CHAPTER I

REVIEW OF LITERATURE

I. Review of literature on *Prosopis juliflora*:-

In order to understand basic problems involved in the investigation, a brief review of literature on various aspects of *Prosopis juliflora* is necessary.

a) Distribution in world:-

Prosopis juliflora is distributed widely in Asia, Africa and Australia. In Asian sub continent *Prosopis* is distributed in following countries such as Jordhan, Saudi Arabia, United Arab Emirate, Iran, Kuwait, India, Pakistan, Sri Lanka, Myanmar, Cambodia, Thailand, Vietnams, Indonesia and Philippines.

In the African Subcontinent it is recorded in following countries such as Morocco, Algeria, Tunisia, Libya, Egypt, Senegal, Gambia, Mali, Niger, Namibia, and Zimbabwe. Occurrence of this species is also reported from Australia, New Guinea and Marquesas Island according to (Burkart, 1976; Poynton,1990 and Perry,1998).

i) Distribution of *Prosopis juliflora* in India:-

Luna (1996) reported the first introduction of *Prosopis juliflora* from Mexico in 1857. But Muthana and Arora (1983) and Dubey (1998), have expressed the opinion that first introduction of *Prosopis juliflora* in Sindh took place in 1877.

According to Gurumurthi *et al.,* (1984) and Patel (1986), *Prosopis juliflora* is spread in different states such Andhra Pradesh, Karnataka, Maharashtra, Orissa, Punjab, Uttar Pradesh, Tamil Nadu, West Bengal and almost all district of Haryana and Gujrat. *Prosopis juliflora* was introduced in Rajasthan

state in 1913 (Muthana and Arora,1983). In 1940 *Prosopis juliflora* was declared as 'Royal plant' by government of Rajasthan and directives were issued to protect the plants in this dry state.

b) Botany

i) Systematic Position:-

In 1940 Burkart Pùthforth the authority Swartz. The species *juliflora* was first reported in India by Reddy (1978) from Andhra Pradesh. Raizada and Chatterji (1954) stated that *Prosopis juliflora* was introduced from Mexico in India in 1871. The systematic position of *Prosopis juliflora* is as follows

Kingdom	-	Plantae
Division	-	Angiosperm
Series	-	Chilensis
Family	-	Fabaceae – Mimosidae
Genus	-	*Prosopis*
Species	-	*juliflora*

ii) Vernacular names:-

There are several vernacular names for *Prosopis juliflora* in India. These are given below

Hindi - Vilayati babul

Gujarathi - Vilayati khejra, Gondo baval.

Tamil - Vill karavel or Velimulla

Marathi - Vilayati kikar, Vedi babhul.

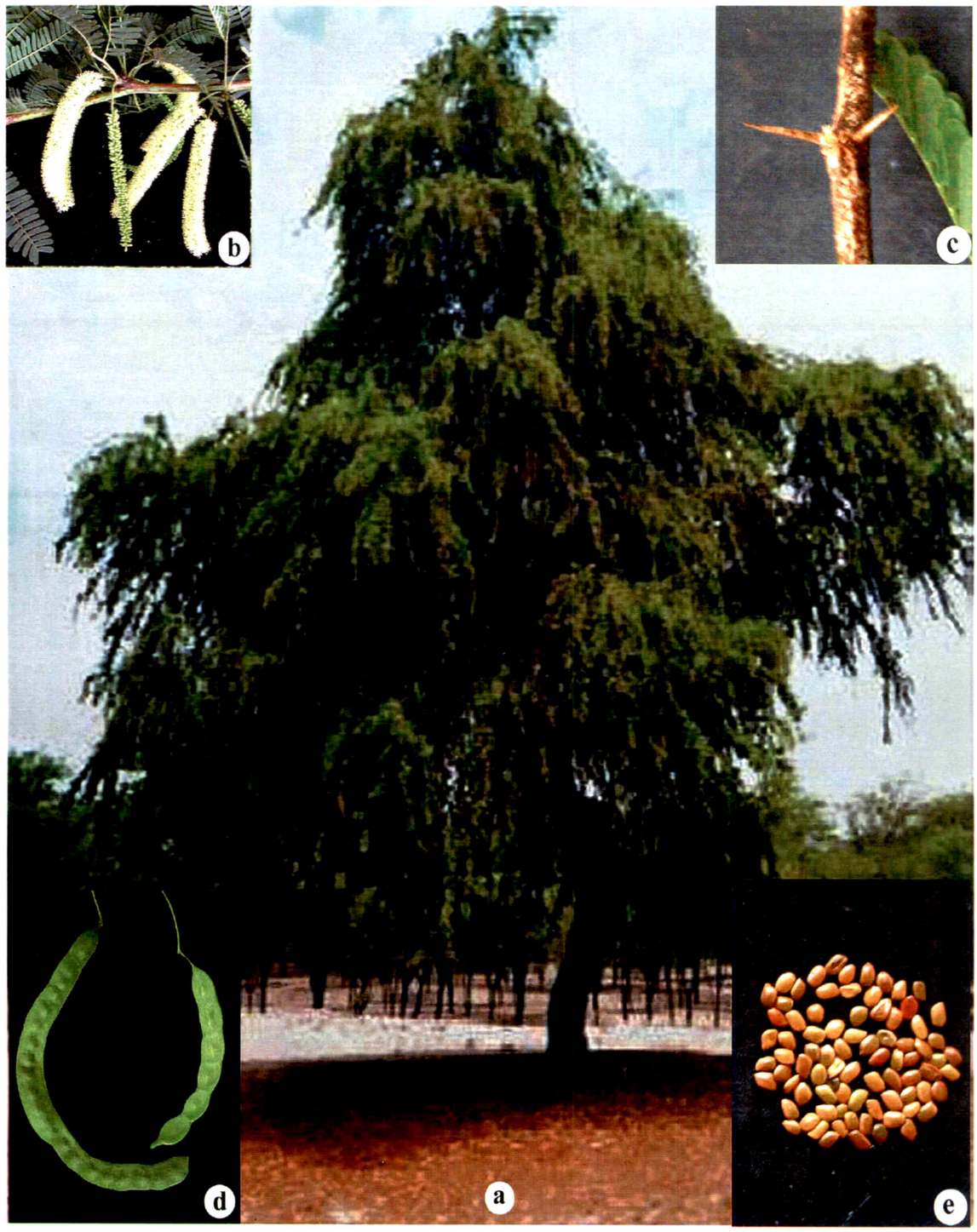

Plate: I: *Prosopis juliflora* (Swart) Dc.: **a:** Habit; **b:** Infloresence; **c:** Thorns; **d:** Pods; **e:** Seeds.

iii) Habit:-

Prosopis juliflora is an evergreen plant with large crown. It is a small spreading shrub or tree about 3 to 8 m tall with a rounded flattened crown. Under favorable conditions it can grow up to 20 m (Singh and Singh, 1993). At early stage of growth the plant grows in prostrate form (Stewart *et al.,* 1993).

iv) Root system:-

Well developed tap root system is a characteristic feature of *Prosopis juliflora.* There are two types of root systems, deep root system and superficial root system. Root can penetrate deep into the soil up to 45 cm in 70 days (Gupta and Balaro, 1972). Deep root system functions in anchoring the plant. Due to impermeable nature of sub soil layer tap root extension is stopped and lateral extension of root takes place (Singh and Singh,1993).

v) Stem:-

Stem is brown in colour. The bark is grey-brown and fibrous varying from finely fissured to furrowed. Spines are axillary in position, present in pairs on young branches which are about 0.5 to 5 cm long and 2.5 cm in diameter.

vi) Leaves:-

Leaves are bipinnately compound 1-10 leaves per node. 5.20 cm long (Diaz Celis, 1995). Leaf-lets are elliptically oblong and most often glabrous. The leaf-lets are occasionally pubescent. Mostly *Prosopis juliflora* is evergreen plant, but due to environmental stresses such as drought or cold leaf senescence may takes place (Johnston, 1962).

vii) Flowering:-

Under favorable condition flowering takes place in first or second year but during unfavorable conditions flowering takes place after 3-5 years of growth (De Oliveira and Pires, 1990). Time duration for flowering is about 4 years from plantation in India (ICFRE 1993). On an average tree began flowering and fruiting in the third year of planting. The time of first flowering is important from the point of view of production of sweet protein rich pods.

Flowers are in spike type of inflorescence, commonly termed racemose. These are yellow to yellowish white in colour. They are hermaphrodite, actinomorphic and pentamerous (Burkart, 1976). Flowers consist of calyx which is green to green yellow in colour, bell shaped and less than 1.5 mm length. The corolla is 3 to 3.2 mm long. There are five stamens which are 4-7 mm long. Ovaries are light green in colour and length of pistil is about 4-5 mm.

Floral formula- **[Ebr, ⊕, $\overset{\sigma}{\varphi}$, K_5, C_5, $A_{(4+4)}$, $\underline{G}_1$ basal]**

viii) Pod:-

The plant produces fruits every year and can be termed as 'unfailing crop' (Simpson *et al.,* 1977). There is great variation in pod size and number of pods produced per inflorescence. The pod is non-dehiscent usually flattened and straight. It is curved or sickle shaped with a coraceous mesocarp divided into several segments. The seeds are rounded , prominences in the middle of the pod. At maturity, the pod become swollen and pulpy. Seeds are compressed, hard and

dark brown with mucilaginous endocarp surrounding the embryo. The cotyledons are flat.

ix) About *Prosopis*:-

The name '*Prosopis*' is derived from Greek word 'Pro' meaning towards and 'opis' means Wife of saturn. This genus was first discovered by Linnaeus in 1767. So far about 44 species of *Prosopis* have been described by Burkart (1976). These are as follows

I. Section *PROSOPIS*

1) *Prosopis cineraria* (L.)

2) *Prosopis farcta* (Solander ex Russell) Mac Bride

3) *Prosopis koelziana* (Burkart)

II. Section ANONYCHIUM

4) *Prosopis africana* (Guill, Perr. & Rich) Toubert.

III. Section STROMBOCARPA

Series:- Strombocarpae

5) *Prosopis strombulifera* (Lam) Bentham

6) *Prosopis reptans* Bentham

7) *Prosopis abbreviata* Bentham

8) *Prosopis torquata* (Cavanilles ex Lagasca) DC

9) *Prosopis pubescens* Bentham

10) *Prosopis palmeri* S.Watson

11) *Prosopis burkartii* Mun˜oz

Series: Cavenicarpae

12) *Prosopis ferox* Grisebach

13) *Prosopis tamarugo* F. Philippi

IV. Section MONILICARPA

14) *Prosopis argentina* Burkart

V. Section ALGAROBIA

Series: Sericanthae

15) *Prosopis sericantha* Gillies ex Hooker & Arnott

16) *Prosopis kuntzei* Harms

Series : Ruscifoliae

17) *Prosopis ruscifolia* Grisebach

18) *Prosopis fiebrigii* Harms

19) *Prosopis vinalillo* Stuckert

20) *Prosopis hassleri* Harms.

Series: Denudantes

21) *Prosopis denudans* Bentham

22) *Prosopis ruizleali* Burkart

23) *Prosopis castellanosii* Burkart

24) *Prosopis calingastana* Burkart

Series: Humiles

25) *Prosopis humilis* Gillies ex Hooker & Arnott

26) *Prosopis rojasiana* Burkart

Series: Pallidae

27) *Prosopis rubriflora* E.Hassler

28) *Prosopis campestris* Grisebach

29) *Prosopis pallida* (Humboldt & Bonpland ex Willd.) H.B.K.

30) *Prosopis affinis* Sprengel

31) *Prosopis articulate* S. Watson

32) *Prosopis elata* (Burkart) Burkart

33) *Prosopis tamaulipana* Burkart

Series: Chilenses

34) *Prosopis chilensis* (Molina) Stuntz emend. Burkart

35) *Prosopis juliflora* (Swartz) DC.

36) *Prosopis nigra* (Grisebach) Hieronymus

37) *Prosopis caldenia* Burkart

38) *Prosopis laevigata* (Humboldt & Bonpland ex Willd)

39) *Prosopis flexuosa* DC

40) *Prosopis glandulosa* Torrey

41) *Prosopis alpataco* R.A.Philippi

42) *Prosopis alba* Grisebach

43) *Prosopis velutina* Wooton

44) *Prosopis pugionata* Burkart

c) Cytology:-

The basic chromosome number in species *Prosopis juliflora* is n= 14 i.e., (2n=28) according to Bandyopadhyay *et al.,* (1990). At the same time in some instances tetraploids in *Prosopis juliflora* have been noticed (Hunziker *et al.,* 1975). Kumar *et al.,* (1998) have reported that, plant shows high level of phenotypic differences or variation in morphological characters. Phenological variation beings a combination of both clonal variation in response to broad climatic factor and ecotypic (discontinuous) variation in response to disjunct environment factor (Burley *et al.,* 1986) such as effect on leaf morphology and change in stomatal density (Graham,1960; Hilu *et al.,* 1982).

d) Anatomy

i) Wood anatomy:-

Extensive work on the *Prosopis* wood anatomy has been done by Kazmi and Singh (1992). According to Gomes and De Muniz (1990) wood is of diffuse porous type with growth rings. Kazmi and Singh (1992) also reported that growth rings are demarcated by fibrous tissue by dark zone which shows presence of parenchyma cells under microscope. Vessels are present at the beginning of growth rings. These are small or large. They are solitary or radial in multiples of two or four vessels. Vessel elements are very short. Perforation plates are simple (Gomes and De Muniz, 1990). Inter vascular pits are present which are alternate and circular to elliptic. Numerous parenchyma cells are present around the vessels. They are fusiform and seriate in strands of 2-4 cells. Rays are broad, mostly wide

and generally 4-5 seriate. Fibres are more with 1.0-1.2 mm length and 0.014 mm in diameter (Rajput and Tewari, 1986). Fibres are angular aligned some what radially in transverse section with a pit on the wall mostly distinct on radial wall. Microscopic analysis reveals that the wood is composed of fibres (48 %), vessels (18 %), Rays (18 %), axial and parenchyma (16 %).

e) Diseases:-

Following diseases of *Prosopis juliflora* have been listed by Srivastava and Mishra (1998).

i) Root knot disease-

Causal organism- *Fusarium spp*

It is observed during rainy season when seedlings are 1to 3 months old.

Symptoms:-

Wilting of the leaves. Diseased seedlings could be uprooted easily due to the rotting of the root and the phloem region could be peeled offeasily with xylem vessel appearing black in colour.

Control measures:-

It can be controlled by avoiding excessive humidity and soil drenching with Bavistin (0.1 %).

ii) Collar rot disease:-

Causal organism:- *Macrophomia phaseoli*

Symptoms:-

The fungus attack the collar region which eventually become black due to black pycnidia. They mostly infect during seedling stage and seed dies.

iii) Stem canker:-

Causal organism:- *Botryodiplodia theobromae.*

Symptoms:-

Fungus enters plant body through natural opening or physical injuries. It mainly affects the quality of sap wood or sap wood deterioration takes place.

Control measure:-

It can be minimized by reducing excessive lopping and other physical injuries.

iv) Leaf blight:-

Causal organism:- *Septoria prosopides*

Symptoms:-

Appearance of light yellow to green colour lesion on the leaf-lets some time complete defoliation takes place during severe stage of infection. Disease development favored by high humidity.

Control measures:-

Copper containing fungicides such as Blitox.

v) Twig blight and Die back

Causal organism:- *Diplodia prosopides*

Symptoms:-

Young shoots usually injured by shoot borer were found to be susceptible to this pathogenic fungus.

According to Yousuf and Gaur (1998) *Prosopis juliflora* is subjected to attack of following pests.

1) *Oxyrachis tarandus* (Hemiptera)
2) *Aleyrodids spp* (Hemiptera)
3) *Poekilocerus pictus* (Orthoptera)
4) *Hayls dentatus*
5) *Homoecocerus signatus* (Hemiptera)
6) *Drosicha spp* (Hemiptera)

f) Economic importance:-

Prosopis juliflora is a multipurpose plant of great economic potential. The ability of this species to grow on the poorest soil and under very arid conditions and on saline soils is well known.

i) Biomass:-

It is one of the valuable species of desert ecosystem, which produce about 25 to 30 ton/ha/year biomass within short period of duration within 4-5 years (Patel, 1986). Government of Gujarat have undertaken large scale production of charcoal from *Prosopis juliflora* and giving a good opportunities of employment to local people. By burning the thick root and stem under anaerobic condition charcoal is prepared, because of its superior quality it is considered as

one of the best charcoal (Vimal and Tyagi, 1986). Nearly about 3-6 kg of wood is required to produce 1 kg of charcoal. Thus, thousands of families have been benefited by preparing charcoal from *Prosopis*. The specific gravity of charcoal is about 0.70 and calorific value is 4800 K cal/ Kg (Vimal and Tyagi, 1986 and Varshney, 1995).

ii) Leaves as Animal fodder:-

Due to presence of adequate amount of nutrients of mineral elements, lignin, cellulose and high level of crude proteins and crude fibres and high digestibility leaves are the best source of animal feed.

Table: Nutrient composition of *Prosopis juliflora* leaves (Vimal and Tyagi, 1986)

Crude protein %	Crude Fiber %	Ether Extract (Fat)	Ash %	Nitrogen free extract %
26.3	24.8	8.5	1.4	31.8

iii) Pods:-

The pods are collected twice in a year during winter and summer season. Large number of pods are produced in the month of March and June (Shukla *et al.*, 1984). Pods are sweet and nutritious containing unpalatable chemicals, possessing digestibility and they play role as a source of nutrition for animal (Raizada and Chatterji, 1954 and Mooney *et al.*, 1977). According to Vimal and Tyagi (1986), chemical constituents of dried pods are fat (42 %), Fibre (16.8 %), Protein (16.5 %), Carbohydrates (57 %) and ash (5.4 %). The calcium

and phosphorus content in the ash are 0.33 % and 0.44 % respectively. Nearly about 13 % glucose is present in the pod and can be used in the preparation of biscuits. At the time of natural calamaties pods are used as food by poor people. Proteins have been isolated from the seeds which become useful for making the breads (Baiao *et al.,* 1987). Caffee substitutes has been made from *Prosopis juliflora* pod in Brazil (Azevedo, 1987). Ripened pods are used for making alcoholic beverages (Mesquitabole, Mesquite wine). Since, the pod contains high sugar Santos and Pereira (1986) used *Prosopis* pods instead of dextrose in culture media for growing various fungi. The proportion of culture media is Potato-200g, *Prosopis juliflora* pod 31 g boiled in 300 ml water for 30 min.Add agar 15 g D.W.- 1000 ml.

iv) Gum:-

The plant secretes translucent yellow colored gum. It is having low viscosity and water soluble. Anderson and Farquhar (1982) stated that gum consists of different type of sugars such as D-galactose (45 %), L-arabinose (24 %), L-rhamnose (13 %) and glucaromic acid (13.7%). In India the gum is used for the preparation of sizing cloth and as a paper adhesive (Vimal and Tyagi, 1986). Nearly about 1-2 kg *Prosopis* gum can be collected by a single person / day in India (Tewari, 1998). Maximum amount of gum is produced in the months of April and May in India.

v) Honey:-

In *Prosopis juliflora* flowering is induced twice in a year. At the time of flowering sweet nector is produced containing very high levels of proteins and sugar. *Prosopis* honey accounts for about 90 % of the total production of the state in Kachchh district (GSFDC records). There is symbiotic association between a rare species of honey bee *Apis floriea* found in Kachchh district only because of peculiar climate and environment condition. According to Central Bee Research and Training Institute (CBTI) Pune, Honey collected by *Apis floriea* is of good quality with 'A' grade and widely used in medicine (Varshney, 1996). Wax is separated though filtration from *Prosopis* honey and it is mostly used in creams, painbalms and medicines.

vi) Medicinal uses:-

Every part of this plant is used in the preparation of medicine. By boiling the wood chips an astringent decoction is made. From the bark extract antiseptic is prepared for healing wounds. Gum is used to cure the eye infection in India (Vimal and Tyagi, 1986). *Prosopis* plant extract is widely used to cure stomach disorder, as skin ointments on superficial wounds. *Prosopis juliflora* is used to treat sexually transmitted disease in Guatemala (Caceres *et al.*, 1995).

vii) Bio – control agent:-

Prosopis juliflora leaf extract is found to be effective against insects, nematodes, pathogens, fungi and viruses. Juliflorine is isolated from this plant and had tetratogenic effect on larvae pupae and adult of the common house fly (Jahan

et al., 1990). Leaf extract has also been found effective against pathogenic fungi, *Rhizoctonia Solani* can be controlled positively (Sundarraj *et al.,* 1996). Diseases caused by *Helminthosporium* are checked by the leaf extract (Valluvaparidasan, 1994). Leaf extract is also effective against some viral diseases such as cowpea aphid-borne mosaic virus (Kannan and Doraiswamy, 1993). Allelopathic effects of *Prosopis juliflora* is also seen on different plant species especially weeds. Dhawan and Gupta (1996) noticed a reduction in seed germination of *Parthenium hysterophorus* due to its leaf extract.

viii) Enrichment of soil fertility:-

Aggarwal *et al.,* (1976) studied soil fertility changes under a 15 years old stand of *Prosopis* and found enrichment of organic matter and macro and micro nutrients. Only iron level was lowered. This is co-related with open field situation. Singh and Lal (1969) also reported a significant importance of *Prosopis* in the improvement of fertility status of soil under *Prosopis juliflora* in arid regions.

Leaves are highly rich in mineral content and leaves are smaller in size, which can be easily decomposed having an ameliorating effect on the soil. Leaf fall and early decomposition play important role in reducing soil salinity (Aggarwal and Lahiri, 1977; Sharma and Gupta, 1989).

ix) Soil Conservation:-

Along with the improvement in soil fertility the tree play important role in soil binding process and the reduction in the eroding action of both water

and wind. Gupta *et al.,* (1983) observed a 36 % reduction in the magnitude of wind erosion behind a *Prosopis juliflora* shelter belt in west Rajasthan.

G) Physiological studies

1) Seed germination:-

Seed germination represent oneof the most important and critical phase in the life cycle of every plant species. Seed of *Prosopis juliflora* is very hard. To stimulate germination, hard seed coat must be brokened or weakened for the absorption of water (Catalan and Balzarini, 1992). Nearly about 90 % of seeds germinate when they are freshly harvested, because seed coat is not hard. Older seeds which are viable, can germinate withouf pre treatment (Pasiecznik and Felker, 1992). Killian (1990) stated that there is no differentiation between closed and open endocarps and mentioned that there is significant increase in germination when endocarp is removed. An allelopathic chemical extracted from pod pericarp was found to decrease germination in *Prosopis juliflora* (Warrag, 1994).

Important factors which influences seed germination process are soil moisture, water quality, available nutrients, temperature and depth of seed sown in the soil. Thirty degree Celsius is the optimum temperature for germination of *Prosopis juliflora* seeds. As temperature decreasesgermination is also decreases and germination is also affected when temperature is above 35^0C (Sundararaj *et al.,* 1966). According to Mutha and Burman (1998), optimum sowing depth for

seed is 10 mm, as the depth of sowing increases germination declined markedly at about 20-30 mm depth. According to El-Sharkawi *et al.,* (1997), under unfavorable condition like drought insufficient nutrient supply and high temperature there was direct effect on allocation of sugar and carbohydrates in germinating *Prosopis juliflora* seeds.

2) Growth:-

Growth is the complex process which involved a series of physiological events and which are influenced by number of endogenous and environmental factors. The capacity of biomass production of *Prosopis* plant is high and it has good ability to grow on poorest soil and under very arid condition where few other species survives (Pasiecznik *et al.,* 2001). Few growth studies in *Prosopis* species have been carried out in controlled atmospheric conditions and effect of different features on growth has been investigated.

Based on long term field trial Singh (1995) concluded that planting *Prosopis* species by augerhole technique growth, biomass and productivity was significantly more as compared to traditional pit and trench planting method. Pasiecznik *et al.,* (2005) studied growth and flowering habit of *Prosopis* species under two different atmospheric condition, such as temperature at 20° and 15°C respectively light photon flux of 180-210 μ mol $m^{-2}s^{-1}$ at bench level and relative humidity was minimum of 70 % , seedling raised in first experiment grew rapidly and reached mean of 92 cm in height with 35 nodes after 3 months, while in second experiment plant grown in cooler climate seedling attempt a mean height

of 45 cm with 15 nodes after a similar time period. They also concluded that flowering commenced after 169 days under controlled climatic condition.

According to Bhatia *et al.,* (1998), there was a significant increase in biomass when *Prosopis juliflora* was inoculated with *G caledonius* alone. There was also significant increase in plant height as compare to controlled (non-inoculated) plants. Singh *et al.,*(1996) reported the effect of soil pH and growth performance and biomass production of *Prosopis juliflora* and *Prosopis alba* in comparison to other salt tolerant woody species such as *Dalbergia sissoo, Terminalia arjuna, Pongamia pinnata, Acacia nilotica* within a microplot for a period of 28 months. Based on 28 month data above species were arranged according to their growth response and biomass production in a soil pH-10. *Prosopis* species showed maximum growth and biomass as compared to other species.

Bhatia *et al.,* (1998) studied biomass production during 120 days. Greater increment in biomass in mesquite seedling occurred during first 80 days, while little growth was added during last 40 days. Seedlings produced a greater biomass after 120 days when supplied with 67 % ammonia and 33 % nitrogen.

3) Photosynthesis:-

According to Nilsen *et al.,* (1981) all the *Prosopis* species are phreatophytes. As the quantum yield decreases the rate of photosynthesis also decreases in *Prosopis* leaves (Siftel *et al.,* 1993). Gas exchange studies (Pathre *et al.,* 1995) observed that during the period from July to October *Prosopis juliflora*

shows typical mid-day depression of net photosynthetic rate and stomatal conductance. Shirke (2001) reported that the rate of photosynthesis is high in winter season where there is cold night (2-8^{0}C) and moderate temperature during day time. While in summer photosynthesis is inhibited due to increase in mid-day temperature. Seasonal studies of photosynthetic parameters showed that only in late monsoon *Prosopis juliflora* and *Prosopis deltoids* exhibit typical mid-day depression of gas exchange. A feed back inhibition of photosynthesis by accumulation of carbohydrates was suggested as a possible reason for such depression by Azcon-Bieto (1986) and Foyer (1988).

Pathre *et al.,* (1998) found that VPD is important than temperature or photosynthetic flux density (PPFD) in causing mid day depression in net photosynthesis and stomatal conductance in *Prosopis juliflora.* Shirke and Pathre (2004) reported that high VPD is responsible for decline in RUBISCO activity affecting carboxylation efficiency and reduction in sucrose and starch content because of decrease in the activity of sucrose phosphate synthatase. These workers concluded that the plant can stand with high VPD by reducing metabolic activity by effective adjustment in the partition of electron flow between assimilation and non assimilation process which in turn imposed a strong limitation on the potential carbon gain. Krause *et al.,* (1995) observed higher photoinhibition in young leaves of *Prosopis juliflora* than that of mature leaves and it is because of young leaves in tropical forest having canopy which were more susceptible to high irradiance. Shirke (2001) studied that photosynthetic characteristic of young,

mature and old leaf of *Prosopis juliflora.* According to them maximum rate of photosynthesis of young leaves is less as compared to mature and old leaves. In young leaves total CO_2 fixation per day was 36 % that in mature leaves, while CO_2 fixation of old leaves was 76 % to that of mature leaves. The rate of dark respiration was more in young leaves as compared to mature and old leaves. In senescing leaves of *Prosopis juliflora* the rate of photosynthesis is altered by decrease in stomatal conductance, chlorophyll content as well as enzyme content (Sestak, 1985). In case of *Prosopis juliflora* there is direct correlation between photosynthesis and availability of water in desert area. According to Chaves and Pereira (1992) and Prospisilova and Santrucek (1994) low water deficit can cause a decrease in photosynthetic ratio either by direct effect on photosynthetic capacity of mesophyll or by CO_2 limitation resulting in stomatal closure. Change in stomatal closure causes change in ψ by altering rate of transpiration (Farquhar and Sharkey, 1982). According to Strain (1978), *Prosopis juliflora* is drought evading species. Thus, photosynthetic potential is higher in the leaves of drought evading species than green plants. Photosynthetic rate is maintained at higher potential than that off drought enduring species. The contribution of photosyntheis in chlorophyllus stem tissue is significant to the survival of these species. Pathre *et al.,* (1998) reported that in case of *Prosopis deltoids* and *Prosopis juliflora* the stomata are quite sensitive to the change of humidity.

4) Transpiration:-

The total water loss through transpiration was maximum in the mature leaves and minimum in the young leaves in *Prosopis juliflora* (Pathre *et al.,* 2004). The total transpiration rate was 129 mol $m^{-2}d^{-1}$ in young leaves, 193 mol $m^{-2}d^{-1}$ in mature leaves and 144 mol $m^{-2}d^{-1}$ in old leaves respectively (Shirke, 2002).

Based on Eamus and Shanahan model (2002) Shrirke and Pathre (2004) concluded that in *Prosopis juliflora* at low VPD, transpiration rate increases with VPD and either remain constant or decreased at high VPD. They also suggested that at high VPD cuticular transpiration from epidermal and guard cell increased substantially. The transpiration rate also increased with increase in VPD up to 30 pa and then gradually decreased at higher VPD. This phenomenon is known as feedforward response in *P. juliflora* (Pathre *et al.,* 1998).

5) Nitrogen metabolism:-

Being a member of family Fabaceae *Prosopis juliflora* is able to fix atmospheric nitrogen through its symbiotic association with *Rhizobium* with its root system. The nitrogen fixation of this species is particularly important in view of its distribution in waste lands (Virginia *et al.,* 1984). The nodules have apical meristem, with indeterminate growth thus with standing harsher stress conditions provoked by temperature, draught and salinity than species with globous nodules (Felker *et al.,* 1981). Mieteinen (1989) isolated eight strains from the nodules. These eight isolated strains are highly tolerant to salinity and temperature and also to drought stress. Diagne (1996) also noticed that Rhizobium associated with

Prosopis juliflora could grow in all soil pH but pH below 3.3 or over 6.8 growth is affected. As the temperature of soil increases growth declined and growth is totally stopped at 50^0C. Kulkarni and Nautiyal (1999) observed that dry weight of *Prosopis juliflora* plant grown in nursery inoculated with Rhizobium sp pie NBRI 330 was 60.6% higher, as compared to un-inoculated control plant. Hahne and Schuch (2004) raised seedlings in the pots by supplying the percent solution of ammonium and nitrate. These workers noticed that Mesquite seedlings produce the greater biomass after 120 days when supplied with a solution of 67 % ammonia and 33% nitrate.

6) Mineral nutrition:-

The physiological functions of each element are different and in many cases the purpose for which the element enters the plant is also unique. Because different elements have different functions within the plant. The content of nutrient varies from organ to organ. In case of *Prosopis juliflora* a strong co-relation between leaf mineral content and the mineral content of the surrounding soil was evident (Sharma, 1984). According to Drumond (1990) *Prosopis juliflora* has lower level of macro - nutrient than the other species. Concentration of macronutrient changes according to change in seasonal effects (Lima, 1990). Difference in the mineral content of foliage was also observed between trees of different diameter classes (Maghembe *et al.,* 1983). Sharma (1984) worked on mineral nutrient of *Prosopis juliflora* and found a co-relation between its foliar nutrient content and cation exchange capacity of the soil. The mineral analysis of

the leaf tissue has been performed by different workers. Their findings are depicted in Table.

References	Mineral Elements									
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	Na
Sharma (1968)	3.3%	0.3%	2.11%	2.25%	0.38%	--	--	--	--	4.08 %
Singh *et al.*, (1986)	4.10%	0.25%	2.10%	1.61%	0.78%	--	--	--	--	0.67%
Patel (1986)	5.57%	0.90%	3.11%	1.01%	--	--	--	--	--	--
Singh *et al.*, (1990)	3.55%	0.19%	1.00%	1.01%	0.70%	--	--	--	--	4.08%
Drumond M.A. (1986)	3.103 %	0.135 %	1.056 %	1.860 %	0.744 ppm	292.0 ppm	37.4 ppm	251.9 ppm	91.4 ppm	153.7 ppm

Table: Mineral composition of the leaves of *Prosopis juliflora*

Most *Prosopis* species found to accumulate more potassium than sodium (Chock and Titus, 1973). *Prosopis juliflora* accumulate the higher percentage of potassium (19.65). The main source of potassium for plant growing under natural condition comes from the weathering of potassium containing minerals (Rich, 1968). Sharma (1984) indicated that the concentration of Magnesium is higher in this species as compared to other species. Accumulation of magnese was

more in the leaves than the stem of *Prosopis juliflora* (Kvalheim, 1967). Zinc has also accumulated in greater quantities in the leaves than the stem (Carles *et al.,* 1969). Nagaraju and Prasad (1998) conducted an experiment in *Prosopis juliflora* that grew on spoil material in the Nellore mica mines and revealed that among the elements like Al, Ca, Fe, Mg, Zn, Mn, B and Li accumulate in higher concentration in a leaf than a twig. According to Nagaraju and Prasad (1998) level of Strontium was more in twig (10158 ppm) than in the leaves. The twig of juliflora is found to be accumulating upto 32 ppm of barium. The distribution of Barium was studied and it was found that the mature leaves containing more Barium than young leaves (Robinson and Wheatstone, 1950). The leaves of this species contained large quantity of Boron (1647 ppm) (Makler *et al.,* 1985). The Nickel content of *Prosopis juliflora* is about 3-16 ppm and these elements has been shown to be an essential plant nutrient for legumes (Eskew *et al.,* 1983). Lithium was found to be more in leaves than twigs (Kent, 1941). Lithium accumulates first in roots and then moves in to older leaves.

h) Salt tolerance studies in *Prosopis juliflora*

1) Introduction

Aronson (1989) has listed following *Prosopis* species in the category of halophytes

Prosopis articulata S. Watson

Prosopis chilensis (Mol.) Stuntz

Prosopis cineraria (L.) Druce

Prosopis farcta (Sol ex Rus) Macbr

Prosopis juliflora (Swartz) DC.

Prosopis nigra (Griseb) Hier

Prosopis pallida (Willd.) H.B.K.

Prosopis reptans Benth

Prosopis ruscifolia Griseb

Prosopis strombulifera (Lam) Benth

Prosopis tamarugo F. Phil.

Prosopis torreyana L Benson

Prosopis velutina Wooton

He has included *P. juliflora* in subcategory of Xerohalophytes. Further he had indicated that the salt tolerant limit in different *Prosopis* differs considerably and it ranges from 11.4 ds/m EC to 31.2 ds/m EC. However the salt tolerance limit for *Prosopis juliflora* is not reported in his list.

The physiological responses of *Prosopis juliflora* to salinity and sodicity have been studied by number of workers.

2) Seed germination

Seed germination in salt affected soil is influenced by the total concentration of dissolved salts as well as by the type of salt involves (Ryan *et al.*, 1975). No decline in germination percentage was noticed when seeds are exposed to 30 % sea water (Khan *et al.*, 1987). At the same time inhibition of seed germination due to NaCl salinity was evident in some experiments. There was significant reduction in *Prosopis juliflora* seed germination at -0.6 Mpa (130 mM) NaCl (Perez and Tambelini, 1995). Scifres and Brock (1969) noticed that no germination occurred at -1.62 Mpa. There was complete inhibition at 400 mM at 40°C and 600 mM NaCl at 25°C (El-keblawy and Al-Rawai, 2005). According to Sosa *et al.*, (2005), during seed germination inhibition is mainly imposed by osmotic effect and mainly noticeable at ψ -1.2 Mpa and ψ -0.4 and -0.8 Mpa NaCl. The germinating seeds could adjust osmotically reaching to final germination percentage equal to that of control. Khan and Ungar, (1985) noticed that during salinity stress there is change in membrane permeability and seed water relation which is due to decline in cytokinins and Gibberellic acid (GA_3) concentration. Killian (1990) stated that there was no effect of salinity on water uptake of seed during initial stage of germination but there were effect later on due to higher concentration of NaCl. Perez and Tambelini (1995) studied the germination in *Prosopis juliflora* in mono saline solution of NaCl, $CaCl_2$ and

Na_2SO_4 at ψ_0 from -0.3 to 1.5 Mpa and they observed that germination percentage was more affected by Na_2SO_4 than NaCl. Joshi and Hinglajia (1999) investigated effect of chloride and sulphate on seed germination of *Prosopis juliflora.* Seeds from different locality and found that seed germination was adversely affected at 30 ppt concentration and recorded the following observation with respect to salt effects as NaCl > $CaCl_2$ > Na_2SO_4>Sea water > KCl > $MgCl_2$>$MgSO_4$.

3) Growth

Ramoliya *et al.,* (2006) noticed reduction in the growth of seedlings in response to increasing salt stress. Dry weight and relative dry weight of plant tissue was decreased due to increasing salinity. According to Gorham *et al.,* (1985), increased root shoot ratio in *Prosopis* appears to be an adaptation to salinity, resulting in a more efficient water and nutrient uptake under saline stress. Hsiao and Xu (2000) viewed that root growth in contrast to leaf growth recovers remarkly well from the addition of salts or other osmotica. In additional visible senescence and necrosis symptoms were found on the basal oldest leaf of young algarobia plant after 12 days at the 600 m mol^{-1} NaCl treatment. Which are the results of excessive sodium and chloride ions (Nabil and Coudert, 1995).

4) Transpiration

According to Viegas *et al.,* (2004), the whole plant transpiration rate of NaCl treated plant dropped suddenly because water transport is passive process. Viegas *et al.,* (2001) concluded that in *Prosopis* due to increase in external NaCl an unfavorable water potential across the root cell membrane was probably created

making it difficult for the plant to keep water absorption comparable to the control.

5) Mineral nutrition

Khan *et al.,* (1987) noticed high accumulation of sodium in the leaves when the plants grown in saline soil or under saline irrigation. The accumulation of root sodium approach plateau under 50 m mol L^{-1} NaCl while in the shoot it increases at all salt concentration. The role of potassium in response to salt stress is also well documented, where sodium depress potassium uptake (Fox and Guerinot, 1998). According to Ramoliya *et al.,* (2006), *Prosopis cineraria* plant have a mechanism of old root turn over (i.e. loss of roots followed by subsequent production of new one) to delay onset of salt stress by indirectly eliminating excess ions through the death of ion saturated old root.

6) Metabolic adaptations

Rhodes and Hanson, (1993) observed that increase in salinity from 300-600 m mol L^{-1} NaCl had no effect on glycine betaine concentration of root and leaves. Accumulation of glycine betaine in *Prosopis alba* represent a major biochemical adaptation in several bacteria, plant and animal. It has been demonstrated that the biosynthesis of glycine betaine is stress inducible (Sakamoto and Murata, 2002). The level of accumulated glycine betaine is correlated with the degree of salt tolerance Hyashi *et al.,* (1988). Salt stress seedling accumulate more total soluble carbohydrate in the root than in the leaves is responsible for the maintenance or even induced root elongation at lower water potential, which can be considered as

an adaptive response to drought and salinity (Balibrea *et al.,* 2002) in *Prosopis alba.*

7) Nitrogen metabolism:-

The information regarding the effect of salinity on the plant is limited and controversial (Viegas *et al.,* 1999). Nitrate uptake and nitrate reductase activity (NRA) decreased in the plants due to salt stress (Rao and Gnaham,1990; Gouiah *et al.,* 1994). At the same time other workers reported that there is NRA stimulation due to salt treatment (Misra and Dwiverdi, 1990 and Sagi *et al.,* 1997).

According to Silveira *et al.,* (2001), plant subjected to NaCl stress present a possible homeostatis between nitrate assimilation and plant growth. According to Diego (2004), nitrate concentration in the root and leaves was not influenced by 300 m mol L^{-1} NaCl. At 600 m mol L^{-1} NaCl nitrate concentration in leaves was reduced by about 69 % to that of control. Salinity interferes with N acquisition and utilization. Different steps of nitrogen metabolisms is affected by salinity such as uptake, reduce ion and protein synthesis which is responsible for reduction in plant growth rate in *Prosopis* species (Frechili *et al.,* 2001).

Nitrogen uptake is affected by soil salinity by direct competition of chloride with nitrate and other by membrane protein by changing plasma lemma integrity (Cramer *et al.,* 1985). Synthesis of In vivo NRA was considerably greater in the leaves that in roots. Cytosolic nitrate seems to protect the NR enzyme against the action of protease and tigger the de novo synthesis of NR protein by induction of NR gene expression (Campbell, 1999).