Fruits for the Future 2
(Revised edition)

Ber and other jujubes

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First published in 2001 by International Centre for Underutilised Crops,
University of Southampton, Southampton, SO17 1BJ, UK

British Library Cataloguing in Publication Data

Ber
1. tropical fruit trees
i Williams ii Smith iii Haq iv Dunsiger

ISBN 085432 8580

Citation: Azam-Ali, Bonkoungou, Bowe, deKock, Godara, Williams. (2006) Ber. International Centre for Underutilised Crops, Southampton, UK.

DFID/FRP and DISCLAIMERS
This publication is an output from a research project funded by the United Kingdom Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID [R7187 Forestry Research Programme].

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Abbreviations

ABA -	Abscissic Acid
AMP -	Adenosine monophosphate
BA -	Benzyladenine
CIAH -	Central Institute for Arid Horticulture
CAN -	Calcium ammonium nitrate (fertiliser)
DFID -	Department for International Development (UK)
dSM -	Decisiemen (unit measurement for soil salinity).
ESP -	Exchangeable Sodium Percentage
FAO -	Food and Agriculture Organization of the United Nations
GA -	Gibberellic Acid
GDH -	Glutamine dehydrogenase
GOT -	Glutamate Oxalacetate Transaminase
IAA -	Indole Acetic Acid
IBA -	Indole Butyric Acid
ICRAF -	World Agroforestry Centre (formerly International Centre for Research in Agroforestry)
ICUC -	International Centre for Underutilised Crops
IPGRI -	International Plant Genetic Resources Institute
IPM -	Integrated Pest Management
IU -	International Unit
MPa -	Megapascals (unit of measurement for osmotic potential)
MS medium -	Murashige and Skoog medium
NAA -	Napthylacetic Acid
NOXA -	Napthoxyacetic Acid
NRCAH -	National Research Centre for Arid Horticulture (India)
RH -	Relative Humidity
SALWA -	Semi Arid Lowlands of West Africa project of ICRAF
SAR -	Sodium Adsorption Ratio
TBZ -	Thiabendazole
TIBA -	2,3,5-tri-iodobenzoic acid
TMV -	Tobacco Mosaic Virus
TSS -	Total Soluble Solids
WHO -	World Health Organization
VAM -	Vesicular Arbuscular Mycorrhizal fungi

Preface

Jujubes are considered to be minor fruits and, from a research and development point of view, have not received any major emphasis from governments. However the fruits are an integral part of the culture and way of life of millions of diverse Asian peoples and have also become so for large regions of Africa after the major cultivated species were introduced.

There has been sustained recognition from scientists, particularly those in national agricultural programmes, that these fruits can be exploited much more widely due to their value in human nutrition and the added benefits to rural people of other products from a multipurpose tree. Additionally the trees are hardy and can be cultivated in a very wide range of climatic and agroecological zones thereby making them of great value in agricultural and human development in areas where intensive agriculture is not currently feasible.

When the International Centre for Underutilised Crops (ICUC) initiated a project on Fruits for the Future one of the first monographs to be produced focused on Indian jujube or ber (*Ziziphus mauritiana*). This was authored by Dr O.P. Pareek and issued in 2001. ICUC was gratified to note the great demand for this monograph (over 1200 copies in 5 years) and also to note that research was accelerating in the period since it was issued. Continual requests for more information, especially from Africa, led ICUC to decide that a revised monograph was needed. This book is the result of that decision; it draws, as would be expected, heavily on the initial work of Dr Pareek, to whom ICUC again expresses its thanks.

This is a multiauthored publication and we would like to thank the authors for their contribution. The preparation and publication of the original monograph and the present one has been funded by the Department for International Development (DFID), UK. The goal of the Fruits for the Future Project is to provide a useful compendium on a priority underutilised fruit to researchers, teachers, students, extensionists, growers, traders and policy makers in the hope that it could encourage enhanced production, processing and marketing of jujubes.

ICUC expresses its thanks to DFID and to the numerous national scientists and others who have contributed in one way or another to the two monographs.

Editors 2006

Chapter 1. Introduction, Taxonomy and History

J.T. Williams

1.1 Introduction

Jujubes are species of the genus *Ziziphus* Tourn. ex L. *Ziziphus* belongs to the family Rhamnaceae named for the genus *Rhamnus*. Along with genera other than *Ziziphus,* Rhamnus does not include many economic species except for some wild species with edible fruits or of interest for medicinal products or dyestuffs. The Rhamnaceae have fruits which are drupes or are dry and are closely related to another family, Vitaceae, which includes major economic species whose fruits are berries.

The name *Ziziphus* is related to an Arabic word used along the North African coast, zizoufo used for *Z. lotus* (L.) Desf., but also related to the ancient Persian words zizfum or zizafun; and ancient Greeks used the word ziziphon for the jujube.

There are two major domesticated jujubes, *Z. mauritiana* Lam. the Indian jujube or ber, and *Z. jujuba* Mill. the Chinese or common jujube. These two species have been cultivated over vast areas of the Old World and a limited number of others have been, and are, cultivated on a more localised scale. However all jujubes remain relatively minor crops although demand for production remains steady in many parts where they were originally domesticated.

Interest in expanding the use of these underutilised crops has been sporadic over the decades particularly in relation to rural development objectives. In 1980 the National Academy of Sciences noted the two major jujubes (along with *Z. nummularia* (Burm.) Wight & Arn. and *Z. spina-christi* (L.) Desf.) are useful species for firewood in arid and semi-arid zones (NAS, 1980, also see Adams *et al,.* 1978). At about the same time an assessment of species for expanded use in the Sahelian regions noted the multipurpose value of jujube species including food, honey production, forage and environmental protection (von Maydell, 1986, originally in German 1981), although this assessment did not accord to these species any value for firewood or charcoal. In the 1990s the International Centre for Underutilised Crops (ICUC), following a number of consultations with national programmes in Africa and Asia, highlighted *Z. mauritiana* as a priority species for enhanced research attention.

India had already included *Z. mauritiana* in its national programme on underutilised crops, and ICUC was fortunate in having a scientist associated with that programme write a specific monograph (Pareek, 2001). Similarly other national programmes were recognizing that jujube species were underutilised and could be given priority e.g. Chinese jujube in Azerbaijan (Tagiev, 1992). In the New World there are some indigenous species of jujube but none are considered economic. Chinese jujube has been introduced and grown under plantation conditions in California and Florida. The USDA has imported germplasm of ber and a small amount is cultivated in Florida.

In general, fruits of jujubes are used in areas where their products are fresh or dried fruits (hence the names Chinese date and Indian date) for later use. A range of processed products also exist wherever the species are grown.

1.2 The genus *Ziziphus*

***Ziziphus* P. Miller, Abbrev. Gard. Dict. 1754**

Erect trees or small to large shrubs or semi-scandent shrubs or climbers; when trees usually with a deep radicle, well developed; species may be spiny or not but more commonly are so and species may be glabrous or relatively hairy. The same species may occasionally be found with specimens which are trees and others which are shrubs.

Leaves are alternate or rarely subopposite; they are simple and coriaceous or membranous, acuminate, toothed or not, and 3-5-nerved from the base; the leaf base is either asymmetrical, slightly asymmetrical or symmetrical. Leaves are petiolated with stipules often spinous and branchlets often zigzag.

Flowers are 5-merous, actinomorphic and hermaphrodite. Flowers are borne sometimes solitary or 2-3 together in axillary cymes or in umbels or racemes arranged in terminal panicles or thyrses. Inflorescences may be pedunculate or sessile.

Calyx with triangular acute lobes up to 2 mm long, dentate; calyx valvate, keeled on the inside and the tube obconical. Petals also about 2 mm long, unguiculate at the base, deflexed with the expanded parts about 1.5 mm wide. The petals clasp the stamens or the filaments. Occasionally petals are absent.

Stamens 5 at least, partly adnate to the petal bases and filaments are inserted under the edge of the disk; stamens usually exceed petals. Ovary is superior or subinferior and sunk into the disk but not coherent with it and adnate to the receptacle, the latter being obconical. The disk has 5 or 10 lobes, is rarely entire and its margin is free. The ovary is 2-4 celled with 2-4 styles (usually 2) which are distinct but can be somewhat connate. When 2-celled usually only 1 produces a seed.

Fruits are subglobose, ovoid or oblong, usually drupes. They are 1-4 celled and 1-4 seeded but drupes mostly contain 1 seed. The flesh of the drupe is usually juicy pulp but may rarely be relatively dry. Young fruits may be pilose or not.

Seeds contain large embryos with endosperm sparse or absent. Fruiting branchlets may or may not be deciduous.

Most earlier divisions of the genus were based on characteristics of the inflorescences (e.g. Hooker, 1875; Brandis, 1906; Sussenguth, 1953). Liu and Cheng (1995) considered details of inflorescence types unstable and suggested that the species are grouped into two Sections, one further divided into two Series:

1. Ziziphus - Occurring in temperate zones. Plants glabrous and with deciduous fruiting branchlets.
2. Perdurans - M. J. Liu and C. Y. Cheng - Occurring in subtropical and tropical zones. Plants pilose and without deciduous fruiting branchlets.
    - 2.1 Series Cymosiflorae - Occurring widely in subtropical and tropical zones. Flowers in axillary cymes. Ovary and fruit glabrous with thick, hard endocarp.
    - 2.2 Series Thyrsiflorae - Occurring in South and Southeast Asia. Flowers in terminal or axillary thyrses. Ovary and young fruit pilose with very thin endocarp.

The Indian jujube belongs to Section Perdurans Series Cymosiflorae and the Chinese jujube belongs to Section Ziziphus. The more minor cultivated species can also be classified in Series Cymosiflorae.

1.3 The species of *Ziziphus*

There is a consensus that the genus contains about 86 species (Evreinoff, 1964; Johnston, 1972) but others suggest there could be up to 135 (Bhansali, 1975) and Liu and Cheng, (1995) suggested there could be up to 170. Much depends on the taxonomist's view of a species; however in the past there have been 271 names given, many of them reduced to synonymy.

One problem in understanding a somewhat complex taxonomy has been that the same specific name has been used by different authors for different species. Sometimes in published papers it is difficult always to be sure which species is meant, especially when an authority for the name is not given or when there is no voucher specimen to ensure the right identity. The Indian jujube (*Z. mauritiana* Lam.) has had the specific name of *jujuba* applied as *Z. jujuba* (L.) Lam. and *Z. jujuba* (L.) Gaertn. and named intraspecific taxa of the latter refer to another species *Z. abyssinica* A. Rich, which in turn had been called *Z. jujuba* Hemsl. There are numerous examples such as this one among the synonymy especially with specific names such as *rotundifolia* or *nummularia*.

Less serious, but also a constraint, is that accounts and naming of species, although they may be based on very wide geographical areas, have not included inter-regional comparisons. For instance, Johnston (1972) considered possible affinities between *Z. lotus* of Mauritania and the Sahara, and *Z. hamer* of East Africa and *Z. leucodermis* (Baki) O. Schwartz of Arabia but concluded that a thorough field study is desirable.

Lastly, in understanding the complexity of the taxonomy of *Ziziphus* species, hybridisation can be a problem. Confusing species boundaries and names have been given to some stabilised segregates. This will be discussed in Chapter 8.

1.4 The major cultivated species

1.4.1 Indian jujube

Ziziphus mauritiana **Lam.**
Synonyms
Z. jujuba (L.) Lam.
Z. jujuba (L.) Gaertn. (including var. *stenocarpa* Kuntze and forma *aequilatrifolia* Engl.)
Z. tomentosa Poir.
Z. rotundata D.C.
Z. aucheri Boiss.
Z. insularis Smith
Z. sororia Roem. and Schult.
Z. orthocantha D.C.

The species has a wide range of morphologies from shrubs to small or medium-sized trees which might be erect, semi-erect or spreading. Height can vary from 3-4 to 10-16 m or more although trees of 20 m are rare. Trees are semi-deciduous and much branched. The bark has deep longitudinal furrows and is greyish brown or reddish in colour. Usually the shrub or tree is spinous, but occasionally unarmed.

Branchlets are densely white pubescent, especially when young and tend to be zig-zag. Branches erect and spreading, becoming flexuous and dull brown-grey. Fruiting branches are not deciduous.

Leaf laminae are elliptic to ovate or nearly orbicular, (1.3-)3-8(-12) cm long and (0.4-)1.5-5(-6.5) cm at the widest point. The apex is rounded, obtuse or subacute to emarginated, the base rounded, sometimes cuneate, mostly symmetrical or nearly so. Margins are minutely serrulate. There are 3 marked nerves almost to the apex, the nerves being depressed in the upper, light or dark green, glabrous surface. Lower surface is whitish due to persistent dense hairs but may be buff coloured. Occasionally the lower surface is glabrous.

Leaves are petiolate 1.1-5.8 mm long and stipules are mostly spines, in each pair one hooked and one straight, or both hooked, or more rarely neither developed into a spine.

Flowers have sepals which are dorsally tomentose, a disk about 3 mm in diameter and a 2-celled ovary, immersed in the disk. Styles are 2, 1 mm long and connate for half their length. Flowers tend to have an acrid smell.

Flowers are borne in cymes or small axillary clusters. Cymes can be sessile or shortly pedunculate, peduncles 1-4 mm tomentose. Pedicels are also tomentose and are 2-4 mm at flowering and 3-6 mm at fruiting.

Fruit is a glabrous globose or oval edible drupe varying greatly in size from (1-) 1.5 (-2) cm diameter but some oval varieties can reach 5 x 3 cm. The pulp is acidic and sweet, the fruit greenish, yellow or sometimes reddish.

The species is distributed throughout the warm subtropics and tropics of South Asia. In cultivation it has spread south-eastwards through Malesia and eastwards through IndoChina and southern China. It is widespread in Africa and southern Arabia, where it was probably first cultivated; however in Africa it has naturalised and so-called 'wild' types are to be found, especially shrubby rather than tree forms. It adapts to warm to hot tropical climates with low to relatively high rainfall, tolerating poor soils.

The intraspecific taxa described are not very meaningful in view of this tendency to naturalise and produce wild heterogeneous populations. Several varietal names have been given to wild morphotypes. One variety, *Z. mauritiana* var. *orthocantha* (D.C.) A. Cher. is found south of the western Sahara and in Mauritania. It produces a dry pulp and is probably valid in view of its specific utilisation by local people.

1.4.2 Chinese jujube

***Ziziphus jujuba* Mill.**
Synonyms
Z. sativa Gaertn.
Z. vulgaris Lam.
Z. flexuosa Wall.
Z. nitida Roxb.
Z. sinensis Lam.
Z. zizyphus (L.) Karst.
Z. mairei Dode
Z. officinarum Med.
Z. chinensis D.C.
Z. chinensis Watt

Shrubs or small trees up to 8-10 m high with rigid spreading boughs and stiff branches; an appearance often producing a gnarled shape. Tree forms tend to have a small canopy extending 3.5-4.5 m. Trunks may be short or long depending on genotype. Branches are armed with paired spikes, one of each pair larger than the other and straight, the shorter one recurved. Older parts of older trees can lose their spines. Branchlets are flexuous, green and glabrous when young. Fruiting branchlets are deciduous.

Leaves are (2-) 2.5-5 (-5.5) cm long oblong, obtuse, glabrous (rarely tomentose beneath), glandular, crenate-serrate, 3-nerved. Petioles are 2.5-7.5 cm long. Stipules form the spines.

Flowers are few in a small axillary cluster or cyme which is larger than its peduncle. Flowers have a disk obscurely lobed. Styles are 2, connate for half their length.

Fruit is an ovoid-oblong edible drupe 1.5-2.3 cm long, dark reddish brown to black, each being short stalked and may be pendulous. Pulp sour to sweet.

Chinese jujube is native to temperate Asia, particularly China and neighbouring areas of Mongolia and the Central Asian Republics. In cultivation it spread westwards to the Mediterranean, throughout the Near East and SW Asia and spread eastwards in cultivation to Korea and Japan. Like *Z. mauritiana* this species also naturalises in many Asian countries and 'wild' populations are to be found which are derivatives from cultivation. It is mostly cultivated in China, India, Central Asia and southwest Asia.

Z. jujuba var. spinosa Hu ex H. F. Chow is typified by possession of small sour fruits and is usually a spiny shrub or small tree (Wang and Sun, 1986). *Z. jujuba* var. *inermis* has unarmed branches and styles not connate (Brandis, 1874).

Chinese jujube is adapted to subtropical and warm temperate areas. It prefers a relatively dry climate during the growing season but cool during its dormancy. It can tolerate lower temperatures than Indian jujube and can survive -10 °C.

There should be no confusion between the Chinese jujube and the description of *Z. jujuba* (L.) Gaertn. var. *hysudrica* Edgew which relates to reputed hybrids of *Z. mauritiana* and *Z. spina-christi*.

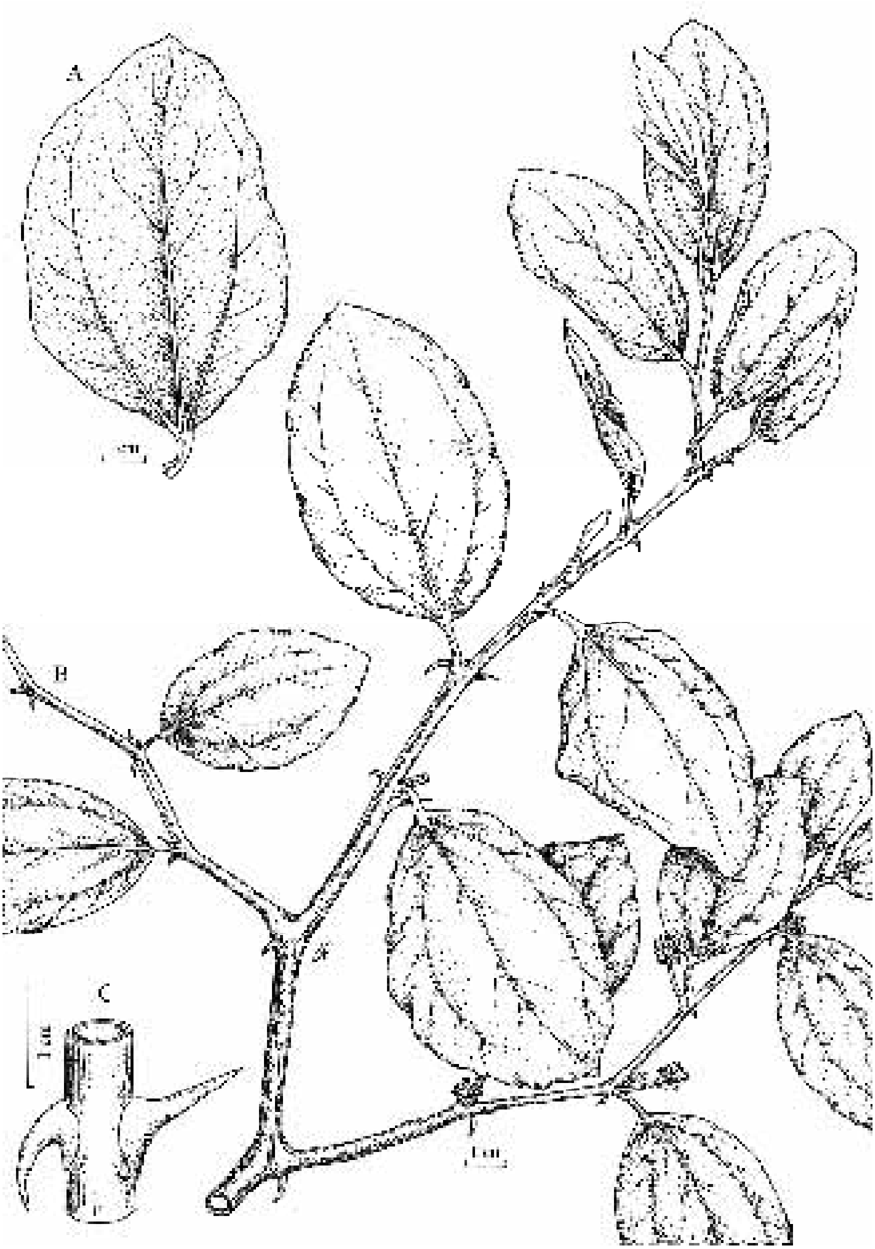


Figure 1.1 Branch and leaf arrangement in ber showing the unequal spines
A - Undersurface of leaf. B - Branch/ twig to show leaf arrangement. C- Detail of unequal spines.

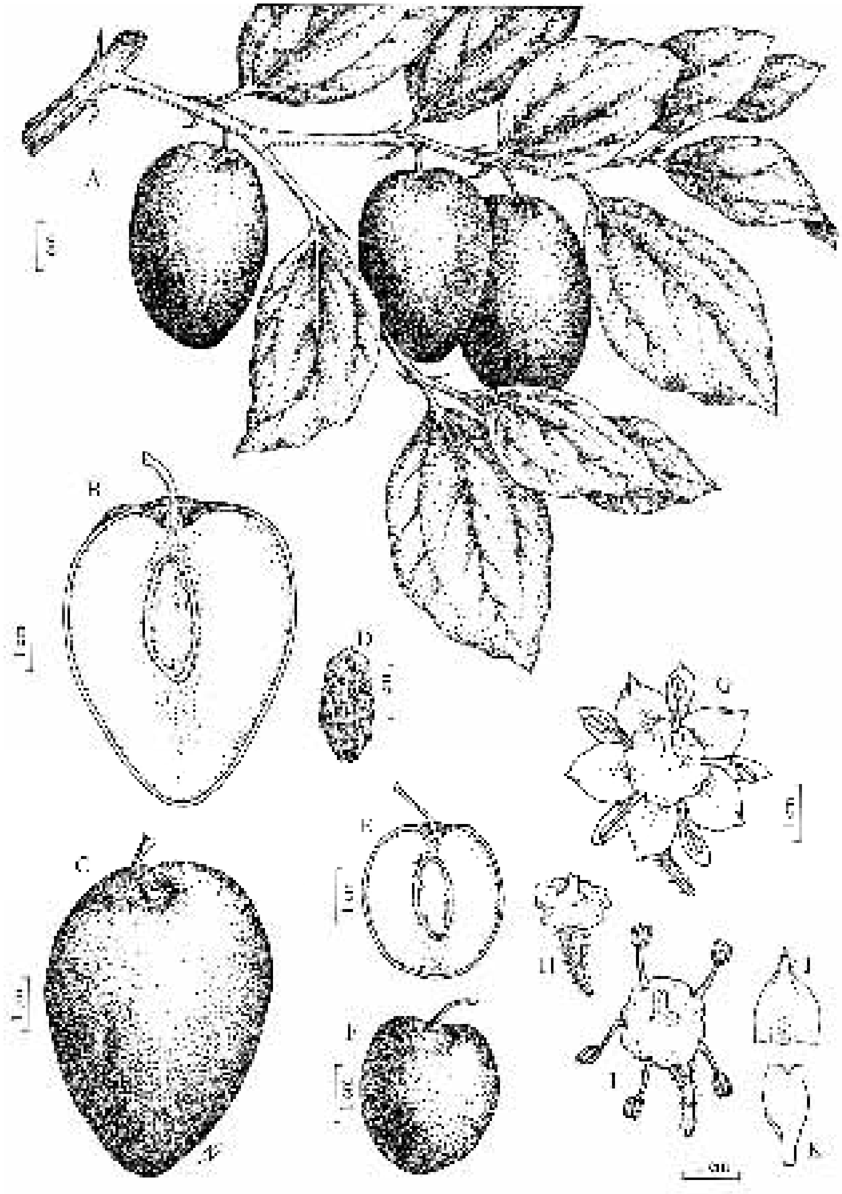


Figure 1.2 Flower and fruit of ber showing the pistil, stamens and seed
A - Fruits on the tree. B - Vertical section through a mature fruit.
C - Mature fruit. D - Stone/seed (from B/C). E - Vertical section through mature fruit - alternative variety. F - Mature fruit - alternative variety. G - Flower. H - Pistil. I - Pistil with stamens. J - Sepal. K - Petal.

1.5 The minor cultivated species

There are two species of *Ziziphus* which are still cultivated on a small scale. They are described below.

1.5.1 *Z. spina-christi* (L.) Desf.

Synonyms
Z. africana Mill.
Z. amphibia A. Chev.
Z. nabeca (Forsk.) Lam.
Z. inermis A. Chev.
Z. sphaerocarpa Tul.
Z. spina-christi Willd. (as used by Bailey, 1947 and Polunin and Huxley, 1965).

Shrub, often with intertwined branches, or small tree up to 10-15 m tall. Bark deeply furrowed and scaly, white-brown to pale grey. Branchlets densely pubescent white when young. Fruiting branchlets are not deciduous. Tends to produce a very deep tap root. Mostly spinous with paired spines, unequal in length, one recurved; rarely unarmed.

Leaves ovate-lanceolate or ovate-elliptic (<1-)2-8(-9) cm long and (1.2-)2-3(-6) cm wide, margin crenulate; rounded at base and nearly symmetrical, obtuse; minutely pubescent beneath when young becoming glabrescent at maturity. Petioles (3-)10-15(-20) mm long.

Flowers in short axillary cymes. Cymes (5-)10-15(-25) flowered. Peduncles 1-3 mm at flowering and 3-6 mm at fruiting. Sepals woolly dorsally.

Fruits subglobose to globose fleshy glabrous drupes**,** yellow, reddish or red-brown, usually about 2 cm long and 1 cm wide. Flesh astringent to taste.

The species is evergreen where water is adequate, but deciduous in the dry season when conditions are drier.

A full picture of the variation across the range is not available. Hence infraspecific taxa can be meaningless e.g. var. *longipes* Engl. and var. *mitissima* Chior. It is best to consider a typical variety, var. *spina-christi* in contrast to var. *microphylla* A. Rich. which is endemic to Africa especially Ethiopia south to Kenya and also in Yemen. This variety is a shrub 4-5 m with more elliptic leaves, fruits about 1 cm long and often forming impenetrable thickets. The tropical form is a tree with more ovate leaves.

Z. spina-christi is a species of the Middle East through Arabia and West Africa to N. E. Africa, Ethiopia and Eastern Africa, especially the drier tropical areas. It is wild in the Middle East, especially Iran, Saudi Arabia and also farther west in Turkey. Its edible fruits are gathered for food. Almost certainly it was introduced to Africa by Arab traders along the Mediterranean coast and also via the Horn of Africa. Its links to African homesteads were maintained because of its value as a shade tree, its use for fruits and its many other uses (von Maydell, 1986; von Sengbusch and Dippolo, 1980). It is known to be a minor cultivated plant in India and Pakistan and more importantly in Egypt, Syria, the Mahgreb, Saharan oases and Zanzibar. This species is of interest because it has probably hybridised with *Z. mauritiana* according to information from Pakistan, Dahomey and Nigeria. Also it can survive with half the annual rainfall needed by *Z. jujuba* and for both major cultivated species could be a source of drought resistance. The species prefers hot tropical or subtropical climates with low to medium rainfall and altitudes usually to 1500 m.

Z. spina-christi is the species which is thought to have been used to make the crown of thorns for Christ. However this is not certain because *Paliurus spina-christi* Mill. (syn. *P. aculeatus* Lam.) has also been proposed. The latter species is very similar to the jujube but has dry fruits with a broad orbicular horizontal wing. It is distributed in maquis, roadsides and waste places, similar to places where *Z. spina-christi* is naturalised. It extends from S.E. Europe to the Levant eastwards to the Himalayas and China. It too is a shrub, often spreading, or a small tree to 8-10 m, spinous in the same way, but the leaves and young twigs are glabrous (Polunin and Huxley, 1965).

1.5.2 *Z. lotus* (L.) Lam.

Synonyms
Z. nummularia Aubrev.
Z. saharae Blatt. & Trab.
Z. lotus (L.) Desf. subsp. s*aharae* Maire
Z. sylvestris Mill.
Z. parviflora Del.

This species is a spiny shrub growing up to 1.5 m tall and resembling *Z. jujuba*. However, fruiting branchlets are not deciduous and twigs are grey. Internodes on branchlets are less than 1 cm long. Leaves are suborbicular or broadly elliptic to ovate, shallowly glandular-crenate, pubescent beneath and less so above; size (0.5-)1.2(-1.5) cm long x (0.4-)1(-1.3) cm broad.

Flowers are solitary or 2(-3) together.

Fruits are subglobose fleshy drupes about 1 cm diameter and deep yellow.

Z. lotus occurs from Asia Minor, south to Arabia, Egypt and along the North African coast and it reaches Cyprus and Greece in Europe. It is also cultivated in S. Portugal and Spain, parts of Italy and Sicily and in Provence, France. This is the lotus fruit of the Lotus eating people of Tunisia/Libya referred to by Homer, Herodotus, Polybius and other ancient writers.

Z. lotus is of interest in rehabilitating certain degraded areas of N. Africa and elsewhere in the eastern range of the species. Also European selections may fill niche markets.

In relation to improvement of Indian jujube, *Z. lotus* could be used in respect to earliness of fruit maturity as well as drought tolerance, if hybridisation was initiated, especially between cultivars. Some confusion exists between *Z. lotus* and wild *Z. nummularia* of India, but they are distinct. The eastern limits of *Z. lotus* need examining in the field.

1.6 Wild species

1.6.1 Asia

There are numerous wild species of *Ziziphus* in Asia and they tend to cluster in two regions: China and the Indian subcontinent. There are 14 species in China. Those, like *Z. jujuba*, belonging to Section *Ziziphus* of the genus are to be found mostly in the central and lower parts of the Huanghe River valley although the primary centre of diversity in China for *Ziziphus* species is south Yunnan and the southeast of Guangxi Province.

Pareek (2001) noted the distribution of wild and naturalised *Z. mauritiana* throughout the greater part of India from the lowlands to 1500 m in the Himalayas and also in Sri Lanka. It is associated with dry areas where tree types can be found or bushy types in grasslands. Early writings on the botany of India recorded the species as wild in the Siwalik forests east of the Ganges and in forests of Central India (Brandis, 1906). *Z. jujuba*, often recorded as *Z. rugosa*, can be found naturalised in the central and eastern sub-Himalayan region east to Bangladesh as well as in many other parts of India such as the Central Provinces and western side of the Peninsula. Other species cluster in the north west desert region of India and only a few in the Himalayas.

In the drier parts of N. W. India, *Z. nummularia* (Burm. F.) Wight and Arn. (syn. *Z. rotundifolia* Lam.) was recognised by the Indian National Genetic Resources Programme as a species worthy of further research. This was identified at an International Workshop on Maintenance and Evaluation of Life Support Species in Asia and the Pacific, held in New Dehli in April 1987. It is also a useful rootstock. The species is a thorny shrub producing red, edible fruits.

Some wild species with wide distributions, such as *Z. oenoplia* Mill., have become weedy in places such as India, Sri Lanka, Myanmar or Malaysia. According to the literature, a few additional wild species cluster in Malaysia (Ridley, 1922) and also in Indonesia (Martin *et al.,* 1987). However wild species from countries such as India, Myanmar and Malaysia or Myanmar eastwards through IndoChina have not been studied in a comparative way and it is likely there is a degree of synonymy to be clarified.

Three other species need mention since they are sometimes used as rootstocks. *Z. xylopyra* Willd. (syn. *Z. rotundifolia* Roth., *Z. cuneata* Wall.) is an erect, small tree frequently unarmed and producing a woody, inedible fruit. It is a species of South India and Sri Lanka. *Z. rugosa* Lam. is a straggly bush tending to have solitary spines and edible fruit, found in the Central Hills and eastern parts of India. *Z. oenoplia* Mill. is a scrambling shrub with spines and small black fruits often used for tanning and found in S. India, Sri Lanka and Myanmar.

1.6.2 Africa

The other wild species in the Old World centre on Africa. Those covering very wide areas are *Z. abyssinica* Hochst. ex A. Rich. in scattered tree grassland 400-2200 m from Senegal to Ethiopia and south to Zimbabwe and Mozambique; *Z. mucronata* Willd. grows in open woodland from 0-200 m above sea level from Senegal to Arabia and south to S. Africa and Madagascar; and *Z. spina-christi* in disturbed areas from 0-1300 m and is indigenous in semi-desert wadis from 600-1000 m above sea level in the Horn of Africa and North Africa. Elsewhere in East Africa it was probably introduced and has become naturalised along roadsides in many parts of Africa and through seed propagation has often reverted from introduced cultivars to wild types.

1.6.3 New World

The few indigenous species are not discussed since they are of minor relevance to the species dealt with in this monograph.

1.7 Vernacular names for jujubes

Vernacular names frequently refer only to a jujube fruit; in other cases different cultigens are identified. Table 1.1 provides names used in different regions, countries and languages, with reference to Indian and Chinese jujubes.

Table 1.1 Vernacular names for jujubes

Region	Country	Name (language in parentheses)
Asia	Afghanistan	Berra (Pashto)
	Bangladesh	Bozoi, Kool, Kul
	Cambodia	Putrea
	China	Hong tsao, Lang tsao, Ta tsao, Tsao tse
	India	Bogori (Assamese); Kul (Bengali); Ber, Bor, Bordi, Boyed (Gujarati); Ber, Beri (Hindi); Badari, Baer, Bogari, Bore, Egasi, Elasi, Ilanji, Ilisi, Jelachi, Karkhandhu, Yolachi (Kannada); Ber, Bhor, Baher, Bor, Bardi, Bora (Marathi); Badaram, Badari, Kolam, Lantu, Elanda, Perintutati (Malayadam); Ber, Beri, Unals (Punjabi); Ajapriya, Badari, Balastha, Dridhabija, Dviparni, Ghonta, Gudaphala, Kantaki, Karkaramadhu, Koli, Kuvali, Madhuraphala, Madadebara, Nakhi, Nripabadari, Nripeshta, Prithukoli, Phalashayashira, Rajabadari, Rajakoli, Rajavallabha, Sukshmaphala, Sukshmapatrika, Srigalakoli, Svachha, Sukorapriya, Suphala, Tanubija, Ubhayakantaka (Sanskrit); Ber, Jangri (Sindhi); Adidarum, Attiram, Ilandai, Iradi, Koli, Kandai, Kullari, Kulvali, Padari, Sivagam, Vadari, Vettiram, Veyam, Elanda (Tamil); Badaramu, Badari, Gangaregu, Gangarenu, Karkhanduvu, Regu, Renu (Telugu); Ber (Urdu); Barholi, Bodokoli, Bodori, Koli (Uriya)
	Indonesia	Widara, Dara, Bidaru
	Iran	Kanar, Kunar, Nabik
	Iraq	Aunnaberhindi, Nabig, Sidr
	Japan	Sanebuto-Natsume
	Laos	Than
	Malaysia	Bidaru, Epal siam, jujube
	Myanmar	Zi, Zee-pen, Zizidaw, Ziben
	Nepal	Baer
	Pakistan	Ber (Urdu); Ber, Berwarter, Kunar (Baluchi)
	Philippines	Manzanites, Manzanas
	Sri Lanka	Ilanda, Mahadebara, Masaka (Sinhalese)
	Thailand	Phutsa, Putsa, Man tan
	Vietnam	Tao, Tao-nhuc
Africa	Ethiopia	Abateri, Gaba-artgie, Gewa-ortigi (Tigre)
	Kenya	Mkunazi (Swahili); Kwkurrah (Borao); Ekalati (Turhana); Olongo (Luo); Tolumuro (Pokot)
	Malawi	Masawo (Chewa); Msondoka (Yao)

Region	Country	**Name** (language in parentheses)
	Somalia	Gob, Bheb, Jujuba
	Sudan	Sidr nabk, Nabbag elfil,
	Tanzania	Mkunazi (Swalihi)
	Uganda	Esilang (Karamajong)
	Zaire	Kankole
	Zambia	Masau (Nyanja); Musawce (Tonga); Akasongole (Bemba)
	Zimbabwe	Masua, Yanja, Musawu (Central Shona, Tangu);
	West Africa and Sahel	Domo, Ntomono, Surgo ntomono, Tomboro, Tomonou (Bambara); Batenluongu, Bu sakonhionabu Inakpayuani, Nan janlwane (Gourmanche); Magaria (Haussa); Magunuga, Mugulga, Mugulanga, Muegunga, Mugunuga, Mug-niga (More); Djabe, Djabi, Tabi, N'giobi (Peulh); Ngit (Sere); Ajzen (Tamachek); Dem, Dim, Sedem (Wolof).
Others	Language	Name
	English	Jujube; Indian jujube, Indian plum, Indian cherry, Indian date; Chinese jujube; Chinese date; Chinese fig; Cottony jujube.
	French	Jujubier; (Le jujube d' Afrique tropicale); Datte chinoise.
	Greek	Tzintzola
	Italian	Guiggiolo
	Portuguese	Jujubeira, Maceira
	Spanish	Azufaifo, Yuyuba

Sources: FAO, 1988; von Maydell, 1986; Pareek 2001; Sundararaj and Balasubramanyam 1959; and editors.

1.8 Historical evidence

1.8.1 Indian jujube

Ber has been recognised as a useful edible fruit since antiquity in India and Watt, (1893) referred to this from references in ancient Sanskrit sources. Macdonell and Keith (1958) noted mention of ber in Vedic sources such as the Yajurved. Pareek (2001) summarised the references to ber and other jujubes in scriptural sources and these references covered the period from 1000 BC- 400 AD.

Such historical evidence attests to the recognition of the fruit and its uses; it does not imply domestication. Numerous writers state that ber has been in use for almost 4000 years in India. However, if the original wild species was spread from India through Myanmar then early domestication efforts would postdate that of the staple foods and possibly occurred when populations increased with the rise of tribal kingdoms across the Gangetic plains.

Excavations relating to the early Indus civilisation produced stones of Chinese jujube (see below) and later cultural links of people with the Mauryan empire would have resulted in cultural appreciation of jujubes, whatever the species. Scriptures mention both *Z. mauritiana* and Z. *jujuba* and even the wild *Z. nummularia* (Majumdar, 1945).

Ber must have been widely appreciated because excavations at Navdatoli-Maheshwar on the Deccan plateau produced ber stones from almost certainly gathered wild fruits. They date to 3500-3000 BP predating the Gangetic civilisation. This area is one where ber is thought to have been truly wild. (Mittre, 1961; Sankalia, 1958; Pareek 2001).

Once cultivated, ber would have been moved with historical migrations of people and their trade. It is thought to have been in Africa for only a few centuries and it is likely that introduction to China and Indonesia is also fairly recent. Introduction to Australia was to Queensland and the Northern Territory late in the nineteenth century (Grice, 1998).

1.8.2 Chinese jujube

The area where *Z. jujube* was domesticated is almost certainly in the Yellow River area. The Yellow River – Huaihe River plain is the main area for this species today with much of the cultivated production in Henan, Shanxi and Shandong provinces. It is thought to have been taken into cultivation about 2000 BP, probably early Shang dynasty of the Bronze Age. It is mentioned in the Book of Songs, a poem of the tenth century BP (Qu, 1983).

The progenitor wild species has a very wide area of distribution from China to Pakistan and wild fruit would have been gathered in many areas. Excavations indicate that people of the earliest farming settlements of the Indus valley civilization at Mehrgar in Balluchistan collected fruits (excavations dates seventh millennium BP). This continued as evidenced by similar finds from Pirah, Pakistan from the later unified Indus culture (Zohary and Hopf, 1988).

Vavilov (1951) considered the primary centre of origin to be wider than China and the cultivation must have spread quickly through Central Asia. Impetus could have related to its carriage along the old trade routes and the later Mongol empires. Kazvini writing in the nineteenth century AD mentioned the excellent jujubes in the Province of Jurjan of the Abbasid Caliphs. Jurjan is located around the border between N. E. Persia and S. Turkmenistan. He wrote that trees fruited twice a year and at 2 – 3 years old (Le Strange, 1930). This particular area was linked to the trade routes from China to the Mediterranean as well as to the Indus valley. Chinese jujube was thought to have reached SW

Asia by 2000-3000 BP (de Candolle, 1886). It was taken, according to Pliny, from the Levantine Coast to Europe in the time of Augustus by the Consul Sextus Popinus. It is thought to have been spread along the North African coast in the seventh century AD.

In relation to West Asia a number of excavations have found remains of jujube fruits linked to numerous Neolithic and Bronze Age sites (Zohary & Hopf, 1988); Egypt 4000 BC (Montet cited by Munier, 1973); also from shell middens near Muscat, Oman from the fourth millennium BC (Biagi and Nisbet, 1992). It is most likely these gathered fruits were of Z. *spina-christi* or Z. *lotus.*

Chinese jujube has however developed a secondary centre of diversity in West Asia and is naturalised in many areas such as along the Black Sea Coast (Tutin, 1968).

Chinese *jujuba* was first introduced from Europe to USA in 1837 by Robert Chisholm and planted in Beaufort, South Carolina and introduced to California and neighbouring states from southern France by Rixford in 1876, (Rixford, 1917). By 1901 jujube had escaped from cultivation in Alabama (Mohr, 1901) and is now naturalised along the Gulf Coast from Alabama to Louisiana (Bonner and Rudolf, 1971).

All of the early jujube introductions into the United States were seedlings from Europe, and it was not until 1908 that the much superior Chinese cultivars began to be introduced (Lyrene, 1979). In that year Frank Meyer, a US Department of Agriculture plant explorer, introduced Lang and other Chinese cultivars (Lanham, 1926; Meyer, 1911). A second group of cultivars introduced in 1914 included Li, which produced the largest fruit he had seen in China (Lanham, 1926). In recent years Russian cultivars have been introduced to boost an improvement programme at the Alabama ADM University.

In the twentieth century superior Chinese materials were introduced to Japan, and also to North Africa by French scientists.

The Chinese jujube (*Z. jujube*) has been introduced into more than 30 countries (Liu *et al.*, 2003a) and is becoming increasingly popular for its wide adaptations, easy management, early bearing, rich nutrition and multiple uses. *Z. jujuba* (*Z. mauritiana*) was brought to the non-French West Indies from India and Indonesia during the colonial period (Barbeau, 1994). In 1993, 160 seeds of the leading varieties of tomentose jujube (*Z. mauritiana*) grown in Burma (Myanmar) were introduced to China. Plants were vigorous and matured very early. Two promising varieties were selected, the fruits of which are crisp, tender, sweet and of very good eating quality (Liub, 1997).

The introduction of *Z. mauritiana* to the Negev desert of Israel has been found most promising (Nerd *et al.*, 1990). 'Taiwan Cuizao' was introduced in 1997

(Xue and Xue, 2001). Six *Z. jujuba* (*Z. sativa*) cultivars were introduced into Macedonia from USSR (Ristevski *et al.*, 1982) which were found to be resistant to low winter and high summer temperatures. Introduction of *Z. mauritiana* was found to grow satisfactorily under the conditions of the Jordan Valley, Negev and Arava areas and to produce fruits of commercial value (Mizrahi *et al.* 1991). Fruit trees suitable for introduction to desert areas of Israel have been described by Mizrahi *et al.*, (2002). Wushizhong is a cultivated variety of *Ziziphus mauritiana*, introduced from Taiwan. It flowers twice a year (in May-July and early September), but spring flowers do not result in much fruit setting. The main production is produced by autumn flowers.

Chapter 2. Composition

C. Bowe

2.1 Introduction

Species of *Ziziphus* are considered to be multipurpose plants although use of the fruits is the major focus of interest. They are of increasing use in agroforestry. The composition of the fruits is therefore of importance especially since they are produced by a limited number of species which have been cultivated for millennia.

There is a great deal of published data on the potential of the species for ethnobotanical uses (Arndt and Kayser, 2001). Pareek (2001) noted that although different parts of the plant have medicinal value due to their constituents their usage appears to be sporadic and not commonplace.

This chapter looks in particular at the nutritive composition of fruits and then provides a summary of the more important ethnopharmacological compounds and their properties, when known.

2.2 Fruit composition

2.2.1 Ber

Much of the data relating to ber fruits are cultivar specific; however the information can be summarised to provide a general picture. The pulp of the fruits is of most importance in relation to nutrition. Pareek (1983) recorded fresh, mature with 81-97 % pulp and Jawanda *et al.*, (1980a,b) considered the range 91.6-92.9 %.

The constituents of the pulp are shown in table 2.1

Table 2.1 Nutritional constituents in fruit pulp of 4 ber cultivars

Constituents	Gola	Kaithli	Banarsi Karaka	Umran
Moisture (%)	81	--	81	--
Starch (%)	0.95	--	0.86	--
TSS (^{O} Brix)	17-20	16-18	13-17	18-20
Total sugars (%)	8.3-12.1	4.9-10	5.4-12.4	7.2-7.4
Reducing sugars (%)	3.3-5.8	1.95-2.7	3.3-3.7	2.6-2.9
Non-reducing sugars (%)	2.4-8.4	2.2-8.0	3.3-8.4	4.8-4.9
Acidity (%)	0.37-0.75	0.16-0.51	0.13-0.48	0.19-0.35
Protein (%)	-	1.18	-	1.03
Total ash (%)	-	0.45	-	0.34
CaO (%)	-	0.04	-	0.03
P_2O_5 (%)	-	0.02	-	0.01
Fe_2O_3 (mg/100g)	-	0.5	-	1.00
Ascorbic acid (mg/100g)	70	89-133	66-110	73-103

(Source: Pareek, 1983).

The richness of the pulp in nutritive compounds has been widely recognised. Nonetheless there are no definitive values for pulp composition. However ber is richer than apple in protein, phosphorus, calcium, carotene and Vitamin C (Bakhshi and Singh, 1974) and oranges in phosphorus, iron, vitamin C and carbohydrates and exceeds them in calorific value. Ripe fruits provide 20.9 Kcalories per 100 g of pulp (Singh *et al.*, 1973a).

In terms of carbohydrates, pulp contains 12.8 – 13.6 % (Singh *et al.*, 1967); (Jawanda *et al.*, 1981) of which 5.6 % is sucrose, 1.5 % glucose, 2.1 % fructose and 1 % starch. Total sugars content is markedly different according to cultivar (Singh *et al.*, 1983a).

The amino acids asparagine, aspartic acid, glycine, glutamic acid, serine, á-serine and threonine, are found in the pulp (Bal, 1981a) but not many analyses or comparisons have been made.

Major interest has focused on Vitamin C content and ber pulp is considered a rich source. Content ranges from 70-165 mg/100 g (Bal and Mann, 1978). The FAO and WHO recommendation (FAO, 1974) that the daily intake for an adult man should be 30 mg, illustrates the value of ber pulp in the diet.

Pulp contains about 70 IU Vitamin A /100 g and the ß-carotene content ranges from 75 to more than 80 mg/100 g (Bal *et al.*, 1978).

2.2.2 Chinese jujube

Pareek (2001) gave details of the composition of Chinese jujube pulp from a number of sources. They include 9.6 – 33 % sugars, 0.3 – 2.5 % acids especially succinic and malic; (Ahmedov and Halmatov, 1969), 2.9 % protein, and 136-363 mg/100 g of vitamin C. (Tasmatov, 1963; Baratov *et al.*, 1975; Ristevski *et al.*, 1982; Cireasa *et al.*, 1984). Fruits average 28 – 40.3 % dry matter (Ristevski *et al.*, 1982). Apart from Vitamin C, Chinese jujube are significant sources of minerals such as iron, phosphorus and calcium (Ming and Sun, 1986), Vitamin B complex and Vitamin P (Troyan and Kruglyakov, 1972; Kuliev and Guseinova, 1974).

Vitamin C content tends to decline as fruits ripen e.g. in cultivar Hamazhao it falls from 1096 to 411 mg/100 g pulp (Bi *et al.* 1990). It appears that Chinese jujube is a richer source of vitamin C than ber depending on the cultivar, which is a point of interest to plant breeders.

Dried fruits of jujube contain volatile substances which help to impart the typical flavour. Seventy eight such compounds have been identified in *Z. jujuba* var. *inermis* among which aliphatic acids and carbonyl compounds accounted for 62.97 % and 29.56 % of total volatiles (Wong *et al.*, 1996). The major components were as follows.

2.3 Ethnopharmaceutical compounds

The bulk of the information relates to Z. jujube and a summary is provided below because of its widespread use in Chinese Herbal and Yunani medicine. In numerous cases the same constituents are also found in ber.

2.3.1 Ascorbic acid, thiamine, riboflavin and bioflavonoids

Ziziphus jujuba fruits are very rich in vitamins C and B1 (thiamine) and B2 (riboflavin) (Troyan and Kruglyakov, 1972; Kuliev and Guseinova, 1974). Compared with ber, one fruit per day would meet the diet requirements for Vitamin C and Vitamin B complex of an adult man recommended by FAO/WHO. It is also known to have a high Vitamin P (bioflavonoid) content. In some fruits Baratov *et al.*, (1975) reported 188 to 544 mg Vitamin C and 354 to 888 mg Vitamin P per 100 g pulp. Ahmedov and Halmatov (1969) and Troyan and Kruglyakov (1972) reported even higher contents of Vitamin C (up to 811 mg/100 g) and vitamin P (up to 1230 mg/100 g). Vitamin P (bioflavonoids) enhances the action of Vitamin C. Vitamin C and Vitamin P also act together to help maintain the thin walls of capillaries. Vitamin P also has antibacterial, anti inflammatory and antioxidant properties, and is known to stimulate bile production, promote circulation and prevent allergies (GreatVista Chemicals, 2004).

2.3.2 Pectin A

Tomoda *et al.*, (1985) isolated pectin A from *Z. jujuba* fruit. Pectin A was found to contain 2,3,6-tri-o-acetyl D lactose units. Pectin has a number of pharmaceutical properties such as binding bile acid, lowering plasma cholesterol and anti diarrhoeal properties (PDRHealth, 2004).

2.3.3 Alkaloids

Stem bark of *Ziziphus* species contain alkaloids (Pareek, 2001). A sapogenin, zizogenin has been isolated from Z. *mauritiana* stems (Srivastava and Srivastava, 1979).
The cyclic peptide alkaloids, mauritine-A, mucronine-D, amphibine-H, nummularine-A and -B (Tschesche *et al.*, 1976), sativanine-A and sativanine-B, frangulanine, nummularine-B and mucronine were isolated from the bark of *Z. jujuba* by Tschesche *et al.* (1976, 1979) at the Institut für Organische Chemie und Biochemie, University of Bonn, Germany. This work was continued by Shah and his group (Shah *et al.*, 1984 a; 1984 b; 1985a; 1986) who isolated the cyclic peptide alkaloids sativanine-C, sativanine-G, sativanine-E, sativanine-H, sativanine-F, sativanine-D and sativanine-K from *Z. jujuba* stem bark. The alkaloids coclaurine, isoboldine, norisoboldine, asimilobine, iusiphine and iusirine were isolated from *Z. jujuba* leaves by Ziyaev *et al.*, (1977). Cyclopeptide and peptide alkaloids from *Z. jujuba* were found to show sedative effects (Han and Park, 1986).

The seeds of *Z. jujuba* var. *spinosa* also contain cyclic peptide alkaloids sanjoinenine, franguloine and amphibine-D and four peptide alkaloids; sanjoinine-B-D-F and -G2 (Han *et al.*, 1990). The seeds are used in Chinese medicine as a sedative.

Chemical studies of *Z. mauritiana* led to the isolation of the cyclopeptide alkaloids, mauritines A and B; C-F, G and H, frangufoline; amphibines D, E, B and F; hysodricanin-A, scutianin-F and aralionin-C (Tschesche *et al.*, 1972; 1974; 1977). The cyclopeptide alkaloid, mauritine J, was isolated from the root bark of *Z. mauritiana* (Jossang *et al.*, 1996).

2.3.4 Glycosides

2.3.4.1 Flavonoid glycosides/spinosins

Woo *et al.*, (1979) gave the structure of spinosin (2”-O- beta –glucosylswertisin) extracted from *Z. jujuba* var. *spinosa* seed. They later identified three acylated flavone-C-glycosides (6’’’-sinapoylspinosin, 6’’’-feruloylspinosin and 6’’’-p-coumaroylspinosin). All showed mild sedative activity in pharmacological tests. Zeng *et al.*, (1987) discovered a new flavonoid, named zivulgarin, compound (4-beta-D-glycopyranosyl swetisin).

2.3.4.2 Glycosides/saponins

The glycoside saponin is found in the seeds, leaf and stem of *Z. jujuba* (Ogihara *et al.*, 1976). Saponins are part of sugar chains which attach themselves to a sterol or triterpene. They are known to bind with cholesterol preventing it from being reabsorbed into the system. They are being widely researched for cancer prevention and cholesterol control**.** Ogihara (1976) developed a method for successful qualitative and quantitative determination of saponins in *Z. jujuba* seeds using counter current chromatography.

The saponins isolated from the seeds of *Z .jujuba* include jujubosides A, B (ZengL *et al.*, 1987), A1 B1 and C and acetyljujuboside B (Yoshikawa *et al.*, 1997) and the protojujubosides A, B and B1 (Matsuda *et al.*, 1999).

Kurihara *et al.* (1988) extracted the saponin, ziziphin, from the dried leaves of *Z. jujuba.* It has a structure, 3-O-a-L-rhamnopyranosyl (1-2)-a-L-arabinopyranosyl-20-O- (2,3)-di-O-acetyl-a-L-rhamnopyranosyl jujubogenin. Ikram *et al.* (1981) isolated a saponin from *Z .jujuba* leaves and stem. It was assigned the structure 3-O- ((2-O- alpha – D – furopyranosyl – 3-O- beta – D – glucopyranosyl) – alpha – L – arabinopyranosyl) jujubogenin. Jujubogenin was also found in extract of *Z. mauritiana* leaves (Sharma and Kumar, 1982)**.**

Saponins show adjuvant (Oda *et al.*, 2000), haemolytic (Oda *et al.*, 2000), sedative (Shou *et al.*, 2002) anxiolytic and sweetness inhibiting properties (Kurihara *et al.*, 1988). Jujuboside A (JuA), is also known to be a non-competitive inhibitor of calmodulin (Zhou *et al.*, 1994), which is an ubiquitous, calcium-binding protein that can bind to and regulate a multitude of different protein targets, thereby affecting many different cellular functions. CaM mediates processes such as inflammation, metabolism, muscle contraction, short-term and long-term memory, and the immune response (McDowall, 2003). Jujuboside inhibition of calmodulin is thought to be linked to its sedative properties (Zhou *et al.*, 1994).

2.3.5 Triterpenoic acids

The following triterpenoic acids have been isolated from the fruits of *Z. jujuba*: colubrinic acid, alphitolic acid, 3-O-cis-p-coumaroylalphitolic acid, 3-O-trans-p-coumaroylalphitolic acid, 3-O-cis-p-coumaroylmaslinic acid, 3-O-trans-p-coumaroylmaslinic acid, oleanolic acid, betulonic acid, oleanonic acid, zizyberenalic acid and betulinic acid (Lee *et al.*, 2003). Triterpenoic acids have shown cytotoxic effects on tumour cell lines (Eiznhamer and Xu, 2004). Triterpenoic acids have also been extracted from roots of *Z. mauritiana* (Kundu *et al*. 1989).

2.3.5.1 Betulinic acid

Betulinic acid is a naturally occurring pentacyclic triterpenoid which has demonstrated selective cytotoxicity against a number of specific tumour types. It has been found to selectively kill human melanoma cells while leaving healthy cells alive (Pisha *et al.*, 1995; Kim *et al.*, 1998) Betulinic acid has also been found to retard the progression of HIV 1 infection, by preventing the formation of syncytia (cellular aggregates). In addition, betulinic acid has been found to have anti-inflammatory activity (Kim *et al.*, 1998) and antibacterial properties and inhibits the growth of both *Staphylococcus aureus* and *Eschericheria coli* (Eiznhamer and Xu, 2004).

2.3.5.2 Oleanolic acid

Oleanolic acid also exhibits known antitumour activity (Hsu *et al.*, 1997; Amsar Private Limited, 2004)

2.3.6 Lipids

Both the pericarp and the seeds of *Z. jujuba* contain two main classes of phospholipids: phosphatidylcholines and phosphatidylglycerols. Oleic acid is present in the fatty oil of the seeds (Goncharova *et al.*, 1990). Bioactivity-guided fractionation of petroleum ether- EtOAc- and soluble extracts of the seeds of *Z. jujuba* indicated that the triglyceride, 1,3-di-O-[9(Z)-octadecenoyl]-2-O-[9(Z),12(Z)-octadecadienoyl] glycerol, and a fatty acid mixture of linoleic, oleic and stearic acids, were the major active components of the seed oil. (Su *et al.*, 2002).

2.4 Nutritional and pharmaceutical studies

2.4.1 Sweetness inhibitors

Triterpenoid sweetness inhibitors were isolated from *Z. jujuba*. Extracts from the leaves of *Z. jujuba* have been found to suppress sweet taste sensation in fly (*Pharma regina*), rat and in hamster. Antisweet substances isolated from *Z. jujuba* included jujubasponins II, III, IV, V and VI and from the leaves, jujuboside B from the leaves and seeds and ziziphus saponins I-III from dried fruit. Ziziphin and jujubosaponins II and III, the only three of the anti-sweet saponins from this plant with acyl groups, were up to 4 times more active in suppressing the sweet taste of sucrose than the other anti-sweet constituents (Suttisri *et al.* 1995).

The saponin, ziziphin extracted by Kurihara and Halpern (1988) suppressed the sweetness induced by D-glucose, D-fructose, stevioside, glycine, sodium saccharin, aspartame and naringin dihydrochalcone. It however showed no suppressive effect on the sour taste of hydrochloric acid and the bitter taste of quinine indicating that ziziphin is highly specific to sweet taste (Kurihara, 1992). Ziziphin was found to inhibit the sweet taste receptors in humans (Smith and Halpern*,* 1983). The mechanism which ziziphin used was identified as taste modification. On comparison with known gymnemic acids, effects suggest that net dissociation of ziziphins from taste receptor membranes and/or inactivation in the membrane may be much faster than with gymnemic acids. The compound is considered useful as a taste modifier resulting in reduced sugar intake and thereby reducing obesity in diabetic or overweight people (Suttisri *et al*., 1995).

2.4.2 Permeability enhancement activity

Delivery of certain classes of drugs such as peptides creates problems in transportation across cell membranes and subsequent diminished bioavailability. To overcome this barrier, permeability enhancers can be used to aid the passage of drugs across cell membranes. To assess the permeability enhancing activity of *Z. jujuba*, an aqueous extract of seeds was compared to two members of a known series of permeability enhancement agents belonging to the alkylglycosides. Cell culture systems were observed after transepithelial electrical resistance (TEER) recorded the results of application of the three agents and changes in cell monolayer resistance. Lowering of resistance across a cell monolayer is an indication of either the opening of tight junctions and/or the fluidisation of cell membranes. *Z. jujuba* extract lowered cell resistance more rapidly in a given time period than the alkylglycosides and allowed full recovery of cells in a relatively short time period. It appears that the extract of *Z. jujuba* may be more efficient as a permeability enhancer than the two alkylglycosides. It remains to further analyse the extract to determine the active agent or agents (Eley and Hossein, 2002).

2.4.3 Cytotoxic effect (chemotherapy)

The *in vitro* cytotoxicities of the triterpenoic acids extracted from *Z. jujuba* were tested against tumour cell lines . The lupane-type triterpenes showed high cytotoxic activities. The cytotoxic activities of 3-O-p- coumaroylalphitolic acids were found to be better than those of non-coumaroic triterpenenoids. These results suggest that the coumaroyl moiety at the C-3 position of the lupane-type triterpene may play an important role in enhancing cytotoxic activity (Lee *et al.*, 2003).

The triterponic acid, betulinic acid, extracted from *Z. jujuba* and *Z. mauritiana*, showed selective toxicity against cultured human melanoma cells (Kim *et al.*, 1998). Betulinic acid is currently undergoing preclinical development (Pisha *et al.*, 1995). It is thought that betulinic acid may also be effective against other types of cancer. Recently, considerable *in vitro* evidence has demonstrated that betulinic acid is effective against small- and non-small-cell lung, ovarian, cervical, and head and neck carcinomas. Published data suggest that betulinic acid induces apoptosis (Kim *et al.*, 1998; Liu *et al.*, 2004) in sensitive cells in a p53- and CD95-independent fashion (Eiznhamer and Xu, 2004)**.**

Oleanolic acid is known to have antitumour effects (Hsu *et al.*, 1997; Amsar Private Limited, 2004) as well as the ability to decrease undesirable radiation damage to the hematopoietic tissue. after radiotherapy (Hsu *et al.*, 1997). Oleanolic acid has been recommended for skin cancer therapy in Japan (Muto *et al.*, 1990). Cosmetic preparations for the prevention of tropical skin cancer containing oleanolic acid have been patented (Ishida *et al.*, 1990).

2.4.4 Neurological properties

2.4.4.1 Hypnotic-sedative and anxiolytic effect

The seeds and leaves of many *Ziziphus* species have been found to have anxiolytic and hypnotic-sedative effects. They are known to depress activity of the central nervous system which reduces anxiety and induces sleep. Saponins and flavonoids from *Z. jujuba* seeds were examined for sedative activity. All compounds tested showed sedative and hypnotic effects. Swertisin, the most potent compound was tested for type of action. It was found that it produced sleep, but was not anticonvulsant or muscle relaxant (Peng *et al.*, 2000).

The saponin jujuboside A (JuA), the main component of jujubogenin extracted from the seed of *Z. jujuba* is widely used in Chinese traditional medicine for the treatment of insomnia and anxiety. A combined research group at the College of Life Science and the Department of Biomedical Engineering at Zhejiang University, China, used *in vivo* (Shou *et al.*, 2002) and *in vitro* (Shou *et al.*, 2001; Feng and Zheng, 2002; Shou *et al.*, 2002) methods, to investigate the inhibitory effects of Jujuboside A (JuA) on rat hippocampus.

Peng and his colleagues also demonstrated the anxiolytic effects in mice of a polyherbal substance containing seed extract of *Z. jujuba* (Lin *et al.*, 2003).

Alkaloids from *Z. jujuba* were also found to show sedative activity. Both sanjoinine A and nuciferine prolonged the sleeping time produced by hexobarbital. When sanjoinine was heated it was found to produce an isomer of even greater sedative effect (Han and Park, 1986).

2.4.4.2 Cognitive activities

Heo *et al.* (2003) suggests that oleamide, a component of *Z. jujuba* extract, could be a useful chemo-preventative agent against Alzheimer's disease. They found that methanolic *Z. jujuba* showed 34.1 % activation effect on choline acetyltransferase *in vitro*, an enzyme that controls the production of acetylcholine which appears to be depleted in the brains of Alzheimer patients. Using sequential fractionation the active ingredient was found to be cis-9-octadecenoamide (oleamide) which showed 65% activation effect. Administration of oleamide to mice significantly reversed the scopolamine-induced memory and/or cognitive impairment in the passive avoidance test and

Y maze test. Mice treated with oleamide before scopolamine injections were protected from the effects.

2.4.5 Antifertility/contraception

The ethyl acetate extract of *Z. jujuba* bark was found to effect anti-steroidogenic activity and hence fertility in adult female mice. It was found to arrest the normal oestrus cycle of adult female mice at diestrus stage and reduced the wet weight of ovaries significantly. Haematological profiles, biochemical estimations of whole blood and serum remained unaltered in extract-treated mice. Normal oestrus cycle and ovarian steroidogenisis were restored after withdrawal of treatment. Antifertility activities of crude extracts were found to be reversible (Gupta *et al.*, 2004).

2.4.6 Hypotensive and antinephritic effect

Ziziphus jujuba has been found to stimulate nitric oxide release *in vitro*, in cultured endothelial cells and *in vivo*, in the kidney tissues of rats (Kim and Han, 1996). Kim and Han believed that the stimulatory effects of *Z. jujuba* on nitric oxide release in the kidney may contribute to its hypotensive (reduction of blood pressure) and antinephritic (reduction of inflammation of the kidney) action, possibly by increasing renal blood flow (Kim and Han, 1996).

2.4.7 Cardiovascular activity

A neo-lignan isolated from *Z. mauritiana* leaves was found to increase the release of endogenous prostaglandin I2 (the most potent natural inhibitor of platelet aggregation yet discovered and a powerful vasodilator) from the rat aorta by up to 25.3 % at 3 micro g/ml (Fukuyama *et al.*, 1986).

2.4.8 Immunostimulant effects

The leaf extract of *Z. jujuba* was found to stimulate chemotactic, phagocytic and intracellular killing potency of human neutrophils (infection fighting white blood cells) at 5-50 micro g/ml (Ganachari *et al.*, 2004).

2.4.9 Antifungal activity

Z. jujuba has been found to show antifungal effects. Ethanol extract from the root showed significant inhibitory activity on the fungi *Candida albicans*, *C. tropicalis*, *Aspergillus flavus*, *A. niger* and *Malassezia furfur* (strains 1374 and 1765), (Sarfaraz *et al.*, 2002; Mukhtar *et al.*, 2003, 2004).

2.4.10 Antidiabetic

Extract of *Z. mauritiana* was found to have anti-diabetic activity in Wistar rats (Cisse *et al.*, 2000).

2.4.11 Antiallergic

The anti-allergic activity of aqueous extracts of *Z. jujuba* was studied by measuring its inhibitory effect on hyaluronidase (bovine testes) activation *in vitro*. *Z. jujuba* was shown to have strong anti-allergic activity (Su *et al.*, 2000).

2.4.12 Antiulcer activity

The results suggest that *Z. mauritiana* leaf extracts (ZJE) possesses significant and dose-dependent antiulcer activity. The antiulcer activity of ZJE can be attributed to its cytoprotective and antisecretory action (Ganachari and Shiv, 2004).

2.4.13 Antiinflammatory effect

The compound prescription Huangqin Tang which contains the fruit of *Z. jujuba* showed marked anti-inflammatory effect (Huang *et al.*, 1990). *Z. mauritiana* leaf extracts were found to possess significant anti-inflammatory activity against carrageenan-induced rat paw oedema (Shiv *et al.*, 2004).

2.4.14 Antispastic effect

The compound prescription Huangqin Tang which contains the fruit of *Z. jujuba* possessed significant antispastic/antispasmodic effect (Huang *et al.*, 1990).

2.4.15 Antibacterial

An extract of root bark of *Z. jujuba* exhibited activity against 20 bacteria (Elmahi *et al.*, 1997). Leaf extracts of *Z. mauritiana* were found to show antibacterial effects against *Escherichia coli*, *Klebsiella* spp., *Pseudomonas* spp., *Proteus vulgaris* and *Bacillus subtilis* when methanol and acetone extract solvent was used (Chowdary and Padashetty, 2000).

2.4.16 Antioxidant effects

Na *et al.* (2001) found that *Z. jujuba* extract showed a relatively strong antioxidative activity.

2.5 Summary

Important nutritional properties of jujube fruits relate particularly to their being sources of vitamin C, P and vitamin B complex in the diet.

Although there is a range of potentially useful medicinal substances in jujubes, the research in this area is in its early stages. There is limited interest from large pharmaceutical companies because many of the useful constituents can be obtained from other botanical sources. The value of such constituents in health products and supplements is undisputed and the hardy nature of jujubes and their wide geographical range means they can provide a potentially cheap and more accessible source of such compounds for traditional medicine.

Chapter 3. Uses

C. deKock

3.1 Introduction

The fruits of many *Ziziphus* species are edible and are prepared for consumption in many ways. They are eaten mostly fresh but may be pickled, dried and made into confectionery, or drinks can be made from the juice.

Ziziphus trees are commonly used for live fencing, fodder and planting to control soil erosion. The wood also finds a number of local uses.

Leaves can be used as a feed for silkworms. Flowers can be the source of nectar for honey bees, and ber trees are used for rearing lac insects.

3.2 Local uses of fruits

3.2.1 South, Southeast and East Asia.

These have been mentioned in Chapter 2 and are the subject of subsequent chapters. In addition, people in Southeast Asia eat unripe fruits with salt (Morton, 1987).

A wild species, *Z. nummularia* (Burm.f.) Wight & Arn. (syn. *Z. rotundifolia* Lam.) is harvested in western India. Fruits are dried and powdered with spices to prepare a product called 'churan' (Pareek, 1983). Standardised products have not been developed.

A wild species *Z. oxyphylla* Edgew. (syn. *Z. rotundifolia DC)* is gathered in Pakistan and used as a subsistence food (Saqib and Sultan, 1994).

3.2.2 Africa

In the Zambezi valley in Zimbabwe, *Ziziphus* fruits are eaten fresh from June – September and after dehydration throughout the year (Funkhouser, 1998). The dry powder is used in baking and to prepare jam (Maposa and Chisuro, 1998) and a traditional loaf (Kadzere, 1998), and kachaso, a crude spirit (Arndt, 2001). An alcoholic drink is also made in Malawi (FACT Net).

In West Africa wild *Z. mauritiana* fruits are used to produce an alcoholic drink. *Z. abyssinica* Hochst., a widespread wild African species is locally cultivated for the fruits in southern Nigeria. Fruits of *Z. spina-christi* are gathered for use in many parts of West Africa (Hutchinson and Dalziel, 1958).

Cakes are made out of dried and fermented pulp in western Sudan (Dalziel, 1937), and in Zambia (Kalikiti, 1998). The Touareg nomads in Mali make flat bread from dry fruit pulp (Chevalier, 1947) using wild species. In Niger ber fruits are dried and pounded into flour as a famine food (Williams, 1998).

In Egypt nomads, especially the Allagi, consume fruits of *Z. spina-christi* (Belal *et al.,* 1998). In North Africa *Z. lotus* (indigenous) and *Z. jujuba* (introduced) are used for fruits.

In Namibia, wild *Z. mucronata* Willd*,* is used for making a hot liquor, and although illegal, provides a source of income for the rural poor (Hailwa, 1998).

3.2.3 Southwest Asia

Fruits of *Z. spina-christi* are gathered and eaten in many parts of Southwest Asia e.g. Yemen, Jordan, Oman, Bahrain and Saudi Arabia (Non-Wood News; Arndt, 2001). Cultivation is practised in many parts, for example, in Shabwah Governate of Yemen, households keep an average of 25-50 trees in and around their irrigated fields for bee keeping, fruit production and other uses (KIT, 2002).

Sun-dried fruits are powdered and mixed with water to make cakes similar to gingerbread.

3.2.4 South America

Introduced *Z. jujuba* fruits are used to make a liqueur called 'crema de ponsigue' (Morton, 1987).

Of the 7 species of *Ziziphus* indigenous to the New World, *Z. mistol* Grisels was found in the Andes of Argentina and Paraguay to be used for making 'mistol jam'. On the whole the New World species are not of economic potential.

3.3 Fodder

Nearly every part of *Ziziphus* plants can be utilised. The leaves and twigs of most species can be used as nutritious fodder for livestock. Due to the high dry weight protein content, leaves are an important source of protein for animals (Arndt, 2001; Dalziel, 1937; Dastur, 1952; Ngwa *et al.,* 2000). Leaves of *Z. mauritiana* and *Z. jujuba* are readily eaten by camels, sheep, goats and cattle (for goats see Tewatia and Khirwar, 2002).

In the Red Sea area pastoralists with camels that are intended for race competitions and that require a special diet utilise the winter range of the Red Sea to collect fruits and pods of local *Ziziphus* species.

Collected pods are also fed to lactating and pregnant female camels or the principal riding camel. The remainder of the herd is allowed to browse for several days (Organisation for Social Science Research in Eastern and Southern Africa).

Species of *Ziziphus* are also browsed by many wild animals.

3.4 Environmental

Ziziphus species can contribute to controlling the rate of desertification. Soil erosion in desert areas is largely due to the removal of structureless topsoil by wind and rain. This can largely be checked by planting wind breaks, creating shelter belts and stabilising sandy tracts and dunes with adapted grasses and shrubs like *Ziziphus* (Khoshoo and Subrahmanyam, 1985). *Ziziphus nummularia* shrubs have been shown to effectively check wind erosion, help in deposition of soil, and bring about a change in the microhabitat, causing favourable conditions for the appearance of successional species such as perennial grasses. In the Sahelian climate, *Z. mauritiana* plays an important part in the conservation of soil because of its abundant and vigorous root systems (Depommier 1988, Arndt 2001). Several species of *Ziziphus* can endure extreme stress caused by drought, salinity, and in some cases waterlogging. This makes the cultivated jujubes ideal for planting on marginal or degraded lands provided the right genotypes are selected for alkali-sodic soils (Dagar *et al*., 2001) and (Hebbara *et al*., 2002).

3.5 Fuelwood

Z. mauritiana is an excellent fuelwood tree and makes a good charcoal, with a heat content of 4900 kcal kg^{-1} (Khoshoo and Subrahmanyam, 1985). In the Sahel zone, it is considered good both as firewood and charcoal (Depommier, 1988). *Z. nummularia* has been reported to produce high-quality hardwood with high calorific value, making it an ideal source of fuel and charcoal (Arndt 2001)

A six year old tree of ber produces an above ground biomass of 11.6 kg in the arid northwest India (Toky and Bisht, 1993) and 8-10 kg air dried fuelwood from annual prunings (Vashishtha, 1997). Reddy (1988) reported that, depending upon pruning severity, the weight of air-dry pruned wood was 4-6 tons per hectare from 8 year old ber trees in Bangalore, India. According to Bajwa *et al.* (1986) the weight of prunings per tree ranged from 19.5 to 37.4 kg from a 13 year old tree. Air-dry biomass of 2 kg/plant was produced two years after planting under rainfed conditions at Dagarkotly in Pakistan (Shah and Noor, 1994). The fuelwood yield from pruned wood varies from 1-5 tons per hectare depending upon spacing, pruning severity and agroclimatic conditions.

3.6 Lac culture

Ber trees are considered amongst the best for rearing lac insects (Hussain and Khan, 1962; Anon., 1996). A lac yield of 1.5 kg per tree per year was obtained by collection during October-November at Ranchi in India (Anon., 1996). Ber is a chief host plant of *Kerria lacca* and *K. sindica* (Li and Hu, 1994). By using 6-8, 2-3 m long shoots of 2-3 cm thickness on a stump for inoculation by lac insects, a yield of 3-6 kg raw lac can be obtained in 3 years. When used for rearing lac insects, use of the trees for fruits is not viable.

Recent surveys collected socio-economic data from Jharkhan, West Bengal and Orissa on lac production (Jaiswal *et al.,* 2002).

3.7 Wood

The wood of *Z. mauritiana* and *Z. jujuba* is reddish, close-grained, fine-textured, hard, tough, durable and planes and polishes well. It has been used to line wells, to make legs for bedsteads, boat ribs, agricultural implements, home poles, tool handles, yokes, gunstocks, saddle trees, sandals, golf clubs, household utensils, toys and general craft work.

In India the wild type of ber is used for many of the above purposes (Pearson and Brown, 1932).

The wood does not have value as a commercial timber.

3.8 Bees and silkworms

In the Islamabad area of Pakistan, *Z. jujuba* flowers attract honey bees which can contribute to conservation and the economic stability of the people in the local area (Chemas and Gray, 1991; Fatima and Ramanujam, 1989; Muzaffar, 1998). In India and Queensland, the flowers of *Z. mauritiana and Z. jujuba* are rated as a minor source of nectar for honeybees (Dash *et al.* 1992). The honey is light and of fair flavour (Morton, 1987).

In Assam, *Ziziphus* leaves have been used as a food for silkworms. *Ziziphus jujuba* has been recorded as a secondary food plant for rearing Indian tasar silkworm*, Antheraea mylitta* Drury, larvae and proved to be better than the primary food plant *Shorea robusta* (Dash *et al*. 1992).

In China *Z. jujuba* is a major source of honey. Some is exported as Zao hua fengmi or 'jujube-flower honey' (Wang *et al.* 1996).

3.9 Medicinal uses

Chapter 2 has already provided information on constituents of various parts of Z*iziphus* species and their applications. However, there are a large number of traditional medicinal uses that are not necessarily based on knowledge of the constituents. Those that are widespread and used consistently are outlined below.

3.9.1 South Asia

According to Ayurveda, the root of *Z. nummularia* is bitter and cooling, and cures coughs, biliousness and headache. The bark cures boils and is good for the treatment of dysentery and diarrhoea. The leaves are antipyretic and reduce obesity. The fruit is cooling, digestible, tonic, aphrodisiac, laxative and removes biliousness, burning sensations, thirst, vomiting and is also good in treating tuberculosis and blood diseases. The seeds cure eye diseases and are also useful in leucorrhoea (Oudhia, 2001-3).

The traditional workers of Chhattisgarh, India use fresh *Z. nummularia* fruit to treat common fevers. The traditional healers of Bastar region use the dried leaves to dress wounds. The fresh leaves are also used for the same purpose. The aqueous paste of the leaves is applied externally to relieve a burning sensation. In cases of vomiting, the people of Chhattisgarh use the seeds with bar sprouts (*Ficus benghalensis*) and sugar. Roots are used to treat dysentery; they are given with cow's milk until the patient is cured. Senior citizens used to use the fresh leaf juice of *Z. nummularia* with buffalo's milk to reduce the intensity of smallpox. Similarly, in the early days, the use of seeds to treat eye troubles was common. To treat hoarseness of the throat, traditional healers advise patients to keep the fresh roots of *Z. nummularia* inside their mouth. The traditional healers of Mudpar village use the fresh leaves of *Z. nummularia* with cumin to treat urinary infections (Oudhia, 2001-3).

According to the Unani system of medicine, the roots and bark of *Z. nummularia* are a tonic, whereas the leaves are anthelmintic, and are good for stomatitis and gum bleeding. The flowers afford a good collyrium for eye diseases, the fruits are sweet and sour, and can cause diarrhoea in large doses. The seeds are astringent, are a tonic to the heart and brain and relieve thirst (Oudhia, 2001-3).

3.9.2 Chinese medicine

The Chinese Materia Medica: Chemistry, Pharmacology and Applications describes *Z. spinosa,* the wild spiny *Z. jujuba,* as having sedative and hypnotic effects in many animal species including humans. In traditional uses it helps to nourish the heart, calm the nerves and is useful for insomnia and dream disturbed sleep (Zhu, 1998).

The wild plant is called suan-tsao. The Chinese have found that the wild *Z. jujuba* fruit improves the health of the body. In fact, the common belief is that if the fruit is taken on a daily basis, it will improve skin colour and tone, both signs of physical well being (Plant Botanic).

Its domestic counterpart, known as pei-tsao in northern China and nan-tsao in the south, is considered to be cooling to the body. Like an Asian version of the aspirin, the fruits somehow reduce pain and distress. They are strongly recommended for cases of sleeplessness caused from mental fatigue, physical weakness, or pain. They are used to treat rheumatic symptoms and are said to rejuvenate the body, whether it is suffering from stress or age. The plant is used to prevent intestinal or respiratory flu and to speed the recovery process along. Fresh *Z. jujuba* is also used to increase strength of the seriously ill and reverse the process of disease (Plant Botanic).

In modern Chinese medicine, *Z. jujuba* is used to tone the spleen and stomach, to treat shortness of breath and severe emotional upset and debility due to nerves, and to mask the flavours of unpleasant-tasting herbs (Plant Botanic).

Z. jujuba pips, when aged for three years, are considered excellent for wounds and abdominal pain. The leaves are used to treat children suffering from typhoid fever. They induce sweating which is thought to break the fever. They are also used for a number of infectious diseases. The heartwood is considered a powerful blood tonic. The root is used to promote hair growth and in treating fevers in children such as smallpox, measles, and chicken pox. The bark is used to make an eye wash for inflamed eyes (Plant Botanic).

3.9.3 Other areas

The Arabs use the fruits of *Z. jujuba*, Z. *mauritiana* and *Z. spina-christi* to ensure health. The leaves of the plant kill diarrhoea-causing parasites and worms in the intestinal tract. The fruits are said to cure coughs, resolve any other lung complaints, soothe the internal organs and reduce water retention.

In Saudi Arabia, fruits of *Z. spina-christi* when in sufficient strength act as a laxative. Stem bark is used to relieve toothache and fevers (Al-Khalifa and Sharkas, 1984; Al-Akeely, 1985). Leaves of *Z. spina-christi* are used in traditional medicine in Egypt for the treatment of abscesses, boils and swollen eyes and its wood ash for the treatment of snakebite (Abdul-Galil and El-Jissary, 1991). The root, stem bark and leaves are used in various medicinal preparations in tropical Africa, particularly in the Kapisiki country (Dalziel, 1937; Heyne, 1950; Williamson, 1957; Depommier, 1988).

In Zimbabwe, *Z. mucronata* roots are a commonly used part of the plant for urinary and gynaecological complaints, but traditional practices vary from region to region; bark decoctions have been recorded in South Africa for chest diseases (Tree Society of Zimbabwe, 2001).

In Haiti, fruits, leaves and roots of introduced *Z. jujuba* are boiled to make a decoction and this is used as tea for an antidote to poison (Plant Botanic).

Z. juazeiro is used in Brazilian herbal medicine. However, this species is not discussed in this monograph: for further information see Raintree Nutrition.

Chapter 4. Climate and Ecology

(Revised by J.T. Williams)

4.1 Introduction

Most species of *Ziziphus* can be found in low rainfall areas. The climatic and ecological background to the three important cultivated species is shown in Table 4.1.

Table 4.1 Ecological background of three *Ziziphus* species

	Z. mauritiana	*Z. jujuba*	*Z. spina-christi*
Latitude	30^o N to 30^o S	30^o S to 51^o N	0^o to 20^o N
Altitude m	< 1500	Up to 2800	< 1000
Eco-region	Warm lowland plains	Cool highlands	Mediterranean drylands
Minimum temperature	4^o to 12^o C	-10^o to -20^o C	-5 to 2^o C
Maximum temperature	39^o to 45^o C	36^o C	±5 ^{o}C
Rainfall	> 300 mm	200 to 450 mm	ca. 100 mm
Soil type	Shallow to deep aridisols	Alluvial plains and hills	Poor soils of arid areas
Soil salinity	Neutral to slightly alkaline (5 dSm^{-i})	Highly tolerant	Medium tolerance
Alkalinity	< 45 ESP	Highly tolerant	Some tolerance

This background explains the extremely wide distribution of wild and cultivated forms of the species. Information given below is mostly taken from (Pareek, 2001).

4.2 Temperature

4.2.1 Ber

Ber grows well under varying climatic conditions from sea level up to an elevation of 1000 m (Singh *et al.*, 1973 a) although it produces best below 600 m; it can be grown to altitudes up to 1500 m. Commercial ber plantations are found growing in areas having a minimum temperature of 4 to 12° C and occasionally reaching as low as -2° C for short periods, although this can injure young shoots and fruits. Freezing temperatures and frost, however, cause damage to young twigs and developing fruits and result in considerable crop loss and decline in tree growth.

Pareek (1983) outlined the temperature dependency for time of growth, flowering and fruit maturity. Ber trees can withstand extremely high summer temperatures and are found to grow well in regions having maximum temperatures of 39 to 42° C, and can tolerate temperatures as high as 49-50° C. However, fruit set is adversely affected at temperatures above 35° C. The trees shed leaves and enter dormancy during the extremely hot summers in the subtropics of northern India. In northern Australia, leaf senescence and leaf fall begins in April as the dry season sets in, and the new leaves emerge with the onset of rainfall in September and October (Grice, 1998). This appears to be an adaptive mechanism to escape damage through desiccation during hot weather. Desiccation damage in ber is caused by high cuticular transpiration, which is reported to be associated with high levels of fatty acids and low levels of aldehydes and alcohols in the wax cuticle rather than with the thickness of the cuticle and wax itself (Rao *et al.,* 1981). During the dormancy phase, along with leaf fall, growth ceases. Dark tan-coloured hard and pubescent scales develop on the buds and the bark and buds lose moisture and show lower nitrogen contents (Singh *et al*., 1974 b).

In regions with less extreme temperatures, summer dormancy either does not occur or is very brief, resulting in almost no check in growth. Thus growth, flowering and development all vary depending upon prevailing temperature conditions.

4.2.2 Chinese jujube

Chinese jujube grows well at average temperatures of 20-28° C in areas having a frost-free period of 100-180 days a year and can tolerate winter temperatures of -10° to -20° C (Ming and Sun, 1986). Fruits mature 2 weeks earlier in the warmer areas of Azerbaijan where summer temperature rises to 36° C (Tagiev, 1992). In the USA, Chinese jujube has withstood temperatures of -22° C without injury (Thomas, 1924) and has tolerated -30° C in Azerbaijan (Troyan and Kruglyakov, 1972).

Tolerance to low temperatures seems to be due to cultivar differences (Kucherova and Sin'ko, 1984 b; Sin'ko *et al*., 1987; Ivanova *et al*., 1989). Wild forms of Chinese jujube are also resistant to low temperatures.

Cultivars can be evaluated for frost tolerance on the basis of resistance to dehydration. Water retaining capacity in shoots of different cultivars varies. The cultivars having high water retaining capacity are capable of tolerating drying spring winds which retard bud break in Chinese jujube growing in the steppe region of Crimea (Kucherova and Sin'ko, 1989).

Chinese jujube remains in the dormant stage from the middle of October through the winter until the end of January (Kim *et al*., 1982 a). During this period, the total carbohydrate content (reducing and non reducing sugars) decreases steadily but starts increasing again from March. The peak activity of β-amylase and invertase was observed in November, that of α-amylase, acid phosphatase and alkaline phosphatase in January and protease activity increased from January to April.

4.3 Rainfall

4.3.1 Ber

Natural groves of ber grow and produce well in subtropical and tropical regions receiving over 400 mm annual rainfall. Fruit yields are higher during higher rainfall years (Singh *et al.,* 1998). Management of trees in low rainfall areas necessitates some irrigation. Conditions of high atmospheric vapour pressure deficit result in the production of better quality (sweet and large sized) fruits than in humid areas. The incidence of pests and diseases is also lower in drier regions. Ber exhibits drought tolerance by osmotic adjustment and the deep tap root (Arndt *et al.,* 2000). Species used as rootstocks (see Chapter 5) tend to be those occurring in areas receiving low rainfall. Ber can, depending on the cultivar, withstand slightly waterlogged conditions.

4.3.2 Chinese jujube

Chinese jujube plantations are common in north-west China, including arid areas with annual rainfall below 200 mm, semi-arid areas with 200 to 450 mm rainfall and sub-humid areas with 450 to 650 mm rainfall (Ming and Sun, 1986). Chinese jujube is reported to withstand severe drought (Lanham, 1926; Locke, 1948; Sin'ko, 1971) because its vertical root system reaches a depth of 13 m (Ming and Sun, 1986).

4.4 Soils

4.4.1 Ber

Ber grows on a wide range of soils from gravelly, shallow soils to deep aridisols and to some extent on entisols (Pareek, 1983). Even in soils underlain with *murram* (calcic subhorizon) within one metre depth, roots were found to penetrate up to 4.5 m (Pareek, 1977). Data from field trials in India and Zimbabwe suggest that in *Ziziphus* rooting depth is critical for the maintenance of high rates of assimilation and conductance throughout the day making it tolerant to drought conditions (Clifford *et al.,* 1996).

4.4.2 Chinese jujube

Chinese jujube also grows on a variety of soils. In the Yeongnam region of Korea, 42 % of Chinese jujube plantations are on alluvial plains, 23 % on mountain foothills, 22 % in valleys and 13 % on hills (Kim *et al.,* 1989). Fruit yields are higher on alluvial soils and on gently sloping fans than on the hill lands and steeper slopes where the soils are shallow. In Azerbaijan, jujube plantations have been established on sandy as well as clay soils (Tagiev, 1992).

4.4.3 Stress conditions

Both major cultivated species are tolerant to a degree of salinity; ber up to 6 dSm^{-1} and Chinese jujube higher (Oganesjan, 1953; Dhankhar *et al.*, 1980; Dahiya *et al.,* 1981; Rao and Khandelwal, 2001). Species used for rootstocks for ber are also salt tolerant (Meena *et al.* 2003). In terms of soil fertility, both species require N and P but K has little effect on their growth (Lal *et al.,* 2003). Boron inhibits uptake of P and K in Chinese jujube (Lee and Choi, 1992). Ber is of great interest for production and reclamation of the alkali soils of India (ca. 3.58 million ha) which have high pH, low organic carbon, low fertility, excessive exchangeable sodium and indurated $CaCO_3$ (Dagar *et al.,* 2001).

Ber is known to survive even in soils having pH as high as 9.2 (Jawanda *et al*., 1981). No leaf scorching in trees growing on alkaline soils was observed while those of mango and guava were seriously damaged (Samra, 1985). Young ber seedlings survived when transplanted in soils up to 66 ESP (Exchangeable Sodium Percentage) in a greenhouse (Singh, *et al.*, 1983 b). Increasing ESP levels, however, reduced growth, decreased Ca and Mn, but increased Na and Fe contents in the leaves. In pot experiments, seed germination and emergence was reduced in 40 ESP soil and a further increase in ESP resulted in reduction in the amount of P, K, Ca, Mg, Zn and Mn (Patil *et al*., 1981; Mehta, 1982) and increase in the amounts of Na, B and Fe in the plants (Mehta, 1982). Kumar *et al*. (1990) also observed a decrease in leaf micronutrient content with an increase in ESP levels from 5 to 45.3. The total chlorophyll, free amino acid and proline contents increased with increasing sodicity (Pandey *et al*., 1991). Awasthi *et al*. (1994) reported that 62.5 % ber seedlings survived at 60.5 ESP but none of the grafted plants of Umran and Gola survived. Shoot and root growth of Umran ber decreased with increasing ESP (Patil *et al*., 1981).

Chapter 5. Propagation

E. Bonkoungou

5.1 Introduction

Wild populations of *Ziziphus* regenerate naturally by seed, and frequently produce root sprouts. However, collecting and germinating seed is the way by which *Ziziphus* seedlings are raised directly in the field or in nurseries for a wide range of purposes.

Reproduction by seed, however, does not guarantee true-to-type reproduction of the desirable traits of the mother tree due to cross pollination and subsequent segregation of plant characters in the progeny. Hence commercial and much local propagation for orchards of improved cultivars is by vegetative means.

Outside its native area, uncontrolled propagation of *Ziziphus* can lead to serious weed problems. In Australia, where the species was introduced in the 1800s for horticultural and ornamental purposes, it is now declared a noxious weed. Initially planted around early settlements, it is said to form dense thickets which seriously hamper livestock management and reduce pasture production and accessibility in parts of Queensland (Grice, 1996). Thus, although ber, and Chinese jujube, are extremely valuable trees in the correct environment, their potential to become weeds should not be ignored, particularly in areas where trees have naturalised (William and West, 2000) such as Australia or New Zealand.

5.2 Seed propagation

5.2.1 Seed characteristics

Ber seeds are enclosed within a hard woody endocarp known as the stone which is sometimes wrongly referred to as the seed. Each fruit contains one stone embedded in the pulp at the centre of the fruit. The stone (see Fig 1.2) can be depulped in many ways: manually by removing the pulp, pounding dried fruits in a mortar, or by running the fruits through a macerator with water and floating off the pulp. Stones vary in shape from round to subovate to ovate with more or less pronounced ridges on the outer surface (ICUC, 2002). Cleaned stones are about 1-2 cm in size.

The stone may contain as many as three seeds embedded in the endocarp of the drupe (Pareek, 2001) but the presence of only one and two seeds per stone also has been reported. In Australia, Grice (1996) found that the most frequent case is a single seed per stone and occasionally two. ICRAF (1992) reports two to three seeds per stone in Kenya, whereas in Tanzania the most frequent number is two seeds in a large stone (Kuffo *et al.,* 2002; Mbuya *et al*., 1994). In West and Central Africa, Diallo (2002) reported one to two seeds per stone in a study conducted on *Ziziphus mauritiana* provenances from Senegal, the Gambia and Chad. All the Chad provenances had two seeds per stone. In Senegal, 80 % of the stones from fruits collected at Dahra and in Dakar had two seeds each (Danthu *et al*., 1992).

Ziziphus stones and seeds are relatively light in weight. For *Z. mauritiana*, Roussel (1995) reported 3,500 to 4,000 stones to the kilogram. In Burkina Faso, Ouedraogo and Nikiema (1997) also found 3,500 stones to the kilogram. Von Maydell (1983) reported a wide range from 3,600 to 7,000 stones to the kilogram for the Sahel region and explained that the wide range was due to impurities in some of the seedlots. In northern Cameroon, Depommier (1988) reports only 350 to 650 stones to the kilogram. If confirmed, this would be a case of unusually heavy seeds (ten times heavier than the average weight commonly reported for *Z. mauritiana* throughout the region). For *Z. mucronata*, Roussel (1995) found 2,000 to 2,200 stones to the kilogram. Thus, apart from the rather unusual case reported in Cameroon, *Z. mucronata* seeds appear to be heavier than those of *Z. mauritiana.*

5.2.2 Seed viability

Under natural conditions, seeds from fruits that fall and lie on the soil surface may remain viable for up to 12 months. Data currently available do not suggest that a large proportion of seeds remain dormant in the soil for much longer periods. In Australia, Grice (1996) observed that germination rate in *Z. mauritiana* seeds collected from the soil surface declined from a rate of 56 % in the control (fresh dehulled seeds) to 31 % after six months, then to 20 % at 12 months. For seeds that remain buried in the soil (at 2 cm depth) the germination rate declines sharply to 7 % after six months. In Tamil Nadu, India, Srimathi *et al*. (2002) found that cv. Umran seeds from fruits collected from the crown exhibited higher germination rates than those collected from the ground.

Storage conditions have an expected significant effect on seed germination. A review by Pareek (2001) indicated that storage at reduced temperatures of $4.5 \pm 0.5\ ^{o}C$ in perforated polythene bags result in retention of viability for longer periods. Ber seeds can remain viable for two and half years when kept in a dry and cool environment, but storage time is dependent on the condition of the seeds and how well they have been dried prior to storage (ICUC, 2002). For long-term storage seeds behave in an orthodox manner and can be stored in low temperatures when dried properly (see Chapter 8 Genetic Resources).

A simple and rapid method to test seed viability is to float the stones in salt solution. Seeds that float probably have air pockets caused by insect damage or dead embryos. Such seeds should be discarded. Seeds that sink are viable.

Srimathi *et al*. (2002) soaked dried stones of ber cv. Umran in 15, 18 and 20 % salt solution and found that only the seeds which sink could be used for seedling production in a nursery. The recovery of floaters increased with increasing salt concentration and germination was improved by grading the stones using 20 % salt solution.

As indicated by Pareek (2001), the viability of seeds can also be assessed by the tetrazolium test. For this test, the indicator used is a colourless solution of triphenyl tetrazolium chloride or bromide (Kamra, 1992). In actively respiring areas of the seed the colourless solution reacts with hydrogen ions produced by the dehydrogenase enzyme and turns into a red, stable and non diffusible substance. This makes it possible to distinguish the red coloured living parts of seeds from the colourless dead ones. However, this test is time consuming; also interpretation of results may be difficult.

5.2.3 Seed germination

Seed germination is affected by the initial percentage viability at the time of seed collection, and by storage conditions, environmental conditions at sowing time, and treatments applied to break dormancy.

The degree of fruit ripeness has a significant effect on germination of the enclosed seed. Ber seed germination in Senegal increased from a mere 2 % for seeds from green fruits to 28 % when fruits are more mature and have turned yellow and 56 % for seeds from fully ripe fruits that have turned red. The rate declines to 46 % for seeds from overripe fruits that have turned brown (Danthu *et al*., 1992). This has practical implications for seed collection as fruit colour can be used to determine the most appropriate time to collect seeds.

Pareek (2001) also noted the importance of seed age for optimum germination as ber seeds can germinate only after a period of after-ripening. One or two months after extraction, germination increases and one year old seeds germinate better than the freshly extracted ones. Sowing freshly extracted seeds gave only 33 % germination which increased after two months, reaching 50 % after storage for eight months. Seedling vigour was also the highest when the seeds were sown after eight months storage. Seed size (small, medium and large) also affects germination. Singh *et al*. (2004) report greatest ber seed germination and tallest seedlings from medium sized seeds.

5.2.4 Seed pretreatments

Even when they are viable ber seeds do not germinate readily. Suitable conditions for germination must be created. Under natural conditions in the field, seed dormancy gradually breaks down as the stone weathers naturally on the ground. For controlled germination, a common nursery practice is to pretreat seeds if samples take more than a week to germinate. Pretreatment falls into two main categories: mechanical scarification, and non mechanical methods.

Mechanical scarification of ber seeds involves cracking, nicking, or partial removal of the stony endocarp. This appears to be the single most efficient pretreatment to achieve highest percentage of germination. Less than 10 % of fresh ber seeds will germinate without removal of the endocarp (Grice, 1996). Cracking the endocarp can achieve 100 % germination in two weeks (Billand and Diallo, 1991). A rate of 85 – 90 % germination over a period of 12 days with this treatment has been reported by Ouedraogo and Nikiema (1997). Murthy *et al.* (1989) reported a germination rate of 44.58 % for cracked stones while the control of intact stones achieved a mere 17.50 %. Mechanical scarification of the endocarp not only achieves high percentages of germination; it also speeds up germination. Germination of non scarified stones is slow and may take up to four weeks, whereas extracted seeds germinate within a week and the seedlings are more vigorous (ICUC, 2002).

Non mechanical pretreatments involve soaking whole stones or dehulled seeds in water or in various chemical solutions such as sulphuric acid or a range of growth regulators. A review by Pareek (2001) indicated that ABA- like substances are present in the testa of the seed and that germination was reduced as a result of soaking the seeds in 500 ppm abscissic acid solution. Treatment with 5 ppm abscissic acid inhibits germination of Chinese jujube seeds.

When viable stones are dipped in 500 ppm thiourea for four hours and then cracked, the separated seeds will germinate in seven days (Morton, 1987) while seeds in uncracked stones require 21 to 28 days. Vashishtha (1998) reported that pretreatment of stones in concentrated sulphuric acid and GA improved germination, but soaking in water even for 48 hours was not helpful. A common pretreatment of ber stones in Burkina Faso is to soak the stones in sulphuric acid (97 %) for 30 minutes then in water for 24 hours. Results of 80 – 100 % germination have been obtained this way (Billand and Diallo, 1991; Ouedraogo and Nikiema, 1997).

Passage of stones through the digestive tract of animals hastens germination. The stones can remain in the digestive tract for at least 12 days. A large proportion of seeds excreted by cattle contain viable seeds that achieve 88 % germination (Grice, 1996).

Other non mechanical pretreatments include exposing stones or seeds to environmental factors such as specific temperature or various growth media. In germination tests of seeds under four temperature regimes (25, 30, 35 and 40° C) in darkness by Danthu *et al.* (1992), germination rate after seven days was 90 – 91 % at 35° C, 85 – 87 % at both 30 and 25° C, and no germination was observed at 40° C. Although final rates of germination at 25, 30 and 35° C are comparable after seven days, speed of germination is markedly different.

Germination after two days was a mere 0 – 10% at 25º C, but reached 80 % and more at both 30 and 35º C. A review by Pareek (2001) reported similar results. For Chinese jujube seeds, 25º C proves to be optimum.

Conditions of the growing medium have considerable effects on germination. The available data have been reviewed in detail by Pareek (2001) as follows. Salinity in the growing medium delays or inhibits germination of ber seeds. Increasing chloride and bicarbonate concentration from 2 to 10 dSm^{-1} in irrigation waters tended to decrease seed germination with significant reduction at 4 dSm^{-1} of chloride waters and 7.5 dSm^{-1} of bicarbonate waters. Germination declined to 50 % at 6 dSm^{-1} EC compared to that at 1.5 dSm^{-1} and failed completely at 12 dSm^{-1}. Increasing soil boron levels from 4 to 16 ppm has no appreciable effect on final emergence but in combination with salinity delays the germination. Alkalinity at ESP 40 in the growing medium also delayed seed emergence.

Seeds of Chinese jujube sown in the open and covered with plastic sheeting emerge 20 days earlier than non covered seeds and also gave 22 % higher emergence.

Dehulled seeds do not appear to require major pretreatments. Danthu *et al.* (1992) observed that *Z. mauritiana* seeds do not require any pretreatment; they will germinate readily. Prins and Maghembe (1994) achieved more than 80 % germination by simply cleaning and soaking the seeds in water. Dehulled seeds soaked in water for 24 hours reached 100 % germination in two weeks (Billand and Diallo, 1991). In Chinese jujube, a review by Pareek (2001) showed that one group of cultivars gives 85 % seed germination (e.g. Ya-tszao) and the other (e.g. Nikitskii 84, 92 and 94) gives 98 % germination. Some Chinese jujube seeds take one to three days to germinate while others take seven days.

5.2.5 The nursery

5.2.5.1 Seed propagation

Ber seedlings raised from seeds are not used directly for fruit production in commercial plantations because the time taken for such plants to reach bearing age is usually longer than for trees propagated using vegetative methods (ICUC, 2002). Also the desirable traits of improved cultivars (growth, fruiting and fruit quality) are not guaranteed through seed reproduction.

Nonetheless, propagation of ber and the other major jujubes by seed remains of great value for several reasons:

(i) Propagation by seed is necessary to raise appropriate rootstocks for vegetative propagation of improved cultivars.

(ii) In regions where jujubes are propagated not solely for fruits but also for a range of products and services (live hedges, fodder, timber etc.), propagation by seed is a much easier and more economical method than vegetative propagation. Until the recent introduction of improved cultivars to the Sahel region of West Africa, most research and development programmes on *Z. mauritiana* in the region focused on performance in live hedge technology in agroforestry systems under rainfed conditions. This requires large scale production of seedlings sown directly in the field or raised in private and community nurseries in villages throughout the region. In such situations, propagation by seed is the safest way to produce seedlings with deep tap roots that can survive in the field under extended moisture stress even when the surface soil completely dries out.

(iii) Sexual reproduction by seed offers opportunities for variation and evolutionary advancement, which is of immense value to the plant breeder.

(iv) Conservation of *Ziziphus* biodiversity and rehabilitation of natural vegetation is best served through seed reproduction.

5.2.5.2 Techniques for raising seedlings

Seedlings may be raised in nurseries by sowing seeds in seedbeds or in containers. Quality seedlings in the nursery are fundamental to quality trees in the field. As Jaenicke (1999) pointed out, the best looking seedling in the nursery is worthless if it does not survive and grow after planting out (see Plates 1.2).

For ber, seeds should be sown at a depth of 2 cm at 30 x 30 cm spacing in the seedbed any time from spring through the monsoon period (Pareek, 2001). For transplanting in the field, nursery bed raised seedlings have to be lifted, packed and transported to the planting site. Seedlings can be transplanted in the field with 20 x 15 cm earth ball; they can also be transplanted bare rooted (without ball) when they are not growing actively during the winter in subtropical climates (Pareek, 2001). Bed raised seedlings often suffer high mortalities during transplanting because of root injuries when seedlings are lifted from the bed, or because of insufficient care during packing and transportation to the planting site. Hardening of seedlings can be beneficial before transplanting (Bhatia *et al.*, 2001).

From a review by Pareek (2001), it appears that treatment of roots with 250 ppm IBA improves transplanting success. Shifting the seedlings within the nursery one month after sowing and then transplanting them in the field after 7 months also results in better survival. Nonetheless, overall risks of mortality remain quite high when transplanting bed raised seedlings. Thus, the method of raising seedlings in nursery beds is not very popular. Seedlings raised that way are not considered suitable for planting under rainfed conditions.

Another way of raising seedlings is through the use of containers. Types of containers commonly used are pots, polythene tubes or bags. In Burkina Faso, baskets woven with leaves of the palm tree *Borassus aethiopum* are used in addition to polythene containers for nursery production of fruit tree seedlings. Containers most commonly used in India are 28 x 23 cm pots, 23 x 10 cm polythene bags and polythene tubes of 25 x 10 cm size in 300 gauge (Pareek, 2001). Polythene containers must be protected from direct sun heat to avoid rapid disintegration. Protection is done through proper shading in the nursery or by keeping the containers buried in sunken beds.

Several seeds are normally sown per container and then the young seedlings (at the four leaf stage) are pricked out into separate pots before finally planting in the field. Pareek (2001) reports 8-10 stones sown in a 30 cm pot. In Burkina Faso, two dehulled seeds are sown per polythene bag (Billand and Diallo, 1991). At the time of pricking out, only one seedling is left per container. In Burkina Faso seedlings two months old were 12 to 21 cm high, with a collar diameter of 2 to 3 mm (Dao, 1993). Seedlings ready for transplanting in the field are five-six months old with a height of 36 to 47 cm and a collar diameter of 4 to 5 mm (Billand and Diallo, 1991).

Weeds can cause problems, and have to be removed from the nursery. Weeding is usually done manually. Pareek (2001) reports that *Cyperus rotundus* can also be controlled by application of oxyfluorfan at 0.6 $kg.ha^{-1}$ or oxadiazon at 1.5 $kg.ha^{-1}$ without damaging the seedlings.

A frequent constraint is deformity of roots which can be severe due to the deep taproot. Root deformities occur in both seed beds and containers (Jaenicke and Wightman, 1999). Root deformities can be caused by poor pricking out. Seedlings squeezed into holes that are too short for the root system will develop root deformities and any roots which are curled upwards will bend back and grow into a 'knee' or even a complete loop. In container raised seedlings, the smooth plastic bags cause the main root to coil or spiral along the walls or at the bottom of the container. This invariably happens when plants are left in the nursery too long. However, it can happen even to small *Ziziphus* seedlings because of the deep taproot. Two months old seedlings only 12 – 21 cm high were found to have taproots that were longer than the plant height, reaching 21.5 cm (Dao, 1993).

As with any other tree seedling, root deformities of Z*iziphus* seedlings should be cut off before planting, as they retard plant growth and can even result in the plant's death. Root deformities do not correct themselves over time and may even become more acute as the tree grows.

Another constraint would relate to seed sowing at depths more than 3 cm. This causes poor germination.

In addition to proper weeding and the application of good nursery practice to minimise root deformities, good seedling management to produce balanced quality plants in the nursery means that regular watering is essential. Fertilisation and inoculation with mycorrhizal fungi also have proved beneficial.

Although *Ziziphus* species are drought resistant, adequate water supply in the nursery is essential. Pareek (2001) reported that maintenance of pre-irrigation moisture of 80 % in the nursery soil has been helpful in the development of over 98 % Chinese jujube seedlings (to be used for budding). In India, a major breakthrough was achieved in the early 1990s with the development of a device known as 'jaltripti'. The device, as described by Pareek (2001), comprises two earthenware pots of the same height but of different diameters joined at the base, keeping the base of the inner pot open and that of the outer pot closed. The outer pot can regularly be filled with water. The ber plant is grown in the inner pot in a manure/soil mixture. The device results in very good growth of the plants and saves 75 % irrigation water.

Under water stress, inoculation of arbuscular mycorrhizae improves ber seedling growth, nutrient uptake and water stress tolerance. Mathur and Vyas (2000) used six arbuscular mycorrhizal species to inoculate 15 day old *Z. mauritiana* seedlings subjected to increasing water stress from field capacity to near wilting point over a period of 16 weeks. The six mycorrhizal species used for inoculation were: *Gigaspora margarita, Glomus constrictum, Glomus fasciculatum, G. mosseae, Sclerocystis rubiformis and Scutellospora calospora* maintained on *Cenchrus ciliaris*. Seedling mycorrhizal dependency was high for all six fungi, ranging from 111 % to 208 %. Compared to non treated seedlings, nutrient uptake in mycorrhizal plants increased significantly, ranging 115-223 % for nitrogen and 154-400 % for phosphorus, depending on the mycorrhizal species. Mycorrhizal plants also showed increased uptake of potassium and accumulation of proline, both of which are known to play important roles in plant water stress management through stomatal movement and osmotic adjustment respectively. Although the magnitude of seedling incremental growth varied with VAM species, overall growth of inoculated seedlings was significantly better than the non inoculated ones. *G. fasciculatum*, the most efficient species in the experiment, resulted in almost a doubling of plant dry weight compared with the non inoculated plants. It also enhanced proline content of seedlings by 37 %. Thus, by whatever mechanism (increasing N and P uptake, increasing potassium uptake or by higher proline accumulation), inoculation of arbuscular mycorrhizal fungi resulted in efficient water stress tolerance in *Z. mauritiana* seedlings. Thus, *G. fasciculatum* could be of great importance in cultivation of *Z. mauritiana* in drought prone areas.

Mycorrhizal inoculation combined with the application of rock phosphate has been tested in a series of studies conducted in Burkina Faso to improve *Z. mauritiana* seedling growth and vigour in the nursery (Ba *et al.*, 1998; Guissou, 1996, 2001; Guissou *et al.*, 1998, 2000). Five mycorrhizal species were tested:

Glomus aggregatum, G. intraradices, G. manihotis, G. mosseae and Acaulospora spinosa in various experiments. All five mycorrhizae increased seedling height, collar diameter, stem and root dry weight. *Acaulospora spinosa*, the most efficient fungus, increased seedling height by 171 %, stem dry weight by 309 % and total biomass by 374 %. *Z. mauritiana* seedlings showed a higher mycorrhizal dependency (78 %) than *Tamarindus indica* (34 %) or *Parkia biglobosa* (24 %).

Application of rock phosphate to four month old *Z. mauritiana* seedlings significantly increased seedling height and biomass, indicating that non inoculated *Ziziphus* seedlings were able to utilise phosphate from rock phosphate. This is important because soils in the region are inherently poor and particularly deficient in phosphate, whereas rock phosphate is readily available from large deposits in the region.

Raising *Z. rotundifolia* seedlings for rootstocks and treatment and handling of the seeds is summarised by (Singh *et al*., 2001). There are similarities in the methodology for all *Ziziphus* species.

5.3 Vegetative propagation

Methods of vegetative propagation differ between *Z. mauritiana and Z. jujuba.* Traditional methods such as use of cuttings are not successful with the former whereas in Chinese jujube use of cuttings is, and furthermore Chinese jujube cuttings can be taken from root suckers before emergence. Some success has been observed in ber by stooling. *Z. spina-christi* is propagated by cuttings.

Budding is the major method for propagating ber and can be successfully carried out using several methods. Of the different methods the degree of success varies according to climatic conditions, time and method of budding and the skills of the operators.

Both ber and Chinese jujube can be propagated by grafting, using the wedge method for ber and the whip or tongue method for Chinese jujube.

5.3.1 Rootstocks

For ber, rootstocks are either the same species (wild) or commonly *Z. nummularia* (often referred to by its synonym *Z. rotundifolia).* No incompatibility is seen between scions of the cultivars and rootstock seedlings of *Z. nummularia,* wild *Z. mauritiana*, *Z. oenoplia, Z. rugosa, Z. xylocarpa, Z. jujuba* or *Z. spina-christi* (Pareek, 1983). Nonetheless vigour and growth differ greatly. Use of *Z. nummularia* tends to be less favourable for fruit production than the use of *Z. mauritiana* (Pareek and Nath, 1996).

Z. abyssinica rootstocks can also be used for ber and are more successful than *Z. spina-christi as* the latter often produces a bottleneck form (Nerd and Mizrahi, 1998). In Africa wild *Z. mucronata* does not appear useful due to delayed incompatibility (Kadzere *et al*., 1997).

Rootstock seedling plants of different species, although from variable progenies, influence the vigour, growth form and productivity of the scion and presumably also its adaptation to adverse climatic and soil conditions (Verma *et al*. 2001).

The best choice, at present, seems to be to raise rootstocks from seeds collected from vigorous trees of cultivated ber (*Z. mauritiana)* and boradi (*Z. mauritiana* var. *rotundifolia)* or other suitable wild species such as *Z. abyssinica.* Use of vegetatively propagated or seedling plants from identified genotypes of the selected species should in due course lead to the development of standard rootstocks. This will ensure the desired effects of adaptability, productivity, vigour and form of the scion, and longevity of the scion/rootstock combination under different ecological habitats.

In Chinese jujube, seedlings of *Z. jujuba* var. *spinosa* and other wild species are used as rootstocks (Ming and Sun, 1986). Grafting over 2 cm thick roots of *Paliurus spinosa* has also given success (Zaktreger and Solov'ev, 1962).

5.3.2 Budding

5.3.2.1 The budwood

Budwood becomes available during the active growth period in the summer. The bud sticks, with well swollen and recently matured buds (but still not open) are collected (Fig. 5.1). Immature and undeveloped buds from the upper part of the new shoots and over mature and inactive buds should not be used. Buds collected from flowering shoots give poor success. Buds should be collected from juvenile shoots. Such shoots can be induced to grow by severe pruning of the mother trees.

Figure 5.1 The budwood

After collection, the budwood is often stored for a time or has to be transported, and considerable loss of viability may take place. Budwood retains good viability when kept under ventilated conditions and wrapped in moist jute cloth. Kanwar and Singh (1981) found that buds stored in polythene sheeting, even for one day at 31-38° C and 67-68% relative humidity, failed in bud-take. However, buds kept in moist jute cloth for one day gave bud-take of 68.8% and 36.2% when kept for five days. Singh (1988) found that budwood wrapped in polythene sheeting and moist sphagnum moss gave better results than those stored in moist jute cloth.

5.3.2.2 Time of budding

The best time for successful budding is during the active growth period. The active growth period is indicated by easy and clear separation of the bark from the wood in both scion and the rootstock. Kaundal *et al.* (1984) observed maximum bud-take (80-87 %) at ambient temperature between 30 and 34° C, irrespective of variations in atmospheric relative humidity (RH) from 45 to 73.5 %. Bud-take declines below 36 % RH and when temperatures drop to 18.5-20° C. Such conditions occur during the summer and monsoon period (June to September) in the arid and semi-arid subtropics of northwest India (Joshi, 1960; Singh *et al*., 1972 b; Pareek. 1978 a; Singhrot *et al*., 1980; Anon., 1981; Kaundal *et al*., 1984; Mawani and Singh, 1992 a, b). Maximum sprouting of 93.2 % has been recorded by budding when the maximum temperature was between 33 and 36.5° C and minimum temperature was around 26° C (Kaundal *et al.,* 1984). Some success can be obtained even during the mild winter months of the tropics (Jyotishi *et al*., 1967).

5.3.2.3 Transplanting of budded plants

Budded seedlings prepared in nursery beds are lifted with large earth balls at about 9 to 12 months after budding for transplanting to the field. A number of these plants may be lost due to damage while lifting, packaging, during transport and transplanting (see for instance, Singh *et al*., 2001). The operations are cumbersome and incur high costs due to the large earth balls. Attempts have been made to reduce mortality by:

i) shifting the plants within the nursery 25 days after sprouting (6 leaf stage) to harden them before final transplanting at about 8 months after budding (Singhrot and Makhija, 1979 a; Bhatia *et al*., 2001),
ii) shifting the buddings into polybags of 30 x 20 cm size along with treatment of 12 % Waxol (Kundi and Singhrot, 1990),
iii) transplanting the defoliated buddings without earth ball during the winter in the subtropics (Sandhu and Dhillon, 1983; Sandhu *et al*., 1983; Beniwal *et al.,* 1992),
iv) cutting the tap roots along with treatment with 200 ppm IBA (Singh, 1988) and wrapping the roots with moist sphagnum moss or jute cloth during transport to the field.

All these methods increase establishment success, but only after irrigation as transplanting tends to reduce the drought-hardy character of ber trees owing to loss of tap roots.

Buddings prepared in polytubes become ready for transplanting at about 30 days after budding. The polytubes with the buddings are removed from the nursery and kept in shade for a week. These can then easily be transported and transplanted to the field with over 90 % survival (Pareek, 1978 b) since there is little stress or root damage during lifting, transport and planting. The roots of the plants do not coil and, therefore, retain the drought-hardy character and vigour almost similar to plants raised *in situ.* For long distance transport soil is washed from the roots of polytube raised buddings and covered with sphagnum moistened with 0.2 g potassium nitrate, 0.8 g calcium nitrate, 0.2 g magnesium sulphate, 0.2 g hypophosphate and 1 ml of 0.5 % ferric tartrate with 0.2 % Dithane Z-78 (Pareek and Vashishtha, 1980).

5.3.2.4 Budding method

Budding can be carried out by different methods such as I or T (shield), or ring and patch (Husain, 1973; Moti and Chaturvedi, 1976; Anon., 1981; Mawari and Singh, 1992 a, b), chip (Anon., 1953), flute (Mawari and Singh, 1992 a, b) and forked (Jyotishi *et al*., 1967). However, shield (Singh, 1952; Anon., 1953; Singh, 1957; Joshi, 1960; Singh, 1964; Jyotishi *et al.,* 1967) and patch budding are the most commonly used methods. The ring method needs the scion stick to be of equal diameter to the rootstock and this limits its use on a large scale. Using patch budding, 75-85 % success has been obtained (Anon, 1981) (see Plates 3-6).

Standardisation of the budding methods has been summarised by Nayak and Sen (2000).

Budding should be performed as close to the ground level as practicable to minimise the area for emergence of sprouts from the rootstock portion. Over 93% success has been obtained by budding at the height of 10 cm onto seedlings with a stem diameter of 0.53-0.55 cm (Singh *et al.*, 1981 b; Chattopadhyay and Dey, 1992). Lopping and topping of the rootstock from 8 (Kundu 1983; Singhrot and Kajal, 1986) to 15 days (Singh *et al.,* 1984 c) after budding in the nursery beds has been found to ensure 90 to 100 % success. Topping has also been found to increase growth of buddings (Anon., 1981). Pareek *et al.* (1999) recommend that just before *in situ* budding in the field, rootstock seedlings should be lopped at 30-45 cm height.

When budding onto seedlings raised in polythene tubes, the rootstocks should be prepared by removing all side shoots and leaves from the stem up to a height of 15 cm above ground level. The seedlings are then topped just before budding using either the shield or patch method (Fig. 5.2).

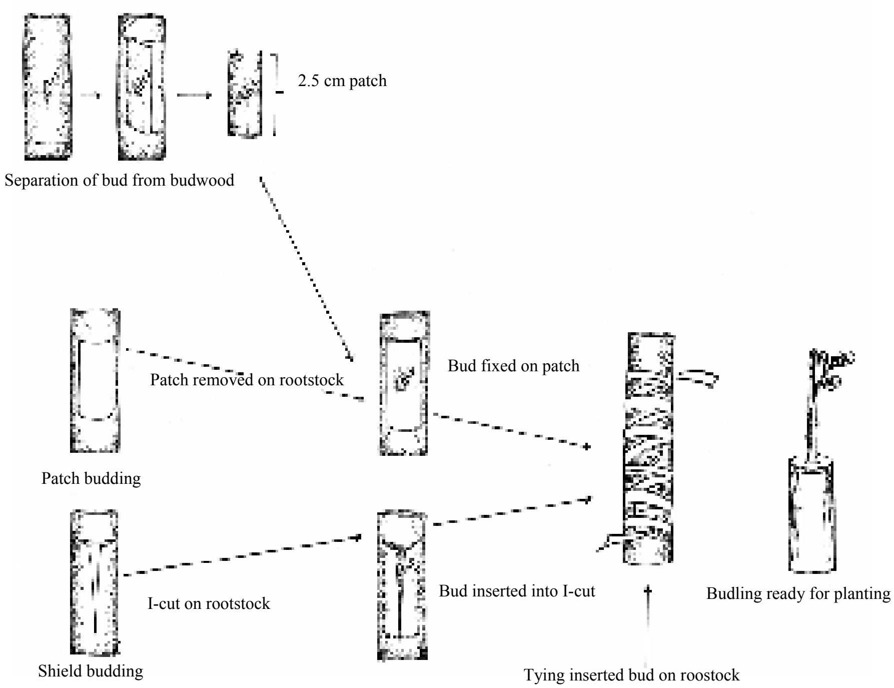


Figure 5.2. Methods of budding

5.3.3 Micropropagation

Tissue culture techniques offer possibilities of rapid cloning of desired genotypes. Pareek (2001) provided the following summary:

5.3.3.1 Ber

Goyal and Arya (1985) induced adventitious root formation within 20 days in shoot segments of Gola and Seb cultivars, in half strength MS medium supplemented with 0.5 mg per litre of IBA and kinetin. Nearly 60 % of the rooted shoots could be successfully transplanted into pots and the total time taken from initial culturing to transplantation was 150 days. The protocol developed by Rathore *et al.* (1992) involves culturing nodal explants on MS medium containing 7.5 mg benzyladenine plus 0.1 mg IAA/l for shoot proliferation, then in White's liquid medium containing 25 mg IBA/litre to induce rooting and then in White's solid medium without growth regulators followed by hardening off before transplanting into pots.

Kabir *et al.* (1994) multiplied shoots through axillary bud elongation on MS medium containing 0.1 mg/litre NAA or IAA and 2 mg/litre bezyladenine, which were rooted by transferring the shoots to MS medium containing 0.5-2 mg/litre IBA. Large-scale multiplication of shoots can be carried out by repeated subculturing of the nodal segments of *in vitro* grown shoots after every 6-8 weeks.

Mathur *et al.* (1995) grew stem explants from mature trees on MS medium containing 3800 mg/litre potassium nitrate, 2475 mg/litre ammonium nitrate, 11 mµ-M benzyladenine and 0.5 mµ-M IAA, which produced 15-20 shoots per inoculum on successive subculturing. Rooting in the shoots could be induced by pre-treatment with 50 mµ-M IAA or NAA for 24 hours followed by their transfer to auxin-free White's medium and then into soil and vermiculite mixture.

Work is proceeding on tissue culture of ber and a recent summary was provided by HU *et al.* (2001).

5.3.3.2 Chinese jujube

By culturing stem segments of jujube lines A 17, A 27 and A 80 in MS medium containing 1 mg BA per litre, the highest percentage of clustered buds (66.7) was differentiated. Maximum root growth (95.9 %) was induced in the medium containing 0.4 mg/litre IBA (Yan *et al.*, 1990). Culture medium containing 2 mg BA + 0.4 mg BA per litre gave 81.8 % differentiated buds which could be excised continuously for multiplication. Kim and Lee (1988) obtained the best shoot and root growth from axillary buds of cultivar Geumsung after eight weeks when 500 mg/litre activated charcoal was added to half strength MS medium with 0.5 mg/litre benzylaminopurine. 1000 mg/litre activated charcoal was required for cultivar Bokjo. Rooting and callus growth of Geumsung microshoots increased as IBA concentration was increased to 3 mg/litre. Rooting was better when treated with paclobutrazol rather than with IBA, NAA or Rooton.

For producing rooted plants from shoot tips and single bud segments, MS medium supplemented with IBA was more effective than with IAA or NAA (Cheong *et al.,* 1987). Kinetin and 2iP (0.5 mg/litre) and BA (1mg/litre) increased plant height, number of nodes and plant weight. A combination of 1 mg/litre IBA and 1 mg/litre BA or 0.5-1.0 mg/litre kinetin also increased plant height and weight. Addition of adenosine sulphate at 40 mg/litre to the shoot tip culture and at 80 mg/litre to bud segment culture in MS medium + 1 mg/litre IBA + 1mg/litre BA further increased plant height and number of nodes. Charcoal, when added to the culture medium decreased root number and length.

5.3.3.3 Callus culture

Attempts have been made to regenerate plantlets of *Ziziphus* cultivars via callus formation from a range of explants followed by organogenesis and somatic embryogenesis (Cheong and Kim, 1984; Kim *et al.,* 1987; Mathur *et al.,* 1993; Mitrofanova and Shevelukka, 1995; Mitrofanova *et al.,* 1994. 1997). This may not, however, provide a practical technique for multiplication of true-to-type plants, and there is a risk of somaclonal variation occurring. More work needs to be done.

5.3.3.4 Other research

Micrografting has received attention in order to multiply a superior cultivar through an *in vitro* micrografting technique which is a miniaturisation of the apex slice involving grafting of scions <10 mm long onto seedling hypocotyls *in vitro.* For ber, cv. Gola, 80 % success resulted (Danthu *et al.*, 2004). Further work has progressed in refining methods for *in vitro* propagation of ber (cv. Umran) by Al-Mazrooei and Ramos (2000) and Sudherson *et al.* (2001) as well as *Z. spina-christi* by Al-Mazrooei and Ramos (2000).

5.3.4 Cuttings for Chinese jujube

Softwood cuttings 5-10 cm long having 2-3 leaves, are taken from the middle or lower part of the shoots during June (Shcherbakova and Kulikov, 1972; Tarasenko and Shaumorov, 1977) when the soil temperature stays consistently above 17° C at 8.00 h (Shen *et al.,* 1992). Optimum temperature for rooting is 26-28° C (Shcherbakova and Kulikov, 1972). Treatment of cuttings with 50 ppm IBA for 12 h (Tarasenko and Shantharov, 1977) or 10 h (Shcherbakova and Kulikov, 1972) induces 88.8 and 96 % rooting respectively. Shen *et al.* (1992) obtained best results by a quick dip in 250-500 ppm IBA or NAA or in a mixture of 250 ppm IBA and 500 ppm NAA. Exposure to 2000 ppm CO_2 for one week immediately after taking the cuttings (Kossuth *et al.*, 1982) and treatments with the strains A4 and TR 105 of *Agrobacterium rhizogenes* (Hatta *et al.,* 1996*)* have also been observed to induce early rooting and to increase rooting percentage.

In Chinese jujube, cuttings taken from root suckers before emergence give 76.8% survival (Dong and Song, 1988). Root sucker differentiation from mature trees is 1000 to 15000 per hectare if 15 cm of the soil surface layer is removed in the orchard during March-April or September-October. Chinese jujube suckers when treated before stooling with 2500 ppm IBA gave 100 % rooting in sand, 66.7 % in vermiculture + perlite and 55.6 % in soil medium but did not root when stooled without IBA treatment (Kim and Suh, 1989).

5.3.5 Grafting

5.3.5.1 Ber

Wedge grafting has been successful for propagating ber in Israel (Nerd and Mizrahi, 1998); budding is on the whole easier to use and more economical.

5.3.5.2 Chinese jujube

Chinese jujube is propagated by whip and tongue grafting, and carried out during the winter when the plants are dormant. Slanting 3-5 cm long cuts are made on both stock and scion shoots of equal diameter. The cut ends of the stock and scion are joined and tied. The grafts become ready for transplanting after one year. One year old, primary shoots of Chinese jujube gave the best results for *in situ* grafting during spring on seedling rootstocks planted in the field (Kim *et al.,* 1982 b*).* Cutting back the reproductive shoot above the third node in the middle of June increased shoot length. Softwood grafting in early spring also gave success of 90 % (Ivanova, 1976).

Chapter 6. Agronomy

(Revised by J.T. Williams)

Propagation to provide planting stocks has been described in Chapter 5. This chapter covers planting and management of orchards or using trees as intercrops, and is mostly devoted to ber.

6.1 Planting

Spots are marked at each site. In India pits of 60 cm^3 size are dug in April or May for planting during the monsoon, or December to January for spring planting (Bajwa *et al.*, 1972; Singh *et al.*, 1973 a; Bakhshi and Singh, 1974). In arid areas the best time for planting is at the onset of the monsoon (Pareek, 1983).

Pits can be treated to control termites and are filled one month before planting with a mix of topsoil and 15-20 kg farmyard manure. Planting then takes place. In arid areas this is early but in others it can extend over two months.

Planting distance depends on soil types, cultivar, climatic conditions and amount of training to be imposed on the plants. Higher density is possible on poor soils if training is rigorous. Where possible, drip irrigation is provided after planting (Singh, 1973 a) for the first two months. Distances are shown in Table 6.1.

Table 6.1 Planting distance of ber (after Singh, 1992)

Distance in m	Plants/ha
6x6	277
6x5	333
5x5	400
6x4	416
5x4	500
6x3	555
4x4	625

In Vietnam higher densities are grown; the mean number/ha is 625, the minimum 555 and the highest 1000 (Le Thi Thu Hong, 1998). Planting layout is usually a square pattern.

6.1.1 Training of plants: ber

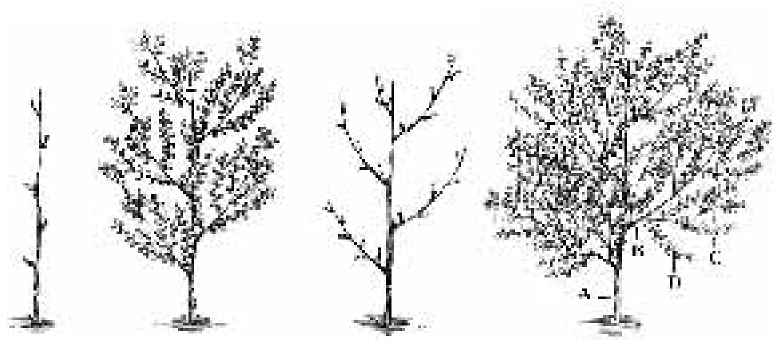
Ber has a vine-like downwards growth habit and to develop a strong tree training is essential and is carried out usually after the first year. Initially trees can be supported by bamboo sticks. Timing of training varies as described below.

In subtropical regions, with cold winters and warm summers, ber trees are trained during the first three years after planting. During the first year, after planting or *in situ* budding at the onset of monsoon (June-July in India), the plants are allowed to grow until the following spring (March in India). The bush is headed back keeping 1-2 basal buds on the scion portion just above the graft union to induce development of vigorous new shoots. Only one upright vigorous shoot is allowed to grow from the scion bud. The emerging shoot forms the tree trunk in due course. The trunk is kept clean up to 30 cm from ground level by removing all branches (Pareek, 1978 a). Bajwa and Sarowa (1977) and Singh *et al.* (1973 a), however, recommended that the tree trunk should be kept clean up to 75 cm. From the trunk, 3 or 4 well spaced and favourably placed branches are allowed to grow. The top of the trunk is headed back during summer (May in India) to encourage growth of these branches (Fig. 6.1).

Subtropics Year	June-July 1	March 2	March 2	May 2	March 2
Tropics Year	June 1	December 2	December 2	February 2	July 2

Figure 6.1 Training ber - after planting or *in situ* budding

Ber has a characteristic growth form producing branches usually starting from the sixth or ninth node from the base. Secondary branches form at regular intervals of three internodes (Reddy and Chadha, 1993). During spring or summer of the following year, shoots emerge from the basal buds of the secondaries and grow vigorously but the secondaries themselves either dry out or remain insignificant. Therefore, during the spring of the second year, the secondaries are pruned to retain their basal buds from which vigorous shoots emerge. More than one shoot may emerge from the basal bud, but only one of these is retained and others are removed. These form the main branches of the tree frame. On the main branches, 3-4 or sometimes 4-6 upright growing and properly spaced side shoots are retained and then the top of the main branches are headed back. During the spring of the third year, these side shoots are pruned retaining their basal buds. From these buds, vigorous shoots emerge to form the sub-main branches of the tree frame.



Subtropics Year	March 3	March 4	March 4	July 5
Tropics Year	July 2	January 3	January 3	July 3

Figure 6.2 Training in ber. A - trunk, B - main branch, C - Secondary (I Order sylleptic branch), D - Tertiary (II Order sylleptic branch).

In tropical regions, ber plants continue to grow during the winter months and thus can be trained within the first two years. About 5-6 months after planting, the scion portion is cut back retaining only the basal 1-2 buds. From the new growth emerging from the scion buds, only one upright growing vigorous shoot is retained and the others are removed. This forms the tree trunk. The tree trunk, main branches and sub-main branches are similarly developed as in the subtropical region except that the intervening growth periods between the lopping operations are shorter (about 6 months) compared to about one year in the subtropics.

6.1.2 Chinese jujube

Generally Chinese jujubes are planted at 3.5 x 4 m up to 6 x 6 m. In China rows are often planted in an intercropping pattern. In Azerbaijan they are more often orchards (Tagiev and Gadzhier, 1990).

6.2 Water management

Availability of water is the major determinant for growth and productivity of all cultivated jujubes.

6.2.1 Rainfed areas

6.2.1.1 Water harvesting

Many ber orchards are found in dry areas and depend only on annual rainfall for water. Productivity of these orchards depends mainly upon the quantity and distribution of rainfall and the extent of its subsequent use by the trees. A considerable quantity of rain water is lost as runoff and cannot be used by the trees unless water harvesting methods are employed. These may be *in situ* where runoff is concentrated into catchments surrounding a tree or group of trees, or *ex situ* where runoff from large rocky areas is diverted directly to nearby orchards or after collection in reservoirs or farm ponds.

For *in situ* water harvesting land shaping may be used to prepare sloping catchments on both sides of the rows of ber trees. In the subtropical sandy planes, which receive 360 mm annual rainfall in northwest India, higher runoff yield was obtained from catchments having 5 % slope than from the usual land slope of 0.5 % (Yadav *et al.,* 1980; Sharma *et al.,* 1982, 1986). In due course, the sandy catchments stabilised as a result of compaction and levelling, and generated runoff even with rainfall of only 25 mm.

On natural undulating wastelands, trees can be planted at the lowermost point of each microcatchment where runoff accumulates. For this, the area is divided into microcatchment plots of 150 to 500 m^2 each. The size of plots depend upon the required quantity of runoff supplement which in turn depends upon rainfall, catchment slope, antecedent catchment characters (compaction, smoothness, etc.) and the runoff coefficient of the soil (Evenari *et al.,* 1971). Bhati *et al.* (1997) used rainwater collected in small farm ponds to irrigate ber trees during the fruit development period.

6.2.2 Irrigated areas: ber

Irrigation during early growth can be beneficial. Drip irrigation is most effective for this (Yaragattikar and Itnal, 2003). Farmers do not generally irrigate established ber orchards other than for intercrops (Verma and Gujar, 1994). However, water deficits decrease the productivity of trees by reducing the assimilation rate. In the subtropical semi-arid region of north India, irrigation during the fruit development period has been observed to increase productivity by decreasing fruit drop (Bakhshi and Singh, 1974). Although irrigation during the flowering period causes flower shedding in ber (Singh *et al.,* 1973 a), watering may have to be done if there are prolonged breaks in the monsoon during the growth and flowering period. Irrigation at the time of fruit maturity delays and prolongs the maturity period.

6.2.3 Chinese jujube

Chinese jujube productivity also increases with irrigation (fruit yield increasing by 60 %: Tagier and Gadzhier, 1990). Where irrigation is practised there are normally about six irrigations in a season.

In both major jujubes saline water up to almost 6 dSm^{-1} can be used; higher contents result in a decrease in fruit yield (Jin *et al.*, 1988; Jain and Dass, 1988).

6.2.4 Conservation of moisture

Mulching conserves moisture in the soil and suppresses weed growth. A range of organic wastes can be used. Normally a bed is prepared around the trunk covering three quarters of the area of the canopy. Black polythene sheeting is also useful and the most effective treatment (see Pareek and Nath, 1996 for ber; and Byun *et al.*, 1989, 1991 and Ming and Sun, 1986 for Chinese Jujuba).

A number of chemical sprays have been tested to reduce loss of water through transpiration. Other chemicals can be watered in the soil around the trees for this purpose. However, they are not yet cost-effective.

6.3 Weeding

Weeding is normally carried out through regular hoeings which are shallow tillings. Particular attention in all jujube species is paid to removal of root suckers in order to maintain the individual tree.

Annual ploughing of inter-row spaces helps weed control when carried out after weed emergence, followed by harrowing later.

Herbicides can be used e.g. dalapon followed by paraquat, each at the rate of 5 kg/ha (Bajwa *et al.*, 1990) and glycophosphate at 4 kg/ha (Bajwa *et al.*, 1993).

6.4 Manure and fertilisers

Small orchards are seldom manured. In the arid region of northwest India, farmers do not apply any manure or fertiliser in ber orchards other than that given at planting time (Verma and Gujar, 1994). Regular manuring is, however, essential to replenish the nutrient removal by the tree through fruit harvests and annual pruning besides losses from the soil. According to Ahlawat *et al.* (1990), as many as 75 % of the orchards in the arid subtropics were deficient in organic N and 90 % in P but none in K. Under subtropical and tropical agroclimates, nitrogen deficiency is widespread and thus it plays a major role in determining fruit yields . Deficiencies of N, P and K reduce shoot length, leaf number and size, axillary branch number, flowering and fruit set and consequently productivity of the tree (Sadhu *et al.*, 1978).

A ber tree removes from the soil, 142 to 191 g N, 59 to 87 g P and 467 to 684 g K on average during a single growing season (Mehrotra *et al.*, 1987). Most is due to fruit harvesting. According to Pandey *et al.,* (1990), 43.8 g N, 7.5 g P, 101.2 g K, 4.5 g Ca and 22.7 g Mg are removed by 100 kg harvest of fruits.

Judicious manuring and fertilisation are necessary to replace nutrient losses and to correct deficiencies due to imbalances in the soil or plant. Nitrogen and phosphorus fertilisation in the light soils of the arid and semi-arid subtropics is critical and potash may be applied to guard against its possible limitation as a result of annual removal over several years.

6.4.1 Nutrients recommended

In irrigated ber orchards 20-30 kg FYM or 400-500 g N, 200 g K20 and 200 g P205 can be provided annually when planted widely. In rainfed conditions half these doses are recommended (Singh, 1992). Actual practices are shown in Table 6.2

Table 6.2 Nutrient practices in ber orchards in India (amounts in kg)

Manurial Practices	Punjab	Rajasthan	Haryana
Farm yard manure			
Year 1	10	10	10
Annual increment	10	10	5
Year 5 onwards	--	50	30
Year 10 onwards	100	--	--
Calcium ammonium nitrate			
Year 1	0.5	--	0.5
Annual increment	0.5	--	0.5
Year 5 onwards	--	--	2.0
Year 10 onwards	ca 5		--
Superphosphate			
Year 1	--	--	0.25
Annual increment	--	--	0.25
Year 5 onwards	--	--	1.00
Bone meal			
Year 1	--	0.25	--
Year 2	--	0.25	--
Year 3	--	0.50	--

Source: Singh *et al.*, 1973 a (Punjab); Pareek, 1978 a (Rajasthan); Chundawat and Srivastava, 1978 (Haryana).

In the low fertility soils of arid and semi-arid regions, application of organic manures is considered essential for sustained nutrient supply. Organic manures also enable greater moisture retention for longer periods in these light soils. Similarly, fertilisers having lower losses of nutrients, e.g. calcium ammonium nitrate rather than urea, are preferred.

The best results have been obtained in young orchards of cv. Umran by application of 400 g N + 100 g P + 200 g K per tree (Dhatt *et al.*, 1993); in established orchards of Umran by application of 750 g N per tree (Dahiya *et al.*, 1985); in 8 year old orchards of Kaithli by application of 500 g N per tree (Yamdagni *et al.,* 1980); and in 6 year old orchards of Gola cultivar by application of 1000 g N + 1000 g P + 150 g K per tree (Singh *et al.*, 1986). A multi-location trial indicated good results by application of 750 g N per tree in deep sandy soils of the north-western subtropics and by 250 g N per tree in the shallow sandy loam soils in the southern tropics of India (Pareek and Nath, 1996). Thus, it appears that ber trees require 500 to 1000 g N, 400 to 800 g P and 100 to 200 g K per tree depending upon age of the tree and edaphic and climatic conditions of the area.

The method of placement of fertilisers depends on the root growth pattern. In an irrigated orchard, most of the active roots of 10-year old ber trees are located 2.35 m from the trunk and up to 0.5 m deep (Khera *et al.*, 1981). Under rainfed conditions, however, the roots make more vertical growth down to a depth of 4.5 m (Pareek, 1977).

6.4.2 Foliar feeding

Under rainfed conditions, foliar feeding is often a practical method of supplementing nutrient requirements, particularly of nitrogen and micronutrients. Nitrogen fertilisation of ber trees through foliar sprays of urea increased fruit set, fruit retention and yield, and improved fruit quality in cultivars Banarsi Karaka (Rajput and Singh, 1976; 1977), Umran (Chauhan and Gupta, 1985; Singh and Ahlawat, 1995) and Gola (Joon *et al.*, 1984). Dahiya *et al.* (1985) found that application of 375 g N through foliar spray and 375 g N to the soil gave a fruit yield of 128-130 kg per tree, higher than by applying all the nitrogen either through soil or foliage. The optimum concentration of urea for foliar application seems to be 1 to 2 % (Joon *et al.*, 1984; Chauhan and Gupta, 1985; Dahiya *et al.*, 1985; Singh and Ahlawat, 1995). Two sprays may be required at monthly intervals depending upon the nitrogen requirement. The best time for spray application seems to be after the fruit has set (Joon *et al.,* 1984; Chauhan and Gupta, 1985; Dahiya *et al.*, 1985; Singh and Ahlawat, 1995).

Supplementing micronutrients through foliar sprays of 0.2 to 0.4 % $ZnSO_4$ or $FeSO_4$ or $MnSO_4$ and 0.2 % boric acid has been observed to increase TSS and ascorbic acid contents (Kamble and Desai, 1996). This resulted in development of golden-yellow rather than green-yellow fruit colour in tropical regions. In the arid subtropics where zinc deficiency is more common and widespread, higher concentrations of $ZnSO_4$, i.e. 0.5 % (Singh and Ahlawat, 1995) and 0.8 % (Joon *et al.*, 1984) have given a better response.

Combined sprays of micronutrients (0.03 % boric acid and 0.5 % $ZnSO_4$) and growth regulator (50 ppm NAA) have been found to improve fruit quality in ber by increasing total soluble solids, total sugars and ascorbic acid and decreasing acidity (Singh *et al.*, 1989 a, b).

In Chinese jujube 200 ppm ethephon along with urea sprays accelerated movement of nitrogen from leaves to other parts of the tree and increased the length of fruit bearing branches, fruit set and fruit weight (Hao and Zeng, 1991).

6.4.3 Microbial inoculations

Microbial inoculations of soil and ber roots with *Azospirillum*, *Azotobacter* (Rao and Dass, 1989), vesicular arbuscular mycorrhizal fungi (VAM) (Mathur and Vyas, 1995 a,b,c,d; 1996) and other nitrogen fixing actinomycetes (Tuohy *et al.*, 1991) can help in effective nutrient management. Soil inoculation with cell suspensions of *Azospirillum brasilense* strains S_{14}, S_{51} and S_{54} or *Azotobacter chroococcum* increased height and weight of young plants of cv. Gola (Rao and Dass, 1989).

6.5 Pruning

Pruning is essential to maintain vigour in the trees and to maintain fruit productivity, quality and size.

Fruit bearing in ber is on the current season's shoots (Singh *et al.*, 1970; Pareek, 1983) and remains confined to the secondary and tertiary branches (Reddy, 1983). Pruning should therefore induce the emergence of a maximum number of secondaries and tertiaries on vigorous shoots. This can be done by pruning at the right time and with the right intensity depending upon location and cultivar.

6.5.1 Pruning intensity

The severity of annual pruning is determined by the length of the past season's shoot retained after the pruning operation, e.g. 20 or 25 cm (very severe), 40 or 50 or 60 cm (severe), 70 or 75 or 90 cm (moderate), 100 or 120 or 125 cm (light), 150 cm (very light) (Singh *et al.*, 1978 b; Gupta and Singh, 1979; Lal and Prasad, 1979; 1980 a, b, c; 1981; Dhaliwal and Sandhu, 1984; Bajwa *et al.*, 1986, 1987; Syamal and Rajput, 1989; Nanthakumar, 1991). However, the severity of pruning varies depending on the vigour of the shoot (total length and diameter). An alternative approach has been to base light, moderate and severe pruning on removal of one-quarter, half and three-quarters of the length of the shoot respectively (Sharma, *et al.*, 1980; Singh and Godara, 1985; Yadav and Godara, 1987, 1992). The three severity levels have also been based on pruning the shoot at a point where it is 1, 2 or 3 cm in diameter (Bisla *et al.*, 1988, 1990, 1991).

With increasing pruning severity, the shoot (length and width) increases (Gupta and Singh, 1979; Singh and Godara, 1985; Bisla *et al.*, 1988; Syamal and Rajput, 1989) and produces a larger number of secondary and tertiary branches (Bisla *et al.*, 1990). Lal and Prasad (1979) and Dhaliwal and Sandhu (1984) reported that the growth in terms of number of shoots, shoot length and diameter was greatest using moderate pruning. Moderate pruning also induces maximum flowering (Lal and Prasad, 1980 a), fruit set and fruit retention (Lal and Prasad, 1980 a; Dhaliwal and Sandhu, 1984; Gupta *et al.*, 1990; Yadav and Godara, 1992) and severe pruning decreases the number of flowers per cyme (Dhaliwal and Sandhu, 1984), fruit set and retention (Syamal and Rajput, 1989; Yadav and Godara, 1992) and delayed fruit maturity (Yadav and Godara, 1992). Light pruning reduces fruit drop (Lal and Prasad, 1980 c) and increases fruit set and retention (Bajwa *et al.*, 1986). Pruning has been observed to increase leaf area (Singh and Godara, 1985; Bisla *et al.*, 1990; Nanthakumar, 1991).

Fruit yield falls as pruning severity increases, and is at its lowest in unpruned trees (Dhaliwal and Sandhu, 1984; Bajwa *et al.*, 1986, 1987; Syamal and Rajput, 1989; Kundu *et al.*, 1995). Dinesh (2002) has reported on pruning intensity especially in semi-arid conditions. The best results have been obtained by moderate to light pruning in terms of yield and quality of fruits (Singh *et al.*, 1978 b; Lal and Prasad, 1979, 1980 b, c, 1981; Sharma *et al.*, 1980; Gupta and Godara, 1989; Islam, 1989; Gupta *et al.*, 1990; Bisla *et al.*, 1991).

Reddy (1983) observed that if the nodes up to the fourth or sixth secondaries (17-23 nodes) on the main axis are induced to sprout by pruning, vigorous shoots giving maximum fruit yield are produced. Also the new growth from the nodes on the main axis is significantly more productive than that from the secondaries. The secondaries should therefore be completely removed at the time of pruning. Multilocation trials have confirmed these results (Pareek and Nath, 1996), and it has been recommended that the main axis should be pruned at 15 to 25 nodes depending upon agroclimatic conditions, i.e. at 20-25 nodes in arid areas and at 15 nodes in semi-arid or more moderate regions, along with complete removal of secondaries.

There are some differences according to cultivar. Mukherjee and Soni (1993) obtained best fruit production by pruning to the sixth secondaries (25 nodes) in cv. Seo. Kundu *et al.* (1995) found that pruning up to 15 nodes was best in cv. Umran.

Old, unpruned, jujube species can be rehabilitated by reducing overlapping branches and precipitate fruit bearing towards the outer part of the crown. Half the number of shoots on a tree are pruned at 15 to 25 nodes depending upon cultivar, and the remaining half are pruned severely retaining only the basal node (Anon., 1989 b; Kundu *et al*., 1995). From the basal node of the severely pruned shoots, vigorous foundation shoots emerge which during the next year are pruned at 15 or 25 nodes while the remaining half are pruned severely. This pattern of pruning helps to maintain sustainable production as well as tree form. Even 30 year old trees can be brought back to bearing (Bal *et al*., 2004)

Kurian (1985) was able to induce early bud break and increase the number of vigorous sprouts by a pre-pruning spray of 3% thiourea combined with two post-pruning sprays of 100 ppm benzyladenine or 50 ppm TIBA at monthly intervals. A pre-pruning spray (before 48 h) with 3% thiourea and then pruning half the shoots at 25 nodes and the remaining half to the previous season's growth gave the highest fruit yield of 128 kg/tree.

6.5.2 Pruning in Chinese jujube

Tian *et al*. (1983) described pruning, one year after training, by cutting back long branches (over 2 m) and by nipping terminal buds. All secondary branches on the main stem are retained to increase the number of bearing spurs. During the fourth year, the main stems are ringed or notched and sprayed with 10 ppm GA. Plant height is determined by pruning in Chinese jujube. There are advantages in keeping trees below 3 m height.

6.5.3 Pruning time

Whereas Chinese jujube is pruned in summer the time of pruning in Indian jujube varies in different climates. In subtropical regions, the most appropriate time is during summer (between May and June in parts of India) when the trees shed their leaves and enter dormancy (Nijjar, 1972, 1975; Singh and Sandhu, 1984; Gupta and Godara, 1989; Gupta *et al.,* 1990; Kundu *et al.,* 1995) and before putting forth new growth. Early pruning has been observed to advance flowering and fruit maturity (Singh and Sandhu, 1984; Pareek and Nath, 1996).

In tropical regions with a mild winter and rainfall during December-January and early onset of summer rainfall (e.g. Tamil Nadu), pruning can be carried out any time from January to April. It is also possible to regulate fruit maturity so that bearing occurs at the desired time (Pareek and Nath, 1996). In tropical regions without winter rainfall (e.g. Andhra Pradesh), pruning during the first two weeks of April results in early flowering and therefore early harvest; however, the maximum yield of good quality fruits is obtained by pruning in the second two weeks of April (Ramadevi, 1989). In Maharashtra, the best time for pruning is before the end of April (Pareek and Nath, 1996; Deotate *et al*., 1997) as further delay causes reduction in fruit yield.

6.6 Pests

There are six major insect pests described below. A few others are listed and a comprehensive list is provided in Appendix I.

6.6.1 Fruitfly

Carpomyia vesuviana, *Dacus correctus* and *D. dorsalis* (Diptera: Tephritidae) infest ber fruits (Basha, 1952; Batra, 1953; Saen, 1986). *Carpomyia vesuviana* has been observed to damage as much as 80% of the crop under severe infestations (Cherian and Sunderam, 1941). It is the most serious pest of ber. (see Plate 7)

Infestation starts with the onset of fruit setting. The adult female lays eggs singly by inserting its ovipositor in the young developing fruit. After 2 to 5 days, the larvae hatch, start feeding on the pulp and make galleries in it. Generally, only one larva is found in one fruit. The excreta of the larva accumulate in the galleries, which may sometimes result in rotting of the fruit. Infested fruits become deformed and their growth becomes checked. A large number of such fruits drop off. The larval stage lasts 9 to 12 days. When full grown (6 mm length), the larva finds its way out by making a hole in the fruit skin and drops to the ground. The larva bores down into the soil up to a depth of 2 to 12 cm where it pupates. The pupal period lasts about 2 weeks after which the adult fly (5 to 8 mm long, 3 mm broad) emerges. There may be 2 or 3 generations of the pest during the active period (Batra, 1953), while the fruit matures (from November to April in north India).

6.6.1.1 Prophylaxis

To prevent infestation, prophylactic sprays can be carried out with 0.03 % oxidematon or dimethoate starting from the stage when 70-80 % fruits attain pea size and then repeating the spray at one-month intervals (Pareek and Nath, 1996). During the maturity of fruits, if necessary, spraying should be done with 0.5% Malathion + 0.05% sugar solution at weekly intervals. Malathion has been observed to dissipate quickly in ber fruits decreasing well below the tolerance level of 3 ppm within 2 days after spraying (Popli *et al*., 1980).

6.6.1.2 Control

Cultivation of the orchard soil during spring (Singh *et al.*, 1973 a), summer (Chundawat and Srivastava, 1978) and rainy season (Bakhshi and Singh, 1974) destroys the hibernating pupae by exposing them to bright sunlight and birds and thus the extent of infestation is considerably reduced. Heating the soil by burning grass and irrigation during the summer also kills the pupae. Infested fruits having larvae should be collected and buried.

Infected fruit have to be collected and destroyed. The pest has been effectively controlled by insecticidal spray schedules such as,

i) three applications of 0.1 % fenthion or two sprays of Endosulfan or Malathion (Chundawat and Srivastava, 1978; Patel *et al*., 1989),
ii) 0.005 % Fenvalerate or 0.0015 % deltamethrin or 0.05 % monocrotophos or phosphamidon (Bagle, 1992),
iii) two applications with 0.1 % Dichlorvos, one at pea stage of fruit and another after one month (Raghumoorthi and Arumugam, 1992) and Monocrotophos or Phosphamidon + carbaryl treatments (Patel and Patel, 1979).
Recent data on the efficiency of insecticides to control fruit fly have been given by Gyi *et al,*.(2003) and Gyi *et al*., (2003a) .

6.6.1.3 Resistant cultivars

Mann and Bindra (1976) reported that cultivars Sanaur-1, Safeda Selected, Illaichi, Mirchia, ZG-3 and Umran resisted fruitfly damage. Singh (1984 b) observed that the extent of infestation varied between cultivars from 6.7 % in Tikadi to 73 % in Gola, Gola Gurgaon-3 and Kaithli (Singh and Vashishtha, 1984) and that the percentage of larvae hatched also varied indicating varying degrees of resistance .

6.6.1.4 Biological control

This has not yet been developed. However, *Bracon fletcheri, Opius carpomyiae* and *Omphalina* sp. (Hymenoptera: Braconidae) have been recorded to parasitise fruitfly but could not provide effective control (Saxena and Rawat, 1968). *Biosteres carpomyiae* and *Opius fletcheri* (Hymenoptera: Braconidae) are also reported to parasitise fruitfly.

6.6.2 Fruit borer

Damage by larvae of the fruit borer moth *Meridarchis scyrodes* (Lepidoptera: Carposinidae) has been observed mainly in southern and western India (Sonawane and Dorge, 1971; Pareek and Nath, 1996). The reddish larvae bore into the fruit and feed on the pulp. The moths are dark brown.

6.6.2.1 Control

Chemical control consists of the following: first spray at pea stage with Monocrotophos (0.03 %), second spray after 15 days with Fenthion (0.05 %) and a third spray 15 days after the second spray with 0.01 % Carbaryl has been recommended (Pareek and Nath, 1996).

Collection and destruction of fallen fruits and digging the orchard soil under the tree canopy have also given good control. *Microbracon* sp. (Hymenoptera: Braconidae), and *Opius carpomyiae* (Hymenoptera: Braconidae) have been found to parasitise the borer. Resistant cultivars Banarsi Pewandi, Ajmeri, Gola Gurgaon and Jhajjar Selection have been found to be resistant to the pest.

6.6.3 Bark eating caterpillar

The caterpillars of *Indarbela quadrinotata*, *I. watsoni* and *I. tetraonis* (Coleoptera: Cerambycidae) have been reported to make winding galleries of frassy web on the stem near the forks and angles of branches. The caterpillar is hidden in the stem in the day-time and becomes active at night, eating the bark. Heavy infestation by this pest stunts the trees and adversely affects fruit yield.

The moth is pale with grey marks on the forewings. It lays eggs with the onset of the rainy season in batches of 15 to 25. A single female moth can lay 300 to 400 eggs. Incubation period lasts 8 to 10 days. After emerging, the caterpillars start devouring the bark. The dark brown, full-grown caterpillar is 37 to 50 mm long and has a dark head; its body is covered with long, thin hairs. The caterpillars pupate during the summer for about four weeks and from the pupae adult moths emerge, mate, and lay eggs again.

6.6.3.1 Control

Frassy galleries caused by the pest need to be removed and cleaned. Then 0.05% Monocrotophos is painted on the bark, followed by 0.2 % Trichlophos and 0.05 % Chlorofenvinsphos (Verma and Singh, 1975). Application of the solution, made up by mixing one litre of kerosene and 100 g soap in 9 litres of water, to the holes has been found to effectively control the bark eating caterpillar. Alternatively, each hole should be filled with a solution of 2 ml Monocrotophos or 20 ml Trichlorphon 50 EC or 30 ml Endosulfan 35 EC in 10 litres of water and then the holes closed with mud. The Dipteran, *Zenillia heterusiae* (Diptera: Tachinidae) parasitises *I. quadrinotata.*

6.6.3.2 Resistant cultivars

Singh (1984 a) found no cultivars that are resistant. However, pest-tolerant cultivars include, Rohtak Gola, Laddu Glory, Chuhara and Desi Alwar. Gola, Kaithli, Illaichi are susceptible (Verma and Singh, 1974; Mann and Bindra, 1977).

6.6.4 Hairy caterpillars

Hairy caterpillars (*Dasychira mendosa*, *Euproctis fraterna* (Lepidoptera: Lamantriidae), *Thiacidas postica* (Lepidoptera: Noctuidae)) feed on the young leaves and fruits. The older caterpillars spread in all directions and devour leaves and fruits and sometimes even tender shoots. They start eating new foliage as it grows after pruning and this is continued by overlapping generations. The full-grown larva is reddish brown with a dark brown head. The larva pupates on the plant in a yellowish, hairy cocoon from which a yellowish moth with pale transverse lines on the forewings emerges. It then lays flat, circular yellowish eggs in masses on the lower surface of the leaves. The females lay 92-241 eggs, which hatch in 9-14 days (Bhatnagar and Lakra, 1992). The pre-oviposition, oviposition and post-oviposition periods last 2, 1 and 4 days respectively, and the larval, pre-pupal, pupal and adult stages last 25-56, 2-3, 7-15 and 5-7 days respectively. As many as six generations each of 44-84 days' duration have been observed in a year.

6.6.4.1 Control

BHC 10 % can be dusted to control caterpillars in the young stages. All the instars were controlled by treatment with 0.1 % Carbaryl or Endosulfan or Trichlorphon or 0.05 % Methyl parathion (Verma *et al.,* 1972). Bhatnagar and Lakra (1992) obtained the most effective control of 3rd to 6th instar larvae by 0.005 % Cypermethrin, 0.0014 % Deltamethrin, 0.0075 % Fluvalinate and 0.0005 % Fenvalerate. A spray of 0.05 % Monocrotophos and 0.2 % Carbaryl (Killex carbaryl 50WP) was found most effective in controlling the pest (Pareek and Nath, 1996).

The hairy caterpillar is parasitised by *Apanteles taprobanae* (Hymenoptera: Braconidae), *Brachymeria* sp. (Hymenoptera: Chalcididae), *Charops obtusus* and *Goryphus* sp. (Hymenoptera: Ichneumonidae). *Exorista* species has recently been found to be a parasitoid of the caterpillar in Karnataka (Mani *et al.,* 2001).

6.6.5 Chafer beetle (ber beetle or leaf chafer)

Chafer beetles (*Adoretus decanus*, *A. kanarensis*, *A. stoliezkae*, *A. pallens*, *A. versutus*) (Coleoptera: Scarabaeidae) devour ber leaves mainly during the night. They become active with the onset of the rainy season when new growth starts. Leaves become like sieves and, in severe cases, the whole tree is rendered leafless. Eggs are laid in the soil during the early part of the rainy season (May to August in north India). Larvae hatch out in one week and feed on roots and vegetation. Adults emerge with the onset of rains. There is only one generation per year.

6.6.5.1 Control

Beetles can be controlled effectively by spraying 0.2 % Carbaryl 50WP and 0.05 % Monocrotophos (Pareek and Nath, 1996). *Adoretus pallens* can be controlled by spraying 1 % lead arsenate (Trehan, 1956). The beetles can be trapped by using any source of light and killed by dropping them into water containing kerosene.

6.6.6 Lac insect

Ber is a host of the lac insects, *Kerria lacca* and *K. sindica* (Li and Hu, 1994). The small insects become active in summer (April-May). They secrete a thick, resinous substance which envelopes their bodies. The secretions form a hard crust on the twigs, which is collected to form a commercial resin, lac. Lac production is an important business in India. However, the insect devitalises the tree and causes great loss in fruit production. It sucks the sap from the branches, and ultimately kills the tree. An infestation of 5000 nymphs/100 cm twigs caused a loss of 52.5-58.5 % fruit yield (Lakra and Kher, 1990). Obviously production of lac and fruits cannot be done simultaneously (see Plate 8).

6.6.6.1 Control

Infected twigs should be cut off at the time of annual pruning and destroyed. If required, this can be repeated after about 3 months. After pruning, the trees should be sprayed with 0.1 % Dimethoate or 0.03 % phosphamidon. The lac insect is parasitised by several wasp species, two species of moths and 3 species of lacewing flies. Cultivar Gola was found to be the most susceptible cultivar to the attack of lac insect followed by Kaithli and Umran (Lakra and Kher, 1990).

6.6.7 Other insect pests

The following may also cause damage on ber:

Leaf Hopper	*Zyginida pakistanica*
Mealy Bug	*Droschiella tamarindus*
Weevil	*Xanthochelus supercilosus*
Leaf Gall	*Phyllodiplosis jujubae*
Wax Scale	*Drepanococcus chiton*

6.6.8 Mites

Mites produce galls in floral buds preventing fruit production (Yamdagni and Gill, 1968). The mite, *Eriophes cernuus* occurs in India throughout the year (Mukherjee *et al.,* 1994). Galled tissues contain higher total carbohydrates and reducing sugars and more α-amylase activity compared to the normal tissue (Tandon and Arya, 1979). Treatment with 0.04 % dicofol gave the best control. The fungus, *Fusarium demicellulare* is found on the galls and this seems to check the development and spread of galls during the initial stages (Singh and Singh, 1978).

Incidence of the mite *Larvacarus transitans* can be high during June. Cultivar Sev was the most susceptible (Sharma, 1992). The population of the red mite was least on the leaves of cultivar Kaithli (Pareek and Nath, 1996).

6.7 Diseases

6.7.1 Powdery mildew

Powdery mildew (*Oidium erysiphoides* f. sp. *ziziphi*) causes great losses in ber in India, particularly in humid areas, and also in Africa. While most of the cultivars were observed to be susceptible at a humid location in southern India, 31 out of 66 cultivars observed by Lodha *et al.,* (1984), under the arid conditions of northwest India, did not show any symptoms of the disease. Maximum development of powdery mildew occurs when the maximum temperature is between 24-35^{o} C, minimum temperature between 4-22^{o} C, morning RH 64-91 % and evening RH 24-57 % (Pareek and Nath, 1996). Cultivar Umran was studied and similar results obtained (Thind *et al.* 2004). The disease occurs with increased virulence during high rainfall years (Sharma, 2003), and disease incidence can relate to time of pruning as well as to weather (Jamadar and Venkatesh*.,* 2003).

The symptoms of the disease are noticed on flowers and newly set fruits. The disease may appear earlier if conditions are favourable. The developing young leaves show a whitish powdery mass, which causes them to shrink and defoliate. The disease also appears in the form of white powdery spots on the surface of the fruits and later covers the whole fruit surface. The spots turn into light brown to dark brown discolouration. The infected area becomes slightly raised and rough. Affected fruits either drop off prematurely or become corky, cracked, misshapen and remain underdeveloped. Sometimes the whole crop is rendered unmarketable (see Plate 9).

The mycelium remains external on the host with white, single, upright conidiophores. The fungus survives in the bud wood of the host or in some alternate hosts during the absence of ber flowers and fruits. Mehta (1950) reported that the mycelium over-winters and arises annually in the new growth. These become primary sources of infection. Air-borne spores act as a secondary source of infection. The disease is observed on both cultivated and wild forms of ber.

6.7.1.1 Control

The disease can be controlled by spraying Dinocap (0.2 % Karathane WP or 0.1 % Karathane EC), 0.2 % Sulfex (Gupta *et al.,* 1977, 1978; Yadav and Singh*,* 1985; Singh *et al.,* 1995), 0.2 % Carbendazim (Yadav *et al.,* 1980; Singh and Sidhu, 1985) or Trideomorph (Singh *et al.,* 1995). According to Kapoor *et al.* (1975) spray of 0.07 % Karathane EC or 0.3 % Sulfex achieved satisfactory control. Multi-location trials in India have shown that fungicides such as Dinocap (0.1 %), Carbendazim (0.1 %), wettable Sulphur (0.2 %), Trideomorph (0.1 %), Sulphur dust (250 g/tree) and Thiophenate Methyl (0.1 %) were effective for the control of powdery mildew. Sharma *et al.*

(2001) evaluated Bayleton and Karathane sprays for control and both are effective but the former costs twice the latter. Starting with the initiation of the disease, 2 to 4 sprays at 15-20 day intervals should be carried out depending upon disease intensity. The time of spray is critical for effective control. Gupta *et al.* (1978) and Singh and Sidhu (1985) suggested that spraying should be started as soon as the disease appears on fruits of peanut size and repeated at 3-week intervals. In regions with an established record of recurrence of the disease, one spray of fungicide should be applied as a prophylactic measure as soon as growth appears after pruning (Pareek and Nath, 1996).

6.7.1.2 Cultivars

Although some cultivars have been reported to be resistant under field conditions (Jeyarajan and Cheema, 1972; Kapoor *et al.*, 1975; Gupta *et al.,* 1978; Lodha *et al.,* 1984), the reaction of these cultivars to the disease has varied at different locations and in different years. The disease affects several *Ziziphus* species and all the ber cultivars. Ber cultivars Illaichi Jhajjar, Gola, Seb, Safed Rohtak and Mehrun have shown comparative tolerance to the disease in northern India. Five local genotypes (Darakhi-1, Darakhi-2, Guli, Villaiti and Seedless) have been reported to be free from the disease. Umran Sandhura, Narul, Iuaichia and Kaithli are susceptible. Safeda Rohtak is a recent cultivar selected for resistance to powdery mildew (Godhara *et al*., 2002). Wax levels of immature fruits and leaves play a role in degree of susceptibility (Pradeep and Jambhale, 2001).

6.7.2 *Alternaria* leaf spot

Several species of *Alternaria* cause this disease, e.g. *Alternaria* anomorph of *Lewia (Pleospora) infectoria* (Gupta and Madaan, 1977 a), *Alternaria* anomorph of *Pleospora caricola, Pleospora passeriniana* (Panwar and Vyas, 1971), *Alternaria* sp. (Jeyarajan and Cheema, 1972), *Alternaria chartarum* (Rao, 1971), *Alternaria tenuissima* (Kanaujia and Kishore, 1977). In *Ziziphus oenoplia,* the disease is caused by *Annellophorella* (Chary and Ramarao, 1971).

The disease caused by the *Alternaria* anomorph of *Leiwa (Pleospora) infectoria*, produces small, irregular brown spots on the upper surface of the leaves and dark brown to black spots on the lower surface. The spots coalesce forming large blighted patches and the affected leaves drop (see Plate 10).

The disease develops at temperatures from 20 to 30^{o} C (Madaan and Chand, 1985), but high humidity and frequent rainfall appear to be more important. Plant debris seems to be a source of primary infection. Secondary infection is possibly caused by dissemination of spores under frequent rainfall.

6.7.2.1 Control

The disease can be controlled by spraying 0.3 % mancozeb or 0.2 % captafol or 0.3 % copper oxychloride (Pareek and Nath, 1996). Gupta and Madaan, (1978) recommended a spray of 0.2 % difolatan or Dithane Z-78.

6.7.2.2 Cultivars

Jeyarajan and Cheema (1972) found all 35 ber cultivars tested to be susceptible to *Alternaria* leaf spot disease. Cultivars Govindgarh Special, Gola, Gurgaon, Popular Gola, Seo-Bahadirgarhia, ZG-3, Sofed Rohtak and Jhajjar Special were reported to be resistant by Gupta and Malaan, (1978, 1980).

6.7.3 Black leaf spot

This is caused by *Isariopsis indica* var. *ziziphi* and is also known as *Isariopsis* mouldy leaf spot (Gupta and Madaan, 1977 b). The disease has been observed under comparatively humid conditions. (see Plate 11)

The disease is characterised by sooty tuft-like circular to irregular black spots on the underside of the leaves. Later, it covers the entire lower surface giving a sooty appearance. The leaves show yellowish and brownish discolouration on the upper surface and drop prematurely. The fungus survives in plant debris and soil, which are the primary sources of infection. Secondary infection is initiated from spores present in the air.

6.7.3.1 Control

The disease can be controlled by captafol (0.2 %), carbendazim (0.1 %), mancozeb (0.2 %) and copper oxychloride (0.2 %). The sprays should be applied 2-3 times at 15 day intervals starting with the first sign of symptoms (Pareek and Nath, 1996). Rawal and Saxena (1989) obtained good control by 0.1 % carbendazim and 0.2 % chlorothalonil. Sharma *et al.* (1983) obtained best control by 0.3 % zineb or 0.6 % Blitox. Singh and Andotra (1989) controlled the disease by sprays of 0.1 % Bengard and thiophenate methyl. Chand *et al.* (1986) recommended spraying 0.2 % carbendazim or captafol. Gupta and Madaan (1979) found a mycoparasite, *Hansfordia pulvinata* growing on the diseased spots which checked further disease growth on the host. More investigations are required on use of such biocontrol agents.

6.7.3.2 Cultivars

Ber cultivars Seo-Bahadurgarhia, ZG-3, Safed Rohtak and Sanaur-1 have been found to resist the disease infection in a multilocation trial in India (Pareek and Nath, 1996). Cultivars Mundia, Banarsi Karaka, Banarsi Pewandi and Bagwadi also showed resistance to the disease at some locations.

6.7.4 *Cercospora* leaf spot

Cercospora ziziphae (Rao, 1962; Yadav, 1963a; Govindu and Thirumalachar, 1964; Gupta and Madaan, 1975 b) and *C. jujubae* (Chona *et al.*, 1959; Vasudeva, 1960; Agarwal and Sahni, 1964; Golsen and Rubin, 1964) infect ber, but the former is the most common and occurs during spring. The disease manifests itself in the form of circular to oval spots, measuring up to 4 mm in diameter, epiphyllous, yellow at first and turning brown surrounded by a dark-brown margin. The spots grow larger and become visible on both sides of the leaves. The infected leaves fall off.

Cercospora leaf spot is also found on Chinese jujube, causing leaf yellowing.

The fungus produces dark coloured stroma. It survives in debris and soil, the primary sources of infection. The spores are disseminated by wind.

6.7.4.1 Control

The disease can be controlled by spraying 0.2 % Dithane Z-78 or Dithane M-45. Cultivars Safed Rohtak, ZG-3, Seo-Bahadurgarhia, Popular Gola, Rashmi and Jhajjar Selection were resistant to *Cercospora* (Chand *et al.*, 1986).

6.7.5 *Cladosporium* leaf spot

Cladosporium ziziphi (Uppal *et al.,* 1935; Prasad and Verma, 1970; Saini and Suppal, 1981) and *C. herbarum* (Gupta and Madaan, 1975b) cause this disease, with attacks occurring in the autumn.

The symptoms appear in the form of small, light brown to brown irregular spots on the lower surface of leaves. The disease starts on leaves closest to the soil surface, where the fungus occurs. It is also spread by spores present in the air. The fungal spores survive in plant debris and soil, the primary sources of infection.

6.7.5.1 Control

Two sprays of 0.2 % copper oxychloride or zineb or mancozeb should be applied at 2-week intervals (Pareek and Nath, 1996) starting from the appearance of the symptoms.

6.7.5.2 Cultivars

Cultivars Sandhura Narnaul and Jogia were found to be resistant. Chand *et al.* (1986) observed that cultivars ZG-3, Banarsi, Govindgarh Selection-3, Jhajjar Selection and Jogia were also resistant.

6.7.6 Rust

Although rust can be serious in ber, it is less so in Chinese jujube (see Plate 12).

Rust is caused by *Phakospora ziziphi-vulgaris* (Sydow and Sydow, 1907; Yadav, 1963b; Gupta *et al*., 1984). The disease appears towards the end of winter on the leaves in the form of small, irregular, reddish-brown uredopustules on the lower surface. Pustules aggregate on the tips and margins resulting in large necrotic spots and death of tissues. The infection advances over the whole surface and the infected leaves become dry and fall off.

6.7.6.1 Control

The disease can be controlled by application of 0.4 % copper oxychloride or 0.2 % zineb or captafol (Pareek and Nath, 1996). In Chinese jujube, the disease severity was reduced by 84.9-97.5 % after application of metalaxyl and Bordeaux mixture (Sun *et al*., 1989).

6.7.6.2 Cultivars

Chand *et al.* (1986) reported cultivars Banarsi, Seo, Katha Gurgaon, Gola Gurgaon-2, Dandan, Sanaur-1, Safeda Selected and Sanaur-3 to be resistant. Several other foliar pathogens have also been reported to infect ber (Appendix I).

6.7.7 Witches' broom

Witches' broom affects both Indian and Chinese jujubes (Kim, 1965; Zhu *et al*., 1983).

Pandey *et al.* (1976) first reported the disease in ber. The affected trees become weak and produce small, yellow leaves typical of other phytoplasma diseases. The disease is transmitted to healthy seedlings by budding and graftingwith diseased scions.

6.7.7.1 Control

The disease can be contained by treatment with 500 and 1000 ppm oxytetracycline. La *et al.* (1977) recommended control through transfer of 1000 ppm tetracycline hydrochloride into the trees from a plastic reservoir through plastic tubes. Wang *et al.* (1980) successfully controlled it by two commercial formulations of oxytetracycline.

6.7.8 Fruit rot

Fruit rot is caused by *Phoma hissarensis* (Gupta and Madaan, 1975 a), *Colletotrichum gloeosporioides* (Gupta and Madaan, 1977 c), *Trichothecium roseum* (Gupta and Madaan, 1977 c), *Alternaria* state of *Pleospora infectoria*

(Chand *et al.*, 1986), *Cladosporium hebarum* and a number of minor pathogens. Sources of resistance have been looked for by Nallathambi *et al.* (2000).

6.7.8.1 *Phoma* fruit rot

The disease appears on the ripening fruit. The infected fruits remain small and develop slightly depressed, dark brown spots near the stem ends. The lesions become irregular in shape and measure 15-25 mm in diameter.

The fungus survives in plant debris, the primary source of infection. The disease can be controlled by spraying of 0.2 % Dithane Z-78 or Dithane M-45 (Chand *et al.*, 1986).

6.7.8.2 *Alternaria* fruit rot

Slightly depressed, brown to dark brown, circular lesions appear on the fruit. Sometimes concentric rings are also present on these spots. The smaller spots coalesce to form larger spots. The fungus survives in debris and soil. The fruits touching the soil become infected and the disease spreads later by dissemination of spores through the air. The disease can be controlled by spraying of 0.2 % Dithane Z-78 (Chand *et al.*, 1986) (see Plate 13).

6.7.8.3 *Colletotrichum* fruit rot

The disease appears at the start of ripening of the fruit in the form of small, slightly depressed, light brown, water-soaked lesions. These spots coalesce and enlarge. Under humid conditions, the acervuli are formed in masses on these spots.

Being saprophytic the pathogen survives in soil, along with the debris, for a long period. This becomes the primary source of infection. The spores are present in the air and act as secondary sources of infection and are disseminated by rain splashes. The disease can be controlled by 2-3 sprays of 0.2 % copper oxychloride at 3-weekly intervals (Chand *et al.*, 1986).

6.7.8.4 *Trichothecium* fruit rot

The disease is observed during the spring in the form of pink spots on the fruits. The fungus can survive in the soil for a long time. Fruits touching the soil may become infected and develop symptoms.

6.7.8.5 *Cladosporium* fruit rot

The disease appears near the time of fruit ripening. Injured fruits become infected. The symptoms of the disease start from the tip of the fruit forming light brown to dark brown spots. Later, a greenish fungal growth is also seen on these spots.

6.7.8.6 Other fruit rot fungi

A range of minor fungal pathogens also cause fruit rot. They are listed by Chand *et al.* (1986).

6.7.9 Minor foliar pathogens

A range of minor foliar pathogens affect leaves of ber. They are also listed by Chand *et al.* (1986).

6.8 Cropping systems

Jujube species provide nutritious fruits at relatively low costs. Fruits are produced even under adverse agroclimatic conditions. Except for China, Vietnam and the Central Asian Republics jujubes are still produced under less intensive cropping systems, although more intensive orchards are increasing in India and Bangladesh.

In many areas, especially with arid zones, there is great interest in using *Ziziphus* species for hedging and enhanced local use at the smallholder level. This is being expanded, particularly in Africa, through agroforestry.

Preliminary results obtained from provenance trials conducted in African countries under the Semi Arid Lowlands of West Africa (SALWA) programme of the International Centre for Research on Agroforestry (ICRAF), have provided encouraging results. They show compatibility of ber within an agroforestry system and as a live fence along with other adapted tree species. In India, ber is one of the most suitable agroforestry trees in arid and semi-arid areas.

In China intercropping is widespread and this is increasing in India also.

At maturity, ber trees cover the entire inter-row spaces about five years after planting. In the meantime, considerable losses occur from vacant interspaces. By growing intercrops, the losses can be minimised and additional income generated. Intercrops such as mung bean, moth bean, cowpea, clusterbean and sesame can be grown under rainfed conditions during the summer. The yields of both ber and the intercrops are higher than in monoculture and no adverse effects are observed for up to five years after planting the ber trees (Singh *et al.,* 1997, Patel *et al.,* 2003). Under irrigated conditions, horse gram, cumin, chillies and other vegetables are more profitable (Pareek, 1983). In the semi-arid plateau of western India, a ber + clusterbean combination gave the highest net returns per hectare followed by ber + cowpea, ber + okra, and ber + brinjal combinations (Raturi and Chadha, 1993). Under arid and semi-arid conditions, strong competition has been observed by Khan (1993) between ber trees and crops like wheat and chickpea. He suggested that the cost of keeping *Ziziphus* trees was more than the value foregone by growing these crops. Thus, such crops should not be grown as intercrops in ber orchards (see Plate 14).

Cover cropping with kulthi (*Dolichos biflorus*) was found to increase water-holding capacity of light soils as a result of increased organic carbon content in arid regions of the tropics (Pareek and Nath, 1996). The legume *Stylosanthes hamata* is a good cover crop in the semi-arid regions of western India (Raturi and Chadha, 1993).

Ber trees fit very well into agroforestry systems when the companion species suited to the same agroclimatic conditions of the location are selected, e.g. the leguminous tree, *Prosopis cineraria*, under the arid climate of northwest India. However, appropriate spacing and management systems should be used. Most of such systems will be locally developed, although where governments have a national institute or programme dedicated to agroforestry research, sharing of experiences at diverse local levels can be expected.

Chapter 7. Breeding

A. Godara

7.1 Introduction

Plant breeders look for ideal plant types or ideotypes, in addition to selection for yield and other screenable characters. The idea is to combine maximum desirable traits in a cultivar. Characters that are determined by a few genes with clear effect are much simpler and more effective to select than traits determined by the additive effects of many genes, each having limited individual effect. Table 7.1 shows the desirable forms of some morphological traits as well as those for yield attributes in Indian jujube.

Table 7.1 Ideotypes of ber

Character	Ideotype	Character	Ideotype
Root system	Deep (> 2 m)	Fruit size	> 30 g
Canopy	Spreading, low headed and thornless	TSS in pulp	> 15^{o} Brix
Leaf area	High	Acidity in pulp	< 0.3%
Internodal length	Short (< 5 cm)	Fruit shape	Round to oval
Leaf colour	Dark green (chlorophyll > 0.04 mg/kg fresh wt.)	Fruit colour	Bright golden
Leaf surface	Glossy dorsal and tomentose ventral	Fruit surface	Glossy and smooth
Leaf size	Large (> 50 cm^{2})	Pulp/stone ratio	> 20

(Source: Pareek, 2001)

The inflorescence consists of male and hermaphrodite flowers. It is highly heterozygous because of cross-pollination. The existence of polyploidy and a range of self and cross incompatibilities in *Ziziphus* species has resulted in wide hybridisation. Current ber cultivars have evolved through selection of superior types from the wide natural variability. Some of the selected genotypes received widespread popularity and became established as cultivars suitable for orchard planting, although cultivars tend to lack good quality, or high productivity and tolerance to biotic and abiotic stresses. There is a need to improve the crop for commercial cultivation in different agro-ecological environments.

Various techniques of breeding can be grouped into broad headings viz., introduction, selection, hybridisation, polyploidy, mutation, breeding, biotechnological methods and genetic engineering. Like any other crop they have been widely used for improvement of tropical fruit crops. The investigations and breeding work required to develop *Z. mauritiana* and *Z. jujuba* into a commercial crop in Australia have been outlined (Possingham, 1990). Most of this chapter relates to Indian jujube.

7.2 Breeding objectives

The breeding programme must have well defined objectives which are both economically and biologically reasonable. Despite wide cultivar diversity of the two major jujubes, only a few cultivars are commercially important. It appears that productivity along with ability to withstand transport and storage are the basic requirements in a cultivar. In addition, it should have high TSS, good sugar-acid blend, crisp flesh, and good flavour besides resistance to common insect pests and diseases. Earliness is a desirable trait in cultivars meant for dry, rainfed regions or to be grown under irrigated conditions. The objectives for the breeding of ber have been described by Chadha (1998) and Ray (2002).

So far, yield and fruit quality are the traits that have received the greatest emphasis in ber breeding. Precociousness, profuse bearing, attractive fruit colour, crispy pulp, firm texture, high soluble solids, good eating quality, smaller seed size, long shelf life, resistances to pests, diseases and environmental stress have been other major objectives. Time of maturity is also an important characteristic to be considered. It is associated primarily with the response of genotype to photoperiod and temperature. Selection for time of maturity is a major initial step in evaluating genotypes and the extent and availability of variation among genotypes to hand greatly influence decision making. Limited variation in germplasm imposes restrictions. Setting the objectives must also take account that specific traits have different inheritance patterns. Variation in inheritance pattern of different traits can complicate the process of easy parent selection for crosses to be made.

Resistance to diseases, particularly powdery mildew (*Oidium erysiphoides* f. *ziziphi*) and *Isariopsis;* pests, like fruitfly (*Carpomyia vesuviana*) and fruit borer (*Meridarchis scyrodes*); salt and low temperature tolerances, giving good fruit set under high temperature conditions; and fruits with better eating and processing quality are major objectives for *Z. mauritiana*. Rootstocks suitable for high density orchards are also required. In *Z. jujuba*, resistance to cracking, disease resistance particularly JWB, and tolerance to high temperature are important. The present and future goals for cultivar improvement in China-Taiwan are presented for *Z. mauritiana* in preparation for World Trade Organization standards. The development of consumer orientated, small scale local and all year round producing cultivars is needed (Wang *et al.*, 1997 a).

7.3 Constraints/ bottlenecks in breeding

Ber breeding is hampered by the long juvenile phase, high heterozygosity (and cross-pollination), inadequate knowledge of inheritance patterns and well established pre-selection criteria of traits such as incompatibility patterns, sterility and fruit drop. The small size of flowers and their behaviour at anthesis dehiscence pose practical constraints in ber improvement.

Ber shows ranges of polyploidy and incompatibilities in its cultivars (Pareek, 1996). Most ber cultivars are tetraploids, showing much segregation. Accordingly, many cultivars have been reported to be reciprocally cross incompatible (Teaotia and Chauhan, 1963, 1964), while several cultivars including Umran are self incompatible (Godara, 1980). Godara (1980) showed cross compatibility in Illaichi x Kakrola Gola giving high seed set while the crosses Kathaphal x Safeda Selected and Kaithali x Kakrola Gola were incompatible. Umran show the best combining ability with other cultivars when used as female or male. Fruit set under open pollination ranged from 3.56% in ZG2 to 18.7% in Illaichi; Illaichi and Umran set fruit when flowers were bagged but ZG 2 and Sanaur 2 did not (Mehrotra and Gupta, 1985).

7.4 Breeding methods

Plant breeders need a range of germplasm carrying different desirable genes in order to combine such genes through recombination breeding. The acquisition of diverse and elite germplasm from exotic sources is an important activity in germplasm management.

7.4.1 Selection

Most of the cultivars of ber grown in tropical, subtropical and temperate regions of the world are straightforward historical selections. Major emphasis has been put on clonal selection especially of early maturing clones. The local cultivars are the result of selection made by local people.

Selection does not create genetic variability but merely acts on the genetic variability already available. Thus the breeder must first create a variable population through building up a collection of a large number of genotypes from different regions and/or countries. Selection is straightforward in an asexually propagated crop since any genotype may be perpetuated intact; however, the measure of success is how to test for the most desirable genotypes. Obtaining segregating populations, from which superior genotypes may be found, is difficult in asexually propagated material. Unfortunately, the most desirable selections do not always make the best parents; consequently, potential parents are best selected on the basis of progeny performance.

A wide range of variability exists in ber in India for all important characters suggesting substantial scope for improvement. An early maturing clone, Early Umran (Pareek, 1996) has been identified from normally late maturing Umran. Promising cultivars under commercial cultivation are Gola, Seb, Banarsi Karaka, Banarsi Peondi, ZG-1, Sanour-1, 2,3,4, Kath, Umran, and Mundia. Gomakirti is a clonal selection from Umran which flowered 25 days earlier. A recent selection, CIAH Sel-1 developed by CIAH Bikaner, from local material collected from Bhusawar area of Rajasthan, is more juicy and sweet and is also an early bearer besides being resistant to fruit rot (Shukla *et al*., 2004).

A clonal selection for earliness with quality fruits and better storage life with consistent productivity from Umran was identified at Central Horticultural Experiment Station, Godhara, and Gujarat, India. After evaluation trials, the selection was found to be early compared to Umran, flowering three weeks earlier, and it matured with the early cultivar Gola. It has been released as Goma Kirti (Hiwale, 2005).

The distribution and vegetative and fruiting characteristics of *Z mauritiana* trees in the Korean Republic were studied between 1968 and 1971. Thirty six strains scored high marks on a selection scale for disease resistance, high yield and fruit quality and five were selected for general use (Kim *et al.*, 1980). Wonye-A-Ol was selected from 254 lines developed from Moodeung and Geumsung (Kim *et al.*, 1988). Gaolang 1 is a selection of *Z. mauritiana* from Taiwan (Chen *et al.,* 2000). In Azerbaijan, Tagiev (1976) evaluated 3762 seedlings. The best 40 were selected, of which 25 were included as elites. The eleven best forms were given cultivar names: the major ones being Nasimi, Mardakyan, Akhmedi, Khazari and Irada. Two small fruited forms were selected for use as rootstocks.

Several attempts have been made in the recent past to select high yielding, better quality *Z. mauritiana* in China (Yu *et al.*, 1991 and Zhu *et al.*, 1998). Some of these selections have been described: Lejin-1 and Lejin-2 (derived from Jinsixlao Zao) and Leling Seedless-1 (derived from Wahexiaozao or Seedless Xiaozao). All these have larger fruits, better eating quality and higher resistance to fruit cracking. Six Chinese cultivars: Sovetskii, Tavrika, Tayantszao, Suontszao, Druzhba and Kitaiskii, have been reported to be promising in the Ukraine (Sin'ko and Litvinova, 1996). Recently five superior Russian cultivars (Yuzhanin, Khurman, Burnim, Kitaiskii-93 and Finik) have been registered (Kudenkov and Beloshtskaya, 1998). Cultivar Jinsixiaozao was closely related to Wuhexiaozao, Wuhexiaozao might have evolved from Jinsixiaozao, and Guangyangzao was closely related to Chuanganzao (Peng *et al.*, 1996).

Yanliang xiaozao is a cultivar selected from Lintong Chizao jujube orchards in Yanliang District, Xi'an, China (Li *et al.*, 2004 a). Juzhou Gongzao is derived from a chance seedling (Ma *et al.*, 2000). Cangwu 1 and Cangwu 3 are selections of *Z. jujuba* cv. seedless (Ji *et al.*, 2001). Jiaxian Youzao was selected from *Z. jujuba* cv. Zhongyang Muzao orchards in Jiaxian country in Shaanxi, (Li *et al.*, 2003). Qiyuexian was selected as a highly nutritious clone suitable for the production of table fruits in Heyang country, Shaanxi Province, (Wang *et al.*, 2003). Two cultivars with good emergence were selected; Gissarskii Semennoi-3 (Gissar seed) and Gissarskii Semennoi-7, (Massover 1976).

7.4.2 Hybridisation

Combining characters by sexual crossing is by far the most popular method for obtaining plants that have more favourable combinations of desirable traits. When the characters are distributed in many cultivars, or the desirable characters are associated with many undesirable ones, the procedure requires many crosses and many generations. It has two main virtues: one is to increase the genetic variation in plants and their progenies and to keep the population stable, while the other is to increase plant vigour and thus make the plants or cultivar more able to compete with others. Not all hybrid combinations result in above average vigour (heterosis) but commercially desirable types can be identified by suitable experimentation.

In perennial fruit trees improvement through hybridisation requires several decades. For vegetatively propagated fruit crops the aim is a single desirable genotype. This genotype may be of any degree of heterozygosity with no problem of genetic maintenance due to asexual propagation. Asexually propagated crops are usually cross pollinated and consequently highly heterozygous, thus in developing populations from which to select a desirable genotype, inbreeding should be avoided. Unrelated plants are usually hybridised in order to obtain a vigorous population from which the most desirable individuals may be selected. Once a good genetic combination has been identified it can be propagated immediately as a new cultivar.

In order to find superior hybrids with a wide range of fruit traits, as well as adaptation to diverse climates, several cultivars have been used in India as parents. Extensively used ones are Umran, Banarsi Karaka, Kakrola, Gola, Mundia Murhara, Sanori, Illaichi, Safeda Selected, Kaithali, Reshmi, Chhuhara and Seb. At Hisar, Umran and Banarsi Karaka were used for high yield, Gola for quality and earliness, Illaichi for profuse bearing, BS 7S-3 for drought and fruit fly tolerance, Reshmi for fruit quality and Mundia Murhara and Kathaphal for attractive colour and fruit quality (softness). At Jodhpur, Katha was crossed with Seb and Seb with Tikadi (Pareek, 2001). At the CIAH Bikaner, CIAH hybrid 1 (Seb x Katha) was found to be a promising, precocious, prolific bearer, and early maturer with good fruit set at high temperature under arid conditions (Shukla *et al.*, 2004). For fruit fly resistance BCF1 (Seb x Tikadi F_1 x Seb) is under evaluation (Anon., 2002).

Fruit setting of four *Z. mauritiana* cultivars (Umran, Karaka, Popular Gola and Chhuhara) after pollination with powdery mildew resistant cultivars Villaiti, Darakhi 1, Darakhi 2 and Guli was observed. The best female parents were Umran and Gola, both setting fruit with each of the pollinators, whereas, the best male parent was Darakhi 2, setting fruit with each of the female cultivars (Karale *et al.*, 1992).

Hybridisation to evolve superior quality, high yielding, early and drought tolerant cultivars was taken up at Hisar, and for inducing long shelf life and resistance to fruit fly at Jodhpur. Evaluation of hybrids is in progress.

The cultivar Seb was crossed with a local cultivar, Tikadi, resistant to fruit fly (*Carpomyia vesuviana*) in order to develop a pest resistant cultivar. The F1 was 90 % resistant, but had poor fruit quality. By backcrossing to Seb, a BCI line with 87-90 % resistance and desirable fruit characters was obtained. A mean of 13 % fruit fly infestation was observed in this line, along with a high level of antibiosis. Fruits weighed around 16 g (4.5 g in the F1) and Brix value was 24^0 (Faroda, 1996).

By crossing large fruited introduced *Z. jujuba* cultivars Tayan-tszao, Dardomskii, Yubilainyi with a local small fruited form, diverse new material was produced in Azerbaizhan. These exhibited large fruit and good flavour, high yield and disease resistance, including the variety Khurman (bred using Tayan-tszao). This had large fruits weighing 15-17 g, with an acid sweet flavour, a thin skin and tender flesh (Akhundova and Agaev, 1989).

More information is needed on the relationship between *Z. jujuba* and *Z. mauritiana*, on the possibility of hybridising the two groups, on the chilling requirement of *Z. jujuba* and the frost tolerance of *Z. mauritiana*. Although Meyer (1911) travelled widely in China more than 60 years ago and introduced many of the then best cultivars to the USA, there are probably others that would be of value in USA. Meyer mentioned a 'seedless jujube cultivar: Wuhu tsao had a kernel so soft that it is almost imperceptible when eaten'. He was told that this was the only seedless cultivar in China. Meyer also mentioned several flat-fruited jujubes, a white-fruited jujube and the quaint 'dragon's claw' jujube, which had peculiar gnarled and twisted branches and was cultivated as an ornamental (Meyer, 1911). India may also have jujubes that would be useful in USA. The US Department of Agriculture initiated a jujube breeding programme at Chico, California in 1952 but this was terminated about 1959 (Ackerman, 1961).

7.4.3 Mutation

Changes in individual genes or whole chromosomes introduce new heritable characters known as mutations. Mutations provide a valuable source of variation in plant material from which the breeder can make selections. In nature, gene mutation occurs at a very low frequency, but the rate can be speeded up and mutation can be induced artificially by ionizing radiation, non-ionising radiation, and by treating with chemical mutagens such as ethyl methane sulphonate, diethyl sulphate, nitroso-compounds (nitrous acid), nucleoside analogues and sodium azide. Since a number of useful alterations have been accomplished by means of induced mutations, it has been tried successfully in many fruit crops. Mutated shoots or other parts can usually be propagated readily after recognition of a desired mutation. This makes it possible to improve one or a few characters of leading cultivars without changing the remaining, unique, genotype.

The heterozygosity of most vegetatively propagated plants is another cause of increasing application of mutation breeding to them. In such plants mutations, from dominant to recessive, can be observed in the irradiated material itself, especially when easily selectable characters (form, colour, size) are concerned (Broertjes, 1968).

The use of spontaneous mutants with an improved agronomic or horticultural value is probably as old as agriculture itself. Most early examples, often outlined in extensive reports, refer to so-called bud mutations in vegetatively propagated crops such as fruit trees, ornamentals etc. (Darwin, 1868; Shamel and Pomeroy, 1936). Somatic mutations of spontaneous origin within vegetatively propagated material are commonly referred to as sports. Desirable mutations occurring in adapted, asexually propagated plants may result in an immediate improvement. Tainung No.1, a bud sport of Kaolung No.1, was found in Pintung, Taiwan (Chang *et. al*., 2001). Thereafter, the Fengshan Tropical Horticultural Experiment Station conducted a stability evaluation on this new selected mutation cultivar in 1992 and 1993, and confirmed that this new cultivar was a hereditary cultivar. Luyuan Xiaozao is a sport of Xiaozao discovered in 1990 in Zhangjiapo, Yiyuan country, China (Li *et al*., 1996).

Mutations that occur in somatic tissue may be confined to only a sector of tissue, resulting in a chimera. Such chimeras, when vegetatively propagated, tend to be unstable because buds may be formed from tissue with or without the mutation. The selection of desirable sports is an important means of improving asexually propagated crops.

Artificially-induced mutation has been used. The highest induction with colchicine treatment (0.15 %/18 h) was 50 % in cv. Linyilizao and 43.3 % in Dongzao and Lajiaozao reported by Jiang and Liu (2004). The chromosome number of the mutated plants (2n = 4x = 44) and DNA content were both twice that of the control. Useful mutants have also been produced by gamma irradiation and colchicine treatment in *Z. jujuba* (Akhundova and Agaev, 1989). Variation in seedlings of *Z. jujuba* after treatment with ethyeneimine, ethyl methanesulphonate, dimethyl sulphate; and gamma radiation was observed and some propagated vegetatively for further trials (Sin'ko and

Chemarin, 1979 b, 1982). Sin'ko and Chemarin (1979 a) reported on seeds of *Z. jujuba* irradiated at 0.1 to 100 Krad some 60-98 % germination obtained from seeds treated with low doses (0.5-2.0 Krad). The 30 Krad dose was critical. The treatment had no effect on the rate of emergence. Treatment with 0.5-5 Krad stimulated seedling growth, development of lateral shoots and root length and advanced cropping whereas higher doses inhibited these processes.

Colchicine and ethyl methanesulphonate treatments of *Z. mauritiana* increased crossability and reduced premature fruit drop (Gupta and Minhas, 1991). Gamma irradiation resulted in high fruit set.

Mutants selected following N-methyl-N-nitrosourea treatment (0.02-0.04 % for 12 h) of pregerminated seeds of *Ziziphus mauritiana* cultivars included cultivar Ma Hong, which maintains the early maturity of its parental cultivars, Gia Loc, allowing two harvests per year. Fruits, however, are round rather than oval, pink rather than yellow and sweet rather than sour. Also released is Dao Tien, which produces round fruits which are larger (25 vs. 20 g) with better flavour than those of its parental cultivar, Thien Phien. It also is one month earlier in maturity, allowing two harvests/year rather than the one produced by Thien Phien (Hoang and Tuynh, 1989). Sin'ko and Chemarin (1979 b) studied the seeds of four cultivars treated with various concentrations of ethylene imine, ethyl methanesulphonate and dimethyl sulphate. Some morphological changes induced in the first year, which included shortened internodes and altered leaf shape and size, were retained in subsequent years. Treatment tended to delay flowering, especially in Nikitskii-58, but increased precocity, with numerous seedlings fruiting in the third year.

7.4.4 Polyploidy

Another technique for improvement is exploitation of polyploidy; the condition of chromosome duplication giving numbers of chromosomes over and above the basic duplicate number. Unless the number of chromosomes is an exact multiple of the diploid, the polyploid is unstable and gives rise to gametes with irregular numbers of chromosomes. Gametes with irregular numbers may combine in a fortuitous manner however, to give rise to a polyploid with even chromosome numbers (a multiple of the diploid), and plants from the newly formed seeds may then be fully fertile. Any sterility results from the inability of chromosomes to pair at meiosis; fertility is restored by doubling the chromosome number of the sterile hybrid or by crossing autotetraploids of each species.

Polyploidy may be important in conferring desirable characteristics. Polyploidy may be artificially induced by using colchicine at a concentration of 0.05 to 0.3 per cent. Induced polyploidy makes it possible to overcome sterility associated with interspecific hybrids.

Transfer of powdery mildew resistance from diploid genotypes of *Ziziphus* to tetraploid cultivars required doubling of chromosomes in resistant genotypes in order to overcome the possible post-fertilisation barrier. Attempts have been made to induce polyploidy in some of the resistant diploid genotypes of *Ziziphus* that were confirmed cytologically (Pradeep and Jambhale, 2003).

The behaviour at meiosis e.g. bivalents and quadrivalents can show some cultivars of *Z. mauritiana* are cytologically alloploid (Pradeep and Jambhab, 2002). The numbers of stomata and chloroplasts in diploid, tetraploid, pentaploid and octaploid *Z. mauritiana* genotypes indicate significant differences in stomatal dimensions, frequency of their occurrence and chloroplast number per two stomatal guard cells among the different ploidy levels. However, no significant differences were observed between pentaploid and octoploid genotypes for these attributes, indicating the deleterious effects of high gene dose beyond the pentaploid level (Pradeep and Jambhale, 2000). In a triploid *Z. jujuba* (*Z. sativa*) cultivar the water saturation deficit, transpiration rate and daily maximum transpiration rate were lower than two diploid cultivars (Wan, 1994).

7.4.5 Biotechnological methods

7.4.5.1 Tissue culture

Tissue culture is one of the most widely used techniques for rapid asexual *in vitro* propagation. This technique is economical in time and space, affords greater output, and provides disease free and elite propagules. It also facilitates safer movements of germplasm between nations.

Protocols have been developed for clonal propagation of *Z. nummularia* and *Z. mauritiana* (Rathore *et al.*, 1992) and of *Z. jujuba* (Zhao *et al.*, 2001). Methods for rapid *in vitro* multiplication of ber using stem explants of mature trees have been developed (Yan *et al.*, 1990; Mathur *et al.*, 1995). Benzyladenine promoted bud differentiation and IBA promoted root growth when added to MS medium on which stem segments of *Z. jujuba* lines A17, A27 and A80 were cultured (Yan *et al.*, 1990). Gola and Seb cultivars of *Z. mauritiana* take 150 days from initial culturing to transplanting (Goyal and Arya, 1985).

The present taxonomic systems of ber and Chinese jujube are based mainly on morphological characters, utilisation or distribution, which cannot accurately reflect the genetic relationship and result in serious nomenclature problems. This situation has hindered the scientific exploitation, germplasm conservation and academic exchange of jujubes. Use of molecular markers can facilitate proper identification of genotypes and help to overcome the problem of duplicity in genebanks. Raja (2004) looked at the technique to identify 12 ber genotypes at Hisar, India for categorisation and identification by molecular markers. DNA finger printing is used to identify genes resistant to biotic and abiotic stresses. Such research deserves the attention of scientists and need to be initiated on priority.

A protocol was developed for RAPD analysis of *Z. jujuba* Zanhuangdazao; Zanxindazao clones and a total of 70 bands were amplified where 19 (27.14 %) were polymorphic (Zhao and Liu, 2003). Jiang *et al.* (2004) standardised tube-shoot multiplication in *Z. jujuba* var. *sihongensis.* A medium of direct regeneration of seedlings from stem fragments of jujube has been reported by Chen *et al.* (2005) and Wu *et al.* (2004). *Z. jujuba* buds and stem with side buds culturing in media MS + 6 – BA (4 mg litre^{-1}) + IBA (0.3-0.4 mg litre^{-1}) produced 100 % of regeneration of adventitious buds and 4.15-4.19 fold proliferation (Wang *et al.,* 2002).

7.4.5.2 Genetic engineering

Genetic engineering involves three major steps: identification and isolation of suitable genes for transfer; a delivery system to insert desired genes into recipient cells; and an expression of new genetic information in recipient cells. Transgenic Chinese jujube plants have been obtained using young stems precultured for one day and infected with *Agrobacterium tumefaciens* which contained the anti-ACC synthase gene (He, 2004 b).

7.4.5.3 Molecular markers

The possibilities of using gene tags or molecular markers for selecting agronomic traits have made the job of the breeder easier. It has been possible to score the plants for different traits e.g. disease resistance, at the seedling stage itself. The uses of RFLP (Restriction Fragment Length polymorphism), RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism) and isozyme markers in plant breeding are numerous.

The genetic relationship between 27 cultivar strains, and related species (*Z. acidojujuba* and, *Z. mauritiana*) of *Z. jujuba* were studied using random amplified polymorphic DNA (RAPD) technique by Lui *et al.* (2003). They reported a total of 92 DNA bands were amplified with 15 primers screened from 80 arbitrary 10-mer primers, 77 of which (83.7 %) were polymorphic beside. RAPD fingerprint of 11 excellent strains of Zanhuangdazao were established using five primers. The S154-780 bp band was regarded as a molecular marker linked to the stoneless character according to the study of 17 samples of two closely related groups viz., Jinsixiaozao (with stones) and Wuhexiaozao (without stones).

The DNA based marker systems, namely, random amplified polymorphic DNA (RAPD) and restriction fragment length polymorphism (RFLP) have been used in ber. RAPD analysis of germplasm resources on Chinese jujube has also been reported by Peng *et al*. (2000). Genomic DNA was isolated from leaves of *Z. mauritiana* suitable for RAPD analysis without liquid nitrogen, making it advantageous over other common protocols (Sharma *et al.*, 2003). Polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) can be used to determine the relationships among the phytoplasms infecting various woody host species. Amplification of the DNA with primers specific to the 16S rRNA gene generated a 1.4 kb band in *Z. jujuba* (Han *et al.*, 1996). *Ziziphus jujuba* has been reported to be infected with phytoplasms in Korea. Isolation and PCR amplification of genomic DNA from *Ziziphus nummularia* has been reported by Shukla *et al*. (2000).

7.4.5.4 Embryo rescue

Embryo rescue is another area where plant breeders are able to rescue their crosses which would otherwise abort. Culture of excised embryos at suitable stages of development can circumvent problems encountered in post zygotic incompatibility. This technique is highly significant in intractable and long duration horticultural species.

Most cultivars of Chinese jujube have very serious embryo abortion (Qi and Liu, 2004). Liu and Qi (2004) established an optimised system for embryo culture in order to get hybrids of four excellent cultivars Dongzao, Jisifeng, Wudeng, and Fuzao. Embryo rescue techniques may help developing hybrids of suitable combination in Indian ber especially in sterile and incompatible cultivars. Plant regeneration by somatic embryogenesis has been attempted successfully in Chinese jujube by Mitrofanova *et al.* (1997).

7.4.5.5 *In vitro* screening

The flower number per fruit branch, pollen number, time of anther dehiscence, pollen germination percentage, pollen vigour and storage of pollen collected at different stages of flowering in *Z. jujuba* and var. *spinosa*, have been studied *in vitro* by Liu *et al.* (2004b). The two taxa varied in flower number per fruit branch, pollen number and pollen germination percentage and these parameters were grouped in three grades by probability grading for quantitative characters. The time of anther dehiscence in both the species was at the yellow bud stage or bud breaking stage. The pollen germination percentage after storage showed a drop-rise-drop tendency.

7.4.6 Current situation

The enormous variability in *Z. mauritiana* and *Z. jujuba* and related species has been inadequately exploited. Most breeding work has been done in India and China. There is tremendous scope for using improved methods.

Ber has attracted sustained breeding attention owing to its wide adaptability, good quality and nutritive fruits. However, problems like poor shelf life, powdery mildew disease, fruit fly and fruit borer have hindered the extension of the area under this crop. In Chinese jujube the problem of fruit cracking and jujube witches broom disease are the major hindrances to be addressed.

Thus the following priorities are identified for:

- Systematic collection, characterization of germplasm and identification of cultivars with desirable traits.
- Study of patterns of inheritance of many qualitative characters.
- Breeding for cultivars to suit different agroclimatic conditions.
- Development of resistance to biotic and abiotic factors including fruit cracking.
- Development of quality cultivars with attractive golden yellow colour and good keeping quality.

Chapter 8. Genetic Resources

A. Godara

8.1 The *Ziziphus* genepool

Chapter 1 pointed out that the two major cultivated species are widely distributed in suitable climates in Asia and they cover vast regions. Most of these distributions comprise wild or naturalised materials superimposed on the patterns of distribution in the areas where the species are cultivated.

The wild populations are heterozygous and extremely variable and it is from these that farmers have selected the best trees in terms of production and propagated them vegetatively, but are now doing so more and more through grafting. Indian jujube is not easily propagated through cuttings but Chinese jujube is. A study of wild populations of Chinese jujube has identified promising types to use as germplasm (Liu and Wang, 1991).

As a result of the millennia of local selection many cultivars arose, some of which have become widely recognised.

Nonetheless, virtually nothing is known about the patterns of genetic variation in the wild populations of any of the other cultivated species of jujube. Nor has there been much research on identifying the traits of the large number of *Ziziphus* species. What little is known will be apparent from the following sections of this chapter.

8.1.1 Chromosome numbers

A good number of chromosome counts have been made for the two major cultivated jujubes. The counts are not always easy to interpret because a range of synonyms were used for the taxa investigated and without voucher specimens some counts can be interpreted differently. However, it appears that Indian jujube is usually polyploidy with counts of n = 12, 20, 24, 30, 36, or 48. Khoshoo and Singh (1963) looked at a range of cultivars and found n = 24 in most, but in two it was n = 48 and in one it was n = 30. In some wild material. Nehra *et al.* (1983) found n = 48; and also in naturalised 'wild' material it was the same count.

Not too many wild species have been counted but from the few that have (particularly *Z. lotus, Z. nummularia and Z. oenoplia)*, n = 10, 12, or 36. *Z. lotus* appears to be diploid, *Z. oenoplia* tetraploid and *Z. nummularia* shows a polyploid series. The possibility exists that the genus is tribasic with x = 10, 12, or 13 (Darlington and Wylie, 1955).

It is now generally thought that Indian jujube shows a range of polyploids: diploid, triploid, tetraploid, pentaploid and octoploid (Mehetre and Dahat, 2000). Chinese jujube also represents a polyploid series, chromosome counts tending to represent 2n = 45, 60, 90.

The phylogenetic relationship between the two major species (*Z. mauritiana* and *Z. jujuba*) has not been worked out nor has their cross compatibility been investigated. Chinese jujube exhibited high diversity in chromosome karyotypes, shape, size and surface sculpture of pollen, leaf length and flower diameter, shape, colour, weight of fruit, growth period and soluble solids and ascorbic acid of fruits.

The level of ploidy appears to be important for some cultivars of Indian jujube. Tekale (1997) noted that powdery mildew resistant genotypes were diploids and a seedless form was octoploid. However, other diploid cultivars were susceptible to powdery mildew.

More focused research is needed to see whether cytology relates to specific patterns of adaptation or to other types of variation, especially in wild materials. Knowledge of basic cytology is needed to plan introgression from wild species or for planning a crossing programme.

8.1.2 Hybridisation

The taxonomic literature on *Ziziphus* refers to reputed hybrids between certain wild species. It is highly likely that a number of the taxa generally accepted will turn out to be stabilised hybrid segregates. Further insight into this could be useful in relation to genetic resources for use in breeding.

In practice, improvement programmes have not yet successfully used hybridisation with wild species, although such interspecific hybridisation would be of potential value to expand adaptation of cultivars to wider ecological areas and to introduce resistances to pests and diseases.

In Indian jujube there in a long juvenile period and as with any woody perennial this poses constraints. Additionally, in both major cultivated jujubes the flowers are very small and the procedures for making crosses are delicate. For hybridisation between cultivars, constraints may arise due to some being incompatible with others and the presence of polyploidy; again emphasising the need for more cytological investigation.

A number of the constraints can be overcome by the use of tissue culture, particularly for rapid propagation and overcoming the need to wait for seasonal growth. Use of shoot tips of Indian jujube is now practicable (Sudherson *et al.*, 2001; Hu *et al*,. 2001; Mathur *et al.*, 1993). For Chinese jujube see Kim and

Lee, 1988; Metrofonova and Shevelukha 1995; Zhao *et al*., 2001; Liu and Qi, 2004).

8.2 Cultivars

The majority of cultivars of both Indian and Chinese jujubes are selections from heterogeneous populations. Superior genotypes had been protected and used over millennia by local people so that location specific cultivars are widespread. Those that are used nowadays tend to be propagated clonally and some have become very widespread e.g. Umran in Indian jujube; or Sui Men or Li in Chinese jujube.

The cultivated ber has more than 300 varieties but only a few are commercially important (Pareek and Nath, 1996). Over 180 named cultivars have been mentioned in the literature (Pareek, 2001). Numerous cultivars have been selected during a long period. A Chinese work published over 300 years ago listed 43 cultivars (Locke, 1948). In China, there are at least 400 cultivars of Chinese jujube (Hayes, 1945) but Qu and Wang, (1993) have reported more than 700 cultivars. These can be divided into two groups: the sour type mainly used as rootstocks, medicines or animal fodder, and the cultivated type (Ciminata, 1996). Information on genetic resources of *Z. jujuba* in Tongyu county, Jilin province, China has been given by Wang *et al.* (1999 b).

8.2.1 Morphological variability and characterisation

A wide variation due to cross pollination is exhibited by the jujubes in vegetative, leaf, floral, fruit and quality traits. Variation in morphological and physicochemical characters of ber cultivated types have been reported by Shobha *et al*. (2001) and many others. Details of the morphological variability in ber are provided below in order to illustrate constraints in attempting to classify cultivars and to sort out descriptors for characterisation.

8.2.1.1 Variations in vegetative characters

The most appropriate vegetative characters for classification are leaf area and branching habit, while the most dependable fruit characters are apex type, stalk and stylar flesh cavities and shape (Bal, 1992). *Ziziphus mauritiana* genotypes Umran, Illaichi, Desi-1 and Desi-3 plants have a spreading habit, whereas, Kathapal and Desi-2 plants exhibit a semi-spreading habit. The cultivars of Gola group (Gola Gurgaon No. 3, Bhadurgarhia Gola, Dankan Gola, and Kakrola Gola) produce erect plants (Gupta *et al.,* 2003).

Leaf margins of some cultivated and wild forms of ber variously referred to as *Z. mauritiana*, *Z. rotundifolia* or *Z. nummularia* are serrated except in Desi-3 and Jharber as reported by Gupta *et al.* (2003). Chitkara and Khera (1973) evaluated 15 varieties for leaf area. The product of maximum leaf length x breadth had a highly significant positive correlation with planimeter measurement of leaf area. The varieties may be classified into three groups, according to the percentage variation around the planimeter values. A non-destructive method of determining leaf area using linear parameter has been described (Hiwale and Raturi, 1991). The minimum stomatal density, internodal length and plant height were recorded in Gola budded onto *Z. nummularia* and was found to be the most dwarfing combination. Whereas, scion combination of Ponda budded onto rootstock *Z. mauritiana* ecotype-Assam-Gauhati was found the most vigorous, and the maximum stomatal density, internodal length and plant height were observed. The rootstock *Z. mauritiana* ecotype-291 was found most compatible and moderate in plant growth, stomatal density and internodal length thereby giving moderate vigour to trees (Verma *et al.,* 2001).

A range of variability in leaf size, shape, area and colour of 50 cultivars of *Z. mauritiana* can be seen in Plate 15. The list of cultivars is:

1. Banarsi Karaka; 2. BS-75-1; 3. BS-75-2; 4. BS-75-3; 5. Chhuhara; 6. Chonchal; 7. Dandan; 8. Desi; 9. Gola; 10. Gola Gurgaon No. 2; 11. Gola Gurgaon No. 3; 12. Golar, 13. Gora; 14. Govindgarh Special; 15. Hsiang Taso; 16. Hsiang Tsao Chinese; 17. Hybrid G 1; 18. Illaichi; 19. Illaichi Jhajjar; 20. Jhajjar Special; 21. Jogia; 22. Jullundhari; 23. Kaithali;, 24. Kakrola Gola; 25. Katha Gurgaon; 26. Katha Rajasthan; 27. Kathaphal; 28. Kishmish; 29. Laddu; 30. Mirchia; 31. Mundia Murhara; 32. Nari Kali; 33. Narma; 34. Noki; 35. Pathan; 36. Ponda; 37. Popular Gola; 38. Rashmi; 39. Safeda Rohtak; 40. Safeda Selected; 41. Sandhura Narnaul; 42. Sanori No. 1; 43. Sanori No. 3; 44. Sanori No. 5; 45. Seo; 46. Seo Bhadurgarhia; 47. Sua; 48. Tasbtaro; 49. Thornless; 50. Triloki No. 1.

Metroglyph and index score analysis showed wide morphological variation in 80 germplasm accessions of *Z. mauritiana* and eight distinct groups were recognised on the basis of variation in 23 morphological and fruit characters (Pradeep and Jambhale, 2002). Paired spines were observed in many cultivars of *Z. mauritiana* like Umran, Kathaphal, Gola Gurgaon No. 3, Bhadurgarhia Gola, Dankan Gola and Kakrola Gola (Gupta *et al,.* 2003).

8.2.1.2 Variations in growth characters

Variation in the height (cv. Gola tallest and Akola shortest), spread (cv. Akola maximum spread) and branching nature was found in different cultivars at Hyderabad, India (Babu and Kumar, 1988). The maximum tree height was recorded in Desi Alwar while tree spread was in Sanori No.5 (Saran, 2005). Maximum height of a 15 year old tree of *Z. mauritiana* was recorded in LR-13 (6.59 m); girth was maximum (3.32 m) in LR 11 (Kundi *et al.,* 1989a). Data on growth of different species including *Z. mauritiana* at the International Centre for Research in Agroforestry, Machakos, Kenya (a sub-humid to semi-arid climatic zone) have been presented by Jama *et al.* (1989).

8.2.2 Reproductive variability

8.2.2.1 Flowering

The peak period of flowering and fruit set in *Z. mauritiana* cultivars Banarsi Karaka, Ponda, Illaichi, Gola and Tikdi was September-October. Tikadi had the shortest duration of flowering (47 days) and fruit set (36 days) but the highest number of fruits/branch (239), fruit set (28 %), number of fruits reaching maturity/branch (48) and fruit retention (20 %) (Sharma *et al.,* 1990). Whereas, Saran (2005) found the longest period of bloom in Katha Rajasthan (78 days) ranged from 6 August to 23 October and the minimum period of bloom in the Safeda Rohtak (23 days). Flowering occurred from 57 to 75 days, depending on cultivar (Dhaliwal and Bal, 1998). Only one flowering season was observed in Hyderabad from May to July and its total duration varied from 68-94 days. Cultivars Gola, Mundia and Akola flowered early; Umran and Seb in mid-season; Banarsi and Kaki were late flowering (Babu and Kumar, 1988). The number of flowers per branch is quite high. Umran had the highest number of hermaphrodite flowers (22.2 %) followed by Gola Gurgaon with 20.1 % (Darbara and Jindal, 1982). Cultivars of *Z. mauritiana* differed in the time of flowering (on set and duration and peak) in Maharastra, India (Desai *et al.,* 1986) (see Plates 16, 17).

Healthy trees of Chinese jujube tend to produce a prodigious number of flowers and set of only a small fraction of these is necessary for a substantial crop (Ackerman, 1961). Variation in flower number per fruit branch and pollen number in *Z. jujuba* and *Z. spinosa* were studied *in vitro* by Liu *et al.* (2004 b).

The pollen of ber varieties has three zonicolporate aperture, psilate exine pattern and circular endocolpium. The pollen grains were sub-prolate to prolate spheroidal. Pollen germination was more than 50 per cent in most of the ber cultivars in 25 per cent sucrose solution whereas Illaichi cultivar was found to be sterile. The wild as well as cultivated ber types are tetraploid to octaploid.

Scanning electron microscopic (SEM) and light microscopic studies were carried out on pollen samples of three *Ziziphus* species and six *Z. mauritiana* varieties. Pollen grains differed in size, shape and exine characteristics. Studies showed uniformity in apertural characteristics and presence of tricolporate pollen. Size and shape of pollen within cultivars were quite uniform. Differences in exine pattern, size and P/E ratios could be used for identification of *Ziziphus* genotypes (Diwakar *et al.,* 1996).

Size of pollen grains of *Z. mauritiana* Illaichi, Umran and four wild forms was different (Nehra *et al.,* 1984). Pollen diameter in seven cultivars of ber (*Ziziphus mauritiana*) ranged from 20.05 mμ in Darakhi 1 to 32.04 mμ in Seedless. Pollen stain ability ranged from 63.69 % in Seedless to 87.12 % in Darakhi 1. *In vitro* germination was a better indicator of fertility than the stain test (Hulwale *et al.,* 1995). Similarly, considerable differences were also observed for pollen diameter among the different ploidy levels (Pradeep and Jambhale, 2000). Phenetic relationships among 32 genotypes of *Ziziphus mauritiana* and one of *Z. nummularia* were studied using data on 54 characters and summarised in the form of dendrograms. Overall, *Z. nummularia* did not show a close similarity to any of the *Z. mauritiana* genotypes (Diwakar *et al.,* 1992).

Studies in India have indicated that in *Z. mauritiana*, some cultivars have cross incompatibility (Teaotia and Chauhan, 1964). Ackerman (1961) showed many jujube cultivars fruit poorly without cross pollination. Another problem with jujube is that the fruit of some cultivars tends to split during rainy weather. The best time for pollen collection in crossbreeding has been discussed by Liu *et al.* (2004 b).

8.2.2.2 Fruit set

Umran was compatible as female parent with Sanuar 2, but Sanaur 2 did not set fruit after pollination by Umran (Mehrotra and Gupta, 1985). The requirement for cross pollination, incompatibility and pollen sterility means that fruit set depends on physiological and environmental conditions. The mode and time of anthesis was also cultivar specific. Anther dehiscence started about two hours after anthesis and continued for two to four hours. Peak receptivity of the stigma appeared to be just as the flower opened (Dhaliwal and Bal, 1998).

Some Chinese jujube clones developed fruits through self fertilization but few set appreciable crops by this means and fruits developed from self pollination were usually smaller than normal and tended to drop prematurely. Cross fertilisation was found necessary for the development of viable seeds and many of the aborted seeds apparently were the result of self fertilisation (Ackerman, 1961).

Fruit set in *Z. mauritiana* cultivars took place almost at the same time in Tikadi, Gola, Seb, Umran and the hybrid Umran x Seb cultivars, but Gola fruits matured earlier than those of all other cultivars in the region. Neeraja *et al.* (1995) reported higher fruit set in hand pollination than open pollination and 60 % fruit set was observed in Umran X Seb.

In Chinese jujube, fruit set was uniformly high in Ya and Nikitskii Melkoplodnyi (Sin'ko, 1974a). Yakobashvili (1973) in a six year study of fruit set, yield and other characters, showed the following were promising varieties: Ta Yan Tszao, Seedling 2, Seedling 1 and 3.

Fruit drop studied in seven *Z. mauritiana* cultivars indicated the lowest drop (24.1 %) in Ponda and highest in Illaichi (68.6 %) (Vashishtha and Pareek, 1979). Kakrola Gola had considerably higher drop (up to 80.6 %) than Kaithali and Umran which did not differ significantly, showing 7.2 and 12.1 % drop, respectively (Panwar, 1980). More than 50 % of the drop was of fruit <1.0 cm diameter. As fruit development advanced, less fruit drop occurred. Neeraja *et al*. (1995) recorded the highest in Seb (87.94 %) followed by Umran (83.43 %) and Gola (82.14 %).

The bearing and related characters provide useful information on proper times of flower and fruit set and harvesting for the categorisation of ber varieties (Singh *et al.,*1972 b). Fruit maturity in different cultivars of *Z. mauritiana* was reached in 174 to 200 days (Kumar *et al.,* 1986). Gola was the earliest (108 days) and Umran was the latest (147 days) to ripen under Gurgaon conditions (Singh *et al.,* 1983 a). Fruit growth in length and diameter showed three distinct phases (double sigmoid curve) in cultivar ZG-2 and Kaithali studied by Jawanda and Bal (1980). Bal (1981 b) studied the physical character of ber fruit of six year old plants of cultivar Sanur-2. The fruit ripened 180 days after fruit set. There was a rapid growth phase up to 75 days, from 90 to 105 days and from the 120th day after fruit set. Maturity of ber (*Z. mauritiana*) starts from the first week of November in South India and continues up to mid April in North India.

Variation in maturity period of ber (*Z. mauritiana*) in different parts of India has been indicated by Vishal *et al.* (2002). Saran *et al.* (2005) studied the bearing behaviour in 35 cultivars of ber at Hisar, India and classified them into three categories based on harvesting time, as early, medium and late. Umran, Katha Bombay, Chhuhara, Illaichi, 2g-3, Kathaphal, Jogia, Ponda, BS-2 and Desi Alwar are late bearing varieties while Gola, Gola Gurgaon No. 2, Gola Gurgaon No.3, Safeda Rohtak, Seo, Katha Rajasthan, Laddu and Akhrota were early bearing varieties and Kaithali, Dandan and Mirchia varieties bear during the mid-season. Daulta and Chauhan, (1982) also observed that Umran is late and has large, oval, golden yellow fruits which turn chocolate brown at maturity and transport well. Kathaphal is late ripening while Gola is early and Kaithali comes in midseason. Seo, Sanaur No.2 and Umran are recommended as early, mid and late cultivars, respectively for commercial cultivation (Chadha *et al.,* 1972) in northern India.

8.2.2.3 Fruit and seed

High variability was observed for all fruit and seed characters (Bisla and Daulta, 1988 b). The variability of fruits of *Z mauritiana* is shown in Plates 26 and 27. Considerable variation in fruit length and breadth in different cultivars of *Z. mauritiana* like Banarsi Karaka (5.4 and 3.4 cm), Dandan (5.1 and 3.0 cm), Jogia (4.9 and 3.8 cm) and Umran (4.8 and 3.8 cm) was reported by Ghosh and Mathew (2002). Karaka had the largest fruit (Singh and Singh, 1973). Fruit size, weight and pulp/stone ratio were highest in Umran (Dhingra *et al.,* 1973). Fruit characters of 40 *Z. mauritiana* cultivars have been described by Singh *et al.* (1972 a) and variations in nine cultivars were described by Teaotia *et al.* (1974). Cultivars Seo Bahadurgarhia, Nari Keli, Desi Alwar and Banarsi Karaka produced fruits weighing > 20 g each (Godara, 1980). Umran produced the heaviest fruits (39.8 g), Gola Gurgaon showed the highest content of pulp (97.2%), total soluble solids in Gurgaon, Haryana (Singh and Jindal, 1980). The fruit weighed 70-90 g and reaches even 150 g in Wugianzhong, a *Z. mauritiana* cultivar (Li *et al.,* 1999) (see Plates 18-25).

The average fruit weight varied from 8 to 17.68 g in 10 local ber genotypes grown in West Bengal (Ghosh and Mitra, 2004). Nine varieties were evaluated by Teaotia *et al.* (1974). Pewandi was considered to be the best variety for commercial cultivation, having the largest fruit, a high percentage of edible pulp and good skin colour. There were considerable differences in seven ber cultivars in fruit weight (29.340 to 9.544 g), fruit size (length 3.27-4.33 cm), pulp/seed ratio and fruit quality at Ratta Kulachi, D. I. Khan, Pakistan (Kundi *et al* , 1989b). BS-2 had the highest pulp/stone ratio; and the maximum fruit and stone size was recorded in Ponda (Saran, 2005). Cultivars Dabailing, Daguazao and Linyi Lizao are large fruited, with fruit sizes of 23-26.1 g, Jinsi 3 and Jinsi 4 are small fruited varieties (Chen *et al.,* 2003).

The best *Ziziphus jujuba* varieties for uniformity of fruit size are Ta-Pai and Hsueh-pai (Sin'ko, 1974).

A lot of variation exists in ber genotypes for pulp/stone ratio. Pulp/stone ratio was maximum in Sanur-6 and minimum in Punjab Chhuhara (Bharad *et al*., 2002), The pulp/stone ratio was highest in Umran (Dhingra *et al.,* 1973). Madalageri *et al.* (1977) reported the highest pulp/stone ratio in HB-2, a wild local strain of *Z. mauritiana*.

The list of cultivars as shown in Plates 26 and 27 is:

1. Kaithali; 2. Umran; 3. Chonchal; 4. Noki; 5. Katha Rajasthan; 6. Laddu; 7. Chhuhara; 8. Sandura Narnaul; 9. Illaichi; 10. Dandan; 11. ZG-3; 12. Kantha Phal; 13. Akhrota; 14. Bahaduragarhia; 15. Govindgarh Selection; 16. Thornless; 17. Gola Gurgaon No. 3; 18. Gola Gurgaon No. 2; 19. Desi Alwar; 20. Nari Kali; 21. Gora; 22. Narina; 23. Sanori No. 5; 24. Sanori No. 1; 25. Seo Bahadurgarh; 26. Illaichi Jhajjar; 27. Sua; 28. Kishmish; 29. Popular Gola; 30. Mirchia; 31. Jogia; 32. Mundia Murhara; 33. Ponda; 34. Bawal Selection-2; 35. Gola; 36. Banarasi Karaka.

Significant genotypic differences were found in the seed characters of *Z. mauritiana* varieties (Babu and Kumar, 1986). Saran (2005) observed variation in stone size of 35 cultivars of ber and reported that maximum (3.72 cm) was in Ponda and the minimum (0.53 cm) in Illaichi.

Seeds of *Ziziphus mauritiana* trees taken from 5 districts in Yunnan Province, China and Narkum, Myanmar, were tested for their morphological characteristics, germination characteristics, and the growth patterns of the seedlings and young trees. A close relationship was found between these characters and their geographical distribution and climatic condition. This information will be helpful for choosing better forms of the tree (Wang and Wang, 1994).

In Chinese jujube, one group of cultivars gives 85 % seed germination (e.g. Ya-tszao) and the other gives 98 % germination, e.g. Nikitskii 84, 92 and 94. The results on seed germination with and without the endocarp in temperatures ranging from 15 to 30^{o} C are also presented (Sin'ko, 1973). Similarly, some Chinese jujube seeds take one to three days to germinate while others take seven days (Kim and Kim, 1984a). Seed stones collected from fallen fruits of ber often have poor viability and 50 –70 % of the seed stones have non-viable seeds. The quickness and extent of germination depends upon viability and after-ripening status of the seed, presence of endogenous inhibitors, weathering of the stony endocarp and environmental conditions such as the temperature, moisture, salinity and alkalinity of the growing medium. The thinnest seed coat wall was observed in the case of Godhan (Singh, *et al.,* 1973 a).

8.2.3 Yield

Variation in yields of *Z. mauritiana* cultivars (55.5 to 116.11 kg/tree) have been observed by Kumar *et al.* (1986). In the semi-arid subtropical climate of northern India under irrigated conditions, the fruit yield per tree ranges from 80 to 200 kg depending on the varieties and management practices during the prime bearing age of 10 to 20 years (Bakhshi and Singh, 1974). Fruit yield was highest in Gola (38.4 kg/tree) and lowest in the local cultivar Sukavani (3.54 kg/tree) at Sardar Krushinagar in Gujarat (Chovatia *et al.* 1992). Highest yields were obtained from Umran (210 kg/tree) followed by Sanaur No. 2, Dandan and ZG 2 (Gupta, 1977). Thornless gave the highest yield/tree (74.4 kg) followed by Sanaur 5 (71.3 kg) and Sanaur 4 (Singh and Tomar, 1988) at Bhatinda, Punjab, India. Kharki had the highest fruit yield at Hoshangabad, Madhya Pradesh (Gupta and Mehta, 2000).

At Hyderabad, Mundia was the highest yielder (116.1 kg/tree) followed by Umran and Gola (s and Babu, 1987) whereas, yield in different cultivars of *Z. mauritiana* in Maharashtra (India) indicated maximum fruit, pulp and stone weights in Kadaka when pruned on 25 March (Bharad *et al.,* 2002). Banarasi Karaka fruits had the highest nutritive value and yield (99.8 kg fruits/tree) (Tiwari and Banafar, 1995). Reddy *et al.* (1998) carried out an economic analysis of cost and returns to determine the most profitable cultivars at Dharwad, Karnataka, India. The performance of 11 cultivars showed that Dandan, Sanaur-2 and Chhuhara, with mean fruit yields of 6.78, 6.36 and 6.08 t/ha and benefit: cost ratios of 5.64, 5.32 and 5.09, respectively were the most promising. Cultivar Pewandi is considered best for commercial cultivation in Uttar Pradesh, India (Teaotia *et al.,* 1974).

Chinese jujube cultivars yield 50 to 300 kg fruits per year depending upon cultivar, location and age of tree (Ciminata, 1996). On the basis of yield, ripening date, frost resistance and storage quality in 7 ber cultivars Ta-Yan-tszao, Da-bai tszao, Ya-tszao, 93, 58, 107, 52 and 48 are recommended for cultivation (Sin'ko, 1977). In the Arava valley of Israel, a fruit yield of 12 tons per hectare has been obtained from 3-year old ber trees (Nerd and Mizrahi, 1998). From the naturally growing, scattered wild trees in Zimbabwe, a yield of 4-5 tons has been obtained from a 3-4 hectare area (Maposa and Chisuro, 1998). In China - Taiwan, fruit yields of 158.6 kg per tree in cultivar Kaolang-1 and 140.8 kg per tree in cultivar Telong have been obtained (Chiv Chu Ying, 1997).

8.2.4 Chemical variability

A wide range of varietal variability for quality traits was detected in 30 cultivars of ber (*Z. mauritiana*) at Hisar (Bisla and Daulta, 1986). Ber germplasm collection and evaluation at Amer, Bharatpur, Deeg, Tijara and Jhunjhunu areas of Rajasthan, India indicated significant variation in physicochemical characteristics of 23 genotypes, and ten produced fruits of excellent quality (Lal *et al.,* 2003). Variation in 10 local ber genotypes grown in West Bengal, were noted for soluble solids, total sugars, acidity and ascorbic acid content; ranges of these parameters were 9.53-19.13 %, 4.94-12.30 %, 0.38-2.60 % and 17.25-51.98 mg/100g respectively (Ghosh and Mitra, 2004).

The cultivar Umran has 19 % TSS and 1.2 % acidity. In the case of Kathaphal, the TSS is 23 % and acidity was 0.77 % while in Gola, the TSS is 17-19 % and 0.46 - 0.5 % acidity. In Kaithali TSS is 18 % and acidity 0.5 % (Daulta and Chauhan, 1982). Godara (1980) evaluated 16 cultivars for quality characters. The fruits of Mundia Murhara and Chhuhara had the highest TSS content (22.8 and 22.4 %, respectively). Banarasi Karaka fruits had the highest nutritive value (Tiwari and Banafar, 1995). HB-1 and LB had excellent flavour and HB-2, KB1, SB and SB-2 were rated good at Bangalore. Under rainfed conditions of Bawal, Haryana cv. Nazuk had the highest total soluble solids (28.9 %) followed by Illaichi (Yamdagni *et al*., 1985 b).

Kadaka had maximum sugar and minimum acidity content and was considered outstanding (Singh and Singh, 1973). Some cultivars show variation in acidity (0.228-0.78 %) and ascorbic acid (80.85-178.04 mg/100 g pulp) (Godara, 1980). Fruit ascorbic acid content of several cultivars ranged 70-165 mg/100g of pulp (Jawanda and Bal, 1978). Bisla *et al.* (1980) observed the highest Vitamin-C content (120.15 mg/100g) in cv. Illaichi. The Vitamin-C content was highest in Narikelee, followed by Kaithali 165 and 125 mg/100g fruit pulp, respectively (Gupta, 1977). Jinsi 3 and Jinsi 4 (both small fruited), had sugar content over 35 % (Chen *et al.,* 2003). Godhan was the most nutritive with regard to total soluble solids and ascorbic acid content, whereas Kharki was the sweetest at Hoshangabad, Madhya Pradesh, India. The highest acidity (0.49 %) was exhibited by Soni while the lowest acidity (0.25 %) was exhibited by Kabra and Amrabati. The highest total sugar content (14.48 %) was exhibited by Bekanta and the lowest (8.5 %) by Karka (Gupta *et al.,* 2004). The highest total soluble solids were recorded for Umran and the highest acid content in Sanaur 4 at Bhatinda (Tomar and Singh, 1987).

Singh and Jindal (1980) found the highest contents of pulp (97.2 %) TSS (21.4 %) and total sugar (10.7 %) in Gola Gurgaon, and Kaithli had the highest (113.5 mg/100 g) ascorbic acid content. The TSS content was highest in Chonchal and Illaichi and the latter cultivar had the highest ascorbic acid content. The highest content of non-reducing and total sugars was found in Chhuhara (Dhingra *et al*., 1973).

Munier (1973) studied for quality characters. Cultivars grown in China, the United States and Pakistan contained, respectively, 500-600, 300-500 and 45.2-160.8 mg Vitamin C/100 g. Variations in ascorbic acid content of 10 varieties have been reported by Ahmad and Malik (1971). Late ripening varieties generally contain more ascorbic acid than early ripening ones. Catechin content remains unchanged during the first half of the ripening period but declines 10-20 times below the original level during the later period. A close correlation was observed between ascorbic acid and catechin content during the ripening period (Kuliev and Akhundov, 1975).

The most promising *Ziziphus jujuba* cultivars for quality were Nos. 1, 2 and 16/5. Ascorbic acid content was highest in Nikitskii 17 and Da-bai-tszao (774 mg) and pectin content in U-sin-khun and Nikitskii 62 (up to 1 %) (Sin'ko, 1974 b). He also listed the best varieties for conserving, drying and eating fresh among 25 cultivars studied for quality. Lomakina (1976) evaluated jujube varieties in south-west Turkmenistan. The best cultivars were Ya-tszao and Ta-Yan-tszao.

The soluble protein in fruits and leaves on a fresh weight basis ranged from 9.37 to 26.90 mg and 25.40 to 56.98 mg per gram respectively in 42 cultivars of *Z. mauritiana* (Sudhir *et al.,* 1999). Umran was noted for high sugar and protein contents, followed closely by Kathaphal (Khera and Singh, 1976). Free amino acids isolated from fruit pulp of wild taxa and 40 cultivars of *Z. mauritiana* did not show any relationship between the number and types of amino acids in wild samples and cultivars (Gill *et al.,* 1997). In wild samples, the number of amino acids per sample was in the range 4-8. Of the 17 free amino acids represented in wild samples, glutamic acid, amino-butyric acid, threonine, proline and alanine were well represented. In cultivars the number of amino acids per sample was in the range 3-10. Of the 22 amino acids represented in these cultivars, arginine, cysteine, cystine, alanine and proline were common. The most widely represented amino acids in cultivars (arginine, cysteine and cystine) were absent in wild taxa. The commonly represented amino acids in wild samples (glutamic acid, amino-butyric acid and threonine) were not common in cultivars. The free amino acid profile of fruit pulp was different from that of mature leaves in the same taxa.

8.2.5 Genetic variability

Information on genetic variability, heritability and correlation coefficients derived from data on leaf area, relative water content, stomatal index, stomatal frequency and yield in four year old ber plants of 12 popular ber cultivars, grown at Raichur, was observed. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were greatest for stomatal frequency. GCV and PCV values were lowest for relative water content (RWC). High values of heritability and genetic gain were observed for stomatal index. Significant and positive correlations were observed between yield per plant and stomatal frequency, leaf area and stomatal index (Praveen and Patil, 1998). High estimates of GCV, PCV, heritability and genetic advance were recorded for stone size, pulp stone ratio, fruit weight and yield indicating the effectiveness of improvement through simple selection (Saran, 2005).

8.2.5.1 Correlation and coefficients of variation

The correlation coefficient of 12 growth, fruiting and quality characters of 24 ber cultivars indicated that the stem girth was positively and significantly correlated with total soluble solids, leaf area with leaf dry weight, stone weight with acidity, fruit set with fruit drop, and negatively correlated with fruit set, and stone weight with fruit drop (Rajesh and Misra, 2004). Significant and positive correlations were observed for leaf breadth, fruit diameter, fruit weight and fruit retention with yield. Selection of these traits may be effective for the improvement of ber (Gupta and Mehta, 2000). There were significant positive correlations between fruit yield, fruit set, and pulp/stone ratio of ber (cv. Umran) whereas yield had significant negative correlations with fruit drop and stone weight. The total variation accounted for by all the characters was 86 %. Path analysis revealed a positive direct contribution of fruit set and fruit length and a negative contribution of fruit drop and stone weight. It is concluded that in breeding programmes importance should be given to these four characters in developing high yielding ber genotypes (Prajapati *et al.*, 1996).

In a study of 30 cultivars at Hisar, India, fruit weight, fruit size, seed weight and pulp/stone ratio were significantly correlated with yield (Bisla and Daulta, 1987). Yield was positively correlated with total sugar content and disease intensity (Bisla and Daulta, 1988b). Gola, Sanori No.5, Kishmish, Ponda and Kaithali were found superior among the genotypes. TSS had positive and high correlation with total sugar while yield had negative correlation with quality traits except ascorbic acid and non-reducing sugars (Saran, 2005).

The genetic co-efficient of variation measures the range of genetic variability which helps to compare the variability present in different genotypes. The genetic coefficient of variation ranged from three (fruit breadth) to 31.01% (yield kg/plant). Characters such as TSS, fruit breadth and fruit length showed comparatively low genetic coefficient of variation, whereas weight/fruit, pulp/stone ratio and yield (kg/plant) exhibited high genetic coefficient of variation.

Correlation and path coefficients of eight commercial cultivars (Gola, Seb, Umran, Mundia, Illaichi, Tikkadi, Jogia and Bhagwadi) and three local selections of *Z. rotundifolia* were assessed for 13 yield attributes at Jobner, Rajasthan, India. Fruit set, fruit length, fruit breadth, fruit weight, stone diameter, pulp weight, specific gravity and harvest duration had significant positive correlation with fruit yield, whereas the fruit length had the highest direct positive effect on yield (Pareek *et al.,* 2003).

The success of any breeding programme depends on the extent of genetic variability in the source population. The assessment of variability is, therefore, a basic requirement of breeding programmes. Since most of the plant characters of economic importance are governed by a group of genes and are highly influenced by environmental variation, it is difficult to judge whether the observed variability is heritable or due to environment. This necessitates the optimising of phenotypic variation into its heritable and non heritable components, and the more known about this, the better the characterisation of germplasm collections.

The fruit weight, yield/plant and pulp/stone ratio in 13 *Z. mauritiana* cultivars showed high genetic coefficients of variation in Gujarat, India (Nanohar *et al*., 1986). Bisla and Daulta (1988a) also observed that the coefficient of variation was highest for fruit set (16.9) followed by the number of leaves per shoot (14.2), yield (12.9), fruit drop percentage, shoot length and tree height.

Liu (1996) studied nine major quantitative characters of Chinese jujube. There was significant difference among characters in level of variation. The coefficient of variation was highest in fruit weight (51.95 %) and lowest in edible part of the fruit (2.67 %). Saran (2005) studied 10 quantitative characters for 35 genotypes. Saran (2005) also observed that high estimates of genetic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were recorded for stone size, pulp stone ratio, fruit weight and yield. It indicates the effectiveness of improvement through selection. He observed that fruit yield had positive and significant correlation with tree spread (0.319) fruit weight (0.515) and stone size (0.353). He also observed that fruit size (0.580) and flesh thickness (0.811) were indirectly contributing via fruit weight. Fruit weight (0.998) contributed to yield mainly through its direct effect followed by the indirect effect of stone size and number of flowers per cyme.

8.2.5.2 Path analysis

Path analysis showed that fruit weight, seed weight and pulp/stone ratio had a positive, direct effect on yield of *Z. mauritiana* varieties (Bisla and Daulta, 1987). Both total sugar content and disease intensity contributed directly to yield, and attention should be given to these while selecting the genotypes for improvement in yield (Bisla and Daulta, 1986).

Correlation and path coefficients of 35 ber genotypes indicated that the traits like fruit weight, fruit size and stone size should be given due consideration while performing selection for yield in segregating generations of ber. So spread, fruit weight, stone size and fruit size were found to be effective selection indices. Yield of ber genotypes had significant positive correlation with spread, fruit weight and stone size. Fruit size had highly positive correlation with fruit weight and stone size. Fruit weight, fruit size and stone size were the main contributors towards yield which contribute via fruit weight (Saran, 2005).

8.2.5.3 Inheritance

Some work has been done to study the inheritance patterns of jujubes. Detailed genetic studies are yet to be carried out to unfold the riddles underlying heritability of quantitative and qualitative characters. Some attempts have been made in the past to understand the genetic correlation between desirable traits.

The inheritance of the characteristics chosen as breeding objectives will greatly influence the strategy employed for cultivar development. Qualitative characteristics controlled by one or a few major genes are more readily manipulated in a breeding programme than quantitative traits controlled by many genes (polygenes). Similarly characteristics whose expression is not influenced by the environment are more easily and effectively selected than those that are strongly affected by environmental factors.

8.2.5.4 Heritability

The estimation of heritability has been helpful to plant breeders, as it enables the selection programme to be based on phenotypic performance. Johnson *et al.* (1955) suggested that the heritability estimate in conjunction with genetic advance is usually helpful in predicting its resultant effect from selecting the best individuals.

Heritability in 30 ber cultivars ranged from 54.2 % for total soluble solids to 99.63 % for disease intensity, and the value for acidity was 91.61 % (Bisla and Daulta, 1988a). To improve the yield through hybridisation in *Z. mauritiana* individual trees with low fruit acidity and low disease intensity should be selected. Twelve cultivars evaluated for ten economic characters showed high heritability with high genetic advance for fruit weight and leaf length (Gupta and Mehta, 2000). Heritability was high for fruit weight (97.2 %) and size (87.9 %), pulp/stone ratio (87.5 %) and seed weight (84.6 %) in *Z. mauritiana* at Hisar (Bisla and Daulta, 1988b).

The highest heritability values were seen for days from fruit set to ripening (99.2 %), fruit set (94.7 %), days from pruning to sprouting (93.6 %), fruit drop

(85.0 %) and shoot length (82.0 %). High heritability coupled with genetic advance for yield (kg/plant), pulp/stone ratio indicated that high heritability obtained for these characters was probably due to additive gene effect (Panse, 1957). Expected genetic gain was highest for fruit set (142.8 %) and lowest for days from pruning to flower initiation (3.5 %). Selection for higher fruit set and lower fruit drop was recommended to improve the yield by Bisla and Daulta (1988a).

Heritability estimates were moderate for fruit breadth (66.67) but low for fruit weight (44.03) in addition to fruit length. Heritability ranged from 42.25 % (fruit length) to 93.75 % (TSS). High heritability was expressed by yield (kg/plant) (91.62) and pulp/stone ratio (91.67) in addition to the TSS (Nanohar *et al.*, 1986).

High genetic advance has been reported in yield and pulp/stone ratio in different cultivars (Nanohar *et al.,* 1986). Fruit weight, fruit size and seed weight showed high genetic advance (Bisla and Daulta, 1988b). The genetic advance expressed as percentage of mean ranged from 12.48% (fruit length) to 61.16 % (yield/plant). The fruit length, fruit breadth and weight per fruit had low heritability along with low genetic advance, indicating that dominance of epistatic effect is of considerable value for these characters and hence little improvement in these characters is possible through selection. Individual plant selection for yield (kg/plant) and pulp/stone ratio would be satisfactorily effective in ber as these characters exhibited high heritability as well as high genetic advance, whereas for other characters, selection may not be so effective.

Saran (2005) studied 35 ber (*Z. mauritiana*) genotypes and revealed nine genetically divergent clusters (Table 8.1).

Table 8.1 Classification of germplasm of ber in different clusters

Clusters	No. of cultivars	Name of germplasm
I	8	Kaithali, Govindgarh selection, Sanori No. 1, Noki, Chonchal, Mirchia, Sandhura Narnul and Jogia
II	6	Seo, Laddu, Safeda Rohtak, Dandan, Popular Gola and Seo Bhadurgarh
III	1	Illaichi
IV	5	Katha Rajasthan, Ponda, Gola, Sanori No. 5 and Sua
V	6	Katha Bombay, Bhadurgadhia, Thornless, Umran, Banarsi Karaka and Desi Alwar
VI	2	Mundia Murhara and Bawal Selection-2
VII	1	Chhuhara
VIII	4	ZG-3, Akhrota, Gola Gurgaon No. 3 and Gola Gurgaon No. 2
IX	2	Kathaphal and Kishmish

8.2.6 Distribution of important traits

The important traits in some ber cultivars have been described by Saran (2005) (Table 8.2) and the traits identified by others are shown in Table 8.3.

Table 8.2 Important traits in ber

Cultivar	Characters
Umran	Yield, stem girth, fruit size, fruit weight, flesh thickness, flowers per cyme and pulp/stone ratio.
Ponda	Yield, spread, number of flowers per cyme, fruit weight, fruit size and flesh thickness.
Sanori 5	Yield, number of flowers per cyme, fruit weight, size of fruit and flesh thickness.
Laddu	Yield, spread and number of flowers per cyme
Gola	Spread, fruit weight, flesh thickness and stone weight
Chhuhara	Spread, stem girth

Important traits have been identified by various workers which can be used by breeders; some breeders are listed in Table 8.4.

Table 8.3 Traits identified in ber cultivars

Traits	Cultivars	Author
Fruit maturity	Early (Gola, Mundia), mid season (Banarsi, Kaithli), late (Umran)	Vashishtha, 1983
Sweetness (high TSS)	Reshmi, Umran	Vashishtha, 1983
Pulp texture	Coconut-like (Umran), Juicy (Gola, Aliganj), Melting (Illaichi)	Vashishtha, 1983
Fruit size	Very large (Ponda), large (Umran), Medium (Mundia, Banarsi, Gola), small (Illaichi)	Vashishtha, 1983
Fruit shape	Apple like (Seb), cardamom-shaped (Illaichi), bell shaped (Mundia), Round (Gola), oblong (Umran)	Vashishtha, 1983
Fruit colour at maturity	Bright golden (Sanaur), bright yellow (Gola), Greenish yellow with brown blush (Kathaphal)	Vashishtha, 1983
Acidity	Very low (Umran), low (Gola), Moderate acidic (Sanaur), acidic (Kathaphal)	Vashishtha, 1983
Shelf life of fruits	Good (Umran, Maharwali), poor (Gola)	
Processing uses	Dehydration (Vikas, Raja, Babu, Jeevan, Chinese cultivars, Umran, Bagwari, Chhuhara) Preserve (Umran, Banarsi Karaka, Kaithli) Candy (Illaichi, Umran, Kathaphal, Kaithli) Beverage (Gola, Mundia)	Gopani, 1976 b Khurdiya, 1980 Gupta *et al.* 1981b Gupta *et al.* 1981a Khurdiya and Singh, 1975
Resistance to fruitfly	Tikadi, Meharun, Illaichi	Singh and Vashishtha, 1984
Resistance to fruit borer	Banarsi Pewandi, Gola Gurgaon, Jhajjar Selection	Pareek and Vashishtha, 1986
Tolerance to powdery mildew	Illaichi Jhajjar, Sanaur-5, Safed Rohtak, Kathaphal, Gola, Seb, Meharun	Pareek and Nath, 1996
Field resistance to powdery mildew	Dharkhi-1, Dharkhi-2, Guli, Villaiti, Seedless	Pareek and Nath, 1996
Tolerance to *Isariopsis*	Safed Rohtak, Sanaur-1, Seo Bahadugarhia, Jhajjar Selection,	Pareek and Nath, 1996

(Source: Pareek, 2001)

8.3 Collections

8.3.1 Genetic erosion

Accelerated selection and wider adoption of clonally-propagated cultivars will lead to a degree of genetic erosion. However, whilst wild and naturalised populations persist in such large geographic areas in the primary centres of diversity, and numerous areas in other parts have become secondary centres, (e.g. tropical Africa for *Z. mauritiana,* Central Asia and South-west Asia and parts of Africa for *Z. jujuba*), there is not a major cause for concern.

It is fairly common practice to top work wild trees with improved cultivars (Singh et al*.,* 1973a; Yadav, 1991), and many rural communities use jujubes for fencing, wind-breaks and other purposes. These activities provide a degree of protection.

8.3.2 Existing collections

Collections of germplasm which are currently maintained are largely geared to maintenance of cultivars and other selections, including in some cases mutants, which are used to support the national improvement efforts. Sometimes they represent introductions which have been or might be tested for adaptation far from their places of origin. In effect, the collections are active collections rather than field gene-banks since costs of maintenance are related to utility rather than maintenance for long term conservation.

As research progresses on characterisation and genetic affinities, it will be possible to develop strategic planning to rationalise existing collections so that synonyms of cultivars can be eliminated and the accessions can truly represent specific patterns of genetic variability and still be related to improvement needs, including ecological and climatic tolerances. Many of the traits considered in improvement are polygenic and there will always be the need to err on the side of maintaining a larger number of accessions than actual utilisation needs require.

A large number of Institutions particularly in India are holding ber germplasm and are working on their evaluation and improvement (Table 8.4).

Table 8.4 Indian Institutions holding ber germplasm collections (number of accessions)

Institutions	*Ziziphus* species	Ber cultivars
Central Institute for Arid Horticulture, Bikaner - 334 006, Rajasthan, India	7	162
Central Arid Zone Research Institute, Jodhpur -342 003, Rajasthan, India	--	68
Indian Institute of Horticultural Research, Bangalore-560 089, Karnataka, India	3	32
Central Horticultural Research Station, Godhra-389 001, Gujarat, India.	--	22
Haryana Agricultural University, Hisar-125 004, Harayana, India	--	74
Narendradeo University of Agriculture and Technology, Kumarganj, Faizabad- 224 229, U.P, India	--	32
Mahatma Phule Agricultural University, Rahuri- 413 722, Maharasthra, India	--	87
Gujarat Agricultural University, Sardar Krushinagar- 385 506, Gujarat, India	--	75
Fruit Research Station, Punjab Agricultural University, Bahadurgarh, Patiala- 147 001, Punjab, India	--	42
Indian Agricultural Research Institute, New Delhi - 110 012, India	4	52
Dryland Agriculture Research Station, Haryana Agricultural University, Bawal-123 501, Haryana, India	--	36

(Pareek, 1988; Pareek and Sharma, 1993).

Chinese jujube is maintained at a number of sites in Hebei, Shanxi, Henan and Shantung provinces and the Jujube Institute at the Hebei Agricultural University, Baodong, Hebei 071001 can always provide information, as can the Chinese Academy of Forestry.

Other collections of jujubes are to be found at the Apsheron Experimental Station for Subtropical Crops, Azerbaijan, where in the 1990s the best 40 seedlings of ber were selected from 3762 jujube seedlings, and 25 were included among the elites. The 11 best forms were given varietal names.

A collection of subtropical fruits is maintained at the Turkmen Experimental Station Turkmenistan and includes several local, foreign and Soviet bred varieties of jujube. There are 65 forms of *Ziziphus jujuba* at the Turkmen Experimental Station.

A number of accessions of *Z. jujuba* are held at the Research Institute of Plant Production, Prague, Czechoslovakia. The Fruit-Tree Research Station (FTRS) in Japan has a collection of *Z. jujuba* maintained at the Okitsu Branch (Moriguchi *et al.*, 1994).

The National Germplasm System of the USA also holds significant accession numbers of the two major jujubes. European countries bordering the Mediterranean have been involved in documenting germplasm of minor fruits, including jujubes, through a cooperative European Union Project, and national programmes recognised the need to collect materials in the latter part of the 1990s. Some work is still ongoing. Turkey also, through its national genetic resources programmes, maintains a number of accessions of *Z. jujuba* at ARARI, Meneme, Izmir.

Other countries maintain small collections of jujubes but they are not maintained for genetic conservation but for short-term use e.g. Bangladesh maintains 35 accessions but only two of these cultivars are under cultivation on farms (Saha, 1997). Similar collections are present in Korea, Pakistan and Thailand.

8.3.2.1 The need to consider rootstock resources

In addition to cultivars more attention needs to be given to wild sources of current or potential use as rootstocks and their maintenance in the collections. Much of the research on using rootstocks, other than those of cultivars, has been hit and miss because very limited genetic material of each wild species used has been tested for rootstocks. Table 8.5 shows the situation for ber (Bal *et al.*, 1997).

Table 8.5 Species used for rootstocks for Indian jujube

Compatibility	Species
Most successful	*Z. mauritiana cultivars*
Can be widely used	*Z. mauritiana* var. rotundifolia (wild/naturalised)
	Z. abyssinia
Less successful but mostly compatible;often cultivar specific	*Z. nummularia*
	Z. xylopyrus
	Z. spina-christi
	Z. mucronata
	Z. oenoplia
	Z. jujuba

Source: comprehensive summary by Pareek (2001).

Chinese jujube rootstocks are most frequently wild materials (especially var. *spinosa)* related to the cultivars, but a number of other wild species have been tried in areas of China with more extreme climates (Ming and Sun, 1986).

8.3.2.2 The need to consider wild species for breeding

Wild species are sources of diversity for jujube improvement. Pareek (2001) noted the attributes of several in the case of ber (Table 8.6).

Table 8.6 Exploitable attributes of wild species in ber improvement

Wild Relatives	Exploitable Attributes
Z. nummularia and	i) Drought tolerance
Z. lotus	ii) Dwarf tree stature and extensive root system
	iii) Early fruit maturity
Z. jujuba	i) Resistance to low temperature damage
	ii) Excellent dehydration quality of fruits
	iii) High vitamin C and P contents in fruits
Z. mistol	i) Resistance to low temperature damage
Z. mauritiana var.	i) Vigorous tree frame
rotundifolia	ii) Wood of marginal timber value

(Source: Pareek, 2001)

8.3.4 Conservation methodologies

Not a great deal of attention has been paid to storage of seeds of jujubes for long-term conservation because of the heterozygosity present and the loss of a particular cultivar if seed is propagated.

Two other factors are relevant. Firstly seeds of jujubes are not easy to handle as seed 'lots', and secondly, regeneration of the sample when needed is difficult because it means growing out a tree population, waiting for fruiting age and then replacing a seed lot in cold storage.

Nonetheless, seeds of jujube species, both cultivated and wild show an orthodox behaviour when dried and stored at low temperatures. The Millennium Seed Bank of the Royal Botanic Gardens, Kew, UK stores accessions of *Ziziphus*, mostly wild species of arid zones of Africa. This institution has also looked at the relations between seed moisture contents, viability and storability at low temperatures. Further information is available at www.icuc-iwmi.org and advice can be given to any national programme considering placing jujube seeds into seed genebanks.

The rationalisation of a number of the existing germplasm collections will enable these to be transferred into field genebanks but there are many gaps in the collections. Also more systematic evaluation of existing resources is essential to utilise the variable genepools. The lack of sufficient information on performance accessions is due to the enormity of the task, and this has lead to their current limited use. Thus, proper characterisation and evaluation of germplasm and dissemination of the information to breeders and others is very important.

8.3.4.1 The need for *in situ* conservation

At present, much of the conservation is through use of the ranges of cultivars on-farm (e.g. Vietnam: see Le, 1998). Any on-farm conservation to be built into any national programme has to be based on farmers who are interested and willing to do so. Natural genetic resources programmes are still grappling with principles, practices and policy issues in this area but those involved with jujube production should be part of the dialogues whenever possible.

Many more practicable opportunities exist for conservation of *Ziziphus in situ* in natural habitats or in the areas where it grows naturally, achieved by protecting areas from human interference; such areas include natural parks, biosphere reserves or gene sanctuaries. A gene sanctuary is best located within the centre of origin of the crop species concerned, preferably covering the micro-centre within the centre of origin (Singh, 2004). A gene sanctuary conserves the existing genetic diversity present in the population; it also allows for new gene combinations which appear with time. But it is difficult to establish and very difficult to maintain, especially in countries like India, which have an ever increasing population pressure. There is a need to establish gene sanctuaries in India for the conservation of *Z. mauritiana* and in China for *Z jujuba*. *In situ* conservation has two approaches i) biosphere reserve; (ii) habitat approach. The natural biosphere reserve is a useful solution for species that are endangered and almost on the point of extinction. Habitat approach refers to management of target species in its original habitat, through protected areas, managed forests, natural reserves with multiple uses, preservation plots, wildlife sanctuaries, habitat or national parks and agro-ecosystems through on-site or on farm conservation.

8.3.4.2 *In vitro* conservation

In vitro genebanks can be very useful for clonally propagated material using slow growth in tissue culture and long-term cryopreservation of tissues and/or embryos. No such facilities exist for jujubes yet but a technique for *in vitro* storage of plants including *Z. jujuba* was developed in the Nikitsky Botanical Gardens, Ukraine (Mitrofanova *et al.,* 2002). The growth of explants was retarded using physical (temperature, light and culture conditions), chemical (osmoticum application and optimization of culture medium) and plant physiological factors (plant age, dormancy and crop growth stage).

Chapter 9. Harvesting, post-harvest handling and processing

S. Azam-Ali

9.1 Introduction

This chapter is mainly devoted to ber. Other jujube species show similarities in harvesting, ripening and grading requirements. After thorough discussion of ber, some details are added for Chinese jujube and *Z. spina-christi*.

9.2 Ber

9.2.1 Harvesting

Ber fruits should be harvested at the correct stage of maturity since they do not mature after picking and the organoleptic (taste and texture) and visual qualities of fruits decline with increased maturity. Immature fruits lack sweetness and have an acrid taste. Over-mature or fully ripe fruits turn from yellow or golden-yellow colour to red or dark brown. The texture changes from crisp and juicy to soft and slimy. It is essential to harvest ber fruits at the optimum stage of maturity. On the same tree, fruits ripen at different rates Fruits are ripe when they are a golden yellow colour with a sweet and sour taste.

9.2.1.1 Harvesting season

The harvesting season varies according to cultivar and location. Some varieties ripen as early as October, others ripen from mid-February until mid-March and others in March or mid-March until the end of April. In any location, diverse cultivars can be harvested over a period of months e.g. in North India from February to April, in west India from December to January, but in south India in November. In the Assiut Governorate there are two crops a year, the main being in early spring and the second in the autumn (www.hort.purdue.edu). In India there are two or three pickings which are done by hand ladders. One worker is capable of manually harvesting about 50 kg of fruit per day. After wrapping in white cloth, the fruits are put into paper-lined burlap bags of 50 kg capacity for carriage to markets throughout the country.

9.2.1.2 Maturity standard

Maturation time for ber fruits varies with genotype and environment. Some mature after 120 days while others may take up to 170 days before they are mature. Harvesting the fruits at the appropriate maturity is vital for improving the shelf-life and quality of the fruits. Maturity in ber fruits is usually judged by external colour. Fruits are harvested at the mature green and mature golden yellow stages depending on several factors: the cultivar, distance from market and expected post-harvest use.

The various cultivars of ber mature at different rates and hence are harvested at different times. The Umran cultivar is best harvested at the mature golden yellow stage when fruits have good organoleptic qualities. They also have a low respiration rate and can be stored for long periods when harvested at this stage (Singh *et al.*, 1981 a). Fruits of the cultivar Kaithli should be harvested at the green-yellow stage and the optimum stage for harvesting fruits of the Gola cultivar is the green mature, green-yellow or yellow stage (Siddiqui and Gupta, 1989). Fully ripe fruits (red brown in colour) lose their crisp texture, but are suitable for dehydration.

The total soluble solids (TSS) and the ratio of TSS to acid can be used as measures of fruit maturity. The TSS and TSS/acid ratio vary between cultivars. The optimum values are presented in Table 9.1. Other indices such as the degree day heat unit accumulation and fruit weight and volume have been suggested as viable indicators of maturity. However, these measurements are either less reliable than the visual colour method or not practical for use in the field (Pareek, 2001).

Table 9.1 Maturity indices for cultivars of ber (Bhatia and Gupta, 1985)

Cultivar	TSS (%)	TSS/Acid ratio
Gola	16.7-17.0	76-84
Kaithli	16.2-16.5	75-100
Umran	17.1-17.4	93-100

The period for fruit development and maturation and subsequently the quality and shelf life of the fresh fruits also vary with cultivar. The cultivars are known to influence the quality of the fruits by their specific physico-chemical properties. For post-harvest use, the cultivar and its nutritional composition have to be considered as important traits that determine the most appropriate end use, the storage life and the quality of fruit. The cultivars Umran, Kathapal and Gola are the most promising varieties of ber in North India (Kudachikar *et al.*, 2000).

The different ber cultivars grown in north India have been studied for their physico-chemical attributes and have been grouped according to their physico-chemical traits, harvesting season, suitability of specific cultivars for short and long distance transport and the shelf life of harvested fruits.

9.2.1.3 Attributes of important Indian ber fruits

Umran

This cultivar is commercially cultivated on a large scale in Punjab, and Haryana states of India. It was developed from germplasm from Rajasthan at the Fruit Research Station at Bahadurgarch, Punjab. It fetches the highest price. The fruits are large sized, oval in shape and have a roundish apex. They weigh on average between 30 and 80 g. They are an attractive golden yellow colour which later turns into a chocolate brown at full maturity. The fruit matures in the mid-season (February to March) and ripens during mid-March to mid- April. The fruit is sweet with 19 % total soluble solids (TSS) and 0.12 % acidity. It has a pleasant flavour and excellent dessert quality. Umran fruits have a good keeping quality and can withstand long transportation. The main reason for its popularity is the long shelf life (15 to 20 days) and excellent organoleptic qualities. The fruit is also known locally as Ketha, Ajmeri and Chamdi.

Kathapal

This is a late ripening cultivar of ber well known in Gujarat that has small to medium size fruits. At maturity, the fruits remain green on one side while the other side develops a reddish yellow tinge. The average fruit weighs 10 g. They have a high TSS (23 %) and an acidity of about 0.77 %.

Gola

Gola is an early-maturing cultivar that is grown in Uttar Pradesh, Gujarat, Punjab, Rajasthan, Haryana and Delhi. It starts to bear fruit in the first week of January. The fruits are very attractive, roundish in shape and golden yellow in colour with an average weight of 20 g. The white flesh is very juicy, semi-soft and has a delicious taste. The fruit pulp has a TSS of 17 to 19 % and 0.46 to 0.51 % acidity. The ratio of pulp to stone is 14.

Kaithali

This is a mid-season cultivar of ber well known in the Punjab that ripens during March. It was developed from the collection from the Kaithali area of Karukshestra in Haryana. The fruit is medium in size with an average weight of 18 g, oval in shape and has a tapering apex. The fruit pulp is quite soft, has a TSS of 18 % and 0.5 % acidity. Unlike Umran, this fruit does not withstand transportation and has a poor keeping quality.

Tikadi.

This ber cultivar is a late maturing type that ripens in Rajasthan during February and March. The fruits are small, weighing on average 10 g. The fruits become edible, with a creamy soft flesh, when the skin turns to a red colour during a short (7 to 10 day) ripening period of the fruits on the trees. The ripe fruit has a high TSS (25 %) with a large stone (the pulp to stone ratio of ripe fruit is 6.9).

Jogia
The fruits of this cultivar are also well known in Rajasthan and have a light purple tinge when they are unripe, but are still edible at this time. Because of this, they have an extended harvest period up to early February. The skin surface has coarse ridges and is greenish yellow in colour. The flesh is white, soft, juicy and sweet with a TSS of 19 % and a pulp to stone ratio of 14.

Mundia
This is an early Rajasthan, high yielding, cultivar that matures during mid-January. The fruits are large, juicy and bell shaped with an average weight of 40 g. They have a yellowish green skin with smooth depressions. The flesh is white and soft with a TSS of 20 % and a pulp to stone ratio of 23.

9.2.1.4 Harvesting method

The most common method of harvesting ber fruits is by manually shaking or beating the tree branches to cause the ripe or mature fruits to fall to the ground. Sometimes a cloth is spread on the ground to facilitate collecting the fruits. Harvesting can also be carried out by mechanical shaking of the tree. Neither of these methods of harvesting is very satisfactory as they cause considerable damage to the fruit and the harvest includes a mixture of mature and immature fruit. Ber fruits ripen at different times even on a single tree and have a golden yellow appearance when they are fully ripe. Other more suitable methods of harvest include plucking the fruit using a clipper (an iron hook attached to a long bamboo pole) and hand picking the individual fruit. Both these methods are more time consuming and more difficult and are therefore not favoured by local farmers.

In well managed fruit orchards, manual picking ensures the harvest of fruits with the pedicels[1] attached. Research has shown that fruits with the pedicel attached have a longer storage life (Pareek, 2001). Since ber fruits mature at different rates and do not ripen simultaneously, four to five or even up to seven pickings are needed to complete the harvest, especially for late maturing varieties such as Umran. This results in higher labour costs. The cumbersome picking operation and the associated costs could be markedly reduced by using suitable plant growth regulators. Indian researchers have investigated the effects of applying plant growth regulators prior to harvest on the maturity and subsequent ripening period of ber fruits. They have also looked at the ability of plant growth regulators to reduce spoilage during the pre-harvest and storage periods, and to improve the physico-chemical characteristics of the fruit. Ripening can be delayed and the number of pickings reduced by spraying with pre-harvest ethephon sprays (see Table 9.2). The application of the plant growth regulators can help to ensure early market returns or early and uniform ripening of fruits.

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[1] A small stalk, attached to the fruit

Pre-harvest spraying of ethephon at 400 and 500 ppm to the Umran cultivar can accelerate the maturing of fruits. The mature fruits turn a deep golden yellow colour and have a high total soluble solids content, ascorbic acid and total sugars and a low specific gravity and acidity. Further, these treated fruits become more palatable and can be ripened two weeks earlier than untreated ones. The benefit of inducing maturity is that early ripened fruits could fetch a higher market price. Also, the harvesting period can be stretched from two to four weeks which would ease the strain of marketing at peak ripening time.

Table 9.2 The effects of spraying Ethephon on the number of harvests of ber fruit (Pareek and Nath, 1996)

Ethephon (ppm)	Cultivar	
	Gola	Sev
0	5	4
500	4	3
750	3	2
1000	3	3

9.2.1.5 Fruit growth and maturation

Ber requires a relatively long period of 150 to 190 days (22 to 27 weeks) after fruit set for fruit growth and maturation. Some cultivars grown in the Hissar region of the north of India can be harvested at 120 days after fruit set. The fruit growth period can be divided into three distinct phases:

1. the most active fruit growth phase during the first 6 to 7 weeks
2. slow growth rate for the middle eight weeks
3. active growth rate for the last 8 to 10 weeks.

Studies on the developmental physiology of fruit of the Umran cultivar in the Punjab illustrate the distinct physical and chemical changes during the growth and development of the fruit. Fruits of cultivar Umran attain the ripe stage in 190 days after fruit set. Fruit growth in terms of length and diameter showed three distinct phases. The increase in length was faster than the growth of the diameter during the first phase. Conversely, during the third phase, the increase in diameter was greater than the increase in length. That is, the fruits grew in length at the start of their growing period and 'filled out' during the final growth phase.

The major chemical changes that take place during fruit growth and development are changes in the content of total soluble solids (TSS). The TSS increases from fruit set through to ripening. This increase is very pronounced during the latter stages of maturity. There is a corresponding decrease in acidity (an increase in pH) of the fruit pulp as the fruit ripens. When the fruit is physiologically mature, the fruit colour turns to dark green followed by ripening with a change in colour as the ripening process advances. The stalk end of the fruit starts to turn yellow and later turns to bright yellow and then brown at the end of ripening. There is a wide variation in the TSS (12.2 to 19.2° Brix) and acidity (0.23 to 0.52 %) in different cultivars of the ripe fruit (Teaotia *et al*., 1974). Changes in the levels of other chemical components such as ascorbic acid, total phenolics and minerals during the maturation of ber fruits have been reported (Bal and Singh, 1987). The level of ascorbic acid gradually increased during growth and development (from 15 days after fruit set until 190 days). The total phenolics content increased initially, reached a peak in the developing fruits and later showed a fall as fruit maturity advanced. The calcium content showed a gradual downward trend up to 150 days and then remained constant until ripening. The phosphorus content showed a steady decline with the advancement of maturity. The iron content remained almost constant in the beginning and thereafter gradually decreased towards ripening.

9.2.1.6 Fruit drop and its control

Fruit drop is a major and serious problem in ber production. Generally the number of fruit set is very high, but the extent of fruit retention varies according to the cultivar type and on the level of production of endogenous plant hormones. Several studies have been made on fruit set, fruit drop and level of fruit retention. Sharma *et al.,* (1990) found that early maturing cultivars (that were eight years of age) were resistant to fruit drop while the late cultivars were the most susceptible to fruit drop. Garwal *et al.* (1993) observed a similar pattern, but also noticed that the fruit drop in later maturing cultivars (var. Sendbura and Narnaul) could be controlled by spraying the fruit with 10 ppm of NOXA growth regulator. This treatment resulted in the production of large size fruits with significantly higher total soluble solids and ascorbic acid content and lower acidity, total sugars and reducing sugar content than most other treatments.

9.2.1.7 Time of harvest and fruit yield

The time of harvest affects the storage life of fruits. For practical reasons, harvesting in the morning is generally preferred as the fruits are cool and turgid at this time of day and can be sold or further processed the same day. However, one study reported that fruits harvested at midday had a better storage life than those harvested in the morning or evening. This may be due to greater loss of water from the morning or evening harvested fruits (Pareek, 2001).

Bal *et al.* (1995) reported that the pre-harvest spray of ethephon at a concentration of 300 ppm to ber trees induced uniform ripening of fruits, and the fruits harvested at optimum maturity could be stored for up to forty days at a temperature of 0 to 3.3° C and relative humidity of 85 to 90 %.

Ber trees can produce fruit after the first year of planting from budded plants or after *in situ* budding in the field. However, during the first two years in the tropics, and three years in the sub-tropics, young plants are trained to develop into well balanced trees rather than for fruit production. Fruit production therefore starts from the third year in the tropics and the fourth year in the subtropics. Ber trees can become prime fruit bearers at an early age (i.e. from the fifth to sixth year under intensive management).

The fruit yield per tree varies with cultivar, age of the tree, climate and location of the tree. Seedling trees bear between 5000–10,000 fruits per year and superior grafted trees can bear up to 30,000 fruits. The best cultivar in India reportedly bears fruits that give an average of 66 fruits per kg and that yields 77 kg annually. Both fruit size and number can be increased by simple cultural treatment (www.hort.purdue.edu). Yields of 80 to 200 kg per mature (10 to 20 year old) tree have been reported in India for trees under irrigated conditions. Yields as low as 50-75 kg per tree have also been reported. In Israel, yields of 12 tons per hectare have been obtained from three year old ber trees (Pareek, 2001). Water availability has a significant impact on yield. In rainfed agriculture, the yield can be as low as 80-100 kg per tree in semi-arid areas, while in arid areas it can fall to 50 kg per tree (see Pareek, 2001).

Researchers in India (Kudachikar *et al.*, 2000) have investigated the effect of pruning the tree on fruit yield and quality. Pruning is considered to be one of the most important horticultural practices for the production and maintenance of regular fruit bearing, both in terms of quality and quantity of fruit. Ber fruits are borne in the leaf axils on the young growing shoots of the current season. Pruning has been discussed in Chapter 6 but details relevant for fruiting are provided below. The best time for pruning ber trees is during the hot and dry season when the tree sheds its leaves and becomes dormant after the harvesting of fruits (Sharma and Kore, 1990). The effects of severity of pruning on flowering, fruit setting, fruit yield and quality of ber fruits of different cultivars in different agro-climatic growing regions have been investigated by Bajwa *et al,* (1986), Bisla *et al.* (1991) and Kundu *et al,* (1994).

Kundu *et al.* (1994) looked at pruning of thirteen year old Umran trees. When pruning was too severe and the planting distance close, flowering and fruit production was decreased. However, when the planting distance was wider, even though the pruning was severe, the percentage of fruit set increased. The percentage of fruit retention increased with increased planting distance and decreased pruning severity. Yadhav and Godara (1992) found that the best combination for ber trees was medium pruning combined with a planting distance of 7.2 m x 7.2 m or 9.6 m x 9.6 m.

The fruit yield in un-pruned trees is often on a par with pruned trees, but the fruit quality is poor. Pruned trees tend to produce large fruits of good quality and with a significantly higher fruit weight.

As noted in 9.2.1.4 researchers have investigated the effects of applying plant growth regulators prior to harvesting on fruit maturity, yield and quality. The application of calcium compounds such as calcium chloride and calcium nitrate (CCC) at 1.7 g per litre as a pre-harvest spray reduced the fruit weight loss, delayed colour development and maintained good quality ber fruits during storage (Gupta *et al*., 1987). Bankar and Prasad (1990) investigated the effects of pre-harvest spraying of ber fruit with gibberellic acid (GA3) and napthalein acetic acid (NAA) at three different rates (10, 20 and 30 ppm) either alone or in combination at two different times (at the time of flowering and at 15 days after flowering). They found that both growth regulators, at all concentrations and applied at both times, alone and in combination, increased the number of fruit set and decreased fruit drop (i.e. they increased fruit retention). The fruit weight and fruit length were both significantly increased by application of GA3 or NAA at 30 ppm concentration. The total soluble solids (TSS) content was improved by treatment with GA3. Masalkar and Wavhal (1991) reported that the pre-harvest application of GA3 (10-20 ppm) and ethephon (400 ppm) to ber trees of Umran cultivar improved the physico-chemical characteristics of ber fruits. Significant increase in fruit weight, fruit volume, pulp percentage, non-reducing sugars and ascorbic acid contents and lower stone percentage were obtained with treatments of GA3 alone, while ethephon treatment resulted in high TSS content and also improved the fruit colour to golden yellow. Other growth regulators have been tested; 2,4-D at 10-15 ppm and CCC at 100 ppm but CCC can reduce the size of fruits.

9.2.2 Post harvest handling

9.2.2.1 Post harvest ripening

After harvest at the mature green to mature golden yellow stages, ber fruits start to ripen at ambient temperature. Ripening is signified by a change in colour from green or golden yellow to red or red brown. It takes place after 4 to 15 days, depending upon cultivar and storage environment.

The fruits are considered to have the best organoleptic qualities (taste and texture) when they are at the mature green to mature golden yellow stages. Therefore, attempts are made to delay the ripening process and prolong the keeping quality by modifying the storage environment.

Plant growth regulators may be applied to ber fruits after harvest to accelerate the uniform rate of ripening and to reduce losses through post-harvest decay. Ethephon has been found to be the most effective growth regulator that accelerates the ripening and improves the quality of ber fruit (Kudachikar *et al.*, 2000). Siddiqui and Gupta (1995) found that post harvest dipping of ber fruits (cultivar Umran) at the colour turning stage in cycocel or chloromequot (500 or 1000 ppm) for 15 minutes, followed by storage in wooden boxes packed with newspaper at 25 ± 5° C significantly reduced the decay loss of fruits and retarded the ripening process, thereby extending the shelf-life of fruits.

9.2.2.2 Grading

The harvested fruits are usually at different stages of maturity and need to be sorted into different groups before they are sold, stored or further processed.

They are sorted and graded according to maturity, size, shape and colour. First the fruits are sorted by hand. The under-ripe, over-ripe, damaged and misshapen fruits are removed. The under-ripe fruits are set aside and left to ripen. Over-ripe fruits are not desirable for fresh sales or processing and should be discarded.

The remaining fruits are graded into two or three groups based on the size and colour of fruit. Grading can either be carried out manually or by passing through sieves of different mesh sizes. A grading standard for ber fruits is included in Table 9.3.

Table 9.3 Grading criteria for ber (Pareek and Gupta, 1988)

Grade	Standard
A	Shining yellow, large (>35 mm) to medium size (24-35 mm) fruits of uniform size with no blemishes.
B	Uneven yellow or yellow red, large (>35 mm) to medium (25-35 mm) fruits of uniform shape with some blemishes.
C	Red, large (>35 mm) to small (<25 mm) fruits. Uneven yellow, small (<25 mm) fruits.

After grading, fruits for processing are washed using chlorinated water (100 ppm), drained and used for further processing. Fruits for sale are packed and either stored or transported to market.

9.2.2.3 Packaging

After harvest, fruits are brought to the packing house or under shade for cleaning, packing or for post-harvest treatments to extend their shelf life. The fruits are packed either for controlled storage or for safe transport to local or distant markets. Correct and appropriate packaging of the fruit is essential for the safe transport of the fruits during transportation and storage.

An ideal fruit package ensures that the fruit is completely protected from spoilage and physical damage. Pareek and Gupta (1988) suggest various types of container for packaging ber fruit depending upon the bulk of the fruits.

During transport and storage, ber fruits are susceptible to damage and spoilage by infection with bacteria and fungi, especially if organic packing or cushioning material is used for packaging.

Microbial damage can be reduced by spraying the fruit with anti-fungicides and anti-bacterial chemicals such as captaf, thiobendazole or Dithane M-45. Fruit can also be washed with a solution of 0.05-0.1 % potassium permanganate ($KMnO_4$), or washed with bleaching powder to reduce spoilage at a rate of 5 g bleach powder per kg of fruit. Diphenyl impregnated paper can also be used for packaging to reduce bacterial spoilage (Pareek, 2001).

The use of chemical preservatives is not always desirable. It is preferable to pack ber fruits in non-organic materials, which avoids the need for chemicals. Perforated polythene bags (150 gauge), nylon nets or cardboard cartons can be used to package small quantities of 1-2 kg. For larger volumes of fruit of 10-20kg, gunny bags, cloth packages or wooden boxes with holes or slits are used. Baskets made from locally available materials such as bamboo can be used. Shredded paper is the best material to use for cushioning and protection during transport.

For transportation, corrugated cardboard cartons of about 10 kg are the most suitable packaging material. For short distances, cheaper materials such as gunny bags, cloth or old boxes can be used provided that the fruit are cushioned and ventilation is provided. The best packages are nylon nets or perforated polythene bags for small quantities of about 1 to 3 kg fruit for retail sale.

9.2.2.4 Storage

Ber fruits are relatively perishable and have a shelf life of only four to five days at ambient temperatures. Transportation of ripe fruits to distant places is difficult and results in large post-harvest losses. Both pre-harvest and post-harvest factors have been found to influence the storage life and post-harvest quality of ber fruits (Kudachikar *et al.*, 2000). Pre-harvest factors that influence the storage life include the following:

- pruning of the tree
- control of fruit drop by exogenous application of plant growth regulators
- the stage of maturity
- physico-chemical composition of the fruits at the time of harvest.

Post-harvest factors that influence storage life and fruit quality include the following:

- the use of plant growth regulators
- irradiation
- storage conditions

Storage experiments in India have demonstrated that slightly under-ripe fruits ripen and keep for eight days under wheat straw, seven days under leaves and four days in carbide (50 to 60 g) (www.hort.purdue.edu). Other studies in India (Kudachikar *et al.*, 2000), demonstrated that the shelf life of ber fruits could be significantly extended by coating the fruits in wax, packing them in polyethylene bags and storing at 0 to 3.3° C and 0 to 4° C, up to 40 days and 21 days respectively. This is in comparison to untreated fruits that are stored at ambient temperature (30 to 35° C) and only have a maximum shelf life of seven days. The improved storage life at reduced temperatures gives potential for transporting ber over long distances, from the growing areas in North India to consumers in southern India, if refrigerated transport lorries are available.

Storage at room temperature

After harvest, ber fruits are usually stored at ambient temperature (25-35° C) until they are either sold or further processed. The fruit is often stored in heaps under shade or in storage rooms, but it is better to store in packages such as gunny bags, net bags, polythene bags and boxes. Depending upon cultivar and the storage conditions, fruit can be kept for 4 to 15 days without loss of organoleptic quality.

During storage, the fruits lose weight and shrivel, change colour from green yellow or golden yellow to reddish brown and lose acidity and ascorbic acid (vitamin C), but gain in sweetness. Typical values for quality parameters of ber fruits (cultivar Umran) in storage are found in Table 9.4.

Table 9.4. Typical changes in quality characteristics of ber fruit during storage at ambient temperature (from Pareek, 2001)

	Ber fruits (Umran cultivar)	
Quality parameters	**At harvest**	**After 9 days storage at 30-35°C**
Colour	Golden yellow	Grey orange
TSS (%)	17.5	19.5
Total sugars (%)	10.19	16.38
Acidity (%)	0.21	0.12
Ascorbic acid (mg/100g)	117.13	93.72
Total phenolics (%)	0.108	0.039

Cool storage

The shelf life of fruits can be extended by storage in cool chambers. Cool chambers are simple, double walled structures made from locally available materials such as mud or brick. The space between the two walls is filled with sand or wood shavings that are kept cool by sprinkling with water. Cooling is achieved by evaporation of water from the walls of the chamber.

With prolonged storage in a cool chamber, a high level of humidity can develop within the chamber which is conducive to spoilage in the fruit. Fruits have been stored successfully for 6 to 10 days in cool chambers without any loss in quality. However, the length of storage within a cool chamber very much depends on the cultivar, ambient and internal temperature, humidity level, quantity of fruit within the chamber and the maturity of the fruit at harvest.

If cold storage is available, fruits can withstand temperatures as low as 10° C without any damage. At this temperature, the shelf life can be extended for 28 to 42 days depending upon cultivar. At temperatures of 13° C, fruits can be stored in perforated polythene bags and baskets for up to 3 weeks without any loss in quality (Pareek, 2001). At lower storage temperatures (at 0 to 4° C), the fruits become an unattractive brown colour.

Treatments to extend shelf life
Various treatments are available to extend the shelf life of fruits. Some of these are applied to the fruit whilst still on the tree while others are post-harvest treatments. The use of the various chemicals to extend the storage life of fruits should be carried out with caution, especially if the fruit is being sold as organic. Certain chemicals are not permissible for use on fruits that are destined for the organic market. National and international regulations should be consulted regarding the use of any chemical. All safety regulations regarding the dosage and application of spray and the use of the fruit after spraying, for example, the number of days that must elapse before the fruit is safe for consumption, should be observed.

Pre-harvest treatments
The calcium content of fruits influences the shelf life. Therefore, pre-harvest applications of calcium compounds can have an effect on the storage life. Fruits naturally contain calcium as compounds of pectate, carbonate, oxalate and phosphate. One treatment is to spray the fruit 10 days before harvest with a solution of calcium chloride at 1.7 g calcium per litre with 1 % Teepol as a surfactant. A second treatment is to apply calcium nitrate to the fruit. A 1 % solution of calcium nitrate is sprayed on the fruit 10 days before harvest, when the fruit is at the colour turning stage.

Post-harvest treatments
There are several possible treatments that can be used to extend the shelf life of harvested fruits. These include cleaning, dipping in cold water to remove field heat, treatment with chemicals such as calcium compounds, anti-oxidants, growth regulators and fungicides.

Dipping the fruits in cold water for two hours or exposing to cold air for four hours immediately after harvest to remove field heat has been shown to prolong shelf life.

Dipping the fruits in a solution of calcium chloride (1 to 2 %) containing a surfactant can prolong the shelf life of ber fruits by delaying the onset of ripening.

Post-harvest dipping of fruits into a solution of ascorbic acid (150 to 300 ppm ascorbic acid) can reduce over-ripening and increase the levels of TSS.

However, this treatment has no effect on the acidity or ascorbic acid content of the fruit.

Dipping the fruits (Gola cultivar) in a solution (1000 ppm) of potassium permanganate ($KMnO_4$) at the colour turning stage gave the best result of extending the shelf life of fruits to 14 days at room temperature (Ramkrishan Godara, 1994). Also, Umran fruits harvested at the golden yellow colour stage and dipped in a solution of 10 ppm benzyl adenine for five minutes, then packed in polyethylene bags, had a lower weight loss, higher TSS, sugars and ascorbic acid and a greater palatability rating after storage for eight days (Sandhbhor and Desai, 1991).

Treatment with a range of different growth regulators has been successful at delaying the ripening of harvested fruits and maintaining the high quality of ber fruits during storage. The application of cycocel (500 ppm for 15 minutes and 1000 to 2000 ppm for 10 minutes), maleic hydrazide (200 ppm) and benzyladenine (10 ppm and 100 ppm) have all been shown to reduce weight loss and improve the quality of stored ber fruits when stored in wooden boxes or polythene bags (Pareek, 2001).

Spraying with a fungicide such as thiobendazole (500 ppm) or zinc sulphate ($ZnSO_4$) (0.2 %) also reduces decay of the fruit during storage. Care to follow health and safety regulations (see box) should be taken when using fungicides.

Health and safety when using Thiobendazole and Zinc sulphate ($ZnSO_4$)

Handling and storage:
Store the material in a well ventilated, secure area out of reach of children and domestic animals. Do not store food, beverages or tobacco products in the storage area. Prevent eating, drinking and tobacco use in areas where there is a potential for exposure to the material. Wear protective clothing and avoid contact with the skin and eyes .Where eye contact is likely, use chemical splash goggles. Wash thoroughly with soap and water after handling.

Environmental impact:
Thiobendazole: Very toxic to aquatic organisms
$ZnSO_4$: no ecological problems are expected when the product is handled and used with care.

Wax treatment

Coating with wax has been shown to be effective at retaining the physical appearance of Umran fruits, but had no effect on their organoleptic quality. After dipping fruits in Waxol-O-12 for 30 seconds, they remained in good condition for 30 to 40 days when kept in polythene bags and stored at 0-3.3° C. At room temperature, they could only be stored for 12 days. Fruits coated in paraffin wax (2 %) and treated with 10 ppm NAA or 100 ppm ascorbic acid could be stored for 12 days at room temperature and up to 18 days when the temperature was reduced to 10-12° C.

Wax coated fruits must be washed properly before use.

Irradiation of fruits

Radiation preservation of ber fruits is one post-harvest strategy that may help to delay post-harvest ripening and senescence and thereby reduce losses and extend the shelf life of fruits. Studies carried out on the use of irradiation on ber have been found to be encouraging. Ahmed *et al.* (1972) treated mature hard, green ber fruits of cultivar Umran-13 with 10, 20, 30, 40 and 50 k rad of gamma rays. They found that those fruits treated with 20 to 40 k rad doses were relatively firmer and greener than the controls during a subsequent storage period of eight days at room temperature (30 ± 2° C). Irradiation had no detectable adverse effects on the taste and flavour of ripened fruits, or on the chemical composition of the fruit.

9.2.3 Processing

In India the ripe ber fruits are mostly consumed raw, but are sometimes stewed. In Southeast Asia, the unripe fruits are often eaten with salt.

Ber fruits are used to make a number of different products. One of the simplest forms of processing is dehydration, which is essential for prolonged storage of the fruit. The dried ripe fruits are sometimes ground into a powder for prolonged storage and out-of-season use. Both dried and fresh ber can be used for further processing. Slightly under-ripe fruits are candied by a process of pricking, immersing in a salt solution that gradually increases from 2 to 8 %, draining, immersing in another solution of 8 % salt and 0.2 % potassium metabisulphite, storing for one to three months, rinsing and cooking in sugar syrup with citric acid. Acidic types of fruit are used for pickling or chutneys. In Africa, the dried and fermented pulp is pressed into cakes that are similar to gingerbread. In Venezuela a liqueur is made from the fruits and sold as 'Crema de ponsigue'.

Traditionally, ber fruits are washed, drained and sun dried. The quality of the dried product varies according to the different varieties of ber, the level of maturity at harvest and the environmental and physical conditions during dehydration. See flow chart 1 for an outline of the ber dehydration process. The quality of dried product from different cultivars varies. Fruits of the cultivars Katha or Umran, Bagwadi, Chhuhura, Mehrun, Sanaur-2, Sanaur-3, Sanaur-4, Illaicji and Karaka all give a good dehydrated product. In general, the quality is better from varieties of Umran or Katha and Chhuhura, although some consumers prefer the more acidic fruits of Sanaur-2, Sanaur-3, Sanaur-4 and Mehrun.

The stage of maturity of the fruit also determines the quality and recovery of the dehydrated product. Recovery of the dried product is greater when ripe, but firm rather than mature fruits are used. Golden yellow to reddish brown fruits give the best quality of dehydrated product.

Pre-treatments such as blanching (dipping the fruit in boiling water for 2-6 minutes) and sulphuring before dehydration improve the product quality. Blanching induces the development of a uniform yellow colour, stops the activity of enzymes and micro-organisms that cause spoilage and softens the fruit so that dehydration takes place at a uniform rate. The optimum time for blanching varies between cultivars and is dependent upon the size of the fruit and softness of the pulp (see Table 9.5).

Table 9.5 Optimum blanching times for ber cultivars

Cultivar	Blanching time (minutes)
Illaichi	2
Bagwadi	4
Karaka and Umran	6

After blanching, the fruits can be sulphured. This process helps to preserve the colour of the dried ber and retain some of the ascorbic acid content. Sulphuring is an optional step and depends upon the final market for the fruit. Fruits are sulphured by exposing them to the fumes of sulphur dioxide, which is generated by burning sulphur powder (3.5 to 10 g per kg fruit) in an enclosed chamber or sulphur tent.

The quality of dried ber is also dependent upon the drying methods and conditions. Traditionally drying is carried out by spreading the fruits on the floor, on mats or on polythene sheets and leaving in the sun for 7 to 10 days. The quality of these fruit depends on the local weather and sanitary conditions. Usually a fairly good product is obtained by sun drying. The quality of the dried product can be improved by using a solar cabinet, which reduces the number of days taken to dry the product to about four or five.

Sulphuring

Sulphur dioxide is sometimes used as an additional form of preservative when drying fruits. The addition of sulphur dioxide improves the colour and increases the shelf life of the dried ber. There are two main methods of applying sulphur dioxide (SO_2) to fruits:

- by burning elemental sulphur in a sulphur cabinet or tent
- by soaking fruits in a solution of sodium sulphite, sodium metabisulphite or potassium metabisulphite.

The strength of the sulphite solution or the amount of sulphur used and the time of exposure, depend on the commodity, its moisture content and the residual levels permitted in the final product, which are set by legal standards in each country. Typically a 3 g per litre solution of sulphite or 2 g of sulphur for each kg of prepared fruit is used. The sulphuring time varies from 1 to 3 hours and is dependent upon the size and texture of the fruit being sulphured. The permitted levels for use are 0.005 to 0.2 % concentration in dried fruits. If too much sulphite is used, it taints the fruit.

Importers in the European Union and United States of America may specify that sulphur dioxide is not used for the products.

Sulphuring is an optional stage during the drying of ber fruits. Its use really depends upon the facilities available for sulphuring and the intended end use of the dried fruit. When ber fruits are dried for home preservation, it is not usually economically feasible to include sulphuring as part of the process.

After dehydration, the fruits should be packaged in moisture-proof containers, e.g. 400 gauge food grade polythene bags or airtight tins. The dried product can be used for a dessert or it can be reconstituted in a 10 % sugar solution and consumed as a liquid beverage.

Sun-drying is the simplest and cheapest form of drying fruits. However, it is very weather dependent and does not always produce the highest quality dried fruit. There are various driers that could be used to improve the quality of the product, but their use very much depends on the intended use of the fruit. High value fruits would be dried using mechanical driers. Unless there is a market for high quality dried ber fruit, it would not be economically viable to use an improved form of drying.

Flow chart 1. The preparation of dehydrated ber

Process	Process notes + quality control
Graded, ripe fruits ↓	Only use ripe, firm fruits without marks or bruising. Golden yellow to reddish brown fruits give the best quality.
Wash and sort ↓	Wash in clean water. Remove any leaves, twigs and other material.
Blanch fruits ↓	Blanch fruits by plunging them in boiling water for 2 to 6 minutes.
Sulphur fruits (optional) ↓	Fruit is either sulphured using SO_2 gas or sulphited by dipping in a solution of sodium metabisulphite: 1. Create a chamber in which the sulphur powder (3.5 to 10 g/kg fruit) can be burned. The chamber must be airtight to prevent the fumes from escaping. The chamber can be made from a large cardboard box or from a polythene tent. Wooden sulphur cabinets are available for purchase. Place the fruit in single layers on trays inside the chamber. Burn the sulphur at the base of the chamber, away from the side of the box. Leave the fruit in the chamber for up to 3 hours. 2. Make a solution of sodium sulphite or sodium metabisulphite (3 g sodium per litre water). Dip the fruits into the solution for 60 to 90 minutes.
Place on mesh trays ↓	Place the fruit in a single layer on mesh trays. The fruits should be as close together as possible, but not touching.
Dry ↓	There are several options for drying, depending on the facilities available, the value of the product and the intended end use. a. Sun drying. Dry under the bright sun for 7 to 10 days until dry. Turn the fruits over daily. b. Solar drying. Place fruits in a solar drier for 4 to 5 days until dried. c. Cabinet drier. Place the fruits in a cabinet drier at 60-65° C for 20 to 30 hours until dry. For all drying methods, the final moisture content of dried fruits should be 15 %. The fruits will have a soft rubbery texture. With experience, processors will know when dried ber have reached the correct moisture level.
Package and seal ↓	Pack the dried fruits in moisture-proof containers e.g. 400 gauge polythene or polypropylene pouches and heat seal them. Fruits that are being dried for home storage should be transferred to storage sacks.
Label (optional) ↓	If fruits are being dried for sale, the packages should be labelled. Label with the product name and date of drying.
Store	Dried fruits should be stored in a dry, cool environment, away from pests and animals and away from chemicals which may contaminate the product.

9.2.3.1 Ber preserve

Mature fruits can be used to make a preserve, known locally in India as murabba. Fruits of the cultivars Umran, Banarsi, Karaka and Kaithli are the best for the preparation of preserve (Pareek, 2001).

The best preserve is made from fully mature fruits that are at the hard stage. Ripe fruits are not suitable since the structure will be too soft.

After washing and sorting the fruits, the skins need to be pricked so that sugar can impregnate the fruit. They are either pricked with a fork or by using a pricking board or pricking machine, similar to the one that is used for pricking olives. The pricked fruits then need to be softened. One method of softening the fruits is to soak them in brine solutions of gradually increasing concentration. For example, 2 % brine for the first day, 4 % brine the second day, 6 % brine on the third day and then 8 % brine solution for one to three months. However, this method proved to be too time consuming and it was difficult to remove all traces of salt from the fruit (Pareek, 2001). Therefore alternative methods of softening have been used.

A simpler method of softening the fruit is to blanch the pricked fruits by plunging them into boiling water for anything from 2 to 190 minutes depending upon the cultivar, stage of maturity and size of fruit. After blanching, the fruits are dipped in cold water to stop the process.

At this stage, the fruit can be peeled if desired, by using a pectinase enzyme (fruits are dipped in a solution of 2.5 % pectinase enzyme for 72 hours). This is an optional stage.

Flow chart 2. The preparation of ber preserve

Process	Process notes + quality control
Graded ripe fruits ↓	Only use fully mature fruits at the hard stage.
Wash and sort ↓	Wash fruits in clean water. Discard bruised and over-ripe fruits.
Prick ↓	Prick the skin to improve the uptake of sugar. A fork can be used or a pricking board.
Blanch ↓	Plunge into boiling water for 2 to 10 minutes depending upon cultivar, stage of maturity and size of fruit.
Rinse ↓	Dip in cold water to stop the blanching process.
De-stone (optional) ↓	Remove the stones from the centre of the fruits using a cork borer.
Impregnate with sugar ↓	Submerge overnight in 30° Brix sugar syrup and add 0.5 % citric acid. Slowly increase the strength of the sugar syrup.
Remove fruit from the syrup and increase the strength of sugar syrup ↓	Add 250 g sugar per kg fruit to the syrup. Boil for a few minutes. Cool to room temperature and replace the fruits in the syrup. Leave to soak for two days.
Increase the strength of sugar syrup ↓	Repeat the above step twice more until the final sugar content is 65 to 70° Brix. Leave to equalise for about two days.
Bottle	Pour the fruits and 70° Brix syrup into sterilised bottles. Seal and label.

Fruits can also be de-stoned if desired. This is an optional step and depends on the consumer demand and taste.

The softened fruits are then ready for impregnation with sugar. This is achieved by submerging the fruits in a solution of sugar syrup. The concentration of the sugar syrup is gradually increased while the fruits soak. On day one, the fruits are immersed in a sugar syrup of 30° Brix. Citric acid (0.5 %) is added to the syrup to help maintain the colour of the fruit and to reduce the pH of the syrup. This gives a slightly acidic taste to the product, and also helps to prevent fermentation of the fruit during the soaking period. It is possible to start the soaking process with a stronger sugar syrup (say of 50° Brix), but experience has shown that the fruits are liable to shrink when a high concentration is used from the start as water is drawn out of the fruit too quickly. The principle of this method of preservation is that water is drawn out of the fruit by osmosis. It is best if this happens at a slow rate. As the water is drawn out of the fruit, the sugar content (the total soluble solids content) of the fruit increases. The water that is drawn out of the fruit into the surrounding syrup dilutes the sugar syrup, therefore it is necessary to keep adding more sugar to the syrup to increase the concentration of the syrup. Water will continue to be removed from the fruit until the total soluble solids content of the fruit reaches about 70° Brix measured using a refractometer.

There are many different methods of preserving ber, and they differ in the length of time it takes to reach the end point at 70 % total solids. The following method is one that is recommended by Khurdiya and Singh, (1975):

Day 1. Immerse the fruits in a 30° Brix sugar solution. Add 0.5 % citric acid and leave overnight.
Day 2. Remove the fruits from the syrup, add sugar (about 250 g/kg fruit) to the syrup and boil to dissolve the sugar. Allow the syrup to cool and replace the fruits into it. Leave for two days.
Day 4. Remove the fruits from the syrup, add sugar (about 250 g/kg fruit) to the syrup and boil to dissolve the sugar. Allow the syrup to cool and replace the fruits into it. Leave for two days
Day 6. Remove the fruits from the syrup, add sugar (about 250 g/kg fruit) to the syrup and boil to dissolve the sugar. Allow the syrup to cool and replace the fruits into it. Leave for two days.
Day 8. Measure the TSS of the product. It should be between 65 and 70° Brix.
Bottle the preserved fruit in the 70° Brix syrup. The total soluble solids (TSS) content of the fruits becomes equalised at 65 to 70° Brix.

9.2.3.2 Ber candy

Mature ber fruits can also be used to make candied ber. Fruits of the cultivar Illaichi have the best organoleptic properties for candy making. Kaithli, Kathaphal, Umran and Narma are also good cultivars for candy making. Fruits should have a high total soluble solids (TSS) content, low acidity and be of average size (Pareek, 2001).

The best candy is made from fully mature fruits that are at the hard stage. Ripe fruits are not suitable since they may be too soft.

Flow sheet 3. The preparation of ber candy

Process	Process notes + quality control
Graded ripe fruits ↓	Only use fully mature fruits at the hard stage.
Wash and sort ↓	Wash fruits in clean water. Discard bruised and over-ripe fruits.
Prick ↓	Prick the skin to improve the uptake of sugar. A fork can be used or a pricking board.
Blanch ↓	Plunge into boiling water for 2 to 10 minutes depending upon cultivar, stage of maturity and size of fruit.
Rinse ↓	Dip in cold water to stop the blanching process.
De-stone (optional) ↓	Remove the stones from the centre of the fruits using a cork borer.
Impregnate with sugar ↓	Submerge overnight in 30° Brix sugar syrup and add 0.5 % citric acid. Slowly increase the strength of the sugar syrup.
Remove fruit from the syrup and increase the strength of sugar syrup ↓	Add 250 g sugar per kg fruit to the syrup. Boil for a few minutes. Cool to room temperature and replace the fruits in the syrup. Leave to soak for two days.
Increase the strength of sugar syrup ↓	Repeat the above step twice more until the final sugar content is 65 to 70° Brix. Leave to equalise for about two days.
Leave to impregnate ↓	Leave the fruits in the 65-70° Brix sugar solution for 10 to 25 days.
Drain ↓	Remove the fruits from the syrup and drain on wire mesh trays.
Dry ↓	Dry the drained fruits in the sun or in a warm room until they reach a final moisture content of 10-15 %.
Roll in sugar (optional) ↓	Roll the dried fruits in sugar powder to make crystallised fruits.
Pack	Package in moisture-proof containers such as tins, jars or polythene pouches.

The process for making candied ber fruits is essentially the same as for making ber preserve outlined above. Ber fruits are submerged in sugar syrups of slowly increasing strength until a final concentration of 70° Brix is reached. At this point, the fruits are left to soak in the 70° Brix syrup for a further ten to twenty five days. After this time, the fruits are taken from the syrup and spread on wire fruit trays for the excess syrup to drain off. The drained fruits are dried in the sun or in a warm room until they reach a final moisture content of 10-15 per cent.

As an option, dried candied fruits can be rolled in powdered sugar to make a crystallised product. The dried fruits should be packed in moisture-proof packets such as jars, tins or polythene pouches.

9.2.3.3 Ber pulp

Ber fruits can be partially processed into a pulp that has a relatively long shelf life of up to six months. This pulp can be used to make a range of products including squash, jam, fruit beverage, fruit nectar, chutney, pickle and fruit leather. The advantage of making fruit pulp is to extend the period of availability of ber for processing into further products. Thus, the processing season for jams, chutneys etc. can be spread out over a longer period.

Ber fruits are processed into pulp at times when there is a glut of fruit. Juicy varieties of ber are the best type for making pulp, but most varieties can be used.

The fruits are de-stoned and cut into small pieces. These pieces are heated with water (2 parts fruit to 1 part water) for a few minutes to soften the flesh and then passed though a stainless steel sieve or through a pulping machine to form a smooth pulp or puree. Sodium metabisulphite (1.2-1.5 g/kg pulp) is added to the pulp as a preservative. The pulp is packaged in sterile sealed containers and stored for use at a later date. Treated like this, the pulp will have a shelf life of up to 6 months depending on storage conditions and hygiene during the preparation. When the pulp is used, it should be heated well to liberate some of the sulphur dioxide gas and reduce levels to those which are legally acceptable.

9.2.3.4 Ber chutney

Dried ber, fresh fruits or pulp can be used to prepare a spicy fruit chutney (see box for ingredients). In the following example from Bangladesh, dried fruit is used. After cleaning and sorting, the fruit is soaked overnight in water to rehydrate it. Usually this length of time is sufficient to soften the fruit but if any remains hard after soaking, the fruit should be heated. The soaked fruit is removed from the soaking water, rinsed and placed in a pan with sugar at 700 g to 1 kg per kg dried fruit, according to taste. The ber and sugar are stirred to dissolve the fruit and then heated for 10 to 15 minutes until the total soluble solids content is 55° Brix, measured with a refractometer. Spices such as chilli powder, cumin, aniseed, ground cinnamon, ground nutmeg and black pepper are dry roasted in a heavy iron pan before use. They are then added, together with mustard powder, to the heated ber fruits, stirred well to mix and heated. Acetic acid (vinegar) and salt are added, stirred well to mix and heated again. Heating is continued until the TSS reaches 60° Brix. The chutney is then ready for bottling. A preservative, potassium or sodium metabisulphite (KMS or NaMS) can be added as an option at this stage if desired.

Ingredients for ber chutney

1 kg dried ber
700 g -1 kg sugar depending upon cultivar and taste
5 g chilli powder
10 g mustard powder
2 g cumin
2 g aniseed
2 g cinnamon
1 g cardamom
1 g nutmeg
1 g black pepper
5 ml acetic acid
30 g salt
2 g potassium metabisulphite (KMS) (optional)

The amount of spices used can be varied according to local taste and preference

The chemical helps to preserve the chutney and protect against fungal damage. However, some consumers prefer to buy a product that is free from preservatives. Preservatives are not an essential component of a chutney. When a chutney is prepared correctly, the combination of a high sugar content and a high level of acidity (from using vinegar) should be sufficient to preserve the product.

Some processors choose to add the preservative as an added measure of caution, especially when the products are being made at the small scale and are likely to be stored in humid environments. Adding preservative such as KMS should never be seen as an alternative to observing good hygienic practice and following the correct production method.

The method for producing ber chutney, together with the quality control steps, is included in flow chart 4.

Flow chart 4. The preparation of ber chutney

Process	Process notes + quality control
Dried ber fruit ↓	Select 1 kg dried ber fruit.
Soak in clean water ↓	Soak overnight to soften the fruit. If it remains hard after about 12 hours soaking, heat gently until all fruit is softened.
Add sugar ↓	700 g-1kg per kg dried fruit depending upon local taste.
Heat ↓	Heat the mixture for about 10 to 15 minutes until the mixture thickens and the TSS is 55° Brix.
Dry roast spices ↓	Dry roast the spices (chilli powder, cumin, aniseed, ground cinnamon, ground nutmeg and black pepper) on a heavy iron pan.
Add spices ↓	Add the roasted ground spices and the mustard powder to the chutney. Mix well.
Heat ↓	Stir well and continue to heat.
Add acetic acid and salt ↓	Add acetic acid (vinegar) and salt to the chutney. Mix well.
Heat ↓	Continue heating until the chutney has a TSS of 60° Brix.
Add preservative (optional) ↓	Disperse the KMS in a little hot water. Add to the chutney, stir well to mix.
Bottle	Pour into clean sterile glass jars. Cap and label.

9.2.3.5 Ber beverage

Fresh ripe ber fruits can be used for the preparation of a fruit beverage. The juicy varieties of ber make the best juice. The fruits are washed and de-stoned then the flesh is cut into small pieces. The fruit pieces are boiled with water (1 litre of water per kg fruit pieces) for 20 to 30 minutes until the fruits are softened. The fruit pulp is passed through a stainless steel sieve or strained through a muslin juice bag to produce a clear juice. The juice is sweetened by adding sugar (500 g per litre of extracted juice), acidified by adding citric acid (10 g per litre juice extract) and diluted with clean water (2.5 litres water per litre of juice extract). The ber juice mixture is then boiled for 5 to 10 minutes and filtered again through a muslin cloth. The clear juice is hot filled into pre-sterilised bottles which are capped using a corking machine. The bottles should be filled to within about 5 cm of the top of the bottle to allow for expansion of the juice during pasteurisation. The sealed bottles are pasteurised by placing in a hot water bath (at 80-95° C) for 10 to 20 minutes depending upon the size of the bottle. The pasteurised bottles are cooled to room temperature by immersing in cool water – do not use cold water as this will crack the bottles. After cooling, the bottles are labelled and stored.

In Zimbabwe, dried and fresh ber fruits have been used to make an alcoholic drink with 2 % alcohol. The fruits are crushed and fermented for seven days in earthenware containers using yeast and lactic acid bacteria. Kainsa and Gupta (1979), investigated the preparation of wine from Umran cultivar of ber (Pareek, 2001). They reported that it is preferable to treat the fruit with a pectinase enzyme before fermentation as this gives about 9 % higher yield, higher alcohol content and a better clear and golden yellow wine colour than without pectinase enzyme.

Flow chart 5. The preparation of ber beverage

Process	Process notes + quality control
Fresh ripe fruits ↓	Select fruits that are juicy and fully ripe, free from damage and signs of deterioration.
Wash and de-stone ↓	Wash fruits in clean water and remove the stones manually.
Cut fruits ↓	Cut the flesh into small pieces.
Boil with water ↓	Add water (1 litre water per kg chopped fruit) to the fruit and boil for 20-30 minutes until the fruit is soft and pulpy.
Filter ↓	Pass the pulp through a stainless steel sieve or a muslin filter bag to produce a clear juice.
Add sugar, citric acid and water ↓	Add sugar (500 g per litre extracted juice), citric acid (10 g per litre extracted juice) and clean water (2.5 litres per litre of extracted juice). Mix well.
Boil ↓	Boil for 10 to 15 minutes to dissolve the sugar.
Filter ↓	Filter through a muslin cloth to remove any impurities and sediments.
Pour into bottles ↓	Hot-fill into pre-sterilised glass bottles. Leave a space of about 5 cm at the top of the bottle. Cap the bottles using a crown cork.
Pasteurise ↓	Place capped bottles into a water bath of hot water (80-95° C) and leave for 10 to 20 minutes depending upon the bottle capacity.
Cool ↓	Cool to room temperature by immersing in cool, not cold, water. Cool down gradually or the glass bottles will crack.
Label	Label the bottles and store.

9.2.3.6 Ber jam

Ripe ber fruits can be used to make jam. Preserved ber pulp can also be used as the starting material for ber jam. If the pulp has been preserved with potassium metabisulphite, it is important to boil the pulp well to drive off the excess sulphur dioxide gas before using for jam. Sulphur dioxide is not usually used as a preservative for jam. If the correct production method is followed and the jam has a high enough sugar content and has been prepared and bottled hygienically, there is no need to add chemical preservatives. Occasionally citric acid (or lemon juice) is added. This chemical has two purposes – to reduce the pH of the fruit mixture so that the pectin can form a gel and also as an anti-bacterial agent. If a preservative has to be added to the jam, ascorbic acid or benzoic acid are the usual chemicals that are used.

Researchers in India investigated the benefits of adding pectin and ber fruit peel to jams prepared from fruits of two cultivars, Umran and Sannaur-6. They concluded that the jam with the best texture and taste was prepared from Umran fruits, without the peel on and with 1 % added pectin. More specifically, they found that the best recipe for ber jam included 750 g sugar per kg pulp and with an acidity of 0.75 % (Dawney Thomas and Kulwal, 2002).

Ripe or slightly under-ripe fruits are the best type for jam making. Over-ripe and damaged fruits should be discarded as they will spoil the jam. The fruits are washed in clean water and chopped into small pieces. The stones can be removed if desired, although they will be sifted out at a subsequent stage. The fruit pieces are boiled with clean water (2 kg fruit per litre of water) for a few minutes until they have softened. The soft fruit pulp is passed through a wire stainless steel mesh sieve to obtain a smooth pulp, free of skins and stones. Water (1 litre per kg of pulp) and sugar (725 g per kg pulp) are added to the pulp and mixed well. Citric acid (8 g per kg pulp) is dissolved in a small amount of water and added to the pulp. The mixture is heated in a stainless steel pan, gently at first to dissolve the sugar and then rapidly to reduce the water content and the mixture thickens. The mixture should be stirred to prevent it sticking to the base of the pan and burning. As the jam is being heated it should be regularly tested with a refractometer to determine when the total soluble solids (TSS) are 65° Brix. At this point, the jam should be removed from the heat, allowed to cool slightly to about 82-85° C and then hot-filled into clean, sterilised jars. The jars are capped and allowed to cool to room temperature.

Flow chart 6. Preparation of ber jam

Process	Process notes + quality control
Ripe fruit – grade and wash ↓	Use fully ripe fruits from juicy varieties. Remove any over-ripe or damaged fruits. Wash in clean water.
Chop into small pieces and de-stone (optional) ↓	Chop the fruit into small pieces. Stones can be removed at this stage if desired, or they can be sifted out at a later stage.
Boil fruit pieces ↓	Add water (2 kg fruit pieces to 1 litre of water) and boil for a few minutes to soften the fruit.
Filter ↓	Pass through a stainless steel sieve or mesh to remove the skins and stones and to obtain a smooth fruit pulp.
Pulp ↓	The process can be started from this point if pre-made pulp is used as the starting material. The preserved pulp must be heated and boiled thoroughly to eliminate traces of sulphur from the KMS used as preservative.
Add ingredients ↓	Add water (1 litre per kg pulp) and sugar (725 g per kg pulp) to the pulp and mix well. Dissolve citric acid (8 g per kg pulp) in water and add to the pulp. Mix well.
Heat ↓	Heat gently at first to dissolve the sugar, then increase the heat and boil the mixture to reduce the moisture content. Heat until the mixture thickens and reaches a TSS of 65° Brix.
Cool ↓	Cool to about 82-85° C then hot-fill into clean, sterilised jars.
Cap and label	Add screw tops to the jars and label.

9.3 Other jujubes

9.3.1 Ripening

Harvesting is either manual or by shaking the trees/shrubs. A mechanical shaker is commonly used for Chinese jujube (Anon, 1993). However such mechanical methods tend to increase the number of immature fruits harvested. This can be a constraint because green fruits of Chinese jujube do not ripen. If gathered when white-green they turn brown in two weeks and show a non-climacteric ripening, the optimum temperature being 20-25° C (Kader *et al.,* 1982).

Fruits of *Z. spina-christi* also have climacteric ripening and the physico-chemical changes have been analysed (Abbas *et al.,* 1988, 1989; Abbas and Saggar, 1989; Al-Niami *et al.,* 1992).

9.3.2 Treatments

Exposure of fruits of Chinese jujube to ethylene (100 ppm at 20°C for four hours or dipping in 2000 ppm ethylene solution for two minutes) induces uniform rapid ripening (Kader *et al.,* 1982). Fruits of *Z. spina-christi* ripen rapidly by dipping in 5000 ppm ethaphon for one minute (Abbas *et al.,*1994).

9.3.3 Storage

Storage of fruits of other species at ambient temperatures is similar to that of ber. Both Chinese jujube and *Z. spina-christi* can be freeze-dried or frozen although vitamin C content tends to decrease (Dzheneeva and Chernogorod, 1989; Al-Hijiya *et al.,* 1989).

Fumigation to remove insects is possible for jujubes; use of hydrogen phosphide for this purpose has been demonstrated for fruits of Chinese jujube intended for herbal medicines (Khalid *et al.,* 1988).

9.3.4 Processing of Chinese jujube

Shin *et al.,* (1992) investigated various processing methods for *Z. jujuba* fruits. Based on sensory evaluation and chemical analysis, it was found that dried fruits, nectar, jam, fruit extracts and a powdered tea were the most promising products. The processing of damaged or defective *Z. jujuba* fruit was investigated by Zhang *et al.,* (2004). This is useful if mechanical harvesters increase the percentage of damaged fruits. They looked at the processing technology and parameters required for fermenting vinegar. Alcohol fermentation of vinegar was carried out using *Z. jujuba* fruits fermented with 8-10 % sugars and *Saccharomyces ellipsodieus*. Ethane acid fermentation was achieved using 5 % *Acetobacter rancens*. The optimum conditions for clarifying the resultant Chinese jujube vinegar involved heating at 95° C for two minutes, and filtering with diatomite after cooling.

9.3.4.1 Jujube cake

(California Rare Fruit Growers, 1996)

- 1 cup sugar
- ½ cup butter
- 2 cups dried, minced jujube
- cup water

These are brought to the boil, then set aside to cool

- 2 cups wheat flour
- 1 teaspoonful soda
- ½ teaspoonful salt

sifted together and then added to the above mixture, the whole baked at 160° C.

Plate 1. 30 day old rootstock seedling in polytube

Plate 2. 100 day old rootstock seedling in polytube ready for transplanting or budding

Plate 3. Scion buds successfully sprouted

Plate 4. Rootstock prepared for patch or shield budding

Plate 5. Patch and shield buds inserted on the rootstocks

Plate 6. Scion buds tied after insertion

Plate 7. Fruitfly infested ber fruits

Plate 8. Twigs infested by lac insects

Plate 9. Powdery mildew infestation on young fruits and leaves

Plate 10. *Alternaria* leaf spot

Plate 11. *Isariopsis* leaf spot Plate 12. Rust on leaves

Plate 13. *Alternaria* fruit spot

Plate 14. Chinese date and peanut intercropping (Photo: IDRC (www.idrc.ca), used with permission.)

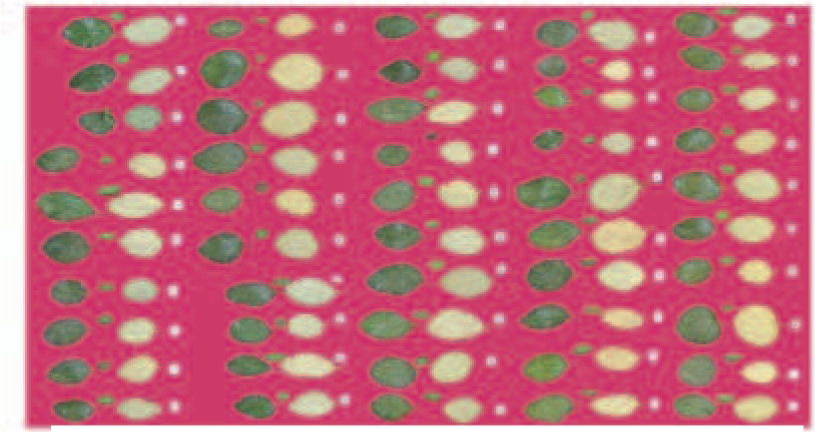

Plate 15. Morphological variability of leaves in *Z. mauritiana*

Plates 16 & 17. Flowering and fruit set in *Z. mauritiana*

Plate 18. cv. Ponda

Plate 19. cv. Illaoichi

Plate 20. cv. Umran

Plate 21. cv. Kaithli

Plate 22. cv. Banarsi Kadaka

Plate 23. cv. Seb

Plate 24. cv. Gola

Plate 25. cv. Katha Phal

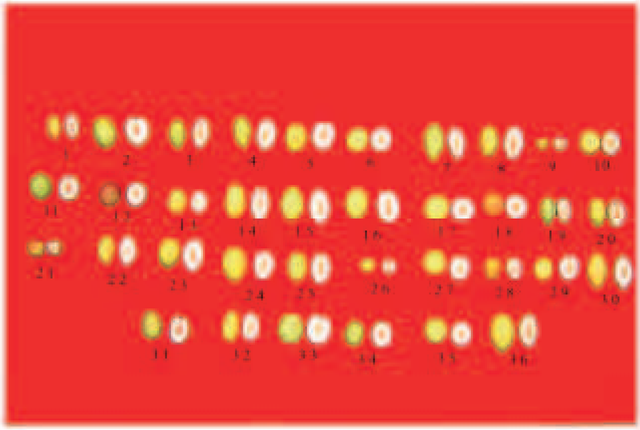

Plate 26. Morphological variability of fruits in *Z. mauritiana*

Plate 27. Morphological variability of stones in *Z. mauritiana*

9.3.4.2 Candied jujubes and jujube syrup

(California Rare Fruit Growers 1996)
Wash about 1.5 kg dried jujubes; drain and prick each several times with a fork. In a kettle bring to a boil 5 cups water, 5½ cups sugar, and 1 tablespoon corn starch. Add the jujubes and simmer, uncovered, stirring occasionally, for 30 minutes. Cool, cover, and chill overnight.

The next day bring mixture to a boil and simmer, uncovered, for 30 minutes. With a slotted spoon lift jujubes from syrup and place slightly apart on rimmed pans. The fruit (jujubes) should be dried in an oven or in sun until date-like, turning occasionally. Boil the syrup remaining from the candied jujubes, uncovered, until reduced to about two cups.

9.3.4.3 Jujube butter

(USDA 1980)
3.5 l jujube pulp
1 teaspoon nutmeg
½ teaspoon cloves
2 teaspoons cinnamon
2.75 l sugar
125 ml vinegar
1 lemon

Boil fruit until tender in sufficient water to cover it. Rub cooked fruit through a sieve or colander to remove the skin and seeds. Cook slowly until thick, put in jars, and seal while hot.

9.3.5 Other Chinese jujube products

Traditional uses for *Z. jujuba* include cakes and rounded flat bread, jam, candy, dried fruit, juice, and tea, the latter often used as a remedy for sore throat (California Rare Fruit Growers, 1996).

A search for products currently available or advertised on the internet revealed few results and related to use as food supplements. Products that were found included pure fruit extracts (www.kwlyx.com/store) (www.1stchineseherbs.com), as liver purifier – dietary supplement (www.healthkingenterprise.com/dsupplements.html), and MiAmora a dietary supplement for male sexual enhancement (www.botanic-art.com/miamora-more).

Chapter 10. Marketing

S. Azam-Ali

10.1 Introduction

The following information on ber is mostly that given by Pareek (2001). In India, ber fruits are marketed though a marketing channel that differs according to the quality of produce, distance from the market and available storage and marketing infrastructure.

Other producing countries in Asia (e.g. Afghanistan, Bangladesh, Myanmar, China) produce fruit largely for the local rural people and local markets. Thailand contrasts with these countries because enhanced production has been geared to potential exports.

Chinese jujube is becoming more intensively grown in China, especially in standardised agroforestry systems, and its production is increasing in Vietnam and Azerbaijan. Government policies provide for production for known local demands and China national markets are targets as well as exports.

However in many cases, practices relate to growth of jujubes on a number of marginal lands since trees are considered to be extremely hardy. The major cultivated species also produce naturalised populations in many areas of Africa and Asia; providing local produce and the fruits are relatively unimproved.

10.2 Ber

Verma and Gujar (1994) outlined six main marketing channels which operate in Rajasthan in India. These are:

1. Producer-Retailer[1]-Consumer
2. Producer-Commission agent[2]-Retailer-Consumer
3. Producer-Wholesaler[3]-Retailer-Consumer

[1] Retailer purchases fruits in the market from producers or pre-harvest contractors through the commission agent, or from a wholesaler, and sells them in the local market or outside areas.
[2] Commission agent is a licence holder middleman trader with a permanent shop in the market. He sells on a commission basis. This is fixed by the market committee on the basis of the value of the produce.

4. Producer-Commission agent-Wholesaler-Retailer-Consumer
5. Producer-Pre-harvest contractor[4]-Commission agent-Retailer-Consumer
6. Producer-Pre-harvest contractor-Commission agent-Wholesaler-Retailer-Consumer

Marketing of ber fruits is also carried out through the following two channels:

1. Producer-Commission agent-Wholesaler-Outside markets
2. Producer-Pre-harvest contractor-Commission agent-Wholesaler-Outside markets.

The farmer-seller brings the fruit to the market and pays charges for transportation from the farm to the market, including loading and unloading costs. The buyer pays overhead charges such as market fee (1.6 % of the value of the produce), commission (4 % of the value of the produce) and weighing charges.

In Chomu market in India, the producer, pre-harvest contractor, wholesaler and retailer respectively, incurred 1.68-1.70 %, 5.80-6.62 %, 0.84-3.31 % and 0.07-6.92 % of the total marketing cost whereas the margins shared by them were respectively 29.5-49.92 %, 7.36-8.35 %, 2.86-3.57 % and 41.14-48.31 % depending upon the marketing channel adopted (see Table 10.1). This reveals that the producer's share of the consumer's price is more than 46 % if sold directly in the market. But in that case, the producer would incur the cost of overseeing the fruit development period and the cost of harvesting, packing, transport to market and the work involved in dealing with the market functionaries. Thus, the highest share that could be obtained is nearly 33 % though pre-harvest contracts, which is rather low.

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[3] Wholesaler is a licence holder in the market network who purchases fruits in bulk from farmers and other market functionaries and sells them in the market at a higher price.
[4] Pre-harvest contractor takes out a contract for the orchard at the maturity stage (before harvest), fixing terms and conditions regarding the harvest with the farmer.

Table 10.1 Percent price spread of ber in marketing through different channels in Chomu market (India) (from Pareek, 2001)

Particulars	**Marketing channels**					
	1	**2**	**3**	**4**	**5**	**6**
Producers net price	49.92	47.05	46.68	46.55	33.21	29.50
Cost incurred by:						
Producer	1.70	1.70	1.68	1.68	-	-
Pre-harvest contractor	-	-		-	6.62	5.80
Wholesaler	-	-	0.84	3.31	-	2.83
Retailer	0.07	6.92	4.11	3.98	6.95	3.71
Total	**1.77**	**8.62**	**6.63**	**8.97**	**13.57**	**12.34**
Margin of:						
Pre-harvest contractor	-	-	-	-	8.35	7.36
Wholesaler	-	-	3.57	3.34	-	2.86
Retailer	48.31	44.33	43.12	41.14	44.87	47.94
Total	**48.31**	**44.33**	**46.69**	**44.48**	**53.22**	**58.16**

A study of the marketing of ber in Chomu market in India is presented in table 10.2. The table provides an analysis of the marketing costs of ber. The data in the table reveal that getting the produce into the market involves considerable effort and cost for transportation, packing and loading/unloading of the produce. In addition, marketing of perishable produce is risk prone to spoilage. The harvesting season may coincide with other farm activities and the local market infrastructure may be inadequate and lack managerial assistance. The producer also has to deal with several market functionaries such as commission agents and wholesalers which is a cumbersome process and involves some uncertainties in the sale deeds. As a result, the producers often prefer to sell their produce by pre-harvest auction to contractors, just before fruit maturity. The contracts are fixed either on the basis of a share of the income or on the basis of a lump sum to be paid by the contractor in instalments. In the first case, the contractor takes care of overseeing the fruit development and picking and grading, but the marketing is done jointly with the grower. In the second case, which is most common, the contractor picks the fruit according to his convenience and sells it in local or distant markets.

Table 10.2 Components of cost (%) in marketing of ber through different channels at Chomu market in India (from Pareek, 2001)

Particulars	1		2		3			4			5		6		
	P*	**R****	**P**	**R**	**P**	**W*****	**R**	**P**	**W**	**R**	**C**	**R**	**C**	**W**	**R**
Packing charges	-	-	-	-	-	-	-	-	-	-	30.59	-	29.48	-	-
Overseeing the fruit development	-	-	-	-	-	-	-	-	-	-	5.73	-	5.52	-	-
Transportation	35.87	-	7.36	7.81	9.45	-	12.78	6.99	6.04	9.64	4.64	6.39	4.47	3.13	6.25
Packing	23.84	-	4.89	7.49	6.28	-	6.78	4.65	-	5.05	3.08	3.75	2.97	-	3.16
Loading and unloading	36.43	-	7.46	8.18	9.60	-	9.74	7.10	-	7.16	4.71	4.85	4.53	-	4.51
Loss due to damage	-	-	-	24.33	-	-	32.66	-	-	22.50	-	15.87	-	-	16.15
Commission	-	-	-	22.63	-	-	-	-	21.51	-	-	14.20	-	13.82	-
Market fee	-	-	-	9.06	-	11.69	-	-	8.60	-	-	5.69	-	5.53	-
Weighing	-	3.86	-	0.79	-	1.02	-	-	0.76	-	-	0.50	-	0.48	-
Total	**96.14**	**3.86**	**19.71**	**80.29**	**25.33**	**12.71**	**61.96**	**18.74**	**36.91**	**44.35**	**48.75**	**51.25**	**46.97**	**22.96**	**30.07**

* Producer; ** Retailer; *** Wholesaler; 1-6 See text

In countries of southern Africa where ber trees occur mostly as natural groves, small orchards, fences around fields or in homesteads, the fruits are sold after harvest either in rural markets or are transported for sale in urban markets. There do not appear to be any defined marketing channels and transport is considered unreliable. Market studies in Malawi (Kaaria, 1998) in two urban markets (in Lilongwe and Limbe) and two rural markets (Salima and Monkey Bay) revealed the following:

- Distance from and access to the market determines who participates in the marketing of ber.
- Rural markets are mainly dominated by women while urban markets are dominated by male traders, who control the market and set the prices.
- Marketing margins were higher in rural markets than in urban markets.
- Although the quantities of fruit sold and the prices have shown a steady increase, the markets will only grow if the governments initiate enabling policies that facilitate the development of rural-based marketing information systems and build infrastructures that improve the transportation and market facilities.
- There is a need to develop mechanisms to standardise the packaging and added value.

In Zimbabwe, ber fruits are either sold in local markets (e.g. in Chikafa market) or in urban markets such as Harare, Mutare and Kadoma. Marketing is mainly done by women and youths, but occasionally men are involved (Kadzere, 1998). Market studies on ber in Zimbabwe have revealed the following:

- The fruit production areas close to the Mozambique border are at some distance from the nearest market.
- Transport is unreliable.
- Formal markets do not exist and pricing is poor.
- There is a need for government policy for access to communal forestry resources, sale of traditional liquors in towns and levies etc.
- There is a need to develop a standard product for the market.

Fruits are sold to bulk buyers in 20 litre tins containing between 15 and 20 kg of fruit at $5 to 20 per tin (Maposa and Chisuro, 1998). There is a barter system in place where fruits are exchanged for food items such as maize meal. This system is particularly active during food shortage years. A similar situation exists in Zambia (Kalikiti, 1998).

Ber has remained almost unknown in the export market. The majority of fresh fruit is sold in local markets. However, there is a growing demand for the fruit outside of its place of growth. During the year 1995 to 1996, 645 MT of fresh ber fruit were exported from India to countries such as South Africa, Bangladesh, Saudi Arabia, Bahrain and UAR.

10.3 Chinese jujube

Chinese jujube is produced mostly in quantity in countries with a centralised economy. In such countries, apart from satisfying the national requirements, some government attention is given to exports, and China exports to Thailand in particular, after satisfying sustained demand in regions such as Hong Kong and Taiwan. Both fruits and a powdered tea are promising products.

Dehydrated fruits 'Chinese Dates' are exported from China (Kim *et al.,* 1981); Yang and Niu, 1992) and the products are standardised. There is a clear growth potential here.

10.4 Market prospects

At present the markets for jujube fruits are mostly restricted to producing regions. The main reasons for this are:

- Most demand being for fresh fruits rather than any processed products.
- Consumer interest somewhat limited due to a lack of awareness regarding the fruit, its nutritive value and its uses.
- Limited availability of fruits of an acceptable quality standard.
- Lack of standards for processed products.
- Lack of market information systems and market infrastructure to meet the requirements of different stakeholders in local and export markets as well as processors.

However, the demand for the fruits is growing rapidly in inland markets, but only slowly for export. Advertising through various media channels should further increase consumer awareness and may lead to higher demands for the fruit. Demand for processed products can also be similarly created if the standards of the products are improved and the quality maintained.

Chapter 11. Current situation and research needs

J.T. Williams

11.1 Summary of the current situation

Both major jujubes are grown for their edible fruits which are high in vitamin C; fruits are eaten fresh, dried as dessert fruits, or candied and preserved in various ways. The Chinese jujube is a temperate tree growing in relatively dry areas and the Indian Jujube (ber) is grown in hot dry areas of the tropics and the subtropics.

Compared to other fruit trees, jujubes provide nutritious fruits at relatively low costs but they remain under-utilised despite their multipurpose uses – whichever cultivated species is considered and wherever cultivated. In many areas fruits are still gathered from wild stands. Especially for Indian jujube (ber) and Chinese jujube a great deal of know-how exists on production techniques but many of these have not been transferred through extension and NGOs to poor farmers. There are vast regions of Asia and Africa where the crops have been introduced and where transfer of existing technology would repay immediate dividends.

Research and development studies on ber were limited until the 1960s to varietal trials and vegetative propagation studies in the States of Punjab and Utter Pradesh in India. Since that time studies have expanded much more widely and addressed all aspects of ber cultivation, harvesting, grading, packaging and processing. Research in India has been paralleled by some research in Pakistan, Bangladesh and a number of countries in Africa.

In India the past 40 years have witnessed very large increases in *Z. mauritiana* fruit production and much of this increase has been due to making ber profitable in ecologically poor, drought prone areas; there is evidence of new larger-scale plantations being established in areas where other crops are not profitable.

In China Chinese jujube, *Z. jujuba* has for the past 600 years traditionally been grown in an intercropping system and this accounts for 65 % of total supplies throughout China. In Hebei and Shandang provinces research attention has been given to the need for higher trunks before branching, crown densities, and to plant spacing and orientation to maximise light penetration and duration. As a result wind speeds during the hot, dry wind season were greatly reduced to the benefit of intercrops (maize, cotton in the open parts and shade tolerant soybean, mung bean and others nearer the trees) in summer. Wheat was most suitable in the winter when jujube trees are bare.

Ziziphus mauritiana is also cultivated traditionally in Yunnan province of China where shifting cultivation was widely practised. In this region research attention has been given to more sustainable agrisilvicultural systems and especially to insect pests which can become more of a problem when small orchards rather than scattered trees of ber are raised. Similar constraints relating to pests and diseases are likely to be apparent when an increase in jujube cultivation occurs in African countries and attention to them will avoid economic losses.

The major interests related to jujube production in whatever region or agro-climatic niche appear to be:

1. Improving production and utilisation where the trees have long been cultivated so that enhanced production can be sustainable and economic.
2. Improving socio-economic impacts by proving incomes for a range of off-farm activities related to marketing and processing.
3. Developing management practices which are environmentally friendly and avoid large chemical inputs.
4. Incorporating jujubes into land systems aimed at helping environmental stability, in particular by incorporating jujubes into agroforestry systems, and as live fences.

These interests will only be addressed by continued basic research to provide reliable planting materials of selected superior genotypes (especially with good fruit characteristics), protecting from major pests and diseases, and adaptation of genotypes to stress conditions.

A range of applied research is also needed to adapt available agronomic techniques to planting systems for particular agroecological and climatic zones, to address processing techniques to prepare standard products from fruits, and to understand the socio-economic inputs and outputs over time – the results of which could justify credit systems to meet any recurrent high-cost farm operations.

11.2 Need for information dissemination

ICUC issued its monograph on ber (Pareek, 2001) because there was widespread need for information prompted by a number of development initiatives, including provenance trials conducted in African countries under the Semi Arid Lowlands of West Africa programme of ICRAF. This had already linked to related activities in other parts of the continent e.g. in Botswana, Kenya, Malawi, Zimbabwe, Zambia and Lesotho.

The monograph summarised important results of R & D in all parts of Asia and Africa and much of the information would not have been readily available otherwise. This current monograph attempts to update the original compilation of information so that it can be applied to any situation where any cultivated jujube will be the focus of interest.

ICUC's associated manual on ber (2002) was an essential adjunct for these development initiatives involved with the transfer of technology.

The attention of development initiates/organisations is drawn to the continued need to disseminate the results of ongoing research from one part of the world to another.

11.3 Research needs

Whereas all aspects along the production to consumption chain require research, the following are most important.

11.3.1 Understanding the genetic variation

A modern assessment of the taxonomy of the genus *Ziziphus* is needed. The cultivated jujubes represent polyploid series and not enough is known about the distribution of ploidy levels; there are few, if any, voucher specimens with chromosome counts carried out and many taxa may be geographical variants or stabilised hybrids. Polyploid series exist within species and there appears to be a range of self- and cross-incompatibilities in *Ziziphus* species, and although hybridisation has undoubtedly occurred it is hardly understood.

Knowledge of the taxonomy would be rapidly enhanced by the wider use of molecular methods of analysis, not only in clarifying the status of taxa but in understanding the patterns of genetic diversity within wild and cultivated taxa. A genepool approach needs to be taken rather than one based solely on morphological types. Breeders simply do not know enough about those species which may have the required productivity, fruit quality or pest and disease resistance attributes which can be of great use in improvement programmes. Current cultivars are genetically hardly advanced from wild progenitors.

Coupled with the need to understand the genepool for targeted crop improvement is the need to identify taxa and a series of specific genotypes which can be of immediate value as rootstocks since jujubes will be more and more propagated by grafting to perpetuate selected cultivar genotypes.

In such research endeavours the limited research carried out to date using biochemical and molecular techniques should be expanded.

Understanding the broader taxonomy of *Ziziphus* and the patterns of genetic variation in the cultivated species and their wild forms can only emerge if concerted and well-planned research is initiated on an ecogeographical basis in parallel with assessment of ecotypic differentiation.

For crops which are underutilised it cannot be expected that national programmes dealing with them – and with minimal funding levels – can readily take on such wide-ranging research projects entailing geographical exploration, taxonomic and molecular analyses, grow-outs in several environments, testing as rootstocks and other related activities. Nor will such research necessarily be completed in a short time, e.g. that of a three-year project cycle, because the materials may require several years of growth.

There will be the need for national programmes to seek the cooperation of universities to work together through strategic planning and joint research so that postgraduate research projects can be integral parts of the overall research programme. Additionally the value of networking across regions is clear to build a critical mass of researchers and to develop cooperative goals and research. ICUC and UTFANET were responsible for recognition being accorded to jujubes as underutilised fruits and in the accelerated work on them in the past few years. Such networking benefits the national programmes and should be continued.

On specific aspects of jujube variation, almost nothing is known about the diversity in the primary centres of variation of the cultivated species and even less about any specific patterns of diversity that have emerged in secondary centres.

11.3.2 Genetic improvement

A large number of selections or cultivars is available for both Indian and Chinese jujubes. These are named but there is a great deal of confusion in the naming. Better characterisation and perhaps molecular fingerprinting of accessions is needed in all existing germplasm collections. Additionally the existing collections all appear to be inadequate and need expansion (see Chapter 9). Expansion is possible without the research proposed in 11.3.1 above if related solely to cultivars, but there is little point in adding to the collections' wild representatives of the cultivars until the variation patterns of the accessions are more fully understood. The objective has to be justifiable and meaningful germplasm collections to best serve improvement needs.

Specific improvement objectives have been outlined in Chapter 8. However, there is the need to carry out research through detailed genetic studies to understand the heritability of quantitative and qualitative characters, especially those chosen as breeding targets. Selection is currently best served on very

limited characters e.g. yield (kg/plant) or fruit attributes such as pulp/stone ratio.
As jujubes become cultivated more and more in small- or medium-sized plantations there is likely to be enhanced need to build into cultivars tolerances or resistances to pests and diseases; this requires continued research. The possibilities of polyclonal plantations to provide some insurance if there are specific attacks is an area of research that has not been explored.

Also as jujubes become cultivated more in marginal areas and on wastelands there will be the need to research satisfactory growth and fruit set under more extreme temperatures and to focus concerted breeding efforts to tailor cultivars to more diverse agroclimatic conditions. In this respect knowing more about the genetic relations between *Z. mauritiana* and *Z. jujuba*, and the possibilities of their crossing, would be helpful. Their climatic adaptations are different and their vitamin C production differs but combining some attributes would be of interest and value, especially in new environments which currently result in poor production.

Variation within cultivars exists for quality attributes although they have been evaluated by multi-location testing so that they can be recommended for particular regions and conditions.

Improvement is needed to incorporate resistances to major pests and diseases, adapt some cultivars to particular environmental stresses and to improve the quality of fruits.

When the research in 11.3.1 produces major results it can be used to assess the existing germplasm collections to gauge how representative they are in terms of covering the range of variation, what gaps exist which could usefully be filled in terms of materials readily available for genetic improvement and genetic conservations, and then progressively modify the collections. This also means that existing collections need further research on characterisation.

Due to the wide heterozygosity of natural populations it is important that any restructuring of germplasm collections does not result in them becoming very large and costly to maintain. Linkages can be made with conservation organisations to maintain specific wild germplasm *in situ* when specific ecotypes or genotypes have been identified and characterised.

The results of research on the taxonomy and analysis of patterns of variation will depend on exploration and sampling over large geographical regions and also on assessing any ecogeographic difference. Strategic planning of the research and funding for travel will be essential.

11.3.3 Propagation

It is likely that most jujubes used for enhanced production will be grafted. There is a need to develop rootstocks which can control the overall tree morphology and its vigour and to maximise its adaptation to different edaphic conditions. There is a need to standardise rootstocks in relation to productivity objectives, for use in orchard versus agroforestry systems because particular tree forms (and vigour) are required and for use in adaptation to stress conditions. As pointed out in 11.3.2 there is a need for basic research on rootstock genotypes and the ultimate goal should be to standardise a limited number of rootstocks which can be widely applied. Chapters 5 and 6 pointed to the value of mycorrhizae, and further work on these should be linked to the selection of rootstocks.

Knowledge derived from 11.3.1 above is basic in selecting the range of rootstocks and grafts to be attempted in order to lead to standard forms.

Further research on rapid propagation using tissue culture and cuttings would be beneficial. The development of planting supply systems would benefit from accelerated research on cost-effective, replicable techniques of propagation, including micropropagation.

11.3.4 Pruning/cropping systems

Initial training of plants and subsequent pruning is needed. There is still scope to research pruning type and intensity in specific cultivars especially for agroforestry situations which require a relatively open canopy.

Reliable planting material of recommended cultivars needs to be accompanied by such information, especially for situations where trees may be grown adjacent to houses, as windbreaks or in agroforestry systems all in the same area. A range of cultivars might be required to provide economic insurance to the growers. This is equally important as researching compatible intercrops.

Jujubes are cultivated as scattered trees, in rainfed orchards or woodlots, in irrigated plantations and in rainfed and irrigated forestry systems. There is a need to research the optimal use of water and nutrients for sustained productivity of the jujubes and/or the cropping systems.

Genotypes need to be selected for specific regimes of irrigation, rainfed systems and salinity and sodicity. This will require research on growth, assimilation rates and productivity and should be combined with land management to conserve water on wastelands.

11.3.5 Post-harvest studies

Work on harvesting, grading and packaging of fruits has been undertaken and a number of recommendations exist. However, standard grading related to end use has hardly been implemented and more research is needed, not only on the economics along the production to consumption chain but on the socio-economic benefits particularly those affecting the well-being of family producers.

Processing methods require standardisation with attention to cost-effectiveness and marketability of products from fruits. This requires additional research, especially if processing is to be at the community level. Incomes will be increased when processing methods to develop standard products acceptable in the markets are refined, standardised and downstreamed.

In some cases suitable genotypes will need to be identified and/or selected for specific processing needs.

11.3.6 Marketing

As with all underutilised crops attention has to be given to applied research such as storage, packaging and transportation of fruits and marketing. Since in many cases and many areas there is limited availability of acceptable quality fruits and also lack of market information systems, it is essential that researchers keep abreast of their development so that any interventions can be recommended.

11.3.7 Other relevant development issues

Expansion of production, particularly at the local level, bears an initial establishment cost which at present is relatively high for clonal materials. Credit for such activities is often unavailable, as indeed it is for many aspects of rural development. NGOs should take seriously the need to set up cooperative credit mechanisms to assist in all aspects of production, processing and marketing, as well as to assist where infrastructure is not readily available for provision of inputs such as planting materials, chemicals and advice.

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Appendix I Insect and mite pests of ber

(Pareek 2001, updated).

Order	Scientific name	Common name	Author	Occurrence
Diptera	*Carpomyia vesuviana*	Fruitfly	Basha, 1952; Batra, 1953	India (Punjab, Aruppukottai, Jobner, Rahuri, S.K.Nagar)
	Dacus correctus, *D. dorsalis*	Fruitfly	Basha, 1952; Batra, 1953	India (Jobner)
	Phyllodiplosis jujubae	Galls	Gangwar, 1983	India (Allahabad)
Lepidoptera	*Meridarchis scyrodes*	Fruit borer	Sonawane and Dorge, 1971	India (Anantapur, Rahuri)
	Meridarchis scyrodes	Fruit borer	Basha, 1952	India (Coimbatore)
	Carposina niponensis	--	Huan *et al*. 1987	China (Shanxi)
	Indarbela quadrinotata, *I. watsoni*, *I. tetraonis*	Bark eating caterpillar	Verma and Singh, 1974; Mann and Bindra, 1977	India (Jobner, Rahuri, & S.K.Nagar)
	Dasychira mendosa, *Thiacidas postica*	Hairy caterpillar	Verma *et al.*, 1972; Bhatnagar and Lakra, 1992, Kavitha and Sovothri, 2001a	India (Jobner, Rahuri)
	Synclera univocalis	Leaf roller	Nayar *et al.*, 1989	India (Jobner, Rahuri)
	Ancylis lutescens, *Archips* sp.	Leaf roller	Pareek and Nath, 1996	India (Rahuri)
	Porthmolga paracina	Leaf roller	Chowdhury and Majid, 1954	India
	Tarucus balkanica, *T. theophrastus*	Ber butterfly	Nayar *et al.*, 1989	India (Rahuri)
	Pingasa dispensata	Semi looper	Pareek and Nath, 1996	India (Rahuri)

Order	Scientific name	Common name	Author	Occurrence
	Psorosticha (Tonica) *zizyphi*	Leaf webber	Verma, 1993	India (Jodhpur)
Coleoptera	*Holotrichia consanguinea*	Cockchafer beetle	Verma *et al.*, 1972; Bhatnagar and Lakra, 1992	India (Jobner)
	Aubeus sp.	Grey weevil	Pareek and Nath, 1996	India (Rahuri, Jobner)
	Myllocerus sp.	Grey weevil	Wadhi and Batra, 1964	India
	Aubeus himalayanus	Stone weevil	Pareek and Nath, 1996; Gour and Sriramulu, 1994	India (Jobner, Rahuri, Hyderabad)
	Xanthochelus superciliosus	Black weevil	Pareek and Nath, 1996	India (Rahuri)
	Adoretus sp.	Cockchafer beetle	Trehan, 1956	India (Jobner, Rahuri)
	Holotrichia serrata, *Schizonycha* sp., *Adoretus deccanus*, *A. kanarensis*, *A. stoliczkae*	Cockchafer beetle	Pareek and Nath, 1996	India
Hemiptera	*Kerria lacca*	Lac insect	Lakra and Kher, 1990	India
	Parlatoria zizyphus	Scale insect	Pareek and Nath, 1996	India (Jobner)
	Parlatoria zizyphus	Scale	Gravena *et al.*, 1992	Brazil
	Quadraspidiotus perniciosus	San Jose scale	Ma *et al.*, 1985	China (Akesu, Xinjiang)
	Drepanococus chiton	Wax scale	Mani and Krishnamoorthy, 1997	India
	Selenaspis articulatus	Scale	Gravena *et al.*, 1992	Brazil
	Zyginida pakistanica	Leaf hopper	Khangura and Sandhu, 1976, Kavitha and Sovothri, 2001	India (Punjab) India Anhdra Pradesh)

Order	Scientific name	Common name	Author	Occurrence
	Drosicha sp., *Ferrisia consobrina*, *Nipaecoccus viridis*	Mealy bug	Pareek and Nath, 1996	India (Rahuri)
	Machaerota spangbergii, M. planitae	Spittle bug	Pareek and Nath, 1996; Nayar *et al*., 1989	India
	Eurybrachys sp.	Leaf hopper	Nayar *et al*., 1989	India
	Agonoscelis nubila	Pantatomid bugs	Nayar *et al*., 1989	India (Jobner, Pusa-Bihar)
	Cadra calutella	Pyralid moth	Pareek and Nath, 1996	India (Rahuri)
Thysanoptera		Thrips	Yamdagni and Gill, 1968	India
	Scirtothrips sp., *Haplothrips* sp.	Thrips	Pareek and Nath, 1996	India (Jobner)
	Dolichothrips indicus	Leaf thrips	Nayar *et al*., 1989	India
	Scirtothrips dorsalis	Flower thrips	Nayar *et al*., 1989	India
Isoptera	*Odontotermes* sp.	Termite	Pareek and Nath, 1996	India (Jobner)
Orthoptera	*Taeniopoda eques*		Rivera-Garcia, 1988	Mexico
Acariformes	*Eutetranychus orientalis*	Tetranychid mite	Kant and Arya, 1969; Tandon *et al*., 1976, Yadav *et al.* 2003	India (Jobner)
	Larvacarus transitans, *Eriophyes cernus*	Gall mite Eriophid mite	Sharma, 1992 Mukherjee *et al*., 1994	India India

Appendix II *Ziziphus* cultivars

II.ia *Ziziphus mauritiana* cultivars in India (from Pareek, 2001)

Ajmeri (Umran) (Gopani, 1976 a)
Akhrota (Akrota) (Verma and Singh, 1974)
Akola
Aliganj (Chundawat and Srivastava, 1978)
Babu (Gopani, 1976 a)
Bachcha (Singh, 1969)
Badami (Singh, 1969)
Badshah Pasand (Singh *et al*., 1971, 1972a)
Bagwadi (Pareek and Vashishtha, 1983, 1986)
Bahadurgarhia (Dhingra *et al.,* 1973)
Banarsi (Banarasi) (Singh, 1969; Singh *et al*., 1971, 1972a)
Banarsi Gola (Singh *et al*., 1973a)
Banarsi Kadaka, (Banarsi Karaka, Karaka Varanasi, Kadaka, Karaka) (Singh *et al*., 1971, 1972a; Chundawat and Srivastava, 1978)
Banarsi Pebandi (Singh *et al*., 1971, 1972a)
Banarsi Pewandi
Banarsi Prolific (Singh and Singh, 1973; Singh, 1964)
Baruipur (Singh, 1964)
Batasa
Bawal Selection -2
Bekata Varanasi (Chandra, 1964)
Betawadi
Betawadi Hathed
Bhavnagari
BS- 1
BS- 75-1
BS- 75-2
BS- 75-3
Cantonment (Kundi *et al*., 1989 a)
CAZRI Gola
Chameli (Umran)
Chandani Supari
Chencho (Vashishtha and Pareek, 1989)
Chhuhara (Singh *et al*., 1972a)
Chhuhara Bawal
Chonchal (Chundawat and Srivastava, 1978)
Dandan (Randhawa and Biswas, 1966)
Dao Tien (Hoang and Tuynh, 1989)
Darakhi-1
Darakhi-2
Deedwana (Vashishtha and Pareek, 1989)
Desi Alwar (Alwar Desi) (Singh *et al*., 1971, 1972a)

Dodhia (Chundawat and Srivastava, 1978)
Foliso Alwari
Ghughudanga (Singh, 1964)
Gia Loc (Hoang and Tuynh, 1989)
Glory (Glori) (Singh *et al*., 1971, 1972a)
Gobindgarh Selection
Gobindgarh Special (Verma and Singh, 1974)
Godhan (Singh *et al*., 1973a)
Gol (Singh, 1969)
Gola Agra (Teaotia *et al*., 1974)
Gola (Delhi Gola) (Singh and Khanna, 1968; Singh *et al*., 1973a)
Gola Gurgaon-1 (a selection from Gola Gurgaon) (Dhingra *et al*., 1973)
Gola Gurgaon-2 (a selection from Gola Gurgaon) (Verma and Singh, 1974)
Gola Gurgaon-3 (a selection from Gola Gurgaon)
Golan (Kundi *et al*., 1989 a)
Golar (Singh *et al*., 1971, 1972a)
Goli (Randhawa and Biswas, 1968)
Golia
Goma Kirti (Hiwale and Raturi, 1999)
Gorifa
Gorva (Singh *et al*., 1971, 1972a)
Gularbasi (Singh and Khanna, 1968)
Guli
Harial
Haq Nawaz (Kundi *et al*., 1989 a)
Hoshiarpur
Husain Riso Chinese
Illaichi (Singh *et al*., 1971, 1972a)
Illaichi Jhajjar (a selection of Illaichi)
Jalandhari (Jullundhri) (Dhingra *et al.,* 1973)
Jeevan (Gopani, 1976 a)
Jhajjar Selection
Jhajjar Special
Jogia (Singh *et al*., 1971, 1972a)
JS II (Srivastava and Srivastava, 1978)
Kabra (Singh *et al*., 1973a)
Kadoda
Kaithli (Kaithali) (Singh *et al*., 1971, 1972a)
Kaki
Kakrola Gola (Godara, 1981)
Kala Gola (Singh *et al*., 1971, 1972a)
Kali (Pareek and Vashishtha, 1983, 1986)
Kalianwali
Kaolang-1 (Chiou and Weng, 1996)
Katha (Umran) (Pareek and Vashishtha, 1983, 1986)
Katha (Umran) Bombay (Singh *et al*., 1971, 1972a)

Katha (Umran) Gurgaon (Singh *et al*., 1971, 1972a)
Katha (Umran) Rajasthan
Kathaphal (Katha Phul) (Singh *et al*., 1971, 1972a; Chundawat and Srivastava, 1978)
Kharak, Kharki-2
Kharki-1
Khatti (Bisla *et al.,* 1980)
Kheera (Singh and Khanna, 1968)
Khirni
Kismish
Laddu (Dhingra *et al.,* 1973)
Lakhan
Lal Wali (Kundi *et al.,* 1989 a)
Lam (Vashishtha and Pareek, 1989)
LR-9 (Kundi *et al.,* 1989 a)
LR-11 (Kundi *et al.,* 1989 a)
LR-13 (Kundi *et al.,* 1989 a)
Lucknow Karaka (Teaotia *et al*., 1974)
Madhuri
Maharwali (Vashishtha and Pareek, 1989)
Ma Hong (Hoang and Tuynh, 1989)
Manukhi
Meharun
Mirchia (Dhingra *et al.,* 1973)
MPKV
Mundia (Mundia Murhera, Muria Mahrara) (Chundawat & Srivastava, 1978)
Nagpuri (Singh, 1964)
Nalagarhi
Narikelee (Singh, 1964)
Narikeli (Kasir-Bogri Kool Daccai Kool) (Dutta, 1954)
Narma (Singh, 1969)
Narma (Narma Varanasi)
Nazuk
Nehru Mandal
Nimaj
Noki (Godara *et al.,* 1980)
Pameli
Pathani
Pewandi (Teaotia *et al*., 1974)
Ponda
Popular Gola
Raja (Gopani, 1976 a)
Randeri
Reshmi (Godara *et al.,* 1980)
Rewa Selection (Godara *et al.,* 1980)
Rohtaki Gola

Safarchandi (Padule *et al.,* 1988)
Safarchandi (Hathed)
Safeda (Sufeda) (Chadha *et al*., 1972)
Safeda Rothak (Dhingra *et al*., 1973)
Safeda-1 (a selection of Safeda)
Sakhari (Hathed)
Sanaur-1 (Singh *et al*., 1973 a)
Sanaur-2 (Singh *et al.,* 1973 a)
Sanaur-3
Sanaur-4 (Tomar, 1986)
Sanaur-5 (Khera and Singh, 1976)
Sanaur-6 (Tomer, 1986)
Sandhura Narnaul (Chundawat and Srivastava, 1978)
Sandhura No-1
Sasni Gola
Seb
Seedless
Safeda Selected (Chundawat and Srivastava, 1978)
Seo (Dhingra *et al.,* 1973)
Seo Bahadurgarhia (Godara *et al.,* 1980)
Shamber
Shanba (Hathed)
Singhan
Sua (Khra and Singh, 1976)
Sua Mandi
Sukawani
Supari
Surati, Surti
Surti Katha
Talod Seedless
Telong (Chiou and Weng, 1996)
Tasbataso
Thian Phien (Hoang and Tuynh, 1989)
Thornless (Singh, 1964)
Tikadi
Triloki (Tiloki) (Singh, 1969)
Umran (Katha) (Dhingra *et al.,* 1973)
Vikas (Chovatia *et al.,* 1993)
Vikas -2 (a selection of Vikas)
Villaiti
Wilayti (Walaiti) (Dhingra *et al.,* 1973)
ZG-1
ZG-2 (Tomar, 1986)
ZG-3 (Singh and Singh, 1973)

Cultivar names in brackets are regional forms of the same cultivar.

Appendix II.ib *Ziziphus mauritiana* cultivars widespread in Assam

Bali
Deccaikool
Kasir
Kool
Narkelle (Umran)
Tenga Mitha
Umran

Appendix II.ic *Ziziphus mauritiana* cultivars popular in Pakistan

Chamcal
Dandan
Desi
Karela
Karnal
Khathi Mithi
Rohtak
Saidork
Sofeda Am
Umran

Appendix II.iia *Ziziphus jujuba* cultivars (from Pareek, 2001)

Akhedi (Tagiev, 1976)
Akhmedi (Tagiev, 1992)
Arzu (Tagiev, 1976)
Arzu (Tagiev, 1992)
Bokjo (Park and Yu, 1989)
Buluosa (Yu *et al*., 1991)
Da-bai-tsao or Da-baj-czao (Sin'ko, 1977; Sivakov *et al*., 1988)
Da-bal-tszao (Kucherova and Sin'ko, 1984a)
Dongzao (Zeng, 1997)
Druzhba (Sin'ko and Livinova, 1996)
Gansu (Lu *et al*., 1993)
Geumsung or Jh-12 (Yong *et al*., 1981)
Hamazhao (Bi *et al*., 1990)
Honey Jujube (Ming and Sun, 1986)
Irada (Tagiev, 1976)
Ja-2 (Kim and Kim, 1984 b)
Ja-czao or Ya-tsao (Sivakov *et al*., 1988; Sin'ko, 1977)
Jb- 21 (Kim and Kim, 1984 b)
Jc-31 (Kim and Kim, 1984 b)

Je-8 (Yong *et al*., 1981)
Je-10 (Yong *et al*., 1981)
Jg-10 (Kim and Kim, 1984 b)
Ji-3 (Yong *et al*., 1981)
Jianzhao (Bi *et al*., 1990)
Jin Jujube (Ming and Sun, 1986)
Jishen Hama Zao (Yu *et al*., 1991)
Jixin Mi Jao (Yu *et al*., 1991)
Jj-3 (Kim and Kim, 1984 b)
Jk-4 (Kim and Kim, 1984 b)
Khazari (Tagiev, 1976)
Khurman (Akhundova and Agaev, 1989)
Kitaiskii 60 (Sin'ko and Litvinova, 1996)
Kitalskil 50 (Kucherova and Sin'ko, 1984 a)
Kitalskil 52 (Romanova *et al*., 1985)
Kitalskil 58 (Kucherova and Sin'ko, 1984 a)
Kitalskil 86 (Romanova *et al*., 1985)
Laohuyan (Liu and Wang, 1991)
Lang (Lanham, 1926)
Li (Lanham, 1926)
Li Zao (Yu *et al*., 1991)
Lingding Zao (Yu *et al*., 1991)
Linze Small Jujube (Ming and Sun, 1986)
Mardakyan (Tagiev, 1976)
Mardakyanskil 6 (Kucherova and Sin'ko, 1984 a)
Ming Shan Large Jujube (Ming and Sun, 1986)
Moodeung or Ja-5 (Yong *et al*., 1981)
Mu Shing Hong (Lanham, 1926)
Nasimi (Tagiev, 1976)
No. 1, 2, and 16/5 (Baratov *et al*., 1975)
Ordubadi (Tagiev, 1992)
Sanjo
Sihong Dazao (Wan, 1994)
Sovetskij (Sin'ko and Litvinova, 1996)
Suantszao (Sin'ko and Litvinova, 1996)
Sui-Men (Lanham, 1926)
Taiso (Nikaido *et al*., 1990)
Ta-jan-czao or Ta-yan-tsao or Ta-yan-tszao (Sivakov *et al*., 1988)
Tan-yan-tszao (Rathore, 1986; Goncharova *et al*., 1990)
Tavrika (Sin'ko and Litvinova, 1996)
Tyantszao (Sin'ko and Litvinova, 1996)
Ulduz (Tagiev, 1992)
Vakhsh (Sin'ko *et al*., 1987)
Vakhshskil 30/16 (Kucherova and Sin'ko, 1984 a)
Vakhshskil 40/5 (Kucherova and Sin'ko, 1984 a)
Vakhshskil 41-19 (Romanova *et al*., 1985)

Vakhshskil 46/17 (Kucherova and Sin'ko, 1984 a)
Wolchul Daechu (Kim *et al*., 1988)
Ya-tszav (Romanova *et al*., 1985)
Yan-jhao (Rathore, 1986)
Yan-yan-tsao (Sin'ko, 1977)
Yougji Hama Zao (Yu *et al*., 1991)
Yubilenyl (Romanova *et al*., 1985)
Ziangfen Hulu Zao (Yu *et al*., 1991)

Appendix II.iib *Ziziphus jujuba* cultivars in the USA
(from http://doityourself.com/fruits/givejujubeatry.htm and Outlaw, 2002**)**

GA 866
Li (Swoboda, Geant, Leen Burk)
Lang
Sherwood
Silverhill (Tiger Tooth)
So
Sui Men (Shui Men)

Sherwood is a columnar tree; So is a dwarf bush; others are mostly small trees.

Appendix III Research organisations working on jujubes

***Ziziphus mauritiana* (ber)**

India: Organisations involved in ber research are as follows:

The Indian Council of Agricultural Research (ICAR) initiated research on *ber* as a multi-location project in 1976 and later in 1978 as an All India Co-ordinated Research Project at the following ten centres:

- Department of Horticulture, CCS Haryana Agricultural University, Hisar - 124 004, India (N.R. Godara, S. Siddiqui, C. Gupta, R. K. Lakra, A. K. Gupta, P. K. Mehta, S. S. Dahiya).
- Dryland Agriculture Research Station, CCS Haryana Agricultural University, Bawal, Haryana, India (R.A. Kaushik).
- Department of Horticulture, Rajasthan College of Agriculture, Rajasthan Agricultural University, Udaipur - 313 001, India.
- Department of Horticulture, SKN College of Agriculture, Rajasthan Agricultural University, Jobner - 303 329, India (N. L. Sen).
- Department of Horticulture, Mahatma Phule Agricultural University, Rahuri, Ahmednagar - 413 722, India (S. N. Kaulgud, K. N. Wavhal, D. P. Waskar).
- Dryland Agriculture Research Station, Andhra Pradesh Agricultural University, Anantapur, India (K. S. Reddy).
- Division of Fruit Crops, Indian Institute of Horticultural Research, Hessarghatta Lake, Bangalore - 560 089, India (S. H. Jalikop, R. D. Rawal).
- Dryland Agricultural Research Station, Tamilnadu Agricultural University, Aruppukottai, India (M. Selvarajan).
- Dryland Agricultural Research Station, Gujarat Agricultural University, Sardarkrushinagar - 385 506, India (M. M. Patel).
- Department of Horticulture, Narendra Deo University of Agriculture and Technology, Kumarganj, Faizabad - 224 001, India (H. K. Singh).

The following research institutes of the ICAR also conduct research programmes on ber:

- Central Institute for Arid Horticulture, Bikaner - 334 006, India (B. B. Vashishtha).
- Central Arid Zone Research Institute, Jodhpur - 342 003, India (R. N. Prasad, S. K. Lodha, K. D. Sharma, M. P. Singh).
- Central Horticulture Research Station, Indian Institute of Horticultural Research, Godhra - 389 001, Gujarat, India (S. S. Hiwale, B. G. Bagle).

- Division of Fruits and Horticultural Technology, Indian Agricultural Research Institute, New Delhi - 110 012 (V. P. Sharma, D. S. Khurdiya).
- Central Research Institute for Dryland Agriculture, Hyderabad - 500 059, India.

Ber research was also initiated at several other Indian centres some of which are as follows:

- Regional Horticultural Research Station, Punjab Agricultural University, Bahadurgarh, Patiala, Punjab, India (H. Singh).
- Department of Horticulture, Punjab Agricultural University, Ludhiana - 141 004, Punjab, India (J. S. Bal, A. S. Dhatt, G. S. Bajwa, G. S. Mann).
- College of Agriculture, Gujarat Agricultural University, Junagadh, Gujarat, India (S. P. Singh).
- College of Agriculture, Gujarat Agricultural University, Anand - 388 001, Gujarat, India.
- Agriculture College and Research Institute, Tamilnadu Agricultural University, Madurai, Tamilnadu, India.
- University of Jodhpur, Jodhpur-342001, India (M. M. Bhandari, N. Mathur, A. Vyas).
- Marathwada Agricultural University, Parbhani - 431401, India (V. K. Patil, S. D. Chavan).
- Department of Horticulture, CS Azad University of Agriculture and Technology, Kanpur, India (A. Prasad, J. P. Shukla, U. R. Singh).
- Department of Horticulture, University of Agriculture and Technology, Pantnagar, UP, India.
- Department of Horticulture, Faculty of Agriculture, Banaras Hindu University, Varanasi, India (C. B. Singh, S. P. Singh).

Other countries: Organisations involved in ber research in several other countries are as follows:

- Pakistan Forest Research Institute, Peshawar, Pakistan (F. S. Khan).
- Dept. of Botany, University of Peshawar, Pakistan (F. Hussain).
- The Horticultural Research Institute, Department of Research & Specialist Services, PO Box 810, Marondera, Zimbabwe (N. Nenguwo).
- Department of Research & Specialist Services, Agronomy Institute, PO Box Cy 550, Causeway, Harare, Zimbabwe (I. Kadzere).
- Scientific and Industrial Research and Development Centre, PO Box 6640, Harare, Zimbabwe (C. Mawadza, E. Chivero).
- Forestry Commission, PO Box 595, Highlands, Harare, Zimbabwe (D. Rukuni).
- African Distillers, Box 2346, Harare, Zimbabwe (C. Guyo).
- International Centre for Research on Agroforestry, Bp 320, Samanko, Mali (M. Djimde).

- Institut D'Economie Rurale, BP 258, Bamako, Mali (M. Sidibe).
- ISRA/CIRAD- Foret Senegal, BP 2312, Dakar, Senegal (P. Danthu).
- Chercheur ISRA - Productions Forestieres Senegal, BP 2312, Dakar, Senegal (I. Diallo).
- Thusano Lefatsheng, P/Bag 00251, Gaborone, Botswana (T. Matlhare).
- Centre National de Semences Forestieres, 01 BP 2682 Ouagadougou, Burkina Faso (M. Ouedraogo).
- Kenya Forestry Research Institute, Social Forestry Programme, PO Box 0412, Nairobi, Kenya (B. Owuor Odit).
- Detache du CTFT-CIRAD Aupres de l'ICRAF, Nairobi, Kenya (D. Depommier).
- Forestry Research Institute of Malawi, Kufa Road, PO Box 270, Zomba, Malawi (L. Mwabumba).
- SADCC/ICRAF Agroforestry Project, PO BOX 134, Zomba, Malawi (H. Prins, J. A. Maghembe).
- Bunda College, University of Malawi, PO Box 219, Lilongwe, Malawi (M. Maliro).
- Agricultural Research Division, PO Box 829, Maseru 100, Lesotho (M. Mabusa).
- Ben Gurion University of the Negev, PO Box 653, Beer Sheva 841051, Israel (A. Nerd, Y. Mizrahi).
- Tel Aviv University, Israel (Y. Waisel).

***Ziziphus jujuba* (Chinese jujube)**

- Research Centre of Chinese jujube, Hebei Agricultural University Baoding, Hebei 071001, China (M. J. Liu).
- Pharmaceutical Faculty, Beijing Medical University, Beijing 100083, China (C.Y. Cheng).
- Hebei Provincial Academy of Medical Sciences, Shijiazhuang 050021, China (S. Wu, J. Zhang).
- Institute of Forest Science, Xingiang Vygur Autonomous Region, China (W. L. Ma).
- Station of Plant Protection and Quarantine, Jingyang County, Shanxi, China (J. L. Huan).
- Shanxi Agricultural University, Shanxi, China (K. Z. Li, Z. S. Gao).
- Department of Agriculture, Southeast Prefecture, Shanxi Province, China (Y. X. Wang).
- Institute of Forestry, Henan Academy of Agricultural Sciences, Zhenzhou, China (J. Z. Sun).
- Shangtung Academy of Agricultural Sciences, China (Z. Wang).
- Institute of Microbiology, Academia Sinicia, Peking, China (K. C. Mang).

- Research Institute of Economic Insects, CAF, Kunming 650 216, China (J. Li, X. Hu).
- Forestry Research Institute, Seoul 130 012, Republic of Korea (W. C. Bak).
- Department of Horticulture, Yeungnam University, Gyongsan 713-748, Republic of Korea (J. K. Byun, J. H. Do, K. H. Cheng).
- Naju Pear Research Institute, Fruit Tree Research Institute, R.D.A., Naju 523-820, Republic of Korea (M. S. Yun, Y. S. Kim, C. S. Ahn).
- Department of Forestry, Kon-Kuk University, Seoul 133-701, Republic of Korea (G. C. Choo).
- Tokyo University of Agriculture, Japan (S. Nakayama).
- Apsheronskaya Opythaya, Stantsiva Subtropicheskikh Kul'tur, Baku, Azerbaijan (T. M. Tagiev).
- Samarkandskil Filial NPO 703000 Samarkand, Uzbekistan (G. M. Semenov).

Other *Ziziphus* species

- Laboratoire de Botanique Fundamental et Appliqué, Faculté des Sciences, Campus Universitaire, 1060 Tunis, Tunisia (M. B. Nasri-Ayachi).
- Botany Department, Faculty of Science, Mansoura University, Egypt (M. A. El-Demardesh).
- Botany Department, Faculty of Science, University of Cairo, Giza, Egypt (M. A. El-Demardesh).
- Botany Department, Faculty of Science, Assiut University, Assiut, Egypt (Z. A. R. El-Karemy).
- Institut Nationale de la Recherche Agronomique, BP 589, Seltat, Morocco (A. Tanji, F. Nassif).
- King Faisal University, Biology Department, Box 1759, Al-Hofuf 31982, Saudi Arabia (K. H. Shaltout).
- Laboratorios de Botanica Lorenzo R. Parodi, Facultad de Agronomia de la Universidad de Buenos Aires, Avda. San Martin 4453. RA-1417, Buenos Aires, Argentina (G. M. Tourn).
- Institut fur Spezielle Botanik des Museums fur Naturkunde der Humboldt-Universitat zu Berlin, Spathstrasse 80/81, Berlin 1195, Germany (C. Schirarend).
- Institut Angewandte Botanik, University Muenster, Hindenburgplatz 55, D-48143, Muenster, Germany (M. Popp, D. J. Von-Willert).
- Université Aix-Marseille III, URA CNRS 1152, Case 461, Saint Jerome, F-1 3397 Marseille/Cedex 20, France (P. Quezel).
- University Research International, Efford, Lymington SO41 0LZ, UK (S. C. Clifford).
- Horticulture Research International, Wellesbourne, Warwick, CV35 9EF, UK (H. G. Jones).

- Institute of Plant Physiology, University of Vienna, Vienna, Austria (K. Stefan).
- TAES, Research and Extension Centre, 17360 Coit Road, Dallas, TX 78252-6582, USA (N. Sankhala).
- Fruit Crops Department, University of Florida, Gainesville, Florida 32611, USA (P. M. Lyrene).
- California University, Davis, California, USA (A. A. Kader, A. Chordas).
- College of Agriculture, Basrah University, Basra, Iraq (M. F. Abbas, J. H. Al-Niami).

Appendix IV List of jujube specialists

1. Dr. Bal, J. S.
   Department of Horticulture
   Punjab Agricultural University
   Ludhiana - 141004, India.

2. Dr. Batra, R. C.
   Department of Horticulture
   Punjab Agricultural University
   Ludhiana - 141004, India.

3. Dr. Bhargava, B. S.
   Division of Soil Science
   Indian Institute of Horticulture
   Hassarghatta Lake
   Bangalore - 560 089, India

4. Dr. Gupta, O.P.
   H.No. R25, Raghunagar, Pankha Road
   PALAM, New Delhi -110 058, India

5. Dr. Gupta, O. P.
   Department of Plant Pathology
   CCS Haryana Agricultural University
   Hisar -125 004, India

6. Dr. Khurdiya, D. S.
   Division of Fruits & Horticulture Technology
   Indian Agriculture Research Institute
   New Delhi -110 012, India.

7. Dr. Lakra, R. K.
   Department of Entomology
   CCS Haryana Agricultural University
   Hisar -125 004, India.

8. Dr. Pareek, O. P.
   Central Institute for Arid Horticulture,
   Bikaner -334006, India.
   (Res.- A-239, Karninagar Lalgarh, Bikaner - 334001)

9. Dr. Raturi, G. B.
   Central Institute for Arid Horticulture
   Bikaner -334 006, India

10. Dr. Rawal, R. D.
Division of Plant Pathology
Indian Institute of Horticultural Research
Hesarghatta Lake, Bangalore - 560 089, India.

11. Dr. Reddy, Y. N.
College of Agriculture
N.G. Ranga Andhra Pradesh Agricultural University
Rajendranagar, Hyderabad - 500030, India.

12. Dr. Singh, I. S.
Department of Horticulture
N.D. University of Agricultural & Technology,
Kumarganj, Faizabad - 224 001, India.

13. Dr. Vashishtha, B. B.
Central Institute for Arid Horticulture
Bikaner - 334 006, India

Appendix V Seed suppliers directory

AUSTRALIA

Harvest Seeds
325 Mc Carrs Creek Road
NSW 2084
Australia
Tel: (61-2) 94502699
Fax: (61-2) 94502750
Email: *harvest@ozemail.com.au*

M.L. Farrar Pty. Limited
PO Box 1046
Bomaderry, NSW 2541
Australia
Tel: (61-44) 217966
Fax: (61-44) 210051
Telex: AA171133 FLAMY

BURKINA FASO

Centre National De Semences
Forestieres C.N.S.F
01 BP 2682
Ouagadougou 01
Burkina Faso
Tel: (226) 35 80 13, 35 61 11
Fax: (226) 35 61 10
Email: *cnsf@fasonet.bf*
Website:
http://members.spree.com/business/cnsf_bf/

FRANCE

CIRAD-Forêt
Laboratoire de graines,
Campus International de
Baillarguet, BP 5035,
34032 Montpellier Cedex 01
France
Tel: (33-4) 67593751
Fax: (33-4) 67593733
Email: *labograine@cirad.fr*

UNITED KINGDOM

Royal Botanic Gardens Kew
Seed Conservation Dept.,
Wakehurst Place,
Ardingly, West Sussex. RH17 6TN.
United Kingdom
Tel: 01444 894123
Fax: 01444 894069
Email: *Seedbank@rbgkew.org.uk*
Website:
rbgkew.org.uk/seedbank/msb.html

The Henry Doubleday Research Association
Ryton on Dunsmore
Coventry, CV8 3LG
United Kingdom
Tel: (44-1203) 308215
Fax: (44-1203) 639229
Email:
eroycrof@hdra.demon.co.uk

INDIA

Bisht Enterprises
19, 1st Floor, Devki Complex
Moti Bazar,
Dehra Dun-248001 (UP)
India
Tel: (91-135) 773014 (Res)
Fax: (91-135) 773331

Gautam Global
34 Old Connought Place
Dehra Dun-248001, UP
India

Tel: (91/135) 656222
Fax: (91/135) 651108, 650944, 652766
Email: *npsonudd@nde.vsnl.net.in*
Website: *www.garhwalhimalayas.com/gautamglobal*

Kumar International
Ajitmal 206121
Etawah (UP)
India
Tel: 05683 - 54221
Fax: 091 - 5688 - 51036
Cable: Kumar International

Neelkantheshwar Agro-Seeds and Plantations
Commercial complex, 'C' Block - C-29/X3, Dilshad Garden,
DELHI-110 095
India
Tel: 2274277, 2119790, 2119744
Fax: (0091-11) 2112974

Shivalik Seeds Corporation
47 - Panditwari, P.O. Prem Nagar
Dehra Dun - 248007, U.P.
India
Tel: 91-135 - 773348
Fax: 91-135 - 773776
Email: *hilander@vsnl.com*

Tosha Trading Company
161, Indira Nagar Colony,
PO - New Forest,
Dehra Dun, 248006 , U.P.,
India
Tel: (91-135) 620984
Fax: (91-135) 620196

Tropical Nursery & Seeds
Panditwari, Lane No. 9
P.O. Prem Nagar Hehra Dun-248 007 (U.P)
India
Tel: 0135 - 77 37 22
Fax: 91 - 135 - 77 37 22

Viyaj Seed Stores
PO Ranjhawawala (Raipur)
Dehra Dun-248008 (U.P.)
India
Fax: (91-135) 629944

KENYA

Floral Products Agencies
Mbale Township, Makutano;
Mbale-Magada Rd,
PO Box 1402 Maragoli
Kenya
Tel: (254-0331) 51454, 51308
Fax: (254-0331) 51217
Email: *fpagencies@kakamega.africaonline.com.*

Kenya Forestry Seed Centre
PO Box 20412
Nairobi
Kenya
Tel: (254-154) 32484, 32893
Fax: (254-154) 32844

MALAWI

Forestry Research Institute of Malawi
PO Box 270
Zomba
Malawi
Tel: (265) 522866, 522548
Fax: (265) 522782

NIGER

Centre des Semences Forestieres
BP 578
Niamey
Niger
Tel: (227) 723182, 733339

Fax: (227) 732784

NETHERLANDS

Setropa Ltd.
PO Box 203
1400 AE Bussum
Netherlands
Tel: (31-35) 5258754
Fax: (31-35) 5265424
Cable: SETROPA BUSSUM

SENEGAL

Project National de Semences
Forestieres (PRONASEF)
BP 3818
Dakar
Senegal
Tel: 836/14/11
Fax: 836/14/09
Email: *pronasef@ns.arc.sn*

SINGAPORE

The Inland & Foreign Trading Co
(Pte) Ltd.
Block 79A Indus Road #04-418
Singapore 169589
Singapore
Tel: (65) 2722711 (3 lines)
Fax: (65) 2716118
Email: *iftco@pacific.net.sg*

TANZANIA

National Tree Seed Programme
PO Box 373
Morogoro
Tanzania
Tel: (255-56) 3192, 3903
Fax: (255-56) 3275
Email: *ntsp@twiga.com*
Website:
http://www.twiga.com/ntsp

USA

F. W. Schumacher Co., Inc.
36 Spring Hill Rd. Sandwich.
MA 02563-1023
United States of America
Tel: (1-508) 8880659
Fax: (1-508) 8330322

Lawyer Nursery Inc.
950 Highway
200 West Plains, Montana 59859
United States of America
Tel: (1-406) 8263881
Fax: (1-406) 8265700
Telex: 406-31-9547
Email: *lawyrnsy@montana.com*

Source: Kindt *et al*. (2001)

Glossary

actinomorphic - having radially symmetric shape, usually refers to the petals of a flower.
acuminate - the shape of a tip or base of a leaf or perianth segment where the part tapers gradually and usually in a concave manner.
adnate - joined to or attached to.
albumen - Starchy and other nutritive material in a seed, stored as endosperm inside the embryo sac, or as perisperm in the surrounding nucellar cells; any deposit of nutritive material accompanying the embryo.
anatropous - bent over through 180 degrees to lie alongside the stalk.
androecium - all the male reproductive organs of a flower; the stamens. cf. gynoecium.
angiosperm - a plant producing seed enclosed in an ovary. A flowering plant.
annual - a plant that completes its life cycle from germination to death within one year.
anterior - front; on the front side; away from the axis.
anther - the pollen-bearing (terminal) part of the male organs (stamen), borne at the top of a stalk (filament).
anthesis - flower bud opening; strictly, the time of expansion of a flower when pollination takes place, but often used to designate the flowering period; the act of flower bud opening.
antrorse - turning upward and forward.
apex - the tip of an organ, the growing point.
apical - pertaining to the apex.
apiculate - having a short point at the tip.
arcuate - bow-shaped.
aril (arillus) - a fleshy or sometimes hairy appendage or outer covering of a seed.
arillate - provided with an aril.
auricle (adj. auriculate) - small ear-like projections at the base of a leaf or leaf-blade or bract.
axil - the upper angle formed by the union of a leaf with the stem.
axillary - pertaining to the organs in the axil, e.g. buds, flowers or inflorescence.
axis - the main or central stem of a herbaceous plant or of an inflorescence.
basal - borne on or near the base.
bifarous - in two rows; two-fold; pointing in two directions.
bifid - forked; having a deep fissure near the centre.
bilabiate - two-lipped.
bipinnate - (of leaves) a pinnate leaf with primary leaflets themselves divided in a pinnate manner; cf pinnate.

biseriate - in two rows.
bisexual - having both sexes present and functional in one flower.
blade - the flattened part of a leaf; the lamina.
bract - a much-reduced leaf, particularly the small or scale-like leaves in a flower cluster or associated with the flowers; morphologically a foliar organ.
bracteole - a secondary bract; a bractlet.
caducous - falling off early, or prematurely, as the sepals in some plants.
calyx - the outer whorl of floral envelopes, composed of the sepals.
carinate - keeled; provided with a projecting central longitudinal line or ridge on the under surface.
carpel - one of the flowers' female reproductive organs, comprising an ovary and a stigma, and containing one or more ovules.
clone - a group of plants that have arisen by vegetative reproduction from a single parent, and which therefore all have identical genetic material.
colpus (colpi pl.) - aperture within the pollen grain wall.
concave - the interior of a curved surface.
confluent - merging or blending together.
connate - united or joined; in particular, said of like or similar structures joined as one body or organ.
convex - arched outward.
cordate - heart-shaped, often restricted to the basal portion rather than to the outline of the entire organ.
coriaceous - of leathery texture.
cotyledon - seed leaf; the primary leaf or leaves in the embryo.
crenate - shallowly round-toothed, scalloped.
crenulate - finely crenate.
cross pollination - the transfer of pollen from the anther of the flower of one plant to the flowers of a different plant.
crustaceous - of hard and brittle texture.
cucullate - hooded; hood-shaped.
cultivar - a race or variety of a plant that has been created or selected intentionally and maintained through cultivation.
cuneate - wedge-shaped; triangular with the narrow end at point of attachment, as in the bases of leaves or petals.
cuspidate - with an apex abruptly and sharply constricted into an elongated, sharp-pointed tip.
cyme - a broad, more or less flat-topped, determinate flower cluster, with central flowers opening first.
cymose - inflorescence showing the cyme arrangement.
deciduous - falling at the end of one season of growth or life, as the leaves of non-evergreen trees.
decoction - herbal preparation made by boiling a plant part in water.
deflexed - bent abruptly downward; deflected.

degree-day -	a unit that represents one degree of difference from a given point (as 65°) in the mean daily outdoor temperature and that is used especially to measure heat requirements.
dehiscence -	the method or process of opening a seed pod or anther.
dentate -	with sharp, spreading, course indentations or teeth, perpendicular to the margin.
denticulate -	minutely or finely dentate.
derived -	originating from an earlier form or group.
dichotomous -	forked, in one or two pairs.
dicotyledon -	a flowering plant with two cotyledons.
dioecious -	having male (staminate) and female (pistillate) flowers on different plants.
diploid -	having two sets of chromosomes.
dipterous -	having two wings.
distichous -	two-ranked, with leaves, leaflets or flowers on opposite sides of a stem and in the same plane.
divaricate -	spreading very far apart; extremely divergent.
downy -	covered with short and weak soft hairs.
drupacious -	a fruit showing the characteristics of a drupe.
drupe -	a fleshy one-seeded indehiscent fruit with seed enclosed in a stony endocarp; stone fruit.
elliptic -	oval in outline.
emarginate -	having a shallow notch at the extremity.
endocarp -	the inner layer of the pericarp or fruit wall.
endosperm -	the starch and oil-containing tissue of many seeds.
entomophilous -	insect pollinated.
epigynous -	borne on or arising from the ovary; used of floral parts when the ovary is inferior and flower not perigynous.
exalbuminous -	without albumen.
exine -	the outer coat of a pollen grain.
exocarp -	the outer layer of the pericarp or fruit wall.
falcate -	scythe-shaped; curved and flat, tapering gradually.
fasicle -	a condensed or close cluster.
faveolate -	honey-combed.
ferrugineous -	pertaining to or coloured like iron rust.
filament -	thread; particularly the stalk of the stamen, terminated by the anther.
filiform -	thread-shaped, long, slender and terete.
flexuose -	zig-zag; bending from side to side; wavy.
fulvous -	dull, brownish-yellow.
fuscous -	dusky, greyish-brown.
genus -	a group of related species, the taxonomic category ranking above a species and below a family.
genotype -	the genetic constitution of an organism, acquired from its parents and available for transmission to its offspring.
glabrous -	not hairy.

glaucous - bluish white; covered or whitened with a very fine, powdery substance.
globose - globe-shaped.
glabrescent - becoming glabrous with age.
glomeruliform - showing a compactly, clustered form.
gynoecium - all the female parts of a flower.
hoary (pubescent) - greyish white with a fine, close pubescence.
homonym - a scientific name given two or more times to plants of the same taxonomic rank but which are quite distinct from each other.
hymenopterous - having four membranous wings.
hypocotyl - the axis of an embryo below the cotyledons which on seed germination develops into the radicle.
indehiscent - not regularly opening, as a seed pod or anther.
indigenous - native and original to the region.
inflorescence - the flowering part of a plant and especially the mode of its arrangement.
integuments - an outer covering or coat.
IU (international unit) - a unit used to measure the mass of certain vitamins and drugs based on their expected effects. For each substance to which this unit applies, there is an international agreement specifying the biological effect expected with a dose of 1 IU. Other quantities of the substance are then expressed as multiples of this standard. Examples: 1 IU represents 45.5 micrograms of a standard preparation of insulin or 0.6 microgram of a standard preparation of penicillin. Consumers most often see IUs on the labels of vitamin packages: the equivalent of 1 IU is 0.3 microgram (0.0003 mg) for vitamin A, 50 micrograms (0.05 mg) for vitamin C, 25 nanograms (0.000 025 mg) for vitamin D, and ⅔ milligram for vitamin E.
lateral - side shoot, bud etc.
lamellae - a thin, flat plate or laterally flattened ridge.
lanceolate - shaped like a lance head, several times longer than wide, broadest above the base and narrowed toward the apex.
lenticellate - having a body of cells as a pore, formed on the periderm of a stem, and appearing on the surface of the plant as a lens-shaped spot.
liane - various high-climbing woody plants, usually found in the tropics.
locular - having a cavity or chamber inside the ovary, anther or fruit.
membranous - thin in texture, soft and pliable.
mesocarp - the fleshy middle portion of the wall of a succulent fruit between the skin and the stony layer.
monophyletic - descended from a single ancestral line, see also: polyphyletic.
mucronate - terminated abruptly by a distinct and obvious spur or spiny tip.

naturalised - to cause a plant to become established and grow undisturbed as if native.
nectar - sweet secretion of glands in many kinds of flower.
necrotic - Death of cells or tissues through injury or disease.
nectiferous - producing nectar.
nervules - small/minute nerves or veins.
nodose - knobbly, knotty.
obconical - inversely conical, having the attachment at the apex.
oblique - slanting, unequal sided.
obovate - inverted ovate; egg-shaped, with the broadest part above.
obtuse - blunt or rounded at the end.
octaploid - having eight times the basic number of chromosomes.
orbicular - circular.
osseous - bony.
ovary inferior - with the flower-parts growing from above the ovary.
ovary superior - with the flower-parts growing from below the ovary.
ovate - egg-shaped, with the broader end at the base.
ovule - the body which after fertilisation becomes the seed.
panicle - a loose irregularly compound inflorescence with pedicellate flowers.
paniculate - borne in a panicle.
papillose - bearing minute, nipple-shaped projections.
paripinnate - a pinnate (compound) leaf with all leaflets in pairs.
pedicel - a tiny stalk; the support of a single flower.
pendulous - more or less hanging or declined.
perianth - the floral envelope consisting of the calyx and corolla.
pericycle - the tissue of the stele lying just inside the endodermis.
perigynous - adnate to the perianth, and therefore around the ovary and not at its base.
petal - a division of the corolla; one of a circle of modified leaves immediately outside the reproductive organs, usually brightly coloured.
petiole - the stalk of a leaf that attaches it to the stem.
phenotype - the morphological, physiological, behavioural, and other outwardly recognisable forms of an organism that develop through the interaction of genes and environment.
pilose - hairy, especially with soft hairs.
pilosulous - minutely pilose.
pinnate - a compound leaf consisting of several leaflets arranged on each side of a common petiole.
polygamous - bearing male and female flowers on the same plant.
polyphyletic - having members that originated, independently, from more than one evolutionary line.
polyploidy - having more than two sets of chromosomes.
polyporate - pollen grain with many apertures.

porate (see tricolporate, polycolporate) - describes a pollen grain which has rounded apertures only.

prolate - having flattened sides due to lengthwise elongation.

propagate - to produce new plants, either by vegetative means involving the rooting or grafting of pieces of a plant, or sexually by sowing seeds.

protandrous - refers to a flower, when the shedding of the pollen occurs before the stigma is receptive.

protogynous - referring to a flower where the shedding of the pollen occurs after the stigma has ceased to be receptive.

psilate - referring to a pollen grain having a smooth surface.

pubescent - covered with hairs, especially short, soft and down-like.

pulvinus - a swelling at the base of a leaf or leaflet.

putamen - the shell of a nut, the bony part of a stone fruit.

pyriform - pear-shaped.

raceme - a simple inflorescence of pediceled flowers upon a common more or less elongated axis.

rachis - the main stalk of a flower cluster or the main leafstalk of a compound leaf.

radicle - the portion of the embryo below the cotyledons that will form the roots.

ramification - branching

reticulate - in the form of a network, net veined.

retuse - with a shallow notch at a rounded apex.

rootstock - the root system and lower portion of a woody plant to which a graft of a more desirable plant is attached.

rotundate - nearly circular; orbicular to oblong.

rufous - reddish-brown.

rugose - wrinkled.

rugulose - covered with minute wrinkles.

scandent - climbing but not self-supporting.

scarify - to scar or nick the seed coat to enhance germination.

sclerenchymatous - tissue composed of cells with thickened and hardened walls.

scurfy - covered with tiny, broad scales.

self pollination - the transfer of pollen from the anther of a flower to the stigma of the same flower, or different flowers on the same plant.

sepal - a division of a calyx; one of the outermost circle of modified leaves surrounding the reproductive organs of the flower.

sericeous - bearing fine, usually straight, appressed hairs.

serrate - having sharp teeth pointing forward.

serrulate - finely serrate.

sessile - without a stalk.

sheath - a tubular envelop.

spathulate - gradually narrowing downward to a summit; spoon shaped.

spinescent - 1. having spines, 2. terminating in a spine, 3. modified to form a spine.

stamen -	one of the male pollen-bearing organs of the flower.
staminode -	a sterile stamen, or any structure without anther corresponding to a stamen.
stigma -	that part of a pistil through which fertilisation by the pollen is effected.
stipule -	an appendage at the base of a petiole, often appearing in pairs, one on each side, as in roses.
strigose -	beset with appressed, sharp and stiff hairs.
style -	the usually attenuated portion of the pistil connecting the stigma and ovary.
subulate -	awl-shaped.
sulcate -	grooved or furrowed.
tetraploid -	having four sets of chromosomes (twice the normal number of chromosomes).
testa -	the outer seed coat.
thyrse -	a contracted, cylindrical or ovoid and usually compact panicle.
tomentose -	covered with a thick felt of radicles; densely pubescent with matted wool.
tomentulose -	rather tomentose.
tomentum -	closely matted, woolly hairs.
trabecular -	a transverse partition, complete or incomplete.
transverse -	cross-wise in position.
tricolporate -	having three apertures in the pollen grain wall.
trifid -	deeply divided or left in three parts.
tropism -	the movement of an organism in response to an external source of stimulus, usually toward or away from it.
truncate -	ending abruptly, as if cut off transversely.
tuberculate -	bearing tubercles, covered with warty lumps.
unguiculate -	narrowed, clawed.
valvate -	open by valves.
virgate -	wand-shaped; slender, straight and erect.
zygomorphic -	capable of division by only one plane of symmetry.

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