Floral biology and seed development in *Prosopis juliflora** (Sw.) DC.

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The paper describes the floral biology, structure of seed and seed coat of *Prosopis juliflora* (Sw.) DC. The inflorescence is a simple raceme and appears twice a year in January and October. It bears flowers in acropetal succession, their anthesis being initiated from base to the apex. The stigma is funnel-shaped and slightly folded, terminating over a solid and slender style. The monocarpellary and multi-ovulate ovary has marginal placenta. Usually, out of the 6-22 ovules borne in an ovary, only a few develop into mature seeds. The endosperm development is of the Nuclear type. The mature embryo shows two thick cotyledons, a distinct plumule and the hypocotyl-root axis. The cells of the inner integument get entirely consumed during seed development. The components of the sub-epidermal layer of the outer integument are differentiated from the rest, which constitute the osteoclereids. The outer epidermal cells show radial elongation, become palisade-like, get lignified on the radial walls, and finally form the macrosclereids. The mature seed coat is characterized by lignified macrosclereids through which the *linea lucida* runs uniformly. An important feature of the mature seed is an open pleurogram, an elliptical line running on both sides of the seed opening at the hilar end of the testa. Under SEM, the spermoderm shows irregular cracks on its surface, which are in direct contact with the pleurogram. The present investigation has shown that the majority of pollen in this species are non-viable, which can be, however, isolated by gravity separation method. The aborted and functional types of seeds have different histology and morphology.

Key-words - *Prosopis juliflora*, Mimosoideae, floral biology, seed development.

INTRODUCTION

The sub-family Mimosoideae is represented by 60 genera distributed throughout the temperate regions of the world (Elias, 1974). *Prosopis* Linn. is one of the primitive genera possessing free petals and ten stamens (Burkart, 1976). Its close relatives are *Adenanthera* L. and *Pseudoprosopis* Harms. *Prosopis* possibly originated in tropical Africa where *P. africana* -- its least specialized species, persists even today. The prickly Asian species of the Section *Prosopis* developed in the eastern arid desert zones whereas the spiny American species thrived in the western hemisphere, evolving into two sharply differentiated parallel groups--Section *Stombocarpa* (with spiny stipules) and Section *Algarobia* (with cauline, mostly axillary stipules). Land connections between east and west were easier at the time when these plant-groups might have originated (Burkart, 1976). As such, the ancestors of the present day species of *Prosopis* might have migrated widely from their original home in Africa to both east and west.

About 44 species of this genus are distributed in south-west Asia, Africa and predominantly in America, with the centre of polymorphism in Argentina. All the plants of *Prosopis*, Section *Algarobia* DC., are included in one polymorphic species, *P. juliflora* (Sw.) DC., distributed in the United States (Bentham, 1875). It is abundant in Chile, along the Andes, to Mexico and Texas where it is frequently planted.

P. juliflora commonly occurs in dry and arid regions of India, namely Punjab, Rajasthan, drier parts of Uttar Pradesh, Gujarat, the Deccan, and drier parts of south India. It appears to have been introduced in India from seeds obtained through Kew (Elias, 1974). In desert areas it has proved to be the most useful soil-binder and has been growing in profusion, reproducing naturally through seeds distributed by goats which eat the pods. As a result, it has fixed the sand and acted as an efficient screen against

*New name *Prosopis glandulosa* Torrey
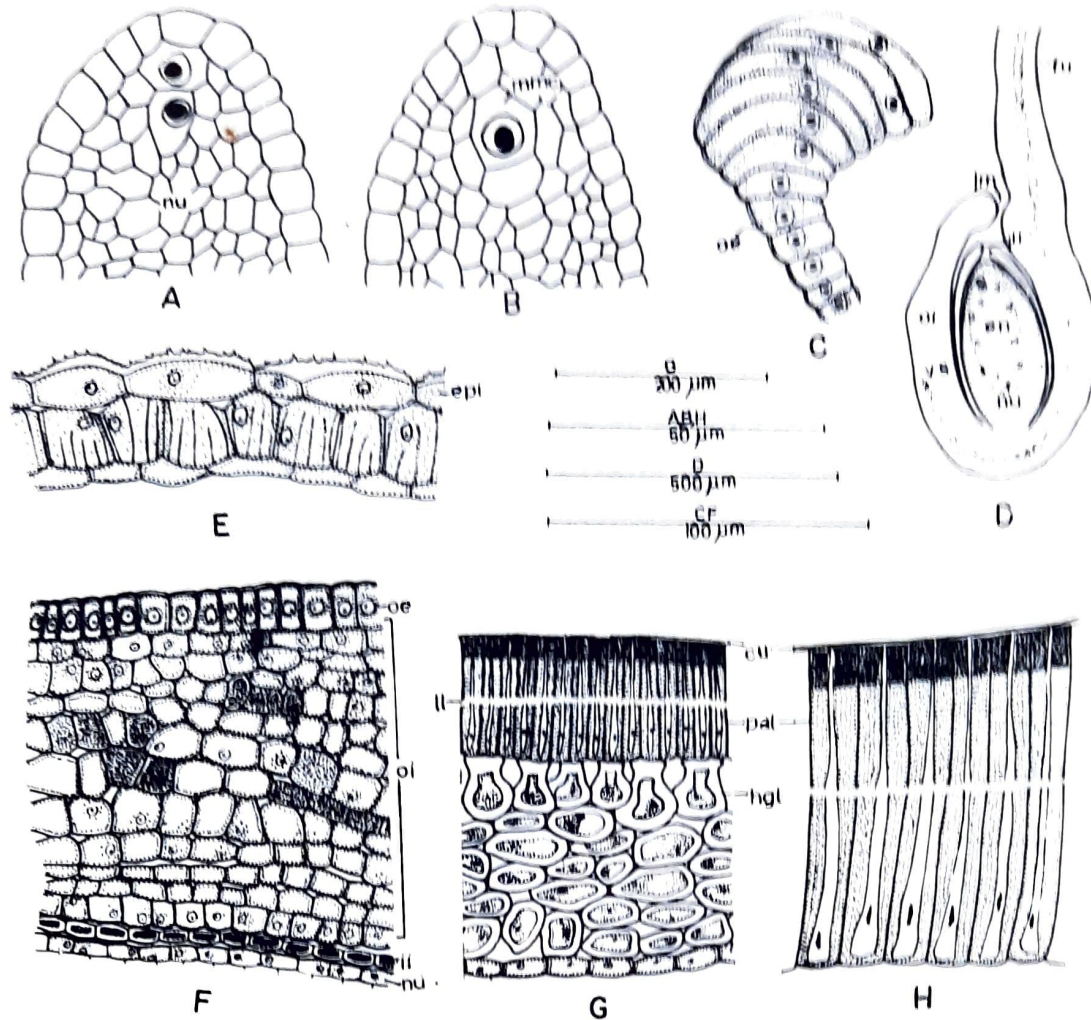
Text-figure A-H -A. A part of longi-section of ovule showing lower primary sporogenous cells and upper primary parietal cell.
B. Longi-section of ovule showing megaspore mother cell.
C. Palisade-like outer epidermal cells of the outer integument towards the micropylar side.
D. Longi-section of a ovule at the stage of 2-celled pro-embryo, showing a long funicle, endosperm nuclei, nucellus and integuments.
E. Middle layers showing endothecial thickenings.
F. A part of longi-section of seed coat at young globular stage of the embryo showing cuticle, outer integument, inner integument, and the nucellar epidermis.
G. A part of longi-section of mature seed coat showing cuticle, malpighian cells and hour-glass cells.
H. A part of longi-section of mature seed coat showing cuticle and elongated malpighian cells.
Abbreviations - Cu - cuticles; en - endosperm; fu - funicle; hgl- hour-glass cell; ii - inner integument; ll - linea lucida; m - micropyle; nu - nucellus; Oe - outer epidermis; Oi - outer-integuments; pal - palisade layer; Vs - vascular supply.

further inroads of drifting sand.

In Punjab, forests of *Prosopis* occur between the main rivers. Likewise, in Rajasthan it grows on high grounds (Bharatpur, Kishengarh and all over Mewar). Pure forest of this taxon generally ascend to 500 m on the hills in trans-Indus area and the Salt Range, Pakistan.

In the desert area of north-west India, the natural reproduction of seeds of this species is confined almost exclusively to moist depressions and other places which are not far from rivers. It forms extensive forests, purely or

PLATE 1

Prosopis juliflora (Sw.) DC.

1. A portion of longitudinal section of a young pod showing few aborted as well as functional ovules, x25.

2. Trans-section of style showing compactly organized parenchymatous cells, x 420.

3. A part of longi-section of ovule at the fully organized female gametophyte stage; integument seen to be composed of several layers, x 400.

4. A part of longi-section of developing seed at late globular stage of embryo; two integuments and nucellus seen, x 400; Oi, outer integument.
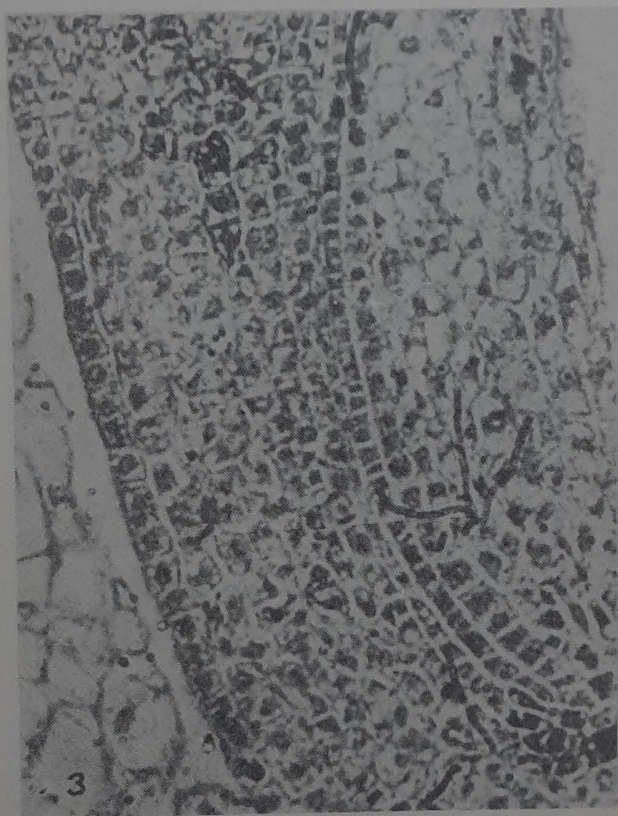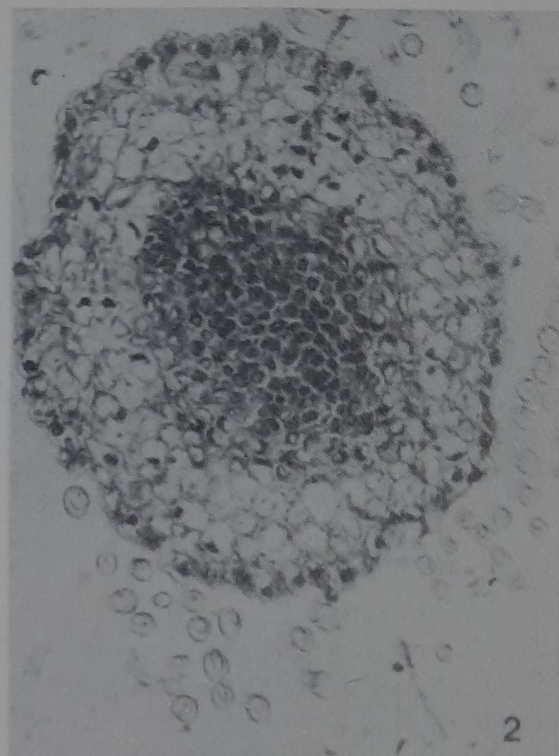
PLATE 1

petal lobes on the margin, adnate to the calyx tube. The stamens of the outer whorl, opposite calyx to the lobes, are longer than those of the inner whorl. Each connective is mounted with a conspicuous apical globose gland which in transverse section is slightly triangular in outline and its outer epidermal cells are arranged compactly and possess dense cytoplasm. In the younger stages of flower, the gland is yellowish-green but gradually changes to reddish-brown. Most of the pollen in a given lot do not take copious stain and also show high vacuolation, indicating non-viability. The ratio of number of viable pollen : non-viable pollen observed in the population of twenty-five discrete specimens is 3 : 4. This seems to be the chief cause of low fruit/high flower ratio.

The monocarpellary gynoecium (Pl.1, fig.1) and the shortly stalked, superior unilocular, and multi-ovuled ovary characterize the species. The number of ovules per locule ranges from six to twenty-two. The stigma is funnel-shaped and slightly folded towards the terminal end. The stigmatic surface shows elongated striations arranged in a compactly organized manner in the form of thick ridges and furrows. In the furrows the rugae are smaller and located apart from each other, whereas on the elevated regions these are closely packed and appear to be interwoven. The style is slender and filiform; its length increases as the flower attains maturity and the stigma becomes ready to receive the pollen grains. Under the SEM, the stylar surface shows the presence of thick wavy bands arranged in a linear fashion. The organization and length of these bands exhibit wavy, smooth, uniformly thick, cylindrical ribs. In a cross section, the style bears a solid and compact appearance (Pl.2, fig.2). The cells of the outer five or six layers are thin-walled and parenchymatous, having limited amount of cytoplasm, whereas those of the inner layers and the central core are small, densely cytoplasmic and compactly arranged (Pl.1, figs 3,4). The epidermis is composed of radially elongated cells.

The entire surface of the ovary wall is covered with elongated, ribbon-shaped, twisted trichomes. Small verrucae are randomly dispersed on both the surfaces of these trichomes and are seen attached to them.

The ovules are arranged on the marginal placenta along the ventral suture of the ovary, a feature typical of Mimosoideae. These are bitegmic, crassinucellate and anatropous possessing a long funicle (Pl.1, fig.1; Text-fig.D). Primordia of both the integuments differentiate simultaneously on the developing ovule, but that of the outer integument grows faster along the dorsal suture of the carpel and forms a flap over the inner integument. At the fully organized stages of the female gametophyte, both the integuments have still not grown enough to completely cover the nucellus and form the micropyle. In the early stages, the vascular supply of the ovule extends from the funicle through the raphe up to the base of the chalaza; it ramifies in the outer integument on the antiraphe side.

Megasporogenesis and megagametogenesis

At the time of differentiation of integumentary primordia, the ovule primordium shows a single archesporial cell in the hypodermal region of the nucellus. It divides periclinally to form an outer primary parietal cell and an inner primary sporogenous cell, which later functions as the megaspore mother cells (Text-figs A,B).

At the fully organized female gametophyte stage of the ovule, the nucellus represents a massive structure on the chalazal as well as the micropylar sides of the embryo sac, whereas it is only two to three-cell layered thick on the lateral sides. The inner integument layer is 2-3 cells thick in the most part (Pl. 1, fig.3) but towards the micropylar side, the number may reach up to 6. The cells of this integument are parenchymatous and compactly arranged, having prominent nuclei. At this stage, the outer integument is 5-6 cells thick on the lateral sides but towards the chalazal and micropylar ends the number increases. The cells of the outer epidermis of outer integument are conspicuous, radially elongated and thin-walled. Towards the extreme micropylar side, these are highly elongated in the radial plane (Pl. 1, figs 3,4; Text-fig.F).

Seed development

Usually, out of several ovules only a few develop into seeds (Pl.1, fig.1) and during this process, marked changes are brought about in the ovule.

Endosperm-The endosperm development is of the Nuclear type. The primary endosperm divides earlier than the zygote, resulting in the formation of numerous nuclei which become dispersed in the cytoplasm of embryo sac (Text-fig.D). Some of these aggregate densely around the globular pro-embryo. The wall formation within the free nuclear endosperm commences from the micropylar region and gradually proceeds towards the chalazal side. The endosperm on the chalazal side, however, remains free

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PLATE 3

(Scanning Electron Micrographs)

1. Hilum in seed, two sub-hilar plugs and micropylar opening arranged in a row, x 125.

2. Longi-section of a mature seed showing seed coat and two elongated cotyledons, x 20.

3. A part of longi-section of seed coat with macrosclereids, light line, hour-glass cells and mesophyll cells, x 450.

4. Spermoderm exhibiting a pleurogram and side branches, x 300.

5. Pleurogram and rugose ornamentation of sporderm, x 1,650.

6. Details of Spermoderm, x 1,550.

PLATE 3
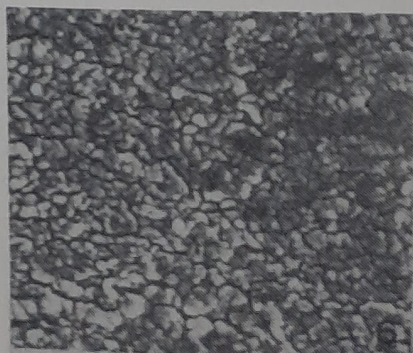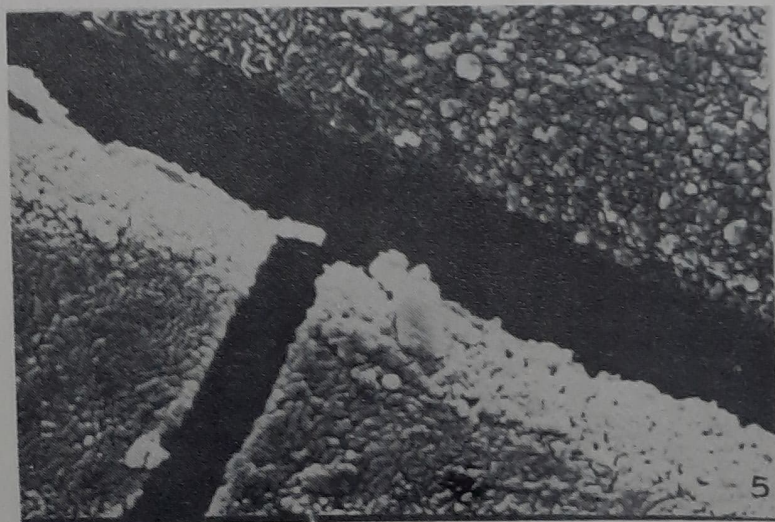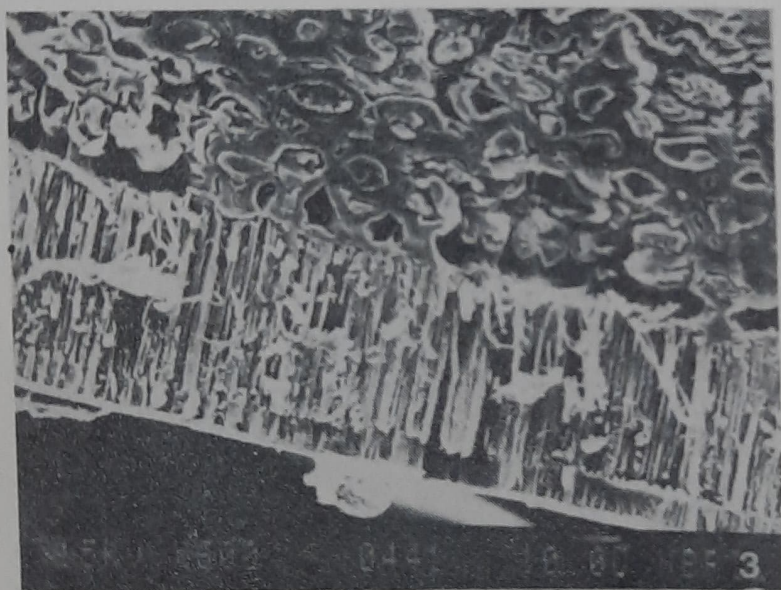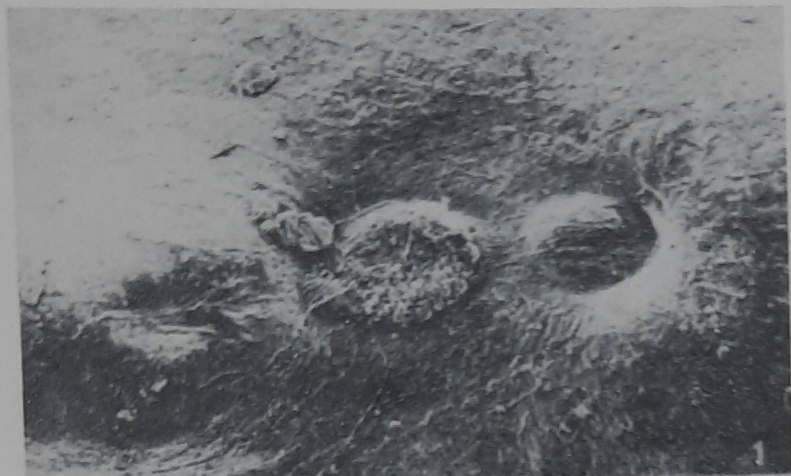
nuclear even up to the cotyledonary stage of the embryo, probably functioning as a haustorium. As the seed develops further, most part of the endosperm tissue is consumed by the growing embryo and only a few layers persist.

Nucellus -At the zygote stage, the cells of the nucellus multiply rapidly making it massive, especially towards the chalazal side. Gradually, these cells increase considerably in size and become vacuolated. The growing embryo and endosperm crushes the nucellar cells on the micropylar side and thus it gets degenerated.

Embryo-- The first division of the zygote is transverse resulting in a 2-celled pro-embryo; repeated divisions lead to the formation of a globular or pear-shaped pro-embryo (Text-figs A,C) which ultimately gets differentiated into two, thick, fleshy cotyledons, a distinct plumule and hypocotyl-root-axis. The embryonic axis is straight and the two cotyledons are basally cordate. In a cross section of the seed, the cotyledons are seen to be composed of two to three rows of palisade parenchyma aligned on the adaxial side. However, regularly oriented cells are present in the centre and towards the abaxial side. The relationship between these tissues can be seen best in an illustration of the mature seed (Pl. 2, fig. 1).

Inner integument- The cells in the outer epidermis of the inner integument become highly vacuolated and get tangentially stretched as the embryo reaches the globular stage (Pl.1, fig.4). Concomitantly, the cells of the inner epidermis also grow considerably. The disintegration of cells of the outer epidermal layer is initiated from the raphe and antiraphe sides, progressing towards the chalazal and the micropylar ends, at the dicot embryo stage. During further development of embryo, the complete outer epidermal layer disappears and the inner epidermal cells also show depletion in the cell contents. By the time the embryo matures, the cells of inner epidermis are also consumed, making no contribution to the formation of seed coat.

Outer integument - In the post-fertilization stages, the cells of the inner epidermis start dividing periclinally, the divisions being more active in the micropylar region. This results in the formation of 4-8 cell layers on raphe and antiraphe ends. By the time the dicot embryo stage is reached, the outer region of integument becomes 7 to 10 cells thick for the major part. The cells of the outermost sub-epidermal layer, i.e. the hypodermal layer, differentiate from the rest of the underlying cells, and as the seed matures these cells become highly thick-walled with conspicuous air-spaces between them and get converted into osteosclereids (Pl.2, fig.3; Pl.3, fig.3).

The outer epidermal cells which are full of tanniniferous deposits do not show any remarkable change during the major part of the seed development till the embryo reaches the globular stage. However, at the micropylar and chalazal ends, these cells show radial elongation immediately after fertilization; by the time the embryo reaches maturity, the remaining epidermal cells also start elongating radially. Later all the cells of the epidermis become palisade-like, get lignified on the radial wall and form macrosclereids. A thin cuticular deposition on the outer surface of palisade-like layer has been observed in the younger stages of the embryo (Pl.2, fig.4) which becomes moderately thick in the mature seed (Pl.2,figs 1,2).

Mature seed coat - The number of cell-layers in the major part of seed coat ranges from 8-10 of which the outermost shows palisade-like lignified macrosclereids. Because of the differential deposition of lignin on the radial walls of macrosclereids, the lumen of the cell remains broad at the base and becomes narrow towards the outer surface of the cells. The *linea lucida* which runs uniformly throughout the macrosclereid layer is more prominent towards the outer surface (Pl.2, fig.3). This is followed by the thick-walled osteosclereid-layer, with typically biconcave cells possessing a broad beam and flat ends. The remaining 2-6 layers of the seed coat are composed of parenchymatous cells.

Seed -- The mature seeds are oval to spherical, their lateral sides being somewhat convex (Pl.3, fig.2), brownish green, with smooth, shiny surface. The hilum appears as a simple, punctiform crescentic scar, positioned adjacent to the usually straight radicle. The elongated cells of the micropylar opening are located nearest to the hilum. A conspicuous radicular lobe is visible externally (Pl.3, fig.1) which is best seen in the surface view. A round and slightly depressed pad of tissue is present close to the micropyle. The most characteristic feature of the mature seeds of *P. juliflora* is the open pleurogram. It is an elliptical line running on both the sides of the seed, opening at the hilar end of the testa. Under the SEM, the spermoderm of *P. juliflora* shows irregular cracks on its surface which vary in size and give rise to a rugose pattern. It is interesting to observe that the major cracks of the seed coat are connected with the pleurogram (Pl.3, figs 4-6).

DISCUSSION

Prosopis juliflora flowers twice a year in October and February, in Uttar Pradesh. A large number of flowers are produced in each crop. On the other hand, the flowering of the South American species, *P. chilensis*, *P. flexusoa* and *P. velutina* occurs in a single burst of bloom in October and November. The timings may vary by a week or two, from site to site, but within any given population, the onset of flowering is highly synchronized. Solbrig and Cantino (1975) suggested that flowering is triggered by photoperiod. Our present investigation also indicates that the environmental conditions favour flowering to occur in a given part of the year.

The production of a large number of small and

inconspicuous flowers per spike in *Prosopis* species is an adaptation that can serve to attract insects. Burkart (1976) thinks that majority of the flowers serve as functional equivalents of the petals although any one of them is potentially capable of developing into a fruit. The production of a large number of flowers for each mature fruit is characteristic of many genera of the Mimosoideae, e.g. *Dichrostachys* and *Neptunia* (Dnyansagar, 1954 a,b).

The ovules are bitegmic and crassinucellate, and at the organized female gametophyte stage they are anatropous. These features have been found to be constant in several taxa of Mimosoideae (Corner, 1951, 1976) where the ovules are initiated as small protuberances from carpellary margin at the stage when microspore mother cells are formed in the anther (Dnyansagar, 1949). At this stage, the carpel has a linear structure folded upwards along the mid-rib. This fact coincides with the classical interpretation of the foliar nature of carpel. The ovule begins to curve towards the stylar end and becomes anatropous, as has been reported in *Albizia lebbek* (Maheshwari, 1931), *Leucaena glauca* (Dnyansagar, 1955) and *Prosopis spicigera* (Dnyansagar, 1956). In *Acacia auriculaeformis* and *A. baileyana* hemianatropous condition is reported (Newman, 1933).

The ovule in *P. juliflora* increases considerably in size, the growth being more pronounced on the antiraphe side bringing the micropyle more towards the funicle. According to Reeves (1930), the curvature of the ovule is caused by mechanical pressure on the dorsal wall of carpel which is exerted when the nearly straight-growing ovular primordium comes in contact with the dorsal wall of the ovary, and since no space is left to grow straight, the advancing ovular primordium bends. Present observations fully support this view. In *P. juliflora* only the outer integument takes part in the formation of the micropyle which is narrow and short as in *P. spicigera* (Dnyansagar, 1956).

The integumentary vascular bundles described in more than one hundred species, spread over in about thirty families of angiosperms (Eames, 1961) are considered to be a primitive feature (Sporne, 1974; Corner, 1976). Contrary to this, Reeves (1930) opined that it represents a derived condition. Furthermore, Eames (1961) and Puri (1970) think that strands in the integments in angiosperms--at one time considered to be of morphological and phylogenetic significance, are not of much importance. Maheshwari Devi (1963) suggests that vascular strands in integuments may serve as a device for efficient supply and transport of water and nourishment to the developing seed. The vascular supply of ovule in *P. juliflora* runs through the funicle, from raphe up to the chalaza, and has been observed to extend in the outer integument in the antiraphe side at the organised female gametophyte stage. In view of its well-organized nature, the present authors agree to the suggestion put forth by Maheshwari Devi (1963).

The primary endosperm nucleus divides prior to the zygote, and the endosperm development is of the Nuclear type, as also reported in the other taxa of this family. As the development proceeds, aggregation of endosperm nuclei occurs in the vicinity of pro-embryo. The cellularization of the free-nuclear endosperm commences from this region only and gradually proceeds towards the chalazal end. The endosperm in the chalazal region remains free-nuclear up to late stage of seed development.

In the presently studied taxon, the straight embryo fills almost entire area within the seed coat. It has two thick, fleshy cotyledons, a distinct plumule, and hypocotyl-root axis. In the mimosoid genera, the radicle tip is usually the only part which is not concealed by cotyledons (Gunn, 1981). The cotyledons are basally cordate. The embryonic axis usually runs straight and the embryo is greenish-white is colour. The straight or curved embryo has been a feature of importance as De Candolle (1825) divided Leguminosae into Rectembryeae and Curvembriae on the basis of the straight or curved embryonic axis. Burkart (1952) utilized this feature alongwith the other seed characters in identifying sub-families for establishing a legume-seed key.

Not only in Mimosoidae but in the entire Leguminosae, the inner integument does not contribute to the formation of seed coat but gets disintegrated by the time the seed is fully developed; this may happen even earlier (Corner, 1951, 1976). However, it is opined by Dnyansagar (1958) that it is persistent in *Calliandra haematocephalla* where it can be seen even in the mature seed, and the cells of inner layer of the inner integument assume a nutritive role.

At the organized female gametophyte stage, the outer integument is two-layered but towards the micropylar side the number of layers is more. The radial elongation of the outer epidermal cells which is initiated even prior to fertilization at the micropylar end proceeds throughout the length of the developing seed in post-fertilization stages, and by the time the dicot stage of embryo is attained, these get elongated radially forming palisade-like cells, a feature which has been reported in majority of the Leguminosae (Corner, 1951). As the seed grows further, these cells develop thickenings on their radial walls forming macrosclereids.

Just after the differentiation of palisade-like cells, the cells of hypodermal layer immediately below the epidermis elongate radially to some extent, develop air-spaces between them, and their walls get thickened. At later stages of seed development, their ends undergo a greater tangential expansion than their equatorial region. Because of their differential stress of growth, the radial walls get separated creating wide air-spaces in between and make the hour-glass cells. The palisade cells are generally longer at the micropylar end as recorded in the present investigation. It is convincing to suggest that the elongation of epidermal cells in the micropylar region is to provide additional

protection to the emerging delicate root and shoot.

The mature seed coat consists of 8-10 layers of cells in *P. juliflora*. The outermost palisade-like macrosclereid layer is covered with a layer of cuticle which, although undulating in outline, is more or less uniformly thick; such a feature has also been reported in most of the taxa of Mimosoideae (Corner, 1976). Although the chemical nature of the cuticle, which is thought to be the impermeable layer of seed coat, has not been studied here, Rees (1911) found it to be hemicellulosic.

The cuticular layer is followed by a single layer of palisade-like macrosclereid cells having their long axis at right angles to the seed axis. A similar pattern of elongation of these cells has been reported in all members of the Leguminosae (Netolitzky, 1926; Corner, 1976). These palisade-like cells, the macrosclereids or malpighian cells, have well-developed deposition in the form of thickenings in *P. juliflora*; it is reported to be variable to different species. These cells are prominently developed towards the outer surface but get thinner towards the inner side, resulting into a narrower lumen towards the outer or the peripheral side (Reeve, 1946). Thus, the surface level--smooth or wavy--of the macrosclereid layer may prove to be an important character in classifying species into definite groups.

A distinct *linea lucida*, or light line, is seen in *P. juliflora*; this is also a character found in most of the species of Leguminosae. It demarcates two distinct zones in the macrosclereid layer. The cells in the zone below the light line have lumen full of tanniniferous depositions whereas those of the upper zone are free from such accumulation. Watson (1948) has designated this upper zone, i.e., from light line to the cuticle, as the subcuticular zone having traces of suberin and cutin. The light line is continuous almost remaining parallel to the surface of the epidermis; it exhibits optical birefringence through crossed polarizers, confirming the crystalline nature of the cellulose (Esau, 1970). According to Corner (1951), the light line is caused by twisting of internal thickening of the epidermal cells which results from almost complete occlusion of the lumen of each cell at the same level; it causes an optical illusion of the two layers of macrosclereids. Thus, it is clear that *linea lucida* is not a specific morphological entity.

The shape of the seed of *P. juliflora* is oval to oblong or spherical. Under low magnification, the surface of mimosoid seeds appears to be smooth. The shape of hilum is variable in Mimosoideae, appearing as a black dot, a simple punctiform, orbicular, shortly oblong or rarely in the form of a crescentic scar (Gunn, 1981). Although the micropyle is generally present on the fringe of the hilum--nearest to the radicular lobe, it is inconspicuous in the mimosoid seeds. According to Gunn (1981), mimosoid seed has a pad and a sub-hilar plug under the hilum.

The most characteristic feature in mature seeds of *P.*

juliflora is the open pleurogram. The area encompassed by the pleurogram may be called as areole (face line; Isely, 1955). The differences between the areole and the remainder of the face is conspicuous or may be represented by slight variation in colour, surface texture, or the fracture lines. Corner (1976) noted that most of the modifications of the ovule, during the course of its development into seed, effect the hilum and chalaza. This process may also effect the faces (lateral sides) of the seeds and the pleurogram.

The spermoderm pattern of *P. juliflora* as seen under the SEM revealed irregular cracks on its outer surface. The surface pattern is of the rugose type. These cracks are visible by naked eyes or under the low power of the light microscope. Rugae are irregular in shape and size, their thickness also being variable from place to place.

Trivedi *et al*. (1979) studied the spermoderm pattern in *Prosopis stephaniana*, *P. spicigera*, and a few other Mimosoideae and recorded that the rugose pattern is the most common type of ornamentation found on the spermoderm of mimosoid seeds. However, it has been observed that this type of ornamentation also occurs in some papilionaceous taxa (Trivedi *et al*., 1978b). The presence of cracks in *Prosopis stephaniana* and *Acacia catechu*, ridges in *P. spicigera*, elevations and depressions in *Leucaena glauca*, and rounded projections in *Neptunia* is characteristic of the spermoderm. The spermoderm characters of different species within the genus *Prosopis* vary, showing totally different types of ornamentation (Trivedi *et al*., 1978a, b, 1979).

The presence of pleurogram, a loop line, is characteristic of mimosoid seeds (Corner, 1951). Under SEM it appears as a grove, in the form of horse-shoe-shaped line in the tests, on both the flat sides of the seed. It hasbeen observed under the transmitted light microscope that these cracks are continuous with the pleurogram of the seed. They open or close as the amount of moisture in the seed increases or decreases respectively. Thus, it plays an important role in the dehydration of seeds at the time of maturation and absorption of water during germination.

CONCLUSIONS

The present investigation has led to suggest that:

1. In *P. juliflora*, all the flowers in a given inflorescence do not mature at the same time but exhibit variability by setting anthesis at the basal end.

2. In this species, the funnel-shaped stigma is characterized by the rugose pattern; the style elongates just prior to pollination in order to receive the pollen. This might serve as an adaptation to catch large quantities of pollen grains.

3. The majority of pollen in this species are non-viable. For achieving pollination as well as fertilization, leading to the formation of the viable seeds; this information should be

of immense significance to the plant breeders since by centrifuging the entire mass of pollen grain it would be possible to separate the viable ones from the non-viable, owing to the higher specific gravity of the former.

4. The detailed histological study of two types of seeds of *P. juliflora*, the aborted and functional ones, has permitted us to understand the stage and causes of non-formation, incomplete formation, or even the arrested growth of the embryo. This should naturally enable the tree-breeders to excise the embryo at an early stage of development and to rear it in the artificial culture medium to raise the healthy seedlings.

5. The waxy layer of cuticle, light-line and the macrosclereids in seed coat are the special devices to enable the plant to withstand the unfavourable climatic conditions, especially the drought. They also assist the seeds to remain viable for longer durations.

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