has significant impact on the germination (p = 0.00 Table 4.2, Figure 4.2). Figure 4.2 clearly indicates that the seed germination was maximum (51.33%) at 7 days storage.

Table 4.2: Analysis of Variance (ANOVA)

General Linear Model: Germinated Seed versus Salinity, Storage

Source		DF	Adj SS	Adj MS	F-Value	P-Value	F crit
	Salinity	6	659.7	109.952	24.22	0.000	2.32
	Storage	2	376.3	188.143	41.44	0.000	3.22
	Salinity*Storage	12	181.0	15.087	3.32	0.002	1.99
Error		42	190.7	4.540			
Total		62	1407.7				

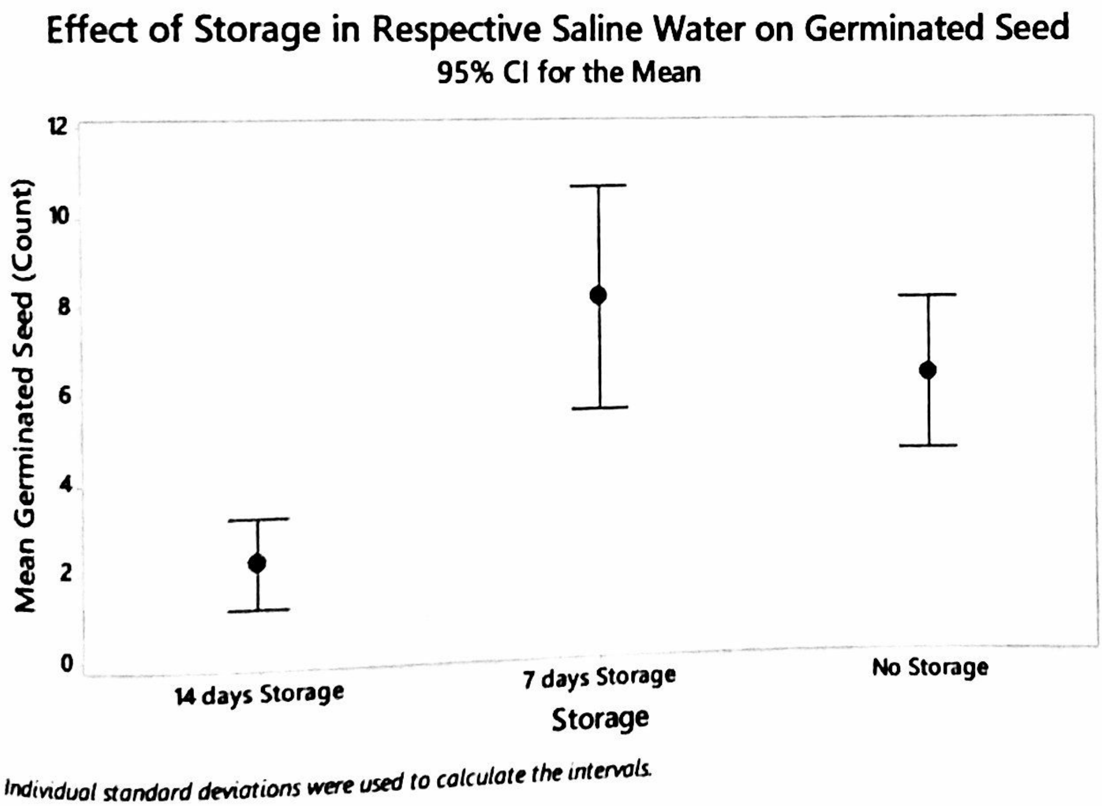

Figure 4.2: Effect of Storage in Respective Saline Water on the Germinated Seed

4.2 Discussion

P. juliflora has been reported to be salt tolerant (Pasiecznik *et al.*, 2004, El-Keblawy and Al-Rawai, 2005). In our study also it is observed that *P. juliflora* seeds germinated without any significant impact up to the salinity level 15 ppt.

In this study it was observed that the length of seed storage time had significant impact on the germination success. Seeds stored up to seven days produced maximum germination. Pasiecznik and Felker (1992) observed that *P. juliflora* seeds exhibit high level of dormancy. From this study it appears that the species might have some obligate dormancy as germination success after seven days storage was higher than that with no storage. However, when seeds are stored for longer period (e.g., 14 days) in salt-water germination success (i.e., longevity of seeds) diminishes very quickly.

In this study the impact of seed storage (in saline water) was investigated for our concern that *P. juliflora* might migrate to the coast of Bangladesh from the southeast coast of India where the species is prolific (e.g., Tamil Nadu; Tewari *et al.*, 2000; Harris *et al.*, 2003). It is reported that water is an important dispersal agent for *P. juliflora* seeds and the seed (while in pod) might migrate across long distances with ocean current.

Tomczak and Godfrey (1994) reported that the persistent velocity of northward current in the Bay of Bengal in monsoon is 2.5-3.6 km/hour. Considering water flows in high and ebb tides, roughly *P. juliflora* seeds should take about 90 days to travel from Tamil Nadu (where the species is prolific) to the coast of Bangladesh. Considering the impact of storage in salt water on the longevity of *P. juliflora* seeds that we have observed in this study (depleting significantly after 7 days of storage), it is less likely that the species can reach the coast of Bangladesh through the Bay of Bengal. Hitherto, absence of the species in the Sundarbans also support this proposition. However, it is important to note that fruits of *P. juliflora* are indehiscent and seeds inside the pod remain effectively protected against seawater (Pasiecznik *et al.*, 2001). In addition, during high-energy events in the sea (e.g., cyclone and tidal surge) viable seeds of *P. juliflora* might reach the coast of Bangladesh.

CHAPTER FIVE

CONCLUSION

There is a significant impact of salinity and seed storage on the germination of *Prosopis juliflora* seeds. At higher salinities (> 15 ppt) and longer storage in saline water (> 7 days) germination of *P. juliflora* seeds decreases rapidly. Considering distance, tidal velocity, and pattern (diurnal tide) and longevity of seeds in seawater it could be concluded that the possibility of migration of *P. juliflora* from the eastern coast of south India to Bangladesh through the Bay of Bengal is minimum. However, regular vigilance is needed as such migration might take place during high-energy events e.g., cyclone/tidal surge.

Discovery of *P. juliflora* in Munshiganj, Shamnagar, Satkhira makes us concerned for its potential impact on regional biodiversity, particularly for the Sundarbans. Being favoured by local people the species is spreading fast. Further studies to ascertain the route of its migration and understand adaptation of the species in the region are urgently needed. Meanwhile creation of awareness among local people and other institutions needed for eradicating the species.

REFERENCES

Azam, M.M., Tewari, J.C., Singh, Y., and Roy, M.M. (2011). *Prosopis juliflora*: A Rich Source of Antioxidant Product. Folder. Central Arid Zone Research Institute, Jodhpur.

Bailey, P.C.E., and James, K. (2000). Riverine and wetland salinity impacts-Assessment of R and D needs. Land and Water Resources Research and Development Corporation. Occasional Paper 25/99, LWRRDC, Canberra.

Brugnoli, E., and Lauteri, M. (1990). Effects of Salinity on Stomatal Conductance, Photosynthetic Capacity, and Carbon Isotope Discrimination of Salt- Tolerant (*Gossypium hirsutum* L.) and Salt-Sensitive (*Phaseolus vulgaris* L.) C3 Non-Halophytes. C.N.R. Istituto per I'Agroselvicoltura, Via Marconi, 2, 05010 Porano (TR), Italy. Plant Physiology, 95:628-635.

Burkart, A. (1976). A monograph of the genus *Prosopis* (Leguminosae, subfam. Mimosoideae). (Part 1 and 2.) Catalogue of the recognized species of *Prosopis*. Journal of the Arnold Arboretum, 57:217-525.

CABI, (2005). Forestry Compendium. Wallingford, UK: CABI.

Castro, P., and Huber, M.E. (2003). Marine Biology. 4th ed. McGraw Hill, Boston.

Celis, A.D. (1995). Los Algarrobos. Concytec, Lima, Peru.

Chaudhry, B., and Vijayaraghavan, M.R. (1992). Structure and function of the anther gland in *Prosopis juliflora* (leguminosae, mimosoideae) - A Histochemical Analysis. Phyton-Annales Rei Botanicae, 32:1-7.

Choge, S.K., Ngujiri, F.D., Kuria, M.N., Busaka, E.A., and Muthondeki, J.K. (2002). The status and impact of *Prosopis* spp in Kenya. Kenya Forestry Research Institute (KEFRI), Nairobi, Kenya, Pp 59.

Clarke, L.D., and Hannon, N.J. (1970). The mangrove swamps and salt marsh communities of the Sydney District, III. Plant growth in relation to salinity and water logging. Journal of Ecology, 58: 351-369.

El Fadl, M.A. (1997). Management of *Prosopis juliflora* for use in agroforestry systems in the Sudan. Tropical Forestry Reports 16. University of Helsinki, Helsinki, Finland.

El-Keblawy, A., and Al-Rawai, A. (2005). Effects of salinity, temperature and light on germination of invasive *Prosopis juliflora* (Sw.) D.C., Journal of Arid Environments, 61:555–565.

Felker, P., Clark, P.R., Nash, P., Osborn, J.F., and Cannell, G.H. (1982). Screening *Prosopis* (mesquite) for cold tolerance. Forest Science, 28:556-562.

Ferreras, A. E., Funes, G., and Galetto, L. (2014). The role of seed germination in the invasion process of Honey locust (*Gleditsia triacanthos* L., Fabaceae): comparison with a native confamilial. The Society for the Study of Species Biology.

Goel, V.L., and Behl, H.M. (1995). Propagation of *Prosopis juliflora* from rooted stem cuttings. International Tree Crops Journal, 8:193-201.

Goel, V.L., and Behl, H.M. (1996). Variation in thorn character within and among *Prosopis* species and vegetative multiplication of selected genotypes. Indian Journal of Forestry, 19(2):132-136.

Gomes, P.A. (1961). An Mesquite Tree , Ministry of Agriculture , Agricultural Information Service, Rio de Janeiro, Pp 40.

Harris, P.J.C., Pasiecznik, N.M., Smith, S.J., Billington, J., and Ramirez, L. (2003). Differentiation of *Prosopis juliflora* (Sw.) DC. and *Prosopis pallida* (H. and B. ex. Willd.) H.B.K. using foliar characters and ploidy. Forest Ecology and Management, 180:153-164.

Harsh, L.N., and Tewari, J.C. (1998). *Prosopis* in the arid regions of India: Some important aspects of research and development. Kingsville, Texas, USA.

Hoque, A. K.F. (2014). Professor, Khulna University, Khulna. Personal communication.

Hossain, A.T.M.E., Alam, M.L., Paul, S.P., and Khan, Z.H. (2001). Salinity Trends in the Sunderbans and Its Vegetation. Proceedings of the National Workshop on Mangrove Research and Development at Bangladesh. Forest Research Institute, Chittagong, Pp 11-16.

Hunziker, J.H., Poggio, L., Naranjo, C.A., and Palacios, R.A. (1975). Cytogenetics of some species and natural hybrids in *Prosopis* (Leguminosae). Canadian Journal of Genetics and Cytology, 17:253-262.

Hutchings, P., and Saenger, P. (1987). Ecology of Mangroves. University of Queensland Press, St Lucia.

Hyde, E.A., Pasiecznik, N., and Harris, P.J.C. (1990). Evaluation of multi-purpose trees in southern Spain. Nitrogen Fixing Tree Research Reports, 8:73-74.

Kaur, R., Gonzáles, W.L., Llambi, L.D., Soriano, P.J., Callaway, R.M., Rout, M.E., Gallaher, T.J., and Indrajit. (2012). Community Impacts of *Prosopis juliflora* Invasion: Biogeographic and Congeneric Comparisons. PLoS ONE, 7(9).

Khan, D., Ahmad, R., and Ismail, S. (1986). Case History of *Prosopis juliflora* Plantation at Makran Coast through Saline Water Irrigation. Proceeding of US-Pakistan Biosaline Research Workshop, Karachi, Pakistan.

Khan, D., Ahmad, R., and Ismail, S. (1987). Germination, growth and ion regulation in *Prosopis juliflora* (Swartz) DC under saline conditions. Pakistan Journal of Botany, 19:131-138.

Killian, S., and McMichael, J. (2004). The human allergens of mesquite (*Prosopis juliflora*). Clinical and Molecular Allergy, 2(8).

Kozlowski, T.T. (1997). Responses of woody plants to flooding and salinity. Tree Physiology Monograph No. 1. Heron Publishing, Victoria, Canada.

Krochmal, A., Paur, S., and Duisber, P. (1954). Useful native plants in American southwestern deserts. Economic Botany, 8:3-20.

Laxen, J. (2007). Is *Prosopis* a curse or a blessing? - An ecological – economical analysis of an invasive alien tree species in Sudan. **In:** Luukkanan, O. Ed. Tropical Forestry Reports. VITRI, University of Helsinki, Finland.

Lowe, S., Browne, M., Boudjelas, S., and De Poorter, M. (2000). 100 of the World's Worst Invasive Alien Species A selection from the Global Invasive Species Database. Species Survival Commission (SSC) of the World Conservation Union (IUCN), Pp 12.

Luna, R.K. (1996). *Prosopis juliflora* (Swartz) DC. **In:** Plantation Trees. Delhi, India: International Book Distributors.

Madan, R.N., and Tandon, B. (1991). Utilization of some of plantation, agro-forestry and social forestry species for the production of dissolving pulps. Indian Forester, 117:29-36.

Maundu, P., Kibet, S., Morimoto, Y., Imbumi, M., Adekar, R. (2009). Impact of *Prosopis juliflora* on Kenya's semi-arid and arid ecosystems and local livelihoods. Biodiversity, 10(2-3):33.

Muthana, K.D. (1974). A note on frost susceptibility in arid zone trees. Annals of Arid Zone, 13:370-373.

Mwangi, E., and Swallow, B. (2008). Invasion of *Prosopis juliflora* and local Livelihoods in the lake Baringo area of Kenya. Conservation and Society, 6(2): 130-140.

Pasiecznik, N., and Felker, P. (1992). Mechanical cleaning of *Prosopis* seed. Nitrogen Fixing Tree Research Reports, 10: 186-188.

Pasiecznik, N.M., Felker, P., Harris, P.J.C., Harsh, L.N., Cruz, G., Tewari, J.C., Cadoret, K., and Maldonado, L.J. (2001). The *Prosopis juliflora - Prosopis pallida* Complex: A Monograph. HDRA, Coventry, UK.

Pasiecznik, N.M., Harris, P.J.C., and Smith, S.J. (2004). Identifying Tropical *Prosopis* Species: A Field Guide. HDRA, Coventry, UK.

Patel, V.J. (1986). The Role of *Prosopis* in Wasteland Development. Jivrajbhai Patel Agroforestry Center, Surendrabag, Gujarat, India.

Perry, G. (1998). *Prosopis*. Flora of Australia, 12:7-13.

Rahman, A.H.M.M. (1995). Integrated Resource Development of the Sunderbans Reserve Forests, Bangladesh. Fo: Dp/BGD/84/056, Pp 115.

Rocha, R.G.A. (1990). *P. juliflora* as a source of food and medicine for rural inhabitants in Rio Grande do Norte. **In:** Habit, M. A., and Saavedra, J. C. Ed. The Current State of Knowledge on *Prosopis juliflora*. FAO, Rome, Italy, Pp 397-403.

Sareen, T.S., and Yadav, S.K. (1987). Self-incompatibility in *Prosopis juliflora* DC (Leguminosae). Incompatibility Newsletter, 19:66-68.

Shannon, M.C., Grieve, C.M. and Francois, L.E. (1994). Whole-plant response to salinity. In Plant-Environment Interactions. Ed. R. E. Wilkinson. Marcel Dekker, New York, Pp 199-244.

Siddiqi, N.A. (1992). Regeneration Status and Influence of Animals on Regeneration in the Sunderbans Mangrove Forest. Ph. D. thesis submitted to the facilities of Biological Science, University of Dhaka, Pp 199.

Siddiqi, N.A. (2001). Mangrove Forestry in Bangladesh. Institute of Forestry and Environment Science, University of Chittagong, Pp 1-201.

Simpson, B.B. (1977). Mesquite, its Biology in Two Desert Shrub Ecosystems. Stroudsberg, Pennsylvania, USA: Dowden, Hutchinson and Ross.

Singh, G. (1996). The role of *Prosopis* in reclaiming high-pH soils and in meeting firewood and forage needs of small farmers. **In:** Felker, P., Moss, J. Ed. *Prosopis*: Semiarid Fuelwood and Forage Tree; Building Consensus for the Disenfranchised. Kingsville, Texas, USA: Center for Semi-Arid Resources, 1.3-1.27.

Singh, G. (2008). Managing *Prosopis* for livelihood security in salt affected and dry areas. Technical bulletin No. 10. Central Soil Salinity research Institute, Karnal, India.

Sinha, A.K., Shirke, P.A., Pathre, U., and Sane, P.V. (1997). Sucrose-phosphate synthase in tree species: light/dark regulation involves a component of protein turnover in *Prosopis juliflora* (SW DC). Biochemistry and Molecular Biology International, 43:421-431.

Solbrig, O., and Cantino, P. (1975). Reproductive adaptations in *Prosopis* (Leguminosae-Mimosoideae). Journal of the Arnold Arboretum, 56(2):185-210.

Solbrig, O.T., Bawa, K., Carman, N.J., Hunziker, J.H., Naranjo, C.A., Palacios, R.A., Poggio, L., and Simpson, B.B. (1977). Patterns of variation. **In:** Simpson BB, Ed. Mesquite, its Biology in Two Desert Shrub Ecosystems. Stroudsberg, Pennsylvania, USA: Dowden, Hutchinson and Ross, Pp 44-60.

Srinivasu, V., and Toky, O. (1996). Effect of alkalinities on seed germination and seedling growth of important arid trees. Indian Journal of Forestry, 19:227-233.

Tewari, D.D. (1998). Economics and Management of Non-timber Forest Products: A Case Study of Gujarat, India. Oxford and IBH Publishing Co. PVT. Ltd, New Delhi, Calcutta, India.

Tewari, J.C., Harris, P.J.C., Harsh, L.N., Cadoret, K., and Pasiecznik, N.M. (2000). Managing *Prosopis juliflora* (Vilayati babul): a Technical Manual. CAZRI, Jodhpur, India. HDRA, Coventry, UK.

Tewari, J. C., Mathur, B. K., Tewari, P., Singh, Y., Singh, M., Ram, M., and Sharma, A. (2013). *Prosopis juliflora*: A Miracle Species of Hot Arid and Semi-Arid Regions of India. Popular Kheti, 1(2):53-59.

Timyan, J. (1996) Bwa Yo: Important Trees of Haiti. South East Consortium for International Development, Washington DC, USA.

Tomczak, M., and Godfrey, J.S. (1994). Regional Oceanography: An Introduction. Pergamon, Pp 422.

Vimal, O.P., and Tyagi, P.D. (1986). *Prosopis juliflora*: Chemistry and Utilization In The Role of *Prosopis* in Wasteland Development. (Ed.) V. J. Patel. Javrajbhai Patel Agroforestry Center, Surendrabag, Gujarat, India.

Warrag, M.O.A. (1994). Autotoxicity of mesquite (*Prosopis juliflora*) pericarps on seed germination and seedling growth. Journal of Arid Environments, 27:79-84.