STUDIES ON GENETIC DIVERSITY AND REPRODUCTIVE BIOLOGY OF *PROSOPIS JULIFLORA* (SWARTZ) DC.

BY

DEEPAK CHOPRA
Admn.No.98 A 83 D

Dissertation submitted to the CCS Haryana Agricultural University, Hisar in partial fulfilment of the requirements for the degree of:

DOCTOR OF PHILOSOPHY
IN
AGROFORESTRY

DEPARTMENT OF FORESTRY
COLLEGE OF AGRICULTURE
CHAUDHARY CHARAN SINGH HARYANA AGRICULTURAL UNIVERSITY
HISAR - 125 004

2001


Dedicated to
my friend
parents

CERTIFICATE-I

This is to certify that this dissertation entitled, "**Studies on genetic diversity and reproductive biology of *Prosopis juliflora* (Swartz) DC.**" submitted for the degree of **Doctor of Philosophy** in the subject of **Agroforestry** to the C.C.S. Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Mr. Deepak Chopra,** Admn.No. 98A83D under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

Studola
23/11/2001

(DR. M.S.HOODA)
Major Advisor
Senior Scientist
Department of Forestry
CCS Haryana Agricultural University
Hisar 125 004

CERTIFICATE-II

This is to certify that this dissertation entitled, **"Studies on genetic diversity and reproductive biology of *Prosopis juliflora* (Swartz) DC."** submitted by **Mr. Deepak Chopra**, Admn.No. 98A83D to the C.C.S. Haryana Agricultural University, Hisar in partial fulfilment of the requirements for the degree of **Doctor of Philosophy** in the subject of **Agroforestry** has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

5/11/2002
MAJOR ADVISOR

5.1.02
EXTERNAL EXAMINER

HEAD OF THE DEPARTMENT

DEAN, POST-GRADUATE STUDIES

ACKNOWLEDGEMENTS

I feel privileged to express my heartiest sense of gratitude to my Major Advisor Dr.M.S.Hooda, Senior Scientist, Department of Forestry, for his very kind initiation, inspiring guidance, invaluable counsel, affectionate advisement and persistent encouragement throughout the course of investigation and the vital suggestions during the preparation of this manuscript. It was indeed an unforgettable experience of working under his guidance.

I extend my sincere thanks to Dr.R.R.Singh, Professor and Head, Department of Forestry, CCS HAU, Hisar for providing facilities to carry out the present investigation.

I phrase my solemn regards to the members of my advisory committee Dr.S.S.Bisla, Director of Students Welfare, Dr. Man Singh, Professor & Head, Math & Statistics, Dr.C.Ram, Professor, Department of Seed Science and Technology, Dr.R.P.S.Arewal, Professor, Department of Plant Breeding, for their guidance, prolific suggestions and useful comments during the course of this investigation.

Thanks are also due to the faculty members, Department of Forestry for providing me a congenial and homely almosphere in our Department during the entire period of my study.

With immense pleasure, indebtedness and profound sense of gratitude, I express most sincere thanks to Dr.A.K. Chhabra, Associate Professor (Plant Breeding), Dr.R.K. Behl, Professor (Plant Breeding), Dr.V.S.Lather, Associate Professor (Plant Breeding), Dr.H.K.Bajaj, Professor and Head (Nematology), Dr.S.C.Goel, Professor (Botany) for their

cooperation and valuable suggestions at various stages of this investigation.

My special thanks are due to Dr.(Mrs.) Sucheta Kokhar and Dr.S.K.Sharma, Professors, Department of Entomology, CCS HAU, Hisar, Dr.S.L.Gupta and Dr.(Mrs.) Debjani Dey, Senior Scientists, Division of Entomology, IARI, New Delhi and Director, Zoological Survey of India, Calcutta.

I extend my thanks to my batchmates Dr.R.S.Dhillon and Dr.R.C.Verma, Assistant Scientists and Dr.S.Kaushik for their invaluable, benevolent and cordial company during the present investigation.

A word of appreciation is due to my friends at IARI, Dr.Ravi Hegde, Dr.B.Shivanna, Dr.Vinod Sharma and Dr.Puneet Luthra, Research Associates for providing an oasis in the middle of a sandy desert.

Timely and needy help rendered by Dr.(Mrs.) Anita Mann and Dr.Raghu Narwal, Research Associates, Department of Seed Science and Technology, Dr.Pawan Tyagi, Research Associate, Department of Agronomy, Dr.Karambir and Dr.Dharmender, is ever unforgettable.

I extend my sincere thanks to my beloved juniors Jagdeep, Amit, Krishan, Sushil and Shyam for their love and affection.

Indeed, the words at my command are not adequate either in form or spirit to convey the depth of my feeling and gratitude to the affection, blessings, encouragement and sacrifice of reverend parents, sisters Preeti and Simmi and uncle Dr.S.K.Chopra, who have brought me to this stage of scientific pursuit and career building.

Even the best coached words of thanks fall short to express my intense feelings to my friends Raj, Chintu, Jogesh,

Parveen, Neeraj, Ravinder, Rishi, Ashish, Prashant, Manish, Sandeep, Rupesh, Anil, Baljinder, Partha, Parminder, Gaurav, Manoj and Dev Vart, for providing love, affection and help which made this work possible.

A formal line of appreciation would hardly meet ends of justice in expressing my gratitude and indebtedness to my laboratory and field staff Sh. Hari Ram ji, Sh. Laxman ji, Mr.Hawa Singh and Mr.Ram Chander for their everwilling help throughout this study.

I extend my heartfelt thanks to Dr.Ram Niwas, Computer Centre, CCS HAU, Hisar for assistance in statistical analysis of data.

Financial assistance in the form of Merit Fellowship awarded by CCS HAU, Hisar is thankfully acknowledged.

Elegant typing of this manuscript by Mr.Lawan Jain is thankfully acknowledged.

Without blessings of the 'Almighty' this effort would have remained a far-fetched dream and a sheath of notes.

HISAR
NOVEMBER 26, 2001

(Deepak Chopra)

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

ABBREVIATIONS USED

APS	Ammonium per sulphate
CAI	Current annual increment
CD	Critical difference
Cm	Centimeter
d.f.	degree of freedom
g	Gram
GA	Genetic Advance
gbh	Girth at breast height
GCV	Genotypic coefficient of variation
h	Hour
h^2	Heritability
m	Metre
MAI	Mean annual increment
mm	Millimeter
PAGE	Polyacrylamide gel electrophoresis
PCV	Phenotypic coefficient of variation
PT	Progeny
Rm	Relative mobility
SDS	Sodium dodecyl sulphate
SS	Seed source
TCA	Trichloroacetic acid
TEMED	N,N,N'N'-tetra methylenediamine
Tris	Tris-hydroxymethyl aminomethane

CHAPTER-I

INTRODUCTION

India's forest cover is becoming thinner day by day and in many areas, forests, with their wildlife and biodiversity have disappeared because of development projects like dams and mines. Population and livestock pressure is a major threat to our green gold. Total land area of India is 328.8 m ha out of which 175 m ha is wasteland and 63.3 million hectares under forest cover (Rai, 2000). The National Forest Policy (NFP) prescribes that ideally India should have 33 per cent forest cover. The only way to meet the demand of fuel, fodder, timber and to improve the degrading environment is through reclamation of wastelands by afforestation programme of genetically improved tree species.

The trees of *Prosopis* sp. are remarkably found growing in poor soil conditions and require relatively low moisture for survival (NAS, 1979), of which *Prosopis juliflora* is highly useful tree species for afforestation of the saline and alkaline terrains, eroded hills and river beds, shifting sand dunes, coastal sands, dry and degraded grasslands and wastelands, where rainfall is scanty and erratic. It plays an important role in building up soil fertility and reclamation of high pH soils (Muthana, 1988).

P.juliflora (Swartz) DC, commonly known as Mesquite belongs to the genus *Prosopis*, family Fabaceae and sub-family Mimosoideae (Watson and Dallwitz, 2001). Genus *Prosopis* comprises about 42 species and most of the species are cytologically diploid (2n=28) with some exception as tetraploid species (2n=56) as reported by Burkart (1937, 1940, 1943, 1952) and Hunziker *et al.* (1975). Different local names of this species are Mesquite (English), Vilayati babul (Hindi), Vilayati kikar (Punjabi) and Ganda babul (Gujarati). It is reported to be a native of south western America, Mexico, Israel, Venezuela, Peru and Colombia and was introduced in Sindh province of erstwhile India in 1877 (Sharma *et al.*, 1994) and from there it has spread in many parts of India such as Bellary, Delhi, Hageri, Haryana, Punjab and Uttar Pradesh. It was introduced in 1913, by the then Ruler of Jodhpur state in many arid and semi-arid parts of Rajasthan for stabilization of sand dunes. The then State Government of Rajasthan declared this species as a "Royal Plant" in 1940 and directed public to protect *P.juliflora* plants and also encouraged large scale plantation of this species (Singh and Singh, 1993).

Plants of *P.juliflora* are medium sized evergreen shrubs or short trunked trees. Under better soil conditions they may attain a height of 9-10 m. It is a light demander, drought hardy and can even tolerate temperature up to 48°C (Evans, 1982). Leaves are pinnate, alternate, 3-16 cm long and dark green in colour. New leaves emerge by February-

April. Plants begin flowering within one or two years. Therefore, yield of pods starts by the second or third year after planting and can amount to 20-40 t/ha/yr (Von Maydell, 1986). The plants grow rapidly by seed, sucker, planting of seedlings or coppice shoots (Rawat *et al.*, 1992). Tree has a deep and wide rooting habit, lateral roots extending up to 30 m or more from the stem to scavenge surface water from the least precipitation.

P.juliflora is commercially exploited for fuel, fodder and timber (Felker, 1979). Being thorny, it is highly suitable for "live fence" or hedge. The wood is hard, dense (about 800 kg/m^3) and very strong (Hocking, 1993). It is suitable for farm implements, construction of posts and poles, furniture, railway ties, wheel felloes, tool handles, and any appliance demanding strength and hardness. The potential exists for the utilization of the pods of *P.juliflora* as they are rich in carbohydrates and proteins (Chopra and Hooda, 2001). There are several interesting food uses of *P.juliflora* beans. In Mexico, cakes prepared from Mesquite meal are consumed as candy. Mesquite beans also serve as raw material for preparation of beverages, both non-fermented and fermented. In South Western United States, the Pima Indians ground the pods into a meal called "Pinole", which is used for making nutritious bread. Mesquite beans are also used as cattle feed (Allen and Allen, 1981).

The reproductive capability of improved plant type is very important for production of large quantities of good quality seed. The

efficiency of reproductive system depends upon understanding of factors affecting reproductive biology. Pollination mechanism affect seed set, fertility, gene flow, breeding systems, hybridization and genetic constitutions of tree population. Hence, it is important to understand reproductive biology, crossing technique/reproductive methods.

Genetic variability is necessary for any type of breeding or improvement programme. For determining the genetic variability, the descriptors currently available are restricted to plant morphology characters examined in the field. Though, morphological description of genotypes do not require sophisticated laboratory techniques, the generation of data are time consuming and laborious and the characters are liable to be influenced by a complex genotype x environment interaction. Due to limitations in the number, their power to discern differences is also limited, particularly for closely related genotypes. Hence, it is essential to develop alternative methods which are rapid, reliable and less influenced by environment. During the last decade, the development of electrophoresis of total soluble protein has been an important step towards elucidation of genetic structure on gene level of tree population (Lundkvist and Rudin, 1977). Electrophoresis of total soluble protein has many advantages over the other conventional methods, i.e. (i) they are considered the direct products of specific allelic genes, (ii) their phenotype is not affected by environmental variation, and (iii) they are relatively easy to handle. Analyzing

polymorphism at molecular level can differentiate the genotypes, which are non-distinguishable by other tests.

To interpret the genetic value of this species and to utilize genetic variation for improvement and development strategies for the conservation of the genetic resources of the species, there is need to understand the genetic diversity, reproductive biology and breeding system of *P. juliflora.*

In light of the foregoing importance of this versatile tree species, the study was conducted with the following objectives:

1. To evaluate various seed sources of *Prosopis juliflora* by seed morphology and electrophoresis of seed protein.
2. To study the extent of phenotypic variation in progenies of various seed sources.
3. To study the reproductive biology of the species.

CHAPTER-II

REVIEW OF LITERATURE

Tree species with wide geographical distribution exhibit considerable variation in anatomy, morphology and physiology. Zobel and Talbert (1984) reported that trees attain genetic diversity in nature for defence and survival against all types of risks encountered in their life span. In this process, variation results from interaction between genetic and environmental factors. By growing tree populations of different geographic regions under similar environment, the inherent variation of a species is identified from environment variation. The prime objective of the variation study of different seed sources is to locate as quickly and as possible those seed sources which are high yielding, well adapted and productive trees of good quality. For this purpose, collection, maintenance and evaluation of germplasm are the main pre-requisites (Kedharnath, 1982 a).

With the increasing pressure on land it has become essential to choose provenances which suit best to particular environmental conditions so as to obtain the highest yield per unit area (Rawat *et al.*, 1987). Provenance/seed source trials may also be useful in shortening of rotation age, and for selecting populations tolerant to drought, salts, mineral stress, pests, etc. However, till date, no well-planned and

systematic research work aimed at genetic improvement of *Prosopis juliflora* has so far been undertaken. Only limited information is available on the seed source variation, progeny testing and reproductive biology of *Prosopis juliflora* with the results that references are scanty. Therefore, the most relevant literature on other tree species along with *P.juliflora* has been reviewed under the following heads:

2.1 EVALUATION OF VARIOUS SEED SOURCES

2.2 PROGENY TESTING OF VARIOUS SEED SOURCES

2.3 REPRODUCTIVE BIOLOGY

2.1 EVALUATION OF VARIOUS SEED SOURCES

The use of genetic diversity of wild species for gain is the basis of tree improvement work. Geographic variation associated with distinct climatic regions in which the species grows results from genetic and environmental factors. The existing genetic variability differs in different species and populations. The success of genetic improvement programmes, thus, depends upon the location, nature and exploitation of genetic variability present in the species.

2.1.1 Morphological parameters of seed:

Seed size of *P.juliflora* was reported highly variable: 8,000-15,000/kg (Von Maydell, 1986) to about 35,000/kg (Sargent, 1947; Bainbridge and Virginia, 1990). Kackar *et al.* (1986) reported that 100-

seed weight of *P.cineraria* varied from 2.0 g in Ajmer to 7.4 g in Churu provenance.

Arya *et al.* (1992) studied 31 provenances of *P.cineraria* collected from five states of India (Haryana, Rajasthan, Gujarat, Maharashtra and Karnataka) and reported that length, width, thickness and weight of the seed varied significantly among provenances from 5.54 to 7.98 mm, 3.57 to 5.23 mm, 2.07 to 2.40 mm and 3.74 to 5.2 g, respectively. Tewari *et al.* (1993) reported 0.03 g average seed weight of *P.juliflora.*

Sharma *et al.* (1994) collected *P.juliflora* germplasm from 41 provenances of Rajasthan and Gujarat and reported that seed morphological characters such as 100-seed weight, seed length, seed width and seed thickness varied from 3.00 to 4.40 g, 5.66 to 6.90 (mm), 3.58 to 4.96 (mm) and 1.88 to 2.00 (mm), respectively.

Bahadur and Hooda (1995) reported that genotypic and phenotypic coefficient of variation were high for all the seed characters except seed length in twenty-five trees of *P.cineraria.* Heritability was also high for all the characters except seed length while genetic advance was high for seed weight. Seed weight and volume exhibited high genetic variability, heritability and genetic gain in *P.cineraria* (Manga and Sen, 1996).

Sharma *et al.* (1996) analysed the ecological implications of seed characteristics of the native *P.cineraria* and the alien *P.juliflora* and

reported that seeds of *P.cineraria* were heavier than those of *P.juliflora.*

Four exploration trips were conducted by Dwivedi *et al.* (1997) during 1989, 1990, 1992 and 1995 in 21 districts of Haryana and Rajasthan resulting in 430 collections of *P.cineraria.* A wide range of variation in seed size, shape and colour, etc. was noticed. Kumar (1998) collected seeds of 30 'plus' trees of *P.cineraria* from Rajasthan and Haryana. He reported large variation among seed lots for all the seed parameters viz., weight, length and breadth. Out of all the parameters, highest variability was observed for seed weight.

Burley (1965) assessed variability for seed weight in thirty provenances of Sitka spruce. He did not find any apparent relationship of seed weight with latitude. However, there was a trend for northern provenances to have comparatively heavier seeds.

Solanki, *et al.* (1985) reported phenotypic variation in seed characters of *Acacia senegal* in the natural stands of western Rajasthan. From their studies of 52 individual trees, they reported substantial variability for character 100-seed weight and seeds per pod.

Shivkumar and Banerjee (1986) studied seed polymorphism of different provenances of *A.nilotica* and reported that seed parameters 100-seed weight and seed thickness showed significant variations while for seed length and seed width variations were non-significant. A

considerable variation in external seed characters of *A.nilotica* was found.

Goda (1987) conducted a study on seed purity and weight of *Acacia nilotica* and reported that weight of 100-seeds was 10.25 g. Huang (1989) reported significant differences between provenances of *Acacia auriculiformis* in seed weight.

Bagchi and Sharma (1989) in a study of seed length, breadth and weight in ten phenotypically superior trees of sandal from different localities, reported high significant variation between trees and also found high heritability for above said seed characters.

Hooda and Bahadur (1993) observed significant differences among different genotypes of *Leucaena leucocephala* with respect to seed size, seed length, breadth, thickness and found positive correlations between these parameters.

Arya *et al.* (1993) reported that seed weight of *Tecomella undulata* in 12 provenances from Indian desert varied significantly from 0.65 g per 100 seed in Bikaner provenance to 12.4 g 100 per seed in Jodhpur provenance.

Dhillon *et al.* (1995) reported high variability for almost all seed characters in *Dalbergia sissoo*. Ginwal *et al.* (1996) demonstrated the existence of significant variation among seed sources of *Acacia nilotica* for some seed traits. They further suggested that variation obtained for seed morphology might be due to geographical differences.

Kaushik *et al.* (1996) studied weight and volume of 100 seeds of *A.nilotica* collected from 6 provenances viz., Hisar, Luharu, Kaithal, Rohtak, Ambala and Yamunanagar and reported highly significant differences for both the parameters.

An exploratory survey of *Acacia nilotica* from 21 provenances around India was undertaken by Krishan and Toky (1996), representing the species entire natural range. Significant differences were noticed in all the characters viz. seed length, seed width, seed thickness and 100-seed weight. A significant correlation was also noticed between seed length and seed width.

Suresh *et al.* (1997) observed the effect of seed sources on seed quality in *A.nilotica* and revealed that 100-seed weight showed significant trend among the different seed sources.

The extent of genetic variation in seed length, width, thickness and weight among and within 12 African provenances of *Faidherbia albida* was examined at the Kenya Forestry Research Institute (Dangasuk *et al.*, 1997). The regional provenances showed a consistent variation in morphological characteristics of seed; the south African provenances had the largest seed and west African provenances had the smallest.

Vanangamudi *et al.* (1998) reported significant differences between seed sources (7 different climatic zones of Tamil Nadu) for all

the seed characteristics of *A.nilotica* including length, width, thickness and 100-seed weight.

2.1.2 Electrophoresis:

The analysis of seed and seedling protein or isoenzymes by electrophoresis and the subsequent use of the information provided for varietal identification is now well established and has been reviewed comprehensively in the recent years (Cooke, 1988, 1995; Smith and Smith, 1992). The success of electrophoresis depends on the extent of polymorphism of the plant proteins and the fact that the proximity of protein to primary genetic information limits the extent of environmental interaction on their expression. There are different kinds of electrophoretic methods available, which can be used depending on the plant species and nature of protein to be analysed.

2.1.2.1 SDS-PAGE of seed proteins:

One of the simplest yet most useful method is polyacrylamide gel electrophoresis (PAGE) in the presence of Sodium dodecyl sulphate (SDS).

Saidman and Vilardi (1987) analysed the genetic similarities among seven species of *Prosopis* and reported that phenotypic relationship agreed with other reported biochemical evidence (such as chromatography of phenol compounds, electrophoresis of seed proteins) but not with morphological groupings.

Marangoni and Alli (1988) worked on polyacrylamide gel electrophoresis of seed and pods of *P.juliflora* and revealed that the separated proteins gave less intense staining with Coomassie brilliant blue as compared with proteins from other legume seeds. The proteins prepared from the *P.juliflora* seed were fractionated into three bands, while those prepared from the pods were fractionated into at least seven bands.

Medina and Cardemil (1993) observed the fluorography of SDS-polyacrylamide gel electrophoresis of the proteins of *Prosopis chilensis* seedlings synthesized and accumulated during 2 h at temperatures of 35, 40, 45 and 50°C in the presence of [35 S] methionine revealed the expression of 11 proteins not detectable at 35°C. Most of the proteins present at 35°C also increased in expression. The temperature for maximal expression of these proteins was 45°C.

Rodriguez and Cardemil (1995) characterized four cell wall proteins of seedling cotyledons of *Prosopis chilensis* by SDS-polyacrylamide gel electrophoresis. The molecular masses of these proteins were 180, 126, 107 and 63 KDa.

Yadav (1996) analysed the total leaf protein pattern of *Prosopis cineraria* seedlings collected from six provenances. He reported that it resolved into 4 to 17 bands with Rf values ranging from 0.523 to 0.977. Large variations among and within the provenances were observed.

Similarity index showed that Jodhpur and Hisar provenances were the most similar ones.

Burghardt and Palacios (1998) studied acqueous seed protein profiles of *Prosopis ruscifolia* intra- and inter-populations by polyacrylamide gel electrophoresis. Forty-eight different protein bands were identified. Populations from Formosa, Chaco, Salta, Tucuman and Santiago del Estero differred both in presence/absence of bands and in frequencies of several bands.

Lajudie *et al.* (1998) isolated number of rhizobia from root nodules of *P.juliflora*, Acacia senegal and *A.tortilis* subsp. raddiana made their taxonomic characterization with the help of electrophoresis of total cell protein and some other techniques such as auxanographic tests, rRNA-DNA hybridization, DNA base composition and DNA-DNA hybridization.

Hare and Switzer (1969) reported that the electrophoretic pattern of seed proteins from western sources of loblolly pine (*Pinus taeda*) are more similar to those of short leaf pine (*P.echinata*) than the eastern sources.

Prus-Glowacki and Rudin (1981) had observed the variation of protein pattern in *Pinus sylvestris* of 6 Swedish populations. They had observed that one fraction of proteins twice as frequent in the northern populations as in the southern ones. The range of variation within each group of samples is less than zero per cent of each mean value.

Hippolyte *et al.* (1996) reported that *Acacia senegal* callus cultivated *in vitro* produced glycosylated proteins, which were examined by PAGE analysis and their molecular weights (30,000 and 50,000) determined. A commercial sample of gum arabic (exuded upon injury by *A.senegal*) was examined by electrophoresis, and a glycosylated polypeptide (molecular weight 50,000) was identified. Silver nitrate staining identified polypeptides of molecular weight 30,000 and 21,000.

2.2 PROGENY TESTING OF VARIOUS SEED SOURCES

It is necessary to test the progenies of plus trees to confirm that they possess a good genotype and are capable of transmitting their good traits to the progeny (Kedharnath, 1982a). Plus trees are the superior phenotypes with most desired features, selected from natural forest or plantations. This is the first step for initiating any long term tree improvement programme to produce genetically superior seeds on mass scale.

Jatasara (1982) collected germplasm of *Prosopis cineraria* from Thar desert and reported wide range of genetic variability for tree height, stem girth, canopy diameter among 223 strains.

Solanki *et al.* (1984) studied variability, heritability and correlations in *P.cineraria* and reported that progenies of different trees showed significant variation for plant height. High heritabilities accompanied by high genetic advance were observed in 3rd, 4th and 5th

years of growth indicating that selection for tree height may be effective in 3rd year.

In another progeny trial, seeds of 17 individual trees of *P.cineraria* from 9 districts of Rajasthan state showed significant variations for survival percentage and height growth. After one year of transplantation, the height varied from 17 cm to 189 cm (Solanki *et al.*, 1985).

Three provenances of *P.cineraria*, 8 of *Acacia nilotica*, 3 of *A.radiana* and 2 of *A.senegal* were tested for survival and height at Jodhpur, India (Harsh, 1985). The provenances of *P.cineraria* from Tamil Nadu had least height, while provenances of *A.nilotica* from Hisar showed the greatest height.

Khosla (1985) introduced the possibility of genetic improvement of agroforestry trees. Sheikh (1988) raised a large tree form of *P.juliflora* by collecting seed from plus trees. He further proposed to use the straight tree form for planting in arid and semi-arid areas.

Rehman *et al.* (1988) discussed height growth data of a number of indigenous and exotic tree species and seed sources of *P.cineraria* and *A.nilotica* at the nursery stage. Significant differences were noticed between the sources pointing to the possibility of selection of the best seed sources for afforestation in Pakistan.

Germplasm of *P.cineraria* , *A.nilotica*, *A.senegal* and *T.undulata* were collected by Solanki *et al.* (1989) from Thar desert. Entries of

P.cineraria from Barmer, Jodhpur, Bikaner and Tonk showed more than 225 cm height, 2.8 cm dbh and 4.3 cm basal diameter after 3½ years.

Parent juvenile progeny relationship in *P.cineraria* was studied by Singh *et al.* (1991). They found that there was nc association of morphological traits of parent with height growth, root length etc. of their juvenile progenies. However, 100-seed weight was correlated with progeny height in the nursery, implying that it may be inappropriate to select or reject progenies on the basis of their juvenile height.

A progeny trial of 70 open-pollinated families of *Prosopis* (*Prosopis* spp., *P.alba*, *P.juliflora*, *P.velutina*, *P.glandulosa*, *P.flexuosa*, *P.nigra*, *P.tamarugo*) representing seed sources from Haiti, Peru, Chile, Argentina and South-western USA was done by Wojtusik *et al.*(1993). At the end of 4 years of growth, the tallest 6 families were of Peruvian origin.

Sharma *et al.* (1994) studied the pod and seed traits of *P.juliflora*, collected from Rajasthan and Gujarat provenances and reported enormous variability with respect to pod weight, no. of seeds/pod and pulp weight/pod. Maximum intensity of correlation among all the characters was found between pod weight and pulp weight/pod (0.9619) in Rajasthan provenance.

Bahadur and Hooda (1995) studied the genetic variability in pod and seeds of 25 trees of Khejri (*P.cineraria*) and reported that 100-seed

weight had significant and positive correlation with all the pod and seed characters.

A detailed survey was undertaken by Solanki *et al.* (1996) to collect the seeds of *P.cineraria* , followed by testing of collected seeds under progeny trials. A half-sib progeny trial of 142 plus trees indicated an appreciable amount of variability between and with in progenies. Some of the trees from the progenies attained a height of 7.3 m in 6 years against the average height of 2.1 m.

Goel *et al.* (1997) carried out a single half-sib progeny test of selected plus trees (and control) of *P.juliflora* in the nursery. Six families outperformed the other families and the control both in respect to their height and collar diameter. Out of six, three outstanding single tree progenies were examined in the field, which showed different adaptive growth among and within progenies and outperformed the base population.

Toky (2000) collected seeds of *P.cineraria* from different provenances and studied them in the nursery through their progenies. At the 6-month stage, the stem height was greatest in Himatnagar provenance (73 cm) and least (24 cm) in Kurnool provenance. After 15 months, the plant height was the greatest in Hisar provenance, closely followed by that of Jodhpur and Bawal, and the least was in Bharuch provenance. Significant variation was also observed at 27 months stage.

It has been found that in *Pinus roxburghii, P.wallichiana, Tectona grandis, Dalbergia sissoo, Acacia arabica,* seed origin makes big differences in growth and quality of plantations (Suri and Seth, 1959; Champion and Seth, 1968).

Vidakovic and Siddiqui (1968) made a study about heritability of height and diameter growth in *Dalbergia sissoo* using parent progeny test. Heritability for diameter and height were carried out by using regression. They further reported that heritability for height and diameter was very low.

Both half-sib and full-sib progeny trials were laid out for *Bombax* (Venkatesh, 1969). Half-sib progeny trials were also conducted for *E.tereticornis, E.camaldulensis, E.grandis* (Venkatesh and Vakshasya, 1977; Kedharnath, 1982 b) and *Santalum album* (Bagchi and Kulkarni, 1987; Bagchi *et al.*, 1987). There were evidences for sufficient genetic variation in mean plant height between families.

Kandya (1978) found that there is significant degree of correlations of seed weight with height, dry weight and collar diameter of seedling in *Pinus oocarpaschiede.*

Correlations between seed weight, growth and biomass production of seedlings were reported in some tree species like, *Acacia tortilis* (Pathak *et al.*, 1980); *Casuarina equisetifolia* (Halos, 1983); *Leucaena leucocephala* (Gupta *et al.*, 1983; Natarajan and Vinaya Rai, 1984);

Pinus roxburghii (Thapliyal, 1986) and in *Picea smithiana* (Singh *et al.*, 1990).

Surendran and Chandrasekharan (1984) studied heritable variation and genetic gain estimates in half-sib progenies of *Eucalyptus tereticornis*. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability estimates and genetic advance as percentage of mean were worked out for eight characters studied in 35 plus trees. The heritability estimates for girth at base was consistent at different stages of growth.

Results of a study on growth among 6-years old tree geographic sources of *Dalbergia sissoo* in Pakistan have been reported by Rehman and Hussain (1986). The trial indicated that the average diameter of the trees originating from Chichawatni, Changa Manga and Mardan were 7.1, 7.0 and 6.4 cm, respectively. These preliminary results have shown that generally the trees originating from Chichawatni are significantly better than Mardan.

Dean *et al.* (1988) estimated genetic parameters for height, stem diameter, straightness, internode length and wood density, 5-16 years after planting, in 4 open pollinated progeny tests of hoop pine in Australia. All the traits appeared to be moderately heritable and favourable genetically correlated.

Gupta and Patil (1988) made an investigation of the variation in different plant characteristics in 40 accessions of *L.leucocephala*. The

analysis of variance indicated significant differences among the accession for all the characters. Moderate to high estimates of broad sense heritability was observed for most characters.

Madoffe and Maghembe (1988) reported that provenance variation existed for growth characters after seventeen years in teak. They recommended that selection of superior trees to be made from all the provenances in order to maintain a broad genetic base for teak in Tanzania.

Volker *et al.* (1990) estimated genetic parameters for growth, stem form and branch size from measurements made at around six years in seedling seed orchard of *Eucalyptus globulus*. Individual heritabilities for volume and stem form were moderate.

Jindal *et al.* (1991) studied variability and changes in genetic parameter of height in juvenile progenies of *Tecomella undulata*. Significant difference, among progenies was observed. Heritability and genetic advance showed decreasing trend with increasing age. They also reported that correlation of juvenile height at different stages with mean height of one year old progenies in field was non-significant suggesting that selection for height at juvenile stages in nursery may not be effective.

Kumar (1993) reported provenance variations in *Albizia lebbek*. He observed that provenances from south India particularly from Madurai and Madras showed superior growth up to one year stage in the

nursery while after three years a reverse trend was observed i.e. north provenances excelled in growth over south ones.

Gupta and Kumar (1999) collected seeds from twenty plus trees of *Azadirachta indica* including check from different parts of central India and planted them in 1994 in a randomized block design in two replications. It was observed that nine progenies for plant height and ten each for collar diameter, dbh and estimated standing volume excelled their performance in comparison to check.

A field experiment was carried out by Rai *et al.* (2000) from July 1988 to June 1998. The mean annual increment (MAI) between progenies of 12 multipurpose tree species was maximum for height in *D.sissoo* (1.08 m) followed by *A.procera* (0.95 m) and *L.leucocephala* (0.90 m). While maximum MAI for dbh was in *D.sissoo* (2.0 cm) followed by *A.procera* and *E.officinalis* (1.87 cm). MAI in respect of height and dbh was lowest in *A.pendula*, which revealed that *A.pendula* is a slow growing species.

2.3 REPRODUCTIVE BIOLOGY

Breeding methods to be adapted for genetic improvement of a species, basically, depend upon two main factors viz. gene effects involved in the expression of various economic traits, most of which are polygenic in nature, and the extent of mating flexibilities. While the former is difficult and too much time consuming in the long lived species like forest trees, information on latter can easily be generated.

As such to conserve and utilize forest genetic resources knowledge of ecology, reproductive biology and factors influencing pollination and pod setting is necessary.

2.3.1 Blooming, flowering and fruiting phases and flower structure:

Bawa and Opler (1975) reported that in tropical lowland forests, one fourth to one half of all species had unisexual flowers and majority of such species was dioecious. Almost all-dioecious species have relatively small pale yellow to pale green flowers.

Distel and Pelaez (1985) studied the phenology of some species of the Calden including *Prosopis flexuosa* and *Prosopis caldenia* and identified vegetative, flowering, fruiting and seeding phase of the species during their investigation.

Smith (1985) reported that inflorescence of *P.juliflora* is axilary, spicate or spiciform-racemose. Flowers are small, 5-merous, calyx campanulate, short-dentate; petals free or proximally connate and stamens are free and ten in numbers.

Mathur and Bhatnager (1992) studied the phenology of *P.juliflora* and *P.cineraria*. Five trees of each species were selected for the study and the occurrence of different 'phenophases' (e.g. ripe and unripe fruit, flowers buds and blossoms) were determined.

Bahadur and Hooda (1994) reported that in *P.cineraria*, the peak period of flowering was from mid-April to mid-May, and the duration of flowering varied from 28 to 48 days.

Masilamani and Vadivelu (1997) analysed the physiological maturity of seed and pod of *P.juliflora*. Flowers were tagged on a 10-years old tree at the time of anthesis. At 91 days after anthesis pod colour turned from green to straw yellow, therefore, physiologically seed maturity is about 91 days after anthesis.

Dhillon *et al.* (2000) reported that in *P.cineraria*, the floral buds began to open during mid April. Peak period of flowering was from mid-April to mid-May. Flowers were small, yellow and creamy white in colour. Stigma receptivity occurs between 0800-1100 h. Natural pod setting started in last week of April and these were ready for harvest in first week of June. However, in *P.juliflora* floral buds began to open towards the end of March. Peak period of flowering varied from 30-50 days. The time of stigma receptivity was observed 0900 h onwards.

In *Tamarindus indica* small yellow flowers streaked with red, appear shortly after new flush of leaves, from April to June. The trees vary considerably in flowering. Occasionally fresh leaves and flowers are seen simultaneously in September-October. The pods appear during the winter and ripen in spring (Feb-March-April) about 10-11 months after the first appearance of the flowers (Brandis, 1906; Troup, 1921).

Sheikh (1989) reported that in *Dalbergia sissoo* Roxb., the young flower-buds appear in the first half of February and yellowish flowers in axillary panicles of short recemes open in March or April. The inflorescence is an axillary panicle, composed of several short spikes.

Tybrik (1989) reported that *Acacia nilotica* tree flowers during the rainy season in Kenya and less than one third of the flowers were hermaphrodite.

Sedgley *et al.* (1992) studied reproductive biology of *Acacia mangium* and *Acacia auriculiformis* in Queensland, Peninsular Malaysia and Sabah. Both species flowered between February and May, producing mature pods between October and April. The flower of both the species were similar in structure and showed weak protogyny. Male flowers either lacked pistils completely or had small sterile pistils.

Dhillon and Khajuria (1994) observed flowering behaviour, inflorescence morphology and pollen viability in *A.nilotica* subsp. *indica* in 3 agroclimatic regions of the Indian Punjab. Flowering started in June in sub-mountain region, followed by the central plains region, and lastly (July-August) the western region. Flowering was at its peak in all the three regions during September to October. Distal and median parts of the inflorescence had a higher number of hermaphrodite flowers, and many proximal flowers had either no carpel or no functional carpel. In general, pollen viability was quite high (86.76%).

Abrol (1996) reported that in Jammu region *Acacia modesta* Wall. flowers in the second half of April and May. Similarly, Suresh *et al.* (1998) reported that the flowering season of babul (*Acacia nilotica*) in India varies within populations and between subspecies. It is generally

in June-July, but may extend into September, and some times into December or January.

Pandey (1999) reported that in inflorescence of *Acacia nilotica*, the flowers are arranged in compound cymose heads. Flowers are sessile, actinomorphic, hypogynous and yellow in colour. Sepals varied from 4 to 5, minute, calyx is gamosepalous, campanulate and inferior. Petals also varied from 4 to 5, corolla is gamopetalous and inferior. Stamens indefinite, polyandrous and yellow. Ovary superior, monocarpellary and unilocular. Its floral formula is as given below:

Flower formula: $\mathbf{Br} \oplus \overset{\nearrow}{\varphi} \mathbf{K}_{(4\text{-}5)}, \mathbf{C}_{(4\text{-}5)}, \mathbf{A}_{\alpha}, \mathbf{G}_{\underline{1}}$

2.3.2 Flower visitors:

Genise *et al.* (1990) reported that *Prosopis* flowers were pollinated by the bees *Caupolicana mendocina, Xylocopa splendidula* and *Apis mellifera*. A recently provided nest of *C.mendocina* contained 50 per cent *Prosopis flexuosa* pollen and 50 per cent *Prosopis chilensis* pollen. A nest of *X.splendidula* contained 50 per cent *Prosopis flexuousa* pollen and 50 per cent *Prosopis pugionata* pollen. Pollen loads from *A.mellifera* contained a mixture of *Prosopis flexuosa* and *Prosopis pugionata* pollen.

Bryndum and Hedgart (1969) studied the pollination of teak and reported that insects were the principal agents of natural pollination. Similarly, Eldridge (1976) studied the breeding system of tropical

Eucalyptus and reported that flowers of all the species are open to any pollen vector-insects or birds.

In parts of north America, nearly all the insect visitors of citrus have been reported to be honey bees but elsewhere bumble bees, thrips and mites are sometime also common visitors (Moffett and Rodney, 1971).

Mathew *et al.* (1987) identified seventeen insect species, 13 from the order Hymenoptera, 2 Diptera and 2 Lepidoptera visiting *Tectona grandis* Linn. F. inflorescence. The Hymenopterans were the most frequent visitors, especially the solitary bees. The insect activity was greater during the cooler morning hours (0800-1000 h) than during the rest of the day (until 1700 h).

Kumar (1990) on Ber (*Zizyphus mauritiana* Lamk.) found that the abundance of *Apis* spp. was more than the other insect visitors during bloom period.

Sedgley *et al.* (1992) studied the reproductive biology of *Acacia mangium* and *Acacia auriculiformis* and reported that there were relatively few insect visitors to the flowering branches, but the same suite of insects was observed foraging for pollen on both species. Native bees belonging to the Halictidae act as pollinating agents.

Tybirk (1993) studied the flower visitors of *Acacia albida*, *A.nilotica*, *A.tortilis* and *A.senegal* and reported a high diversity of floral foragers. One hundred and eighteen taxa of insects, mainly

Hymenoptera, Lepidoptera, Coleoptera and Diptera were collected. The most important pollen vectors were bees from the families Magachilidae and Halictidae and wasps from the families Scoliidae and Eumenidae. Beetles, flies and butterflies were secondary pollen vectors. Diversity and frequency of flower visitors of species with floral nectar (*A.senegal* and *A.albida*) were not clearly different from the species without floral nectar (*A.tortilis* and *A.nilotica*).

Gill (1994) observed higher abundance of honey bees on Phalsa (*Grewia subinaequalis* D.C.) during flowering. In Malta [*Citrus sinesis* (L.) Osbeck], the maximum activity of *Apis* spp. was observed around 1000 h. Among honey bees, *A.mellifera* and *A.cerana indica* were recorded high in numbers on Citrus flowers (Bhatia *et al.*, 1995).

Singh and Chopra (1997) recorded thirty three insect visitors belonging to 21 families of 6 insect orders viz. Hymenoptera, Diptera, Coleoptera, Lepidoptera, Hemiptera were frequently visiting Citrus species. The majority of insects primarily belonged to the insect orders Hymenoptera and Diptera viz. *A.dorsata* F., *A.cerana indica* F. and *Episyrphus balteatus* (De Geen).

Thangaraja *et al.* (1999) observed 15 flower visitors on *Acacia nilotica*, of which most were insects, including *A.mellifera.* The sunbird and *Nectarina* sp., were also recorded.

Sharma *et al.* (2001) reported that abundance of *A.florea* was maximum (4.99 bees/branch/5 min.) followed by *A.mellifera* (1.03

bees/branch/5 min.) and *A.dorsata* (0.48 bees/branch/5 min.) on Ber (*Zizyphus mauritiana*).

2.3.3 Foraging speed of honey bees:

It is evident that sugar concentration of nectars within flight range of the apiary influences bee activity greatly. Not only do species and varieties complete for bee visitation but also the same kind of blossoms of various ages (Vansell and Watkins, 1942). Foraging speed of the insects depend upon the foraging behaviour and floral structure of the crop (Free, 1970). It is a trade between amount of the nectar expected from a flower and time required to extracting it (Pyke *et al.*, 1977).

Kumar (1990) reported that time spent by different *Apis* spp. on the bloom of *Z.mauritiana* Lamk. showed that *A.florea* significantly spent less time (3.81 sec/flower), while *A.mellifera* (5.80 sec/flower) and *A.dorsata* (6.01 sec/flower) were at par with one another.

Bhatia *et al.* (1995) observed that in Malta [*Citrus sinesis* (L.) Osbeck], the time taken for nectar was 10-15 seconds/flower (recorded for *A.mellifera*) during the period of their maximum activity between 8000-1000 h.

Dhankar *et al.* (2001) reported that in *Citrus* spp. maximum mean (12.95) abundance of insect visitors (av. number of insects/metre shoot length/5 min.) was at 1200-1300 h, which was significantly higher than abundance at other hours of the day. The time spent per flower by *Apis*

spp. showed that *A.florea* spent significantly less time (4.3 sec/flower) than *A.mellifera* (7.62 sec/flower) and *A.dorsata* (8.05 sec/flower).

2.3.4 Pollination studies:

Sareen and Yadav (1987) reported that when flowers of 5 trees of *Prosopis juliflora* were artificially selfed, pollen grains did not germinate, and of 50 selfed flowers only 2 (4%) developed into fruits. Fruit set after cross-pollination was 38 percent, compared with 6 per cent for open pollination. Pollen fertility was 70-76 per cent.

Zapata *et al.* (1989) reported that 5 to 10 inflorescence from each of six trees of *P.flexuosa* D.C. were bagged, then selfed or cross-pollinated. To describe the breeding system, the Zapata and Arroyo self-incompatibility index was used, values obtained ranged between 0 and 0.12, indicating high levels of incompatibility.

Bahadur and Hooda (1994) studied the breeding system of *khejri* [*Prosopis cineraria* (L.) Druce] and reported that pod setting was poor. Self incompatibility was observed in this species but apomixis was not. The species is predominantly cross-pollinated.

Villasenor *et al.* (1996) carried out experiments on selfing in *Prosopis tamarugo* Phil. In consecutive years, inflorescence was bagged and the fruit set was recorded. The results showed a degree of self-compatibility and self-pollination for this species.

Dhillon *et al.* (2001) examined breeding behaviour in *Prosopis cineraria* and *Prosopis juliflora.* In both the species cross-pollination

was pre-dominant. Percent pod set varied from 0.19 for selfing/bagging to 1.58 for natural open pollination in *P.cineraria* while in *P.juliflora* it was 0 and 0.72 per cent, respectively.

Bryndum and Hedgart (1969) reported that *Tectona grandis* is mainly cross-pollinated species but there is fruit formation after self-pollination too. Apomixis has not been observed. In sweet lime, Nijjar and Sandhu (1971) found that the percent fruit set was 6.87 and 5.84 under open and self-pollination, respectively.

Bawa (1974) studied the nature of breeding system of tree species of lowland tropical community and found that out of 130 tree species, 14 per cent were self-compatible, 54 per cent self-incompatible, 22 per cent dioecious and 10 per cent monoecious. The figures for self-compatible species were based on results of controlled pollination on 34 out of 80 hermaphroditic species (bisexual flowers) that occurs in the study area.

Flowers of *Acacia retinodes* var. *uncifolia, Acacia terminalis* in natural populations of Australia were selfed and cross-pollinated. Both the tree species were found self-incompatible (Bernhardt *et al.* 1984; Kenrick *et al.*, 1984; Kenrick and Knox, 1985; Kenrick *et al.*, 1986).

Tybirk (1989) reported that in *Acacia nilotica* pod set per hermaphrodite flower was 0.3 per cent. While *Acacia tortilis* was almost exclusively out-crossed (Index of self-incompatibility=0.2) with 5.5 per cent of inflorescence (0.13% of the flowers) developing fruits.

Bangarwa (1993) studied pollen viability in shisham (*Dalbergia sissoo*) by acetocarmine test, which was found to vary from 46.0 per cent in April to 56.0 per cent in March. He further reported that shisham is a self fertilizing species. Under natural conditions, pod setting was about 40 per cent.

2.3.5 Evaluation of seeds and pods (obtained through different reproductive methods)

Dhillon *et al.* (2001) conducted reciprocal hybridization between *P.juliflora* and *P.cineraria* and reported that the growth performance of hybrid seedlings resulting from reciprocal crossing between the two species was much more than the parental species showing appreciable heterosis.

Minessy (1959), in Egypt confirmed that there were more seeds per fruit in 'Clementine' tangerine following suitable cross-pollination than self-pollination and there was a positive relationship between number of seeds per fruit and fruit size.

Bryndum and Hedgart (1969) reported that in Teak (*Tectona grandis*) germination of fruits obtained from self-pollination was poor as compared to that of fruits from cross-pollination.

Haq *et al.* (1978) recorded a mean of 15.6 number of seeds/fruit in bagged branches as compared to 17.0 number of seeds/fruit in open pollinated branches in Kinnow mandarin (*Citrus reticulata*).

Rohidas and Chakrawar (1982) observed 17.00 number of seeds per fruit in open pollination as compared to 12.00 seeds per fruit in self-pollination in Nagpur mandarin.

Since no report was available on the analysis of total soluble protein of seed obtained through different reproductive methods, hence the information in this aspect has not been included.

CHAPTER-III

MATERIALS AND METHODS

The present study on *Prosopis juliflora* (Swartz) DC. comprised of 18 seed sources with reference to their seed morphology, electrophoresis of total seed protein and their progeny testing. Studies on reproductive biology were also undertaken. The studies were conducted at laboratory and Forestry Farm of CCS Haryana Agricultural University, Hisar.

The study was conducted with three major experiments as per the objectives of the investigation:

3.1 EVALUATION OF VARIOUS SEED SOURCES

3.2 PROGENY TESTING OF VARIOUS SEED SOURCES

3.3 REPRODUCTIVE BIOLOGY

For first two objectives, experimental material comprised of seeds of Mesquite (*Prosopis juliflora*) collected from plus trees of 18 different places (Table 1) in the month of June 1997. Seeds collected from each place were treated as separate seed source.

3.1 EVALUATION OF VARIOUS SEED SOURCES

3.1.1 Observations on seed morphology:

3.1.1.1 100-seed weight (g):

One hundred seeds from all the seed sources were taken randomly and weighed individually on Owalabor Top Pan Electric Balance.

Table 1: Seed sources and progenies under investigation

Seed Source	Seed Source No.	Progeny No.	Seed Source	Seed Source No.	Progeny No.
Anupgarh	SS-1	PT-101	Mohannagar	SS-10	PT-110
Mansa	SS-2	PT-102	Solani River	SS-11	PT-111
Rawli Ghat	SS-3	PT-103	Pilibanga	SS-12	PT-112
Gharsana	SS-4	PT-104	Sardargarh	SS-13	PT-113
Bhatinda	SS-5	PT-105	Rawatsar	SS-14	PT-114
Suratgarh	SS-6	PT-106	Raisingh Nagar	SS-15	PT-115
Karnal	SS-7	PT-107	Dabwali	SS-16	PT-116
Kola Farm	SS-8	PT-108	Kurukshetra	SS-17	PT-117
Ganganagar	SS-9	PT-109	Hisar	SS-18	PT-118

3.1.1.2 *Seed length, width and thickness (mm):*

The length, width and thickness of the seeds from each seed source were measured with the help of digital vernier calliper. For all the three observations seeds were taken randomly from each seed source.

3.1.1.3 Seed colour:

To observe the seed colour, seeds from each seed source were taken randomly and these seeds were compared with the Munsell soil colour charts (USDA, 1975).

3.1.1.4 Seed shape:

Seeds from each seed source were taken randomly and observed visually for their shape.

There were five replications of observations on all the above mentioned seed parameters.

3.1.2 Electrophoresis:

To study Tris-HCl soluble seed protein banding pattern on SDS-PAGE (Sodium dodecyl sulphate - polyacrylamide gel electrophoresis), method of Dadlani and Varier (1993) was used.

A. ***Reagents:***

All reagents were prepared in distilled water and stored in brown bottles in refrigerator.

A.1 ***Reserving gel buffer: 1.875M Tris-HCl buffer, pH 8.8:***

22.69 g of Tris was dissolved in 50 ml of distilled water. The pH was adjusted to 8.8 by adding conc. HCl drop by drop. The volume was made upto 100 ml by adding distilled water.

A.2 ***Stacking gel buffer: 0.6M Tris-HCl buffer, pH 6.8:***

7.26 g of Tris dissolved in about 50 ml of distilled water and pH adjusted to 6.8 by adding conc. HCl drop by drop. To make up the volume 100 ml distilled water was added.

A.3 ***Stock SDS solution (10%):***

10 g SDS dissolved in distilled water with constant stirring and gentle heating. Distilled water was added to make volume 100 ml.

A.4 ***Ammonium per sulphate (5%):***

Prepared freshly just before used. 0.5 g ammonium persulphate dissolved in distilled water to make 10 ml.

A.5 ***Stock protein extraction solution:***

2 g SDS and 10 mg Pyronin G dissolved in 10.4 ml 0.6 M Tris-HCl buffer (pH 6.6), 7.9 ml distilled water and 10 ml glycerol, warm gently and mixed well.

A.6 ***Electrode (tank) buffer SDS-Tris glycine pH 8.3:***

9.0 g Tris, 42.3 g glycine and 3 g SDS dissolved in distilled water to make 3 litres.

A.7 ***Fixing solution (15% TCA):***

150 g trichloracetic acid dissolved in distilled water to make one litre.

A.8 ***Staining solution:***

To prepare 100 ml of 15 per cent TCA solution, 10 ml of 1 per cent commassie blue prepared in methanol was added.

A.9 ***Defatting solvent mixture (2:1:1 chloroform:methanol:acetone):***

To 200 ml of chloroform, 100 ml methanol and 100 ml acetone was added.

A.10 ***30% acrylamide for stacking gel:***

75 g acrylamide and 2 g bis acrylamide dissolved in distilled water to make 250 ml.

A.11 ***30% acrylamide for running gel:***

75 g acrylamide and 1 g bis acrylamide dissolved in distilled water to make 250 ml.

B. ***Sample Preparation:***

Ten seeds of *Prosopis juliflora* from each seed source crushed and defatted in 3 to 4 changes of defatting solvent mixture. Defatted meal then decant and dried at room temperature.

C. ***Protein Extraction:***

Working protein extraction solution was prepared by mixing 4.25 ml of stock protein extraction (A.5) solution to 0.75 ml of mercaptoethanol, and adding distilled water to make 10 ml.

Defatted seed meal transferred then to 1.5 ml eppendorf tubes and 0.3 ml of above mentioned working protein extraction solution was added to each tube. The samples were left for 2 hr at room temperature and then kept in a refrigerator overnight. The samples were then given heating in a boiling water bath for 10 min. and cooled. After that the samples were centrifuged at 15,000 rpm for 10 min. The clear supernatant was taken for electrophoresis.

D. ***Preparation of Gel:***

D.1 ***Separating gel:***

Tris buffer (A.1) pH 8.8	12.0 ml
Water	7.4 ml
30% running gel acrylamide (A.11)	20.0 ml
5% APS (A.4)	0.4 ml
10% SDS (A.3)	0.4 ml

0.04 ml of TEMED just before pouring the gel mixture was added.

D.2 ***Stacking gel:***

Tris buffer pH 6.8 (A.2)	1.50 ml
Water	6.00 ml
30% stacking gel acrylamide (A.10)	2.00 ml
5% APS (A.4)	0.40 ml
10% SDS (A.3)	0.10 ml

0.04 ml of TEMED just before pouring of solution was added.

Procedure:

Electrophoresis was carried out using the apparatus of M/s Atto, Japan. The glass plates were thoroughly washed with water and ethanol and then air dried. The plates were fitted in gel cast assembly and tygon tube was used to make it air-tight. After mixing the components of resolving gel solution (See D.1), the solution mixture was poured immediately into the chambers of the assembly. A layer of water was

then gently overlaid using a syringe and after the gel polymerised, water was removed using filter paper strips and stacking gel mixture was prepared as per the composition of gel (See D.2) and immediately poured above the running gel and the comb was inserted with care so that no air bubble was trapped.

Comb and tygon tube were removed after polymerisation of the stacking gel and the gel assembly was fitted in the electrophoretic apparatus. Reservoir buffer was poured in the upper and lower reservoir tanks of the electrophoretic apparatus. The wells were properly washed (rinsed) with reservoir buffer. Samples (25 µl) were loaded. Electrophoresis carried out initially at 18 mA till the sample migrates into the running gel, and subsequently at 36 mA until the tracking dye reaches the bottom of the gel. After the completion of electrophoresis, the gel was removed from glass plates transferred to 15 per cent TCA and kept overnight. Then TCA was decanted, gel washed with distilled water and kept in staining solution (A.8) for 6-18 hours. Excess of stain was removed by 7 per cent acetic acid. After proper destaining, gels were photographed and stored in 7 per cent acetic acid solution.

3.1.2.1 Evaluation and documentation:

The gel was placed over a trans-illuminator for evaluation. The electrophoregrams were prepared measuring the distance of each band from the point of loading.

Relative mobility (Rm) of each band was calculated as:

$$Rm = \frac{\text{Distance travelled by the band}}{\text{Distance travelled by the tracking dye}}$$

Bands were numbered on the basis of increasing Rm values.

3.1.2.2 Calculation of similarity indices:

Similarity index values were calculated based on proportion of common fragments between two lanes by using the formulae:

$$F = \frac{2\,Mxy}{Mx + My}$$

Where, F is the similarity index, Mx is the number of bands in seed source X, My is the number of bands in seed source Y, and Mxy is the number of bands common to both X and Y. Thus, F=1.0 would mean that the patterns in the two seed sources are identical.

3.2 PROGENY TESTING OF SEED SOURCES

3.2.1 Layout of experiment:

One hundred seeds from each plus tree of 18 different seed sources were sown in polythene bags (22 x 10 cm) containing FYM, sand and clay (1:2:1) in the 1st week of August 1997. In March 1998, seedlings of all the seed sources were transplanted at 6 x 3 m spacing after assigning the progeny numbers (Table 1) in the Forestry Farm of CCS Haryana Agricultural University, Hisar following randomized block design with three replications, each containing three plants.

3.2.2 Observations recorded:

The following observations were recorded in the month of July during the years 2000 and 2001.

3.2.2.1 Total height (m):

Total height of a standing tree is the perpendicular distance from the top of the shoot to the ground level. The total height of tree was recorded with the help of marked pole.

3.2.2.2 Clear bole (m):

Bole height is the distance between ground level and crown point. The crown point is the position of the first crown forming branch, living or dead. Clear bole height of all the progenies were recorded with the help of marked pole.

3.2.2.3 Girth at breast height (cm):

For girth at breast height (gbh), the diameter of the individual tree was recorded with the help of electronic vernier calliper. Measurements were taken at a height of 1.37 m from the ground level. For calculating girth following formula was used:

$$\text{Girth} = \pi D$$

Where, D is the diameter of the tree

3.2.2.4 100-seed weight (g):

One hundred seeds were taken randomly from each replication and weighed on Owalabor Top Pan Electric Balance.

3.2.2.5 Current annual increment (m):

The growth that takes place in a particular year is called the Current annual increment (CAI) for that year. For both height and girth CAI was calculated by subtracting the values of July 2000 from July 2001.

3.2.2.6 Mean annual increment (m):

The total increment upto a given age divided by that age is mean annual increment (MAI). Therefore, MAI for height and growth was calculated by dividing the values of July 2001 by 4 (age of the progenies).

3.2.2.7 Pod length (cm):

Fifteen pods were taken randomly from each replication and measured with the help of scale and average length was worked out for the progenies of all the seed sources.

3.2.2.8 Pod width and thickness (mm):

Pod width and thickness both were measured for fifteen pods collected randomly from each replication, with the help of electronic vernier calliper and their average values were worked out.

3.2.2.9 Weight/pod (g):

Fifteen pods from each replication were taken randomly and weighed individually on Owalabor Top Pan Electric Balance and then average weight/pod worked out.

3.2.2.10 Seed weight/pod (g):

For seed weight/pod, fifteen pods were selected from each replication and seeds from each pod were removed and weighed on Owalabor Top Pan Electric Balance upto two decimal points and then their average was worked out.

3.2.2.11 Pulp weight/pod (g):

After removing seeds from each of the fifteen pods, the remaining part i.e. pulp was weighed on Owalabor Top Pan Electric Balance and their average value was calculated.

3.2.2.12 Number of seeds/pod:

Number of seeds was counted for all the fifteen pods which were collected randomly from each replication and their average was calculated.

3.3 REPRODUCTIVE BIOLOGY

For this study, 10 trees from a population of research area transplanted in March 1998 were marked randomly and following observations were undertaken from the month January to June during the years 2000 and 2001.

3.3.1 Blooming period:

The observations on various aspects such as spike initiation, commencement of flowering, peak period of flowering, cessation of flowering, duration of peak period of flowering (days) and duration of

flowering period (days) were observed during spring season of the years 2000 and 2001.

3.3.2 Flower structure:

To study the structure of the flower, five flowers each on five different spikes of all the ten trees of *Prosopis juliflora* were examined under the microscope.

3.3.3 Duration of flowering and fruiting phases:

To study the duration of several sequential phases in the reproductive process of *P.juliflora*, different observations commencing with spike initiation and eventually ending in pod ripening were taken during spring season of study period. Observations were, spike initiation to completion of elongation (days), completion of spike elongation to flower opening (days), stigma emergence before flower opening (hrs), period of florets opening per spike (hrs), flower opening to pod setting (hrs), pod setting to initiation of seed formation (days), seed formation to pod maturity (days)[growth of pod was completed but pod was still green] and pod maturity to pod ripening (days) [pod became pale yellow]. For this study, three spikes on each of the ten trees were tagged just after emergence of the spike for recording data from one phase to another.

3.3.4 The insects (floral visitors) collection and identification:

Insects visiting the spikes of *Prosopis juliflora* were collected by using a cone type hand net with 30 cm diameter of ring. The sweeps

were made throughout the blossoms of the species at an hourly interval from 0700 h to 1800 h. Collected insects were then killed in killing bottle and preserved as dry specimen. Insect collection was started after commencement of the flowering and continued till 90 per cent flowering was over. Insects thus, collected from spikes were got identified from the Taxonomy Section, Division of Entomology, Indian Agricultural Research Institute, New Delhi and Department of Entomology, CCS Haryana Agricultural University, Hisar.

3.3.5 Abundance of honey bees (*Apis* spp.):

Density of *Apis* spp. namely *A.dorsata* , *A.mellifera* and *A.florea* was recorded on *Prosopis juliflora* by selecting one metre shoot length per 5 minutes. The observations were recorded from 11th to 15th of April 2000 and 2001 between 0800-0900 h, 1000-1100 h, 1200-1300 h, 1400-1500 h and 1600-1700 h of the day and mean of five days was worked out.

3.3.6 Foraging speed of honey bees (*Apis* spp.):

Foraging speed of the *A.dorsata*, *A.mellifera* and *A.florea* was recorded in terms of the time spent by them on each spike for floral reward. The time spent to insert the proboscis and suck up the nectar was considered as the time spent per spike. The time spent/spike was recorded during 11th to 15th of April 2000 and 2001 at 1100 h of the day with the help of stop watch (chronometer). Mean of five days was worked out.

3.3.7 Pollen stainability:

The pollen stainability was studied in 2 per cent acetocarmine solution. Pollen from freshly opened flower was dusted on a clean slide and 1-2 drops of acetocarmine solution were added to the pollen mass. The slides were then left for 10-15 minutes to allow the pollen to take the stain. The deeply stained normal looking grains were recorded as stainable which are usually considered as viable and shrivelled and weakly stained pollen grains were recorded as non-viable. The observations were repeated for three days during March and April of both the years. In each observation, more than 100 pollen grains were seen and from these figures the percentage fertile pollen grains were determined.

3.3.8 Pollination studies:

To understand the mode of pollination, the following types of reproductive methods were carried out during March and April of 2000 and 2001.

3.3.8.1 Open pollination:

Twenty spikes were tagged and left unmanipulated for open pollination in each of the ten trees and subsequently number of fruit setting was recorded. Average number of flower buds per spike was calculated by counting the flower buds of five spikes on each of the trees under trial. Average number of flower buds/spike/tree was then multiplied with total number of spikes tagged/tree. On the basis of

number of flower buds/tree and number of fruit setting, percent fruit setting was calculated.

3.3.8.2 *Open pollination after emasculation:*

Twenty-five flower buds per spike were selected on twenty spikes and rest of the flower buds were removed to avoid inconvenience. The flower buds were emasculated one day before opening with the help of fine forceps and left unbagged for open pollination.

3.3.8.3 Apomixis:

Twenty five flower buds per spike on twenty spikes of each of the ten trees were emasculated one day before opening and each spike was bagged individually.

3.3.8.4 Autogamy (one spike per bag):

Twenty spikes on each of the ten trees were bagged individually one day before opening and were left as such without any external interference.

3.3.8.5 Selfing in muslin cloth bag (more than one spike per bag):

Twenty spikes were covered in 2-3 muslin cloth bags (Plate 1) on each tree and then number of fruit set was recorded.

3.3.8.6 Enforced geitonogamy:

Twenty five flower buds per spike on twenty spikes were emasculated (Plate 2) one day before opening and then were hand pollinated next day from 0700-1000 h, 1000-1300 h and 1500-1800 h with the pollen collected from the same tree and bagged.

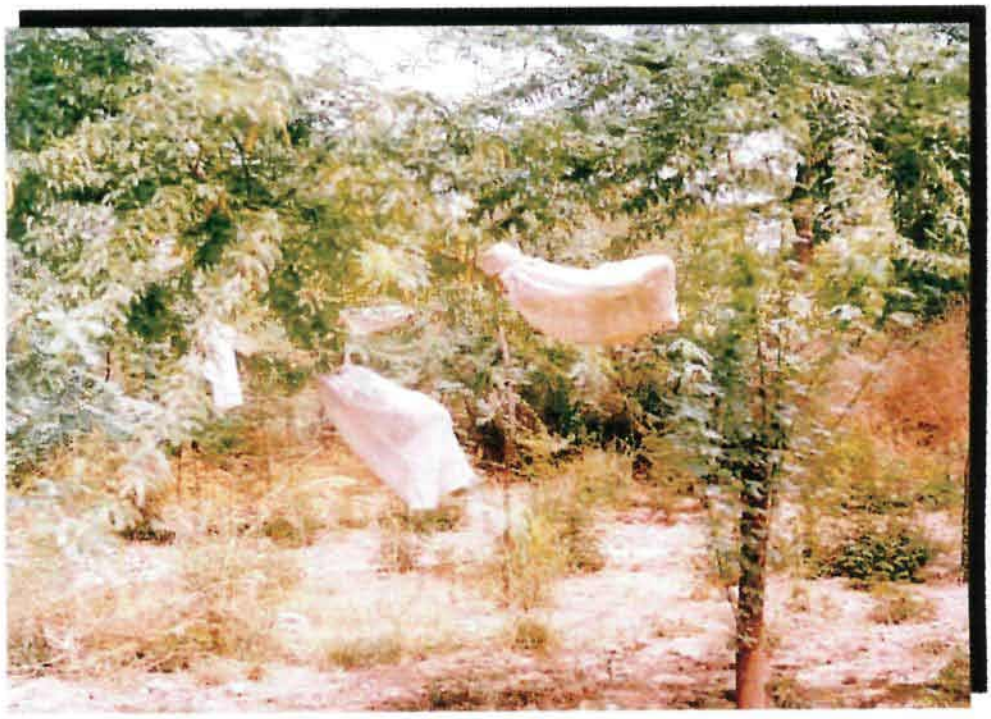


Plate 1: Spikes of *Prosopis juliflora* for selfing

Plate 2: Spikes of *Prosopis juliflora* after emasculation

3.3.8.7 Enforced allogamy:

Twenty five flower buds per spike on twenty spikes were emasculated one day before opening and then were hand pollinated next day from 0700-1000 h, 1000-1300 h and 1500-1800 h with the pollen collected from the other trees and bagged.

3.3.9 Evaluation of seeds and pods (obtained through different reproductive methods)

Pods and seeds obtained through different reproductive methods were further analysed for their morphological traits and total soluble protein in seeds through electrophoresis.

3.3.9.1 Observations on seed and pod morphology:

The observations on seed and pod parameters (obtained through different reproductive methods) were taken in three replications.

3.3.9.1.1 100-seed weight (g):

One hundred seeds were taken randomly and weighed on Owalabor Top Pan Electric Balance.

3.3.9.1.2 Seed length, width and thickness (mm):

The length, width and thickness of the seeds from each of the treatment were measured with the help of digital vernier calliper. For all the three observations seeds were selected randomly.

3.3.9.1.3 Number of seeds/pod:

For this study, pods were selected randomly and seeds were removed from them and counted.

3.3.9.1.4 Seed weight/pod (g):

Seeds removed from each pod were weighed on Owalabor Top Pan Electric Balance.

3.3.9.1.5 Weight/pod (g):

Pods (including seeds) were taken randomly and weighed individually on Owalabor Top Pan Electric Balance.

3.3.9.1.6 Pod length (cm):

For measuring pod length, pods were selected randomly and measured with the help of scale.

3.3.9.1.7 Standard germination (%):

Ten seeds obtained through different reproductive methods were sown in three replications in polythene bags (22 x 10 cm size) containing FYM, sand and clay (1:2:1) in the 1st week of March 2001. Number of seeds germinated were counted and then percent germination was calculated through mean of all the replications.

3.3.9.1.8 Seedling length (cm):

Seedling length was calculated by taking mean height of all the seedlings in each treatment with the help of scale at three different intervals i.e. after 30, 60 and 90 days of sowing.

3.3.9.1.9 Collar diameter (mm):

Collar diameter was calculated by measuring mean collar diameter of all the seedlings in each treatment with the help of electronic vernier

calliper at three different intervals i.e. after 30, 60 and 90 days of sowing.

3.3.9.2 Electrophoresis of seeds (obtained through different reproductive methods):

Seeds of tree no.5 were used for SDS-PAGE (sodium dodecyl sulphate - polyacrylamide gel electrophoresis) of total soluble protein by following standard techniques (Dadlani and Varier, 1993) as described (3.1.2) earlier.

3.4 STATISTICAL ANALYSIS

3.4.1 Phenotypic variation:

Data recorded on morphological parameters were compiled and analysed statistically to compute mean, range and coefficient of variation in different seed sources/progenies. The data on different parameters were recorded and analysis of variation was carried out.

3.4.2 Seed source and progeny testing:

3.4.2.1 Analysis of variance:

The replicated data for all parameters recorded for various seed sources/progenies were analysed statistically (Panse and Sukhatme, 1978).

3.4.2.2 Analysis of variance for seed source testing:

Source	d.f.	Expected mean squares
Replications	(r-1)	$\sigma^2e + s\,\sigma^2r$
Seed sources/progenies	(s-1)	$\sigma^2e + r\,\sigma^2s$
Error	(r-1) (s-1)	σ^2e

Where, r = number of replications, s = number of seed sources/progenies, e = error variance, σ = standard deviation

Significance ratio was tested at P≤ 0.05 using 'F' table by Fisher and Yates (1963).

3.4.2.3 Mean:

The mean value of each parameter was worked out by dividing the totals by corresponding number of observations:

$$\overline{X} = \frac{X_{ij}}{N}$$

Where,
X_{ij} = Any observation in i^{th} seed source and j^{th} replication
N = Total number of observations

3.4.2.4 Range:

The lowest and the highest values for each parameter were recorded.

3.4.2.5 Standard error (SEd):

Standard error for difference between two means were calculated with the help of error mean square from the analysis of variance table.

$$SEd \pm = \sqrt{\frac{2\ EMS}{r}}$$

Where,

EMS = error mean square
r = number of replications

3.4.2.6 Critical difference:

Critical difference for all the parameters was calculated to compare the seed sources. Critical difference were calculated with the

help of standard error for the difference of two means and tabulated value of 't' at 5% level of significance for error degree of freedom like.

C.D.= $\sqrt{\frac{2\ EMS}{r}}$ X 't' value at error d.f. for 1% or 5% level of significance.

3.4.3 Coefficient of variation:

Genotypic and phenotypic coefficient of variation were estimated for all the viability and vigour parameters by the formula suggested by Burton (1952).

Genotypic coefficient of variation:

$$GCV = \frac{\sigma g}{\overline{X}} \times 100$$

Phenotypic coefficient of variation:

$$PCV = \frac{\sigma p}{\overline{X}} \times 100$$

Where,
$\overline{X}$ = mean of a particular parameter
σg = genotypic standard deviation
σp = phenotypic standard deviation

The phenotypic correlation coefficients were tested against standardized tabulated significant values of r with (n-2) degree of freedom as per the procedure by Fisher and Yates (1963).

Where,
n = number of seed sources

3.4.4 Heritability (broad sense):

Heritability in broad sense was calculated according to the formula suggested by Johnson *et al.* (1955) for each parameter.

Heritability (broad sense) in per cent:

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,
h^2 = heritability in broad sense
$\sigma^2 g$ = genotypic variance
$\sigma^2 p$ = phenotypic variance

3.4.5 Genetic advance expressed in percentage of mean:

Estimates of appropriate variance components were substituted for the parameters to predict expected genetic gain as suggested by Lush (1949). The expected genetic advance was calculated at 5 per cent selection intensity for each parameter as:

$$\text{Genetic advance (\% of mean)} = \frac{K.\ \sigma p.h^2}{\overline{X}}$$

Where,
K = selection differential (2.06)
σp = phenotypic standard deviation
h^2 = heritability in broad sense
$\overline{X}$ = mean value for that parameter over all the genotypes.

3.4.6 Simple correlations:

The simple correlation among different parameters combinations was calculated using the following formula:

$$r = \frac{\Sigma (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\Sigma (X_i - \overline{X})^2 \ \Sigma (Y_i - \overline{Y})^2}}$$

Where,
r = simple correlation
X_i = individual value of one parameter
Y_i = individual value of other parameter

3.5 Meteorological Data:

The climatic conditions that prevailed during the course of investigation (August 1999 to July 2001) at Hisar are given in Figure 1 and the data are presented in Appendix.

3.5.1 Temperature (°C):

(a) Maximum

(b) Minimum

3.5.2 Relative humidity (%)

(a) Morning

(b) Evening

3.5.3 Wind speed (KMPH)

3.5.4 Total rainfall (mm)

3.5.5 Rainy days (No.)

3.5.6 Sunshine (h)

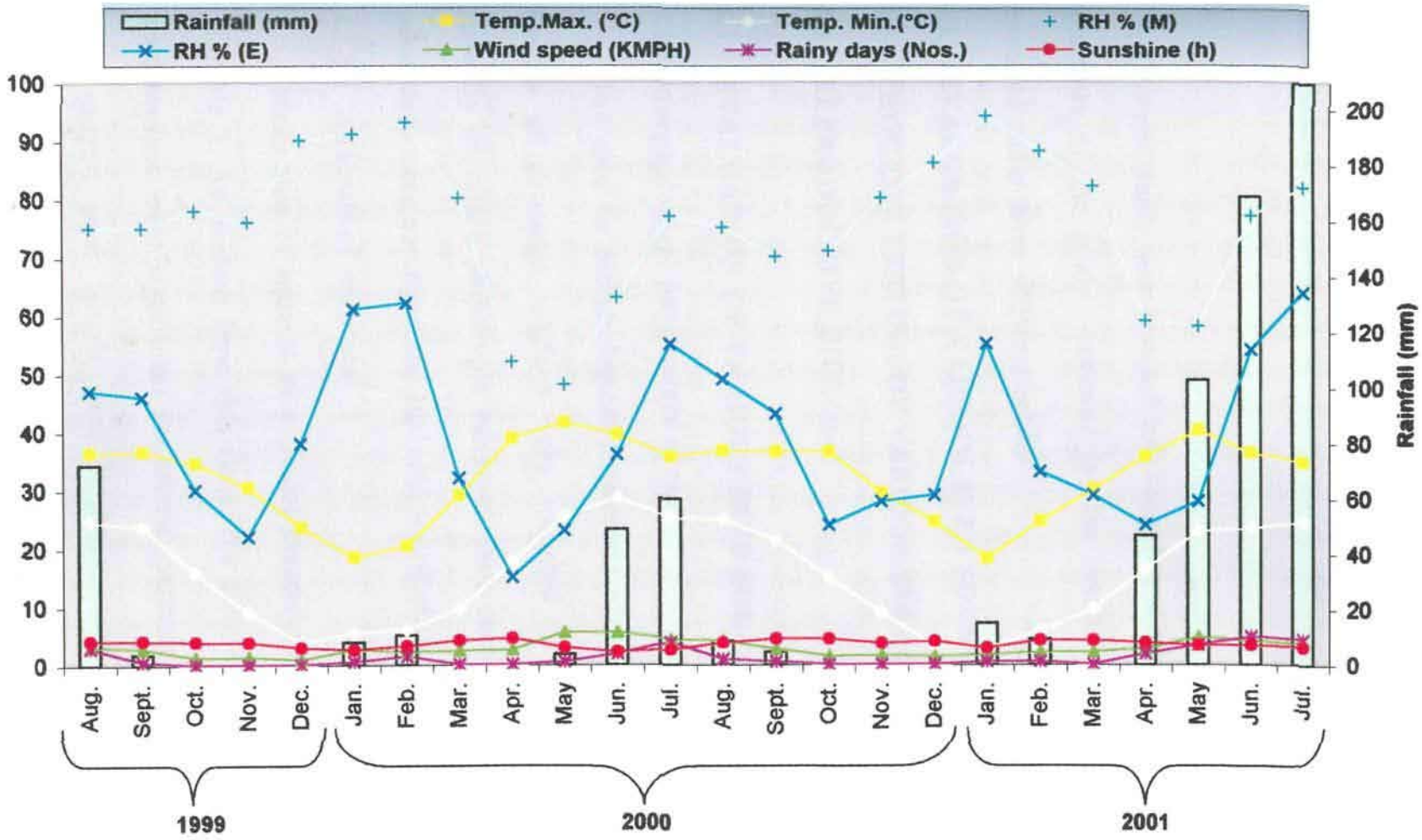


Fig.1: Monthly meteorological data during research period (August 1999 to July 2001) at Hisar.

CHAPTER-IV

EXPERIMENTAL RESULTS

Present study was grouped into three broad experiments as per the objectives of the study. Accordingly, the results obtained have been presented under three different heads:

4.1 EVALUATION OF VARIOUS SEED SOURCES

4.2 PROGENY TESTING OF VARIOUS SEED SOURCES

4.3 REPRODUCTIVE BIOLOGY

4.1 EVALUATION OF VARIOUS SEED SOURCES

4.1.1 Morphological parameters of seed:

The data on morphological parameters of seeds of different seed sources of *Prosopis juliflora* were recorded in order to study the naturally occurring phenotypic variation. Data recorded on various seed parameters were compiled and analysed statistically.

4.1.1.1 Analysis of variance:

Mean sum of squares of different parameters have been presented in Table 2. As evident from this table, the differences between various seed sources were significant for all the parameters studied viz., 100-seed weight, seed length, seed thickness and seed width, thereby

Table 2: Analysis of variance for seed parameters in *Prosopis juliflora* seed sources

S.No.	Parameters	Mean sum of squares		
		Replication	Seed source	Error
1.	100-seed weight	0.00	0.46*	0.0002
2.	Seed length	0.00	0.48*	0.0014
3.	Seed thickness	0.00	0.12*	0.0013
4.	Seed width	0.00	0.52*	0.0013
	d.f.	4	17	68

* Significant at $P \leq 0.05$.

indicating that substantial variation existed between the seed sources with respect to different seed parameters.

4.1.1.2 100-seed weight:

The perusal of Table 3 reveals that the mean 100-seed weight among various seed sources varied from 2.72 g in SS-14 to 3.72 g in SS-10 with general mean of 3.30 g. All the seed sources except SS-1, SS-2, SS-4, SS-8, SS-9, SS-11 and SS-14 had significantly higher 100-seed weight than general mean.

4.1.1.3 Seed length:

Table 3 indicates that range of mean seed length among various seed sources varied from 5.36 mm in SS-15 to 6.47 mm in SS-7, with general mean of 5.96 mm. The seed sources SS-3, SS-5, SS-7, SS-9, SS-10, SS-12, SS-13, SS-17 and SS-18 had significantly higher seed length than general mean.

4.1.1.4 Seed thickness:

The data in Table 3 reveal that seed thickness among various seed sources varied from 1.92 mm in SS-8 to 2.48 mm in SS-15. The seed sources SS-4, SS-5, SS-6, SS-7, SS-10, SS-14 and SS-15 had significantly higher seed thickness than general mean (2.21 mm).

4.1.1.5 Seed width:

The mean seed width varied from 3.66 mm in SS-7 to 4.69 mm in SS-8, with general mean of 4.12 mm. All the seed sources except SS-1,

SS-2, SS-3, SS-4, SS-6, SS-7, SS-9, SS-14 and SS-16 had significantly higher seed width than general mean (Table 3).

4.1.1.6 Seed colour:

The seeds obtained from SS-9 were strong brown, while seeds from SS-12, SS-14 and SS-16 were reddish brown in colour. However, seeds from other seed sources viz., SS-1, SS-2, SS-3, SS-4, SS-5, SS-6, SS-7, SS-8, SS-10, SS-11, SS-13, SS-15, SS-17 and SS-18 were dark reddish brown in colour (Table 3).

4.1.1.7 Seed shape:

Data in Table 3 also revealed that the seeds from all the sources were ovoid and flat in their shape.

4.1.1.8 Magnitude of variation:

The genotypic coefficient of variation, phenotypic coefficient of variation, heritability (broad sense) and expected genetic advance of the seed parameters of different seed sources have been presented in Table 4.

The maximum genotypic coefficient of variation was observed for 100-seed weight (9.16) followed by seed thickness (7.81). The minimum GCV was found for seed length (5.19). Similarly maximum PCV was observed for 100-seed weight (9.18) followed by seed thickness (7.87), whereas, the minimum PCV was observed for seed length (5.23).

Heritability (broad sense) estimates were high for all the seed parameters. The maximum heritability value was observed for 100-seed

Table 3: Variation in seed parameters in *Prosopis juliflora* seed sources

Seed Source No.	100-seed weight (g)	Seed length (mm)	Seed thickness (mm)	Seed width (mm)	Seed colour	Seed Shape
SS-1	3.32	5.95	2.18	4.06	Dark reddish brown	Ovoid and Flat
SS-2	3.08	5.82	2.03	3.90	Dark reddish brown	Ovoid and Flat
SS-3	3.39	6.30	2.00	3.67	Dark reddish brown	Ovoid and Flat
SS-4	2.89	5.62	2.30	3.79	Dark reddish brown	Ovoid and Flat
SS-5	3.62	6.20	2.34	4.32	Dark reddish brown	Ovoid and Flat
SS-6	3.40	5.74	2.44	4.04	Dark reddish brown	Ovoid and Flat
SS-7	3.50	6.47	2.29	3.66	Dark reddish brown	Ovoid and Flat
SS-8	3.04	5.47	1.92	4.69	Dark reddish brown	Ovoid and Flat
SS-9	2.75	6.03	2.03	3.68	Strong brown	Ovoid and Flat
SS-10	3.72	6.42	2.28	4.43	Dark reddish brown	Ovoid and Flat
SS-11	3.12	5.91	2.12	4.32	Dark reddish brown	Ovoid and Flat
SS-12	3.56	6.26	2.23	4.60	Reddish brown	Ovoid and Flat
SS-13	3.50	6.04	2.23	4.26	Dark reddish brown	Ovoid and Flat
SS-14	2.72	5.79	2.38	3.85	Reddish brown	Ovoid and Flat
SS-15	3.36	5.36	2.48	4.14	Dark reddish brown	Ovoid and Flat
SS-16	3.40	5.73	2.12	4.02	Reddish brown	Ovoid and Flat
SS-17	3.51	6.09	2.13	4.27	Dark reddish brown	Ovoid and Flat
SS-18	3.62	6.04	2.25	4.50	Dark reddish brown	Ovoid and Flat
Mean	3.30	5.96	2.21	4.12		
SEd±	0.01	0.02	0.02	0.02		
CD at 5%	**0.02**	**0.05**	**0.04**	**0.05**		
Range	2.72-3.72	5.36-6.47	1.92-2.48	3.66-4.69		

Table 4: Magnitude of variation for seed parameters in *Prosopis juliflora* seed sources

Parameters	GCV	PCV	h^2	GA as % of mean
100-seed weight	9.16	9.18	99.70	18.84
Seed length	5.19	5.23	98.43	10.61
Seed width	6.99	7.18	94.94	14.04
Seed thickness	7.81	7.87	98.70	15.99

GCV Genotypic coefficient of variation
PCV Phenotypic coefficient of variation
h^2 Heritability (broad sense)
GA Genetic advance

weight (99.70) followed by seed thickness and seed length. The maximum genetic advance (GA) as percent of mean was recorded for 100-seed weight (18.84) followed by seed thickness, while minimum was recorded for seed length (10.61).

4.1.1.9 Nature of correlation:

Correlation studies were made to find out association at phenotypic and genotypic levels among different seed parameters of various seed sources. These results have been presented in Table 5. The magnitude of correlation coefficients at genotypic level (below diagonal) were higher than the corresponding phenotypic level (above diagonal), thus indicating a good extent of strong inherent association between different parameters.

100-seed weight had significant positive ($P \leq 0.05$) correlation with seed length and seed thickness.

Non-significant correlations were observed among all the other seed parameters studied.

4.1.2 Electrophoresis:

The electrophoretic profile of total soluble seed protein revealed characteristic banding patterns for all the seed sources (Plate 3). A total of 27 bands were resolved (Fig.2) among all the seed sources of *P.juliflora*. The number of bands resolved ranged from 15 (SS-1) to 24 (SS-14) in various seed sources (Table 6). Six bands having Rm values of 0.32, 0.50, 0.60, 0.90, 0.94 and 0.96 were present in all the seed

Table 5: Phenotypic (above diagonal) and genotypic (below diagonal) correlations among seed parameters in *Prosopis juliflora* seed sources

Parameters	100-seed weight	Seed length	Seed width	Seed thickness
100-seed weight	1.000	0.522*	0.252	0.445*
Seed length	0.528	1.000	-0.062	-0.051
Seed width	0.257	-0.062	1.000	-0.028
Seed thickness	0.448	-0.050	-0.023	1.000

* Significant at 5% level of significance.

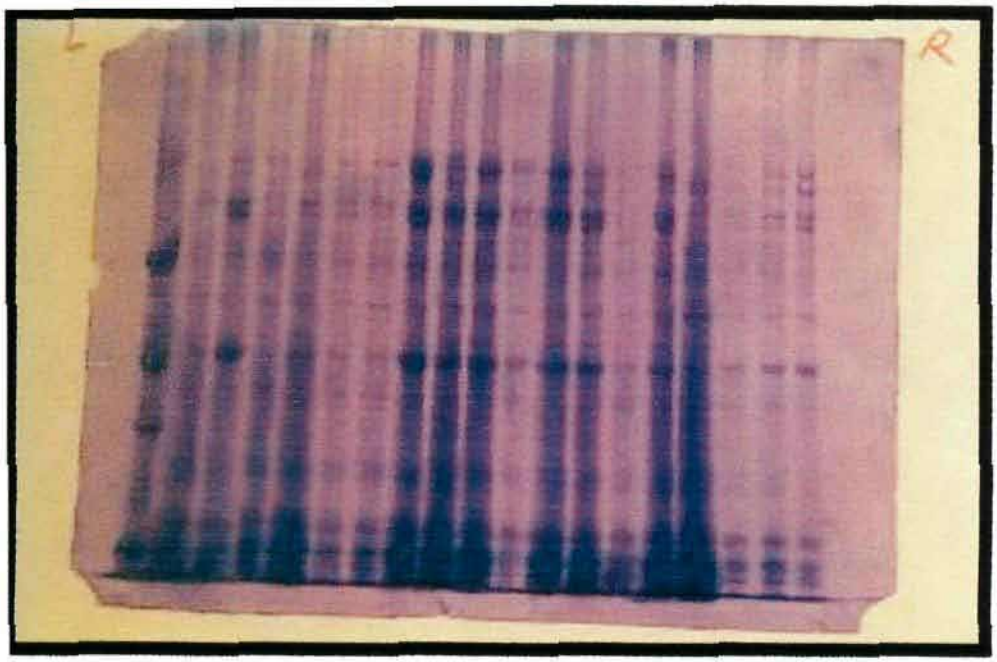


Plate 3: Banding pattern of total seed protein in *Prosopis juliflora* seed sources by SDS-PAGE

Lane 1-19: Protein marker, SS-1, SS-2, SS-3, SS-4,SS-5, SS-6, SS-7, SS-8, SS-9, (L to R) SS-10,SS-11, SS-12, SS-13, SS-14, SS-15, SS-16, SS-17, SS-18

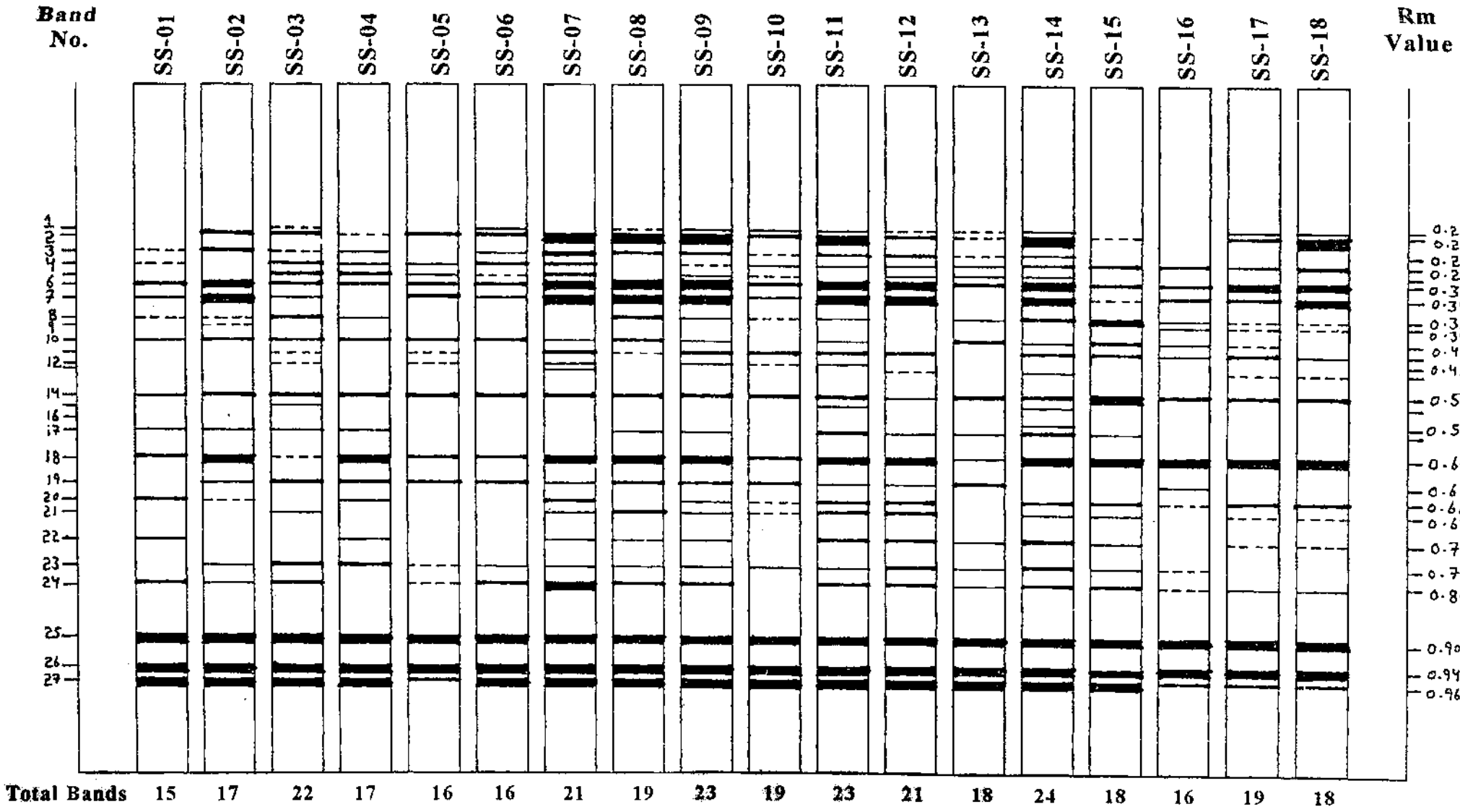


Fig. 2 : Zymogram of total seed protein in *Prosopis juliflora* seed sources by SDS-PAGE

Table 6: Electrophoregram of total seed protein in *Prosopis juliflora* seed sources by SDS-PAGE

Band No.	Rm Value	Protein Marker	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10	SS-11	SS-12	SS13	SS-14	SS-15	SS-16	SS-17	SS-18
1.	0.23	-	-	-	VL	-	-	L	-	VL	L	L	L	VL	VL	L	-	-	L	L
2.	0.24	-	-	M	M	VL	M	M	D	D	D	M	D	M	VL	D	VL	-	M	D
3.	0.27	-	VL	M	VL	L	-	L	D	M	M	VL	M	M	VL	L	-	-	-	-
4.	0.29	-	VL	-	M	L	L	M	M	-	VL	L	L	L	L	M	M	M	M	D
5.	0.30	-	-	-	M	M	L	VL	M	-	L	VL	-	L	L	L	-	-	-	-
6.	0.32	-	M	D	M	M	M	M	D	D	D	M	D	D	L	D	M	M	D	D
7.	0.34	-	L	D	L	-	M	L	D	D	D	L	D	D	-	D	VL	M	M	D
8.	0.38	-	VL	VL	M	L	-	-	-	M	L	VL	L	-	L	M	D	L	VL	VL
9.	0.39	-	-	VL	-	-	-	-	-	-	-	-	-	-	-	-	-	L	VL	VL
10.	0.42	-	L	M	M	M	M	M	L	M	L	-	L	-	M	L	M	L	VL	-
11.	0.44	D	-	-	VL	-	VL	-	M	VL	M	M	M	M	-	M	M	L	M	L
12.	0.45	-	-	-	VL	-	VL	-	L	-	L	VL	L	-	-	-	-	-	-	-
13.	0.46	-	-	-	-	-	-	-	L	-	-	-	-	VL	-	L	-	-	VL	VL
14.	0.50	M	L	M	M	M	M	M	M	M	M	M	M	L	M	M	D	M	M	M
15.	0.52	-	-	-	L	-	-	-	-	-	-	-	L	-	-	L	-	-	-	-
16.	0.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	-	-	-	-
17.	0.55	M	L	L	L	L	-	-	-	L	L	-	M	L	L	M	L	-	-	-
18.	0.60	D	M	D	VL	D	M	M	D	D	D	M	D	D	L	D	D	D	D	D
19.	0.65	-	-	L	M	M	M	M	L	M	M	M	L	L	M	-	-	L	-	-
20.	0.68	-	M	VL	-	L	-	-	M	-	L	VL	M	M	-	M	M	VL	M	M
21.	0.69	-	-	-	L	-	-	-	L	M	L	VL	M	M	-	L	L	-	VL	VL
22.	0.74	D	L	-	-	L	-	-	L	L	L	-	M	M	L	M	L	-	VL	VL
23.	0.78	-	-	L	M	M	VL	L	L	L	L	L	L	M	L	M	L	VL	-	-
24.	0.80	-	M	L	M	-	VL	M	D	M	M	-	M	M	L	M	M	VL	L	L
25.	0.90	-	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
26.	0.94	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
27.	0.96	-	D	D	D	D	M	D	D	D	D	D	D	D	D	D	D	M	M	M
Total Bands		6	15	17	22	17	16	16	21	19	23	19	23	21	18	24	18	16	19	18

D = DARK; M = MEDIUM; L = LIGHT; VL = VERY LIGHT; - = ABSENT

sources, out of which bands having Rm values 0.90, 0.94 and 0.96 were highly intense bands. Based on presence or absence of bands, similarity values (Table 7) were calculated for all pair-wise comparisons made among 18 seed sources. The similarity values on the basis of total seed protein data ranged from 0.63 between SS-4 and SS-18 to 0.97 between SS-17 and SS-18. Their closeness may be either due to common parentage or accumulation of similar genes from different parents.

4.2 PROGENY TESTING OF VARIOUS SEED SOURCES

4.2.1. Growth parameters:

4.2.1.1 Analysis of variance:

Table 8 showed mean sum of squares of different growth parameters in progenies of *P.juliflora* seed sources. The differences between various progenies were significant for total height, clear bole and girth at breast height during the years 2000 and 2001. The difference between various progenies for height and girth increment (CAI and MAI) were also significant.

4.2.1.2 Total height:

The data presented in Table 9 reveals that total height of *Prosopis juliflora* progenies during 2000 varied from 2.81 m (PT-101) to 4.73 m (PT-112). Whereas, during 2001, total height varied from 3.98 m (PT-109) to 6.63 m (PT-112). The progenies PT-107, PT-111, PT-112, PT-116 and PT-117 had significantly higher mean values than general mean of 3.58 m and 5.26 m during 2000 and 2001, respectively.

Table 7: Similarity index in *Prosopis juliflora* seed sources

	SS-1	SS-2	SS-3	SS-4	SS-5	SS-6	SS-7	SS-8	SS-9	SS-10	SS-11	SS-12	SS-13	SS-14	SS-15	SS-16	SS-17	SS-18
SS-1	1.00	0.81	0.70	0.81	0.64	0.71	0.72	0.76	0.79	0.65	0.79	0.72	0.79	0.77	0.84	0.77	0.76	0.72
SS-2		1.00	0.77	0.76	0.72	0.79	0.74	0.83	0.70	0.72	0.80	0.74	0.80	0.68	0.80	0.85	0.72	0.68
SS-3			1.00	0.77	0.84	0.84	0.84	0.88	0.93	0.88	0.93	0.84	0.85	0.87	0.80	0.74	0.73	0.70
SS-4				1.00	0.72	0.79	0.79	0.78	0.85	0.78	0.80	0.79	0.91	0.78	0.80	0.73	0.67	0.63
SS-5					1.00	0.88	0.86	0.74	0.82	0.80	0.77	0.76	0.76	0.70	0.76	0.81	0.68	0.65
SS-6						1.00	0.81	0.80	0.82	0.80	0.77	0.81	0.88	0.75	0.70	0.75	0.68	0.65
SS-7							1.00	0.80	0.91	0.85	0.86	0.90	0.77	0.84	0.82	0.76	0.80	0.77
SS-8								1.00	0.90	0.79	0.90	0.85	0.86	0.84	0.86	0.74	0.79	0.76
SS-9									1.00	0.90	0.96	0.91	0.88	0.89	0.88	0.77	0.81	0.78
SS-10										1.00	0.86	0.85	0.76	0.79	0.76	0.74	0.74	0.76
SS-11											1.00	0.86	0.83	0.89	0.88	0.77	0.81	0.78
SS-12												1.00	0.82	0.89	0.82	0.70	0.80	0.82
SS-13													1.00	0.81	0.78	0.70	0.70	0.67
SS-14														1.00	0.86	0.70	0.84	0.81
SS-15															1.00	0.82	0.86	0.83
SS-16																1.00	0.80	0.76
SS-17																	1.00	0.97
SS-18																		1.00

Table 8: Analysis of variance for growth parameters in progenies of *Prosopis juliflora*

S.No.	Parameters	Mean sum of squares		
		Replication	Progeny	Error
1.	Total Height			
	2000	0.000	1.07*	0.02
	2001	0.005	1.82*	0.01
2.	Clear Bole			
	2000	0.005	0.34*	0.01
	2001	0.000	0.44*	0.02
3.	Girth at Breast Height (gbh)			
	2000	0.410	21.07*	0.15
	2001	0.400	35.96*	0.21
4.	Height Increment			
	CAI	0.005	0.17*	0.01
	MAI	0.000	0.11*	0.0005
5.	Girth Increment			
	CAI	0.005	1.99*	0.01
	MAI	0.050	2.25*	0.01
	d.f.	2	17	34

* Significant at $P \leq 0.05$.

4.2.1.3 Clear bole:

Clear bole (Table 9) of *P.juliflora* progenies during 2000 varied from 1.54 m (PT-101) to 2.56 m (PT-111). Whereas, during 2001, it varied from 1.86 m (PT-106) to 3.04 m (PT-107). The progenies PT-107, PT-111, PT-114, PT-115 ad PT-117 had significantly higher mean value than general mean of 2.05 m and 2.48 m during 2000 and 2001, respectively.

4.2.1.4 Girth at breast height (gbh):

Table 9 indicates that range of mean gbh among various progenies varied from 10.78 cm (PT-102) to 19.80 cm (PT-112) and 14.66 cm (PT-102) to 26.45 cm (PT-112) during 2000 and 2001, respectively. The progenies PT-106, PT-107, PT-111, PT-112, PT-113 and PT-115 had significantly higher mean value than general mean of 14.70 cm and 19.76 cm during 2000 and 2001, respectively.

4.2.1.5 Height increment:

Current annual increment (CAI) in height for the years 2000 and 2001 is presented in Table 9. CAI among progenies varied from 1.11 m (PT-109) to 1.98 m (PT-107) with general mean of 1.67 m. The progenies PT-107, PT-110, PT-112 and PT-116 had significantly higher CAI than general mean. However, mean annual increment (MAI) in height upto 2001 of various progenies varied from 1.00 m (PT-109) to 1.66 m (PT-112) with general mean of 1.31 m. The progenies PT-106,

Table 9: Variation in growth parameters among progenies of *Prosopis juliflora* during 2000 and 2001

Progeny	Total height (m)		Clear bole (m)		gbh (cm)		Height increment (m)		Girth increment (cm)	
No.	2000	2001	2000	2001	2000	2001	CAI	MAI	CAI	MAI
PT-101	2.81	4.17	1.54	1.88	12.05	16.41	1.31	1.03	4.36	4.10
PT-102	2.93	4.23	1.81	2.18	10.78	14.66	1.30	1.06	3.88	3.66
PT-103	3.49	5.26	1.90	2.32	11.38	15.51	1.81	1.32	4.13	3.88
PT-104	3.35	5.14	1.95	2.35	13.04	17.63	1.79	1.29	4.59	4.40
PT-105	3.29	5.00	1.63	1.97	13.64	18.32	1.71	1.25	4.68	4.58
PT-106	3.68	5.45	1.55	1.86	15.64	20.89	1.77	1.36	5.25	5.22
PT-107	4.60	6.58	2.54	3.04	17.58	23.53	1.98	1.64	5.96	5.88
PT-108	3.66	5.33	2.05	2.42	15.27	20.46	1.67	1.33	5.18	5.11
PT-109	2.87	3.98	1.61	2.04	13.00	17.50	1.11	1.00	4.50	4.37
PT-110	3.17	5.02	2.13	2.63	13.87	18.63	1.85	1.25	4.76	4.66
PT-111	4.48	6.24	2.56	2.94	19.23	25.67	1.76	1.56	6.44	6.42
PT-112	4.73	6.63	2.15	2.65	19.80	26.45	1.90	1.66	6.65	6.61
PT-113	3.61	5.15	2.19	2.63	18.11	24.25	1.54	1.29	6.13	6.06
PT-114	3.01	4.49	2.48	2.97	14.46	19.36	1.48	1.12	4.90	4.84
PT-115	3.21	4.99	2.36	2.79	11.57	15.52	1.78	1.25	3.96	3.88
PT-116	4.27	6.13	2.20	2.66	15.15	20.29	1.85	1.53	5.14	5.07
PT-117	3.88	5.69	2.40	2.91	15.57	20.90	1.81	1.42	5.33	5.22
PT-118	3.43	5.13	1.92	2.36	14.56	19.66	1.70	1.28	5.10	4.92
Mean	3.58	5.26	2.05	2.48	14.70	19.76	1.67	1.31	5.05	4.94
SEd±	0.11	0.15	0.10	0.10	0.32	0.37	0.07	0.02	0.09	0.09
CD at 5%	**0.23**	**0.31**	**0.20**	**0.20**	**0.65**	**0.76**	**0.15**	**0.04**	**0.18**	**0.19**
Range	2.81-4.73	3.98-6.63	1.54-2.56	1.86-3.04	10.78-19.80	14.66-26.45	1.11-1.98	1.00-1.66	3.86-6.65	3.66-6.61

PT-107, PT-111, PT-112, PT-116 and PT-117 had significantly higher MAI than general mean.

4.2.1.6 Girth increment:

Current annual increment in girth for the years 2000 and 2001 (Table 9) among various progenies varied from 3.88 cm (PT-102) to 6.65 cm (PT-112) with general mean of 5.05 cm. However, mean annual increment in girth up to 2001 of various progenies varied from 3.66 cm (PT-102) to 6.61 cm (PT-112) with general mean of 4.94 cm. The progenies PT-106, PT-107, PT-111, PT-112, PT-113 and PT-117 had significantly higher CAI and MAI during both the years.

4.2.2 Seed and pod parameters:

4.2.2.1 Analysis of variance:

Mean sum of squares of various seed and pod parameters in progenies of *P.juliflora* seed sources during the years 2000 and 2001 are presented in Table 10. The differences between various seed sources during both the years were found significant for all the seed and pod parameters viz. 100-seed weight, pod length, pod width, pod thickness, weight/pod, seed weight/pod, pulp weight/pod and no. of seeds/pod.

4.2.2.2 100-seed weight:

The mean 100-seed weight (Table 11) among various progenies during 2000 varied from 2.72 g (PT-108) to 3.64 g (PT-105) with general mean of 3.20 g. The progenies PT-101, PT-103, PT-105, PT-106, PT-115, PT-116 and PT-118 had significantly higher 100-seed

Table 10: Analysis of variance for seed and pod parameters in progenies of *Prosopis juliflora* during 2000 and 2001

S.No.	Parameters	Mean sum of squares (2000)			Mean sum of squares (2001)		
		Replication	Progeny	Error	Replication	Progeny	Error
1.	100-seed weight	0.005	0.19*	0.01	0.005	0.18*	0.003
2.	Pod length	0.005	13.08*	0.13	0.10	6.74*	0.18
3.	Pod width	0.00	3.63*	0.02	0.01	2.47*	0.03
4.	Pod thickness	0.03	1.62*	0.01	0.00	1.58*	0.004
5.	Weight per pod	0.00	2.38*	0.01	0.00	1.38*	0.004
6.	Seed weight per pod	0.00	0.04*	0.0005	0.00	0.04*	0.0005
7.	Pulp weight per pod	0.00	2.01*	0.01	0.00	1.25*	0.01
8.	No. of seeds per pod	0.3	40.88*	0.11	0.08	32.52*	0.10
	d.f.	2	17	34	2	17	34

*Significant at $P \leq 0.05$

weight than general mean. Whereas, during 2001, 100-seed weight varied from 2.81 g (PT-108) to 3.70 g (PT-105) with general mean of 3.20 g. The progenies PT-101, PT-102, PT-103, PT-105, PT-106, PT-116 and PT-118 had significantly higher 100-seed weight than general mean. Variation in 100-seed weight was found more during 2000 as compared to 2001.

4.2.2.3 Pod length:

The mean pod length (Table 11) among various progenies during 2000 varied from 10.17 cm (PT-106) to 19.37 cm (PT-113) with general mean of 16.25 cm. The progenies PT-101, PT-103, PT-107, PT-110, PT-113 and PT-114 had significantly higher pod length than general mean. Large amount of variation was observed in various progenies for pod length during the year 2000. Whereas, during 2001, pod length varied from 12.87 cm (PT-106) to 18.37 cm (PT-101) with general mean of 16.46 cm. All the progenies had significantly higher pod length than general mean except PT-102, PT-104, PT-105, PT-106, PT-108, PT-111, PT-115, PT-117 and PT-118. During 2001, pod length varied less among various progenies.

4.2.2.4 Pod width:

The data presented in Table 11 reveals that the mean pod width among various progenies during 2000 ranged from 6.32 mm in PT-104 to 11.16 mm in PT-107. The general mean was 8.58 mm. The pod width of progenies PT-103, PT-106, PT-107, PT-109, PT-113, PT-115 and

Table 11: Variation in seed and pod parameters among progenies of *Prosopis juliflora* during 2000 and 2001

Progeny No.	100-seed weight (g)		Pod length (cm)		Pod width (mm)		Pod thickness (mm)	
	2000	2001	2000	2001	2000	2001	2000	2001
PT-101	3.39	3.30	17.67	18.37	7.95	8.15	3.23	3.15
PT-102	3.30	3.35	13.47	14.53	8.26	8.04	4.56	4.17
PT-103	3.41	3.46	17.83	17.33	9.42	9.14	4.65	4.39
PT-104	2.89	2.85	16.27	15.43	6.32	6.82	2.78	2.94
PT-105	3.64	3.70	15.50	16.97	8.14	8.36	4.55	4.49
PT-106	3.42	3.38	10.17	12.87	8.42	8.94	4.63	4.61
PT-107	3.09	3.03	18.20	17.53	11.16	10.11	4.65	4.58
PT-108	2.72	2.81	14.90	16.13	7.86	7.09	5.18	5.04
PT-109	3.11	3.10	16.23	17.70	9.81	9.74	3.98	3.93
PT-110	3.29	3.20	18.57	17.57	8.65	8.81	4.94	4.82
PT-111	3.15	3.09	16.37	16.07	7.51	7.37	4.96	5.03
PT-112	3.01	3.08	16.80	17.83	8.73	8.94	4.41	4.59
PT-113	3.27	3.21	19.37	17.60	9.01	8.86	4.04	4.28
PT-114	2.99	2.90	17.73	17.43	8.62	9.07	5.17	5.26
PT-115	3.35	3.28	15.50	14.73	9.52	8.71	5.56	5.48
PT-116	3.37	3.35	16.33	17.47	9.73	9.57	5.28	5.47
PT-117	2.78	2.99	15.93	14.63	7.45	7.62	3.53	3.45
PT-118	3.50	3.54	15.60	16.00	7.89	8.15	4.74	4.44
Mean	3.20	3.20	16.25	16.46	8.58	8.53	4.49	4.45
SEd±	0.06	0.05	0.30	0.34	0.11	0.15	0.07	0.05
CD at 5%	**0.13**	**0.09**	**0.61**	**0.70**	**0.21**	**0.31**	**0.14**	**0.11**
Range	2.72-3.64	2.81-3.70	10.17-19.37	12.87-18.37	6.32-11.16	6.82-10.11	2.78-5.56	2.94-5.48

Continue...

Continue...

Progeny	Weight/pod (g)		Seed weight/pod (g)		Pulp weight/pod (g)		No. of seeds/pod	
No.	2000	2001	2000	2001	2000	2001	2000	2001
PT-101	3.99	3.77	0.81	0.88	3.18	2.89	24.30	26.22
PT-102	2.63	3.14	0.76	0.69	1.87	2.45	23.29	20.51
PT-103	4.87	4.13	0.88	0.83	3.99	3.30	26.18	23.68
PT-104	3.66	2.76	0.69	0.61	2.97	2.15	23.89	21.07
PT-105	2.76	3.67	0.72	0.76	2.04	2.91	19.67	20.13
PT-106	2.35	2.74	0.51	0.53	1.84	2.21	14.91	15.80
PT-107	4.80	4.84	0.79	0.74	4.01	4.10	25.91	24.71
PT-108	2.84	2.96	0.66	0.67	2.18	2.29	24.06	23.94
PT-109	4.06	4.42	0.59	0.56	3.47	3.86	18.89	18.23
PT-110	4.99	4.63	0.93	0.86	4.06	3.77	28.33	26.15
PT-111	3.56	3.43	0.68	0.62	2.88	2.78	21.60	19.60
PT-112	3.97	4.54	0.71	0.72	3.26	3.82	22.58	23.54
PT-113	5.23	4.11	0.94	0.89	4.29	3.22	28.60	27.12
PT-114	4.56	4.61	0.70	0.67	3.86	3.94	22.98	21.98
PT-115	3.51	3.60	0.60	0.58	2.91	3.02	17.94	17.98
PT-116	4.23	4.66	0.63	0.63	3.60	4.03	18.73	19.18
PT-117	2.68	3.69	0.70	0.72	1.98	2.97	25.44	24.36
PT-118	4.09	4.05	0.88	0.89	3.21	3.16	25.11	25.58
Mean	3.82	3.88	0.73	0.71	3.09	3.16	22.91	22.21
SEd±	0.06	0.05	0.02	0.02	0.07	0.07	0.28	0.26
CD at 5%	**0.12**	**0.11**	**0.04**	**0.04**	**0.15**	**0.14**	**0.56**	**0.53**
Range	2.35-5.23	2.74-4.84	0.51-0.94	0.53-0.89	1.84-4.29	2.15-4.10	14.91-28.60	15.80-27.12

PT-116 was significantly higher than the general mean. Whereas, the mean pod width during 2001 ranged from 6.82 mm in PT-104 to 10.11 mm in PT-107. The general mean was 8.53 mm. The pod width of progenies PT-103, PT-106, PT-107, PT-109, PT-112, PT-113, PT-114 and PT-116 was significantly higher than the general mean. The variation in pod width was more during 2000 as compared to 2001.

4.2.2.5 Pod thickness:

Table 11 indicates that range of mean pod thickness during 2000 and 2001 varied from2.78 mm (PT-104) to 5.56 mm (PT-115) and 2.94 mm (PT-104) to 5.48 mm (PT-115), respectively. The variation in pod thickness among various progenies was more during 2000 as compared to 2001. The progenies PT-103, PT-107, PT-108, PT-110, PT-111, PT-114, PT-115, PT-116 and PT-118 during 2000 had significantly higher pod thickness than the general mean (4.49 mm). Whereas, during 2001, pod thickness was significantly higher in PT-106, PT-108, PT-110, PT-111, PT-112, PT-114, PT-115 and PT 116 than the general mean (4.45 mm).

4.2.2.6 Weight/pod:

The mean pod weight among various progenies during 2000 varied from 2.35 g in PT-106 to 5.23 g in PT-113 with general mean of 3.82 g (Table 11). All the progenies except PT-102, PT-104, PT-105, PT-106, PT-108, PT-111, PT-115 and PT-117 had significantly higher pod weight than general mean. Whereas, during 2001, the mean pod weight

varied from 2.74 g in PT-106 to 4.84 g in PT-107 with general mean of 3.88 g. All the progenies except PT-101, PT-102, PT-104, PT-105, PT-106, PT-108, PT-111, PT-115 and PT-117 had significantly higher pod weight than general mean. The variation for weight/pod among various progenies was more during 2000 as compared to 2001.

4.2.2.7 Seed weight/pod:

The mean seed weight/pod (Table 11) during 2000 and 2001 varied from 0.51 g (PT-106) to 0.94 g (PT-113) and 0.53 g (PT-106) to 0.89 g (PT-113 and PT-118), respectively indicating wide variation in seed weight/pod among various progenies during 2000. During 2000, the progenies PT-101, PT-103, PT-107, PT-110, PT-113 and PT-118 had significantly higher mean values than general mean (0.73 g). While, during 2001, the progenies PT-101, PT-103, PT-105, PT-110, PT-113 and PT-118 had significantly higher mean values than general mean (0.71 g).

4.2.2.8 Pulp weight/pod:

Th mean pulp weight/pod (Table 11) among various progenies during 2000 varied from 1.84 g (PT-106) to 4.29 g (PT-113) with general mean of 3.09 g. The progenies PT-103, PT-107, PT-109, PT-110, PT-112, PT-113, PT-114 and PT-116 had significantly higher pulp weight/pod than general mean. Whereas, during 2001, it varied from 2.15 g (PT-104) to 4.10 g (PT-107) with general mean of 3.16 g. The progenies PT-107, PT-109, PT-110, PT-112, PT-114 and PT-116

had significantly higher mean values than general mean. Pulp weight/pod varied more among the progenies during 2000 rather than 2001.

4.2.2.9 No. of seeds/pod:

The data presented in Table 11 revcals that mean no. of seeds/pod during 2000 and 2001 varied from 14.91 (PT-106) to 28.60 (PT-113) and 15.80 (PT-106) to 27.12 (PT-113), respectively. The variation for no. of seeds/pod among various progenies was more during 2000 as compared to 2001. During 2001, the progenies PT-101, PT-103, PT-104, PT-107, PT-108, PT-110, PT-113, PT-117 and PT-118 had significantly more no. of seeds/pod than the general mean (22.91). Similarly, during 2001, the progenies PT-101, PT-103, PT-107, PT-108, PT-110, PT-112, PT-113, PT-117 and PT-118 had significantly more no. of seeds/pod than general mean (22.21).

4.2.2.10 Magnitude of variation:

The genotypic coefficient of variation, phenotypic coefficient of variation, heritability (broad sense) and expected genetic advance for seed and pod parameters in progenies of *P.juliflora* during 2000 and 2001, have been presented in Table 12.

The genotypic coefficient of variation was maximum for pulp weight/pod i.e. 26.45 per cent and 20.39 per cent during 2000 and 2001, respectively, followed by weight/pod during both the years. Whereas,

Table 12: Magnitude of variation for seed and pod parameters in progenies of *Prosopis juliflora* during 2000 and 2001.

Parameters	GCV		PCV		h^2		GA as % of mean	
	2000	2001	2000	2001	2000	2001	2000	2001
100-seed weight	7.78	7.51	8.14	7.71	91.32	94.88	15.31	15.08
Pod length	12.79	8.99	12.98	9.34	97.01	92.54	25.95	17.81
Pod width	12.78	10.56	12.87	10.78	98.65	95.89	26.16	21.29
Pod thickness	16.32	16.30	16.43	16.36	98.68	99.24	33.39	33.44
Weight/pod	23.26	17.48	23.34	17.56	99.31	99.04	47.75	35.83
Seed weight/pod	16.30	16.30	16.58	16.67	96.69	95.63	33.02	32.84
Pulp weight/pod	26.45	20.39	26.60	20.56	98.85	98.38	54.17	41.66
No. of seeds/pod	16.09	14.80	16.16	14.87	99.16	99.08	33.01	30.35

GCV was minimum i.e. 7.78 per cent and 7.51 per cent for 100-seed weight during 2000 and 2001, respectively.

The phenotypic coefficient of variation during 2000 ranged from 8.14 per cent for 100-seed weight to 26.60 per cent for pulp weight/pod, whereas during 2001, PCV ranged from 7.71 per cent 100-seed weight to 20.56 per cent for pulp weight/pod. In general, GCV and PCV for all the parameters were found more during 2000 as compared to 2001. A perusal of Table 12 also revealed that PCV during 2000 and 2001 were higher than the GCV during 2000 and 2001.

Heritability (broad sense) estimates were high for all the parameters. During 2000, the maximum heritability value was observed for weight/pod (99.31%) followed by no. of seeds/pod (99.16%), pulp weight/pod (98.85%) and pod thickness (98.68%). Whereas, during 2001, the maximum heritability value (99.08%) was observed for pod thickness followed by no. of seeds/pod, weight/pod (99.04) and pulp weight/pod (98.38%).

The maximum genetic advance (GA) as per cent of mean during 2000 and 2001 was 54.17 and 41.66, respectively, for pulp weight/pod. Whereas, minimum genetic advance as percent of mean during 2000 and 2001 was 15.31 and 15.08, respectively, for 100-seed weight. The results revealed that parameters with high heritability and genetic advance also had high GCV and PCV.

4.2.2.11 Nature of correlation:

Correlation studies were made to find out association at phenotypic and genotypic levels among seed and pod parameters during 2000 (Table 13) and 2001 (Table 14). The magnitude of correlation coefficients at genotypic level (below diagonal) was found to be higher than the corresponding phenotypic level (above diagonal), during both the years, thus indicating a good extent of strong inherent association between different parameters.

100-seed weight showed non-significant correlation with all the other parameters during both the years.

Pod length during 2000 had highly significant (≤0.01) positive correlation with weight/pod, seed weight/pod, pulp weight/pod and no. of seeds/pod. Whereas, during 2001, pod length had highly significant positive correlation with weight/pod and pulp weight/pod and significant (≤ 0.05) positive correlation with seed weight/pod and no.of seeds/pod.

Pod width, during 2000, showed significant (≤ 0.05) positive association with pod thickness, weight/pod and pulp weight/pod. Whereas, during 2001, pod width had highly significant positive correlation with weight/pod and pulp weight/pod.

Weight/pod, during 2000, had highly significant positive correlation with seed weight/pod and pulp weight/pod and it had significant positive correlation with no. of seeds/pod. Whereas, during

Table 13: Phenotypic (above diagonal) and genotypic (below diagonal) correlations among seed and pod parameters in progenies of *Prosopis juliflora* during 2000

Parameters	100-seed weight	Pod length	Pod width	Pod thickness	Weight/ pod	Seed weight/ pod	Pulp weight/ pod	No. of seeds/ pod
100-seed wt.	1.000	-0.115	0.223	0.225	0.083	0.234	0.056	-0.241
Pod length	-0.122	1.000	0.263	-0.124	0.840**	0.659**	0.814**	0.700**
Pod width	0.239	0.265	1.000	0.446*	0.482*	0.032	0.519*	-0.077
Pod thickness	0.231	-0.123	0.455	1.000	0.056	-0.142	0.082	-0.261
Weight/pod	0.095	0.857	0.486	0.057	1.000	0.623**	0.993**	0.559*
Seed wt./pod	0.220	0.684	0.036	-0.146	0.644	1.000	0.528*	0.876**
Pulp wt./pod	0.071	0.832	0.523	0.084	0.994	0.555	1.000	0.477*
No. of seeds/ pod	-0.246	0.712	-0.080	-0.261	0.562	0.891	0.482	1.000

* Significant at 5% level of significance.
**Significant at 1% level of significance.

Table 14: Phenotypic (above diagonal) and genotypic (below diagonal) correlations among seed and pod parameters in progenies of *Prosopis juliflora* during 2001

Parameters	100-seed weight	Pod length	Pod width	Pod thickness	Weight/ pod	Seed weight/ pod	Pulp weight/ pod	No. of seeds/ pod
100-seed wt.	1.000	-0.053	0.245	0.104	0.040	0.324	-0.016	-0.134
Pod length	-0.033	1.000	0.389	0.018	0.732**	0.495*	0.677**	0.508*
Pod width	0.262	0.415	1.000	0.348	0.740**	0.016	0.776**	-0.085
Pod thickness	0.102	0.019	0.361	1.000	0.297	-0.222	0.350	-0.277
Weight/pod	0.040	0.763	0.760	0.298	1.000	0.349	0.985**	0.362
Seed wt./pod	0.326	0.519	0.021	-0.226	0.371	1.000	0.185	0.868**
Pulp wt./pod	-0.015	0.709	0.799	0.352	0.986	0.212	1.000	0.223
No. of seeds/ pod	-0.134	0.532	-0.089	-0.279	0.365	0.894	0.224	1.000

* Significant at 5% level of significance.
** Significant at 1% level of significance.

2001, weight/pod showed highly significant positive association only with pulp weight/pod.

Seed weight/pod during 2000 showed highly significant positive association with no. of seeds/pod and it had significant positive correlation with pulp weight/pod. Whereas, during 2001, it had highly significant positive correlation with no. of seeds/pod.

Pulp weight/pod had significant positive correlation with no. of seeds/pod, during 2000. However, during 2001, pulp weight/pod showed non-significant correlation with all the other parameters studied.

The correlations were found non-significant between all the other parameters studied during 2000 and 2001.

4.3 REPRODUCTIVE BIOLOGY

4.3.1 Blooming period:

Ten randomly taken trees of *Prosopis juliflora* were observed between January to May during 2000 (Table 15) and 2001 (Table 16) to determine the time and duration of flowering period.

It is clear from the tables that spike initiation varied from tree to tree. In some trees, spike initiation started in last week of February, while in others, the spike initiation goes up to mid of March, during both the years.

However, it was observed that the spike initiation in almost all the trees started 5-16 days earlier during 2000 as compared to 2001, which may be due to variation in environmental components.

Table 15: Blooming period of *Prosopis juliflora* during 2000 (January to May)

Tree No.	Date of spike initiation	Commencement of flowering*	Peak period of flowering	Cessation of flowering**	Duration of peak period of flowering (days)	Duration of flowering period (days)
1	17 March	1 April	12 April – 19 May	26 May	38	56
2	11 March	26 March	31 March – 6 May	19 May	37	55
3	28 February	17 March	27 March – 29 April	13 May	34	58
4	12 March	31 March	6 April – 12 May	18 May	37	49
5	5 March	20 March	28 March – 6 May	16 May	40	57
6	27 March	12 April	16 April – 18 May	26 May	33	45
7	1 March	17 March	26 March – 7 May	16 May	43	61
8	29 February	16 March	26 March – 2 May	11 May	38	57
9	15 March	2 April	8 April – 11 May	17 May	34	46
10	12 March	31 March	8 April – 5 May	11 May	28	42

* Earliest five spikes observed on a single tree.
**Last five spikes observed on a single tree.

Table 16: Blooming period of *Prosopis juliflora* during 2001 (January to May)

Tree No.	Date of spike initiation	Commencement of flowering*	Peak period of flowering	Cessation of flowering**	Duration of peak period of flowering (days)	Duration of flowering period (days)
1	1 March	20 March	31 March – 7 May	17 May	38	59
2	1 March	17 March	26 March – 2 May	16 May	38	61
3	21 February	9 March	18 March – 1 May	12 May	45	65
4	4 March	19 March	28 March – 4 May	16 May	38	59
5	24 February	10 March	18 March – 26 April	12 May	40	64
6	14 March	29 March	7 April – 6 May	17 May	30	50
7	25 February	12 March	22 March – 26 April	09 May	36	59
8	21 February	8 March	18 March – 24 April	07 May	38	61
9	7 March	23 March	3 April – 1 May	15 May	26	53
10	5 March	20 March	31 March – 29 April	09 May	30	51

* Earliest five spikes observed on a single tree.
**Last five spikes observed on a single tree.

Commencement of flowering started from 16th March (Tree No.8) to 2nd April (Tree No.9) during 2000 and 8th March (Tree No.8) to 29th March (Tree No.6) during 2001. In both the years, peak period of flowering started after 5 to 11 days of commencement of flowering.

The trees, which flowered earlier, cessation of flowering also took place earlier in these trees during both the years. However, no flowering was observed after 26th of May during 2000 and 17th of May during 2001.

Duration of peak period of flowering varied from 28 (Tree No.10) to 43 (Tree No.7) and 26 (Tree No.8) to 45 (Tree No.3) days during 2000 and 2001, respectively. Similarly, duration of flowering period varied from 42 (Tree No.10) to 61 (Tree No.7) and 50 (Tree No.6) to 65 (Tree No.3) days during 2000 and 2001, respectively. It was found that duration of flowering period varied with individual trees and environmental conditions.

4.3.2 Flower structure:

Trees of *P.juliflora* have racemose-spike inflorescence. Flowers (Plate 4) are fragrant, small, greenish yellow, sessile, bracteate, complete, bisexual, cyclic, pentamerous and hypogynous. Calyx consists of 5 sepals, gamosepalous, minute petaloid, campanulate and inferior. Corolla consists of 5 petals, polypetalous, valvate, greenish yellow and inferior. Androecium consists of 10 stamens, polyandrous, filament long introrse, dorsifixed and dithecous anthers. A round yellowish stalked

Inflorescence of *Prosopis juliflora*

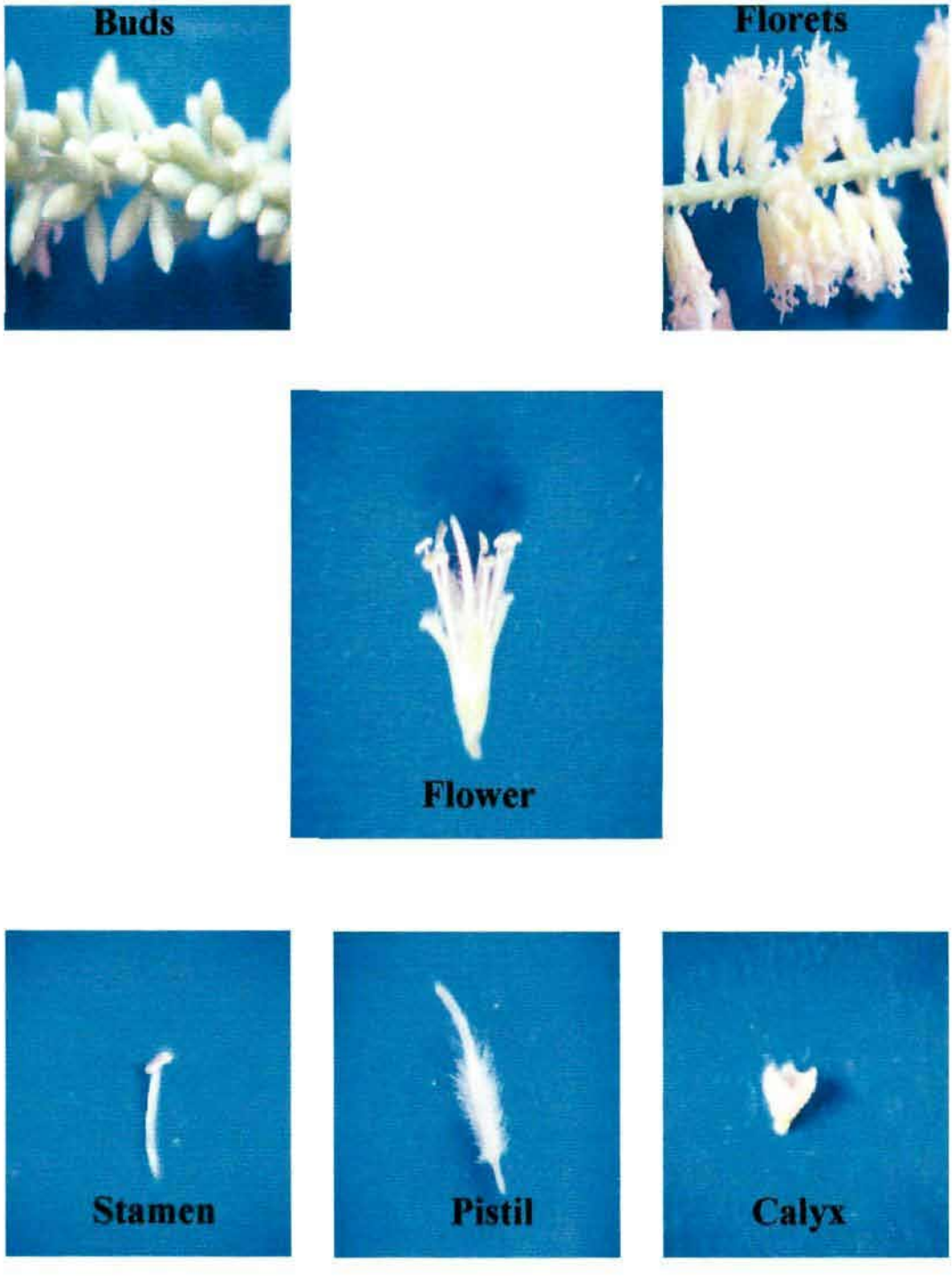


Plate 4: Different parts of spike of *Prosopis juliflora*

food body tips anther. Gynoecium consists of single carpel, unilocular with many ovules, ovary superior and hairy, marginal placentation, style long with minute stigma. The height of carpel is little higher than stamen. Floral formula of *P.juliflora* is as under:

Floral formula: Br $\oplus$ $\mathbb{Q}^{\nearrow}$ $K_{(5)}$, C_5, A_{10}, $\underline{G_1}$

4.3.3 Duration of flowering and fruiting phases:

Duration of flowering and fruiting phases in spring season during 2000 and 2001 are presented in Table 17, while different stages of spike development are shown in Plate 5.

4.3.3.1 Spike initiation to completion of elongation:

Spike initiation to completion of elongation during 2000, took place in 10.00 days (Tree No.5 and 10) to 12.33 days (Tree No.1) with general mean of 11.03 days. Whereas, during 2001, the duration was 9.67 days (Tree No.2) to 12.33 days (Tree No.1) with general mean of 11.20 days. Time taken for spike initiation to completion was maximum in Tree No.1 (12.33 days) which was at par with Tree No 3, 7, 8 and 9 during both the years.

4.3.3.2 Completion of spike elongation to flower opening:

Completion of spike elongation to flower opening during 2000, took place in 2.83 days (Tree No.2, 3, 6, 7 and 9) to 3.00 days (Tree No.1, 4, 5, 8 and 10) with general mean of 2.92 days. However, results were non-significant among all the 10 trees. On the other hand, during 2001, it took place in 2.50 days (Tree No.6) to 3.00 days (Tree No.1, 4,

Table 17: Duration of flowering and fruiting phases in *Prosopis juliflora*

Tree No.	Spike initiation to completion of elongation (days)		Completion of spike elongation to flower opening (days)		Stigma emergence before flower opening (hrs)		Period of florets opening per spike (hrs)	
	2000	2001	2000	2001	2000	2001	2000	2001
1	12.33 (3.65)	12.33 (3.65)	3.00 (2.00)	3.00 (2.00)	7.00 (2.82)	7.33 (2.89)	11.17 (3.49)	11.83 (3.58)
2	10.00 (3.31)	9.67 (3.26)	2.83 (1.96)	2.83 (1.96)	7.67 (2.94)	8.00 (3.00)	9.33 (3.21)	9.50 (3.24)
3	11.67 (3.56)	12.00 (3.61)	2.83 (1.96)	2.67 (1.91)	7.00 (2.82)	6.67 (2.77)	11.50 (3.53)	11.67 (3.56)
4	10.67 (3.42)	10.67 (3.42)	3.00 (2.00)	3.00 (2.00)	7.33 (2.89)	7.67 (2.94)	10.83 (3.44)	11.00 (3.46)
5	10.00 (3.32)	10.67 (3.42)	3.00 (2.00)	2.83 (1.96)	8.00 (3.00)	7.00 (2.82)	9.67 (3.26)	10.17 (3.34)
6	10.33 (3.37)	10.67 (3.42)	2.83 (1.96)	2.50 (1.87)	7.67 (2.94)	7.67 (2.94)	10.17 (3.34)	10.00 (3.17)
7	11.67 (3.56)	11.67 (3.56)	2.83 (1.96)	3.00 (2.00)	7.33 (2.88)	8.00 (3.00)	11.17 (3.49)	11.67 (3.56)
8	12.00 (3.60)	11.67 (3.56)	3.00 (2.00)	2.83 (1.96)	7.33 (2.89)	7.67 (2.94)	11.17 (3.49)	11.00 (3.46)
9	11.67 (3.56)	12.33 (3.65)	2.83 (1.96)	3.00 (2.00)	8.00 (3.00)	8.00 (3.00)	12.17 (3.63)	12.33 (3.65)
10	10.00 (3.31)	10.33 (3.37)	3.00 (2.00)	3.00 (2.00)	7.67 (2.94)	8.00 (3.00)	10.33 (3.36)	9.33 (3.21)
Mean	11.03	11.20	2.92	2.87	7.50	7.60	10.75	10.85
SEd±	(0.09)	(0.07)	(0.04)	(0.04)	(0.10)	(0.08)	(0.10)	(0.09)
CD at 5%	**(0.19)**	**(0.14)**	**NS**	**(0.08)**	**NS**	**NS**	**(0.21)**	**(0.18)**

NS = Non-significant
Figure in parenthesis are $\sqrt{n+1}$ transformed values.

Continue...

Continue...

Tree No.	Flower opening to pod setting (hrs)		Pod setting to initiation of seed formation (days)		Seed formation to pod maturity (days)		Pod maturity to pod ripening (days)	
	2000	2001	2000	2001	2000	2001	2000	2001
1	69.33 (8.39)	74.67 (8.70)	6.67 (2.77)	6.67 (2.77)	17.67 (4.32)	16.67 (4.20)	11.67 (3.56)	11.67 (3.56)
2	76.00 (8.77)	77.00 (8.83)	6.33 (2.71)	6.33 (2.71)	18.00 (4.36)	18.00 (4.36)	12.00 (3.61)	10.33 (3.37)
3	72.33 (8.56)	75.00 (8.72)	6.67 (2.77)	6.67 (2.77)	18.00 (4.36)	16.33 (4.16)	10.67 (3.42)	11.00 (3.46)
4	76.00 (8.77)	71.67 (8.52)	6.67 (2.77)	6.67 (2.77)	17.33 (4.28)	17.67 (4.32)	11.33 (3.51)	11.00 (3.46)
5	78.33 (8.90)	77.67 (8.75)	6.33 (2.71)	6.67 (2.77)	18.33 (4.40)	17.00 (4.24)	12.00 (3.61)	10.67 (3.42)
6	74.00 (8.66)	70.33 (8.87)	6.33 (2.71)	6.33 (2.71)	18.33 (4.40)	16.67 (4.20)	11.67 (3.56)	10.67 (3.42)
7	71.67 (8.52)	72.00 (8.54)	6.67 (2.77)	6.33 (2.71)	18.00 (4.36)	16.33 (4.16)	11.33 (3.51)	11.67 (3.56)
8	76.67 (8.81)	76.00 (8.83)	7.00 (2.83)	6.33 (2.71)	18.00 (4.36)	17.00 (4.24)	11.33 (3.51)	10.33 (3.37)
9	72.67 (8.58)	74.67 (8.70)	6.33 (2.71)	7.00 (2.83)	18.33 (4.40)	16.33 (4.16)	12.00 (3.61)	11.00 (3.46)
10	72.67 (8.58)	75.00 (8.72)	6.67 (2.77)	6.33 (2.71)	18.00 (4.36)	17.00 (4.24)	11.00 (3.46)	11.67 (3.56)
Mean	73.97	74.40	6.57	6.53	18.00	16.90	11.50	11.00
SEd±	(0.16)	(0.13)	(0.08)	(0.08)	(0.06)	(0.06)	(0.08)	(0.07)
CD at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS = Non-significant
Figure in parenthesis are $\sqrt{n+1}$ transformed values.

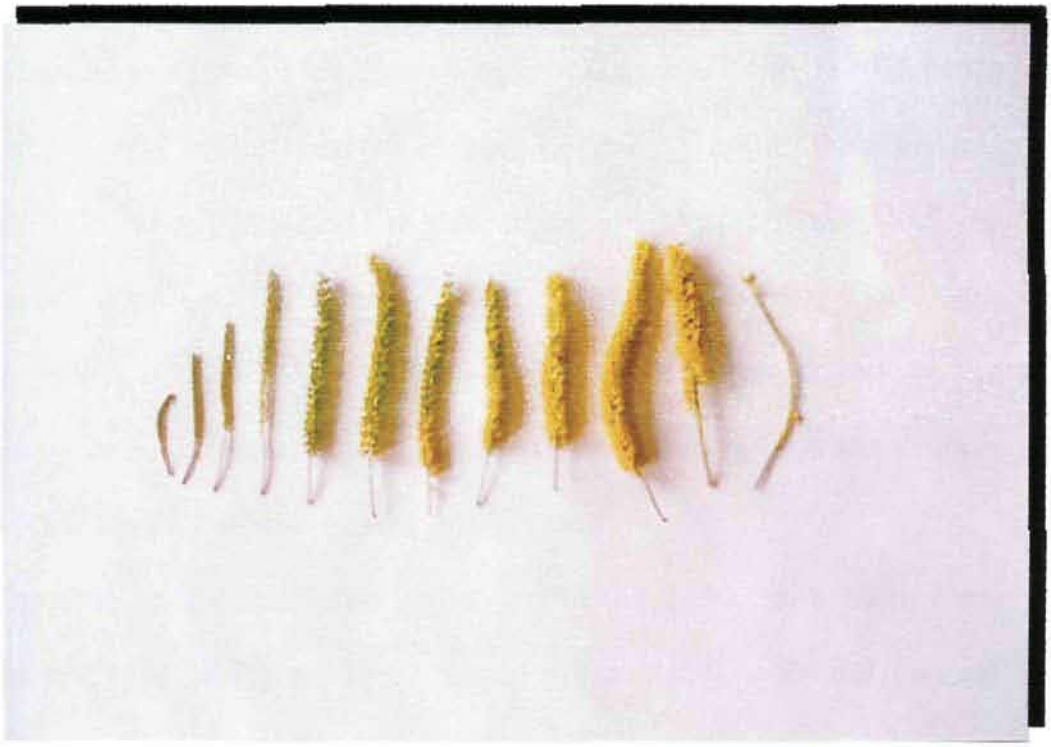


Plate 5: Developmental stages of *Prosopis juliflora* spike

7, 9 and 10) with general mean of 2.87 days. Time taken from completion of spike elongation to flower opening during 2001, was maximum i.e. 3.00 days in Tree No.1, 4, 7, 9 and 10 which was statistically at par with the other trees except Tree No.6.

4.3.3.3 Stigma emergence before flower opening:

Stigma emergence took place 7 hours (Tree No.1 and 3) to 8 hours (Tree No. 5 and 9) before flower opening during 2000, with general mean of 7.50 hours. Whereas, it took place 6.67 hours (Tree No.3) to 8.00 hours (Tree No.2, 7, 9 and 10) before flowering during 2001, with general mean of 7.60 hours. However, results were found to be statistically non-significant among all the 10 trees during both the years.

4.3.3.4 Opening of all the florets per spike:

Opening of all the florets per spike during 2000, took place from 9.33 hours (Tree No.2) to 12.17 hours (Tree No.9) with the general mean of 10.75 hours. The minimum duration (9.33 hours) was in Tree No.2, which was significantly lower than all the other trees except Tree No.5, 6 and 10. Whereas, during 2001, opening of all the florets per spike took place from 9.33 hours (Tree No.10) to 12.33 hours (Tree No.9) with general mean of 10.85 hours. The minimum duration (9.33 hours) was taken by tree no.10 which was significantly lower than all the other trees except Tree No.2, 5 and 6.

4.3.3.5 Flower opening to pod setting:

Flower opening to pod setting during 2000, took place from 69.33 hours (Tree No.1) to 78.33 hours (Tree No.5) with general mean of 73.97 hours. Whereas, during 2001, it took place from 70.33 hours (Tree No.6) to 77.67 hours (Tree No.5) with general mean of 74.40 hours. However, results were statistically non-significant among all the 10 trees during both the years.

4.3.3.6 Pod setting to initiation of seed formation:

Pod setting to initiation of seed formation during 2000, took place from 6.33 days (Tree No.2, 5, 6 and 9) to 7.00 days (Tree No.8) with general mean of 6.57 days. Similarly, during 2001, it took place from 6.33 days (Tree No.2, 6, 7, 8 and 10) to 7.00 days (Tree No.9) with general mean of 6.53 days. However, the results were found to be non-significant between all the 10 trees during both the trees.

4.3.3.7 Seed formation to pod maturity:

Seed formation to pod maturity during 2000, varied from 17.33 days (Tree No.4) to 18.33 days (Tree No.5, 6 and 9) with general mean of 18.00 days. Similarly, during 2001, it varied from 16.33 days (Tree No.3, 7 and 9) to 18.00 days (Tree No.2) with general mean of 16.90 days. However, the results were found to be non-significant between all the 10 trees during both the years.

4.3.3.8 Pod maturity to pod ripening:

Pod maturity to pod ripening during 2000, took place from 10.67 days (Tree No.3) to 12.00 days (Tree No.2, 5 and 9) with general mean of 11.50 days. Similarly, during 2001, it took place from 10.33 days (Tree No.2 and 8) to 11.67 days (Tree No.1, 7 and 10) with general mean of 11.00 days. However, the results during both the years were found to be non-significant among all the 10 trees.

4.3.4 Floral visitors of *Prosopis juliflora*:

During the flowering period (March to May 2000 and 2001) of *P.juliflora*, a total of 11 insect species belonging to 7 families of 4 insect orders viz., Hymenoptera, Lepidoptera, Coleoptera, Diptera were observed on the spikes of *P.juliflora* (Table 18; Plates 6, 7 and 8). Three *Apis* spp. (i.e. *Apis dorsata*, *Apis mellifera* and *Apis florea*) were the most frequent flower visitors, rest of the Hymenopterans, Lepidopterans, Coleopterans and Dipterans were casual visitors of *P.juliflora* bloom.

4.3.5 Abundance of honey bees (*Apis* spp.) on *Prosopis juliflora*:

The data on density of different *Apis* spp. (Average number of honey bees/metre shoot length/5 minutes) on *P.juliflora* in different day hours during bloom period are presented in Table 19.

The data of five hours-day on abundance of *Apis* spp. revealed that during 2000 and 2001, the mean abundance of *A.dorsata* was maximum at 1200-1300 h i.e. 1.04 and 1.43, respectively, which was significantly higher than abundance at other hours of the day.

Table 18: Floral visitors of *Prosopis juliflora*

Order	Family	Scientific name
Hymenoptera	Apidae	*Apis dorsata* Fabricius
		Apis mellifera Fabricius
		Apis florea Fabricius
	Sphecidae	*Sceliphron madraspatnama pictum* Smith
	Megachiledae	*Cephalotes* sp.
	Megachiledae	Unidentified sp.
Lepidoptera	Lycaenidae	*Lampides boeticus* L.
Coleoptera	Bruchidae	*Caryedon* sp. (1)
	Bruchidae	*Caryedon* sp. (2)
Diptera	Syrphidae	Unidentified sp.
	Syrphidae	Unidentified sp.

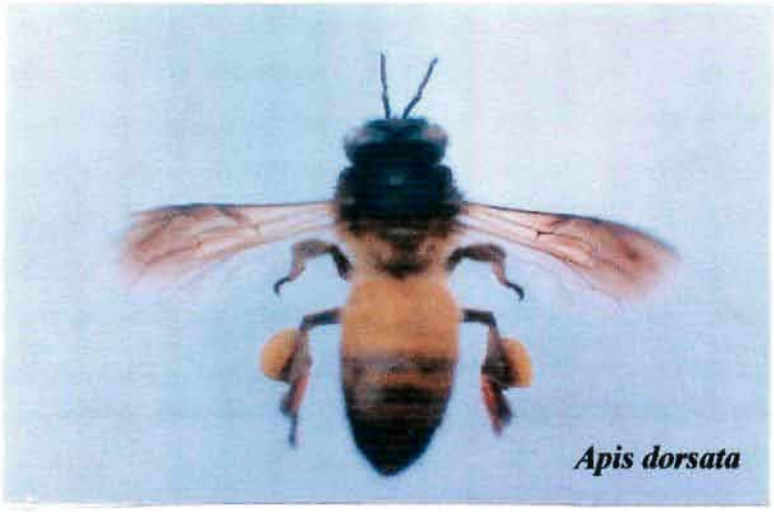
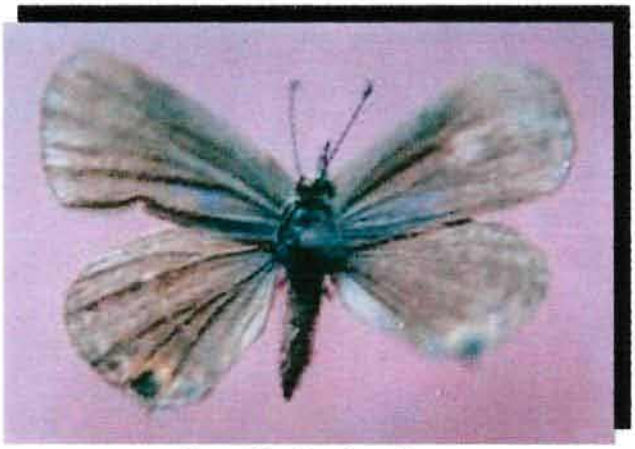


Plate 6: Floral visitors (*Apis* spp.) of *Prosopis juliflora*

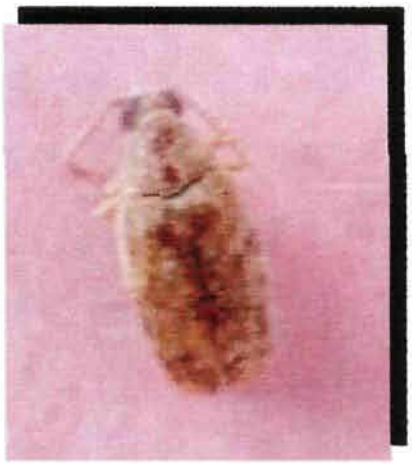
***Sceliphron madraspatnama pictum* Smith**
Family: Sphecidae

***Cephalotes* sp.**
Family: Megachiledae



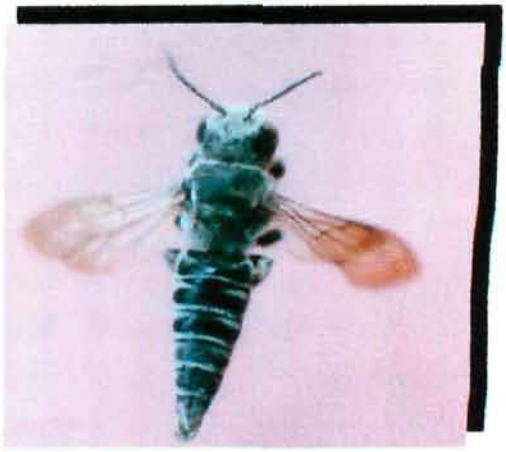
***Lampides boeticus* L.**
Family: Lycaenidae

***Caryedon* sp.(1)**
Family: Bruchidae



***Caryedon* sp.(2)**
Family: Bruchidae

Plate 7: Floral visitors (identified) of *Prosopis juliflora*



Family: Megachiledae

Family: Syrphidae

Family: Syrphidae

Plate 8: Floral visitors (unidentified) of *Prosopis juliflora*

Table 19: Abundance of honey bees on *Prosopis juliflora* at different hours of the day during bloom period (Av. no. of honey bees/metre shoot length/5 min.)

Time	*Apis dorsata*		*Apis mellifera*		*Apis florea*	
(h)	2000	2001	2000	2001	2000	2001
0800-0900	0.34 (1.16)*	0.51 (1.23)	0.46 (1.21)	0.72 (1.31)	0.80 (1.34)	0.96 (1.40)
1000-1100	0.64 (1.28)	0.85 (1.36)	0.96 (1.40)	1.16 (1.47)	2.06 (1.75)	2.46 (1.86)
1200-1300	1.04 (1.43)	1.43 (1.56)	1.53 (1.59)	1.86 (1.69)	3.24 (2.06)	5.20 (2.49)
1400-1500	0.64 (1.28)	0.85 (1.36)	0.90 (1.38)	0.93 (1.39)	1.56 (1.60)	1.92 (1.71)
1600-1700	0.34 (1.16)	0.42 (1.19)	0.44 (1.20)	0.77 (1.33)	0.85 (1.36)	1.13 (1.46)
Mean	0.60	0.81	0.86	0.86	1.70	2.33
SEd±	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
CD at 5%	**(0.03)**	**(0.03)**	**(0.03)**	**(0.02)**	**(0.03)**	**(0.03)**

* Figures in parenthesis are $\sqrt{n+1}$ transformed values.

The mean abundance of *Apis mellifera* was maximum at 1200-1300 h i.e. 1.53 and 1.86 during 2000 and 2001, respectively, which was significantly higher than abundance at other hours of the day. Whereas, minimum abundance was observed i.e. 0.44 at 1600-1700 h during 2000, and 0.72 at 0800-0900 h during 2001.

Similarly, mean abundance of *Apis florea* was maximum 3.24 and 5.20 during 2000 and 2001, respectively, at 1200-1300 h, which was significantly higher than all the other hours of the day studied. Whereas, abundance of *A.florea* was lowest 0.80 and 0.96 during 2000 and 2001, respectively, at 0800-0900 h.

The general mean values of abundance of *A.dorsata*, *A.mellifera* and *A.florea* during 2000 and 2001, were 0.60 and 0.81, 0.86 and 0.86, and 1.70 and 2.33, respectively.

4.3.6 Time spent by *Apis* spp. on the spike of *Prosopis juliflora*:

Time spent (seconds/spike) by *Apis* spp. on the spike of *Prosopis juliflora* has been presented in Table 20. The data revealed that during 2000 maximum time was spent by *A.dorsata* (115.2 seconds/spike) which was significantly higher than the time spent by *A.mellifera* (77.2 seconds/spike) and *A.florea* (58.4 seconds/spike). Similarly, during 2001, maximum time was spent by *A.dorsata* (115.4 seconds/spike) which was significantly higher than the other two species i.e. *A.mellifera* (75.6 seconds/spike) and *A.florea* (57.8 seconds/spike). It

Table 20: Time spent by *Apis* species on the spike of *Prosopis juliflora*

Apis species	Time spent (seconds)/spike	
	2000	**2001**
Apis dorsata	115.2 (10.78)*	115.4 (10.79)
Apis mellifera	77.2 (8.81)	75.6 (8.75)
Apis florea	58.4 (7.70)	57.8 (7.61)
SEd±	(0.11)	(0.11)
CD at 5%	**(0.23)**	**(0.25)**

* Figures in parenthesis are $\sqrt{n+1}$ transformed values.

was found that *A.florea* spent less time during both the years as compared to *A.dorsata* and *A.mellifera.*

4.3.7 Pollen stainability:

The data of observations on pollen stainability (Plate 9) during March and April of 2000 and 2001 are presented in Table 21. It was observed from the data that stainability was more than 75 per cent in all the cases. Pollen fertility varied from 78 to 93 per cent and 81 to 96 per cent during 2000 and 2001, respectively. Viability was comparatively less in March during both the years. The average increase in viability from March to April was 11.67 and 11.33 per cent during 2000 and 2001, respectively.

4.3.8 Pollination studies:

The pod setting resulting through different reproductive methods was observed during 2000 and 2001. No pod setting was found through apomixis and autogamy. Whereas, percent pod setting observed through other reproductive methods are presented in Table 22.

During 2000, the pod setting varied from 0.01 per cent (selfing in muslin cloth bag) to 0.44 per cent (enforced allogamy between 1000-1300 h). Whereas, during 2001 it varied from 0.01 per cent (selfing in muslin cloth bag) to 0.40 (enforced allogamy between 1000-1300 h).

The pod setting during 2000 was maximum (0.44%) through enforced allogamy between 1000-1300 h which was significantly higher than all the other modes of pollination. Similarly, during 2001, pod

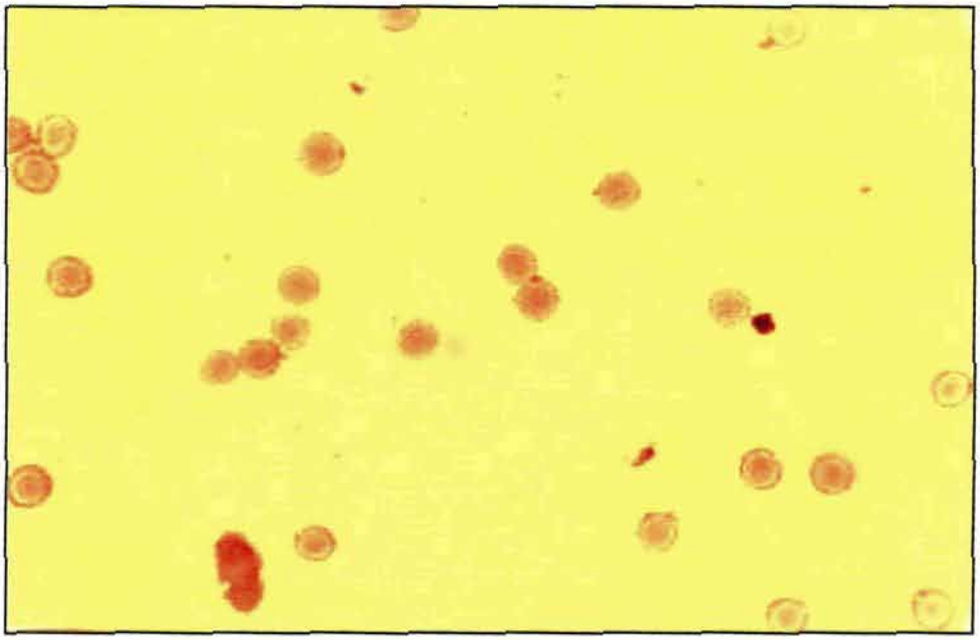


Plate 9: Stained pollens of *Prosopis juliflora* by acetocarmine test

Table 21: Percentage of fertile and sterile pollen grains by acetocarmine test in *Prosopis juliflora*

Date of observation	Percent of fertile pollen grains	Percent of sterile pollen grains
26-3-2000	78.00	22.00
27-3-2000	82.00	18.00
28-3-2000	80.00	20.00
Average	**80.00**	**20.00**
19-4-2000	93.00	07.00
20-4-2000	90.00	10.00
21-4-2000	92.00	08.00
Average	**91.67**	**08.33**
21-3-2001	85.00	15.00
22-3-2001	81.00	19.00
23-3-2001	83.00	17.00
Average	**83.00**	**17.00**
18-4-2001	94.00	06.00
19-4-2001	93.00	07.00
20-4-2001	96.00	04.00
Average	**94.33**	**05.67**

Table 22: Effect of reproductive methods on pod setting (%) in *Prosopis juliflora*

Reproductive methods	Percent pod setting	
	2000	**2001**
Open pollination	0.28 (0.78)*	0.34 (0.84)
Open pollination after emasculation	0.20 (0.70)	0.24 (0.74)
Selfing in muslin cloth bag (more than on spike per bag)	0.01 (0.51)	0.01 (0.51)
Enforced geitonogamy		
0700-1000 h	0.08 (0.58)	0.08 (0.58)
1000-1300 h	0.14 (0.64)	0.12 (0.62)
1500-1800 h	0.08 (0.58)	0.06 (0.56)
Enforced allogamy		
0700-1000 h	0.22 (0.72)	0.18 (0.68)
1000-1300 h	0.44 (0.94)	0.40 (0.90)
1500-1800 h	0.20 (0.70)	0.22 (0.72)
SEd±	(0.07)	(0.06)
CD at 5%	**(0.14)**	**(0.13)**
Range	0.01-0.44	0.01-0.40

* Figures in parenthesis are n+0.5 transformed values.

setting was again found maximum (0.40%) through enforced allogamy between 1000-1300 h, however, the result was statistically non-significant with pod setting through open pollination (0.34%).

Minimum pod setting was observed through selfing in muslin cloth bag i.e. 0.01 per cent, which was at par with pod setting through enforced geitonogamy between 0700-1000, 1000-1300 and 1500-1800 h of the day during both the years.

The pod setting through open pollination during 2000 was 0.28 per cent which was at par with pod setting through open pollination after emasculation (0.20%), enforced geitonogamy between 1000-1300 h (0.14%) and enforced allogamy between 0700-1000 h (0.22%) and 1500-1800 h (0.20%). However, pod setting, during 2001 through open pollination was 0.34 per cent which was statistically at par with pod setting through open pollination after emasculation (0.24%), enforced allogamy between 1000-1300 h (0.40%) and enforced allogamy between 1500-1800 h (0.22%).

The pod setting by hand pollination, i.e. enforced geitonogamy and enforced allogamy between 1000-1300 h was more as compared to pod setting between 0700-1000 h and 1500-1800 h during both the years, which indicated that stigma receptivity was maximum during 1000-1300 h of the day.

Absence of pod setting through autogamy and very poor pod setting through selfing in muslin cloth bag and enforced geitonogamy

showed high degree of self-incompatibility in *Prosopis juliflora* and indicated towards its cross-pollinated nature.

4.3.9 Evaluation of seeds and pods (obtained through different reproductive methods):

4.3.9.1 Observations on seed and pod morphology:

4.3.9.1.1 Analysis of variance:

Mean sum of squares of different parameters of seed and pod (obtained through different reproductive methods) have been presented in Table 23. The differences between different treatments (reproductive methods) were found significant ($P \leq 0.05$) for all the parameters studied viz., 100-seed weight, seed length, seed width, seed thickness, no. of seeds/pod, seed weight/pod, weight/pod, pod length, standard germination, seedling length (30, 60 and 90 days after sowing) and collar diameter (30, 60 and 90 days after sowing), thereby indicating that substantial variation existed between the different reproductive methods with respect to different seed and pod parameters.

4.3.9.1.2 100-seed weight:

The mean 100-seed weight (Table 24) of the seeds obtained through different reproductive methods varied from 0.93 g (selfing in muslin cloth bag) to 3.15 g (open pollination). Maximum 100-seed weight (3.15 g) was obtained through open pollination followed by open pollination after emasculation (2.85 g) and enforced allogamy (2.69 g), however, they differed significantly with each other. Whereas, minimum

Table 23: Analysis of variance for different parameters in *Prosopis juliflora* obtained through different reproductive methods

S. No.	Parameters	Mean sum of squares		
		Replication	Treatment	Error
1.	100-seed weight	0.00	2.38*	0.001
2.	Seed length	0.00	1.08*	0.001
3.	Seed width	0.00	0.51*	0.001
4.	Seed thickness	0.005	1.68*	0.00
5.	No. of seeds/pod	1.865	64.17*	0.37
6.	Seed weight/pod	0.00	0.13*	0.00
7.	Weight/pod	0.00	2.58*	0.001
8.	Pod length	0.00	37.44*	0.001
9.	Standard germination	26.66	2633.33*	43.33
10.	Seedling length (30 DAS**)	0.005	2.20*	0.002
11.	Seedling length (60 DAS)	0.01	10.02*	0.01
12.	Seedling length (90 DAS)	0.01	88.69*	0.01
13.	Collar diameter (30 DAS)	0.005	0.09*	0.003
14.	Collar diameter (60 DAS)	0.005	0.09*	0.005
15.	Collar diameter (90 DAS)	0.005	0.29*	0.003
	d.f.	2	4	8

* Significant at $P \leq 0.05$.
** DAS = Days after sowing.

(0.93 g) seed weight was observed in the seeds obtained through selfing in muslin cloth bag which differed significantly with all the other values.

4.3.9.1.3 Seed length:

Table 24 indicates that the mean seed length was maximum (6.18 mm) of the seeds obtained through open pollination followed by open pollination after emasculation (5.78 mm) and enforced allogamy (5.38 mm), however, they differed significantly with each other. Whereas, minimum seed length (4.62 mm) was of the seeds obtained through enforced geitonogamy, which was significantly lower than the seed length obtained through other reproductive methods.

4.3.9.1.4 Seed width:

The perusal of Table 24 reveals that seed width was obtained maximum (4.51 mm) through open pollination followed by enforced allogamy (4.06 mm) and open pollination after emasculation (3.71 mm), however, they differed significantly with each other. Whereas, significantly lowest seed width was obtained through enforced geitonogamy i.e. 3.52 mm.

4.3.9.1.5 Seed thickness:

The seed thickness ranged from 2.29 mm (open pollination) to 0.52 mm (selfing in muslin cloth bag). The seed thickness was maximum (2.29 mm) obtained through open pollination, which was significantly higher than the seeds obtained through open pollination after

Table 24: Effect of reproductive methods on seed and pod parameters in *Prosopis juliflora*

Reproductive methods	100-seed weight (g)	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	No. of seeds/pod	Seed wt./ pod (g)	Weight/ pod (g)	Pod length (cm)	Standard germination (%)
Open pollination	3.15	6.18	4.51	2.29	21.00	0.65	3.32	19.50	83.33
Open pollination after emasculation	2.85	5.78	3.71	2.21	17.00	0.46	3.06	19.30	60.00
Selfing in muslin cloth bag	0.93	5.11	3.58	0.52	10.00	0.09	1.08	12.00	20.00
Enforced geitonogamy	1.93	4.62	3.52	1.98	10.67	0.27	1.72	12.71	33.33
Enforced allogamy	2.69	5.38	4.06	2.21	13.00	0.31	2.31	15.70	86.67
SEd ±	0.02	0.04	0.02	0.02	0.49	0.01	0.02	0.03	5.38
C.D. at 5%	**0.05**	**0.08**	**0.05**	**0.04**	**1.16**	**0.03**	**0.06**	**0.07**	**12.59**
Range	0.93-3.15	4.62-6.18	3.52-4.51	0.52-2.29	10.00-21.00	0.09-0.65	1.08-3.32	12.00-19.50	20.00-86.67

emasculation and enforced allogamy. However, seeds obtained through open pollination after emasculation and enforced allogamy had the same seed thickness of 2.21 mm. Whereas, significantly lowest seed thickness (0.52 mm) was observed in case of selfing in muslin cloth bag.

4.3.9.1.6 Number of seeds/pod:

Number of seeds/pod (Table 24) were found maximum through open pollination (21) followed by open pollination after emasculation (17) and enforced allogamy (13), however, they differed significantly with each other. Whereas, minimum number of seeds/pod were obtained through selfing in muslin cloth bag (10), which is significantly lower than the number of seeds/pod obtained through other reproductive methods.

4.3.9.1.7 Seed weight/pod:

The seed weight/pod (Table 24) was highest in case of open pollination (0.65 g) followed by open pollination after emasculation (0.46 g) and enforced allogamy (0.31 g), however, they differed significantly with each other. On the other hand, significantly lowest seed weight/pod (0.09 g) was obtained through selfing in muslin cloth bag.

4.3.9.1.8 Weight/pod:

The perusal of Table 24 showed that open pollination gave maximum pod weight (3.32 g) followed by open pollination after emasculation (3.06 g) and enforced allogamy (2.31 g), however, values

were differed significantly with each other. Whereas, minimum pod weight (1.08 g) was obtained through selfing in muslin cloth bag, which is significantly lower than the pod weight obtained through other reproductive methods.

4.3.9.1.9 Pod length:

Open pollination gave maximum pod length (19.50 cm) followed by pollination after emasculation (19.30 cm) and enforced allogamy (15.70 cm), all these three values differed significantly with each other. On the other hand, selfing in muslin cloth bag gave minimum pod length i.e. 12.00 cm, which is significantly lower than the other values (Table 24).

4.3.9.1.10 Standard germination:

Germination percentage (Table 24) was maximum in the seeds obtained through enforced allogamy (86.67%) followed by seeds obtained through open pollination (83.33%), however, both were statistically at par with each other. Whereas, minimum germination was found in the seeds obtained through selfing in muslin cloth bag i.e. 20.00 per cent, which is significantly lower than all the other values.

4.3.9.1.11 Seedling length:

Table 25 shows the effect of reproductive methods on length of *Prosopis juliflora* seedlings. Seedlings raised from the seeds obtained through open pollination had maximum length of 4.57 cm after 30 days of sowing, whereas, after 60 and 90 days, seedlings from the seeds

Table 25: Effect of reproductive methods on length and collar diameter of *Prosopis juliflora* seedlings

Reproductive methods	Seedling length (cm)			Collar diameter (mm)		
	30 DAS*	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Open pollination	4.57	9.06	18.79	0.77	1.08	1.91
Open pollination after emasculation	4.35	9.39	22.02	1.08	1.32	2.14
Selfing in muslin cloth bag	2.43	5.65	11.96	0.65	1.01	1.35
Enforced geitonogamy	3.51	7.82	14.81	0.68	1.05	1.63
Enforcd allogamy	4.09	10.41	25.54	0.92	1.41	1.95
SEd±	0.04	0.06	0.07	0.05	0.05	0.05
CD at 5%	**0.11**	**0.14**	**0.16**	**0.12**	**0.13**	**0.11**
Range	2.43-4.57	5.65-10.41	11.96-25.54	0.65-1.08	1.01-1.41	1.35-2.14

*Days after sowing

obtained through enforced allogamy attained maximum length of 10.41 cm and 25.54 cm, respectively. All these three values were significantly higher as compared to other values during the periods. Whereas, seeds obtained through selfing in muslin cloth bag gave rise to significantly smallest seedlings i.e. 2.43 cm, 5.65 cm and 11.96 cm, after 30, 60 and 90 days of sowing, respectively.

4.3.9.1.12 Collar diameter:

Effect of reproductive methods on collar diameter of *P.juliflora* seedlings is presented in Table 25. Seedling raised from the seeds obtained through enforced allogamy had maximum collar diameter of 0.92 mm and 1.41 mm after 30 and 60 days of sowing, respectively. However, 90 days after sowing, seedling raised from the seeds obtained through open pollination after emasculation had maximum collar diameter of 2.14 mm followed by enforced allogamy (1.95 mm), both differed significantly with each other. Whereas, seeds obtained through selfing in muslin cloth bag gave rise to seedlings having minimum collar diameter of 0.65 mm, 1.01 mm and 1.35 mm, after 30, 60 and 90 days of sowing, respectively, the values were significantly lower as compared to the other values.

4.3.9.1.13 Magnitude of variation:

Table 26 shows the effect of different reproductive methods on genotypic coefficient of variation, phenotypic coefficient of variation,

Table 26: Effect of reproductive methods on magnitude of variation for seed and pod parameters in *Prosopis juliflora*

Parameters	GCV	PCV	h^2	GA as % of mean
100-seed weight	38.58	38.60	99.91	79.45
Seed length	11.06	11.09	99.50	22.73
Seed width	10.67	10.69	99.64	21.94
Seed thickness	40.70	40.72	99.91	83.80
No. of seeds/pod	58.50	58.66	99.43	120.17
Seed weight/pod	51.85	53.14	95.22	104.23
Pod weight	32.17	32.45	98.30	65.71
Pod length	22.30	22.30	99.99	45.94
Standard germination	22.58	22.62	99.58	46.41

GCV Genotypic coefficient of variation
PCV Phenotypic coefficient of variation
h^2 Heritability (broad sense)
GA Genetic advance

heritability (broad sense) and expected genetic advance of the seed and pod parameters.

The maximum genotypic coefficient of variation was observed for number of seeds/pod (58.50) followed by seed weight/pod (51.85) and seed thickness (40.70); while minimum GCV (10.67) was observed for seed width. Similarly, maximum phenotypic coefficient of variation was observed for number of seeds/pod (58.66) followed by seed weight/pod (53.14) and seed thickness (40.72), while minimum PCV (10.69) was observed in case of seed width.

Heritability (broad sense) estimates were high for all the seed and pod parameters. The maximum heritability value (99.99) was observed for pod length followed by 99.91 for 100-seed weight and seed thickness. The maximum genetic advance (GA) as percent of mean (120.17) was recorded for no. of seed per pod followed by seed weight/pod (104.23) and seed thickness (83.80), while minimum GA (21.94) was recorded for seed width.

4.3.9.1.14 Nature of correlation:

Correlation studies were made to find out association at phenotypic and genotypic levels among different seed and pod parameters (obtained through different reproductive methods) of *Prosopis juliflora*.

The results have been presented in Table 27. the magnitude of correlation coefficients at phenotypic level (above diagonal) were lower

Table 27: Phenotypic (above diagonal) and genotypic (below diagonal) correlations among various seed and pod parameters obtained through different reproductive methods in *Prosopis juliflora*

Parameters	100-seed weight	Seed length	Seed width	Seed thickness	No. of seeds/pod	Seed wt./ pod	Weight/ pod	Pod length
100-seed weight	1.000	0.722	0.715	0.931*	0.910*	0.885*	0.837*	0.902*
Seed length	0.723	1.000	0.797	0.423	0.818*	0.694	0.925*	0.909*
Seed width	0.717	0.798	1.000	0.510	0.776	0.822*	0.797	0.680
Seed thickness	0.931	0.424	0.511	1.000	0.781	0.772	0.626	0.711
No. of seeds/pod	0.912	0.821	0.777	0.782	1.000	0.725	0.956**	0.917*
Seed weight/pod	0.904	0.710	0.847	0.790	0.752	1.000	0.702	0.750
Weight/pod	0.846	0.936	0.809	0.632	0.973	0.720	1.000	0.942**
Pod length	0.902	0.912	0.682	0.711	0.920	0.767	0.950	1.000
Standard germination	0.998	0.695	0.678	0.946	0.915	0.870	0.836	0.896

* *Significant at 5% level of significance*
** Significant at 1% level of significance

than the corresponding genotypic level (below diagonal), thus indicating a good extent of strong inherent association between different parameters.

100-seed weight had significant positive (P≤0.05) correlation with seed thickness, no. of seeds/pod, seed weight/pod, weight/pod and pod length.

Seed length showed significant positive association with no. of seeds/pod, weight/pod and pod length.

Seed width and seed weight/pod showed significant positive correlation with each other.

No. of seeds/pod had highly significant (P≤0.01) positive correlation with weight/pod and significant positive correlation with pod length.

Weight/pod and pod length had highly significant positive correlation with each other.

4.3.9.2 Electrophoresis of seeds:

The electrophoretic profile of total soluble seed protein revealed that total 29 bands were resolved (Plate 10, Fig.3) among all the five treatments (seeds obtained through different reproductive methods) of *P.juliflora*.

Number of protein bands (Table 28) were maximum in the seeds obtained through open pollination i.e. 27, where minimum number of bands were observed in case of seeds obtained through selfing in muslin

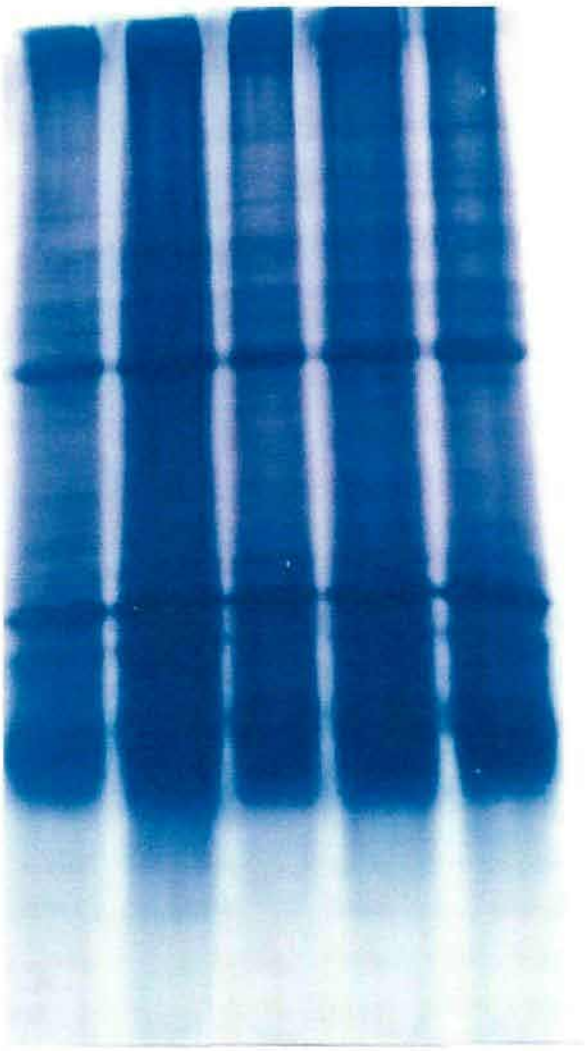


Plate 10: Banding pattern of total seed protein in *Prosopis juliflora* (obtained through different reproductive methods) by SDS-PAGE

Lane 1-5: Open pollination, Open pollination after emasculation, Selfing in (L to R) muslin cloth bag, Enforced geitonogamy,Enforced allogamy

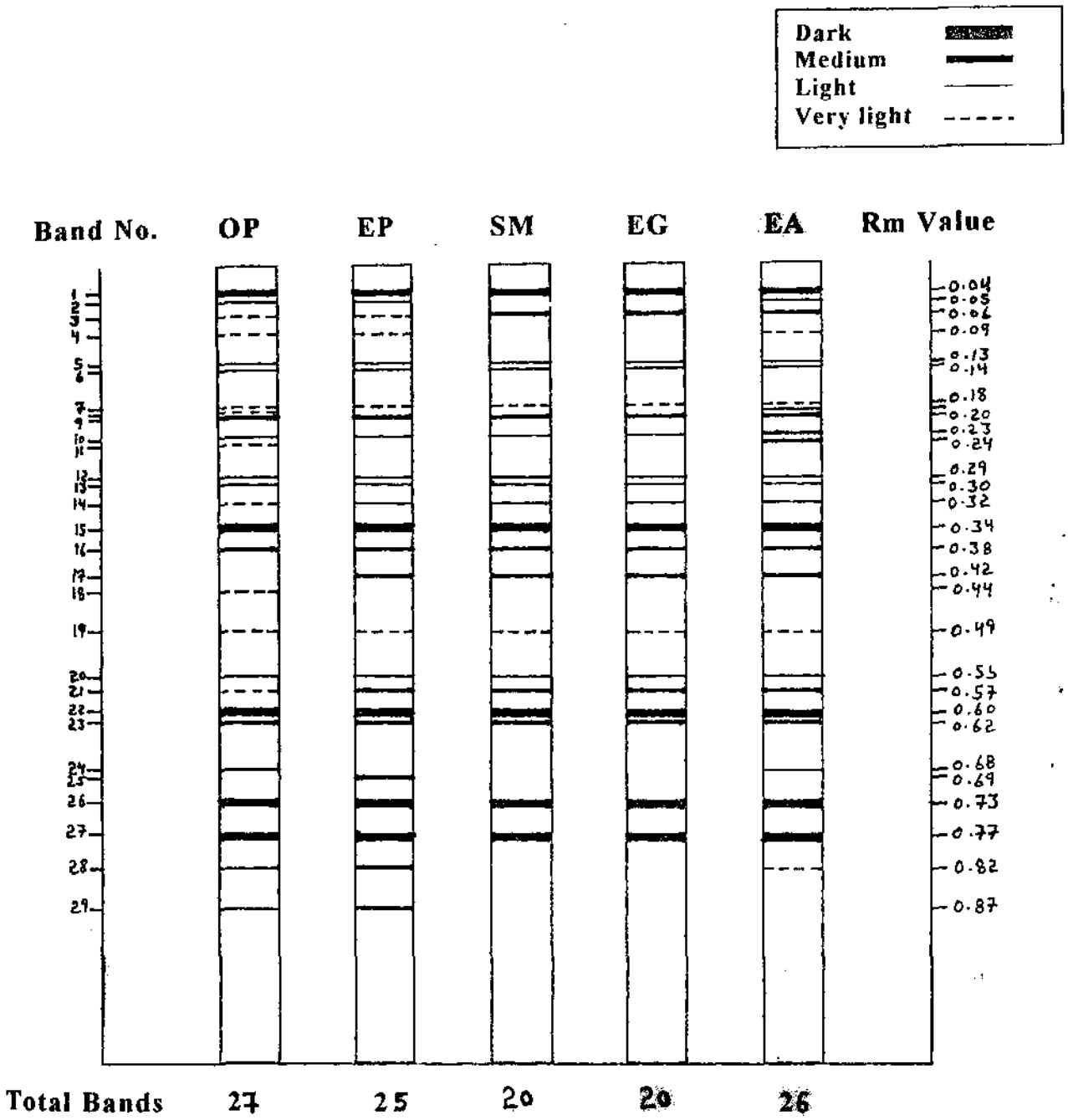


Fig. 3 : Zymogram of total seed protein in *Prosopis juliflora* (obtained through different reproductive methods) by SDS-PAGE

OP=Open pollination; EP=Open pollination after emasculation; SM=Selfing in muslin cloth bag; EG= Enforced geitonogamy; EA=Enforced allogamy

Table 28: Electrophoregram of total seed protein in *Prosopis juliflora* (obtained through different reproductive methods) by SDS-PAGE

Band No.	Rm value	Reproductive Methods				
		OP	EP	SM	EG	EA
1	0.04	D	D	D	D	D
2	0.05	L	L	-	-	L
3	0.06	VL	VL	M	M	M
4	0.09	VL	VL	-	-	VL
5	0.13	L	L	L	L	L
6	0.14	L	L	L	L	L
7	0.18	VL	VL	VL	VL	VL
8	0.19	VL	-	-	-	L
9	0.20	M	M	M	M	M
10	0.23	L	L	L	L	M
11	0.24	VL	-	-	-	M
12	0.29	L	L	L	L	L
13	0.30	L	L	L	L	L
14	0.32	VL	L	L	L	L
15	0.34	D	D	D	D	D
16	0.38	M	M	M	M	M
17	0.42	-	M	M	M	M
18	0.44	VL	-	-	-	-
19	0.49	VL	VL	VL	VL	VL
20	0.55	L	L	L	L	L
21	0.57	VL	M	M	M	M
22	0.60	D	D	D	D	D
23	0.62	M	M	M	M	M
24	0.68	L	-	-	-	L
25	0.69	-	M	-	-	-
26	0.73	D	D	D	D	D
27	0.78	D	D	D	D	D
28	0.80	L	M	-	-	VL
29	0.87	L	M	-	-	-
Total Bands		**27**	**25**	**20**	**20**	**26**

OP=Open pollination; EP=Open pollination after emasculation; SM=Selfing in muslin cloth bag; EG= Enforced geitonogamy; EA=Enforced allogamy

D = DARK; M = MEDIUM; L = LIGHT; VL = VERY LIGHT; - = ABSENT

cloth bag and enforced geitonogamy i.e. 20. The banding pattern obtained through selfing in muslin cloth bag and enforced geitonogamy was similar, as their male and female parents were same. Five bands having Rm values of 0.04, 0.34, 0.60, 0.73 and 0.78 were highly intense bands.

Based on presence or absence of bands, similarity values (Table 29) were calculated for all pair-wise comparisons made among seeds obtained through different reproductive methods. The similarity values on the basis of total seed protein ranged from 0.80 (between open pollination and selfing in muslin cloth bag; between open pollination and enforced geitonogamy) to 1.00 (between selfing in muslin cloth bag and enforced geitonogamy). The similarity value of selfing in muslin cloth bag and enforced geitonogamy i.e. 1.00, indicated that the seeds obtained through these two methods have the common parents. The similarity values were also high for the seeds obtained through other methods because of the same mother tree. The similarity value of open pollination with selfing in muslin cloth bag and enforced geitonogamy was 0.80, however, similarity value of open pollination after emasculation with selfing in muslin cloth bag and enforced geitonogamy was 0.88 which indicated that seeds from open pollination and open pollination after emasculation had different pollen (male) parent which also indicated towards cross-pollinated nature of the tree.

Table 29: Similarity index in *Prosopis juliflora* (obtained through different reproductive methods)

Reproductive methods	OP	EP	SM	EG	EA
OP	1.00	0.88	0.80	0.80	0.94
EP		1.00	0.88	0.88	0.90
SM			1.00	1.00	0.86
EG				1.00	0.86
EA					1.00

OP=Open pollination; EP=Open pollination after emasculation; SM=Selfing in muslin cloth bag; EG= Enforced geitonogamy; EA=Enforced allogamy

CHAPTER-V

DISCUSSION

Prosopis juliflora (Swartz) DC. is one of the most important species for the afforestation of arid and semi-arid regions, due to its adaptation to different soils and terrains. It is a fast growing, hardy, drought resistant species with good coppicing ability. The tree grows on almost any type of soil, including highly saline and alkaline sites and even with its roots in tidal brackish water. It does well with as little as 150 mm and up to 750 mm rainfall. It is highly esteemed fuelwood source and it also provides shade, timber and fodder. Its pods are highly palatable and nutritious, and the flowers produce good quality nectar for honey, which is also consumed by birds (Mathur and Bohra, 1993). Ripe pods, which fall on the ground, are avidly consumed by domestic stock. These are rich in protein and free sugars which gives them sweet taste (Marangoni and Alli, 1988). The tree exudes gum from the sapwood, which is used in industries like sizing of paper, printing and cosmetics (Singh and Singh, 1993). It is a promising windbreak and shelterbelt for stabilization of sand dunes. Being thorny and quick invader, it escapes damage from human being and livestock. Despite the widespread

occurrence and utilization of this species, there has been little genetic improvement of *P.juliflora*.

With the increasing population pressure and justifiable aspiration of the people for improved standards of living and healthy environment, particularly in the under developed and developing regions of the world, there is an urgent need to further increase forest production. Though silviculturists and forest managers have tried to secure the highest possible sustained yield from forests, there is a wide gap between production and requirement. Intensive forest management activities, such as site preparation or application of fertilizers will never yield maximum returns, unless the genetically best trees are used to the maximum extent in subsequent plantations. As a matter of fact, management practices can show their best impact only after the genetic improvement of forest tree species. Tree improvement is an additional tool of silviculture that deals with the kind and genetic make-up of the tree used. Indian forests have not been subjected to the effects of vigorous selection and tree improvement programme. Therefore, genetic improvement of tree is an effective component required to be incorporated in field experimentation of trees for desired success in afforestation programmes.

The principles and practices of plant breeding for tree species are well established (Wright, 1976; Zobel and Talbert, 1984) and they apply equally to industrial plantations and to small agroforestry holdings and

community plantings. Superior phenotypes are selected from the best populations and their breeding potential evaluated in clonal or progeny tests on typical site with typical management. Superior genotypes are then planted in special seed production areas or orchards where open or controlled pollination provides seed for further plantations and if needed for further selection, testing and breeding (Burley, 1980). For improvement in any tree species, it is necessary to:

- Determine the kind and extent of variability within the species.
- Identify plus trees with maximum desired features.
- Find out relationship among various parameters of the species and the external factors (the environment).
- Develop and maintain a genetic base population.

The genetic variability for which, determination of phenotypic variation is the pre-requisite, forms the basis for all tree improvement programmes. All the tree improvement programmes are based on regulating natural variation through the reproductive system (Bawa, 1976). Keeping all these foregoing aspects in view, present study was conducted on *Prosopis juliflora* to generate information on seed source variation, progeny testing and reproductive biology. Salient features of the results are discussed below.

5.1 EVALUATION OF VARIOUS SEED SOURCES

Seed source in tree species denotes the areas from where seed or other propagation material is obtained. The tree species with a wide geographical distribution exhibit considerable provenance variation in anatomy, morphology and physiology. They vary genetically as well. *P.juliflora* occurs in arid and semi-arid regions of various countries such as India, Pakistan, Brazil, Senegal and Sudan. In India, trees of *P.juliflora* are found in Haryana, Punjab, Rajasthan, Delhi, Uttar Pradesh, Andhra Pradesh and Gujarat. This plant species is well known for its wild growth.

For the present study, seeds of *P.juliflora* were collected from 18 places of the four states viz., Haryana, Punjab, Rajasthan and Uttar Pradesh. The seeds collected from each place, were treated as separate seed source. These seed sources were studied individually for seed morphology and electrophoresis of total seed protein.

5.1.1 Observations on seed morphology:

Analysis of variance showed that adequate genotypic variability exists for all the seed parameters studied viz., 100-seed weight, seed length, seed thickness and seed width. The differences due to seed sources were significant for all the parameters. It is evident from the results of present study that out of 18 seed sources, the seed source SS-10 (Mohannagar) ranked highest for 100-seed weight and seed length, whereas SS-7 (Karnal) also ranked highest for seed length. However, for

seed thickness SS-15 (Raisingh Nagar) and SS-6 (Suratgarh) and for seed width SS-8 (Kola Farm) and SS-9 (Ganganagar) obtained highest ranking. The colour of the seeds was dark reddish brown in all the seed sources except SS-9, SS-12, SS-14 and SS-16. The seed colour of SS-9 (Ganganagar) was strong brown, while of SS-12 (Pilibanga), SS-14 (Rawatsar) and SS-16 (Dabwali) was reddish brown. The shape of seeds from all the sources was ovoid and flat.

On the basis of 100-seed weight, it can be inferred that seeds collected from SS-10 (Mohannagar) were of best quality followed by those collected from SS-5 (Bhatinda) and SS-18 (Hisar). As large seeds weigh more per seed than small ones of the same specific gravity and because they contain large food reserves, they are likely to germinate better and produce initially more vigorous seedlings (FAO, 1987). Large amount of variability in seed weight of *P.juliflora* was reported by many workers (Von Maydell, 1986; Sargent, 1947; Bainbridge and Virginia, 1990; Tewari *et al.*, 1993). Similarly, Kackar *et al.* (1986) and Arya *et al.* (1992) found wide genetic variability for various seed parameters in natural stand of *P.cineraria.*

Among seed parameters, the highest heritability was observed for 100-seed weight followed by seed thickness and seed length. Yadav (1993) also observed highest heritability for 100-seed weight among seed parameters in *Dalbergia sissoo.* Characters having high heritability values could be improved directly through selection since these

characters are relatively less influenced by environment. In general, phenotypic coefficient of variation was higher than their corresponding genotypic coefficient of variation. It was because of the fact that phenotypic coefficient of variation include environmental components. Low differences between PCV and GCV observed in the present study indicated the lesser influence of environment and reflect on the reliability of selection based on phenotypic performance. Bisla and Daulta (1988) also observed high variability, heritability and genetic advance for seed weight in Ber. Similarly, Bagchi and Sharma (1989) also reported highly significant variation and high heritability for seed length, breadth and weight in trees of Sandal from different localities. Manga and Sen (1996) reported that seed weight exhibited high genetic variability, heritability and genetic gain in *P.cineraria*.

The magnitude of genotypic correlation coefficients, in general, were found to be higher than the corresponding phenotypic correlation coefficients, indicating thereby that inspite of a strong inherent association between the various seed characters studied, the phenotypic expression of the correlation was lessened under the influence of environment. Results indicated that 100-seed weight had significant positive correlation with seed length and seed thickness. Hooda and Bahadur (1993) reported positive correlation of seed size with seed length, breadth and thickness in *Leucaena leucocephala*. Similarly, in

Acacia nilotica, significant positive correlation between seed length and seed width was observed (Krishan and Toky, 1996).

5.1.2 Electrophoresis:

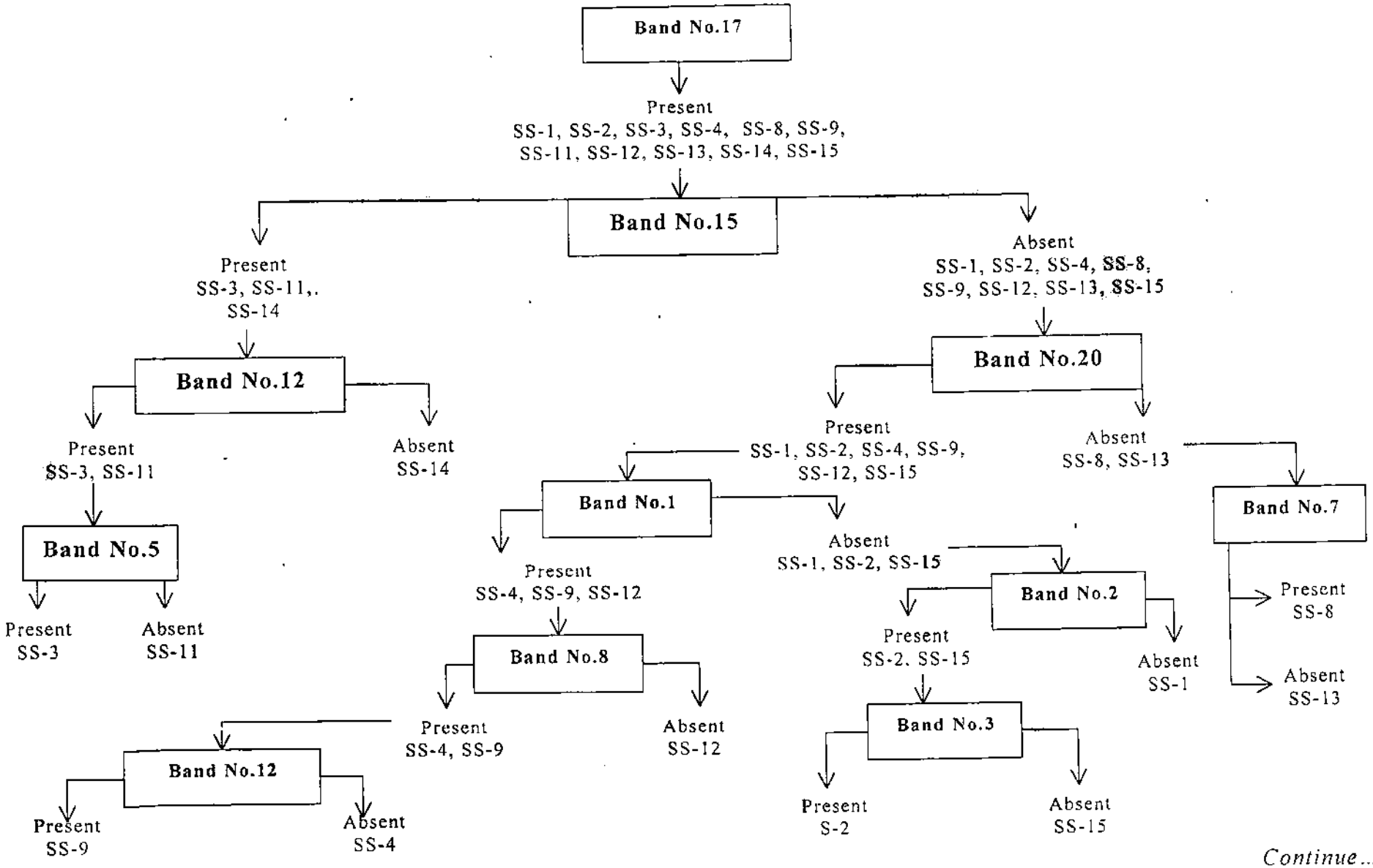
The term electrophoresis is used to describe the migration of a charged particle under the influence of an electric field. The rate of movement depends primarily on two factors i.e. (a) the charge: molecules with the higher charge migrate faster than those with a lower charge and (b) the size of the molecule: particle with smaller molecular weight migrates faster than those with higher weight. Employing this principle, separation of proteins by electrophoresis is utilized for seed source identification.

Denaturing proteins in the presence of sodium dodecyl sulphate (SDS) a strong ionic detergent and a thiol agent (e.g. 2-mercaptoethanol) and then subjecting it to polyacrylamide gel electrophoresis performs separation of proteins on the basis of their molecular mass.

The degree of separation of these proteins is greatly influenced by different conditions of pH, concentration of acrylamide of bis, ionic strength, potential gradient, strength of the electric field (i.e. current/ volts applied), running duration, temperature, etc.

It is very reliable techniques because of its reproducibility and therefore, used extensively for identification of varieties and their genetic purity by many workers in different crops and tree species.

Based on electrophoregram of protein, it was possible to identify each of the seed sources individually. Seed sources were classified on the basis of presence or absence of protein bands. The protein band no.6 (Rm 0.32), 14 (Rm 0.50), 18 (Rm 0.60), 25 (Rm 0.90), 26 (Rm 0.94) and 27 (Rm 0.96) were observed invariably common in all the seed sources. Band No.16 (Rm 0.55) was present only in SS-14, whereas band no.15 (Rm 0.52) was present only in SS-3, SS-11 and SS-14. Band No.17 (Rm 0.55), Band No.15 (Rm 0.52), Band No.12 (Rm 0.45), Band No.5 (Rm 0.30), Band No.20 (Rm 0.68), Band No.1 (Rm 0.23), Band No.2 (Rm 0.24), Band No.8 (Rm 0.38), Band No.7 (Rm 0.34), Band No.3 (Rm 0.27), Band No.13 (Rm 0.46) and Band No.10 (Rm 0.42) helped in identifying/distinguishing the seed sources from each other (Flow chart) Therefore, large amount of variation was observed among different seed sources. Burghardt and Palacios (1998) identified 48 different seed protein bands in *Prosopis ruscifolia* and on the basis of presence/ absence of bands, they differentiated the species, collected from different sites. It is quite surprising that in *P.juliflora*, Marangoni and Alli (1988) found only 3 bands, by polyacrylamide gel electrophoresis of seed proteins. Saidman and Vilardi (1987) reported that phenotypic relationship, for genetic similarities among seven species of *Prosopis*, agreed with electrophoresis of seed proteins but not with morphological groupings.

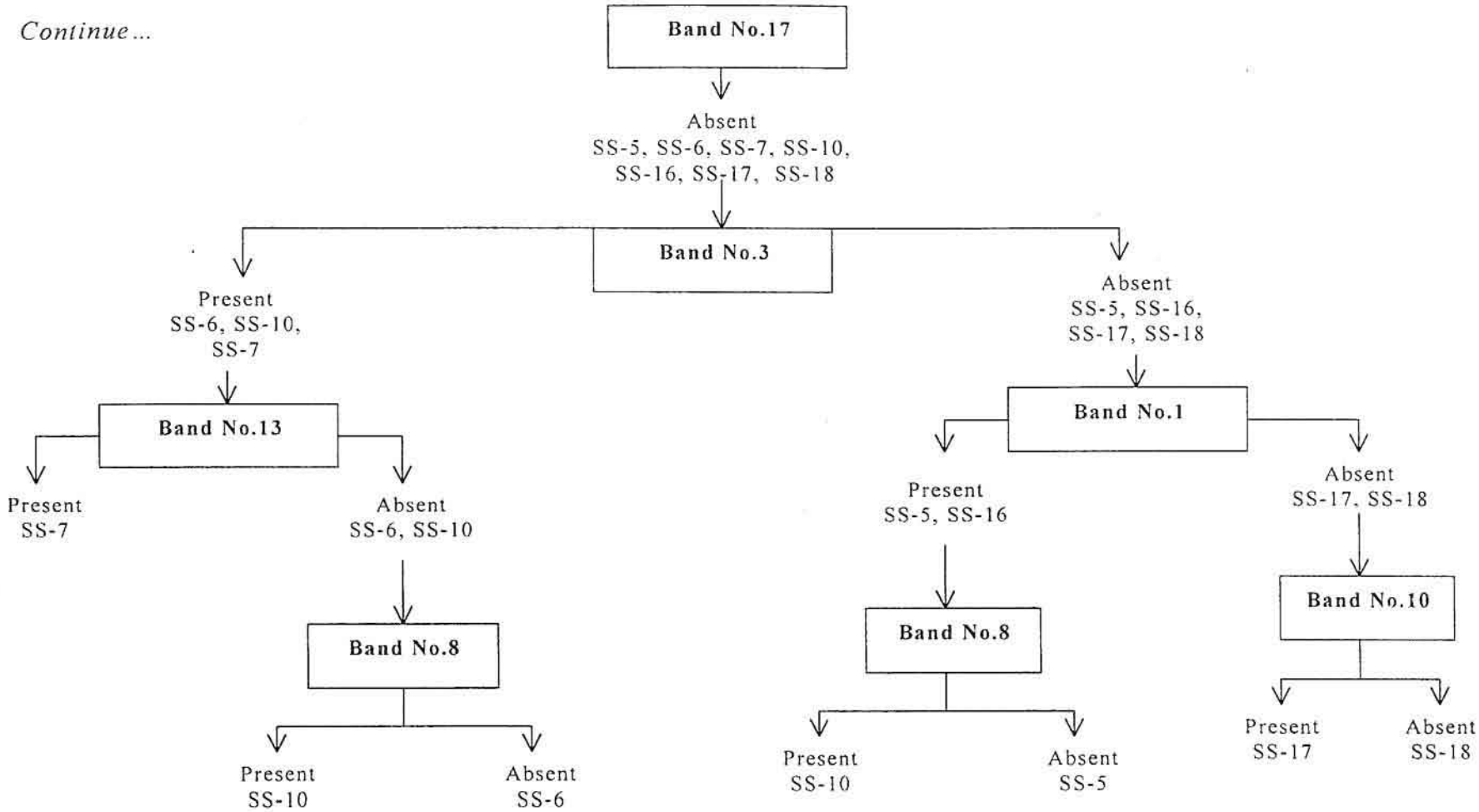


Continue...

FLOW CHART

IDENTIFICATION OF *PROSOPIS JULIFLORA* SEED SOURCES ON THE BASIS OF GEL ELECTROPHORESIS

Continue...


Band No.17
Absent
SS-5, SS-6, SS-7, SS-10,
SS-16, SS-17, SS-18
Band No.3
Present
SS-6, SS-10,
SS-7
Absent
SS-5, SS-16,
SS-17, SS-18
Band No.13
Band No.1
Present
SS-7
Absent
SS-6, SS-10
Present
SS-5, SS-16
Absent
SS-17, SS-18
Band No.8
Band No.8
Band No.10
Present
SS-10
Absent
SS-6
Present
SS-10
Absent
SS-5
Present
SS-17
Absent
SS-18

5.2 PROGENY TESTING OF VARIOUS SEED SOURCES

Success in the establishment and productivity of forest tree plantations is determined largely by the species used and source of seed within species (Larsen, 1954; Challahan, 1964; Lacaze, 1978). The need to use the best adapted seed source has been recognized by Tozawa (1924), Wakeley (1954) and Langlet (1967). Till more sophisticated, expensive and long term breeding techniques for further improvement are employed, the use of best seed source is the only available improvement method for fastest, cheapest and immediate gains. The seed source/provenance testing is well developed field in forestry, which indicated that there exist considerable differences between populations and between trees within populations growing at different sites and even between trees of a single stand. The relative contribution of heredity and environment in the expression of variation may be evaluated by raising seedlings from various seed sources under relatively uniform conditions as in growth chambers, green houses, nurseries or field tests.

In the present study, evaluation of 18 seed sources of *Prosopis juliflora* was done by their progeny testing at the age of 3rd and 4th years (after sowing) i.e. during the years 2000 and 2001. Maximum variations were observed for total height, clear bole and girth at breast height during 2000 and 2001. Similarly CAI and MAI varied significantly for height and girth. It is also clear from the results of present study (Table 30) that progenies PT-112 from Pilibanga and PT-107 from Karnal

Table 30: Better performing progenies of *Prosopis juliflora* during 2000 and 2001

Parameters	2000		2001	
	Rank-I	Rank-II	Rank-I	Rank-II
Growth				
Total height	Pilibanga	Karnal	Pilibanga	Karnal
Clear bole	Solani River	Karnal	Karnal	Solani River
gbh	Pilibanga	Solani River	Pilibanga	Solani River
Seed and Pod				
100-seed weight	Bhatinda	Hisar	Bhatinda	Hisar
Pod length	Sardargarh	Mohannagar	Anupgarh	Pilibanga
Pod width	Karnal	Ganganagar	Karnal	Ganganagar
Pod thickness	Raising Nagar	Dabwali	Raising Nagar	Dabwali
Weight/pod	Sardargarh	Mohannagar	Karnal	Dabwali
Seed weight/pod	Sardargarh	Mohannagar	Sardargarh/Hisar	Anupgarh
Pulp weight/pod	Sardargarh	Mohannagar	Karnal	Dabwali
No. of seeds/pod	Sardargarh	Mohannagar	Sardargarh	Anupgarh

ranked 1st and 2nd, respectively, for total height, whereas PT-112 from Pilibanga and PT-111 from Solani River ranked 1st and 2nd, respectively for gbh during both the years. Similarly, these progenies also performed better for CAI and MAI in height and girth. On the other hand, PT-111 from Solani River and PT-107 from Karnal performed better for clear bole during both the years. From the results it can be inferred that these progenies suit best to the environmental conditions at Hisar. Solanki *et al.* (1984) observed significant variation in height of *Prosopis cineraria* progenies during 3rd, 4th and 5th years of growth. He further suggested that selection of progeny for tree height may be effective in 3rd year. Similarly, Solanki *et al.* (1989) reported that entries of *P.cineraria* from Barmer, Jodhpur, Bikaner and Tonk showed more than 2.25 m height and 8.79 gbh after 3½ years. Solanki *et al.* (1985), Harsh (1985) and Solanki *et al.* (1996), also reported variability in height growth among *P.cineraria* progenies. Half-sib progeny trials were also conducted for *Eucalyptus tereticornis*, *E.camaldulensis*, *E.grandis* (Venkatesh and Vakshasya, 1977; Kedharnath (1982 b), *Santalum album* (Bagchi and Kulkarni, 1987; Bagchi *et al.*, 1987), *Dalbergia sissoo* (Rehman and Hussain, 1986; Bangarwa, 1993), *Tecomella undulata* (Jindal *et al.*, 1991), *Azadirachta indica* (Gupta and Kumar, 1999) and *Leucaena leucocephala* (Gupta and Patil, 1988). There are evidences for sufficient genetic variation in mean plant height between families. In progenies of *P.juliflora* it was found that CAI, in height and girth both,

was more as compared to MAI. Shrivastava (1998) reported that in most of the species during early years of age growth, the CAI remains more as compared to MAI.

During 2000 and 2001, significant variation was observed among the progenies of various seed sources for 100-seed weight, pod length, pod width, pod thickness, weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod.

The results of seed and pod parameters of *P.juliflora* progenies showed (Table 30) that out of 18 progenies, the progeny PT-105 (Bhatinda) ranked first, while PT-118 (Hisar) ranked second for 100-seed weight during both the years. For pod width, Karnal (PT-107) ranked 1st, while Ganganagar (PT-109) ranked 2nd during both the years. Similarly, for pod thickness Raisingh Nagar (PT-115) and Dabwali (PT-116) ranked first and second, respectively, during both the years. However, PT-113 (Sardargarh) and PT-110 (Mohannagar) ranked 1st and 2nd, respectively for pod length, weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod during 2000.

During 2001, progenies of Karnal (PT-107) ranked 1st for pod width, weight/pod and pulp weight/pod, whereas progenies of Dabwali (PT-116) ranked 2nd for pod thickness, weight/pod and pulp weight/pod.

Among seed and pod parameters in progenies of *P.juliflora*, heritability was high for all the parameters during both the years. However, maximum heritability, during 2000, was observed for

weight/pod followed by number of seeds/pod. Whereas, during 2001 it was maximum for number of seeds/pod followed by pod thickness and weight/pod. Genetic advance as percent of mean was maximum for pulp weight/pod followed by weight/pod and pod thickness. Gupta and Patil (1988) observed high estimates of broad sense heritability for most of the characters studied in 40 accessions of *Leucaena leucocephala*. Parameters having high heritability values could be improved directly through selection since these parameters are relatively less influenced by environment. As phenotypic coefficient of variation (PCV) includes environmental components, therefore, it was found higher than genotypic coefficient of variation (GCV) during both the years. On the other hand, the GCV and PCV during 2000 were found higher than the GCV and PCV during 2001, respectively.

Bahadur and Hooda (1995) found that estimates of heritability in broad sense ranged from 61.12 to 97.61 per cent in *P.cineraria*. In the present material high genetic gain coupled with high value of heritability, should, therefore be more useful for improving these parameters. The variation in results during 2000 and 2001 might be due to fluctuations in environmental components at Hisar.

The higher magnitude of genotypic correlation coefficients than the phenotypic correlation coefficients, indicated towards strong inherent association between various parameters studied, the phenotypic expression of correlation was lessened under the influence of

environment. Results showed that 100-seed weight had non-significant association with all the other parameters, during 2000 and 2001. Positive and significant correlation coefficients between weight/pod, seed weight/pod, pulp weight/pod, number of seeds/pod and pod length indicated that these characters are positively interrelated to each other. Similarly, high positively value of genotypic correlation coefficients between these characters suggest that the correlated response in effects of these characters were unidirectional and basically genetic in nature. High positive genotypic and phenotypic correlation between weight/pod and pulp weight/pod during both the years, indicated the strong inherent association between these parameters. Similarly, Sharma *et al.* (1994) reported that maximum intensity of correlation among all the parameters of *P.juliflora,* was found between pod weight and pulp weight/pod. Bahadur and Hooda (1995) reported positive and significant correlation coefficients between pod length, pod weight, seeds/pod, seed length, seed weight/pod and 100-seed weight, and pod length and pod weight of *P.cineraria.*

5.3 REPRODUCTIVE BIOLOGY

About 5000 species of trees and shrubs exist in Indian forest ecosystems (Gamble, 1902; Champion and Seth, 1968). However, very little is known about the biology and breeding systems of these species. Information even on such basic features as to whether these species are self or cross fertilizing, monoecious or dioecious, have hermaphrodite

or unisexual flowers is available only on a very limited scale or lacking completely (Lee, 1967; Bawa, 1974; Bawa and Opler, 1975 and Kaur *et al.*, 1978).

In *Prosopis juliflora* spikes appear in last week of February and the floral buds starts opening from second week of March as observed during 2000 and 2001. However, flowering stopped in last week of May, 2000, and it stopped upto mid of May during 2001, which may be due to sudden increase in temperature. The peak period of flowering in spring season varied from 28 to 43 days during 2000 and 26 to 45 days during 2001. Similarly, duration of flowering period varied from 42 to 61 days and 50 to 65 days during 2000 and 2001, respectively. The variation in duration of peak period of flowering and total flowering period during 2000 and 2001 is due to varied environmental conditions. However, duration of flowering and peak period of flowering also varied with individual tree. The flowering pattern showed a low rate initially during mid March, gradually increase to peak during end of March and early April followed by cessation during mid May in some trees and declined in others. Similarly, Bahadur and Hooda (1994) reported that in *P.cineraria* peak period of flowering was from mid April to mid May, and the duration of flowering varied 28 to 48 days. Dhillon *et al.* (2000) observed that in *P.juliflora* floral buds began to open towards end of March and its peak period of flowering varied from 30-50 days.

The flowering pattern of *P.juliflora* is asynchronous i.e. floral buds and spikes are at different stages of development even on the same tree. Similarly, in *Bombax ceiba* (Khosla *et al.*, 1982) and *Dalbergia sissoo* (Bangarwa, 1993) the flowering pattern is asynchronous. The inflorescence of *P.juliflora* is racemose-spike comprising of several tiny flower buds. The flowers are complete, actinomorphic and hypogynous. Calyx has five coherent sepals, corolla has five free petals. Calyx and corolla, both are inferior. However, gynoecium is superior which has long style with minute stigma. Androecium consists of ten stamens with long filament and dosifixed anthers. The height of carpel is little higher than stamen, which showed herkogamy. Smith (1985) reported that inflorescence of *P.juliflora* is axilary spicate or spiciform-racemose. Flowers are small, 5-merous, calyx campanulate, short-dentate; petals free proximally connate and stamens are free and ten in numbers. In case of *Acacia nilotica*, flowers are sessile, actinomorphic and hypogynous, which are arranged in compound cymose heads. Calyx consist of 4 to 5 minute sepals united with each other. Corolla is gamopetalous with 4 to5 petals. Calyx and corolla are inferior. Distal and median parts of the inflorescence has a higher number of hermaphrodite flowers, and many proximal flowers have either no carpel or no functional carpel (Tybirk, 1989; Dhillon and Khajuria, 1994; Pandey, 1999).

In *P.juliflora*, it was observed that development from spike initiation to pod ripening was divisible into eight distinct phases, on the

basis of their shape, size, colour, etc. Srivastava and Singh (1970) grouped the flower bud development in sweet cherry into seven stages: Nalawadi *et al.* (1973) grouped the flower bud development in Pomegranate into ten stages. Similarly, Teklehaimanot (1997) grouped the floral but initiation to pod maturity into ten different phases. The period of different phases during spring season of 2000 and 2001 showed that spike initiation to completion of elongation took place between 10 to 13 days, stigma emerged 7 to 8 hours before flower opening and opening of all the florets per spike took place within 9 to 12 hours. The duration of pod setting to pod ripening varied from 35 to 37 days and 33 to 36 days during 2000 and 2001, respectively. Mathur and Bhatnager (1992) selected five trees each of *P.juliflora* and *P.cineraria* for study and determined the occurrence of different 'phenophases' (e.g. ripe and unripe fruit, flower buds and blossoms).

During the flowering period (March to May) of *P.juliflora*, a total of 11 insect species (Hymenopterous 6; Lepidopterous 1; Coleopterous 2 and Dipterous 2) were observed visiting the spikes. Out of 11 insects, *Apis dorsata*, *A.mellifera* and *A.florea* were the regular visitors. Genise *et al.* (1990) reported that *Prosopis* flowers were pollinated by the bees *Caupolicana mendocina*, *Xylocopa splendidula* and *Apis mellifera*. Tybirk (1993) studied the flower visitors *Acacia albida*, *A.nilotica*, *A.tortilis* and *A.senegal* and collected one hundred and eighteen texa of insects. Thangaraja *et al.* (1999) observed 15 flower visitors on

A.nilotica, of which most were insects, including *A.mellifera*. Similarly, Sharma *et al.* (2001) observed that three *Apis* species viz., *A.florea*, *A.dorsata* and *A.mellifera* were regular visitors of flowers of *Zizyphus mauritiana*.

The data on the density of *Apis* spp. (Average number of honey bees/metre shoot length/5 min) on *P.juliflora* revealed that the maximum mean abundance of all the three *Apis* spp. was observed at 1200-1300 h which was significantly higher than abundance at 0800-0900 h, 1000-1100 h, 1400-1500 h and 1600-1700 h. The higher abundance might be due to coincidence of anther dehiscence around noon in the day and favourable temperature for their activity in the month of April. The lower abundance might be due to low temperature in early hours of the day. Bhatia *et al.* (1995) reported that maximum activity of *Apis* spp. in malta, *Citrus sinensis* (L.) Osbeck was observed around noon. Irrespective of five observational hours, *A.florea* was the most abundant followed by *A.mellifera* and *A.dorsata* . The abundance of all the three *Apis* spp. was more during 2001 as compared to 2000, which might be due to increase in number of spikes per trees. Sharma *et al.* (2001) found that abundance of *A.florea* was maximum (4.99 bees/branch/5 min.) followed by *A.mellifera* (1.03 bees/branch/5 min) and *A.dorsata* (0.48 bees/branch/5 min.) on *Zizyphus mauritiana*. As the trees at the age of 4 years bear more spikes as compared to trees at the age of 3 years,

therefore, more the number of spikes per tree more the bees were attracted.

The time spent by *Apis* spp. on *P.juliflora* spike showed that *A.dorsata* spent maximum time i.e., 115.2 and 115.4 seconds/spike followed by *A.mellifera* 77.2 and 75.6 seconds/spike and *A.florea* 58.4 and 57.8 seconds/spike during 2000 and 2001, respectively. Therefore, *A.florea* spent significantly lesser time per spike than *A.mellifera* and *A.dorsata*. The differences in time spent were because of the body requirement of *Apis* spp. Kumar (1990) and Gill (1994) also found the similar trend on Ber and Phalsa flowers, respectively under Hisar conditions.

The pollen viability studied be acetocarmine test was found to vary from 80 per cent in March to 94.33 per cent in April. This variation may possibly be due to varying temperature. Sareen and Yadav (1987) observed 70-76 per cent pollen fertility in *P.juliflora*. Khurana and Khosla (1979) reported medium to high pollen viability in some hard wood species. Similarly, Bangarwa (1993) reported that in *Dalbergia sissoo* pollen viability varied from 46 per cent in April to 56 per cent in March.

Mode of pollination in a species is vital to the choice of breeding procedures to be adopted for its genetic improvement. It appears that the knowledge of pollination mechanisms existed even at the dawn of agricultural civilization. Assyrians and Babylonians used to pollinate

date-palm as early as 2000 BC (Robert, 1929). Controlled pollination which is basic to plant improvement depends upon pollination mechanisms.

Present studies on pollination showed that there was no pod setting through autogamy and about 0.01 per cent pod setting through selfing in muslin cloth bag, whereas 0.06 to 0.14 per cent pod setting was observed through enforced geitonogamy, all of these pollination methods indicating the self-incompatible nature of breeding system in this species. To avoid problem of self-pollination, which result in a lack of hybrid vigour, various physical and chemical means have evolved (Peters, 1988; Bawa *et al.*, 1985). The absence of autogamy is probably due to dichogamy (protogyny) and herkogamy. As, in *P.juliflora* flower, the stigma emerges from the bud, before the bud opening (Plate 11) and matures early by the time anthers dehisce (protogyny). On the other hand, in its flowers, structure of male and female sex organs itself proves a barrier to self-pollination, as the stigma projects beyond the stamens so that the pollen do not fall on it (herkogamy). Sedgley *et al.* (1992) reported that flower structure of *Acacia mangium* and *Acacia auriculiformis* showed a weak protogyny. Zapata *et al.* (1989) observed high level of incompatibility in *Prosopis flexuosa* through controlled selfing and crossing. They further reported that pollen tubes made contact with the ovary but the site of arrest was not detected, which suggested that the self-incompatibility system is gametophytic and post

Plate 11: Protogyny in *Prosopis juliflora*

zygotic. Dhillon *et al.* (2001) reported zero per cent pod setting on selfing/bagging of *P.juliflora*, whereas in *P.cineraria* pod setting through selfing/bagging was 0.19 per cent. Similarly, high level of self-incompatibility was reported in *P.cineraria* (Bahadur and Hooda, 1994) and *P.tamarugo* (Villasenor *et al.*, 1996).

As compared to enforced geitonogamy between 0700-1000 h, 1000-1300 h and 1500-1800 h (Fig.4), the corresponding values of enforced allogamy was significantly higher during 2000 and 2001, which indicated towards allogamous nature of *P.juliflora*. In both of these methods maximum pod setting was observed between 1000-1300 h, which showed the receptivity of stigma during this period is more as compared to other hours of the day. Dhillon *et al.* (2001) reported 0.72 per cent pod setting in *P.juliflora*, whereas 1.58 per cent in *P.cineraria* through crossing. He further reported that cross-pollination was predominant in both the species. Therefore, results showed that *P.juliflora* is mainly a cross-pollinated species but there is pod setting after self-pollination too. Bryndum and Hedgart (1969) reported similar pattern in case of *Tectona grandis*.

Analysis of variance for different parameters in *Prosopis juliflora* (obtained through different reproductive methods) showed that large amount of genotypic variability exists for all the parameters studied. The differences due to different reproductive methods were significant for all the parameters. The values for all the seed and pod parameters

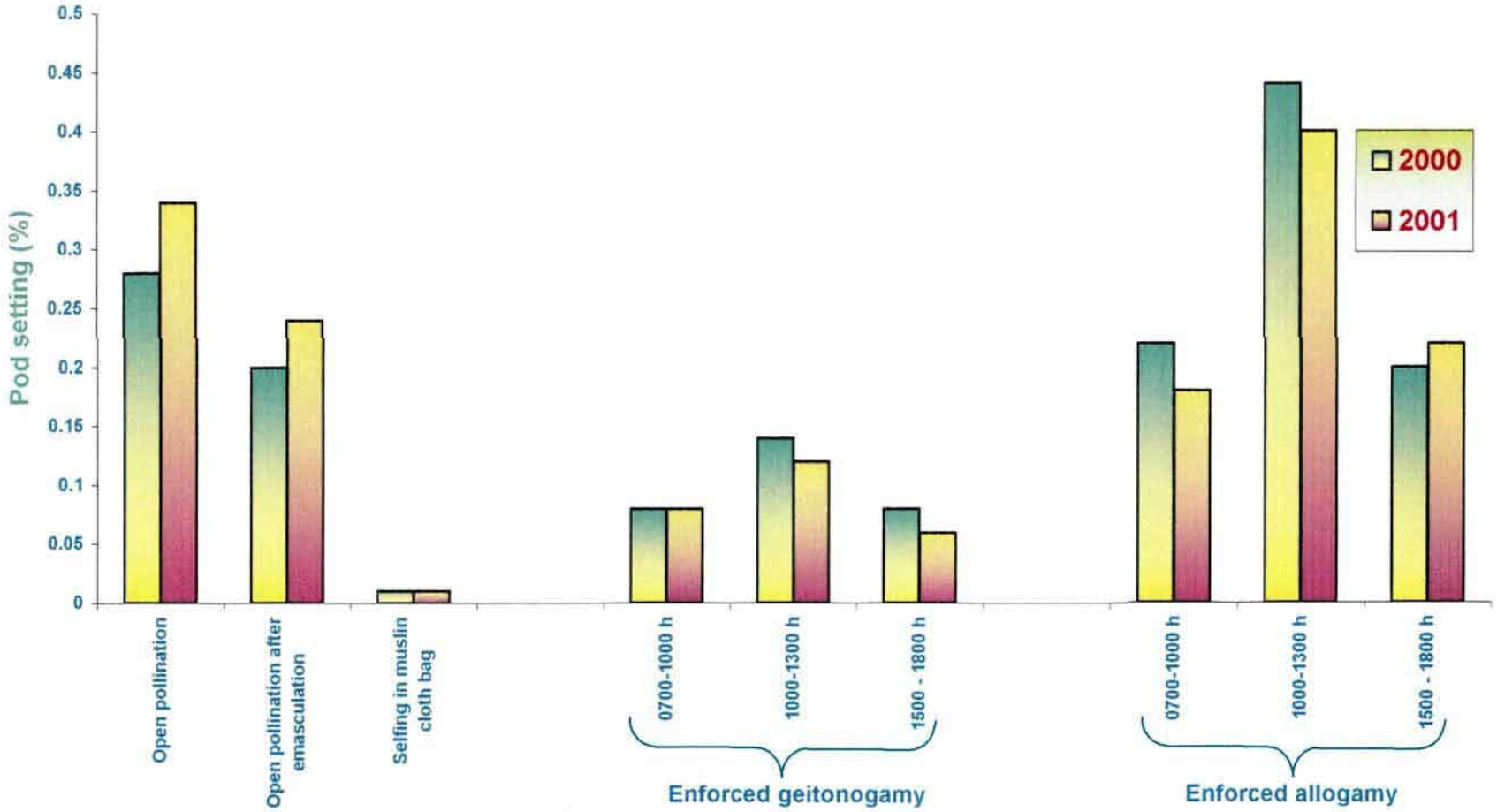


Fig. 4 : Effect of reproductive methods on pod setting (%) in *Prosopis juliflora*

viz., 100-seed weight, seed length, seed thickness, number of seed per pod, seed weight/pod, weight/pod and pod length were higher for open pollination, which suggest that the better quality of seed and pod should be obtained through this method, followed by open pollination after emasculation and enforced allogamy. No. of seeds per fruit were found more through open pollination as compared to self-pollination in Kinnow mandarin (Haq *et al.*, 1978) and Nagpur mandarin (Rohidas and Chakrawar, 1982).

The percent germination was maximum in the seeds obtained through enforced allogamy followed by open-pollination and open-pollination after emasculation. Whereas, germination percentage was very poor in the seeds obtained through selfing in muslin cloth bag and enforced geitonogamy. Similarly, Bryndum and Hedgart (1969) reported that in teak (*Tectona grandis*) germination of fruits obtained from self-pollination was poor as compared to that of fruits from cross-pollination. Seedling length and collar diameter (obtained through different reproductive methods) also showed that the seedlings obtained from the seeds through selfing in muslin cloth bag and enforced geitonogamy were of poor quality. On the other hand, seedlings from the seeds of enforced allogamy, open pollination and open pollination after emasculation were better for length and collar diameter.

The phenotypic and genotypic coefficient of variation was highest for number of seeds/pod followed by seed weight/pod and seed

thickness. Phenotypic coefficient of variation was higher than their corresponding genotypic coefficient of variation because phenotypic coefficient of variation include environmental components. However, differences between phenotypic coefficient of variation and genotypic coefficient were low indicating lesser influence of environment. Heritability values were highest for all the parameters studied. However, highest genetic advance was observed in number of seeds/pod followed by seed weight/pod and seed thickness. Therefore, result indicated that effect of reproductive methods have great impact on the parameters studied. The magnitude of correlation coefficients at phenotypic level were lower than the corresponding genotypic level, thus indicating a good extent of strong inherent association between different parameters studied. 100-seed weight had significant positive correlation with seed thickness, number of seeds/pod, seed weight/pod, weight/pod and pod length.

The banding pattern of total seed protein (obtained through different reproductive methods) showed that the highly intense bands were common in all the five treatments. The protein is the direct product of genes, therefore, the genetic make-up of seeds obtained through different reproductive methods is almost same, which indicated that the mother tree plays major role in the genetic make-up of its seeds. The total number of band, through selfing in muslin cloth bag and enforced geitonogamy, were the same due to their same parentage. However, the

presence of some exceptional light intensity bands in open pollination, open pollination after emasculation and enforced allogamy showed the influence of pollen tree, therefore, occurrence of cross-pollination, which confirms the cross-pollinated nature of the species.

The findings of this study would be important for the improvement of *P.juliflora* as it will facilitate, (1) maximization of selection response for different characters through embarking on correlated response, and (2) enhancing breeding efficiency through efficient management of reproductive features.

CHAPTER-VI

SUMMARY AND CONCLUSION

The present study was undertaken to determine seed source variation, progeny testing and reproductive biology in *Prosopis juliflora* (Swartz) DC. Results of the present investigation are summarized below:

6.1 Evaluation of Various Seed Sources

Large amount of seed pods of plus trees were collected from eighteen different places during June, 1997. The seeds collected from each place were treated as a separate seed source. The data were recorded on different seed parameters viz., 100-seed weight, seed length, seed width, seed thickness, seed colour, seed shape and electrophoretic pattern of total seed protein. The results showed that:

- ☆ Large variation was observed between seed sources for 100-seed weight, seed length, seed width and seed thickness. Seed source SS-10 had maximum 100-seed weight (3.72 g), therefore seed source SS-10 (Mohannagar) of *P.juliflora* was considered as the best seed source for getting better quality seed followed by seed source SS-5 (Bhatinda) and SS-18 (Hisar).
- ☆ The seeds from SS-9 (Ganganagar) were strong brown, whereas seeds from SS-12 (Pilibanga), SS-14 (Rawatsar) and SS-16 (Dabwali) were

reddish brown in colour. The seeds from other seed sources were dark reddish brown in colour. The shape of seeds from all the sources was ovoid and flat.

☆ Considerable genotypic variability was observed for all the seed parameters under study. The highest genotypic and phenotypic coefficient of variation was observed for 100-seed weight followed by seed thickness. Similarly, heritability was also high for 100-seed weight and seed thickness, suggesting that selection of these parameters would be effective. The 100-seed weight showed significant positive correlations with seed length and seed thickness.

☆ Electrophoresis of total seed protein showed large variation among the seed sources. A total of 27 bands were resolved among 18 seed sources. The number of bands resolved varied from 15 in SS-1 (Anupgarh) to 24 in SS-14 (Rawatsar). The seed sources SS-17 (Kurukshetra) and SS-18 (Hisar) had maximum similarity value (0.97) which indicated their closeness either due to common parentage or accumulation of similar genes from different parents.

6.2 Progeny Testing of Various Seed Sources

In March 1998, six months old seedlings of 18 *P.juliflora* seed sources were transplanted at 6 x 3 m spacing in the Forestry Farm, CCS Haryana Agricultural University, Hisar following randomized block design with three replications. The data were recorded in the month of July on total height, clear bole, girth at breast height, current annual

increment, mean annual increment, 100-seed weight, pod length, pod width, pod thickness, weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod during the years 2000 and 2001 in order to identify the better progenies. The results showed that:

- ☆ The progenies varied significantly during both the years for growth as well as the seed and pod parameters viz., total height, clear bole, girth at breast height, current annual increment, mean annual increment, 100-seed weight, pod length, pod width, pod thickness, weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod.
- ☆ The progenies PT-112 (Pilibanga) and PT-107 (Karnal) ranked first and second for total height, whereas progenies PT-112 (Pilibanga) and PT-111 (Solani River) ranked first and second for girth at breast height during both the years. However, PT-111 (Solani River) and PT-107 (Karnal) performed better for clear bole, which showed their ability for fast growth.
- ☆ The progeny PT-105 (Bhatinda) ranked first, while PT-118 (Hisar) ranked second for 100-seed weight during both the years. However, PT-113 (Sardargarh) and PT-110 (Mohannagar) ranked first and second, respectively, for pod length, weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod during 2000. During 2001, PT-107 (Karnal) ranked first for pod width, weight/pod and pulp

weight/pod, whereas, PT-116 (Dabwali) ranked second for pod thickness, weight/pod and pulp weight/pod.

☆ The highest genotypic and phenotypic coefficient of variation were observed for pulp weight/pod followed by weight/pod, seed weight/pod and number of seeds/pod during both the years. The heritability was highest for weight/pod and pod thickness, during 2000 and 2001, respectively, along with high values of genetic advance suggesting the wider scope for selection of these parameters.

☆ The 100-seed weight showed non-significant correlation with all the parameters studied during both the years. However, during 2000, pod length had highly significant positive correlation with weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod. Whereas, during 2001, pod length had highly significant positive correlation with weight/pod and pulp weight/pod and significant positive correlation with seed weight/pod and number of seeds/pod. These parameters may be helpful for selection purpose.

6.3 Reproductive Biology

The investigations on blooming period, flower structure, flowering and fruiting phases, flower visitors and reproductive methods were carried out from the month of January to June during 2000 and 2001, on the trees growing in the Farm Area, CCS Haryana Agricultural University, Hisar. The seed pods obtained through different reproductive

methods were also evaluated. The results of the present study showed that:

☆ The spike initiation started in last week of February, whereas flowering started in the second week of March. The flowering pattern showed a low rate initially during mid March, gradually increasing to peak during end of March and early April followed by cessation during mid of May in some trees and decline in others. Therefore, during spring season, the period from end of March to early May is best for crossing (hand pollination). Duration of peak period of flowering varied with individual trees i.e. 28 to 43 days and 26 to 45 days during 2000 and 2001, respectively.

☆ Inflorescence is racemose-spike. The flowers are actinomorphic, hermaphrodite and hypogynous. Calyx consists of five coherent sepals, campanulate and inferior. Corolla has 5 free petals, valvate and inferior. Androecium consists of 10 stamens with long filament and dorsifixed anthers. Gynoecium is monocarpellary, unilocular and superior. The height of carpel is little higher than stamen, which shows herkogamy in *P.juliflora*.

☆ The duration of different phases showed that spike initiation to completion of elongation took place between 10 to 13 days and all the florets per spike opened within 9 to 12 hours, during both the years. Similarly, duration of pod setting to pod ripening varied from 35 to 37 days and 33 to 36 days during 2000 and 2001, respectively.

The variation in duration of different phases may be due to fluctuation in environmental components. The emergence of stigma, 7 to 8 hours before flower opening, showed protogyny in *P.juliflora.*

☆ During the flowering period of *P.juliflora*, a total of 11 insect species belonging to 7 families of 4 insect orders viz., Hymenoptera, Lepidoptera, Coleoptera, Diptera were observed on its spikes. Three *Apis* species namely *A.dorsata*, *A.mellifera* and *A.florea* were found as regular visitors. The time spent by *Apis dorsata* was maximum i.e. about 115 seconds/spike (both the years) followed by *Apis mellifera* (about 75 to 77 seconds/spike) and *Apis florea* (about 57 to 58 seconds/spike). The maximum mean abundance of all the three *Apis* species was observed at 1200-1300 h.

☆ Pollen viability by acetocarmine test was found to be varied from 80 per cent in March to 91.67 per cent in April, during 2000. Whereas, it varied from 83 per cent in March to 94.33 per cent in April, during 2001.

☆ A high degree of self-incompatibility was observed in *Prosopis juliflora.* There was no pod setting through apomixis and autogamy. Under natural condition pod setting were 0.28 per cent and 0.34 per cent, during 2000 and 2001. However, maximum pod setting was observed through enforced allogamy between 1000-1300 h as compared to crossing between 0700-1000 h and 1500-1800 h, which indicated that stigma receptivity was maximum during 1000-1300 h

of the day. Absence of pod setting through autogamy and very poor pod setting through selfing in muslin cloth bag indicates towards cross-pollination behaviour of *P.juliflora*.

☆ The differences between different reproductive methods were found significant for all the seed and pod parameters studied. For almost all the seed and pod parameters viz., 100-seed weight, seed length, seed width, seed thickness, number of seeds/pod, seed weight/pod, weight/pod and pod length, the values were maximum for seed and pods obtained through open pollination followed by open pollination after emasculation and enforced allogamy. The seeds obtained through these three methods were bold and gave vigorous seedlings, therefore, can be used for plantation establishment to get improved plant types. On the other hand, seed pods obtained through selfing in muslin cloth bag and enforced geitonogamy were of very poor quality and had least germination percentage.

☆ The maximum genotypic and phenotypic coefficient of variation was observed for number of seeds/pod followed by seed weight/pod and seed thickness. Heritability estimates were high for all the parameters, however, it was maximum for pod length (99.99%) followed by both 100-seed weight and seed thickness i.e. 99.91 per cent. The expected gain was observed maximum in number of seeds/pod (120.17%) followed by seed weight/pod (104.23%) and seed thickness (83.80%).

☆ The 100-seed weight showed significant positive correlations with seed thickness, number of seeds/pod, seed weight/pod, weight/pod and pod length. The magnitude of correlation coefficients at genotypic level was higher than the corresponding phenotypic level, thus indicating a good extent of strong inherent association between the parameters studied.

☆ Electrophoretic profile of total seed protein of the seeds obtained through five different reproductive methods resolved into 29 bands. The maximum (27) numbers of bands were observed for open pollination, whereas minimum (20) were observed for selfing in muslin cloth bag and enforced geitonogamy. Similarity index values confirmed the cross-pollinated nature of the *P.juliflora*. However, the similarity value of selfing in muslin cloth with enforced allogamy i.e. 1 indicated that the seeds obtained through these two methods have same parentage.

BIBLIOGRAPHY

Abrol, D.P. 1996. A contribution to the floral biology of *Acacia modesta* Wall. and its importance as a source of forage to honey bees. *Indian Bee Journal* **58** (3): 134-136.

Allen, O.N. and Allen, E.K. 1981. "*The Legumes: A Sourcebook of Characteristics, Uses and Nodulations*". University of Wisconsis Press, Madison, W.I.

Arya, S.; Kumar, N.; Toky, O.P. and Harris, P.J.C. 1993. Provenance variation in pod length and seed weight of 'Marwar' teak (*Tecomella undulata*) (Smith) Seemann. *Journal of Tree Sciences* **12** (2): 115-117.

Arya, S.; Toky, O.P.; Tomar, R.; Bisht, R.P. and Harris, P.J.C. 1992. Provenance variation in seed and pod characteristics of *Prosopis cineraria* (L.) Druce in arid India. *Journal of Tree Sciences* **11**: 86-94.

Bagchi, S.K. and Kulkarni, H.D. 1987. A note on seedling abromaility frequency in the half-sib progenies of *Santalum album* . *Indian Forester* **113**: 650-651.

Bagchi, S.K. and Sharma, V.P. 1989. Biometrical studies on seed characters of *Santalum album* L. *Silvae Genetica* **38**: 152-153.

Bagchi, S.K.; Choubey, A.K. and Kulkarni, H.D. 1987. Variability analysis among half sib seedlings of *Santalum album* L. *Indian Forester* **113**: 370-374.

Bahadur, R. and Hooda, M.S. 1994. Studies on phenology and breeding system of *khejri* [*Prosopis cineraria* (L.) Druce]. *Crop Research* 7 (3): 473-478.

Bahadur, R. and Hooda, M.S. 1995. Genetic variability and correlation studies for some pod and seed traits in Khejri [*Prosopis cineraria* (L.) Druce]. *Indian Journal of Forestry.* **18** (2) : 161-164.

Bainbridge, D.A. and Virginia, R.A. 1990. *Honey Mesquite : A multipurpose tree for arid lands.* NFT Highlights; Nitrogen Fixing Tree Association, Waimanalo, Hawaii.

Bangarwa, K.S. 1993. *Studies on provenance variation, progeny testing and reproductive biology in Dalbergia sissoo Roxb.* Ph.D. thesis, CCS Haryana Agricultural University, Hisar (Haryana), India.

Bawa, K.S. 1974. Breeding system of tree species of a low land tropical community. *Evolution* **28**: 85-92.

*Bawa, K.S. 1976. Breeding of tropical hardwoods on evaluation of underlying bases, current status and future prospects. *In: Tropical Trees, Variation, Breeding and Conservation* (Eds. Burley, J. and Styles, B.T.) London: Acad. Press Linn. Soc. Symp. Serv. **2**: 43-59.

Bawa, K.S. and Opler, P.A. 1975. Dioecism in tropical forest trees. *Evolution* **29**: 167-179.

Bawa, K.S.; Perry, D.R. and Beach, J.H. 1985. Reproductive biology of tropical lowland rain forest trees. 1. Sexual systems and incompatibility mechanisms. *American Journal of Botany* **72**: 331-345.

*Bernhardt, P.; Kenrick, J. and Knox, R.B. 1984. Pollination biology and the breeding system of *Acacia retinodes* (Leguminosae: Mimosoideae). *Annals of the Missouri Botanical Garden.* **71**: 17-29.

Bhatia, R.; Gupta, D.; Chandel, J.S. and Sharma, N.K. 1995. Relative abundance of insect visitors on flowers of major subtropical fruits in Himachal Pradesh and their effect on fruit set. *Indian Journal of Agricultural Science* **65**: 907-912.

Bisla, S.S. and Daulta, B.S. 1988. Studies on variability, heritability and genetic advance for fruit and seed characters in Ber. *Indian Journal of Forest Science* **45**: 29-33.

Brandis, D. 1906. *A forest flora of North Western and Central India.* W.H. Allen, London.

Bryndum, K. and Hedgart, T. 1969. Pollination of teak. *Silvae Genetica* **18**: 77-80.

*Burghardt, A.D. and Palacios, R.A. 1998. Intraspecific variation of seed proteins in *Prosopis ruscifolia Griseb. Physis. Secciones A, ByC.*, **56**: 130-131.

*Burkart, A. 1937. Estudios morfologicos y etologicos en el genero *Prosopis*. *Darwiniana* **3**: 27-47.

*Burkart, A. 1940. Materials para una monografia del genero *Prosopis* (Leguminosae). *Darwiniana* **4**: 57-128.

*Burkart, A. 1943. *Las Leguminosas Argentinas silvestres y cultivadas.* Acme Agency. Buenos Aires. 590 pp.

*Burkart, A. 1952. *Las Leguminosas Argentinas silvestres y cultivadas.* 2a. ed. Acme Agency. Buenos Aires. 569 pp.

*Burley, J. 1965. Genetic variation in *Picea sitchensis* (Bong) Carr. Abstr. of thesis, in Dissert. *Abstract* **26** (4): 1847 ORS.

*Burley, J. 1980. Choice of tree species and possibility of genetic improvement for small holder and community forests. *Commonwealth Forestry Review* **59** (3): 311-325.

*Burton, G.W. 1952. Quantitative inheritance in grasses. *Proceedings 7th International Grassland Congress* **1** : 277-283.

Challahan, R.Z. 1964. Provenance research: Investigation of genetic diversity associated with geography. *Unasylva* **18**: 40-50.

Champion, H.G. and Seth, S.K. 1968. *A Revised Survey of the Forest Type of India*. New Delhi: Govt. of India Press.

Chopra, D. and Hooda, M.S. 2001. Variability in chemical composition of *Prosopis juliflora* seeds and hull. *Indian Journal of Animal Nutrition* **18** (3): 282-284.

Cooke, R.J. 1988. Electrophoresis in plant testing and breeding. *Adv. Electrophoresis*. **2**: 171-261.

Cooke, R.J. 1995. *Varietal identification of crop plants. In: New diagnostics in crop Science* (Eds. Skerrit, I.H. and Apples, R.). CAB International. pp. 33-63.

Dadlani, M. and Varier, A. 1993. *Electrophoresis for variety identification.* Technical Bulletin. Division of Seed Science and Technology, IARI, New Delhi. 18 pp.

Dangasuk, O.G.; Seurei, P. and Gudu, S. 1997. Genetic variation in seed and seedling traits in 12 African provenances of *Faidherbia albida* (Del.)A. Chev. at Lodwar, Kenya. *Agroforestry Systems* 37: 137-141.

Dean, C.A.; Nikles, D.G. and Harding, K.J. 1988. Estimates of genetic parameters and gains expected from selection in hoop pine in south-east Queensland. *Silvae Genetica* 37: 243-247.

Dhankar, N.K.; Kaushik, H.D. and Sharma, S.K. 2001. Insect pollinators of *Citrus* spp. and their foraging behaviour in semi-arid and sub-tropical conditions in Haryana. *In: Abstracts of International Conference "Nature Farming and Ecological Balance"*, ISNF, CCS HAU, Hisar, India from March 7-10, 2001. pp.70.

Dhillon, G.P.S. and Khajuria, H.N. 1994. Floral biology of *Acacia nilotica* ssp. indica under sub-tropical conditions. *Journal of Research* 31(4): 421-426.

Dhillon, R.S.; Arya, S. and Bisla, S.S. 2001. Studies on phenology, breeding behaviour and interspecific hybridization in *Prosopis cineraria* (L.) Druce and *Prosopis juliflora* (Swartz) DC. *In: Abstracts of International Conference "Nature Farming and Ecological Balance"*, ISNF, CCS HAU, Hisar, India from March 7-10, 2001. pp.18.

Dhillon, R.S.; Bisla, S.S. and Tomar, R.P.S. 1995. Variability studies of seed characters in *Dalbergia sissoo* Roxb. *Indian Journal of Forestry* **18**: 53-55.

Dhillon, R.S.; Yadav, M.K.; Sompal and Singh, V.P. 2000. Studies on reproductive biology, interspecific hybridization in *Prosopis cineraria* (L.) Druce and *Prosopis juliflora* (Swartz) DC. *In: Abstracts and Souvenir National Seminar "Man and Forests"*, Department of Botany, Panjab University, Chandigarh from February 18-19, 2000. pp. 40.

*Distel, R.A. and Pelaez, D.V. 1985. Phenology of some species of the Calden (*Prosopis caldenia* Burk) district. *IDIA*. No.**441-444**: 35-40.

Dwivedi, N.K.; Bhandari, D.C. and Verma, S.K. 1997. Collecting *Prosopis cineraria* (L.) Mac Bride germplasm in western India. IPGRI. *Newsletter for Asia, the Pacific and Ocean* **22**:19.

Eldridge, E.G. 1976. Breeding system, variation and genetic improvement of tropical *Eucalyptus*. *In: Tropical trees, variation, breeding and conservation* (Eds. J.Burley and Style, B.T.). Academic Press, London. pp.101-108.

Evans, J. 1982. *Plantation Forestry in Tropics*. Oxford: Clarendon Press. 394 pp.

FAO. 1987. Seed Testing. *In: A Guide to Forest Seed Handling.* (Ed.Willan, R.L.) Food and Agriculture Organization of the United Nations, Rome. 379 pp.

*Felker, P. 1979. *In: New Agricultural Crops* (Ed. Ritchie, G.A.). AAAS Symposium Vol. 38, Westview Press, Boulder, Co.

Fisher, R.A. and Yates, Y. 1963. *Statistical Tables for Biological, Agricultural and Medicinal Research.* Oliver and Boyd. Ltd., Edinburgh: 146 pp.

Free, J.B. 1970. The effect of flower shape and nectar guides on the behaviour of foraging honey bees. *Behaviour* 37: 269-285.

Gamble, J.S. 1902. *A Manual of Indian Timbers*. Dehradun. 868 pp.

*Genise, J.; Palacios, R.A.; Hoc, P.S.; Carrizo, R.; Moffat, L.; Mom, M.P.; Agullo, M.A.; Picca, P. and Torregrosa, S. 1990. Observations on the floral biology of *Prosopis*.2. Floral phases

and visitors in the Chaqueno Serrano district. *Darwiniana* **30** (1-4): 71-85.

Gill, S.S. 1994. *Studies on insect pollination in phalsa* (*Grewia subinaequalis* D.C.). M.Sc. Thesis, CCS Haryana Agricultural University, Hisar (Haryana), India.

Ginwal, H.S.; Gera, M. and Srivastava, R.L. 1996. Seed source variability in some seed and seedling characteristics of twenty provenances of *Acacia nilotica* wild. ex. Del. *Range Management and Agroforestry* **17** (1): 49-59.

*Goda, S. 1987. Germination of *Acacia nilotica* seeds. *Sudan Silva* **6**: 25-32.

Goel,V.L.; Dogra, P.D. and Behl, H.M. 1997. Plus trees selection and their progeny evaluation in *Prosopis juliflora*. *Indian Forester* **123** (3): 196-205.

Gupta, S.K.; Pathak, P.S. and Debroy, R. 1983. Seedling growth of *leucaena leucocephala,* II. Effect of seed size. *Indian Journal of Forestry* **5** (3): 202-204.

Gupta, V.K. and Kumar, R.V. 1999. *Genetics and breeding of Azadirachta indica, Dalbergia sissoo, Acacia nilotica* and *Anogeissus* spp. Annual Report. National Research Centre for Agroforestry, Jhansi, pp.65-77.

Gupta, V.K. and Patil, B.D. 1988. Genetic variability and path analysis in *Leucaena* . *Indian Journal of Agricultural Science* **58**: 483-484.

*Halos, S.C. 1983. Casuarina in Philippines Forest Development. Casuarine Ecology, Management and Utilization (Eds. Midgles, S.S., Turnbull, J.W. and Johston, R.D.). *In: Proceedings*

International Workshop, Canberra, Australia, 17-21 August 1981. CSIRO, Canberra. pp. 89-98.

Haq, M.; Rafie-ul-din, M. and Ghaffar, A. 1978. Effect of insect pollination on fruit bearing in Kinnow mandarin (*Citrus reticulata*), and physical and chemical properties of the fruit. *Journal of Apiculture Research* **17**: 47-49.

Hare, R.C. and Switzer, G.L. 1969. Introgression with short leaf pine may explain rust resistance in western loblolly pine. *USDA For. Serv. Southern For. Expt. Sta. Res. Note* 50-88.

Harsh, L.N. 1985. *Provenance Trials of Different Trees Species*. FAO/ IBPGR Project. CAZRI Annual Report, pp. 58-59.

Hippolyte, I.; Campa, C.; Grigon, C.; Gueye, M. and Hamon, S. 1996. Glycosylated protein content of *in vitro* calluses of *Acacia senegal*. L' *acacia* au *Senegal. Actes de la reunion thematique sur l' acacia au Senegal*, Dakar, Senegal 3-5 decembre. pp. 273-283.

Hocking, D. 1993. *Trees for Drylands*. Oxford and IBH Publishing Company, New Delhi. pp. 279-282.

Hooda, M.S. and Bahadur, R. 1993. Variability, correlation and path co-efficient analysis for some seed traits in subabul (*Leucaena leucocephala*). *Seed Research* **21**: 16-18.

Huang, S.N. 1989. A note on genetic variation in seeds and seedling of five provenances of *Acacia auriculiformis*. *Journal of Tropical Forest Science* **1**: 401-404.

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 Cytology* **17**: 253-262.

Jatasara, D.S. 1982. Germplasm collections of *Prosopis cineraria* Mc Bride from the Indian desert. *Forage Research* **8**: 1-10.

Jindal, S.K.; Singh, M.; Solanki, K.R. and Kackar, N.L. 1991. Variability and changes in genetic parameters of height in juvenile progenies of *Tecomella undulata* (Sm.) Seem. *Journal of Tree Sciences* **10**: 25-28.

Johnson, H.W.; Robinson, H.F. and Comstock. 1955. Estimates of genetic and environmental variability in soybean. *Agronomy Journal* **47**: 314-318.

Kackar, N.L.; Solanki, K.R. and Jindal, S.K. 1986. Variation in fruit and seed characters of *Prosopis cineraria* (L.) Mac Bride in Thar desert. *Indian Journal of Forestry* **9**: 113-115.

Kandya, A.K. 1978. Relationship among seed weight and various growth factors in *Pinus oocarpa* Schiede seedlings. *Indian Forester*. **104** (8): 561-567.

Kaur, A.; Ha,C.O.; Jong, K.; Sands, V.E.; Chan, H.T.; Soepadmoa, E. and Ashton, P.S. 1978. Apomixis may be widespread among trees of the climax rain forest. *Nature* **271**: 440-441.

Kaushik, R.; Bangarwa, K.S. and Kumar, R. 1996. Provenance variation for seed and pod characters in *Acacia nilotica* subsp. *indica* (Benth.) Brenan. *Haryana Journal of Agronomy* **12** (1): 83-84.

Kedharnath, S. 1982a. Plus tree selection – a tool in forest tree improvement. *In: Improvement of Forest Biomass* (Ed. Khosla, P.K.). Indian Society of Tree Scientists, H.P. University, Solan (India). pp. 13-20.

Kedharnath, S. 1982b. Genetic variation and heritability of juvenile height growth in *Eucalyptus grandis*. *Journal of Tree Sciences* **1**: 46-49.

*Kenrick, J. and Knox, R.B. 1985. Self-incompatibility in the nitrogen-fixing tree, *Acacia retinodes*: quantitative cytology of pollen tube growth. *Theoretical and Applied Genetics* **69** (5-6): 481-488.

*Kenrick, J.; Kaul, V. and Knox, R.B. 1984. Self incompatibility and the site of pollen tube arrest in Australian species of *Acacia*. *Plant Cell Incompatibility. Newsletter* **16**: 3-4.

*Kenrick, J.; Kaul, V. and Williams, E.G. 1986. Self-incompatibility in *Acacia retinodes*: site of pollen tube arrest is the nucellus. *Planta* **169** (2): 245-250.

Khosla, P.K. 1985. *Genetic improvement of agroforestry trees. In: Agroforestry Systems – A New Challenge* (Eds. Khosla, P.K. and Puri, S.) Indian Society of Tree Scientists, Solan, H.P.: pp.151-160.

Khosla, P.K., Shamet, G.S. and Sehgal, R.N. 1982. Phenology and Breeding systems of *Bombax ceiba* Linn. *In: Improvement of Forest Biomass* (Ed. Khosla, P.K.), Indian Society of Tree Scientists, Solan, H.P.: pp. 41-49.

Khurana, D.K. and Khosla, P.K. 1979. Pollen viability and germination studies in some hardwood species. *Indian Journal of Forestry* **2**: 191-192.

Krishan, B. and Toky, O.P. 1996. Provenance variation in seed germination and seedling growth of *Acacia nilotica* spp. *indica* in India. *Genetic Resource and Crop Evolution* **43**: 97-101.

Kumar, N. 1993. *Evaluation of Albizia lebbek (L.) Benth from different provenances of India.* Ph.D. Thesis, Kumaun University, Nainital (U.P.) India.

Kumar, S. 1990. *Studies on insect pollination in ber (Zizyphus mauritiana Lamk.).* M.Sc. Thesis, CCS Haryana Agricultural University, Hisar (Haryana), India.

Kumar, R. 1998. *Variation in seed and seedling growth of half-sib progenies of Prosopis cineraria.* M.Sc. Thesis, CCS Haryana Agricultural University, Hisar (Haryana), India.

*Lacaze, J.F. 1978. Advances in species and provenance selection. *Unasylva* **30**: 17-20.

*Lajudie, P.De.; Williems, A.; Nick, G.; Moreira, F.; Molouba, F.; Hoste, B.; Torck, U.; Neyra, M.; Collins, M.D.; Lindstrom, K.; Dreyfus, B. and Gillis, M. 1998. Characterization of tropical tree rhizobia and description of *Mesorhizobium plurifarium* sp. *nov. International Journal of Systematic Bacteriology* **48** (2): 369-382.

*Langlet, O. 1967. *Regional Intraspecific variousness.* IUFRO Congress, Munchen, Germany, Vol. III: 435-458.

*Larsen, C.S. 1954. Provenance testing and forest tree breeding. *Proceedings* 11th *Congress. IUFRO, Rome:* 467-473.

*Lee, M.Y. 1967. Study of Swietenia (Meliaceae). An observation on the sexuality of flowers. *Journal of Arnold Arboretum* **55**: 269-290.

Lundkvist, K. and Rudin, D. 1977. Genetic variation in 11 populations of *Picea abies* as determined by isozyme analysis. *Heredita* **85**: 67-74.

Lush, J.L. 1949. Heritability of quantitative characters in farm animals. *Proceedings of the 8th International Genetics Congress 1948. Heredita* (Suppl.). 356-357.

Madoffe, S.S. and Maghembe, J.A. 1988. Performance of teak provenances seventeen years after planting at Longuza, Tanzania. *Silvae Genetica* **37**: 175-178.

Manga, V.K. and Sen David, N. 1996. Genetic parameters for seed traits in *Prosopis cineraria* (L.) Mac bride. *Indian Journal of Forestry* **19**: 148-151.

Marangoni, A. and Alli, I. 1988. Composition and properties of seeds and pods of the tree legume *Prosopis juliflora* (DC) *Journal of Food Science and Agriculture* **44** : 99-110.

*Masilamani, P. and Vadivelu, K.K. 1997. Seed development and maturation in honey mesquite (*Prosopis juliflora* Swartz. DC). *Bangladesh Journal of Forest Science* **26** (1): 68-73.

Mathew, G.; Koshy, M.P. and Mohanadas, K. 1987. Preliminary studies on insect visitors to teak (*Tectona grandis* Linn. F.) inflorescence in Kerala, India. *Indian Forester* **113** (1): 61-64.

Mathur, B.K. and Bohra, H.C. 1993. Nutritive value and palatability of *Prosopis juliflora* pods. *In: Proceedings of Conference "Prosopis species in the arid and semi-arid zones of India"*, CAZRI, Jodhpur, Rajasthan, India. pp. 117-119.

Mathur, R. and Bhatnager, P.S. 1992. Phenology of major plant species at Ambagarh Reserve Forest, Jaipur. *Indian Journal of Forestry* **15** (3): 224-228.

Medina, C. and Cardemil, L. 1993. *Prosopis chilensis* is a plant highly tolerant to heat shock. *Plant Cell and Environment* **16** (3): 305-310.

*Minessy, F.A. 1959. Effect of different pollinizers on yield and seediness in clementine tangerine. *Alexandria Journal of Agriculture Research* 7: 279-287.

Moffett, J.O. and Rodney, D.R. 1971. Honey bee visits to citrus flowers. *Journal of Arizona Academic Science* **6**: 254-59.

Muthana, K.D. 1988. *Prosopis juliflora* (Swartz) DC- a fast growing tree to blossom the desert. *In: Current State of Knowledge on Prosopis juliflora* (Ed. Mario, A. Hasif) FAO.

Nalawadi, U.G.; Farooqui, A.A.; Dasappa, M.A.; Reddy, N.; Sulikeri, G.S. and Nalini, A.S. 1973. Studies on the floral biology of Pomegranate. *Mysore Journal of Agriculture Sciences* 7: 213-225.

Natarajan, N. and Vinaya Rai, R.S. 1984. *Leucaena leucocephala: a few guidelines for quality seedling production.* IOB Farm Bulletin **3** (8).

NAS. 1979. *Tropical legumes: Resources for the future.* National Academy of Science: Washington, DC.

Nijjar, G.S. and Sandhu, B.S. 1971. A study on the fruit set problem in sweet lime (*Citrus limettioides* Tanaka). *Punjab Agricultural University Journal of Research* **8**: 411-415.

Pandey, B.P. 1999. The Dicotyledons. *In: Taxonomy of Agiosperms.* S.Chand and Company Limited, Ram Nagar, New Delhi 110 055. 600 pp.

Panse, V.G. and Sukhatme, P.V. 1978. *Statistical Methods for Agricultural Workers.* Third Edition, ICAR, New Delhi.

Pathak, P.S.; Gupta, S.K. and Debroy, R. 1980. Studies on seed polymorphism, germination and seedling growth of *Acacia tortilis* Hayne. *Indian Journal of Forestry* 3: 64-67.

Peters, T.M. 1988. *Insects and Human Society.* Van Nortrand Reinhold Company, New York. 450 pp.

Prus-Glowacki, W. and Rudin, D. 1981. Studies on antigenic proteins of *Pinus sylvestris* from six Swedish provenances – A pilot study. *Silvae Genetica* 30: 200-203.

Pyke, G.H.; Pultiam, H.R. and Chamov, E.L. 1977. Optimal foraging: selective review of theory and tests. *Quarterly Review of Biology* 52: 137-154.

Rai, P.; Solanki, K.R. and Singh, U.P. 2000. Growth and biomass production of multipurpose tree species in natural grassland under semi-arid condition. *Indian Journal of Agroforestry* Vol.2: 101-103.

Rai, U. 2000. Planting the right ideas. *The Hindu* (National Daily), Sunday Magazine, May 7: VIII.

Rawat, M.S.; Uniyal, D.P. and Vakshasya, R.K. 1987. Guidelines for the establishment of provenance trials of *Acacia nilotica, Azadirachta indica, Albizia procera, Dalbergia sissoo, Tamarindus indicus, Madhuca latifolia* and *Salix terasperma*. Indo-Danish Project on Seed Procurement and Tree Improvement Centre, Dehradun.

Rawat, M.S.; Uniyal, D.P. and Vakshasya, R.K. 1992. *Prosopis juliflora* (Swartz) DC.; fuel, fodder and food in arid and semi-arid areas: some observations and suggestions. *Indian Journal of Forestry* **15** (2): 164-168.

*Rehman, S.A. and Hussain, A. 1986. Growth and heritability estimates among 6-years old tree geographic source of Shisham (*D.sissoo*). *Pakistan Journal of Forestry* **36**: 67-72.

*Rehman, S.A.; Hussain, A. and Ameen, S. 1988. Results of early selection of *Acacia* and *Prosopis* species/seed sources. *Pakistan Journal of Forestry* **38**: 109-117.

*Robert, H.F. 1929. *Plant Hybridization Before Mendel*. Princeton Uni. Press, New Jersey, USA.

Rodriguez, J.G. and Cardemil, L. 1995. Tissue specific expression of cell wall proteins of seedlings of *Prosopis chilensis* during development and wound stress. *Physiologia Plantarum* **93** (3): 457-463.

Rohidas, S.B. and Chakrawar, V.R. 1982. Studies on floral biology of Nagpur mandarin. *Journal of Maharashtra Agricultural University* 7: 186-187.

*Saidman, B.O. and Vilardi, J.C. 1987. Analysis of the genetic similarities among seven species of *Prosopis* (Leguminosae: Mimosoideae). *Theoretical and Applied Genetics* 75 (1): 109-116.

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

*Sargent, C.S. 1947. *The Silva of North America.* Vol.III. Govt. Printing Office, Washington.

*Sedgley, M.; Harbard, J.; Smith, R.M.M.; Wickneswari, R. and Griffin, A.R. 1992. Reproductive biology and interspecific hybridization of *Acacia mangium* and *Acacia auriculiformis* A.Cunn. ex Benth. (Leguminosae: Mimosoideae). *Australian Journal of Botany* **40** (1): 37-48.

Sharma, N.K.; Burman, U.; Tewari, J.C.; Bohra, M.D. and Harsh, L.N. 1994. Variability studies in pod and seed characteristics of *Prosopis juliflora* (SW.) DC. *Indian Journal of Forestry* **17** (2): 161-165.

*Sharma, R.; Dakshini, K.M.M. and Sharma, R. 1996. Ecological implications of seed characteristics of the native *Prosopis cineraria* and the alien *P.juliflora. Vegetation* **124** (1): 101-105.

Sharma, S.K.; Chhillar, B.S. and Kaushik, H.D. 2001. Pollinating efficiency of three *Apis* species on *ber* (*Zizyphus mauritiana* Lamk.). *In: Abstracts of International. Conference "Nature Farming and Ecological Balance"*, ISNF, CCS HAU, Hisar, India from March 7-10, 2001. pp.72.

*Sheikh, M.I. 1988. Straight trees of *Prosopis juliflora* for desert afforestation. *Pakistan Journal of Forestry* **38**: 119-120.

*Sheikh, M.I. 1989. *Dalbergia sissoo* Roxb.: Its production, management and utilization in Pakistan. GCP/RAS/111/NET. Field Document No.21. FAO Publication.

Shrivastava, M.B. 1998. Management of the forest resource. *In: Introduction to Forestry.* Vikas Publishing House Private Limited, New Delhi. pp. 98-118.

Singh, G. and Singh, N.T. 1993. *Mesquite for the revegetation of salt lands*. Technical Bulletin No.18, CSSRI, Karnal, 24 pp.

Singh, M.; Jindal, S.K.; Solanki, K.R. and Kackar, N.L. 1991. Parent juvenile progeny relationship in *Prosopis cineraria* (L.) Druce. *Myforest* **27** (1): 39-44.

*Singh, R. and Chopra, S.K. 1997. Diversity and abundance of insect visitors of Citrus bloom. *In: Souvenir National Symposium on Citriculture*, November 17-19, 1997, NRCC, Nagpur (Maharashtra).

Singh, V., Bhagat, S. and Singh, O.B. 1990. Effect of seed weight on germination and initial seedling growth in Spruce (*Picea smithiana* Wall. Boiss). *Indian Forester* **116** (5) : 403-406.

Smith, A.C. 1985. *Flora Vitiensis Nova: A New Flora of Fiji.* Lawai, Kauai, Hawaii. *National Tropical Botanical Garden.* **Vol. 3**: 59-60.

Smith, J.S.C. and Smith, O.S. 1992. Finger printing of crop varieties. *Advanced Agronomy* **47**: 85-140.

Solanki, K.R.; Dieters, M.J.; Matheson, A.C.; Nikles, D.G.; Harwood, C.E. and Walker, S.M. 1996. Recent advances in genetic improvement of *Prosopis cineraria* in India. *Tree Improvement for Sustainable Tropical Forestry.* **Vol.2**: 412-415.

Solanki, K.R.; Jindal, S.K. and Kackar, N.L. 1989. Evaluation of germplasm of arid zone trees. *In: Proceedings of National Symposium on Forest Biology in the Service of Mankind*, H.P. University, Solan (India). pp. 17.

Solanki, K.R.; Jindal, S.K.; Muthana, K.D. and Kackar, N.L. 1985. Performance of *Acacia senegal* and *Prosopis cineraria* in Western Rajasthan. *Nitrogen Fixing Tree Research Reports* **3**: 27-28.

Solanki, K.R.; Muthana, K.D.; Jindal, S.K. and Arora, G.D. 1984. Variability, heritability and correlations for growth parameters in *Prosopis cineraria*. *Journal of Tree Sciences* **3**: 86-88.

Srivastava, R.P. and Singh, L. 1970. Floral biology, fruit set, fruit drop and physico-chemical characters of sweet cherry. *Indian Journal Agricultural Sciences* **40**: 400-420.

Surendran, C. and Chandrasekharan, P. 1984. Heritability variation and genetic gain estimates in half sib progenies of *Eucalyptus tereticornis*. *Journal of Tree Sciences* **3**: 1-4.

Suresh, K.K.; Jambulingam, R. and Sekar, I. 1997. Effect of seed sources on seed and seedling quality in *Acacia nilotica*. *Indian Forester* **123** (12): 422-426.

Suresh, K.K.; Jambulingam, R. and Sekar, I. 1998. Effect of situation on the phenology of *Acacia nilotica* (Linn.) Wild. ex. Del. *Van Vigyan* **36** (2-3-4): 78-81.

*Suri, P.N. and Seth, S.K. 1959. *Tree Planting Practices in Temperate Asia, Burma-India-Pakistan, Rome, FAO.* Forest Development Paper **14**.

*Teklehaimanot, Z. 1997. *Germplasm conservation and improvement of Parkia biglobosa (Jacq.) Benth. for multipurpose use.* Project Report. European Commission Directorate General XII Science, Research and Development. 166 pp.

*Tewari, J.C.; Bohra, M.D.; Sharma, N.K.; Burman, U. and Harsh, L.N. 1993. Pre-treatments to enhance germination of *Prosopis juliflora* seed. *In: Proceedings of a Conference "Prosopis species in the arid and semi-arid zones of India"*, CAZRI, Jodhpur, Rajasthan, India. pp. 39-41.

Thangaraja, A.; Kumar, N.S. and Ganesan, V. 1999. Pollinators of a mimosoid legume, *Acacia nilotica*. *Insect Environment* **5** (3): 119.

Thapliyal, R.C. 1986. A study of cone and seed in *Pinus roxburghii*. *Journal of Tree Sciences* **5**: 131-133.

Toky, O.P. 2000. Genetic diversity in three important agroforestry tree species of dry zone: a case study. *Indian Journal of Agroforestry* **2**: 43-47.

*Tozawa, M. 1924. Necessity of provenance test and the urgent need of a test plantation network. *Journal of Korean Forestry Association* **22**: 1-5.

Troup, R.S. 1921. *Silviculture of Indian Trees*: Oxford Clarendon Press.

*Tybirk, K. 1989. Flowering, pollination and seed production of *Acacia nilotica*. *Nordic Journal of Botany* **9**: 375-381.

*Tybirk, K. 1993. Pollination, breeding system and seed abortion in some African Acacias. *Botanical Journal of the Linnean Society* **112** (2): 107-137.

USDA 1975. Munsell Soil Colour Charts. Handbook No.**18**.

Vanangamudi, K.; Umarani, R.; Bharathi, A. and Venkatesh, A. 1998. Effect of seed source on physical and physiological qualities of *Acacia nilotica* seeds. *Seed Research* **26** (2): 114-116.

*Vansell, G.H. and Watkins, W.G. 1942. Nectar and pollen gathering by honey bees and other insects. *U.S. Dept. Agri. Circ.*

*Venkatesh, C.S. 1969. The early growth of certain half-sib progenies of *Bombax ceiba* L. Paper contributed to the FAO sponsored *Second World Consultation of Tree Breeding*, Washington, D.C.

*Venkatesh, C.S. and Vakshasya, R.K. 1977. Effect of selfing, crossing and interspecific hybridization in *Eucalyptus camaldulensis*. *Third World Consultation on Forest Tree Breeding*, Canberra.

*Vidakovic, M. and Siddiqui, K.M. 1968. Heritability of height and diameter growth in shisham (*Dalbergia sissoo*) using one parent progeny test. *Pakistan Journal of Forestry* **18**: 75-94.

*Villasenor, R.; Chiappa, E.; Covarrubias, R. and Toro, H. 1996. The problem of self-pollination in *Prosopis tamarugo* Phil (Mimosaceae). *Multequina* **5**: 33-42.

Volker, P.W.; Dean, C.A.; Tibbits, W.N. and Ravenwood, I.C. 1990. Genetic parameters and gains expected from selection in *Eucalyptus* in Tasmania. *Silvae Genetica* **39**: 18-21.

*Von Maydell, H.J. 1986. *Trees and Shrubs of the Sahel. Their characteristics and uses.* Deutsche Gesellschaft fuer Technische Zusammenarbeit, Eschborn, Germany.

*Wakeley, P.C. 1954. The relation of geographic race to forest tree improvement. *Journal of Forestry* **52**: 653.

Watson, L. and Dallwitz, M.J. 2001. *Ecology and Evolutionary Biology Conservatory of Prosopis juliflora (Swartz) DC.* Ecology and Evolutionary Biology Conservatory and Gardens, 75 North Eagleville Rd., Unit 3043, Storrs, C.T. 06269-3043.

Wojtusik, T.; Felker, P.; Rusell, E.J. and Benge, M.D. 1993. Cloning of erect, thornless, non-browsed nitrogen fixing trees of Haiti's principal fuelwood species (*Prosopis juliflora*). *Agroforestry Systems* **21** (3): 293-300.

Wright, J.W. 1976. *Introduction to Forest Genetics.* Academic Press, New York.

Yadav, A. 1996. *Leaf isoenzymes studies in different provenances of Prosopis cineraria (L.) Druce.* M.Sc. Thesis, CCS Haryana Agricultural University, Hisar (Haryana), India.

Yadav, S.S. 1993. *Studies on extent of variation and association among various seed parameters in relation to tree girth in Dalbergia sissoo.* M.Sc. Thesis, CCS Haryana Agricultural University, Hisar (Haryana), India.

*Zapata, T.R.; Arroyo, M.T.K.; Masuelli, R.S. and Balboa, O. 1989. Self-incompatibility in *Prosopis flexuosa* D.C. *Plant Cell Incompatibility. Newsletter* **21**: 44-48.

Zobel, B.J. and Talbert, J.T. 1984. *Applied Forest Tree Improvement.* John Willey and Sons, New York. 505 pp.

**Original not seen*

Year	Month	Temperature (°C)		Relative humidity (%)		Wind speed (KMPH)	Total rainfall (mm)	Rainy days (Nos.)	Sunshine (h)
		Max.	Min.	0727 h	1427 h				
1999	August	36.4	24.6	75	47	6.6	72.2	6	8.7
	September	36.6	23.7	75	46	5.7	4.0	1	8.6
	October	34.6	15.8	78	30	2.6	0	0	8.3
	November	30.4	9.0	76	22	2.7	0	0	8.1
	December	23.6	3.7	90	38	1.8	0	0	6.1
2000	January	18.4	5.4	91	61	5.3	8.3	1	5.2
	February	20.3	6.0	93	62	4.6	10.7	3	6.6
	March	29.0	9.5	80	32	4.9	0	0	8.6
	April	38.8	17.5	52	15	5.2	0	0	9.5
	May	41.5	25.5	48	23	11.5	4.0	1	6.0
	June	39.5	28.5	63	36	11.5	48.9	4	4.6
	July	35.6	25.2	77	55	9.0	59.9	8	5.3
	August	36.7	24.9	75	49	8.6	8.7	2	7.9
	September	36.5	21.3	70	43	5.4	4.7	1	9.2
	October	36.5	14.8	71	24	2.9	0	0	9.3
	November	29.5	8.9	80	28	3.3	0	0	7.6
	December	24.4	3.1	86	29	2.8	0	0	8.2
2001	January	18.2	3.0	94	55	3.5	15.0	1	5.9
	February	24.5	5.6	88	33	4.3	9.2	1	8.7
	March	30.0	9.5	82	29	4.5	0	0	8.6
	April	35.6	16.4	59	24	5.6	46.6	4	7.9
	May	40.2	22.9	58	28	9.7	102.7	7	6.9
	June	36.3	23.3	77	54	8.4	168.7	10	6.9
	July	34.8	24.5	82	64	7.4	209.8	9	6.2

Monthly meteorological data during research period (August 1999 to July 2001) at Hisar

ABSTRACT

a)	Title of the Thesis	:	**Studies on genetic diversity and reproductive biology of *Prosopis juliflora* (Swartz) DC.**
b)	Full name of the student and Admission No.	:	**Deepak Chopra** **98 A 83 D**
c)	Title of degree	:	**Doctor of Philosophy in Agroforestry**
d)	Name and Address of the Major Advisor	:	Dr. M.S.Hooda Senior Scientist Department of Forestry CCS HAU, Hisar-125 004 (India)
e)	Degree awarding University	:	CCS Haryana Agricultural University, Hisar –125 004 (India)
f)	Year of award of degree	:	2001
g)	Major subject	:	Agroforestry
h)	Total number of pages in thesis	:	185 (117 + 21 Bibliography + 30 Tables + 11 Plates + 4 Figures + 2 Flow chart + 1 Appendix)
i)	Number of words in the abstract	:	560

The present investigation was carried out to study the seed source variation, progeny testing and reproductive biology in *Prosopis juliflora* (Swartz) DC. Seeds of *P.juliflora* were collected from 18 different seed sources of Haryana, Punjab, Rajasthan and Uttar Pradesh during the month of June, 1997 and the work was conducted at CCS Haryana Agricultural University, Hisar. Large amount of variability existed for all the seed parameters except seed shape. The differences due to seed sources were significant for all the parameters. On the basis of 100-seed weight, SS-10 (Mohannagar) was found as the best seed source followed by SS-5 (Bhatinda) and SS-18 (Hisar). The 100-seed weight showed significant positive correlations with seed length and thickness. Banding pattern of total seed protein showed large amount of variation between different seed sources. Total number of bands resolved varied from 15 to 24 among seed souces of *P.juliflora*. The seed sources SS-17 (Kurukshetra) and SS-18 (Hisar) indicated their closeness which might be due to their common parentage or accumulation of similar genes from different parents.

The progenies of 18 seed sources, transplanted at 6 x 3 m spacing were analysed at 3rd and 4th year of their growth (during 2000 and 2001) for various seed, pod and

growth parameters. The progenies varied significantly during both the years for all the parameters. Large amount of genotypic variability was observed for all the seed, pod and growth parameters. The progenies PT-112 (Pilibanga), PT-107 (Karnal) and PT-111 (Solani River) performed better for growth parameters. Similarly, PT-113 (Sardargarh), PT-110 (Mohannagar), PT 107 (Karnal) and PT 116 (Dabwali) performed better for seed and pod parameters. The heritability was observed higher for weight/pod and pod thickness during both the years. The pod length had significant positive correlation with weight/pod, seed weight/pod, pulp weight/pod and number of seeds/pod. Therefore, selection of these parameters would be effective.

In *P.juliflora* studies on reproductive biology during 2000 and 2001 showed that in spring season, flowering was at low rate initially during mid of March, and it increased to peak during end of March and continued up to mid of May. Inflorescence is racemose-spike. Floral formula is: $Br \oplus \overset{\nearrow}{\varphi}\ K_{(5)}, C_5, A_{10}, \underline{G_1}$. Spike initiation to completion of elongation took place between 10 to 13 days during both the years. Similarly, duration of pod setting to pod ripening varied from 35 to 37 days and 33 to 36 days, during 2000 and 2001, respectively. Flower showed herkogamy as well as dichogamy (protogyny). Total 11 insect species were observed on spikes of *P.juliflora*. The maximum mean abundance of all the *Apis* species was at 1200-1300 h. Different reproductive methods showed a high degree of self-incompatibility and cross-pollinated behaviour of *P.juliflora*. The quality of seeds and pods obtained through open pollination, open pollination after emasculation and enforced allogamy was much better and they also gave vigorous seedlings as compared to seed and pods obtained through selfing in muslin cloth bag and enforced geitonogamy. Therefore, seeds obtained through open pollination, open pollination after emasculation and enforced allogamy can be used to get improved plant types. The similarity values derived from electrophoresis of total seed protein of the seeds (of same mother tree) obtained through five different reproductive methods confirmed cross-pollination in *P.juliflora*. The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients, which indicated a strong inherent association between the various characters studied.

MAJOR ADVISOR

PROFESSOR & HEAD

SIGNATURE OF THE STUDENT