CYTO-MORPHOLOGICAL STUDIES IN WILD AND CULTIVATED SPECIES OF *Ziziphus*

By

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DOCTOR OF PHILOSOPHY

in

HORTICULTURE

COLLEGE OF AGRICULTURE

Chaudhary Charan Singh
Haryana Agricultural University
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2001

Dedicated

to

My Beloved Parents

CERTIFICATE I

This is to certify that this dissertation entitled, "**Cyto-morphological studies in wild and cultivated species of *Ziziphus***", submitted for the degree of Doctor of Philosophy in the subject of **Horticulture** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Mr. Ram Bhagat Gupta** under my supervision and that no part of this dissertation has been submitted for any other degree.

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

S. Sharma

[Suneel Sharma]
MAJOR ADVISOR

CERTIFICATE II

This is to certify that this dissertation entitled, "**Cyto-morphological studies in wild and cultivated species of *Ziziphus***", submitted by **Mr. Ram Bhagat Gupta** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfilment of the requirements for the degree of Doctor of Philosophy, in the subject of **Horticulture** has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

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Chapter-I

Introduction

The ber or Indian jujube (*Ziziphus mauritiana* Lamk.) is an ancient fruit of Indo-China region. The fruits have been in use since ancient time. *Ber*, with its several forms and related species grows extensively as a cultivated fruit as well as wild shrub or tree in the arid and semi arid regions of the North India. It is extremely drought hardy plant (Pareek, 1978) and can be successfully grown even on poor and alkaline soils (Ram, 1940). The grafted *ber* tree starts bearing within 2-3 years of planting and the growers are assured of a good income (Jawanda and Bal, 1978). The major *ber* growing states of India are Madhya Pradesh, Bihar, Uttar Pradesh, Punjab, Haryana, Rajasthan, Gujarat, Maharashtra and Andhra Pradesh. In Haryana, *ber* orchards are found in almost all the districts (Singh *et al.*, 1973a). The fruit of superior *cvs.* is either eaten fresh or made into beverage or candied. It excells many fruits in nutritive value. Fruit of *ber* is a rich source of Vitamin C, B, A and also minerals like calcium, phosphorus and iron. It has been reported to contain more ascorbic acid than guava (Li and Chou, 1948), more

carbohydrates than date and more minerals and vitamin C and A than apple and citrus (Khera and Singh, 1976). The fruits, seeds, leaves, bark and roots all have medicinal applications, in particular to aid digestion and to poultice wounds (Verheij and Coronel, 1992).

The *ber* (*Ziziphus mauritiana*) originated in the Indian subcontinent (Pareek *et al.*, 1998). It is cultivated on a small scale throughout tropics and subtropics. Although it is commercially important in India and China only. It belongs to family Rhamnaceae which has about 50 genera and 600 species Genus *Ziziphus* has 40 species (Rendle, 1959) which are scattered in the tropical and subtropical region. The Indian subcontinent has very wide variability of *Ziziphus* species. Kanjilal *et al.* (1934) have described six species found in Assam. Singh and Arora (1978) also listed eight species having edible fruits found in different parts of India. *Z. apetala* Hk. f., *Z. funiculosa* Buch.-Ham. and *Z. incurva* Roxb. occur in North-Eastern hills; *Z. mauritiana* Lamk. and *Z. nummularia* (Burm.f.) Wight and Arn. all over the drier tracts, particularly in North-West India and UP, *Z. oenoplia* Mill. and *Z. rugosa* Lamk. throughout India except in the drier tracts, particularly in Central and Eastern India, and *Z. vulgaris* Lamk. (Sihjuli, unab) grows naturally in the North-Western Himalayas. Besides, *Z. rupicola* T. Anders is found in Central and Eastern India and *Z. xylopyrus* Willd. in MP and the peninsular region (Pareek, 1988). Maheshwari and Singh (1965) recognised six economically important species in India. These are *Z. nummularia* (Burm.f.) Wight and Arn. (*Jharber*), *Z. mauritiana* Lam.

(*Z. jujuba* Lam, ber), *Z. oenoplia* Mill. (makoi, makoh), *Z. rugosa* (suran dhaura), *Z. sativa* Gaertn. *Z. vulgaris* Lam. (kandiari) and *Z. xylopyrus* Willd. (kat ber, goth ber).

Among the existing germplasm, there is a great variability in vegetative and reproductive characters. The taxonomic status of the members of this genus has been rather confused, till recently, even of the cultivated type. This is evident from the nomenclature of cultivated species given by different botanist and horticulturist. The different names for the same type as quoted by Hayes (1957) are *Z. jujuba* Mill., *Z. sativa* Gaertn., *Z. vulgaris* Lamk. and *Z. mauritiana* Lamk. etc. *Z. rotundifolia* is a thorny shrub while *Z. sativa* is a small tree and *Z. mauritiana* is a tall growing tree (Bailey, 1963). The fruits of dwarf type (*Z. nummularia* Burm.f.) are acidic and ripen in October-November, whereas that of tall growing (*Z. mauritiana* Lamk.) are sweet and ripen from February to April. Chatterjee and Randhawa (1952) proposed that two main cultivated species be called as *Z. jujuba* Mill. The Chinese *ber* and name *Z. mauritiana* Lamk. be given to Indian cultivated *ber*. According to these workers, the two species differ from each other distinctly. The *Z. jujuba* Mill. is a small upright tree with bright green leaves which are glabrous on their under surface. The Indian cultivated species i.e. *Z. mauritiana* Lamk. is a spreading tree with drooping branches and dark green leaves which have densely tomentose on their under surface. Indian *ber* is evergreen tree but under hot dry conditions, it sheds its leaves in May and June. In most of the early Indian flora, this species has been named

as *Z. jujuba* Mill. which in fact should be treated as synonym of *Z. mauritiana* Lamk. Maheshwari and Singh (1965) have also agreed to recognise *Z. jujuba* Mill. as synonyms of *Z. mauritiana* Lamk.

Another distinct wild form of this region is locally called *jharber*. Chatterjee and Randhawa (1952) have reported this as *Z. rotundifolia* while Pareek and Mann (1974) have given it the name *Z. nummularia*. However Hayes (1957), Baily (1963) and Maheshwari and Singh (1965) have recognised both these names as synonymous. Another upright form of cultivated ber which grows wild in fields, wastelands and along the road side and canal banks etc. has smaller acute leaves and it flowers earlier than cultivated *ber*. Seeds of this form are used commercially as rootstock for cultivated *ber* in whole of the north-India. In literature this type has been cited as Gola *ber* due to its round shape. (Singhrot *et al.*, 1970). Pareek (1978) has reported an another form named Boradi (*Ziziphus mauritiana* var. *rotundifolia*) is a drought hardy, thorny bush extensively found in degraded and unfertile lands in arid and semi-arid region. Moderate to heavy plant population of boradi with variable types exists throughout the desert especially in the river belts and natural depressions (Pareek *et al.*, 1998). This variability available in the germplasm can be made use in breeding programme to evolve an ideal *ber* cultivar with good eating and keeping quality, high yield and resistance to insect-pests and diseases. Present study will help in resolving taxonomic status of *Ziziphus* and to examine problems of cultivar synonymy.

For a successful breeding programme, the information on different aspects of cytology, palynology and other morphological characters is prerequisite, so that it may be useful in the selection of parents and the breeding procedures. For comparison of various types/forms of *ber*, three wild forms named as Desi-I, Desi-2 and Desi-3 and seven standard cultivars of *Z. mauritiana* namely Umran, Kathaphal, Illaichi, four related cultivars of Gola and wild form of *Jharber* were included in the study with the following objectives :

1. To determine the chromosomes number of different wild and cultivated species of *Ziziphus*.
2. To study the morphological variation in different vegetative and floral characters of wild and cultivated species of *Ziziphus*.
3. To study the quality parameters in fruits of wild and cultivated species of *Ziziphus*.

Chapter-II

Review of Literature

Very little information is available in literature about the cytology of various cultivated and wild (Desi) forms of *Ziziphus*. However, scanty information is available about various morphological characters of plant and physico-chemical characters of the fruits of cultivated *ber* (*Z. mauritiana* Lamk.), but not about various wild forms of *Ziziphus* used as rootstock or having similar potential. Briggs and Walter (1969) stated that even if we carefully examine a group of plants of a species, they are not alike. Such differences or variations could be developmental, environmentally induced or intrinsic and may be temporary i.e. reversible or permanent i.e. irreversible. Intraspecific variations in response to varying habitat factors have been reported in several texa (Bradshaw, 1959; Kurlovich, 1998; Zizumbouillareal and Pinero, 1998). Thus, the published literature about genus *Ziziphus* or other fruit species used either for planning or for execution of present studies entitled "Cytomorphological studies in wild and cultivated species/forms of *Ziziphus*" has been reviewed briefly under following sub heads :

2.1 Cytological studies

The basic principles of classification of plants rests on the morphological characters of the plants. Neverthless cytological studies are also useful for the purpose of identification or drawing intergenetic and interspecific relationships. Darlington and Ammal (1942) reported that chromosome number in *Z. jujuba* (Indian *ber*) and *Z. sativa* (Chinese *ber*) as 2n=24. However, Dodds (1958) recorded 2n=48, 72 and 96 in the *Z. jujuba*. Khoshoo and Singh (1963) also made cytological studies of *Z. jujuba* and *Z. rotundifolia*. Sareen and Singh (1976) reported 2n=48 in seven cultivars of *ber* and 2n=72 in one cultivar. However, Daulta and Sareen (1980) reported 2n=48 in all the four cultivars of *ber* studied by them. Nehra *et al.* (1983) studied the chromosome number in five cultivars/forms/ species of *ber*. The somatic chromosome number (2n) varied from 48 to 96 being 48 in Umran; 48 and 72 in *Jharber* and 96 in Illaichi and wild Boradi at metaphase-I of meiosis. Recently, Pareek and Vishal Nath (1996) reported that the wild as well as cultivated *ber* types are tetraploid to octaploid. The chromosomes number was 2n=48 in Umran and Chonchal, 2n=96 in Gola root stock and boradi and 2n=48 to 72 in *Jharber*. There

is not much published literature on the cytological studies in various forms of *Ziziphus*. Therefore cytological studies in other fruit and ornamental crops have been reviewed which are considered useful in presentation of results.

Mandloi (1967) carried out cytological studies in seedless guava to study chromosomes number and meiotic behaviour. The trees were found to be diploid 2n=22. According to Hirano and Nankasone (1969) polyploidy in *Psidium guajava* appeared to be uncommon but the genus is represented by di, tetra, hexa and octoploid species. They found 2n=22, 44 and 66 in different species of genus *Psidium*. Close resemblence in vegetative characters and gross appearance of chromosomes (2n=22) of *Psidium guajava* and *Psidium polycarpum* cast some doubt as to their identity. Seedless guava had 2n=33 chromosomes. Similarly the detailed cytological studies were made in grape (Sudharsan and Seethaiah, 1973). The meiotic and mitotic chromosomes number in all the six cultivars of grapes studied were 2n=38. Staudt and Kassrawi (1972) observed the same chromosome number in Riesling cultivars.

A detailed study of mitosis and meiosis in numerous species and forms of *Pyrus* has revealed that all the species were diploid (2n=34) though several cultivars and variants were diploid (Zielinski and Thompson, 1967). Jackson and Sherman (1975) found 27 chromosomes at meta phase in "Tahiti" lime. Bhowmik (1977) observed 2n=50 in Kew and Queen cultivars of pineapple. There are contradictory reports on the chromosome number in pomegranate viz., 2n=14, 2n=16 and 2n=18 (Pross, 1938 and Nath and Randhawa, 1959).

Later, Raman *et al.* (1971) concluded that the quadrivalents which commonly occurred at the meiotic association might be responsible for this disparity. The occurrance of 9 distinct bodies at meiosis-1 and 9 chromosomes at metaphase-II showed the chromosome number to be 2n=18. 137 apple clones were studied for chromosomes number by Pratt *et al.* (1978). Out of these, 128 were determined to be diploid (2n=34) and 9 to be triploids (2n=51). Cytological studies carried out by Hore (1974) on 12 cultivars of carrot revealed that chromosomes number in all the cultivars to be 2n=18. Meenakshi (1977) reported from mitotic preparations 2n=28 in 25 rose cultivars.

Besides this, also these are a large number of reports on chromosome number of ornamental and other crops viz. Begonia, 2n=26, 38 and 56 (Lagro, 1971), Hibiscus, 2n=108, (Martin emezel 1974) and impatients 2n=8, 12 and 20, (Arisum, 1974).

2.2 Morphological characters

Presence of morphological variations within a plant species has long been recognised, but it was not until the work of Turesson (1922a, 1925) that any serious attempts were made to try to correlate these variations with the habitats of the plants. It led to the conclusion that such differences are to be expected as the natural outcome of the evolutionary process occurring within the species. Since then a wealth of data on such morphological variations has been obtained (Snaydon, 1973) and morphological characters have been utilized for identifying families, genera, species and cultivars within species in taxonomic studies.

The characters like leaf apex, branching habit, leaf shape, leaf base, leaf colour and petiole length were considered to be the most appropriate vegetative characters for differentiation in fourty two cultivars of *ber*. The most appropriate fruit characters were apex, stalk and stylar flesh cavities, shape, base, colour at maturity, ridges on the base and apex and surface (Bal, 1992). Similarly characters like growth habit of the tree, spine characters, leaf shape, size, nature of leaf margin, length of petiole, size of various flower parts, colour etc., were utilized for differentiation in 39 cultivars of *ber* during vegetative stage by Singh *et al.* (1971). Dutta (1954) had studied the six varieties of jujube mostly cultivated in Assam. These varieties are designated by numbers in the absence of local popular names. Out of these six cultivars, five were tentatively classified under the species *Z. mauritiana* Lamk. and one under *Z. jujuba* Mill.

Literature on various morphological characters viz., growth habit, spine, leaf, flower, fruit and spine characters is reviewed separately under following heads.

(a) Growth habit : Growth habit of the tree is an important character that has been used for differentiation of *ber* cultivars. Bailey (1963) reported prickly branches in *Z. jujuba* Lamk. and *Z. sativa* Gaertn. Whereas, erect branches in shrub of *Z. rotundifolia* Lamk. Spreading type of branches were recorded in cultivars Banarsi Karaka (Chandra, 1964). Likewise spreading habit in cvs. Nazuk, Umran and Chhuhara and erect habit was observed in Rashmi and Goli (Randhawa and Biswas, 1966). Further, they reported that

the tree size of the Umran was smaller. Similary Singh *et al.* (1971) reported spreading habit in Umran, Illaichi and Nazuk whereas it was erect in case of Dandan, Banarasi, Sanaura No.I and semi-erect in Chhuhara. Nehra *et al.* (1984) reported spreading habit in Illaichi, Umran and Desi and erect in Gola, Jharber and Boradi. On the other hand Bal (1992) reported spreading habit in Kala Gola, Surti, Seo, Katha Gurgaon, selected safeda, Sanaur 2, 3, 4, 5, and 6, Umran, Illaichi and erect habit in Sanaur No.I, Laddu, Rashmi, Rohtaki Gola, Banarsi, Kaithli. However, studies conducted in Pakistan, Kundi *et al.* (1989) have reported greatest tree spread in Lalwali and height in LR13 cultivars of *ber*. Praveen and Patil (1998) have reported tree canopy volume in Sanaur-2 and Dandan to be 1744.0 and 2487.3 sq. cm respectively. Similarly Kurian and Reddy (1999) have studied the pattern of shoot growth in *Zizyphus mauritiana* and *Z. oenoplia*.

(b) Bark colour : Very little published reports are available in the literature on this character. However, Nehra *et al.* (1984) reported dark brown colour of trunk phellum in five cultivars and red in one cultivar of *ber*. Where as colour of bark phellogen was pink in five cultivars and light green in one cultivar.

(c) Girth of stock and Scion : Different intensities of pruning had affected the girth of trunk in the deciduous fruit trees. Sharma *et al.* (1980) observed that the unpruned trees had significantly more trunk girth than the pruned ones. Whereas Gupta and Brodara ~~et al.~~ (1989) have reported that girth of scion did not differ significantly with different times of pruning. However, varietal

differences regarding stock and scion girth are present in *ber* (Kundi *et al.,* 1989 and Parveen and Patil, 1998).

(d) Spine : The spines in *ber* are modified stipule, often one straight and other hooked (Bailey, 1963). Their number and arrangement varies from species to species. Some workers have also utilized this character for variation in *ber* cultivars and species. Chandra (1964) has reported that in cv. Banarasi Karaka, the spines were in pairs, one straight and other curved and pointed downwards. Similarly, Singh and Khanna (1968) reported that cv. Seo was moderately thorny and Dandan had no spines at all. However, Randhawa and Biswas (1966) observed less spines in Dandan cv. of *ber*. The spines are persistant in Kheera (Singh and Khanna, 1968). Whereas Nehra *et al.* (1984) have reported that the spines were solitary and curved in Illaichi and in pairs, one being straight and other curved in other five cultivars of *ber* studied by them.

(e) Leaf : Leaf size, colour and shape of overall leaf and shape of apex and base were observed to be the most reliable characters in the identification of the *ber* cultivars (Singh *et al.,* 1971). They used shape of leaf as tertiary character and leaf colour, petiole length and nature of leaf margin were utilized as secondary characters. Dutta (1954) observed various types of leaf shape viz., orbicular, ovate, elliptical ovate in the six varieties described by him. Similarly the same pattern was followed by Nehra *et al.* (1984) in describing the leaf shape of six varieties studied by them. The shape of leaves in Umran and Illaichi was obovate whereas in Dandan and Nazuk was

observed to be oval by Singh *et al.* (1971). However, Umran leaves were described as ovate oblong and that of Nazuk as elliptical oblong by Singh and Khanna (1968); Leaf shape of Umran as described by Randhawa and Biswas (1966) was ovate oblong with serrated margin, ventral surface smooth and dorsal slightly pubescent, apex obstuse whereas in Nazuk the leaf was oblong.

Singh *et al.* (1971) reported length of petiole 1.9 cm; leaf length/ width ratio 1.84 in Umran and length of petiole 2.4 cm and length/width ratio 1.49 in case of Illaichi. Singh *et al.* (1971) prepared a key for differentiation of 39 *ber* cultivars on the basis of leaf size, colour, shape, leaf apex, base and length of petiole. In the same way, there are reports on leaf characters of other cultivars which can be helpful in distinguishing one cultivar from the other. The leaf area of 15 *ber* cultivars was estimated with planimeter by Chitkara and Khera (1973) and they have reported that leaf area of Umran was smaller than Illaichi. Arora and Channa (1975) reported the relationship between leaf area and petiolar length, leaf length and breadth for 10 grape cultivars showed that leaf area was correlated with leaf length. Bal (1992) also considered the leaf apex, leaf shape, leaf base, leaf colour and petiole length as the most appropriate vegetative characters for identification among 42 cultivars of *ber* studied by him.

(f) Flower : For successful breeding and improvement programme of a crop, it is essential to have thorough knowledge of the morphology of flower. The cyme of *ber* is an axillary cyme and the flowers are borne in

the axil of the leaves on the main as well as lateral shoots. Different flowering time has been reported by Dutta (1954) for various cultivars and species. The *ber* flowers are greenish yellow, faintly fragrent, pentamerous, hermaphrodite; calyx with deltoid lobed, hairy outside, glabrous within; petals 5, subspathulate, concave, reflexed; stamens 5; ovary 2-celled, styles bifid, disc 10-lobed or grooved (Chandra, 1964; Singh and Khanna, 1968; Verheij and Coronel, 1992). Flower buds in *ber* are borne on mature wood as well as on current season growth. It was also observed that mature wood up to the age of two years was more prolific than current season growth (Teaotia and Chauhan, 1963). According to Prasad (1964), each leaf-axil gives rise to a flower cluster which contains between 10-75 flowers. Yamdagni *et al.* (1967) observed flowering from third week of September to second week of November under Kanpur condition. However, Chundawat *et al.* (1978) observed that flowering time shows varietal variation. Singh *et al.* (1970) and Nehra *et al.* (1984) obseved that *ber* cultivars flowered from September to November under Hisar condition. Similar results were observed by Gupta *et al.* (1990) in cultivar Umran. However in Pakistan, the time of flowering was reported to be from 1st week of October to 1st week of November in various cultivars of *ber* (Kundi *et al.*, 1989). According to Josan *et al.* (1980) the number of flower buds per cyme varied from 16 to 28. The time of anthesis varies from cultivar to cultivar in *ber*. Vashistha and Pareek (1979) reported two peak period of anthesis in different cultivars. In case of Seb, Jogia, Aliganj, Ponda and Illaichi, the anthesis time was 7.30 to 8.30 AM

whereas in Gola, Mundia it was 12.00 Noon to 1.00 PM. Similar results were also reviewed by Srivastava (1980) and Godara (1980). Whereas Neeraja *et al* (1993) observed that anthesis time was 5.30 AM to 6.30 AM in Seb whereas in Gola and Umran it was 12.30 to 1.30 PM.

The time of dehiscence was reported to be 9.40 AM to 10.15 AM in Illaichi, Kathaphal, Sandura Narnaul and 2.15 PM to 2.30 PM in Banarasi Karka, Kakrola Gola, Safeda Selected and Umran (Godara, 1980). Dhaliwal and Bal (1998) reported that anther dehiscence started about 2 hrs. after anthesis and continued for 2-4 hrs in *ber*.

(g) Pollen morphology

The science of pollen and spores known as "palynology" has attained great importance in recent past due to its application in various fields. Among various aspects of palynology, the study of pollen morphology is of basic significance and has been found to throw light on the inter-relationship of the plants. Nair (1960) has given a detailed classification of pollen grains of various horticultural crops. Pollen morphology and surface topography have been widely accepted to identify plants of divergent and closely related texa (Mass, 1977).

The size of pollen grain in *Ziziphus jujuba* Lamk. have been reported to be 21×17μ, endocolpium, circular, exine psilate, aperture 3-zonicolporate and shape perprolate (25×12μ) (Erdtman, 1952; Nair, 1970). In pollen study of various species of *ber*, the morphological features like shape, location of germ pores, pattern of exine and intine etc. were found to be almost similar in all the pollen grains (Singh and Misra, 1979). Hulwale *et al.* (1995)

in a recent study on *ber* cultivars in Maharashtra have revealed that pollen diameter did not show much variation and it ranged from 20.05μ in Darakhi No.I and 32.04μ in Seedless. Also there was no direct relationship between fertility status of pollen and its size. Neeraja *et al.* (1996) have reported that the fresh pollen of *ber* appeared as fine yellowish powder when seen with the naked eye. Under microscope fresh pollen grain were oval to ellipsoidal shape; but in acetocarmine the pollen became triangular in shape. Each pollen grain has three germpores which were placed equidistantly.

The *Ziziphus* species and cultivars investigated by Hegde and Sharma (1996) also exhibited little diversity in shape, size and exine characteristics and complete uniformity in aperture characteristics. The majority of the pollen grains of any individual cultivar evaluated conformed to a typical shape; however, a few abnormal types were usually observed. Pollen grains of all the *Ziziphus* type studied, was characteristically trizoncolporate. However, the endocolpium was circular in *Z. mauritiana* whereas it was lalongate in *Z. jujuba* and *Z. nummularia*. Pareek and Vishal Nath (1996) reported that pollen of *ber* varieiteis have 3-zonicolporate aperture, psilate exine pattern and circular endocolpium. The pollens are sub-prolate to prolate spheroidal. Kaur (2000) reported that pollen grain of *Z. nummularia* were tricolporate.

Palynological studies of some other horticultural crops made by various workers is also reviewed herewith. Nair and Mehra (1961) studied the pollen morphology of six citrus species. The variations were mainly in the nature

of endocolpium and of lumina in reticulations. In primitive angiosperm family Annonaceae, pollen grain were unique in their size with diameter up to 350μ and lack of exine over 50 per cent of the grain surface. The pollen morphological differences in guava cultivars were recorded by Nair *et al.* (1964). However these differences were restricted to the size of pollen grain only.

They have also investigated the pollen morphology of eight varieties of grape and have observed that the general characters have been found to be the same for all the cultivars. But pollen size showed variations even within the same cultivars, there being large and small sized pollen grains. Moti and Singh (1970) reported that pollen grains in 14 cultivars of *Vitis vinifera* were identical in morphology but there were differences in pollen size viz., the pollen of Gross colaman was the largest and that of Pearl of Csaba, smallest. Similar observations about pollen size and morphology were also drawn by other workers (Nagarajan and Rao, 1970; Moti, 1972 and Lambardo *et al.*, 1978). Prasad (1972) also studied the pollen morphology of some grape cultivars and made similar observations. He recorded largest pollen diameter of 28.49μ in Perlette cv.

In a study of 18 pear species, the pollen morphology showed considerable variability in the size, shape and surface topography of both anther and pollen grains. The combination of pollen and anther feature was unique for each species and thus valuable for identification (Westwood and Challice, 1978).

Studies on pollen morphology of some *Cucurbita* species enabled Rochelle (1977) to identify and classify them. Four fruit tree species viz. peach, plum, apple and sweet cherry were identified by pollen exine patterns (Fogle, 1977). The pollen morphology of 27 cultivars of mango (*Mangifera indica*) and 14 other species of the genus *Mangifera* showed similarity in size (23×19μ) and morphology (Mukherjee, 1951). All the species had tricolporate pollen grains with pitted exine, thus suggesting a homoginity with respect to this character within this genus. Moti *et al.* (1973) also observed similarlity in characters of pollen grains of 101 mango cultivars. But there were large variations in the size of pollen grain was observed in various cultivars of mango.

2.3 Physico-chemical characters

(a) Fruit character

Most appropriate physical characters of fruits such as shape, size, shape of apex, and base and colour etc. are stable parameters and hence helpful in classification and differentiation of various cultivars. Dutta (1954) has defined the fruit shape in different cultivars of *ber* as globose, oblate, spherical and ovate oblong. Chandra (1964) has reported the shape of Banarasi Karaka fruit as globose with depressed base. Randhawa and Biswas (1966) reported that the fruit shape in cultivar Umran was large, elliptical with golden yellow colour and round base and apex. The fruits were 4.21 cm long, 3.22 cm in diameter with mean weight of 26.83g whereas, Singh and Khanna (1968) have reported that fruits were large, ovate oblong with broad

round and depressed base and apex. The length of fruit was 3.84 cm and diameter 2.9 cm. The fruits of Gola were rounded in shape with round apex. On other hand Chadha *et al.* (1972) have described fruit shape of Umran as oval, measuring 4.7×3.5 cm with mean fruit weight 33 g. The same oval shape in Umran was observed by Singh *et al.* (1973). According to the observations of these workers, the fruit of Illaichi was roundish in shape, golden yellow in colour, flat base and round apex, size small 2.3×2.3 cm with mean weight of 6.8g. A tentative key was proposed on the basis of fruit characters in 42 cultivars of *ber* by Singh and Bakshi (1972). Various shapes described were round, oblate, ovate, obovate, beaked and oval, whereas colour of developing fruit defined as light green, green, dark green, green with red pigments and dark red. Where as three size were considered in proposed key as large, medium and small. The shape of Illaichi was oblate and in Umran it was oval, Singh *et al.* (1973) described seven *ber* cultivars and found largest size in Karaka. Descriptions were recorded for four cultivars recommended for commercial cultivation in western Rajasthan (Chopra and Srivastwa, 1973). Teotia *et al.* (1974) studied nine cultivars of *ber* for their physico chemical characters. Pewandi cultivar was found to be the best commercial cultivar owing to its maximum fruit size. Nijjar (1975) and Jawanda and Bal (1978) reported that fruits of Umran were large and oval with roundish base. Singh and Singh (1970) have observed various fruit characters in Umran *ber*. From time of setting, the *ber* fruit required about 190 days to reach the stage of harvest maturity. This was quite a long period

when compared to other fruits. Other fruits like guava take 150 days, banana 135 days and mango 115 days. The size of the fruit increased with the advancement of the season. The weight of the fruit continued to increase from fruit set till maturity. The sequence of change in colour was green, chinese yellow and finally golden yellow. Kundi *et al.* (1989) have studied physico-chemical characteristic of seven *ber* cultivars viz. LR-9, LR-11, LR-13, Haq Nawaz, Cantonment, Golan and Lalwali. Significant variation existed among various fruit parameters. Maximum fruit weight of 29.349g per fruit was found in Lalwali. The size of fruit varied from 3.27 to 4.33 cm in length and 2.04 cm to 3.30 cm in diameter respectively. According to Gupta *et al.* (1990), the weight and size of fruit also depends upon some cultural practices adopted. Bal (1992) has made keys for classification of twenty four cultivars of *ber* on the basis of fruit characters. Fruit characters used in classification were (i) fruit with a distinctly pointed apex, (ii) fruit with a slightly pointed apex (iii) fruit with a round apex and (iv) fruit apex round with a depression. The most commonly shape observed were oval and round. Tiwari and Banafar (1995) have made a study in three varieties of *ber* viz., Seb, Banarasi Karaka and Gola. Length of fruit and yield was higher in cultivar Banarasi Karaka. It had minimum diameter. The data on six biometrical characters was collected in *ber* by Prajapati *et al.* (1996). Path analysis revealed positive direct contribution of fruit set and fruit length and negative contribution of fruit drop and stone weight.

(b) Stone character

Edible portion of a fruit is determined by the size of the seed to some extent. Further, the seed characters aid sometimes in the identification of cultivars as they greatly vary in shape, size colour, surface etc. from cultivar to cultivar. Work on seed characters of different *ber* cultivars is limited (Chadha *et al.*, 1972; Singh *et al.*, 1973 and Teotia *et al.*, 1973). Babu and Kumar (1986) studied stone characters in seven *ber* cultivars and observed that fruits of Mundia had longest seeds (2.63 cm) followed by those of (2.52cm) and shortest seeds (2.13 cm) were found in the fruits of Banarasi and Seb. However, the cultivars did not differ significantly with respect to length of seed. On the other hand, significant differences were observed with regard to diameter of seed. The smallest seed of Seb had highest diameter (1.15 cm). But this was not true with longest seeds. Seed diameter was least in case of Akola.

(c) Chemical characters

Various chemical composition such as total soluble solids, acidity, ascorbic acid etc. are also helpful in assessing the quality of fruits. These constituents are reviewed as follows.

Total soluble solids (T.S.S.)

Singh *et al.* (1973) have reported that total soluble solids vary in different cultivars under different agroclimatic conditions. T.S.S. of 18.5 per cent was reported in Umran whereas it was 16.5 per cent in Seo and 17.5 per cent in Gola. Chadha *et al.* (1972) reported 21 per cent T.S.S.

in Illaichi, 19 per cent in Umran and 17 per cent in Seo. Whereas Singh and Khanna (1968) found 17.5 per cent T.S.S. in Umran and Gola. Teotia *et al.* (1974) reported 16.5 per cent T.S.S. in Pewandi. Nijjar (1975) and Jawanda and Bal (1978) found 19 per cent T.S.S. in Umran whereas 18 and 20 per cent in Kaithli and Nazuk respectively. Bal and Singh (1978) have reported that total soluble solids continued to increase from fruit set to ripening and the increase was very much pronounced at later stage of maturity. The total sugar reported to be ranged between 7.89 to 11.52 per cent in different cvs. of *ber* (Kundi *et al.*, 1989). Gupta and Godara *et al.* (1989) have also reported that the T.S.S. percentage ranged between 16.08 per cent to 17.21 per cent under different pruning treatment in Umran *cv.* of *ber*. Tiwari and Banfar (1995) studied T.S.S. content in three varieties of *ber* viz., Seb, Banarasi Karaka and Gola. Highest T.S.S. percentage was recorded in Seb and Banarasi Karaka followed by Gola. Balakrishnan *et al.* (1998) have reported that T.S.S. as a measure of fruit maturity increased steadily from 30th day after anthesis up to complete maturity.

Acidity

In *ber*, maximum acidity 1.15 per cent was reported in Gola followed by Kaithli (0.51%) and Umran (0.32%). Singh *et al.* (1973) also recorded almost similar results in Umran and Kaithli. According to Chadha *et al.* (1972), acidity varied from 0.20 per cent in ZG-3 to 1.4 per cent in ZG-4. The acidity in Illaichi was 0.49 and 0.22 per cent in Umran. Maximum acidity of 0.9 per cent was reported in Gola cvs. compared to other cvs

studied (Tiwari and Banfar, 1995). According to Balakrishnan *et al* (1998), the acidity of the fruit increased as the growth of the fruit advanced towards maturity and reached up to 0.564 per cent at complete maturity in cultivar Banarsi.

Ascorbic acid

It is well known that *ber* is a rich source of Vitamin C. Chadha *et al.* (1972) reported that Vitamin C content ranged from 70 to 165.5 mg/ 100g of fruit in different *ber* varieties. The Vitamin C content in Illaichi and Umran was 141.2 and 103.9 mg/100 gm fruit respectively. Teotia *et al.* (1974) reported 62.0 mg ascorbic acid/100 gm of fruit weight in Mudhia murrahara, whereas Bal and Mann (1978) reported that Umran fruits at ripening contained 116.3 mg of ascorbic acid/100g fruit pulp. According to Singh and Singh (1970) the ascorbic acid content of the *ber* fruit increased as the maturity advanced. In case of *ber* up to 90 days, there was gradual increase in the content of ascorbic acid and thereafter a sudden increase was observed. Khera and Singh (1976) reported maximum ascorbic acid content in cvs. Kaithli and Sonari No.5 (104 mg/100 g pulp). Fruits of Haq Nawaz cultivar besides having attractive colour and good taste contained the highest quantity of Vitamin C (Kundi *et al.*, 1989). Tiwari and Banafar (1995) also reported 73 mg of Vitamin C per 100 gm of fruit pulp in cultivar Banarasi Karaka and 71 mg/100g of fruit pulp in Gola, whereas Balakrishnan *et al.* (1998) have reported 148.64 mg of ascorbic acid per 100 gm of fruit pulp in Banarasi Karaka cultivar of *ber*.

2.4 Physiological characters

The chlorophyll and carotenoid pigment contents in the leaves as well stomatal conductance, transpiration rate and photosynthesis rate in a particular cultivar/form/species can also be made use for cultivar identification. Although not much published reports are available on physiological aspects of *ber*. However, pigments analysis in fruits is available in literature. Work on these aspects as reported by some workers, is briefly reviewed here. Pandey *et al.* (1991) estimated the chlorophyll contents in leaves of *ber* under salt stress conditions. According to them, total chlorophyll content decreased with the increasing levels of sodicity and salinity. Josan *et al.* (1988) showed the decreased chlorophyll content and increased carotenoids with the advancement of maturity in Wilking mandarin fruit. The chlorophyll content of fruit peel reduced to minimum while total carotenoid showed continuous increase as the fruit approached ripening (Singh *et al.*, 1998).

Wen-Zhiliang *et al.* (1994) compared a triploid *Ziziphus jujuba* cultivar with two diploid cultivars for water balance characteristics. Transpiration rate and daily maximum transpiration rate were lower in the triploid than diploid cultivars. Banker and Prasad (1992) reported higher stomatal density on *Z. mauritiana* rootstock and lowest on *Z. nummularia* which was a dwarfing rootstock. Stomatal size was also greater in the most vigrous rootstocks. Photosynthesis rate of soyabean (Donald *et al.*, 1985) and mungbean leaves (Sirohi *et al.*, 1988) were reduced under excess moisture level.

Chapter-III

Material and Methods

The present investigations entitled "Cytomorphological studies in wild and cultivated species of *Ziziphus*" were carried out during the years 1999-2000 and 2000-2001 in the Department of Horticulture, CCS Haryana Agricultural University, Hisar using the laboratories facilities available in this university. Seven commercial cultivated varieties including four cultivars of Gola group; three wild forms of *Ziziphus* spp. which have been referred during the course of study by local names and one wild form of *Jharber* (*Ziziphus nummularia* (Burm.f.)) constituted the plant material. The plants were 28 years old except *Jharber* which were approximately 5 years old and were given same cultural practices. The names of cultivated and wild forms along with their location are given below :

Sr.No.	Name of cvs./forms/spp.	Location
A.	**(*Z. mauritiana* Lamk.)**	
1.	Cultivated ber cv. Umran	CCS HAU ber orchard

2.	Cultivated ber cv. Illaichi	CCS HAU ber orchard
3.	Cultivated ber cv. Kathaphal	CCS HAU ber orchard
B.	**Cultivars of Gola group of *ber* (*Z. mauritiana* Lamk.)**	
1.	Gola Gurgaon No.3	CCS HAU ber orchard
2.	Bahadurgarhia Gola	CCS HAU ber orchard
3.	Kakrola Gola	CCS HAU ber orchard
4.	Dandan Gola	CCS HAU ber orchard
C.	**Desi *ber* (wild forms) (*Ziziphus* spp.)**	
1.	Desi-1	CCS HAU ber orchard
2.	Desi-2	CCS HAU ber orchard
3.	Desi-3	CCS HAU ber orchard
D.	**Jharber (wild form) (*Ziziphus nummularia* Burm.f.)**	Along the road side in HAU campus

The details of various observations recorded and various materials and methods employed are given below as under.

Observations recorded

3.1 Cytological studies

3.1.1 Chromosomes number of various cultivars/forms/species of *Ziziphus* included in the present investigation

3.2 Plant characters

3.2.1 Growth habit

3.2.2 Height of plant

3.2.3 Trunk and bark colour

3.2.4 Girth of trunk

3.3 Spine characters

3.3.1 Number of spines meter^{-1} of current season growth

3.3.2 Length of spine

3.3.3 Arrangement of spines on nodes

3.3.4 Shape of spine

3.4 Leaf characters

3.4.1 Shape of leaf

3.4.2 Shape of leaf base and apex

3.4.3 Nature of leaf margin

3.4.4 Colour and texture of upper and lower surface

3.4.5 Leaf dimensions (length, breadth and ratio)

3.4.6 Leaf area

3.4.7 Veination pattern of leaf

3.4.8 Length of petiole

3.4.9 Fresh weight of leaf

3.4.10 Dry weight of leaf

3.5 Flower characters

3.5.1 Time and duration of flowering

3.5.2 Number of flowers per cyme

3.5.3 Length of pedicel

3.5.4 Number of sepals

3.5.5 Dimensions of sepal (Length, breadth and ratio)

3.5.6 Number of petals

3.5.7 Diamention of petal (Length, breadth and ratio)

3.5.8 Length of stamen (Filament and anther)

3.5.9 Diameter of the disc

3.5.10 Anthesis time

3.5.11 Dehiscence time

3.6 Pollen morphology

3.6.1 Aperture of pollen

3.6.2 Shape of pollen

3.6.3 Size

3.6.4 Exine thickness

3.6.5 Exine ornamentation

3.7 Fruit characters

3.7.1 Time of ripening

3.7.2 Shape of the fruit

3.7.3 Shape of the base and apex of the fruit

3.7.4 Colour of the fruit at maturity

3.7.5 Length and diameter of the fruit

3.7.6 Weight of fruit

3.7.7 Shape of the stone

3.7.8 Length and diameter of the stone

3.7.9 Weight of the stone

3.7.10 Pulp to stone ratio

3.8 Quality parameters

3.8.1 Total soluble solids (%)

3.8.2 Acidity (%)

3.8.3 T.S.S./Acid ratio

3.8.4 Ascorbic acid (mg/100g fruit pulp)

3.9 Physiological characters

3.9.1 Chlorophyll'a' content in leaves

3.9.2 Chlorophyll'b' content in leaves

3.9.3 Total chlorophyll content in leaves

3.9.4 Carotenoid content in leaves

3.9.5 Transpiration rate

3.9.6 Stomatal conductance

3.9.7 Photosynthesis rate

MATERIALS AND METHODS USED

3.1 Cytological studies

Meiosis was studied in the pollen mother cells (P.M.C.) of all the cultivated varieties/wild forms and species of *Ziziphus*. For this study, new emerging floral buds were collected between 6.00 to 7.30 AM and the buds were fixed in carnoy's fixative prepared fresh at every collection. After 24 hours of fixation, the flower buds were washed with diluted ethanol and finally transferred to 70 per cent ethanol. The preserved material was stored

in a refrigerator till further observations for chromosome number were carried out on microscope by using acetocarmine dye.

3.1.1 Preparation of carnoy's fixative

This fixative solution was prepared afresh everytime for the collection of floral buds. This solution was prepared by mixing one part glacial acetic acid +3 parts chloroform +6 parts ethanol.

3.1.2 Preparation of dye

In the present study one per cent acetocarmine dye was used for staining of chromosomes. For the preparation of dye 100 ml of 45 per cent glacial acetic acid was taken in a flask and boiled gently. The flask was taken off the flame and one gram carmine powder (dye) was added and again heated for 2-3 minutes till cherry red colour developed and again cooled; filtered and stored in staining bottle.

3.1.3 Preparation of slides

For meiotic studies, the anthers from the young floral buds were squeezed in a drop of one per cent acetocarmine dye placed on the glass slide and a cover slip was placed after removing the debris with the help of iron needle. The slides were warmed gently for good separation of chromosomes. Thereafter the slides were pressed carefully between the folds of filter paper and scored for chromosomes number under microscope. The counting of chromosomes was done either at metaphase or diakinesis stage of meiosis.

3.1.4 Photomicrography

The photomicrographs were taken with the help of a Olympus Photomicrographic System Model PM 10AD with a automatic 35 mm camera outfit. All the photographs were taken at a total magnification of 1000X in oil emulsion. Black and white Nova, ASA100 film was used for photomicrography.

3.2 Plant characters

3.2.1 Growth habit

Descriptor term i.e. erect, spreading, semi spreading and drooping were used to describe the growth habit of plants by making visual observation (Table 1).

3.2.2 Height of plant

The height of plant was recorded with the help of meter rod in the month of October, 1999 and October, 2000.

3.2.3 Bark colour

The colour of phellum and phellogen was noticed by using descriptor (Table 1). For observing the colour of phellogen upper dead portion of the bark was removed.

3.2.4 Girth of trunk

The girth of stock and scion 10 cm below and 10 cm above the bud union in case of cultivated cultivars and 40 cm above the base in case of Desi forms was measured with the help of tape.

Table 1: List of morphological descriptors of *Ziziphus* spp. used in the present investigation

Characters	Descriptors
Growth habit	Erect, drooping, spreading, semi-spreading
Bark colour	
Phellum	Dark brown, reddish
Phellogen	Light green, pink
Spine	
Shape	Curved, straight
Arrangement	Paired, solitary
Leaf	
Shape	Cordate, elliptical, oblong, oval, ovate, obovate
Size	(a) Short leafed (length/width ratio <1.50) (b) Long leafed (length/width ratio >1.50)
Apex	Acute, blunt, obtuse, pointed, retuse
Base	Broad, oblique, obtuse, tapering
Margin	Crenate, entire, serrate
Veination	Parallel, reticulate (convergent/divergent)
Colour	Dark green, green, light green, light brown
Texture	Smooth, smooth glabrous, rough tomentose

3.3 Spine characters

3.3.1 Number of spines meter^{-1} of current seeason growth

One meter long current season shoots were removed from each tree in October, 1999 and October, 2000. Number of spines on each shoot were counted and mean of the five shoots was taken as number of spines meter^{-1}.

3.3.2 Length of spine

Similarly from the above removed shoots, the length of spines were recorded with the help of scale and mean value per spine was given.

3.3.3 Arrangement of spines on nodes

The arrangement of spine on nodes whether solitary or paired was observed visually.

3.3.4 Shape of spine

The shape of spine whether curved or straight was recorded by visual observations.

3.4 Leaf characters

For recording leaf characters, fifty normal and healthy leaves were taken randomly from each tree in October, 1999 and October 2000 and observed for various characters.

3.4.1 Shape of leaf

The shape of leaf was observed visually and described as cordate, elliptical, oblong, oval, ovate or obovate.

3.4.2 Shape of leaf apex and base

The shape of leaf apex and base was observed visually and described by using descriptors (Table 1).

3.4.3 Nature of leaf margin

The nature of margin was described as crenate, entire or serrate.

3.4.4 Colour and texture of upper and lower surface

The colour was observed and described as given in descriptors Table 1. The upper and lower surface was visually observed and described by using descriptors (Table 1).

3.4.5 Leaf dimensions (Length, breadth and ratio)

Length and breadth was recorded with the help of scale and leaf to breadth ratio was calculated by dividing length by breadth (Table 1).

3.4.6 Leaf area

The leaf area of 50 mature leaves was measured with the help of "portable leaf area meter" and mean value for individual leaf was calculated and mentioned as square centimeters.

3.4.7 Veination pattern of leaf

Leaf veination pattern was observed and described by using descriptor (Table 1).

3.4.8 Length of petiole

Length of fifty leaves' petiole was measured with the help of scale and mean value was given in mm.

3.4.9 Fresh weight of leaf

The weight of the fifty freshly detached leaves was taken and mean value was calculated and given in grams.

3.4.10 Dry weight of leaf

The above fifty leaves were kept in oven at 40°C for 20 days and then the weight was measured and mean value was given as dry weight/leaf in grams.

3.5 Flower characters

Time of opening of 1st flower and last flower was noticed and the total period was mentioned as duration of flowering. For other characters, fifty cymes from each tree were collected in F.A.A. solution (90 ml of 80% ethanol + 5 ml formalin + 5 ml acetic acid) at peak period of flowering in the month of September, 1999 and 2000 in *Jharber* and October, 1999 and 2000 in other cvs./forms and observed for the various floral characters. The size of petal and length of stamen were recorded with the help of a ocular micrometer at a total magnification of 40X.

Anthesis time: To determine the time of anthesis, five uniform branches were tagged and the number of flowers opening at different intervals of time were recorded in each cultivar/form/species. The opened flowers were removed after every observation to avoid confusion in counting. Data was recorded between 5.00 AM to 6.00 PM at an interval of half an hour for one week in the 1st week of September for Jharber and mid October for others cultivars/forms, which is a peak period of flowering.

Dehiscence time : To study the time of dehiscence, twenty five flowers on each tree were tagged at 6.00 AM on each day for a week. The dehisced anthers were observed at an interval of thirty minutes from 6.00 AM to 6 PM. To avoid confusion in counting, flowers with dehisced anthers were removed. When anthers became yellow in appearance, it was considered to have dehisced. Hand lens was used to observe dehiscence.

3.6 Pollen morphology

The pollens were collected directly from field in vials containing 70 per cent ethanol between 6.30 AM to 7.30 AM in the peak month of flowering i.e. in September for *Jharber* and October for other cultivars/ forms. For preparation of pollens, the acetolysis method was used as described by Nair (1970). The terminology adopted for description of pollen morphology was also the same as that used by Nair (1970). For recording pollen size mean of ten pollen grains in each case was taken at a total magnification of 400x with the help of a ocular micrometer. Exine thickness, exine ornamentation and all other characters were recorded at a total magnification of 1000x in oil emulsion.

Photomicrographs were taken with the help of same Olympus Photomicrographic System Model PM 10AD with a automatic 35 mm camera, which was used for cytological studies. All the photographs were taken at a total magnificaiton of 400x.

Preparation of pollens by acetolysis method

1. Collected the mature anthers directly from the field in the glass

vials containing 70% alcohol and allowed the material to soak in alcohol for 24 hours.

2. Transferred material along with alcohol to a polythene centrifuge tube and crushed the anthers by a glass rod.
3. Passed the dispersion through a brass metal sieve (48 divisions per sq. cm) and collected it in a glass centrifuge tube.
4. Centrifuged the contents and decanted off the alcohol.
5. Washed the sediments with glacial acetic acid. Centrifuged and decanted off the acid.
6. Added about 5 c.c. of freshly prepared "acetolysis mixture" (A mixture of 9 parts acetic anhydride and 1 part concentrated sulphuric acid) into the tube.
7. Placed the tube with acetolysis mixture in a water bath and boiled water from 70°C to boiling point. Stopped flame, when water boiled, but left the tube in hot water for 3-5 minutes. (till the time a medium brown colouration was attained).
8. Centrifuged and decanted off the mixture.
9. Added glacial acetic acid over the sediment. Centrifuged and decanted off the acid.
10. Washed the sediments with distilled water. Centrifuged and decanted off water.
11. Added about 2 c.c. dilute glycerine to the tube and centrifuge and decanted off the glycerine.

12. Cut a small pellet of glycerine jelly with a blade and placed it at the tip of a needle and passed the jelly over a flame to allow the peripheral melting of the jelly in the pellet.

13. Inserted needle into the centrifuge tube and touch the pollen sediments, to catch the grains on the jelly.

14. Transferred the pellet of jelly to a microslide kept on a preparation board. Heated the slide slightly and covered with a cover glass slip and pressed it slightly by a needle and observed for various characters on the electric microscope.

3.7 Fruit characters

Fruit descriptors were used for describing various fruit character (Table 2). When more than 50 per cent fruits were ripened that time was considered as the time of ripening. For other fruit characters, fifty ripe fruits were taken at random from each tree at the time of harvesting during October, 1999 and October, 2000 for Jharber and February - March 2000 and 2001 for others and the observations were recorded and described by using fruit descriptors for various fruit characters (Table 2). Length and diameter was measured with the help of digital vernier's callipar and mean value per fruit was calculated and mentioned in cm and weight in grams. The stone was removed out from these fruits and recorded for various stone characters and mean value per stone was given.

Table 2: List of fruit descriptors used in the present investigation

Characters	Descriptors
Fruit	
Shape	Round, oblong, oval, ovate
Apex	Broad, depressed, flattened, round
Base	Broad, flat, round, round with depression
Colour at maturity	Golden yellow, yellowish with brown patch, dark brown, light green with coffee colour patch.
Size	Large, medium, small

3.8 Quality parameters

3.8.1 Total soluble solids (%)

The fruits out of the composite sample were selected and crushed and the juice thus extracted was used for estimation of T.S.S. The estimation was made with the help of hand refractometer (0-32% range) and expressed as T.S.S. percentage.

3.8.2 Acidity (%)

A known weight of edible pulp was taken and macerated with hot distilled water in glass pastle and morter. The macerated material was boiled on hot water bath for complete extraction of acids from the pulp (as described by A.O.A.C. (1990).

It was then strained through muslin cloth. The filterate was taken and the final volume was made with distilled water. The acidity in fruit extract was estimated by titrating it against 0.1N NaOH using phenolphthalein as indicator. The total acidity was worked out in terms of citric acid and expressed in percentage.

3.8.3 T.S.S./Acid ratio

It was calculated by dividing the T.S.S. with acidity and ratio was expressed as such.

3.8.4 Ascorbic acid (mg/100g fruit pulp)

A known weight of edible pulp was taken from the composite sample and macerated in glass pastle and morter using buffer solution prepared with metaphosphoric acid and glacial acetic acid.

The ascorbic acid was estimated by titrating the extract against 2,6 dichlorophenol indophenol reagent. Ascorbic acid was expressed in mg per 100 gm of fruit pulp.

3.9 Physiological characters

Chlorophyll and carotenoid pigments in leaves : Chlorophyll pigments namely chlorophyll'a', chlorophyll'b', total chlorophyll and carotenoids were estimated in leaves by the method given by Hiscox and Israelstam (1979) and mentioned as μmol cm^{-2}.

Extraction of pigments : Five discs (0.28 cm^2 area) of the leaves were suspended in a test tube containing 10 ml dimethyl sulphoxide (DMSO). The test tubes were then placed in an oven at 60±1°C for four hours to facilitate the extraction of pigments.

Estimation : After four hours of incubation, the test tubes were cooled to room temperature and the absorbance was measured at 454, 645 and 665 nm on a spectrophotometer (Spectronic-20D). DMSO was used as blank.

The chlorophyll pigments were calculated by using the following equations.

Chlorophyll'a' (μg/ml) = 12.19 A665–3.45A645

Chlorophyll'b' (μg/ml) = 21.99 A645–5.32A665

Total chlorophyll (μg/ml) = Chlorophyll'a' + Chlorophyll'b'

$$\text{Carotenoids (μg/ml)} = \frac{1000A454 - 2.86\ \text{Chlorophyll'a'} - 129.2\ \text{Chlorophyll'b'}}{221}$$

The quantity of all the above pigments were expressed in μ moles cm^{-2} by using the following relationships.

$$\text{Chlorophyll'a' content (μmol } cm^{-2}) = \frac{\text{μg/ml chlorophyll'a'} \times \text{volume of DMSO} \times 1.119}{\text{Area of leaf discs}}$$

$$\text{Chlorophyll'b' content (μmol } cm^{-2}) = \frac{\text{μg/ml chlorophyll'b'} \times \text{volume of DMSO} \times 1.102}{\text{Area of leaf discs}}$$

Total chlorophyll (μmol cm^{-2}) = Chlorophyll'a' μ moles cm^{-2} + Chlorophyll'b' μ moles cm^{-2}

$$\text{Carotenoid content (μmol } cm^{-2}) = \frac{\text{μg/ml of carotenoid} \times \text{volume of DMSO} \times 1.809}{\text{Area of leaf discs}}$$

Stomatal conductance, transpiration and photosynthesis rate : These observations were recorded directly from the field between 10.00 AM to 11.30 AM with the help of Portable–IRGA (photosynthesis system model CIRAS-1).

Leaf cuvette was clamped on upper surface (in this position PAR senser faces sunlight and was upward) of the leaf and its position was changed in such a way that maximum photoactive radiation was obtained and minimum differences in CO_2 and water vapours between reference and analytical cell were achieved. At this stage exchange switch was pressed and when the reading were stable, the values were recorded. At each sampling three tagged fully expanded leaves were used for measuring parameters given below.

Transpiration rate = m mol m^{-2} s^{-1}

Stomatal conductance = m mol m^{-2} s^{-1}

Photosynthesis rate = μ mol m^{-2} s^{-1}

3.10 Statistical analysis

For statistical analysis of the data complete randomized design (C.R.D.) was followed. Critical difference was worked out whereever necessary.

Chapter-IV

Results

The present investigation entitled "Cytomorphological studies in wild and cultivated species of *Ziziphus*" was carried out during the years 1999-2000 and 2000-2001 with a view to study and confirm the variations with respect to chromosome number, morphology, physico-chemical characters and physiological characters. The present investigation was undertaken on eleven cultivars/form/species of *Ziziphus*. The results observed during the course of investigation are presented in this chapter under various heads.

4.1 Cytological studies

4.2 Morphological characters

4.3 Physico-chemical characters

4.4 Physiological characters

4.1 Cytological studies

Preliminary investigations were carried out to know the chromosome number of various cultivars/forms/species of *Ziziphus*. For this purpose,

the first step was to standardize the time for collection of flower buds. The best dividing stages were observed in the buds collected between 6.00 AM to 7.00 AM in the month of September for *Jharber* and in October for other cultivars/forms. Out of various fixatives used to fix the pollen mother cells (PMC); the Cornoy's fluid proved to be the most suitable. For squeezing, optimum results were obtained with one per cent acetocarmine stain.

4.1.1 Meiosis

Meiosis was studied in all the cultivated varieties/forms/species of *Ziziphus* for chromosome count. The pollen mother cells were recorded for chromosome number either at diakinesis or at metaphase-I. The present cytological studies revealed that chromosomes were exceedingly small in size, pachytene in *Ziziphus* was very clear which showed pairing of chromosomes and presence of nucleolar organiser. Chromosome number of all the cultivars/forms/species of *Zizipus* along with chromosomal association in terms of univalents, bivalents, trivalents and Quadrivalents are listed in Table 3.

Cultivated varieties

The chromosome number in cvs. Umran and Kathaphal was recorded at diakinesis and found to be 2n=48. The chromosome number in all four cultivars of Gola viz., Gola Gurgaon No.3, Bahadurgarhia Gola, Dandan Gola and Kakrola Gola was also found to be 2n=48 (Plate I). In the other cv. viz., Illaichi of the same species; the chromosome number was 2n=96. The

Table 3: Chromosome number in various cultivars and forms of *Ziziphus* spp.

Name of cultivar/ form/species	Chromosome number (2n)	Chromosomal associations at diakinesis			
		Univalents (I)	Bivalents (II)	Trivalents (III)	Quadrivalents (IV)
Ziziphus mauritiana					
Umran	48	–	24	–	–
Illaichi	96	–	48	–	–
Kathaphal	48	–	22	–	1
Gola Gurgaon No 3	48	–	22	–	1
Bahadurgarhia Gola	48	–	14	–	5
Dandan Gola	48	–	24	–	–
Kakrola Gola	48	–	22	–	1
***Ziziphus* spp.**					
Desi-1	96	–	40	–	4
Desi-2	96	–	40	–	4
Desi-3	96	–	40	–	4
Ziziphus nummularia					
Jharber	72	–	34	–	1

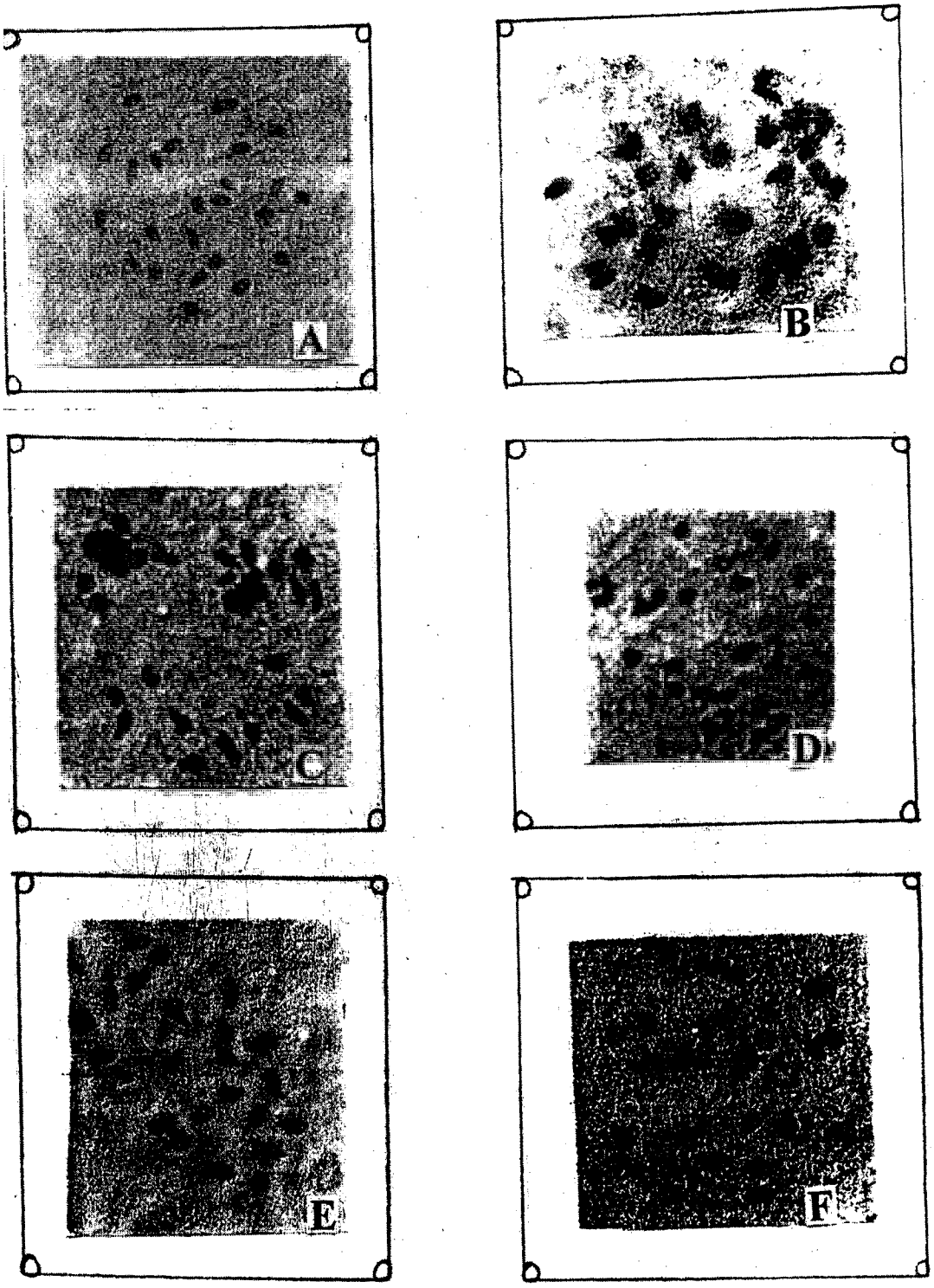


Plate 1: Chromosome number in various cultivars and forms of *Ziziphus* spp. A-Umran; B-Kathaphal; C-Gola Gurgaon No.3; D-Bahadurgarhia Gola; E-Dandan Gola; F-Kakrola Gola

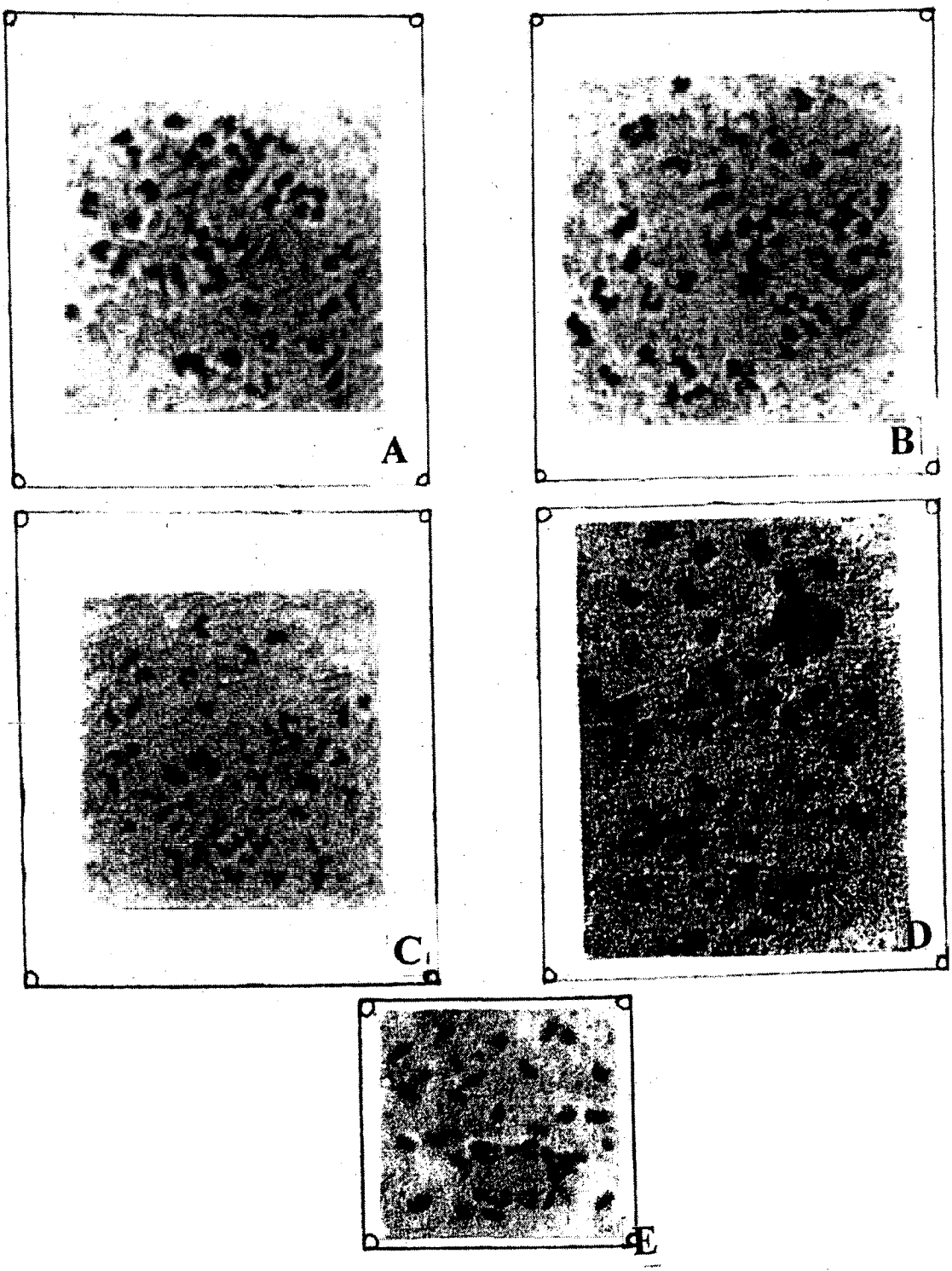


Plate 2: Chromosome number in various cultivars and forms of *Ziziphus* spp. A-Illaichi; B-Desi-I; C-Desi-2; D-Desi-3; E-Jharber;

chromosomal association in Kathaphal, Gola Gurgaon No.3 and Kakrola Gola as observed at diakinesis was $22_{II} + I_{IV}$; in Bahadurgarhia Gola $14_{II} + 5_{IV}$ (Plate-I).

Wild forms/species

The chromosome number in the three wild forms viz., Desi-I, Desi-2 and Desi-3 was observed to be 2n=96 at diakinesis (Plate 2). In another wild species i.e. *Jharber*, chromosome number at diakinesis/ metaphase-I were counted to be 2n=72 (Plate 2).

The chromosomal association in Desi-I, Desi-2 and Desi-3 was $40_{II} + 4_{IV}$ and in *Jharber* $34_{II} + 1_{IV}$ (Plate 2).

4.2 Morphological characters

Growth

There were significant differences among cultivated varieties/forms/ spp. with respect to plant height, plant spread and tree volume (Table 4). The maximum plant height during 1999 was observed in Desi-3 followed by Desi-2 while in Kathaphal followed by Desi-3 during 2000. Minimum plant height was recorded in case of *Jharber* during both the years. However among cultivated varieties, the plant height was minimum in case of cultivar Illaichi. The spread of plant in North-South direction was recorded maximum (10.81 and 10.54 m) in Kathaphal followed by Desi-3 and Bahadurgarhia Gola during both the years. Minimum (1.52 and 1.60 m) plant spread in the same direction was in *Jharber*. Moreover East-West ward spread was observed maximum (11.80 and 11.57 m) in Gola Gurgaon No.3 followed

Table 4: Height, spread and tree volume in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Height of plant (m)			Spread (north-south) (m)			Spread (east-west) (m)			Mean tree volume (m^2)
	1999	2000	Mean	1999	2000	Mean	1999	2000	Mean	
Ziziphus mauritiana										
Umran	6.53	6.03	6.28	7.83	7.37	7.60	8.91	8.72	8.81	221.36
Illaichi	5.17	4.81	4.99	7.67	7.31	7.49	8.61	8.09	8.35	158.54
Kathaphal	7.51	7.43	7.47	10.81	10.54	10.67	10.12	9.90	10.01	418.19
Gola Gurgaon No 3	6.80	6.21	6.51	9.62	9.45	9.53	11.80	11.57	11.68	383.27
Bahadurgarhia Gola	7.03	6.54	6.78	9.83	9.80	9.81	8.41	8.27	8.34	292.24
Dandan Gola	5.14	4.63	4.88	6.21	6.07	6.14	5.33	5.21	5.27	83.09
Kakrola Gola	5.91	5.21	5.56	6.37	6.11	6.24	7.89	7.27	7.58	139.04
***Ziziphus* spp.**										
Desi-1	6.23	6.72	6.47	8.90	9.15	9.02	10.65	10.42	10.53	223.59
Desi-2	7.64	6.91	7.23	9.25	9.30	9.27	6.91	7.00	6.95	248.94
Desi-3	7.83	7.38	7.61	9.80	9.85	9.82	8.20	8.25	8.22	324.19
Ziziphus nummularia										
Jharber	1.61	1.82	1.71	1.52	1.60	1.56	1.45	1.50	1.47	14.56
CD (P=0.05)	**0.185**	**0.219**	–	**0.161**	**0.231**	–	**0.165**	**0.184**	–	–

by Desi-I. Again similar to plant height, the minimum spread in this direction was also of *Jharber*. Tree volume ranged between 14.56 $m^{\backslash 2}$ of *Jharber* to 383.27 m^2 of Gola Gurgaon No.3.

Besides plant height and spread the plant growth habit and branching angles are also of considerate significance. It is evident from data given in Table 5 that the plants of cvs. Umran, Illaichi, Desi-I and Desi-3 were spreading in nature, while Kathaphal and Desi-2 had semi-spreading habit (Table 5). It was also noticed that the plants of all four cvs. of Gola group viz., Gola Gurgaon No.3, Bahadurgarhia Gola, Dandan Gola and Kakrola Gola were of erect growing nature. The branching angle of the genotypes investigated ranged between 53.37° and 63.02° and 53.04° to 66.71° during 1999 and 2000, respectively (Table 5).

The data mentioned in Table 6 clearly indicated that the colour of bark phellum and phellogen was dark brown and pink, respectively in all the cvs./forms/spp. except *Jharber*, where it was reddish and light green. The girth of trunk was maximum (150 cm) of Desi-I followed by Bahadurgarhia Gola and minimum (21.5 cm) in *Jharber* during both years. The other cvs./forms had values between these extremes.

Spines : A perusal of data in Table 7 and Plate 3 revealed that the spines were present in pair in all the cvs/forms/spp except Illaichi where it was present in solitary form. Similarly the shape of one of the paired spines was curved and the other was straight in all the cvs./forms/spp. investigated except that the solitary spines present in Illaichi were curved only. There

Table 5: Growth habit and angle of branching in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Growth habit	Branching angle (°)		
		1999	2000	Mean
Ziziphus mauritiana				
Umran	Spreading	57.89	53.37	55.63
Illaichi	Spreading	59.27	52.21	55.74
Kathaphal	Semi spreading	58.60	55.13	56.87
Gola Gurgaon No 3	Erect	59.54	56.33	57.94
Bahadurgarhia Gola	Erect	56.33	53.04	54.69
Dandan Gola	Erect	62.95	65.22	64.09
Kakrola Gola	Erect	59.03	58.60	58.82
***Ziziphus* spp.**				
Desi-1	Spreading	63.02	66.71	64.87
Desi-2	Semi spreading	61.23	59.94	60.59
Desi-3	Spreading	53.37	53.04	53.21
Ziziphus nummularia				
Jharber	Erect	56.17	54.40	55.29
CD (P=0.05)		**1.166**	**1.027**	–

Table 6: Bark colour and girth of trunk in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Bark colour		Girth of trunk (cm)					
	Phellum	Phellogen	10 cm below the bud union			10 cm above the bud union		
			1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana								
Umran	Dark brown	Pink	144	145	144.5	130	128	129.0
Illaichi	Dark brown	Pink	137	138	137.5	160	158	159.0
Kathaphal	Dark brown	Pink	138	140	139.0	146	147	146.5
Gola Gurgaon No 3	Dark brown	Pink	145	146	145.5	172	175	173.5
Bahadurgarhia Gola	Dark brown	Pink	146	148	147.0	180	180	180.0
Dandan Gola	Dark brown	Pink	142	143	142.5	150	152	151.0
Kakrola Gola	Dark brown	Pink	130	127	128.5	135	136	135.5
***Ziziphus* spp.**								
Desi-1*	Dark brown	Pink	150	150	150.0	150	150	150.0
Desi-2*	Dark brown	Pink	115	117	116.0	115	117	116.0
Desi-3*	Dark brown	Pink	95	96	95.5	95	96	95.5
Ziziphus nummularia								
Jharber*	Reddish	Light green	21.5	21.8	21.65	21.5	21.8	21.65
CD (P=0.05)			**2.235**	**1.663**	–	**3.733**	**4.221**	–

*The girth of trunk was measured from 40 cm above the base

Table 7: Spine characters in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Shape of spine	Arrangement of spines on nodes	Length of spine (mm)			Number of spines meter^{-1} of current season growth		
			1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana								
Umran	I Curved II Straight	Paired	5.85	5.76	5.80	20	21	20.5
Illaichi	Curved	Solitary	4.70	4.82	4.76	18	20	19.0
Kathaphal	I Curved II Straight	Paired	5.32	5.90	5.61	30	33	31.5
Gola Gurgaon No 3	I Curved II Straight	Paired	6.53	6.27	6.40	32	35	33.5
Bahadurgarhia Gola	I Curved II Straight	Paired	6.03	5.91	5.97	40	44	42.0
Dandan Gola	I Curved II Straight	Paired	8.12	8.27	8.19	32	38	35.0
Kakrola Gola	I Curved II Straight	Paired	5.91	5.78	5.84	41	46	43.5
***Ziziphus* spp.**								
Desi-1	I Curved II Straight	Paired	4.11	4.20	4.15	46	47	46.5
Desi-2	I Curved II Straight	Paired	5.63	5.65	5.64	61	64	62.5
Desi-3	I Curved II Straight	Paired	6.11	6.17	6.14	60	68	64.0
Ziziphus nummularia								
Jharber	I Curved II Straight	Paired	10.07	10.21	10.14	48	46	47.0
CD (P=0.05)			**0.085**	**0.109**	–	**5.452**	**6.539**	–

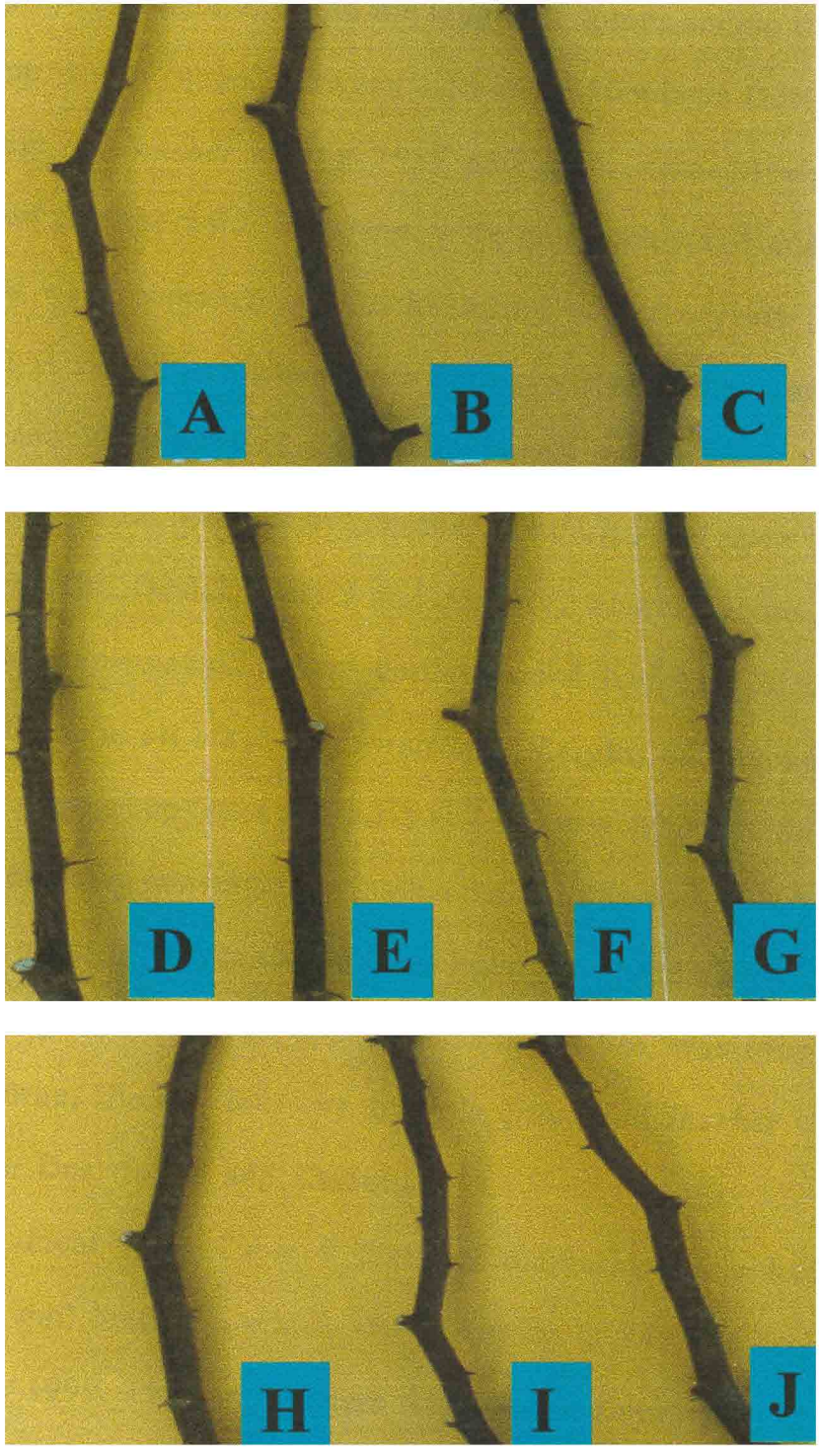


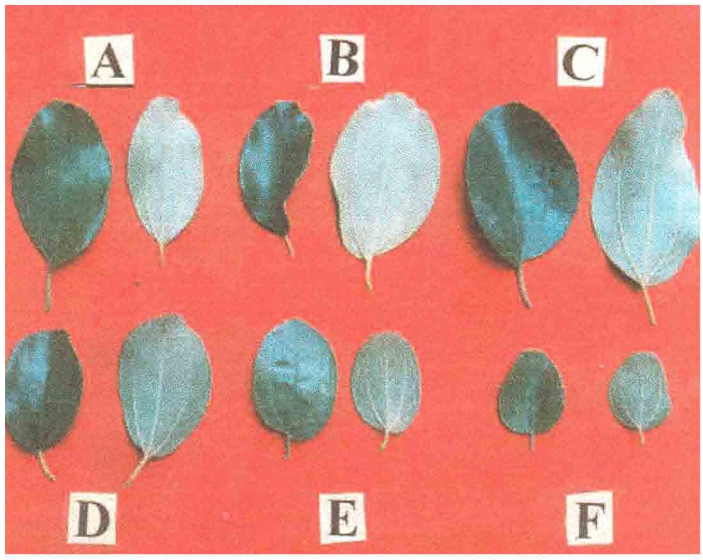
Plate 3: Spine character in various cultivars and forms of *Ziziphus spp*

A-Umran, B- Illaichi, C- Kathaphal, D- Gola Gurgaon no.3, E- Bahadurgarhia, F- Dandan Gola, G-Kakrola Gola, H- Desi-1, I- Desi-2, J- Desi-3

were significant differences in the length of spines among the various cvs./ forms/spp. and it ranged between 4.11 and 4.20 mm in Desi-I to 10.07 and 10.21 mm in *Jharber* during 1999 and 2000, respectively. It was also elucidated that the wild/forms/spp. were more spiny and minimum number of spines were observed in Illaichi during both the years (Table 7).

Leaf : It is amply explained from data given in Table 8 and depicted in Plates 4 and 5 that the leaf shape was elliptical to obovate in Umran, Desi-1, *Jharber* and ovate in other cvs./forms. Similarly, leaf apex was obtuse in Umran, Illaichi, Desi-2, Desi-3 and *Jharber*, whereas acute in rest of the cvs./forms investigated. Except cordate/round leaf base in Desi-3 it was obtuse/oblique in all other cvs./forms/spp. Margins of leaves were serrated in all cvs./forms/spp. except Desi-3 and *Jharber* where it was entire. The reticulate palmatic convergent veination pattern was present in all cvs./forms/ spp. The colour of leaves varied from light green to dark green with upper texture being smooth in all spp. and lower texture, was rough tomentose type in Umran, Illaichi, four cvs. of Gola group and *Jharber* while smooth glabrous in Desi forms and Kataphal.

It is clear from Table 9 that Bahadurgarhia Gola had maximum (9.62×5.62 cm) leaf size, which was minimum (1.84×1.46 cm) in *Jharber* during year 1999. The same pattern was observed during 2000 also. There were significant differences in between various cvs./forms/spp. for length to breadth ratio that ranged between 1.07 to 1.77.



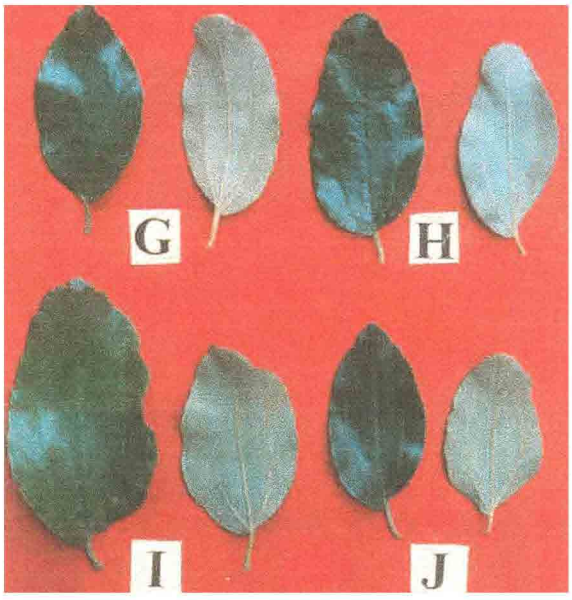


Plate 4: **Leaf characters in various cultivars and forms of *Ziziphus* spp.** A-Umran, B-Illaichi, C-Kathaphal, D-Desi-1, E-Desi-2, F-Desi-3, G-Gola Gurgaon No 3, H-Bahadurgarhia Gola, I-Dandan Gola, J-Kakrola Gola

Plate 5: Leaf and fruit characters in Jharber

Table 8: Leaf characters in various cultivars and forms of *Ziziphus* spp.

Name of cultivar/ form	Leaf							
	Shape	Apex	Base	Nature of margin	Veination . pattern	Colour	Upper texture	Lower texture
Ziziphus mauritiana								
Umran	Elliptical to obovate	Obtuse	Obtuse/ oblique	Serrate	Reticulate (convergent)	Dark green	Smooth	Rough Tomentose
Illaichi	Elliptical to obovate	Obtuse	Obtuse/ oblique	Serrate	- do -	Light green	Smooth	Rough Tomentose
Kathaphal	Ovate	Acute	Obtuse/ oblique	Serrate	- do -	Dark green	Smooth	Smooth glabrous
Gola Gurgaon No 3	Ovate	Acute	Obtuse/ oblique	Serrate	- do -	Dark green	Smooth	Rough Tomentose
Bahadurgarhia Gola	Ovate	Acute	Obtuse/ oblique	Serrate	- do -	Dark green	Smooth	Rough Tomentose
Dandan Gola	Ovate	Acute	Obtuse/ oblique	Serrate	- do -	Light green	Smooth	Rough Tomentose
Kakrola Gola	Ovate	Acute	Obtuse/ oblique	Serrate	- do -	Dark green	Smooth	Rough Tomentose
***Ziziphus* spp.**								
Desi-1	Elliptical to obovate	Acute	Obtuse/ oblique	Serrate	- do -	Dark green	Smooth	Smooth glabrous
Desi-2	Ovate	Obtuse	Obtuse/ oblique	Serrate	- do -	Dark green	Smooth	Smooth glabrous
Desi-3	Ovate	Obtuse	Cordate/ round	Entire	- do -	Light green	Smooth	Smooth glabrous
Ziziphus nummularia								
Jharber	Elliptical to obovate	Obtuse	Obtuse/ oblique	Entire	- do -	Light green	Smooth	Rough Tomentose

Table 9: Dimensions of leaf in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Size category	Leaf dimensions								
		Length (cm)			Breadth (cm)			L/B ratio		
		1999	2000	Mean	1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana										
Umran	LL	9.54	8.97	9.25	5.46	5.11	5.28	1.74	1.75	1.74
Illaichi	LL	8.98	9.32	9.15	5.66	6.18	5.92	1.58	1.51	1.54
Kathaphal	SL	7.90	8.36	8.13	5.34	5.98	5.66	1.48	1.40	1.44
Gola Gurgaon No 3	LL	9.34	8.62	8.98	5.22	4.90	5.06	1.79	1.76	1.77
Bahadurgarhia Gola	LL	9.62	10.14	9.88	5.62	6.32	5.97	1.71	1.60	1.65
Dandan Gola	LL	9.28	9.48	9.38	5.50	5.34	5.42	1.69	1.77	1.73
Kakrola Gola	LL	9.20	9.43	9.32	5.30	5.46	5.38	1.73	1.73	1.73
***Ziziphus* spp.**										
Desi-1	SL	6.90	7.28	7.09	5.02	5.86	5.44	1.37	1.24	1.30
Desi-2	SL	5.36	5.82	5.59	3.86	4.24	4.05	1.39	1.37	1.38
Desi-3	SL	3.76	3.52	3.64	3.62	3.28	3.45	1.04	1.07	1.05
Ziziphus nummularia										
Jharber	SL	1.84	1.98	1.91	1.46	1.61	1.54	1.26	1.23	1.24
CD (P=0.05)		**0.265**	**0.459**	–	**0.332**	**0.263**	–			

LL = Long Leafed; SL = Short leafed

There were significant differences in length of petiole and leaf area of various cvs./forms/spp. investigated (Table 10). The length of petiole was maximum (2.27 and 2.31 mm) in Illaichi followed by Kathaphal, whereas minimum sized petioles were recorded (0.52 and 0.57 mm) in case of *Jharber*. Similarly, the leaf area was also recorded maximum (42.10 and 49.67 cm^2) in Illaichi and minimum (2.16 and 2.76 cm^2) in *Jharber*. The values for other cvs./forms/spp. ranged inbetween these limits.

Perusal of data given in Table 11 clearly indicated that the fresh leaf weight was maximum (1.84 and 1.94 g) in Illaichi and minimum (0.09 and 0.10 g) in *Jharber* during both the years of investigation. However, the fresh leaf weight was at par in Kathaphal, Gola Gurgaon No.3 and Kakrola Gola in 1999 but differed significantly during 2000. Similar pattern was observed with regard to dry leaf weight being maximum in Illaichi and minimum in *Jharber* during both the years (Table 11).

Flower

While recording various flower characters, some common behaviour among all cvs./forms/spp. was also observed, which is briefly described here before explaining the tabulated data.

The inflorescence was cymose and flowers were small and borne in the axil of leaf. Flowers were pentamerous, hermaphrodite, actinomorphic, complete perigynous, bractiate, pedicellate, light green and with a well developed intrastaminal disc. Calyx consisted of five sepals of light green colour. The aestivation was valvate. Five strongly concaved and whitish,

Table 10: Length of petiole and leaf area in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Length of petiole (cm)			Leaf area (cm^2)		
	1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana						
Umran	1.78	1.75	1.76	40.22	38.71	39.46
Illaichi	2.27	2.31	2.29	42.10	49.67	45.88
Kathaphal	2.10	2.22	2.16	33.78	38.93	36.35
Gola Gurgaon No 3	1.93	1.90	1.91	38.18	35.67	36.92
Bahadurgarhia Gola	1.51	1.60	1.55	43.10	46.11	44.60
Dandan Gola	1.87	1.93	1.90	42.08	41.84	41.96
Kakrola Gola	1.60	1.65	1.62	40.50	42.77	41.63
***Ziziphus* spp.**						
Desi-1	1.96	1.82	1.89	27.07	33.19	30.13
Desi-2	1.29	1.40	1.34	18.15	22.10	20.16
Desi-3	0.60	0.68	0.64	12.52	10.91	11.72
Ziziphus nummularia						
Jharber	0.52	0.57	0.54	2.16	2.76	2.46
CD (P=0.05)	**0.067**	**0.072**	–	**0.382**	**0.424**	–

Table 11: Fresh leaf weight and dry leaf weight in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Fresh leaf weight (g)			Dry leaf weight (g)			Fw/Dw Ratio		
	1999	2000	Mean	1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana									
Umran	1.20	1.17	1.185	0.43	0.42	0.425	2.79	2.78	2.788
Illaichi	1.84	1.94	1.890	0.59	0.62	0.605	3.12	3.13	3.125
Kathaphal	1.16	1.22	1.190	0.46	0.48	0.470	2.52	2.54	2.530
Gola Gurgaon No 3	1.17	1.10	1.135	0.41	0.40	0.405	2.85	2.75	2.800
Bahadurgarhia Gola	1.45	1.50	1.475	0.54	0.55	0.545	2.69	2.73	2.710
Dandan Gola	1.36	1.35	1.355	0.52	0.52	0.520	2.61	2.60	2.605
Kakrola Gola	1.17	1.24	1.205	0.38	0.41	0.395	3.08	3.02	3.050
***Ziziphus* spp.**									
Desi-1	0.83	0.90	0.865	0.34	0.37	0.355	2.44	2.43	2.435
Desi-2	0.64	0.70	0.670	0.27	0.29	0.280	2.37	2.41	2.390
Desi-3	0.39	0.36	0.375	0.10	0.09	0.095	3.90	4.00	3.950
Ziziphus nummularia									
Jharber	0.09	0.10	0.095	0.03	0.03	0.030	3.00	3.33	3.166
CD (P=0.05)	**0.020**	**0.023**	–	**0.011**	**0.015**	–	–	–	–

coloured petals constituted the corolla, which was alternating with sepals. The stamens numbered as many as were the petals opposite to them and united with and enclosed by the petals. Filament was longitudinal arising from outside the intrastaminal disc. There were two carpels, syncarpous and bifid at the apex. Ovary was sub-inferior and bilocular with one ovule in each locule attached at the base.

The date of sprouting, duration of flowering, number of flowers per cyme and length of pedicel are presented in Table 12. The flowering duration was from 11th August to 3rd November being earlier in *Jharber* and late in Desi-I. The maximum (20.84) number of flowers/cyme was recorded in Kakrola Gola which was at par with Gola Gurgaon No.3 (20.74), whereas minimum (7.14) in Desi-3 during year 1999. But during year 2000, the maximum (22.00) number of flowers/cyme was present in Gola Gurgaon No.3 closely followed by Kakrola Gola and minimum number of flowers was again recorded in Desi-3. Length of pedicel ranged between 4.02 mm in Desi-2 to 8.52 mm in Illaichi during 1999, however, maximum pedicel length was noted in Umran (8.56 mm) and minimum (4.04 mm) in Desi-3 during 2000. Pedicel length was at par in Desi-2 and Desi-3 during both the years.

The dimensions of sepals and petals are given in Tables 13 and 14, respectively. Sepal length was found maximum in Illaichi which was at par with kathaphal during both the years and minimum sepal length was recorded in *Jharber*. The breadth of sepals also followed the same trend.

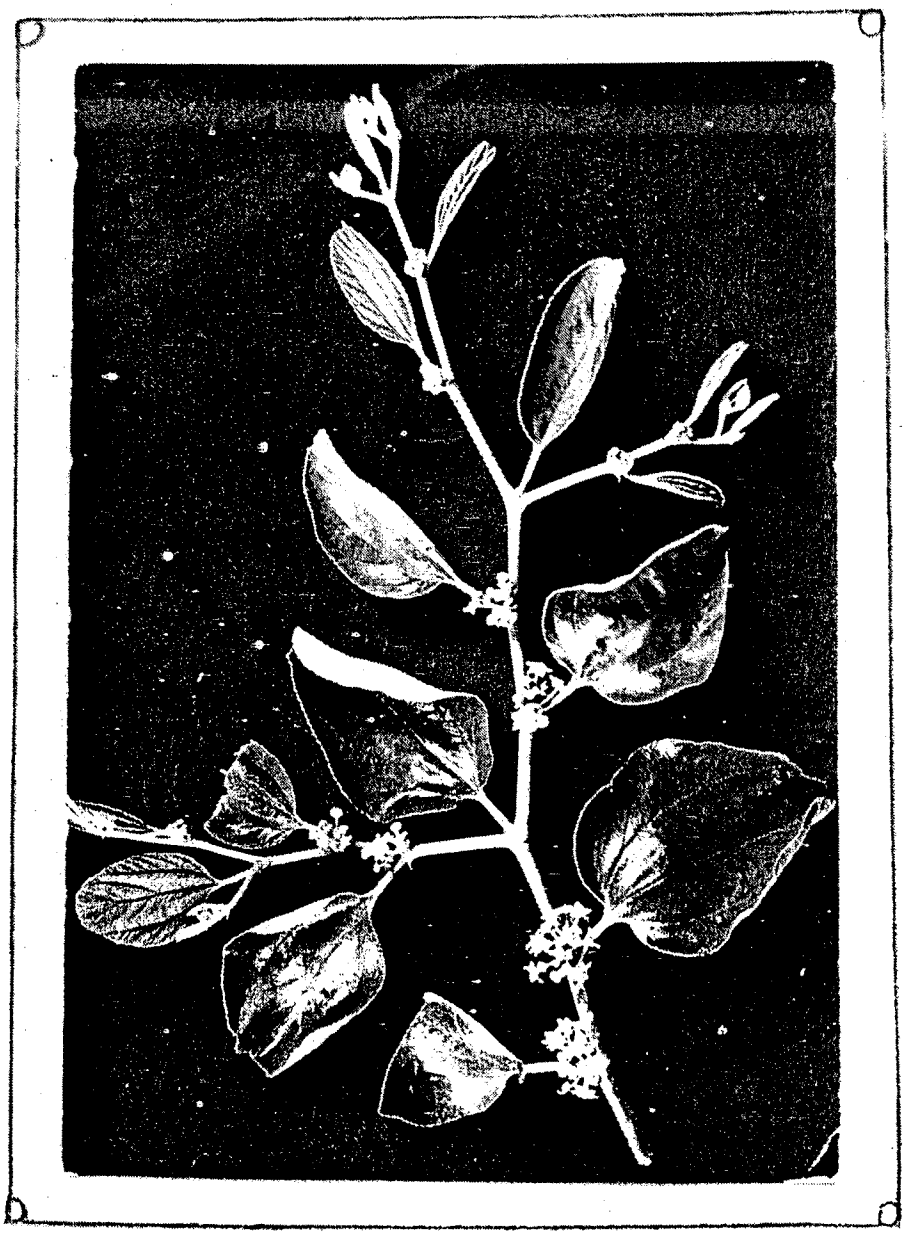


Plate 6: Leafing and flowering behaviour in *Ziziphus* spp.

Table 12: Date of sprouting, duration of flowering and number of flowers/cyme and length of pedicel in various cultivar and form of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Date of sprouting	Duration of flowering	No. of flowers/ cyme			Length of pedicel (mm)		
			1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana								
Umran	10th June	4thSept.–30thOct.	15.64	13.99	14.81	8.44	8.56	8.50
Illaichi	6th June	2ndSept.–27thOct.	18.18	19.76	18.97	8.52	8.46	8.49
Kathaphal	14th June	13thSept.–25thOct.	18.20	18.19	18.19	8.00	7.94	7.97
Gola Gurgaon No.3	12th June	7thSept.–31stOct.	20.74	22.00	21.37	6.72	7.03	6.87
Bahadurgarhia Gola	12th June	7thSept.–28thOct.	19.56	18.10	18.83	7.05	7.01	7.03
Dandan Gola	15th June	11thSept.–25thOct.	19.27	17.87	18.57	8.44	8.37	8.40
Kakrola Gola	12th June	7thSept.–27thOct.	20.84	21.10	20.97	6.50	6.61	6.55
***Ziziphus* spp.**								
Desi-1	10th June	4thSept.–3rdNov.	17.12	16.20	16.66	6.21	6.10	6.15
Desi-2	12th June	2ndSept.–24thOct.	12.37	13.07	12.72	4.02	4.09	4.05
Desi-3	15th June	3rdSept.–24thOct.	7.14	6.91	7.03	4.05	4.04	4.05
Ziziphus nummularia								
Jharber	2nd June	11thAug.–22ndSept.	8.37	7.98	8.17	6.09	6.22	6.15
CD (P=0.05)			**0.521**	**0.182**	–	**0.078**	**0.102**	–

Table 13: Dimensions of sepal in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Sepal dimensions								
	Length (mm)			Breadth (mm)			L/B ratio		
	1999	2000	Mean	1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana									
Umran	2.89	2.94	2.91	2.70	2.74	2.72	1.07	1.07	1.07
Illaichi	3.75	3.65	3.70	3.35	3.41	3.38	1.12	1.07	1.09
Kathaphal	3.74	3.65	3.69	3.05	3.01	3.03	1.23	1.21	1.22
Gola Gurgaon No 3	3.15	3.05	3.10	2.85	2.90	2.87	1.11	1.05	1.08
Bahadurgarhia Gola	3.02	3.10	3.06	2.90	2.87	2.88	1.04	1.08	1.06
Dandan Gola	2.98	2.92	2.95	2.82	2.86	2.84	1.05	1.02	1.03
Kakrola Gola	2.90	2.99	2.94	2.61	2.60	2.60	1.11	1.15	1.13
***Ziziphus* spp.**									
Desi-1	2.85	2.80	2.82	2.74	2.72	2.73	1.04	1.03	1.03
Desi-2	2.61	2.53	2.57	2.10	2.15	2.12	1.24	1.18	1.21
Desi-3	2.11	2.19	2.15	1.92	1.96	1.94	1.09	1.12	1.11
Ziziphus nummularia									
Jharber	2.07	2.13	2.10	1.87	1.90	1.88	0.98	1.12	1.05
CD (P=0.05)	**0.050**	**0.054**	–	**0.063**	**0.062**				

Petal length of varieties/forms/spp. studied ranged between 1.04 and 0.98 mm (*Jharber*) to 1.82 and 1.77 mm (Bahadurgarhia Gola) during years 1999 and 2000, respectively (Table 14). Similar pattern was observed in respect of breadth of petals. The breadth of petal was at par in Umran, Gola Gurgaon No.3, Dandan Gola and Kakrola Gola during 1999.

It is also evident from Table 15 that length of anther was maximum (0.65 and 0.63 mm) in Desi-1 and minimum (0.38 and 0.39 mm) in Dandan Gola during 1999 and 2000, respectively. It was at par in Illaichi, Umran, Kakrola Gola, Desi-2 and Desi-3 during both the years.

In the similar way the length of filament was observed maximum in Desi-I (2.08 and 2.00 mm) and minimum (1.01 and 0.95 mm) in *Jharber* during both the years of investigation, respectively. Diameter of disc in respective years ranged between 2.39 and 2.44 mm in *Jharber* to 4.22 and 4.19 mm in Illaichi. The data mentioned in Table 16 suggested that there were two times of anthesis and dehiscence amongst the cvs./forms/spp. investigated. In Illaichi and Kathaphal, the anthesis took place in the morning (7.00 AM- 7.15 AM) and at noon during day hours (12.00 Noon to 12.45 PM) in other cvs./forms/spp. Similarly, pollen dehiscence occurred about 2 to 2.30 hrs post anthesis in all cvs./forms/spp.

Pollens : The data of pollen morphology of all the genotypes investigated has been given in Table 17 and also supported by Plate 7. The pollen aperture was 3-colporate in all the cvs./forms/spp investigated, whereas shape of pollen was prolate in Illaichi, sub-prolate in Umran, Kathaphal, Gola Gurgaon No.3,

Table 14: Dimensions of petal in various cultivars and forms of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Petal dimensions								
	Length (mm)			Breadth (mm)			L/B ratio		
	1999	2000	Mean	1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana									
Umran	1.42	1.39	1.40	0.89	0.91	0.90	1.59	1.53	1.55
Illaichi	1.35	1.34	1.34	0.81	0.82	0.82	1.66	1.63	1.63
Kathaphal	1.40	1.43	1.41	0.95	0.92	0.93	1.47	1.55	1.52
Gola Gurgaon No 3	1.51	1.47	1.49	0.85	0.81	0.83	1.77	1.81	1.79
Bahadurgarhia Gola	1.82	1.77	1.79	0.98	0.89	0.93	1.86	1.99	1.92
Dandan Gola	1.26	1.29	1.27	0.88	0.90	0.89	1.43	1.43	1.43
Kakrola Gola	1.35	1.31	1.33	0.89	0.83	0.86	1.52	1.58	1.55
***Ziziphus* spp.**									
Desi-1	1.40	1.42	1.41	0.83	0.87	0.85	1.68	1.63	1.66
Desi-2	1.21	1.17	1.19	0.52	0.51	0.52	2.32	2.29	2.30
Desi-3	1.36	1.30	1.33	0.65	0.60	0.63	2.09	2.17	2.11
Ziziphus nummularia									
Jharber	1.04	0.98	1.01	0.50	0.53	0.51	2.08	1.85	1.98
CD (P=0.05)	**0.051**	**0.072**	–	**0.044**	**0.036**	–	–	–	–

Table 15: Length of stamen and diameter of disc of flower in various cultivar and form of *Ziziphus* spp. during 1999 and 2000

Name of cultivar/form/ species	Stamen								
	Length of anther (mm)			Length of filament (mm)			Diameter of disc (mm)		
	1999	2000	Mean	1999	2000	Mean	1999	2000	Mean
Ziziphus mauritiana									
Umran	0.38	0.40	0.39	1.06	1.12	1.09	3.74	3.69	3.71
Illaichi	0.41	0.40	0.41	1.22	1.17	1.19	4.22	4.19	4.20
Kathaphal	0.44	0.42	0.43	1.00	1.03	1.01	3.58	3.50	3.54
Gola Gurgaon No 3	0.51	0.50	0.51	1.72	1.65	1.68	4.18	4.16	4.17
Bahadurgarhia Gola	0.57	0.55	0.56	1.86	1.82	1.84	3.87	3.81	3.84
Dandan Gola	0.38	0.39	0.38	1.85	1.80	1.82	3.52	3.50	3.51
Kakrola Gola	0.41	0.45	0.43	1.55	1.63	1.59	3.47	3.51	3.49
***Ziziphus* spp.**									
Desi-1	0.65	0.63	0.64	2.08	2.00	2.04	3.52	3.47	3.49
Desi-2	0.39	0.40	0.39	1.54	1.43	1.48	3.62	3.65	3.63
Desi-3	0.40	0.38	0.39	1.17	1.10	1.14	3.08	3.12	3.10
Ziziphus nummularia									
Jharber	0.42	0.45	0.43	1.01	0.95	0.98	2.39	2.44	2.41
CD (P=0.05)	**0.056**	**0.036**	–	**0.070**	**0.058**	–	**0.107**	**0.072**	–

Table 16: Anthesis and dehiscence time in various cultivars/forms of *Ziziphus* spp.

Name of cultivar/ form/species	Anthesis time	Dehiscence time
Ziziphus mauritiana		
Umran	12.30 PM	2.15 PM
Illaichi	7.15 AM	9.45 AM
Kathaphal	7.00 AM	9.30 AM
Gola Gurgaon No 3	12.15 PM	2.15 PM
Bahadurgarhia Gola	12.30 PM	2.30 PM
Dandan Gola	12.00 Noon	2.15 PM
Kakrola Gola	12.15 PM	2.15 PM
***Ziziphus* spp.**		
Desi-1	12.45 PM	2.30 PM
Desi-2	12.45 PM	2.30 PM
Desi-3	12.30 PM	2.30 PM
Z. nummularia		
Jharber	12.30 PM	2.45 PM

Table 17: Pollen morphology in various cultivars and forms of *Ziziphus* spp.

Name of cultivar/ form/species	Aperture	Shape	Size (μ)		P/E ratio	Exine thickness (μ)	Exine ornamentation
			Polar	Equitorial			
Ziziphus mauritiana							
Umran	3-Colporate	Subprolate	26.80	25.67	1.04	1.61	Faintly reticulate
Illaichi	3-Colporate	Prolate	21.14	19.93	1.06	1.27	Psilate
Kathaphal	3-Colporate	Subprolate	19.32	18.42	1.05	1.18	Psilate
Gola Gurgaon No 3	3-Colporate	Subprolate	23.02	20.83	1.11	1.36	Faintly reticulate
Bahadurgarhia Gola	3-Colporate	Subprolate	27.25	24.68	1.10	1.47	Faintly reticulate
Dandan Gola	3-Colporate	Subprolate	24.53	22.12	1.11	1.40	Faintly reticulate
Kakrola Gola	3-Colporate	Subprolate	21.82	19.63	1.11	1.37	Faintly reticulate
***Ziziphus* spp.**							
Desi-1	3-Colporate	Prolate spheriodal	29.52	27.48	1.07	1.71	Psilate
Desi-2	3-Colporate	Prolate spheriodal	29.14	28.20	1.04	1.72	Psilate
Desi-3	3-Colporate	Prolate spheriodal	29.44	26.35	1.12	1.68	Psilate
Ziziphus nummularia							
Jharber	3-Colporate	Prolate spheriodal	27.62	25.92	1.06	1.40	Psilate

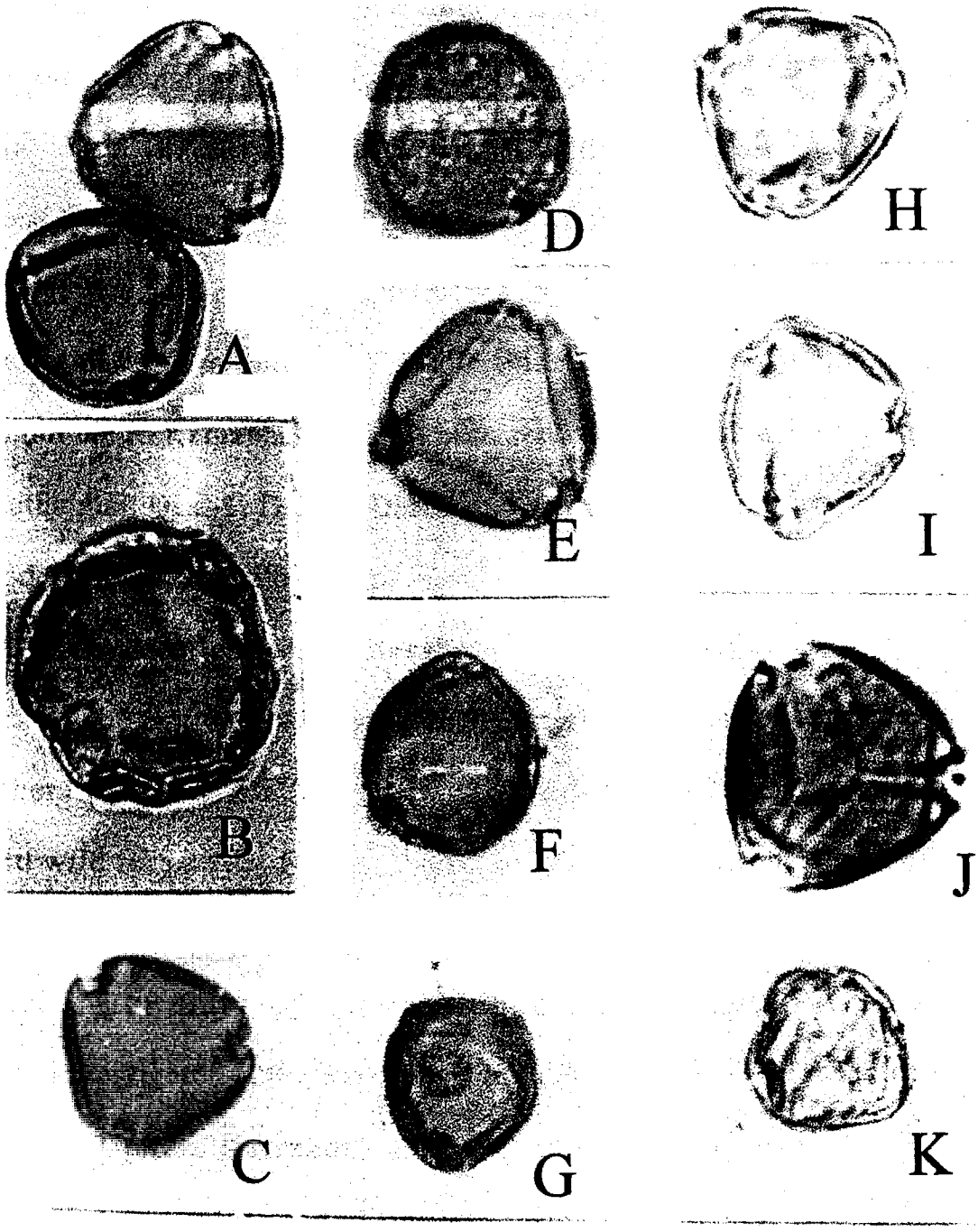


Plate7: Pollen grains of various cultivars and forms of Ziziphus spp.

A-Umran, B- Illaichi, C- Kathaphal, D- Gola Gurgaon no.3, E- Bahadurgarhia, E- Dandan Gola, G-Kakrola Gola, H-Desi-1, I- Desi-2, J- Desi-3, K- Jharber

Bahadurgarhia Gola, Dandan Gola and Kakrola Gola and Prolate spheroidal in wild forms viz., Desi-1, Desi-2, Desi-3 and *Jharber*. The pollen size was maximum (29.52×27.48 μ) in Desi-1 and closely followed by Desi-3 and Desi-2. Minimum sized (19.32×18.42 μ) pollens were observed in Kathaphal. P/E raio of pollens ranged between 1.04 to 1.12 and exine thickness varied between 1.18 μ to 1.72 μ. Exine thickness was maximum in Desi-2 and minimum in Kathaphal while its ornamentation was observed psilate in Illaichi, Kathaphal, Desi-1, Desi-2, Desi-3 and *Jharber* and faintly reticulate in Umran and all cvs. of Gola group.

Physico-chemical characters

The fruits of cultivars Umran, Illaichi and Kathaphal ripened later than others (between 8th March to 4th April) and fruits of cvs. of Gola group and wild forms viz., Desi-1, Desi-2 and Desi-3 ripened between 4th February to 2nd March (Table 18). However no proper ripening was recorded in Desi-3. The fruits of *Jharber* ripened earliest among all the cvs./forms/ spp. investigated (28th September to 12th October). The shape of fruits was oval in Umran, Kathaphal, four cvs. of Gola group and *Jharber*, whereas flattened in Illaichi and Wild/Desi forms viz., Desi-1, Desi-2 and Desi-3, which is also evident from Plates 8 and 9. Fruit apex was round in Umran, Kathaphal, Gola group and *Jharber* and flattened in other cvs./forms. Similarly, base was round with slight depression in Umran and Dandan Gola and round in remaining cvs./forms/spp. investigated. The colour of fruits at maturity was golden yellow in Umran, Illaichi and Gola group, light green

Table 18: Ripening time, shape, size and colour of fruits in various cultivars and forms of *Ziziphus* spp.

Name of cultivar/ form/species	Time of ripering	Grading according to ripening time	Fruit			
			Shape	Apex	Base	Colour at maturity
Ziziphus mauritiana						
Umran	12th March–4th April	9	Oval	Round	Round with slight depression	Golden yellow
Illaichi	8th March–28th March	8	Round	Flattened	Round	Golden yellow
Kathaphal	16th March–6th April	10	Oval	Round	Round	Light green with coffee colour patch
Gola Gurgaon No 3	6th February–28th February	4	Oval	Round	Round	Golden yellow
Bahadurgarhia Gola	8th February–2nd March	5	Oval	Round	Round	Golden yellow
Dandan Gola	13th February–28nd February	6	Oval	Round	Round with slight depression	Golden yellow
Kakrola Gola	4th February–1st March	2	Oval	Round	Round	Golden yellow
***Ziziphus* spp.**						
Desi-1	16th February–16th March	7	Round	Flattened	Round	Golden yellow with coffee colour patch
Desi-2	4th February–2nd March	3	Round	Flattened	Round	Yellowish with brown patch
Desi-3	No ripening	il	Round	Flattened	Round	Light green with coffee colour patch
Ziziphus nummularia						
Jharber	28th September–12th October	1	Round	Round	Round	Dark brown/ coffee colour

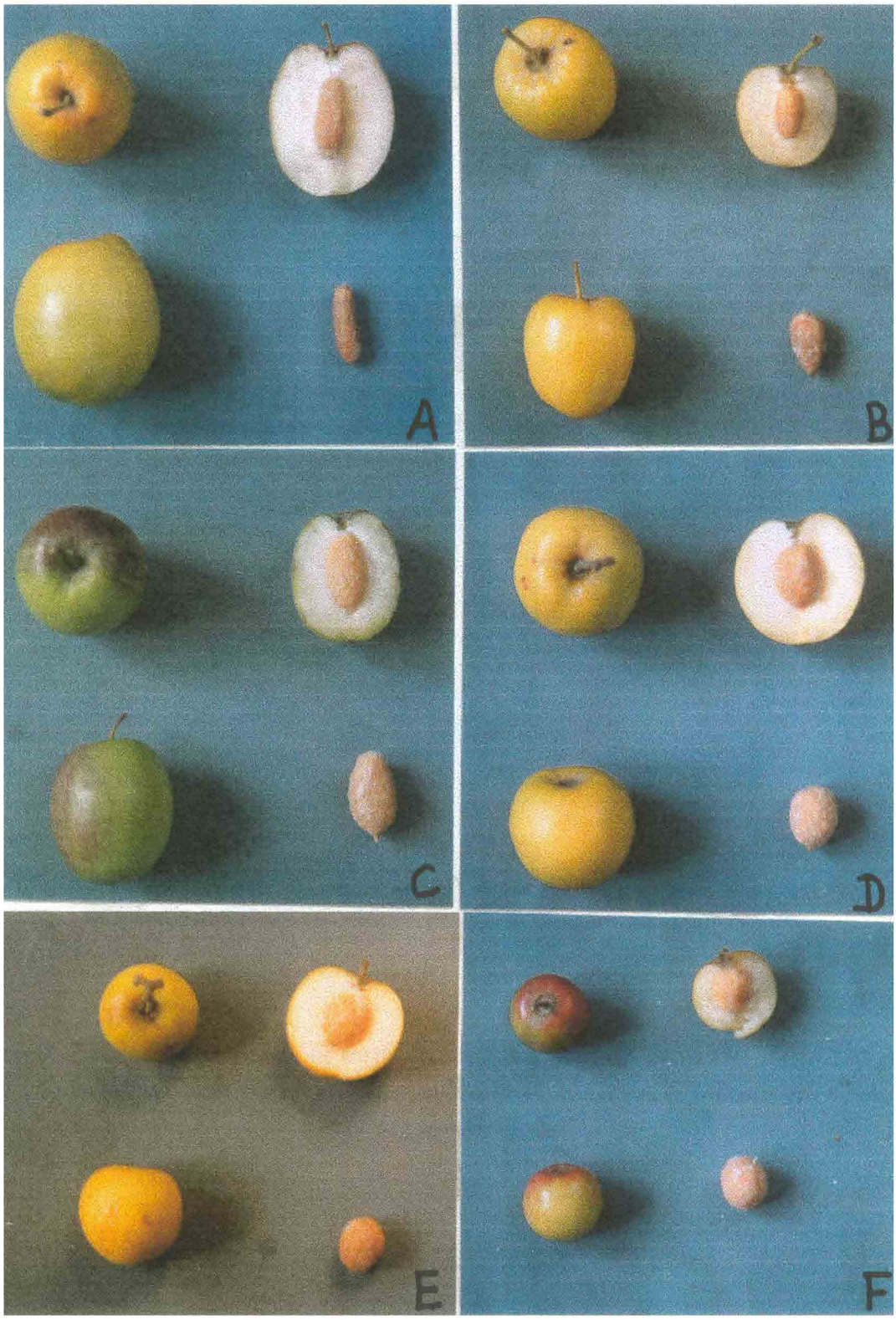


Plate 8: Fruits and stone of various cultivars and forms of Ziziphus spp.

A - Umarn, B - Illaichi, C- Kathaphal, D - Desi-1, E - Desi-2, F - Desi-3

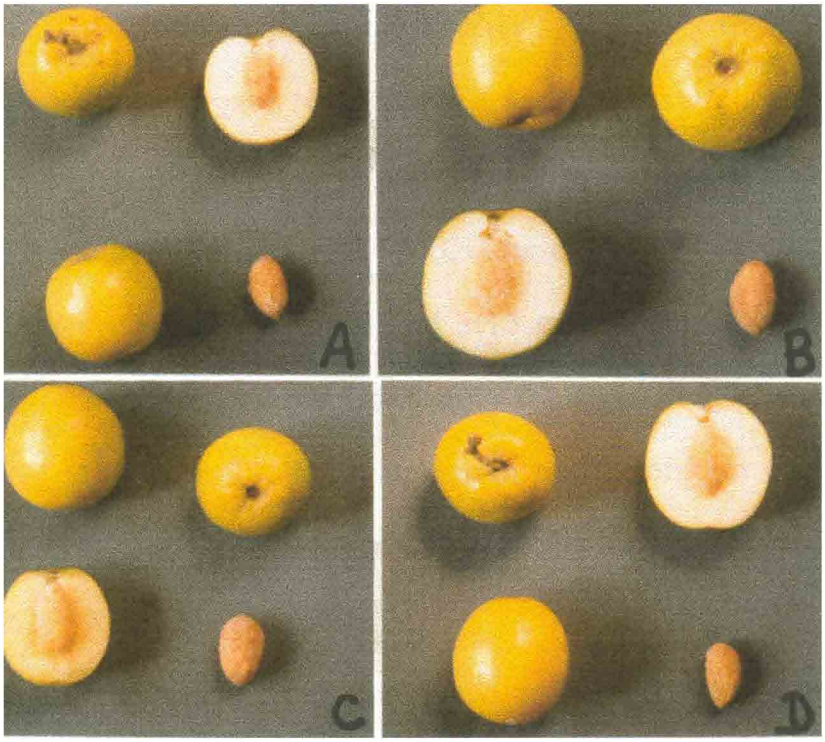


Plate 9: Fruits and stones of various cultivars and forms of *Ziziphus spp.*
A - Gola Gurgaon No. 3, B - Bahadurgarhia Gola, C - Dandan Gola,
D - Kakrola Gola

with coffee colour patches in Kathaphal and Desi-3, and yellow to golden yellow with coffee colour patches in Desi-I and Desi-2 whereas fruits of *jharber* had dark brown coffee colour.

The length of fruit was observed maximum (4.13 and 4.01 cm) in Umran and minimum (1.17 and 1.21 cm) in *Jharber* during years 1999-2000 and 2000-2001, respectively (Table 19). The fruit length was at par in Kathaphal, Gola Gurgaon No.3, Bahadurgarhia Gola and Kakrola Gola during year 1999 and similarly Desi-1 and Desi-2 as well as Kathaphal and Gola Gurgaon No.3 were at par in 2000. Diameter of fruit ranged between 1.20 and 1.11 cm in *Jharber* to 3.04 and 3.13 cm in Umran during years 1999 and 2000, respectively. Correspondingly the fruit weight was also recorded maximum (24.61 and 22.76 g) in Umran and minimum (0.81 and 0.80 g) in *Jharber*, while for other cvs./forms the values were between these extremes.

It can be inferred from data given in Table 20 that T.S.S. percentage ranged between 13.0 per cent (Desi-3) to 19.6 per cent (*Jharber*) in 1999-2000 and 12.2 per cent in Desi-3 to 18.8 per cent in Bahadurgarhia Gola during 2000-2001. The T.S.S. per cent was at par for Umran, Illaichi, Gola Gurgaon No.3, Dandan Gola, Kakrola Gola and Desi-1 during both the years. Acidity varied between 0.183 and 1.220 per cent during year 1999 and 0.196 and 1.305 per cent in 2000 with minimum being in Umran and maximum in *Jharber*.

Table 19: Dimensions and weight of fruit in various cultivars and form of *Ziziphus* spp. during 1999-2000 and 2000-2001

Name of cultivar/form/ species	Fruit dimensions								
	Length (cm)			Diameter/thickness (cm)			Weight of fruit (g)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
Ziziphus mauritiana									
Umran	4.13	4.01	4.07	3.23	3.04	3.13	24.61	22.76	23.68
Illaichi	2.08	1.90	1.99	2.04	1.50	1.77	5.43	5.17	5.30
Kathaphal	3.08	2.92	3.00	2.57	2.56	2.56	10.87	10.01	10.44
Gola Gurgaon No 3	3.06	2.88	2.97	2.80	2.63	2.71	13.75	12.93	13.34
Bahadurgarhia Gola	3.20	3.15	3.17	3.03	2.91	2.97	16.75	15.97	16.36
Dandan Gola	2.82	2.75	2.78	2.51	2.58	2.54	10.75	10.11	10.43
Kakrola Gola	3.02	3.08	3.05	2.82	2.89	2.85	12.00	11.89	11.94
***Ziziphus* spp.**									
Desi-1	2.41	1.94	2.17	2.37	1.98	2.17	7.31	6.43	6.87
Desi-2	2.03	1.91	1.97	2.05	2.07	2.06	5.80	5.45	5.62
Desi-3	1.30	1.24	1.27	1.32	1.14	1.23	1.42	1.31	1.36
Ziziphus nummularia									
Jharber	1.17	1.21	1.19	1.20	1.11	1.15	0.81	0.80	0.80
CD (P=0.05)	**0.278**	**0.108**	–	**0.105**	**0.129**	–	**0.120**	**0.142**	–

Table 20: TSS, acidity and ascorbic acid contents in various cultivars and forms of *Ziziphus* spp. during 1999-2000 and 2000-2001

Name of cultivar/form/ species	T.S.S. (%)			Acidity (%)			T.S.S./Acid ratio			Ascorbic acid (mg/100g pulp)		
	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean
Ziziphus mauritiana												
Umran	15.6	16.1	15.8	0.183	0.196	0.189	85.24	82.14	83.69	145.41	137.75	141.58
Illaichi	15.8	16.7	16.2	0.341	0.324	0.332	46.33	51.54	48.93	170.07	159.86	164.96
Kathaphal	18.2	16.9	17.5	0.789	0.793	0.791	23.06	21.37	22.21	90.98	95.24	93.11
Gola Gurgaon No 3	15.4	15.8	15.6	0.196	0.188	0.192	78.57	84.04	81.30	121.60	115.64	118.62
Bahadurgarhia Gola	17.8	18.8	18.3	0.196	0.209	0.202	90.81	89.95	90.38	97.79	102.04	99.91
Dandan Gola	15.2	16.0	15.6	0.188	0.209	0.198	80.85	76.56	78.70	87.58	93.54	90.56
Kakrola Gola	15.0	16.1	1.55	0.371	0.324	0.347	40.43	49.69	45.06	97.79	105.44	101.61
***Ziziphus* spp.**												
Desi-1	14.6	15.0	14.8	0.820	0.840	0.830	17.80	17.85	17.82	104.59	97.79	101.19
Desi-2	14.5	14.4	14.4	0.960	0.891	0.925	15.10	16.16	15.63	105.44	103.74	104.59
Desi-3	13.0	12.2	12.6	1.015	1.109	1.062	12.81	11.00	11.90	117.35	107.99	112.67
Ziziphus nummularia												
Jharber	19.6	18.7	19.2	1.220	1.305	1.262	16.06	14.33	15.19	119.05	106.29	112.67
CD (P=0.05)	0.986	1.108	–	0.018	0.014	–	–	–	–	9.010	11.545	–

Ascorbic acid content was recorded highest of 170.07 and 159.86 mg/100 g pulp in Illaichi and minimum of 87.58 and 93.54 mg/100 g pulp in Dandan Gola during the years 1999 and 2000, respectively. It was at par in Kathaphal, Bahadurgarhia Gola and Kakrola Gola during both the years.

Stone :

Stone shape was oblong in all seven cultivated cvs and round in Wild and Desi forms/spp. (Table 21). Length of stone varied from 0.61 and 0.58 cm (*Jharber*) to 2.17 and 2.10 cm (Umran). The length of Umran seed was significantly more as compared with other cvs./forms/spp. except Kathaphal during both the years. Likewise the diameter of stone was maximum (1.01 and 1.00 cm) in Kathaphal and minimum (0.59 and 0.57 cm) in *Jharber*. It was at par among all cvs. of Gola group during both the years and in Desi-1 and Desi-2 during 2000 only. The maximum stone weight was recorded in Kathaphal (1.27 and 1.21 g) and minimum in *Jharber* (0.15 and 0.17 g) during years 1999 and 2000, respectively.

Physiological characters

The chlorophyll content of leaves has been presented in Table 22. both the chlorophyll'a' and 'b' contents in the leaves of Kakrola Gola were found highest while it was minimum in Desi-3 among all cvs./forms/spp. investigated.

On the other hand carotenoid content in leaves was recorded highest (24.50 μ mol cm^{-2}) in Gola Gurgaon No.3 followed by Kakrola Gola and Illaichi, while minimum (18.73 μ mol cm^{-2}) in Dandan Gola.

Table 21: Dimensions of stone and pulp/stone ratio in various cultivars and forms of *Ziziphus* spp. during 1999-2000 and 2000-2001

Name of cultivar/form/ species	Shape of the stone	Stone dimensions									Mean pulp/ stone ratio
		Length of stone (cm)			Diameter of stone (cm)			Weight of stone (g)			
		1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	1999-2000	2000-2001	Mean	
Ziziphus mauritiana											
Umran	Oblong	2.17	2.10	2.14	0.78	0.75	0.76	1.00	1.03	1.01	22.44
Illaichi	Oblong	1.12	1.09	1.10	0.58	0.57	0.57	0.28	0.25	0.26	19.38
Kathaphal	Oblong	2.07	2.05	2.06	1.01	1.00	1.00	1.27	1.21	1.24	7.42
Gola Gurgaon No 3	Oblong	1.75	1.74	1.74	0.96	1.01	0.98	1.17	1.10	1.13	10.80
Bahadurgarhia Gola	Oblong	1.83	1.85	1.84	0.99	0.95	0.97	1.21	1.19	1.20	12.63
Dandan Gola	Oblong	1.94	1.91	1.93	0.89	0.93	0.91	1.16	1.19	1.17	7.91
Kakrola Gola	Oblong	1.74	1.70	1.72	0.98	0.95	0.96	1.09	1.11	1.10	9.85
***Ziziphus* spp.**											
Desi-1	Round	1.32	1.28	1.30	0.98	0.96	0.97	0.82	0.85	0.83	7.28
Desi-2	Round	1.17	1.20	1.19	0.91	0.89	0.90	0.71	0.70	0.70	7.03
Desi-3	Round	0.93	0.94	0.93	0.79	0.75	0.77	0.38	0.39	0.38	2.58
Ziziphus nummularia											
Jharber	Round	0.61	0.58	0.59	0.59	0.57	0.58	0.15	0.17	0.16	4.00
CD (P=0.05)		**0.083**	**0.088**	–	**0.063**	**0.070**	–	**0.078**	**0.056**	–	–

Table 22: Chlorophyll and carotenoid contents in leaves of various cultivars and forms of *Ziziphus* spp.

Name of cultivar/ form	Chlorophyll'a' (μmol cm^{-2})	Chlorophyll'b' (μmol cm^{-2})	Total chlorophyll (μmol cm^{-2})	Carotenoid (μmol cm^{-2})
Ziziphus mauritiana				
Umran	29.44	5.29	34.73	22.06
Illaichi	32.70	5.85	38.55	23.64
Kathaphal	30.72	5.72	36.44	21.18
Gola Gurgaon No 3	31.22	5.72	36.94	24.50
Bahadurgarhia Gola	29.27	5.24	34.51	21.83
Dandan Gola	26.89	5.17	32.06	18.73
Kakrola Gola	34.52	5.90	40.42	23.82
***Ziziphus* spp.**				
Desi-1	24.22	4.80	29.02	21.50
Desi-2	23.72	4.51	28.23	20.84
Desi-3	20.70	4.17	24.87	20.28
Ziziphus nummularia				
Jharber	27.64	5.22	32.86	21.41
CD (P=0.05)	**1.83**	**0.54**	**3.22**	**1.70**

The results of transpiration rate mentioned in Table 23 clearly stated that it was maximum (4.93 mmol $m^{-2}s^{-1}$) in Umran followed by Illaichi (4.68 mmol $m^{-2}s^{-1}$) and minimum (2.93 mmol $m^{-2}s^{-1}$) in Dandan Gola. Highest stomatal conductance viz., 1356.00 mmol $m^{-2}s^{-1}$ was recorded in Bahadurgarhia Gola followed by Illaichi (874.00 mmol $m^{-2}s^{-1}$), whereas minimum conductance was recorded in Dandan Gola (274.33 mmol $m^{-2}s^{-1}$). Similarly maximum photosynthesis rate (26.86 µmol $m^{-2}s^{-1}$) was recorded in Umran followed by Kakrola Gola and Desi-1 and minimum (10.16 µmol $m^{-2}s^{-1}$) in Dandan Gola.

On the basis of above parameters, the characterisation of all eleven cvs./forms/spp. investigated was done individually. Descriptions of cultivated cvs. have been given in Appendix-I; cvs. of Gola Group in Appendix-II and of Desi types and wild form of *Jharber* in Appexdix-III given in the last of the dissertation.

Table 23: **Transpiration rate, stomatal conductance and photosynthesis rate in various cultivars/forms of *Ziziphus* spp.**

Name of cultivar/ form/species	Transpiration rate (m mole $m^{-2}s^{-1}$)	Stomatal conductance (m mole $m^{-2}s^{-1}$)	Photosynthesis rate (μ mole $m^{-2}s^{-1}$)
Ziziphus mauritiana			
Umran	4.93	864.00	26.86
Illaichi	4.68	874.00	21.80
Kathaphal	3.91	600.00	21.66
Gola Gurgaon No 3	4.33	461.00	21.70
Bahadurgarhia Gola	4.42	1356.00	21.06
Dandan Gola	2.93	274.33	10.16
Kakrola Gola	4.39	615.33	22.70
***Ziziphus* spp.**			
Desi-1	4.51	674.33	22.60
Desi-2	3.85	446.00	13.10
Desi-3	3.29	310.33	13.60
CD (P=0.05)	**0.636**	**139.00**	**4.37**

Chapter-V

Discussion

For successful planning and execution of improvement programme in *ber*, which is highly heterozygous and outbreeder, basic information on cytology, morphology and floral and fruiting behaviour is necessary. This information is helpful in selection of desirable parents for crossing programme and such parameters are helpful in identification of best combiners for use in future breeding programmes and in finding out correct taxonomic identity of the common cultivated cultivars/forms/spp. as well as for getting rid of cultivar synonimity. In the present investigation, these aspects were studied in eleven cultivars/forms/spp. of *Ziziphus*, which have revealed some interesting information. The salient features of these studies are discussed in the succeeding paragraphs.

Cytological studies

The chromosome counts of commercial cultivated cultivars *viz.*, Umran, Kathaphal and all four cvs. of Gola group was found to be 2n=48, whereas in other cultivated variety Illaichi, it was found to be 2n=96. The chromosome

number in three wild forms Desi-I, Desi-2 and Desi-3 was also found to be 2n=96. In *Jharber*, the chromosome number was 2n=72. A wide variation in the chromosome for *Ziziphus* sp. has been reported (Srinivasachar, 1940; Srinivasan, 1952). The species *Ziziphus lotus* and *Ziziphus sativa* are diploids (Bowden, 1945), *Ziziphus mauritiana* and *Ziziphus oenoplia* are tetraploids (Morinaga *et al.* (1929) and *Z. rotundifolia* is hexaploid while *Z. jujuba* (Indian jujube) ranges from diploid to tetra, penta, hexa and octa types of which tetraploidy is the most prominent (Khoshoo and Singh, 1963). The results observed during these studies are in conformity with that of Daulta and Sareen (1980) who observed chromosome number to be 2n=48 in four cultivated varieties of *Z. mauritiana*, viz., Umran, Kaithli, Seo and Gola. Nehra *et al.* (1983) had also made similar observations in Illaichi, Umran, Gola *ber* (Wild), Boradi and *Jharber*, whereas, Dodd (1958) recorded 2n=96 in *Z. jujuba* which was possibly the cultivated *ber* presently known as *Z. mauritiana* Lamk. All the present cultivars in *ber* are probably the natural selections. Similar chromosome number 2n=96 as noted in cultivar Illaichi was also observed in other wild forms locally named as Desi during present investigation. This indicated that Illaichi may possibly be a selection from some Desi type material. In vegetatively propagated varieties, the difference in chromosome number has a significant role in their identification. Thus, as in the present study, the same chromosome number can be prepetuated that may not be the case in wild forms raised through seeds. Since *ber* is a cross pollinated crop, such variations can be reported.

During the course of this investigation, the attachment of bivalents to the nucleolus in nucleclar organiser region at diakinesis stage was observed as a common feature. However, the number of such bivalents varied considerably. Pachytene stage in *ber* also showed evidence in support of this observation (Nehra *et al.*, 1983). The study further indicated that the occurrance of quadrivalents either at metaphase or at diakinesis was common. However, univalents or trivalents were not recorded. This may result meiotic irregularity leading to chromosomal imbalance because the segregation of chromosome quadrivalents to the two poles may be either 3+1, 2+2, 1+3 or 4+0.

It is also clear from these observations that the commonest variations in chromosome number was the exact multiplication of genomic species number (x=12) in different cultivated and wild forms of *ber*. However, Khoshoo and Singh (1963) were also of the opinion that the correct number of chromosomes of the genus *Ziziphus* is monobasic with X=10, 12, 13. However in present investigation, the basic number of Genus *Ziziphus* is X=12 as chromosome number varied from 2n=48, 72 to 96. These results are in agreement with those of Khoshoo and Singh (1963) who had reported similar variation in chromosome number in *Ziziphus* genera. In such polyploids, the increase or decrease in chromosomes may be due to the fertilization of unreduced gametes. Generally, the lower number is considered to be primitive from which the higher ones might have been derived. Neverthless occasional reduction from higher to lower levels can not be

ruled out. Here in this study, it was also recorded that the size of fruits reduced as the polyploidy increased in Illaichi and other wild forms. In autopolyploids, the meiosis is often disturbed because of the quadrivalents formation in addition to the normal bivalents. According to Stebbins (1971), this might lead to irregularties in chromosomal segregation and consequently result in formation of unbalanced chromosome number. In cultivar Illaichi, Umran and Dandan Gola, multivalents formation was absent. The reason for this might be that due to repeated cultivation over a longtime, the multivalents might have disappeared in the process of diploidization.

Morphological characters

Growth : The growth parameters i.e. tree height, spread, branching angle bark (phellum and phellogen) colour, girth of trunk, etc. are also helpful in the identification of desirable cultivars. The bearing capacity of any genotype is very much influenced by the variation in these attributes. Significant variability was observed in different cultivars with respect to height, spread, tree volume, angle of branching and colour of phellum and phellogen. The height of trees of the eleven cvs./forms/spp. varied from 1.71 to 7.61 meter. The maximum tree height was recorded in Desi, whereas minimum in *Jharber*. This variation in height may be due to some genetical factors as the Desi forms and other cvs. were either spreading or erect in growth habit while *Jharber* was mainly bushy in nature. The colour of phellum and phellogen was similar in all the Desi and cultivated varieties except in *Jharber*, where the phellum colour was red and that of phellogen being

the light green. These findings are in agreement with those of Godara (1980), Nehra *et al.* (1984), Kundi *et al.* (1989) and Praveen and Patil (1998). The tree height and spread also varied considerably over the years of recording which may either be due to severe pruning performed during April-May prior to next season growth and in some others due to annual cumulative increase in growth.

Spine : The number of spines per meter length of current season growth and mean length of spine was maximum in Desi forms and *Jharber*, respectively, whereas minimum number of spines was in Illaichi, which was due to the presence of solitary form of spines in cv. Illaichi and that of paired spines in others cvs./forms/spp. Both of the paired spines were persistent in *Jharber*, whereas in other genotypes the straight spine was deciduous and the curved spines persisted on the mature wood. These results are similar to those reported by Nehra *et al.* (1984).

Leaf : The leaf shape was elliptical to obovate in Umran, Illaichi, Desi-I and *Jharber* and ovate in Gola, Desi-2 and Desi-3. The shape of leaf, apex, base and margins also varied in some cvs./forms/spp. due to their genetical makeup. However, the veination pattern was reticulate palmatic convergent which was same in all the cvs./forms/spp. studied and seems to be very much genus specific. Similarly the upper leaf texture was also identically smooth. The colour of leaf ranged from light green to dark green. Similar results were also reported earlier by Singh *et al.* (1971), Godara (1980), Nehra *et al.* (1984) and Bal (1992). Leaf area determines the

photosynthetic capacity of the plant. It was observed that Illaichi and Gola cvs. had much higher leaf area than rest of the cultivars. Similar observations were also recorded by Singh *et al.* (1971), Chitkara and Khera (1973), Godara (1980) and Nehra *et al.* (1984).

The maximum leaf dry weight was obtained in Illaichi and Gola cvs. and minimum in *Desi* and *Jharber*. Maximum leaf dry weight was probably due to the fact that leaves of these cvs. might have relatively lower moisture and higher lignin and silica contents (Godara, 1980).

Flowering : The knowledge of flowering and fruiting time is important in the execution of successful hybridization programme. Sprouting of bud was completed within 1st fortnight of June. All the cvs./forms/spp. had synchronus flowering time thereby these can be crossed easily. It is also interesting to note that Umran came into flowering later than Illaichi but fruit set was earlier in this cultivar and again fruit ripening was later than Illaichi. It may be due to the fact that the fruit of Umran is bigger and needs more heat degree days to ripen. Out of the *ber* cvs./forms/spp. included in this study, *Jharber* came into flowering much earlier ones (11th August to 22nd September) followed by *Desi forms,* Illaichi and Umran. In present study, Desi forms bloomed 7-8 days later than its usual time and this delay in flowering was probably due to continuous availability of irrigation water to the selected trees which by chance happened to be on the bank of a water canal. The trees growing under unirrigated conditions due to water stress came into flowering much earlier than those growing under irrigated

conditions (Pareek and Mann, 1974). Similar observations were also reported by Yamdagni *et al.* (1967), Godara (1980) and Nehra *et al.* (1984).

The maximum number of flowers per cyme were recorded in Gola Gurgaon No.3 (21.37) and minimum in Desi-3 and *Jharber* (7.03 and 8.17). Such variations in number of flowers per cyme was also reported earlier in cultivated varieties by Teotia and Chauhan (1963), Prasad (1964) and Vashishtha and Pareek (1978). Apparently there were marked variations in the flower size where flowers of Illaichi and Kathaphal being the largest and that of *Jharber* the smallest. Wild forms viz., Desi-2 and Desi-3 had almost equal pedicel length. Nehra *et al.* (1984) also reported similar results in Desi and Boradi forms/spp. of *ber*. The length to breadth ratio of sepals ranged between 1.03 to 1.22 while that of petal between 1.43 to 2.30.

Inspite of such marginal differences observed, these floral characters of cultivated and wild forms/spp. need not much discussion. Moreover, from above details of the flower parts, it can be concluded that these parmeters do not help appreciably in the identification of various cvs./forms/spp. of *Ziziphus*. However, a suggestive variation in respect of time of anthesis and dehiscence was recorded among the studied cvs/forms/spp., which may be attributed to both heriditary and climatic factors mainly because of the differential temperature and vapour pressure deficit requirements of these different cvs./forms/spp. Interestingly the anthesis and dehiscence time of two cultivars viz., Illaichi and Kathaphal ranged between 7.00 AM to 10.00 AM, whereas for others between 12.00 Noon to 2.45 PM. Several other

workers (Teotia and Chauhan, 1963; Yamadagni *et al.*, 1967; Singh *et al.*, 1970 and Vashistha and Pareek, 1979) also made similar observations in *ber* cultivars. This type of variations were also reported by Prasad (1964), who concluded that the temperature greatly influenced the time of anthesis and dehiscence in *ber*. Several workers also concluded that dehiscence started just after anthesis and thereafter completed within four hours (Vashistha and Pareek, 1979; Josan *et al.*, 1980 and Godara, 1980) .

Pollen morphology

The morphological description of the pollen grains (Palynology) with respect to aperture and exine pattern in cultivated and wild forms/spp. was almost similar and congruent for genus *Ziziphus* as described by Nair (1970). However, there were some variations in the size of the pollen grain. The three cultivated varieties, four cvs. of Gola group as well as wild forms/ spp. can be identified on the basis of the size of pollen grains. Among these, the size of the pollen grain was maximum (27.25×24.68 μ) in Bahadurgarhia Gola and minimum (19.32×18.42 μ) in Kathaphal. The overall comparison of cultivated varieties and wild forms/spp. revealed that the size of pollen grain of all the three *wild/Desi* forms was more than others. Similarly Moti *et al.* (1973) classified the 101 cultivars of Mango on the basis of pollen size. Present results of the lines investigated are in agreement with those of Singh and Misra (1979), Nehra *et al.* (1984), Hedge and Sharma (1996) and Neeraja *et al.* (1996) who also found differences in the size of pollen grains of various cvs. of *ber*. The size of the pollen of all *ber* genotypes

studied increased with acetolysis but without change in their shape indicating peripheral effect of the acetolysis. Similar results in citrus were also reported by Bamzai and Randhawa (1965).

Unlike the exine pattern, the ratio of P/E is a quantitative parameter and can be used for classification purposes. Though, the polar and equitorial axes values differ significantly within a population of pollen grains, yet the P/E ratio is constant for that genotype and can be used as an additional parameter for the identification of *ber* genotypes. This study on pollen grains also finds support from the conclusions of Fogle (1977); Mass (1977); Nema and Sharma (1981) and Ahmedullah (1983) that pollen shape, exine pattern and size can be quite useful for taxonomic purposes.

Thus, these pollen characteristics can be utilized along with other morphological characters of plants for cultivar identification.

Fruit characters

The characters like fruit shape, size and weight determine the table quality of fruit crops and influence their marketing. The observations recorded in present investigation suggested that the different cultivars/forms/spp. varied markedly with respect to shape, size and weight of fruits obviously due to their differential genetical behaviour. In conformity with the similar variations observed by Randhawa and Biswas (1966), Singh and Khanna (1968), Dhingra (1972), Singh *et al.* (1972), Nehra *et al.* (1984), Kundi *et al.* (1989) and Bal (1992) further strengthen the above findings. The fruit shape of cultivar Illaichi, the three forms of *Desi/wild* and *Jharber* was round but other had

oval shape. Shape of fruit apex in Umran, four cultivars of Gola, Kathapha and *Jharber* was round while it was flattened in *Desi* forms and Illaichi The fruits of cultivated varieties developed golden yellow colour at ripe stage which was not recorded in Kathaphal and *wild* forms/spp. Here it wa with coffee colour patches in light green or golden yellow fruits whil *Jharber* had dark brown colour at ripe stage. Similar results were als reported by Pareek (1980) and Nehra *et al.* (1984). Maximum fruit weigh as well as size was observed in Umran and minimum in *Jharber*, Desi- and Illaichi. These results are in conformity with the findings of Dhingr (1972), Singh *et al.* (1972), Pareek (1980), Godara (1980) and Nehra *e al.* (1984) under Hisar conditions.

Stone characters

The morphological characters of stone help to identify marke suitability of any cultivar and generally presence of bigger stones reduce its acceptability because fruits with small stones are always preferred b consumers. Similar to fruits, the stone shape, size and weight in differen *ber* cvs./forms/spp. varied markedly. The shape of the stone was observe as oblong in cultivated varieties, whereas all the *Desi* forms and *Jharbe* had round stones. The stone weight was observed maximum (1.24 g) i Kathaphal and related cvs. of Gola. Although variations in stone morphology is a varietal characteristics but up to a certain limit it can be influence by the climatic factors as well as the size and weight of the fruit. Simila variations were noted by Bajwa *et al.* (1972), Dhingra (1972), Godara (1980), Nehra *et al.* (1984) and Sri *et al.* (1986) in several *ber* cultivars.

Quality parameters

The total soluble solids, ascorbic acid and acidity constitute the important chemical constituents for assessing fruit quality of different *ber* cultivars. The data pertaining to chemical composition of fruits showed a remarkable variation in T.S.S. (12.6 to 19.2%), acidity (0.189 to 1.262%) and ascorbic acid (90.56 to 164.96 mg/100 gm pulp), which may be due to varietal behaviour as already suggested by Randhawa and Biswas (1966), Singh and Khanna (1968), Dhingra (1972), Jawanda and Bal (1978), Godara (1980), Tiwari and Banfar (1995), Sharma (1996) and Balakrishnan *et al.* (1998). These differences may be due to environmental factors and cultural practices adopted, since year difference were also present. Similar variations over years and different locations have also been reported by Singh (1964) and Singh and Khanna (1968) who observed different T.S.S. percentage for the same cultivars at different places and over years. The ascorbic acid content was high in late ripening cvs. and low in early and mid ripening cvs, which was probably due to a short period available for fruit growth and development in early and mid maturity cvs. while in late ripening cvs., the high amount may be due to sufficient longer period for fruit growth and also optimum temperature at maturity.

Physiological parameters

The highest chlorophyll'a' and chlorophyll'b' content in leaves was recorded in Kakrola Gola and minimum in Desi-3. The higher chlorophyll content may be due to higher uptake of N, Ca and Mg by these cultivars

(Pandey *et al.*, 1991). Similarly carotenoid content was recorded maximum in Gola Gurgaon No.3 and minimum in Dandan Gola. The chlorophyll content in the leaves helps in the photosynthetic activity, which provides food to all the plant organs. Rate of transpiration by leaves helps in determining the water requirement of a particular species. The transpiration rate was maximum (4.93 mmol $m^{-2}s^{-1}$) in Umran and minimum (2.93 mmol $m^{-2}s^{-1}$) in Dandan Gola. However Wen *et al.* (1994) reported that in triploid plants of *Z. jujuba* cultivar, the water saturation deficit correlated positively with the rate of transpiration and they also concluded that triploid cultivar of *Z. jujuba* (*Z. sativa*) was drought resistant and adopted to dry regions having low precipitation. The stomatal conductance was maximum (1356.0 mmol m^{-2} s^{-1}) in Bahadurgarhia Gola and minimum (274.33 mmol m^{-2} s^{-1}) in Dandan Gola. According to Banker and Prasad (1992) stomatal density was strongly and positively correlated with the growth parameters. In *ber*, highest stomatal density was recorded in more vigorous species. The photosynthetic activity is directly correlated with the vigour as well as yield parameters of a species since it acts as a source of food. The results during this finding clearly indicated the relation of photosynthesis rate with fruiting characters. The photosynthesis rate was maximum (26.86 μ mol m^{-2} s^{-1}) in Umran among all cvs./forms studied and also the fruit size was maximum in this cultivar and ultimately the more yield.

Thus all the cultivated cultivars differed from the *Desi/wild* forms, on the the other hand the cultivated cvs. and Desi forms also differed from

each other. The cytological studies have revealed that cultivated varieties except Illaichi were having same chromosome number and were tetraploid. All the Desi/wild forms except *Jharber*, have equal chromosome number. Basic chromosomes number of *Ziziphus* was x=12. Illaichi cultivar has 2n=96 and octoploid. All the Desi/Wild forms except *Jharber* have equal chromosome number and were octoploid whereas *Jharber* (*Z. nummularia*) was hexploid (2n=72).

Chapter-VI

Summary

These investigations entitled "Cytomorphological studies in wild and cultivated spp. of *Ziziphus*" were conducted in the Department of Horticulture, CCS Haryana Agricultural University, Hisar, during the years 1999-2000 and 2000-2001. The cytological, morphological, physico-chemical and physiological characters of eleven cultivated cultivars and wild forms/species of ber were studied. The observations recorded are briefly summarised below.

- The chromosome number in cultivars Umran, Kathaphal and four cvs. of Gola group *viz.*, Gola Gurgaon No.3, Bahadurgarhia Gola, Dandan Gola and Kakrola Gola was found to be 2n=48.
- The chromosome number in Illaichi and three wild forms *viz.*, Desi-I, Desi-2 and Desi-3 was noted as 2n=96, whereas in *Jharber* it was 2n=72.
- Multivalents formation and association of bivalent to the nucleolus during meiosis was also noticed.

- The morphological descriptions of various cultivars/forms/spp. differed from each other and hence also differed within the species.
- The height of plant ranged from 1.71m in *Jharber* to 7.61m in Desi-3. The plant spread in North-South direction ranged from 1.52 to 10.81m and 1.60 to 10.67m in *Jharber* and Desi-3, respectively during 1999 and 2000. The plant spread in East-West direction ranged from 1.45 to 11.80m and 1.50 to 11.57m during 1999 and 2000, respectively.
- The mean tree volume was maximum (418.19 m^2) of Kathaphal and minimum (14.56 m^2) of *Jharber*. The other cvs./forms were having tree volume in between these two.
- The mean branching angle varied between 53.21 to 64.87 degrees.
- The colour of phellum was dark brown and that of phellogen was pink in all cases, except *Jharber* where it was red and lightgreen, respectively.
- Paired spines were present in all cvs./forms/spp., except Illaichi where it was solitary. Among the paired spines, one was curved and the other was straight but in case of Illaichi only curved type of spine was observed.
- The Desi forms of *ber* followed by *Jharber* were having maximum spines but minimum (19.0) spines were recorded in Illaichi. The length of spine ranged between 4.11 to 10.07 mm and 4.20 to 10.21 mm during 1999 and 2000, respectively.

- Differences in leaf shape, margin and colour were observed in cvs./ forms/spp. However the veination pattern was same in all cvs./forms/ spp. studied. It was reticulate, palmatic, convergent type. The leaf colour varied from light green to darkgreen with upper texure as smooth while lower surface being smooth glabrous in some cases and rough tomentose in others.
- Length of leaf of Bahadurgarhia Gola was maximum (9.62 and 10.14 cm) during both the years, respectively, whereas breadth was maximum in Illaichi and Bahadurgarhia Gola in 1999 and 2000, respectively. Smallest size of leaf recorded was that of *Jharber* during both the years.
- Fresh leaf weight as well as dry leaf weight was maximum in Illaichi and minimum in *Jharber*.
- The general flower characters were found to be similar in all species. The flowers were pentamerous having five sepals and petals each. The small variation in the size of the various flower parts was not enough to identify different forms of *ber*.
- The flowering period extended from 11th August to 3rd November where *Jharber* was earliest and Desi-I the latest. The anther length of genotypes investigated was 0.38 to 0.65 mm and 0.38 to 0.63 mm in the years 1999 and 2000, respectively whereas, the disc diameter was 2.39 to 4.22 mm and 2.44 to 4.19 mm in the year 1999 and 2000, respectively.

- The anthesis was recorded in the morning or at noon time in various cvs./forms/spp. It was in morning time (7.00 to 7.30 AM) for Illaichi and Kathaphal and at noon time (12.00 Noon to 12.30 PM) in others. Accordingly, the pollen dehiscence occurred 2 to 2.30 hrs after anthesis in all cvs./forms/spp. This was perhaps due to the differential requirement of temperature and vapour pressure deficit for this process by the cultivars/forms/species investigated.
- Palynological investigations revealed that all species are morphologically same and aperture of the pollen was 3-colporate. However, the differences in size and exine ornamentation were recorded. The size of pollen was maximum (29.52×27.48μ) in Desi-I and minimum (19.32×18.42μ) in Kathaphal.
- The fruit ripening time was earliest in *Jharber* (28th September to 12th October), whereas late in Kathaphal and Umran (12th March to 6th April, respectively). The Gola cvs. ripened during the month of February.
- Fruit shape of cvs. Umran, Kathaphal and four cvs. of Gola group was oval, whereas in others it was round. The colour of fruit was golden yellow in all cultivated cultivars, except Kathaphal where it was light green with coffee colour patches. In wild forms and *Jharber* fruit colour was light brown to dark brown with coffee colour patches.
- The fruit size of Umran was largest (4.13×3.23 cm and 4.01×3.04 cm) and that of *Jharber* the smallest (1.17×1.20 cm and 1.21×1.11cm) during both the years.

- The quality characters also varied in different species, where the maximum T.S.S. (19.6 and 18.7%) and acidity (1.220 and 1.305%) was recorded in *Jharber* in both the years. The minimum T.S.S. (13.0 and 12.2%) was in Desi-3 and acidity (0.183 and 0.196%) in Umran. Amount of ascorbic acid was maximum (170.07 and 159.86 mg/100 g pulp) in Illaichi and minimum (87.57 and 93.54 mg/100 g pulp) in Dandan Gola during the years 1999-2000 and 2000-2001, respectively.
- The stone of cultivated varieties was oblong and that of wild forms and *Jharber* it was round. Stone length was maximum (2.17 and 2.10cm) in Umran and minimum (0.61 and 0.58 cm) in *Jharber*, whereas, stone diameter was maximum (1.01 and 1.00 cm) in Kathaphal and minimum (0.58 and 0.57 cm) in Illaichi, respectively during both the years.
- The pulp to stone ratio was maximum (22.44) in Umran and minimum (4.00) in *Jharber*.
- Total chlorophyll of leaves ranged between 24.87μ mol cm^{-2} in Desi-3 to 40.42 μ mol cm^{-2} in Kakrola Gola. Carotenoid content was minimum (18.73 μ mol cm^{-2}) in Dandan Gola and maximum (24.50 μ mol cm^{-2}) in Gola Gurgaon No.3.
- Differential transpiration rate, stomatal conductance and photo-synthesis rate were recorded in different cvs./forms/species. Maximum photosynthetic activity was recorded in Umran.

In the present investigation efforts have been made to characterise some important cvs./forms/spp. of *ber* by using plant descriptors. However, there is a need to characterise the vast genetic resources of ber available in the country. Further studies can also be initiated in this crop using new biotechnological techniques such as DNA finger printing, RFLP, RAPD for genotype identification, evolutionary and phylogenetic and taxonomic aspects of *Ziziphus* species.

The study further emphasised that the important cvs. of *ber* belonging to Gola group are different from each other and are not synonyms of Gola. Based on this study it is suggested that Desi types of *Ziziphus* do not belong to *Z. rotundifolia* but fall in the category of *Z. mauritiana* var. *rotundifolia* since most of the characters of Desi *ber* resemble with this species.

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*Original not seen.

APPENDIX-I

Descriptions of cultivated commercial varieties of *ber*

Characters	Umran	Illaichi	Kathaphal
A. Chromosome No. (2n)	48	96	48
B. Growth characters			
Height of plant (m)	6.28	4.99	7.47
Spread (N-S) (m)	7.60	7.49	10.67
Spread (E-W) (m)	8.81	8.35	10.01
Tree volume (m^2)	221.36	158.54	418.19
Growth habit	Spreading	Spreading	Spreading
Branching angle (°)	55.63	55.74	56.87
Phellum colour	Dark brown	Dark brown	Dark brown
Phellogen colour	Pink	Pink	Pink
Girth of trunk 10 cm below the bud union (cm)	144.5	137.5	139.0
Girth of trunk 10 cm above the bud union (cm)	129.0	159.0	146.55
C. Spine characters			
Shape	Curved/ straight	Curved/ straight	Curved/ straight
Arrangement	Paired	Solitary	Paired
Length (mm)	5.80	4.76	5.61
Number of spines $meter^{-1}$ of current season growth	20.5	19.0	31.5
D. Leaf characters			
Shape	Elliptical to obovate	Elliptical to obovate	Ovate
Apex	Obtuse	Obtuse	Acute
Base	Obtuse/ Oblique	Obtuse/ Oblique	Obtuse/ Oblique
Margin	Serrated	Serrated	Serrated
Veination	Reticulate-Palmatic convergent	Reticulate-Palmatic convergent	Reticulate-Palmatic convergent
Colour	Dark green	Light green	Dark green
Upper texture	Smooth	Smooth	Smooth
Lower texture	Rough tomentose	Rough tomentose	Rough tomentose
Length (cm)	9.25	9.15	8.13
Breadth (cm)	5.28	5.92	5.66
L/B ratio	1.74	1.54	1.44
Length of petiole (cm)	1.76	2.29	2.16
Leaf area (cm^2)	39.46	45.88	36.35
Fresh leaf weight (g)	1.18	1.89	1.19
Dry leaf weight (g)	0.42	0.60	0.47
Fw/Dw ratio	2.79	3.12	2.53

Contd.....

(Contd..... APPENDIX-I)

Characters	Umran	Illaichi	Kathaphal
E. Flower characters			
Durtion of flowering			
Number of flowers/cyme	14.81	18.97	18.19
Length of pedicel (mm)	8.50	8.49	7.97
Number of sepals	5	5	5
Sepal length (mm)	2.91	3.70	3.69
Sepal breadth (mm)	2.72	3.38	3.03
Sepal L/B ratio	1.07	1.09	1.22
Number of petals	5	5	5
Petal length (mm)	1.40	1.34	1.41
Petal breadth (mm)	0.90	0.82	0.93
Petal L/B ratio	1.55	1.63	1.53
Length of anther (mm)	0.39	0.41	0.43
Length of filament (mm)	1.09	1.19	1.01
Diameter of disc (mm)	3.71	4.20	3.54
Anthesis time	12.30pm	7.15am	7.00am
Dehiscence time	14.15pm	9.45am	9.30am
F. Pollen morphology			
Aperture	3-colporate	3-colporate	3-colporate
Shape	Subprolate	Prolate	Subprolate
Size (μ)	26.80x25.67	21.14x19.93	19.32x18.42
P/E ratio	1.04	1.06	1.05
Exine thickness (μ)	1.61	1.27	1.18
Exine ornamentation	Faintly reticulate	Psilate	Psilate
G. Fruit characters			
Time of ripening	2nd week of March to 1st week of April	2nd week of March to Last March	3rd week of March to 1st week of April
Shape	Oval	Round	Oval
Apex	Round	Flattened	Round
Base	Round with depression	Round	Round
Colour at maturity	Golden yellow	Golden yellow	Light green with coffee colour patch
Length (cm)	4.07	1.99	3.00
Diameter (cm)	3.13	1.77	2.56
Weight (g)	23.68	5.30	10.44
H. Stone characters			
Shape	Oblong	Oblong	Oblong
Length (cm)	2.14	1.10	2.06
Diameter (cm)	0.76	0.57	1.00
Weight (g)	1.01	0.26	1.24

Contd.....

(Contd..... APPENDIX-I)

Characters	Umran	Illaichi	Kathaphal
I. Quality characters			
T.S.S. (%)	15.80	16.20	17.50
Acidity (%)	0.189	0.332	0.791
T.S.S./Acid ratio	83.69	48.93	22.21
Ascorbic acid (mg/100g pulp)	141.58	164.96	93.11
J. Physiological characters			
Chl 'a' (μmol cm^{-2})	29.44	32.70	30.72
Chl 'b' (μmol cm^{-2})	5.29	5.85	5.74
Total chl. (μmol cm^{-2})	34.73	38.55	36.44
Carotenoid (μmol cm^{-2})	22.06	23.64	21.18
Transpiration rate (mmol m^{-2} s^{-1})	4.93	4.68	3.91
Stomatal conductance (mmol m^{-2} s^{-1})	864.0	874.00	600.0
Photosynthesis rate (μmol m^{-2} s^{-1})	26.86	21.80	21.60

APPENDIX-II

Descriptions of cultivar of Gola group of *ber*

Characters	Gola Gurgaon No.3	Bahadurgarhia Gola	Dandan Gola	Kakrola Gola
A. Chromosome No. (2n)	48	48	48	48
B. Growth characters				
Height of plant (m)	6.51	6.78	4.88	5.56
Spread (N-S) (m)	9.53	9.81	6.14	6.24
Spread (E-W) (m)	11.68	8.34	5.27	7.58
Tree volume (m^2)	383.27	292.24	83.09	139.04
Growth habit	Erect	Erect	Erect	Erect
Branching angle (°)	57.94	54.69	64.09	58.82
Phellum colour	Dark brown	Dark brown	Dark brown	Dark brown
Phellogen colour	Pink	Pink	Pink	Pink
Girth of trunk 10 cm below the bud union (cm)	145.5	147.0	142.5	128.5
Girth of trunk 10 cm above the bud union (cm)	173.5	180.0	151.0	135.5
C. Spine characters				
Shape	Curved/ straight	Curved/ straight	Curved/ straight	Curved/ straight
Arrangement	Paired	Paired	Paired	Paired
Length (mm)	6.40	5.97	8.19	5.84
Number of spines $meter^{-1}$ of current season growth	33.5	42.0	35.0	43.5
D. Leaf characters				
Shape	Ovate	Ovate	Ovate	Ovate
Apex	Acute	Acute	Acute	Acute
Base	Obtuse/ oblique	Obtuse/ oblique	Obtuse/ oblique	Obtuse/ oblique
Margin	Serrated	Serrated	Serrated	Serrated
Veination	Reticulate palmatic convergent	Reticulate palmatic convergent	Reticulate palmatic convergent	Reticulate palmatic convergent
Colour	Dark green	Dark green	Light green	Dark green
Upper texture	Smooth	Smooth	Smooth	Smooth
Lower texture	Rough tomentose	Rough tomentose	Rough tomentose	Rough tomentose
Length (cm)	8.98	9.88	9.38	9.32
Breadth (cm)	5.06	5.97	5.42	5.38
L/B ratio	1.77	1.65	1.73	1.73
Length of petiole (cm)	1.91	1.55	1.90	1.62
Leaf area (cm^2)	36.92	44.60	41.96	41.63
Fresh leaf weight (g)	1.135	1.475	1.355	1.205

Contd.....

(Contd..... APPENDIX-II)

Characters	Gola Gurgaon No.3	Bahadurgarhia Gola	Dandan Gola	Kakrola Gola
Dry leaf weight (g)	0.40	0.54	0.52	0.39
Fw/Dw ratio	2.80	2.71	2.60	3.05
E. Flower characters				
Durtion of flowering	2nd week of Sept. to last of Oct.	2nd week of Sept. to last of Oct.	Mid Sept. to 25th Oct.	2nd of Sep. t last of Oct.
Number of flowers/cyme	21.37	18.83	18.57	20.97
Length of pedicel (mm)	6.87	7.03	8.40	6.55
Number of sepals	5	5	5	5
Sepal length (mm)	3.10	3.06	2.95	2..94
Sepal breadth (mm)	2.87	2.88	2.84	2.60
Sepal L/B ratio	1.08	1.06	1.03	1.13
Number of petals	5	5	5	5
Petal length (mm)	1.49	1.79	1.27	1.33
Petal breadth (mm)	0.83	0.93	0.89	0.86
Petal L/B ratio	1.79	1.92	1.43	1.55
Length of anther (mm)	0.51	0.56	0.38	0.43
Length of filament (mm)	1.68	1.84	1.82	1.59
Diameter of disc (mm)	4.17	3.84	3.51	3.49
Anthesis time	12.15pm	12.30pm	12.00noon	12.15pm
Dehiscence time	14.15pm	14.30pm	14.15pm	14.30pm
F. Pollen morphology				
Aperture	3-colporate	3-colporate	3-colporate	3-colporate
Shape	Subprolate	Subprolate	Subprolate	Subprolate
Size (μ)	23.02×20.83	27.25×24.68	24.53×22.12	21.82×19.63
P/E ratio	1.11	1.10	1.11	1.11
Exine thickness (μ)	1.36	1.47	1.40	1.37
Exine ornamentation				
G. Fruit characters				
Time of ripening	6th Feb. to 28th Feb.	8th Feb. to 2nd March	13th Feb. to 28th Feb.	4th Feb. to 1st March
Shape	Oval	Oval	Oval	Oval
Apex	Round	Round	Round	Round
Base	Round	Round with depression	Round	Round
Colour at maturity	Golden yellow	Golden yellow	Golden yellow	Golden yellow
Length (cm)	2.97	3.17	2.78	3.05
Diameter (cm)	2.71	2.97	2.54	2.85
Weight (g)	13.34	16.36	10.43	11.94

Contd.....

(Contd..... APPENDIX-II)

Characters	Gola Gurgaon No.3	Bahadurgarhia Gola	Dandan Gola	Kakrola Gola
H. Stone characters				
Shape	Oblong	Oblong	Oblong	Oblong
Length (cm)	1.74	1.84	1.93	1.74
Diameter (cm)	0.98	0.97	0.91	0.96
Weight (g)	1.13	1.20	1.17	1.10
I. Quality characters				
T.S.S. (%)	15.6	18.3	15.6	15.5
Acidity (%)	0.192	0.202	0.198	0.347
T.S.S./Acid ratio	81.30	90.38	78.70	45.06
Ascorbic acid (mg/100g pulp)	118.62	99.91	90.56	101.61
J. Physiological characters				
Chl 'a' (μmol cm^{-2})	31.22	29.27	26.89	34.52
Chl 'b' (μmol cm^{-2})	5.72	5.24	5.17	5.90
Total chl. (μmol cm^{-2})	36.94	34.51	32.06	40.42
Carotenoid (μmol cm^{-2})	24.50	21.83	18.73	23.82
Transpiration rate (mmol m^{-2} s^{-1})	4.33	4.42	2.93	4.39
Stomatal conductance (mmol m^{-2} s^{-1})	46.00	1356.00	274.33	615.33
Photosynthesis rate (μmol m^{-2} s^{-1})	21.70	21.06	10.16	22.70

APPENDIX-III

Descriptions of Desi forms and wild *Jharber*

Characters	Desi-1	Desi-2	Desi-3	*Jharber*
A. Chromosome No. (2n)	96	96	96	72
B. Growth characters				
Height of plant (m)	6.47	7.23	7.61	1.71
Spread (N-S) (m)	9.02	9.27	9.82	1.56
Spread (E-W) (m)	10.53	6.95	8.22	1.47
Tree volume (m^2)	323.59	248.94	324.19	14.56
Growth habit	Spreading	Semi-spreading	Spreading	Erect
Branching angle (°)	64.87	60.59	53.21	55.29
Phellum colour	Dark brown	Dark brown	Dark brown	Reddish
Phellogen colour	Pink	Pink	Pink	Lightgreen
Girth of trunk 40 cm above the bu[illegible] (cm)	150.0	116.0	95.5	21.6
C. Spine characters				
Shape	Curved/ straight	Curved/ straight	Curved/ straight	Curved/ straight
Arrangement	Paired	Paired	Paired	Paired
Length (mm)	4.15	5.64	6.14	10.14
Number of spines $meter^{-1}$ of current season growth	46.5	62.5	64.0	47.0
D. Leaf characters				
Shape	Elliptical to obovate	Ovate	Ovate	Elliptical to Obovate
Apex	Acute	Obtuse	Obtuse	Obtuse
Base	Obtuse/ Oblique	Obtuse/ Oblique	Cordate	Obtuse/ Oblique
Margin	Serrated	Serrated	Entire	Entire
Veination	Reticulate-Palmatic convergent	Reticulate-Palmatic convergent	Reticulate-Palmatic convergent	Reticulate-Palmatic convergent
Colour	Dark green	Dark green	Light green	Light green
Upper texture	Smooth	Smooth	Smooth	Smooth
Lower texture	Smooth glabrous	Smooth glabrous	Smooth glabrous	Rough tomentose
Length (cm)	7.09	5.59	3.64	1.91
Breadth (cm)	5.44	4.05	3.45	1.54
L/B ratio	1.30	1.38	1.05	1.24
Length of petiole (cm)	1.89	1.34	0.64	0.54
Leaf area (cm^2)	30.13	20.16	11.72	2.46
Fresh leaf weight (g)	0.86	0.67	0.37	0.09
Dry leaf weight (g)	0.35	0.28	0.09	0.03
Fw/Dw ratio	2.43	2.39	3.95	3.17

Contd...

(Contd..... APPENDIX-III)

Characters	Desi-1	Desi-2	Desi-3	*Jharber*
E. Flower characters				
Durtion of flowering	4th Sept.– 3rd Nov.	2nd Sept.- 24th Oct.	3rd Sept.- 24th Oct.	11th Aug.- 22nd Sept.
Number of flowers/cyme	16.66	12.72	7.03	8.17
Length of pedicel (mm)	6.15	4.05	4.04	6.15
Number of sepals	5	5	5	5
Sepal length (mm)	2.82	2.57	2.15	2.10
Sepal breadth (mm)	2.73	2.12	1.94	1.88
Sepal L/B ratio	1.03	1.21	1.11	1.05
Number of petals	5	5	5	5
Petal length (mm)	1.41	1.19	1.33	1.01
Petal breadth (mm)	0.85	0.52	0.63	0.51
Petal L/B ratio	1.66	2.30	2.11	1.98
Length of anther (mm)	0.64	0.39	0.39	0.43
Length of filament (mm)	2.04	1.48	1.14	0.98
Diameter of disc (mm)	3.49	3.63	3.10	2.41
Anthesis time	12.45pm	12.45pm	12.30pm	12.30pm
Dehiscence time	14.30pm	14.30pm	14.30pm	14.45pm
F. Pollen morphology				
Aperture	3-colporate	3-colporate	3-colporate	3-colporate
Shape	Prolates-pheroidal	Prolates-pheroidal	Prolates-pheroidal	Prolates-pheroidal
Size (μ)	29.52×27.48	29.14×28.20	29.44×26.35	27.65×25.92
P/E ratio	1.07	1.04	1.12	1.06
Exine thickness (μ)	1.71	1.72	1.68	1.40
Exine ornamentation	Psilate	Psilate	Psilate	Psilate
G. Fruit characters				
Time of ripening	Mid-Feb. to Mid March	1st week of Feb. to 1st week of March	No proper ripening	Last Sept. to Mid October
Shape	Round	Round	Round	Round
Apex	Flattened	Flattened	Flattened	Round
Base	Round	Round	Round	Round
Colour at maturity	Golden yellow with coffee colour patch	Yellow with coffee colour patch	Light green with coffee colour patch	Dark brown
Length (cm)	2.17	1.97	1.27	1.19
Diameter (cm)	2.17	2.06	1.23	1.15
Weight (g)	6.87	5.62	1.36	0.80

Contd.....

(Contd..... APPENDIX-III)

Characters	Desi-1	Desi-2	Desi-3	*Jharber*
H. Stone characters				
Shape	Round	Roung	Round	Round
Length (cm)	1.30	1.19	0.93	0.59
Diameter (cm)	0.97	0.90	0.77	0.58
Weight (g)	0.83	0.70	0.38	0.16
I. Quality characters				
T.S.S. (%)	14.8	14.4	12.6	19.2
Acidity (%)	0.830	0.925	1.062	1.262
T.S.S./Acid ratio	17.82	15.63	11.90	15.19
Ascorbic acid (mg/100g pulp)	101.19	104.59	112.67	112.67
J. Physiological characters				
Chl 'a' (μmol cm^{-2})	24.22	23.72	20.70	27.64
Chl 'b' (μmol cm^{-2})	4.80	4.51	4.17	5.22
Total chl. (μmol cm^{-2})	29.02	28.23	24.87	32.86
Carotenoid (μmol cm^{-2})	21.50	20.84	20.28	21.41
Transpiration rate (mmol m^{-2} s^{-1})	4.51	3.85	3.29	NA
Stomatal conductance (mmol m^{-2} s^{-1})	674.33	446.03	310.33	NA
Photosynthesis rate (μmol m^{-2} s^{-1})	22.60	13.10	13.60	NA

ABSTRACT

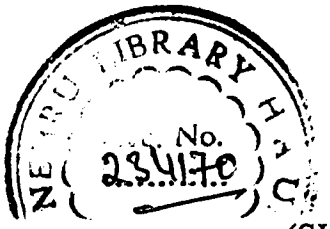
a)	Title of dissertation	:	**CYTO-MORPHOLOGICAL STUDIES IN WILD AND CULTIVATED SPECIES OF *ZIZIPHUS***
b)	Full name of degree holder:		**Ram Bhagat Gupta**
c)	Title of degree	:	Doctor of Philosophy in Horticulture
d)	Name and address of Major Advisor	:	Dr. Suneel Sharma (Horticulturist) Department of Horticulture, CCS Haryana Agricultural University Hisar - 125 004 (Haryana), India
e)	Degree awarding University/Institute	:	CCS Haryana Agricultural University, **Hisar**
f)	Year of award of degree	:	2001
g)	Major subject	:	Horticulture
h)	**Total number of pages in thesis**	:	**94+xiv**
i)	Number of words in the abstract	:	Approximately 250

The present study entitled "Cyto-morphological studies in wild and cultivated species of *Ziziphus*" was carried out during the years 1999-2000 and 2000-2001 at CCS HAU, Hisar. The eleven cvs./forms/spp. of *Ziziphus viz.*, Umran, Illaichi, Kathaphal, Gola Gurgaon No.3, Bahadurgarhia Gola, Dandan Gola, Kakrola Gola, Desi-I, Desi-2, Desi-3 and *Jharber* were included in this study to investigate their chromosome number and morphological, physico-chemical and physiological variations. The chromosome number

of different cultivated varieties including Gola group was observed to be 2n=48 and these were tetraploid except Illaichi where, it was an octoploid with 2n=96. All the desi forms except *Jharber* were also octoploid having equal number of chromosome viz., 2n=96, while *Jharber* was hexaploid with chromosome number 2n=72. Various cvs. showed significant differences for the morphological, physico-chemical as well as physiological characters between and within the groups. Palynological studies suggested that although it was not possible to identify various cvs./forms/spp. on the basis of aperture,shape, exine ornamentation etc. but they could be easily identified on the basis of pollen size and their polar to equatorial ratio. This study further emphasized that the popular cvs. of ber belonging to Gola group are different from each other and hence these are not the synonyms of Gola. Based on this study, it is suggested that Desi forms of *Ziziphus* do not belong to *Z. rotundifolia*, rather falls in the category of *Ziziphus mauritiana* var. *rotundifolia* since most of the characters of desi *ber* resemble with this later species.

S.S.

MAJOR ADVISOR



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