

**INVESTIGATIONS ON DROUGHT TOLERANCE IN
BER (*Zizyphus mauritiana* L.) CULTIVARS**

PRAVEEN JHOLGIKER

**DIVISION OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES
DHARWAD - 580 005.**

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**INVESTIGATIONS ON DROUGHT TOLERANCE IN BER
(*Zizyphus mauritiana* L.) CULTIVARS**

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements
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Degree of

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in
HORTICULTURE

By

PRAVEEN JHOLGIKER

**DIVISION OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD.**

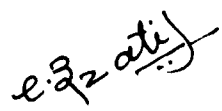
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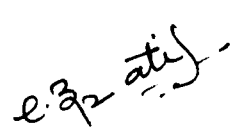
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This is to certify that the thesis entitled "INVESTIGATIONS ON DROUGHT TOLERANCE IN BER (*Zizyphus mauritiana* L.) CULTIVARS" submitted by Mr. PRAVEEN JHOLGIKER, for the degree of MASTER OF SCIENCE (Agri.) in HORTICULTURE, of the UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD, is a record of research work done by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately Dedicated

to my

Beloved Parents

Science of Investigation
brings light to all
knowledge, provides a
means for all actions
and is the basis of
all righteous acts.

"Kautilya's Arthashastra"

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(PRAVEEN JHOLGIKER)

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INTRODUCTION

INTRODUCTION

Arid and semiarid conditions are always a challenge for all biological systems, especially the plants which inhabit in such a conditions, are frequently exposed to multiple stresses like moisture deficits, low and erratic rainfall, intense solar radiations (400-500 cal/cm²/day), and high wind velocity resulting in a high mean aridity index of 74-75 per cent (Pareek, 1983). Nearly 40 per cent of worlds land surface is occupied by arid and semiarid zones (Krishnan, 1988), further he has reported that 12 per cent (31.7 m.ha) of total geographical area of India falls under arid zone category wherein Karnataka has a share of 2.7 per cent (0.86 m.ha).

In recent years, there is a growing emphasis in the country and else where on the cultivation of fruit crops in vast tracts of arid and semiarid regions. Several perennial fruit crops like ber, pomegranate, phalsa, annonaceous spp. have been recognised as ideally suitable for arid regions, as they can withstand long spells of drought during their growth.

Ber (*Zizyphus mauritiana* L.) is one of the hardiest cultivated fruit crops of the arid region with an area of 3,258 ha and production of 19,548 tonnes in Karnataka. The expanding acreage of ber plantation can be attributed to the virtues of its low price and high nutritive value of fruits, as it is rich in vitamin 'C', proteins, phosphorus and calcium (Bakshi and Singh, 1974). The adaptability of ber to marginal soils, under moisture deficit condition is an added feature for its perfection in suitability for harmonising both economic and ecological needs of resource starved dryland regions.

According to Chatterjee and Randhawa (1952) ber belongs to family Rhamnaceae and genus *zizyphus*. There are two prominent species of ber namely Chinese ber (*Zizyphus jujube* Mill.) and Indian ber (*Zizyphus mauritiana* L.). Most of the commercially grown cultivars in India belong to *Z. mauritiana* L (Bal and Uppal, 1992).

The ber being a characteristic xerophytic plant possess striking drought tolerant features. It is a deciduous plant which undergoes dormancy during summer by shedding its leaves their by reducing the total transpiring area. The leaves with thick cuticle with shiny wax deposition on upper surface and dense pubescence on lower surface along with sunken stomata create a natural barrier for exit of water. The deep and extensive tap root system with ability for rapid growth enables the plant for efficient moisture extraction and utilization. Further, its inherent ability to complete its fruiting during the period of moisture availability are the features represent the better adaptability for arid conditions.

A rich genetic resource of ber exists in India and several cultivars of ber are grown commercially in arid regions. Information on nature and magnitude of variability present in the existing plant material and association among the various characters (morphological, physiological, biochemical etc.) are pre-requisite for improvement in the yield. However, a huge variability in phenotype and genotype along with the interacting environment of plant causes a wide fluctuation in yielding behaviour in ber which has been frequently noticed under arid and semi arid regions.

Yield which is a complex character is predominantly controlled by non-additive gene action and it is not only influenced by a number of other

morphological characters which are governed by a large number of genes but is also influenced by environment to a greater extent.

Better adaptability under rainfed conditions of a cultivar is indicated by its high yielding ability in such regions. Therefore, the parameters such as yielding ability, stomatal index and stomatal frequency (Yoshida, 1979), proline accumulation (Aloni and Rosenshtein, 1984) relative water content (Voleti *et al.*, 1990) are some of the parameters which can be used for screening cultivars for their tolerance to drought conditions.

Mutual association of plant characters which is determined by correlation coefficients is useful as a basis for selecting the desirable cultivars, which further permits evaluation of relative influence of various characters on yield. A comprehensive knowledge on the above mentioned genetic parameters is indispensable in a crop improvement programme. A survey of literature reveals that the amount of work done on phenology, biochemical changes and genetics of some of important characters are rather meagre. Therefore, a need was felt to understand and select an ideal cultivar suitable for arid condition with high yielding quality fruits. Accordingly an investigation was planned with the following objectives.

1. To study the yielding ability of different cultivars of ber under rainfed conditions.
2. To study the phenological and biochemical characters with relation to drought tolerance and yielding ability in ber cultivars.
3. To study the stomatal characters in leaves of different ber cultivars.
4. To estimate the extent of variability, heritability and genetic advance, and to assess the extent of association between yield and other related characters.

REVIEW OF
LITERATURE

REVIEW OF LITERATURE

Arid regions which are starved of all resources pose a hostile agro-climatic conditions rendering difficulty in cultivation of various fruit crops. Ber being drought, heat and salinity tolerant, is most ideally suited to these regions. It also provides high nutrition at a low cost. In spite of these facts, this indigenous fruit crop of India has received very little attention both with respect to research and publicity, further there is a paucity of information with respect to screening of different ber genotypes under arid conditions. Therefore, available information on cultivation of ber under arid and semi arid conditions and also information from related perennial species have been reviewed here under. An effort has also been made to review the research work on vegetables and field crops, essentially growing under water deficit conditions.

The literature available has been reviewed under the following broad headlines.

1. The phenological response to water stress.
2. Biochemical changes under water stress conditions.
3. Stomatal distribution and its responses to water deficits.
4. Physico-chemical characters and yielding pattern of ber under different growing conditions.
5. Crop improvement.

2.1 Phenological responses to water stress

2.1.1 Canopy development and tree size

Growth of woody plants, like that of other plants and animals, is controlled by their heredity potentialities, which operate through their physiological processes and by the environment in which they grow (Kozlowski *et al.*, 1991).

Adel-Messaih and Nokrashy (1977) conducted long term experiments and concluded that plant growth is reduced with increasing dryness of soil.

Srihari and Sampat Kumar (1986) reported that the trees of Gola, Banarasi Karaka and Umran were tallest whereas the Mundia and Akola were found shortest. Further, maximum spread was observed in shortest Akola cultivar (7.47 m) while the tree of Seb had least spread (5.27 m).

Anonymous (1988) reported that the plant height, girth of stem and spread of plant varied in different genotypes growing under arid conditions. Plant height varied between 0.90 meters in Sandhura Narnaul to 3.03 meters in Safeda Rohtak. Girth varied between 4.0-51.0 cms and spread 1.25-6.7 m respectively and suggested the presence of wide variation in the phenological characters of different ber genotypes.

However, Spinks (1936) observed that there was no perfect correlation between the size and vigour of apple cultivars growing in a particular set of agro-ecological conditions. Similarly, Hilgeman and Sharp (1970) reported that there was no commensurate increase in yield due to large canopy and size was not correlated with yield in citrus.

2.1.2 Effect on trunk growth

Huguet *et al.* (1984) observed the stem diameter variation on imposition of stress to seek a reliable indicator of water stress, there was a cessation of daily growth of stem diameter as the severity of water stress increased. However, in ber it was found that the girth of the grafted scion was higher in Seb (14.00 cm) which was on par with Banarasi Karaka (13.30 cm) and lower in Gola (12.60 cm) under rainfed conditions (Tiwari and Banafar, 1995).

2.1.3 Impact on leaf area expansion

Several mechanisms for reducing water loss have been identified, one of the most general mechanism is the reduction in the leaf area, due to either reduction in leaf area development or leaf senescence (Kozlowski, 1968).

Turk and Hall (1980) found that increasing levels of drought reduced leaflets and average leaflet area with total leaf area in cowpea plants having greater sensitivity to drought. However, Connor *et al.* (1981) found that MMex-59 cultivar of cassava a drought tolerant maintained higher leaf area index during stress and was least affected in total biomass production.

2.1.4 Relative water content (RWC)

Whenever plants are subjected to water stress changes in various physiological processes occur in plants and these are all due to reduction in water content alone of the tissues. So, the actual water content of the tissue is important in determining the rate of various processes in plant and thus may give an indication of the intensity of stress to which a plant has reached. RWC or relative turgidity

expressed as the measured water content relative to that of full turgor. The water saturation deficit is reciprocal of RWC (Singh, 1985).

Rao and Reddy (1993) observed the effect of artificially withholding of irrigation, at permanent wilting point, in citrus plants aged 15 years grown under water stress condition the mature leaves of Cleopatra mandarin and Rangpur Lime showed highest RWC of 87.66 per cent and 87.38 per cent, respectively. Similarly the highest values for leaf diffusion resistance were also obtained in Rangpur Lime and Cleopatra Mandarin indicating their better tolerance to water deficits.

A screening of tall and dwarf cultivars of coconut under water stress revealed that the RWC was reduced more by desicating than by osmotic stress. A high RWC was maintained by the stress tolerant hybrids namely Tall Laccadive Ordinary x Dwarf Ganga Bondhan and Laccadive Ordinary x Choughat Orange Dwarf and by West Coast Tall (Voleti *et al.*, 1990).

Wilcox and Ashley (1982) were of the opinion that stressed plants of all four cultivars of potato exhibited an increase in leaf diffusive resistance, decrease in RWC transpiration and photosynthesis as the soil moisture content decreased. Significant varietal differences in leaf diffusive resistance of stressed plants were apparent and offered promise for development of a screening technique for varietal sensitivity to drought based on stomatal responses to water deficits.

Yadav and Patil (1984) classified eight cowpea varieties into tolerant, moderately tolerant and susceptible, on the basis of percentage of decrease in yield under non irrigated conditions compared with irrigated conditions. RWC and

diffusive pressure deficit were significantly differed. There was a direct relationship between chlorophyll stability index and reduction in yield.

2.1.5 Effect on water saturation deficit (WSD) and moisture content

Lee and Asahira (1983) classified pepper cultivars into drought resistant (WSD < 20%), intermediate (WSD = 20-40%) or susceptible (WSD > 40%). A highly significant correlation was observed between leaf water potential and WSD.

Similarly in a study of ten varieties of different crops in plastic green house, pepper varieties with good resistance to water stress was identified as 85 per cent water content in the tissues and the water deficit not greater than 5-7 per cent, while for egg plant varieties the respective figures were 86-88 per cent and 8-10 per cent for resistance (Gati, 1982).

Jirali *et al.* (1989) reported differences in leaf moisture content, free proline accumulation, nitrogen content and seed yield in six chickpea genotypes, leaf moisture decreased, whereas free proline increased with age and they were inversely related, this indicates the existence of osmoregulation to combat drought. However, Kozłowski *et al.* (1991) reported that in deciduous forest trees facing frequent drought condition, the water content was stored in trunk portion from where the loss of water was very much reduced compared to loss through leaf.

2.2 Biochemical changes to water stress conditions

Moisture stress is a physiological condition to which tree is subjected whenever, the rate of loss from leaves by transpiration exceeds the rate at which

water is absorbed by root system (Marsh, 1973). These physiological changes brought about in plants are channelised by a series of biochemical changes which are evoked in response to water deficits.

2.2.1 Leaf pigment

Chlorophyll 'a' and 'b' are the major pigments which are associated with trapping of light energy for CO₂ assimilation in plants. Chlorophyll content of leaf is influenced by environmental conditions (Shimizu and Torikata, 1972 and Syvertsen and Smith, 1984). Syvertsen and Smith (1984) reported lower chlorophyll content in sun exposed leaves of grape fruit. Moisture stress affects the chlorophyll content of leaf and chlorophyll stability has been used as indicator of drought tolerance, in several crop species (Sharma and Gill, 1981).

Janet and Rohitashv (1993) proposed in ber (*Zizyphus jujube* L.) that chlorophyll fluorescence as a technique for early detection of plant response to environmental stresses. Three days after withholding water the stomatal conductance and assimilation rate of the non irrigated plants were significantly lower than for the well watered treatment.

Mugnai *et al.* (1995) observed the influence of drought on leaf water relation and gas exchange in dwarf and standard plants of *Nerium oleander*. Dwarf plants had more leaves of smaller size and higher chlorophyll content than standard cultivars under non limiting water conditions. The dwarf genotypes showed lower stomatal conductance and high net photosynthesis than standard plants.

Sankhla *et al.* (1989) observed in seb cultivar that drought, dust, storm and extreme temperature drastically reduced fruit yields. On application of

paclobutrazol there was an intensification of chlorophyll in both leaf and fruits which increased the efficacy of plants to withstand intense light and water shortages.

Johnson *et al.* (1982) observed in *Ficus benzamina* that there was a reduction in chlorophyll content in sunplants with increase in water stress.

2.2.2 Metabolism and accumulation of amino acids

Under the conditions of moisture stress, there was an enormous change in different metabolic activities of crop plants (Aspinal and Paleg, 1981). Rhodes *et al.* (1986) observed changes in carbon metabolism, osmoregulation and nitrogen solute comparatmentalization in tomato cell lines subjected to moisture stress.

Barnett and Naylor (1966), while investigating amino acid and protein synthesis during water stress in Bermuda grass reported that the amino acids were continually synthesised during water stress, but protein levels were decreased.

Analytical data on eight plant species including, spinach, peas, beans and *Solanum laciniatum* had shown that water deficiency in plants resulted in a very high rate of proline accumulation. Amino acids showing three to five folds increase in plants were leucine, isoleucine, phenyl alanine, methionine, valine, threonine, while arginine, histidine and lysine increased two to three folds (Palfi, 1969).

Madeline *et al.* (1980) reported that as the leaf water deficit developed the levels of free amino acids increased by 7 mm and 16 mm in different treatment in sorghum. Under moderate stress the authors found increase in amino acids such as aspartic acid, glutamic acid, proline, alanine and valine. Whereas proline, alanine and valine under more severe stress.

2.2.3 Accumulation of free proline

Accumulation of free proline as a response to imposed water stress has been reviewed by Aspinall and Paleg (1981) but its adaptive significance is still disputed. Accumulation of proline depends upon degree and duration of stress (Joyce *et al.*, 1984). Aloni and Rosenshtein (1984) suggested that proline can be used as a parameter for evaluation of sensitivity to drought stress.

Rajgopal *et al.* (1977) were of the opinion that proline an imino acid is one of the prominent solutes gets accumulated under moisture stress. While Singh *et al.* (1973) noticed that a major portion of the accumulated proline was found in leaves and leaf sheath with very low levels in the roots.

Barnett and Naylor (1966) found that the drought resistant Bermuda grass accumulated nearly four folds more proline than the susceptible species. They suggested that the accumulation of proline served as a storage compound for the carbon and nitrogen requirements of the plant once the water stress is alleviated.

Maestri *et al.* (1995) observed accumulation of proline and quarternary ammonium compounds in mature leaves of water stressed coffee plants.

Blum and Ebercon (1976) brought out a possible association between free proline and amino acid accumulation in water stressed and drought resistant varieties of grain sorghum.

Levy (1983) reported that a marked increase in proline was observed in tubers of more drought susceptible potato cultivars in response to water stress.

However, Aloni and Rosenshtein (1984) found that proline accumulation at the time of dehydration signals drought stress in tomato plants but did not correlated with overall varietal sensitivity to transient dehydration in recovered plants.

2.2.4 Response of solutes

Madeline *et al.* (1980) observed the effect of water deficits on the concentration of different solutes, several of the major solutes such as free amino acids, soluble sugars, carboxylic acids, inorganic cation and anions were together responsible for the osmotic adjustment in leaves of sorghum and sunflower. Further he has reported that the development of leaf water deficits in fully expanded sorghum leaves resulted increase in sugars.

Cutler and Rains (1978) reported that increased water deficits led to accumulation of sugars in cotton and it was found that non reducing sugars had a larger contribution to the total changes in sugars.

Wang and Stutte (1992) were of the opinion that Jonathan apple trees subjected to various levels of water stress, showed an increase in concentration of sorbitol glucose and fructose, while sucrose and starch level decreased significantly as water stress developed revealing the sugar alcohols and the monosaccharides as the most important for osmotic adjustment.

Sugal and Torikata (1976) reported that reducing and non reducing sugars increased in Satsuma Mandarin with reduced soil moisture content. Yelenoski (1979) observed in *Citrus medica* that there was an increase in sugars during forced dehydration of leaves.

Madeline *et al.* (1980) illustrated the probable mechanism by which the sugar is accumulated in the water stressed leaf. He has suggested that starch gets hydrolysed into sugars, or decreased conversion of sugars to other products. Alternatively, increased translocation of carbohydrates into leaves or decrease in translocation of carbohydrate from leaves could also contribute to the observed sugar accumulation.

2.3 Stomatal distribution and its response to water deficits

2.3.1 Stomatal response

Stomata is a critical interference between the inside of the leaf and plant aerial environment for water vapour and CO_2 exchange (Kriedemann and Barrs, 1981), stomatal opening in response to light was indirectly occurring as a result of photosynthetic lowering of CO_2 concentration in leaf intercellular space (Ranchke, 1975). In the environmental conditions apart from light, humidity also affects the stomatal opening (Hall *et al.*, 1975). However, temperature effect was not well recognised and its effect was considered to be through humidity (Kaufmann and Levy, 1976).

2.3.2 Stomatal density and distribution

The ability of stomata to regulate water loss provides an important mechanism for reducing its loss during drought.

Blum (1974) reported that there was a varietal differences in stomatal response to water stress in sorghum and wheat.

Banker and Prasad (1992) correlated stomatal density with growth parameters in four root stocks of ber. They observed the highest number of stomata

in *Zizyphus mauritiana* cultivar Tikdi (61753/cm²) followed by *Z. roundifolia* (36374 stomata/cm²), *Z. spinachristi* (8333 stomata/cm²) and *Z. nummularia* (8099 stomata/cm²). The growth of root stock in terms of height, spread, trunk, diameter and leaf area were positively correlated with number of stomata. The *Z. nummularia* having the lowest number of stomatal density was found to be dwarfing type and *Z. mauritiana* and *Z. rotundifolia* having higher density of stomata were found to have vigourous root stock.

Ehrler and Van Bavel (1968) noticed that stomata are present only on abaxial surface of several citrus species. However, abaxial surface of citrus leaf is cutinised which contains epicuticular wax and this cutinisation checks the loss of water. The cuticular resistance of citrus is calculated to be as high as 400-1600 sec.cm⁻¹ (Schonherr and Schmidt, 1979). Lower surface has lower resistance which is controlled by opening and closing of stomata. Cuticular thickness varies according to leaf age and growing conditions (Syvertsen and Levy, 1982). Stomata are found more in number in abaxial surface of leaf which controls the water vapour exchange with CO₂. The stomatal frequency vary with plant species and growing conditions. Brainerd *et al.*, (1981) reported that the number of stomata increased due to stress in plants.

2.3.3 Stomatal size

Size of the stomata also varies among species and growing conditions (Turrell, 1947). Stomatal size and frequency are inversely correlated (Ciha and Brun, 1975; Miskin and Rosmusson, 1970; Sapra *et al.*, 1975).

Davies and Kozlowski (1973) observed in *Fraxinus americana* which along with *Quercus macrocarpa* had the highest rate of water loss and had lowest

stomatal frequency, largest stomatal pore and lowest relative pore area, while *Quercus macrocarpa* with high stomatal frequency and high relative pore area also had a high transpiration rate.

2.3.4 Anatomy

Syvertsen and Levy (1982) established a close correlation between leaf thickness, leaf water potential, vapour pressure deficit and leaf to air temperature from the diurnal change in the leaves of marsh grape fruit.

Singh (1985) reported that under stress conditions more surface wax is deposited which leads to increase in the thickness of leaves in citrus. Further he observed the arrangement of mesophyll cells in leaf which was found to be arranged in tightly in second and third layers and the cells of the third layers were shorter than the first and second layers. The packing of cells was also influenced by growing conditions.

The anatomical changes have adaptive significance for sustaining drought conditions (Kaufmann, 1977), smaller leaf size more compactness of cells have advantage in high temperature avoidance and fixation of more carbon dioxide per unit loss of water (Hoarse and Barrs, 1974). Increase in cuticular thickness reduces the epicuticular loss of water along with increase in reflectivity which prevents the leaf from reaching high temperature (Singh, 1985).

2.4 Physico-chemical characters and yield performance of ber genotypes under different conditions

Bal *et al.* (1985) reported that during ripening process in ber the TSS total sugars, reducing sugars in fruits showed an increasing trend, while the acid content decreased.

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Room Singh and Tomer (1988) reported that cultivars grown under semiarid tropics, Sanaur-2 produced biggest fruits followed by Umran and Sanaur-5. Umran showed the highest fruit weight (20.48g), TSS (20.67%) and pulp to stone ratio (19.58) with intermediate acidity.

Reddy *et al.* (1991) in their experiment recorded highest mean fruit and pulp weight for two consecutive years in Umran followed by Seb, but the mean pulp to seed ratio were found to be highest in Umran followed by Kaithli, however higher TSS values were recorded in Kaithli, Seb and Gola.

Singh and Jindal (1980) recorded maximum fruit weight in cultivar Umran at Gurgaon whereas Tiwari and Banafar (1995) found that Seb cultivar showed maximum pulp and total soluble solids followed by Banarasi Karaka.

Gupta (1977) screened the performance of 40 ber cultivars collected at Regional Fruits Research Station, Bahadurgarh. The physico-chemical characters for eight promising ber cultivars were reported, out of these Umran and Sanaur-2 were found suitable for commercial cultivation. The maximum pulp and TSS were recorded in variety Seb and Banarasi Karaka, where as maximum acidity, moisture and seed weight were recorded in Gola.

Yamadagni *et al.* (1985) evaluated the performance of 31 cultivars of ber for suitability under rainfed conditions with annual rainfall variation between 300-450mm and with a soil type of sandy loam having high infiltration (9 cm/hr). It was found that the ber cultivar Kaithli performed better when compared to other varieties with TSS 17.8, acidity 15.1% and fruit weight of 19.92 g followed by

Illaichi (TSS 23%, acidity 122% and fruit weight 6.67 gm) other cultivars like Nazuk, Villaiti, were also found suitable for cultivation under rainfed conditions.

2.4.2 Yielding pattern

Fisher and Wood (1979) advocated that it was the combination of the attributes that confer the adaptation, individually the trait appear to have relatively small effect in improving productivity, stress resistance and yield under stress conditions. However, they suggested stress resistance in a genotype was usually equated to maintaining higher yields over its contemporary susceptible genotypes.

Levitt (1980) reported that yield potential plus all the adaptive features of a genotype, whether they are related to a given stress resistance or not, influence the yield under stress.

However, the yielding pattern of ber shows a wide fluctuation from place to place and with variation in growing conditions (Pareek, 1983). Yamadagni *et al.* (1985) found that 15 years old cultivars Kaithli recorded the highest yield (123.15 kg/plant) followed by Banarasi Karaka (86.20 kg/plant). Umran (76.50 kg/plant), Chuhhara (75.62 kg/plant), Illaichi (75.0 kg/plant) and Dandan (60.30 kg/plant).

Reddy *et al.* (1991) reported that cultivar Gola and Seb of three years age recorded the highest mean fruit yield per tree followed by Mundia, Kaithli and Umran.

Chovatia *et al.* (1992) reported that *Zizyphus mauritiana* Cvs. under normal rainfall condition of 625 mm/year, Umran recorded the highest fruit yield

per plant (47.6 kg) followed by Gola (38.4 kg/plant) while the local cultivar Sukhavani produced a mean yield of only 3.45 kgs.

Gupta (1977) during screening of 40 cultivars in Bahadurgarh found that average yield per tree was highest in Umran (210 kg) whereas lowest was in Chuhhara (75.0 kg) while Sanaur-2 and Dandan recorded (200 kg/plant).

2.5 Crop improvement

Importance of ber is well established because of its wide adaptability for arid and semi arid regions. Hence, improvement in crop and popularisation need special attention. The success of breeding programme depends upon the genetic variability present in the available germplasm. A wide range of variability exists in ber in India.

2.5.1 Variability, heritability and genetic advance

Total variability in a metric trait can be divided into genotypes variability and environmental variability. The assessment of genetic variability is a pre-requisite for the improvement of the crop to the desired level.

The hereditary and environmental components of variation were discerned in the early part of this century by Johanson (1909), Nilson Ehle (1909) and East, 1916).

Genotypic variability comprises both additive and non additive variance. Heritability in broadsense was proposed by Hanson (1963) as the ratio of genetic variance to the total variance, while the narrow sense heritability has been defined as the ratio of additive variance to the total (Lush, 1949).

Though heritability value indicates the relative effectiveness of selection based on phenotypic expression of a trait, the genetic advance is more useful in predicting the actual value of selection as shown by Johanson *et al.* (1955).

Bisla and Daulta (1988) observed a wide range of variability for all characters in ber suggesting a substantial scope for improvement. He further reported that the genotypic coefficient of variation, heritability and genetic advance expressed as per cent mean were quite high for disease intensity and acidity.

Anonymous (1985) reported that 72 hybrids were evolved by using different parents like Umran, Kakrola, Gola, Illaichi, Mundia and others with an objective to evolve drought resistant superior quality high yielding cultivars.

Teaotia *et al.* (1974) stated Pewandi as the best cultivar for Uttar Pradesh, While Bajwa *et al.* (1972) recommended Umran Kaithli, Sanaur-2, Dandan and ZG2 for Punjab.

MATERIAL
AND METHODS

MATERIAL AND METHODS

The present investigation was carried out in the new orchard of the Division of Horticulture, Regional Research Station, Raichur Campus, University of Agricultural Sciences, Dharwad, during 1995-96. The materials used, techniques adopted and observations recorded during the course of investigation are furnished in this chapter.

3.1 Geographical location of the experimental site

Raichur is situated in Northern Dry zone (Region-I and Zone-II) of Karnataka between 16°15'N latitude and 77°21'E longitude at an altitude of 389 meters above mean sea level.

3.2 Climate

The climate of this region is characterised by harsh dry summers and cool winters with erratic and low rainfall pattern. The rainfall is mainly confined to the monsoon period from June to November with occasional showers in pre-monsoon months of April and May. The mean maximum temperature is more than 30°C throughout the year except in December. The relative humidity values are uniformly, high during the monsoon months from July to September and low during summer months from March to May respectively.

The total precipitation during the period of experimentation (May 1995 - June 1996) was 911.82 mm with mean monthly rainfall 75.98 mm. The mean maximum temperature varied from 30.6°C to 43.7°C and the mean minimum temperature ranged between 16.4°C and 25.9°C. The relative humidity at 7.00 am

varied from 52.0 per cent to 88.2 per cent while relative humidity at 2.00 pm ranged between 19.00 per cent and 61.4 per cent.

The meteorological observations recorded at Regional Research Station Raichur are Presented in Appendix-I.

3.3 Soil type of experimental site

The experiment was laid out on black sandy loam soil having a depth of 60-90 cms.

3.4 Details of experiment

The experimental plants were grown under rainfed conditions. The common root stock of *Zizyphus mauritiana* L. was raised in main field during August 1991 for budding of different cultivars. The plants selected for the experiment were budded *in situ* with different cultivars on 27th October, 1992. The experiment was laid out in a uniformly sloping plot.

3.4.1 The following cultivars were included for study

| | |
|--------------|--------------|
| A - Umran | G - Sanaur-6 |
| B - Kadaka | H - Rambore |
| C - Chuhhara | I - Manuki |
| D - Dandan | J - Mehroon |
| E - Sanaur-2 | K - Jogia |
| F - Illaichi | L - Seb |

3.4.2 Design and layout of the experiment

Twelve cultivars of ber were planted in randomised block design with three replications. Each cultivar was represented by four plants which were

planted with a spacing of 7 m x 7 m. The plan of the layout of this experiment is given in Fig. 1.

The experiment was designed to study the drought tolerance, yielding ability and association between various phenological and biochemical characters in different ber cultivars. The techniques followed and the observations recorded are described under the following broad headlines.

1. Phenological studies.
2. Biochemical characters of leaf.
3. Stomatal dimension and their distribution.
4. Yielding behaviour in different ber cultivars.
5. Estimation of variability, heritability and genetic advance.

3.5 Phenological studies

3.5.1 Area of leaf

Matured leaves from newly grown shoots were selected from all directions and area of leaf was determined by using planimeter. A mean value of 10 observations was taken to estimate area of leaf and expressed in square centimeters.

3.5.2 Plant height

Plant height was recorded in all the four plants of each cultivar in different replications to compute the differences of height among the cultivars. the height was measured from fixed point (20 cm above the ground) to the tip of the tallest growing branch.

3.5.3 Plant spread

The spread of the plant in all four directions (East-West and North-South) were recorded. Maximum spread in either of the directions was measured every time in each plant and the mean was determined. The values were expressed in centimeters.

3.5.4 Canopy volume

Volume of the tree was calculated as suggested by Wutscher and Shull (1972).

$$V = \frac{W_1 \times W_2 \times H}{4}$$

Where, V = canopy volume

W_1, W_2 = width in and between rows

H = canopy height

3.5.5 Length of the secondary branch

Two secondary branches arising from main branch were selected in each direction of the plant and length was recorded, the mean of all four plants was taken in each cultivar and was expressed in centimeters.

3.5.6 Number of tertiary branches

The number of tertiary branches were counted from base to apex of the secondary branch. Mean number was recorded in each cultivar.

3.5.7 Girth of the stem

The stem girth was determined by using measuring tape near the bud joint. Both girth of stock and scion were recorded in each plant of the cultivar and a mean was determined and was expressed in centimeters.

3.5.8 Relative water content (R.W.C.)

The R.W.C. was determined by a method suggested by Bars and Weatherly (1962). The leaves were sampled at fixed time of day. Fully opened physiologically functional (7-8th) leaf from top were collected. Fresh weight of the samples were recorded by detaching the petiole. The leaf samples were kept in water under diffused light for overnight to get turgidity condition. The turgid weight of sample was recorded, then after oven drying at 72°C for 48 hrs dry weight of samples was recorded. By using the equation given below the R.W.C. was estimated and expressed in per cent.

$$\text{R.W.C. (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

The sampling for R.W.C. estimation was done in the month of February (270 days after pruning).

3.5.10 Water saturation deficit

The water saturation deficit was estimated by subtracting the values of R.W.C. from 100.

3.5.11 Moisture content of leaf

The leaf samples were collected from fixed position and fresh weights were recorded, and then subjected for oven drying at 72°C for 48 hrs. The dry

weights were recorded and the moisture contents were determined by taking the differences, and the values were expressed on per cent fresh weight basis.

3.6 Biochemical studies of leaf

3.6.1 Leaf sampling for biochemical analysis

Matured leaves free from disease and pest infection were collected 5 g of sample was weighed and preserved in 80 per cent alcohol in glass vials. The leaf sampling was done at two stages of plant growth.

Stage I - 165 days after pruning (Before harvest)

Stage II - 315 days after pruning (After harvest)

The sample preserved was used to determine the different biochemical constituents in leaf at two stages except for estimation of chlorophyll where fresh sampling was done.

3.6.2 Estimation of carbohydrates

3.6.2.1 Reducing sugar

A known volume (2 ml) of alcoholic extract was clarified (Add 0.4 ml of saturated lead acetate + drop wise saturated solution of disodium hydrogen phosphate till complete precipitation and kept overnight). The supernatant was filtered and volume made upto 10 ml with 80 per cent alcohol. The clarified extract was used for estimation of reducing sugar as suggested by Nelson Somogyi's method (Nelson, 1944). The values of reducing sugar's obtained were expressed in mg g^{-1} on fresh weight basis.

3.6.2.2 Total sugars

The total sugars were estimated by adopting Nelson Somogyi's method (Nelson, 1944) and values were expressed in mg g^{-1} on fresh weight basis.

Non reducing sugars were estimated by subtracting reducing sugar values from total sugars.

3.6.2.3 Starch

Hundred mg remains of leaf sample after alcoholic extraction was subjected for digestion with perchloric acid (3.62 ml of 52 per cent perchloric acid and 1.5 ml of distilled water was added to residue, mixed thoroughly) and then subjected for centrifugation at 3000 rpm for a period of 10 minutes. The supernatant was collected in 25 ml volumetric flask. The extraction was repeated by increasing the centrifugation time to 20 minutes and finally 30 minutes respectively. Volume was made to 25 ml. Neutralised 1 ml of aliquat was taken and the reducing sugar concentration was estimated by Nelson Somogyi's method (Nelson, 1944). The reducing sugar concentration of the sample was calculated from a glucose standard graph and a conversion factor of 0.9 was used to convert the values to starch and expressed in mg g^{-1} of dried sample.

3.6.3 Estimation of total free amino acids

The total free amino acids were estimated by Ninhydrin method as suggested by Moore and Stein, (1948). The values obtained were expressed in mg of glycine/g of tissue.

3.6.4 Estimation of proline

The content of free-proline was estimated by procedure suggested by Bates *et al.* (1973) with modification. Aliquat of 1 ml alcoholic extract was diluted by adding 1 ml of distilled water, further it was added with 2 ml of acid ninhydrin

reagent (1.25 g of ninhydrin in a warm mixture of 30 ml glacial acetic acid and 20 ml of 6 m. Orthophosphoric acid preserved at 4°C). To this mixture 2 ml of glacial acetic acid was added then the content was kept on boiling water bath for one hour then the tubes were transferred to ice bath to terminate the reaction, further 4 ml of toluene was added, the contents were agitated vigorously by using test tube stirrer for 15-20 seconds. The chromophore containing toluene was separated and absorbance was recorded at 520 nm in spectrophotometer (Spectronic-20-D) by using a reagent blank. The proline content was determined from standard prepared with authentic proline and expressed in mg g^{-1} of fresh sample.

3.6.6 Estimation of chlorophyll content

The chlorophyll content was determined by using Arnon's Acetone method (Arnon, 1949). Fresh leaf sample of 0.25g were homogenised with pure acetone in pestle and mortar, supernatant was decanted and filtered through whatman No-42 filter paper. The extraction was repeated with acetone until the residue is decolourised, volume was made upto 25 ml with 80% acetone and per cent transmittance was recorded on spectrophotometer (Spectronic-20-D) at 663, 643 and 652 nm by using 80% acetone blank. The chlorophyll a 'b' and total chlorophyll were calculated and expressed in mg g^{-1} of fresh weight.

$$\text{Chlorophyll-a} = 12.7 (A_{663}) - 2.69 (A_{645}) \times \frac{V}{1000 \times w \times a}$$

$$\text{Chlorophyll-b} = 22.9 (A_{645}) - 4.68 (A_{663}) \times \frac{V}{1000 \times w \times a}$$

$$\text{Total Chlorophyll-A} = 20.2 (A_{645}) - 8.02 (A_{663}) \times \frac{V}{1000 \times w \times a}$$

Where,

V = Final volume

w = Fresh weight of sample (g)

a = Path length of light (1cm)

3.7 Stomatal studies

3.7.1 Leaf sampling

The leaf sampling was done in the morning hours. Matured leaves 7-8th from the tip were selected, leaf squares of 1 cm² size were cut from right middle half of the leaf for all the cultivars.

3.7.2 Microtoming Procedure

3.7.2.1 Fixation, dehydration, paraffin infiltration and embedding

The leaf samples were fixed in Cornoy's-I (Absolute alcohol and glacial acetic acid in the ratio of 3:1) for 24 hrs. The fixed material was given two washings with 70% alcohol. These material were subjected to gradual dehydration which was accomplished by placing the tissue (leaf segment) successively in increasing concentration of ethyl alcohol 70%, 95% and absolute alcohol when most of the moisture was expelled, the mixture of absolute alcohol and n-Butanol was introduced and the concentration of n-Butanol was gradually increased, (3:1, 1:1, 1:3) and finally immersed in pure n-butanol each change was performed after 90 min. Paraffin wax (58-60°C M.P) was used for infiltration and embedding. Small chips of paraffin wax were added successively to the medium of pure n-butanol containing dehydrated samples. The material was kept in an oven at 58-60°C. Impure paraffin wax was replaced after every 4 hrs with moulten paraffin wax till n-

butanol evaporated completely. After infiltration the material was embedded in paraffin wax employing paper boat technique (Jenson, 1962).

3.7.2.2 Sectioning and affixing of the sections

Paraffin infiltrated and embedded tissues were sectioned longitudinally on a Spencer Rotary microtome. The section of 10μ thickness were prepared and fixed on slides by using 1% gelatin adhesive (Jenson, 1962) (1g of gelatin in 100 ml boiling water + 0.1g of potassium dichromate). The slides were warmed over a warming plate maintained at 45°C to facilitate flattening and stretching of sections. Excessive adhesive was poured out and the slides were dried at room temperature in a dust free environment.

3.7.2.3 Staining and preparation of permanent slides

The sections were deparafinised by dipping in xylene then subjected for hydration by passing through a series of decreasing concentration of ethyl alcohol. The material was first dipped in xylene:Absolute alcohol (1:1) mixture for 3 min then shifted to absolute alcohol and a series of 90, 70 and 50 per cent alcohol concentration with 3 min dipping in each concentration. Then the sections were stained with 1 per cent saffranin, excess stain was washed in running water, then subjected for dehydration by passing through increasing concentration of alcohol of 50, 70, 90% and Ab. alcohol. Then sections were counter stained with fast green (saturated) excess stain was removed by dipping in ab. alcohol, finally the sections were cleared by dipping in xylene and mounted with cover slip by D.P.X. mountant.

3.7.3 Measurement of different features of leaf

3.7.3.1 Micrometry

The Research microscope used for observation was first used to determine the correction factor. The stage micrometer with each division having a known value of $0.01 \text{ mm} = 10\mu$ was mounted on stage. Then ocular micrometer was placed in eyepiece, adjustment was done to coincide the lines with stage micrometer. The number of lines between the coinciding lines were counted and by taking several observation in different position correction factor was determined and used for measurement.

3.7.4 Methods tried for observing Stomatal density

A method prescribed by Beakbane and Majumdar (1975) was tried to get the impressions of stomata, but it was not possible to get in leaf of scion plant as they had dense pubescence on lower surface.

An effort was done to get the impression by smearing Quickfix gel tube, but it also failed.

Further, to remove the pubescence a dilute as well as concentrated HCl, H_2SO_4 , HNO_3 acids were smeared, on lower surface of leaf and on observations it was found that the pubescence were burnt but the tissue got charred.

A sharp blade was also used to remove the pubescence, but the remnants of pubescence made impossible to get impression of stomata.

A method of getting impression by using cellophane tape was also tried unsuccessfully. Further an effort was made to observe directly under

microscope after removing green pigmentation by boiling in DMSO (5-10 min), this attempt was also failure.

Finally Microtoming was followed and fine section were obtained and several observations were recorded.

3.7.4.1 Stomatal and leaf observation

The anatomical observations recorded were stomata density, stomatal index, stomatal size and stomatal dimensions (diameter of stomata, length and breadth of guard cell, pore size, pore area, leaf thickness, thickness of upper and lower epidermis).

3.7.4.2 Stomatal density

Stomatal density was determined on abaxial leaf surface and expressed as number of stomata/mm². For root stock leaves which were devoid of pubescence, stomatal density was determined by method suggested by (Beakbane and Majumdar, 1975).

3.7.4.3 Stomatal index

Stomatal index was determined by using the equation.

$$\text{Stomatal index (\%)} = \frac{\text{Number of stomata per unit area}}{\text{Number of stomata per unit area} + \text{Number of epidermal cells per unit area}}$$

3.7.4.4 Stomatal dimensions

Stomatal dimensions like diameter of stomata, length and breadth of guard cell, pore size were recorded on ocular micrometer and by using correction factor for 10x X 60x (1 div. of ocular = 1.15 μ) and expressed in microns.

3.7.4.5 Thickness of section

The thickness of section was recorded with a magnification of 10x X 20x with a correction factor of (1 div of ocular = 5.016 μ) and expressed in microns of thickness.

3.7.4.6 Thickness of epidermis

Both upper and lower epidermis (including cuticle) were measured at 10x X 20x magnification.

3.8 Yield parameters

3.8.1 Total yield/plant

Yields of each plant in all the cultivars were recorded regularly for all 3 replications as the fruits attained maturity, the total yield/plant was calculated by summation of yields harvested at frequent interval.

3.8.2 Average fruit weight

A mean of 10 fruits was taken to determine average fruit weight and expressed in grams.

3.9 Biochemical characters of fruit

3.9.1 T.S.S.

The total soluble solids was determined by using hand refractometer at maturity and full ripe stage for all 12 cultivars and expressed in per cent.

3.9.2 Titrable acidity

Titration acid content was determined by titrating a suitable aliquot of the juice against 0.1 N standard sodium hydroxide. The contents were expressed in percentage of titration citric acid.

3.10.1 Pulp to stone ratio

Fresh weight of the fruits was recorded after extraction of stone, and after recording its weight the pulp weight was determined by;

pulp weight = fresh wt. of fruit - stone weight.

and the ratio of pulp to stone was expressed.

3.10 Statistical Analysis

The data were subjected to statistical analysis following the procedure of Panse and Sukhatme (1967) using computer by following the Fisher's analysis of variance (ANOVA) technique.

3.10.1 Estimation of genetic parameters

a. Components of variance

The components namely phenotypic (σ_p^2), and genotypic (σ_g^2) and environment (σ_e^2) variance were used for estimation of phenotypic and genotypic coefficients of variation as per the method suggested by Burton and Davane (1953).

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{(\sigma_p^2)}{X} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{(\sigma_g^2)}{X} \times 100$$

Where, X = Mean of population for the characters.

b. Heritability (Broadsense)

It was estimated by the equation suggested by Hanson (1963).

$$h^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where, σ_g^2 = genotypic variance

σ_p^2 = phenotypic variance

c. Genetic advance (GA)

The genetic gain was predicted using the formulae provided by Lush (1949) and Johanson *et al.* (1955).

$$GA = h^2 \sigma_p k$$

Where, h^2 = heritability

σ_p = phenotypic standard deviation

k = standardise selection differential and it is 2.06 at five per cent.

3.10.3 Correlation coefficients

The phenotypic correlation coefficient was determined among all possible combinations of the characters by taking appropriate variances and covariances. The calculations were under as per the formulae suggested by Al-Jibouri *et al.* (1958).

$$r_{g12} = \frac{p_{12}}{\sqrt{\sigma_{p11}^2 \times \sigma_{p22}^2}}$$

Where r_{p12} = Genotypic correlation coefficient between characters X_1 and X_2

p_{12} = Genotypic covariance between the characters X_1 and X_2

σ_{p11}^2 and σ_{p22}^2 = Genotypic variance of X_1 and X_2 respectively.

The significance of genotypic correlation coefficients was tested against 'r' values given by Fisher and Yates (1964).

EXPERIMENTAL
RESULTS

EXPERIMENTAL RESULTS

An experiment was conducted at Regional Research Station, Raichur, during May 1995 - June 1996 to study the performance under rainfed conditions of different ber cultivars and the results obtained from the experiment are presented under the following headings.

4.1 Phenological features of tree

The phenological results obtained on different ber cultivars are presented in Table 1.

4.1.1 Plant spread

The analysis of data on plant spread (EW-NS) indicated significant differences between the cultivars. Significantly highest plant spread was recorded in Rambore (325.0 cm) when compared to all other cultivars followed by Kadaka (308.67 cm), Jogia (307.08 cm), Manuki (306.25 cm) which were found statistically on par with each other. Significantly lowest plant spread was noted in Seb (251.67 cm). The cultivars Sanaur-2 and Dandan have recorded intermediate values.

4.1.2 Plant height

The data pertaining to plant height also showed *significant* differences among the cultivars with significantly highest in Rambore (461.67 cm) followed by Manuki (409.67 c). However, significant lowest plant height was recorded in Sanaur-2 (205.0 c).

Table 1. Phenological characters of different ber cultivars grown under rainfed condition

| Genotypes | Spread of plant (EW-NS cm) | Plant height (cm) | Canopy volume (cm ²) | Length of secondary branch (cm) | Number of teritary branches | Girth of the stem | |
|-----------|-------------------------------|----------------------|-------------------------------------|---------------------------------------|-----------------------------------|-------------------|------------|
| | | | | | | Stock (cm) | Scion (cm) |
| Umrans | 281.58 | 385.67 | 2741.6 | 317.67 | 19.66 | 31.33 | 34.67 |
| Kadaka | 308.67 | 286.67 | 2453.3 | 336.33 | 25.00 | 32.33 | 37.33 |
| Chuhhara | 300.25 | 321.00 | 3444.0 | 314.33 | 19.33 | 33.33 | 40.33 |
| Dandan | 297.33 | 267.67 | 2487.3 | 373.33 | 23.67 | 34.16 | 42.67 |
| Sanaur-2 | 289.25 | 205.00 | 1491.6 | 407.33 | 22.33 | 33.00 | 40.50 |
| Illaichi | 266.50 | 241.00 | 1744.0 | 280.00 | 24.67 | 29.33 | 34.50 |
| Sanaur-6 | 277.92 | 273.33 | 2871.3 | 337.33 | 23.33 | 60.33 | 67.33 |
| Rambore | 325.50 | 461.67 | 4847.0 | 333.33 | 21.00 | 44.83 | 49.33 |
| Manuki | 306.25 | 409.67 | 3685.3 | 348.67 | 22.33 | 40.16 | 47.67 |
| Mehroon | 298.42 | 168.33 | 1361.3 | 403.33 | 27.00 | 39.33 | 42.67 |
| Jogia | 307.08 | 385.33 | 3412.6 | 226.00 | 15.33 | 50.66 | 55.67 |
| Seb | 251.67 | 341.33 | 2146.0 | 293.67 | 19.67 | 43.00 | 47.00 |
| Cv(%) | 6.32 | 6.59 | 24.44 | 8.01 | 9.81 | 9.11 | 10.11 |
| SEm± | 10.57 | 11.88 | 384.4 | 15.31 | 1.243 | 2.067 | 2.624 |
| CD at 5% | 31.29 | 34.84 | 1127.29 | 44.89 | 3.645 | 6.063 | 7.695 |
| CD at 1% | 42.52 | 47.33 | 1531.84 | 61.00 | 4.953 | 8.238 | 10.46 |

4.1.3 Length of secondary branch

The data on the length of secondary branches depicts significant difference among different cultivars, with significantly longest secondary branch in Sanaur-2 (407.33 cm) followed by Mehroon (403.33 cm) and significantly lowest branch length was registered in Jogia (226.00 cm) (Table 1).

4.1.4 Number of tertiary branches

The number of tertiary branches also showed significant differences between the cultivars. The cultivar Mehroon (27.0) registered significantly highest number of tertiary branches followed by Kadaka (25.0), while Jogia recorded significantly lowest number of tertiary branches (15.33).

4.1.5 Canopy volume

The plant canopy volume was found significantly varying between the cultivars. Significantly superior canopy was resistered in Rambore (4847.0 sq cm) over all other cultivars. Whereas lowest canopy volume was found in Mehroon (1361.3 sq cm) followed by Sanaur-2 (1491.6 sq cm).

4.1.6 Girth of stock and scion

Significantly highest stem girth of both stock (60.33 cm) and scion (67.33 cm) was observed in Sanaur-6 followed by Jogia (50.66 cm and 55.67 cm) respectively. Significantly lowest measurements were recorded for both stock (29.33 cm) and scion (34.50 cm) in Illaichi cultivar (Table 1).

4.2 Parameters related to drought tolerance

4.2.1 Relative water content, water saturation deficit and moisture content

The data with reference to relative water content (R.W.C.), water saturation deficit (W.S.D) and Moisture content in leaf are presented in Table 2.

Table 2. Parameters related to water relations of leaf in different ber cultivars

| Genotypes | Relative water content (%) | Water saturation deficit (%) | Moisture content on fresh wt. basis | |
|------------------|----------------------------|------------------------------|-------------------------------------|------------------|
| | | | Stage-I | Stage-II |
| Umrans | 46.78 (53.13)* | 43.29 (46.87) | 49.43 (57.69) | 46.89 (53.33) |
| Kadaka | 51.47 (61.22) | 38.55 (38.78) | 47.67 (54.50) | 47.24 (53.90) |
| Chuhhara | 49.82 (58.28) | 40.21 (41.72) | 49.02 (56.97) | 47.75 (54.78) |
| Dandan | 50.72 (59.91) | 39.28 (40.09) | 46.26 (52.21) | 43.68 (47.67) |
| Sanaur-2 | 50.54 (59.62) | 39.43 (40.38) | 44.54 (49.20) | 42.71 (46.05) |
| Illaichi | 53.33 (64.67) | 39.76 (35.33) | 48.16 (55.48) | 45.17 (50.31) |
| Sanaur-6 | 47.29 (53.91) | 39.42 (46.16) | 46.55 (52.75) | 44.43 (49.03) |
| Rambore | 51.96 (62.04) | 38.02 (37.95) | 47.52 (54.42) | 46.89 (53.28) |
| Manuki | 51.12 (60.58) | 38.87 (39.42) | 49.66 (58.09) | 47.87 (55.00) |
| Mehroon | 45.92 (51.62) | 44.07 (48.38) | 47.47 (54.27) | 46.49 (52.64) |
| Jogia | 54.61 (66.12) | 35.36 (33.88) | 47.98 (55.17) | 47.47 (54.35) |
| Seb | 48.37 (55.88) | 41.63 (44.12) | 46.66 (52.91) | 46.15 (51.97) |
| Cv(%) | 6.79 | 9.49 | 19.52 | 17.59 |
| SEm _t | 1.938 | 2.182 | 5.24 | 5.172 |
| CD at 5% | NS | NS | NS | NS |
| CD at 1% | NS | NS | NS | NS |

* Figures in parenthesis indicate original percentage

The persual of the data showed that the R.W.C., W.S.D. and moisture content in leaf were non significantly differing among the cultivars. However, the moisture content showed a reduction from Stage-I to Stage-II in leaf of all the cultivars under study.

4.2.2 Leaf epidermal and stomatal observations

The data pertaining to evaluation of ber cultivars for leaf area, thickness of leaf, thickness of epidermis, stomatal index and stomatal frequency are presented in Table 3.

4.2.2.1 Area of leaf

The data related to area of leaf recorded at two stages of plant growth, showed significant difference among the cultivars during both the stages. Significantly highest area of leaf was exhibited in cultivar Umran in both stages (Stage-I, 44.22 and Stage-II, 38.64 sq cm) followed by seb for Stage-I and Manuki for Stage-II, respectively. Significantly lowest area of leaf was recorded in Sanaur-2 (21.51 sq cm and 21.16 sq cm) at both stages.

4.2.2.2 Leaf thickness

Significantly maximum leaf thickness was found in Umran (Plate 1) followed by Kadaka (0.284 mm) and Sanaur-2 (0.279 mm), whereas a significant minimum leaf thickness was noticed in Mehroon (0.148 mm).

4.2.2.3 Epidermal thickness

The thickness of upper epidermis (includes epidermis and cuticle) and the lower epidermis were found significantly differing among the cultivars.

Table 3. Area of leaf, leaf thickness, epidermal thickness and stomatal distribution of different ber cultivars

| Genotypes | Area of leaf Stage-I (cm ²) | Area of leaf Stage-II | Leaf thickness in (mm) | Thickness of upper epidermis (microns) | Thickness of lower epidermis (microns) | Stomatal index | Stomatal frequency per (mm ²) |
|-----------|---|-----------------------|------------------------|--|--|----------------|---|
| Umran | 44.22 | 38.64 | 0.332 | 22.32 | 15.22 | 16.99 | 206.33 |
| Kadaka | 39.00 | 35.66 | 0.284 | 19.23 | 14.21 | 22.71 | 402.67 |
| Chuhhara | 33.95 | 32.44 | 0.244 | 19.06 | 12.71 | 22.36 | 397.67 |
| Dandari | 27.67 | 27.03 | 0.184 | — | — | — | — |
| Sanaur-2 | 21.51 | 21.16 | 0.279 | 19.72 | 15.04 | 44.49 | 1304.00 |
| Illalachi | 29.78 | 31.12 | 0.222 | 15.21 | 8.20 | 28.68 | 1258.00 |
| Sanaur-6 | 28.63 | 28.11 | 0.205 | 16.72 | 12.04 | 27.88 | 614.67 |
| Rambore | 34.76 | 36.44 | 0.155 | 17.72 | 13.71 | 20.57 | 347.67 |
| Manukt | 40.93 | 31.85 | 0.154 | 21.40 | 10.87 | 16.50 | 303.33 |
| Mehroon | 28.32 | 27.18 | 0.148 | 13.96 | 11.82 | 18.69 | 645.33 |
| Jogia | 28.12 | 28.85 | 0.268 | 13.54 | 12.87 | 15.15 | 114.67 |
| Seb | 40.43 | 38.53 | 0.243 | 19.81 | 13.37 | 16.10 | 178.67 |
| Cv(%) | 13.07 | 5.23 | 4.81 | 5.56 | 4.31 | 6.60 | 28.46 |
| SEm± | 2.499 | 0.948 | 0.006 | 0.571 | 0.331 | 0.792 | 80.54 |
| CD at 5% | 7.328 | 2.780 | 0.019 | 1.675 | 0.972 | 2.311 | 236.18 |
| CD at 1% | 9.96 | 3.78 | 0.025 | 2.276 | 1.321 | 3.132 | 320.94 |

Magnification (10x X 20x)

— Indicates non availability of figures due to procedural problem

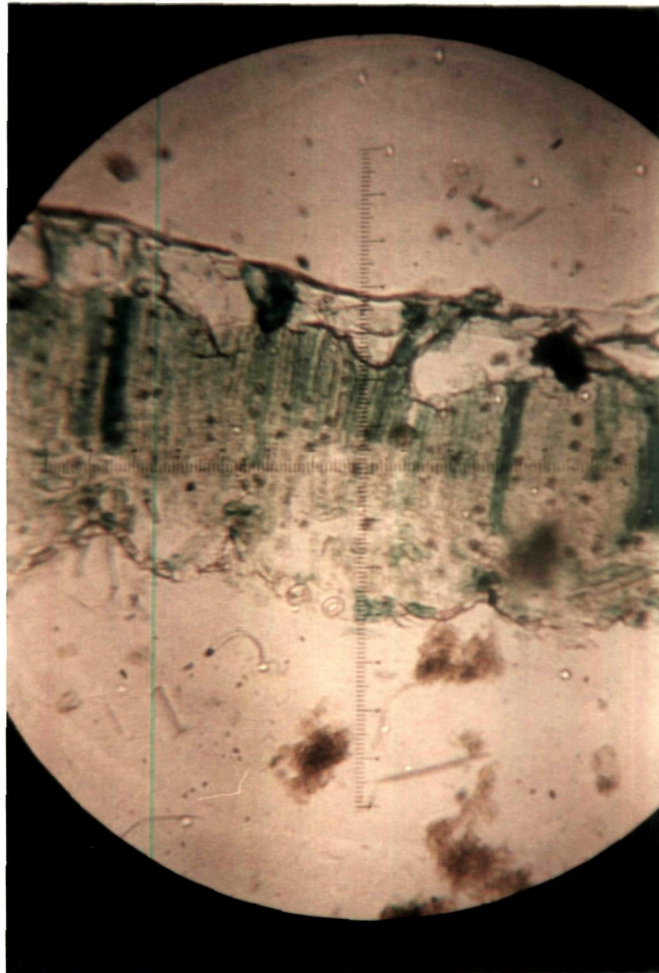


Plate 1.

Microphotograph showing leaf thickness in Umran cultivar (10x X 20x)

Significantly highest thickness of upper epidermis was registered in Umran (22.32 μ) followed by Manuki (21.40 μ) which were statistically on par with each other. Significantly lowest measurements were recorded in Jogia (13.54 μ) followed by Mehroon (13.96 μ), root stock (14.96 μ) which were found statistically on par with each another.

Significantly superior value of lower epidermal thickness was registered in root stock (19.72 μ) over all other cultivars under study. However, significantly lowest value was recorded in Illaichi (8.20 μ) followed by Manuki (10.87 μ).

4.2.2.4 Stomatal index

The analysis of data on stomatal index showed significant differences among the cultivars. Sanaur-2 recorded significantly superior value (44.49%) when compared to all other cultivars. However, significantly lowest per cent of stomatal index was found in Jogia (15.15%) followed by Seb (16.10%), Manuki (16.50%) and Umran (16.99%), which were statistically on par with each other.

4.2.2.5 Stomatal frequency

The data pertaining to stomatal frequency were found significantly differing among the cultivars. Sanaur-2 (1304 stomata/mm²) was found superior over all other cultivars (Plate 2). However, Illaichi (1258 stomata/mm²) (Plate 3) was found on par with Sanaur-2. Significantly minimum stomatal frequency was found in Jogia (114.67 stomata/mm²) followed by Seb (178.67 stomata/mm²) which was on par with value of Jogia.

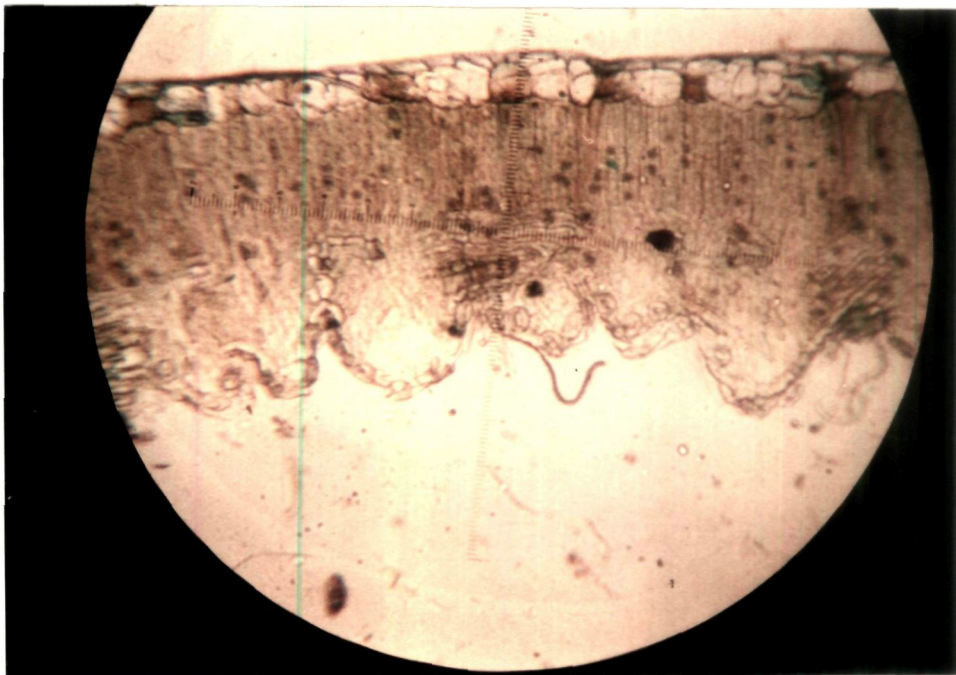


Plate 2. Microphotograph showing high stomatal frequency in Sanaur-2 cultivar (10x X 20x)

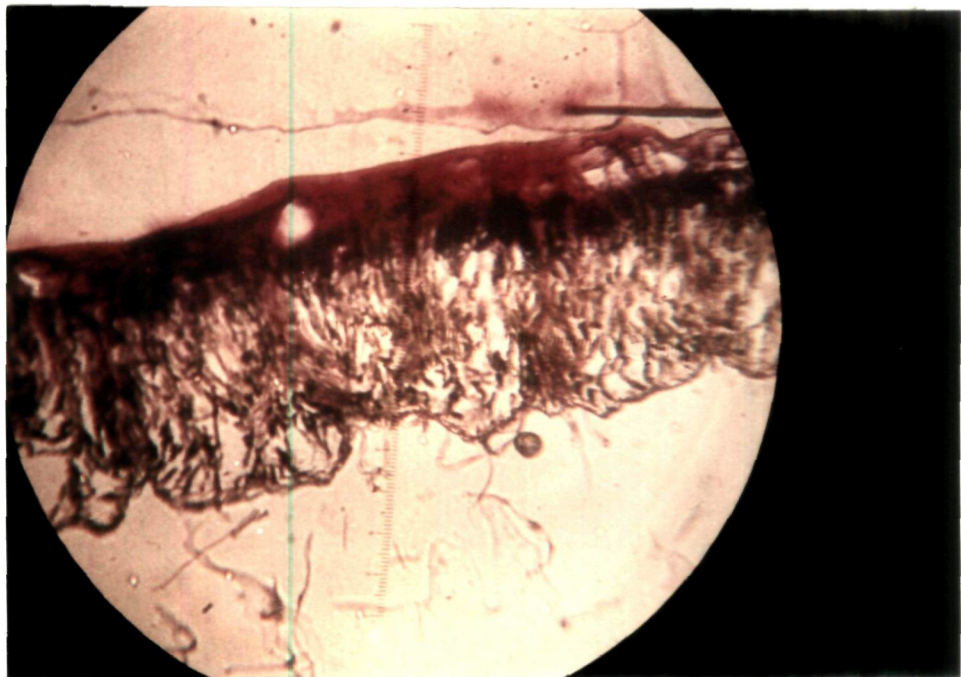


Plate 3. Microphotograph of transverse section of Illaichi cultivar (10x X 20x)

Table 4. Diameter of stomata, length and breadth of guard cell, stomatal size and pore size in different cultivars

| Treatments | Diameter of stomata (microns) | Length of Guard cell (microns) | Breadth of Guard cell (microns) | Stomata size (microns) ² | Length of pore opening (microns) | Breadth of pore opening (microns) | Pore size (microns) |
|------------|-------------------------------|--------------------------------|---------------------------------|-------------------------------------|----------------------------------|-----------------------------------|---------------------|
| Umran | 17.67 | 19.95 | 6.84 | 352.77 | 9.97 | 3.42 | 34.10 |
| Kadaka | 17.67 | 17.67 | 5.70 | 311.79 | 6.27 | 5.13 | 32.16 |
| Chuhhara | 16.50 | 18.24 | 6.84 | 300.56 | 9.12 | 1.81 | 18.03 |
| Dandan | — | — | — | — | — | — | — |
| Sanaur-2 | 18.80 | 19.38 | 9.12 | 365.21 | 7.98 | 3.99 | 32.16 |
| Illaichi | — | — | — | — | — | — | — |
| Sanaur-6 | 17.66 | 18.81 | 6.84 | 332.28 | 7.41 | 4.27 | 31.65 |
| Rambore | 12.54 | 19.38 | 3.42 | 242.69 | 11.40 | 2.56 | 29.22 |
| Manuki | 13.11 | 15.39 | 4.56 | 202.73 | 9.12 | 1.99 | 18.49 |
| Mehroon | 13.11 | 19.38 | 4.56 | 253.42 | 12.54 | 3.42 | 42.88 |
| Jogia | 15.96 | 18.24 | 5.41 | 290.46 | 10.83 | 2.28 | 24.81 |
| Seb | 16.53 | 18.24 | 7.41 | 300.21 | 5.70 | 3.13 | 18.02 |
| Cv (%) | 7.65 | 7.49 | 13.45 | 9.65 | 12.27 | 18.11 | 21.87 |
| SEM± | 0.716 | 0.802 | 0.467 | 16.80 | 0.644 | 0.380 | 4.116 |
| CD at 5% | 2.113 | 2.367 | 1.377 | 49.56 | 1.900 | 1.122 | 12.14 |
| CD at 1% | 2.883 | NS | 1.879 | 67.67 | 2.593 | 1.530 | 16.56 |

Magnification (10x X 60x)

— indicates non availability of figures due to procedural problem

4.2.3 Stomatal dimensions

The data on stomatal dimensions, stomatal size and pore size in different ber cultivars are presented in Table 4 and also shown in Plate 4 and 5.

4.2.3.1 Diameter of stomata

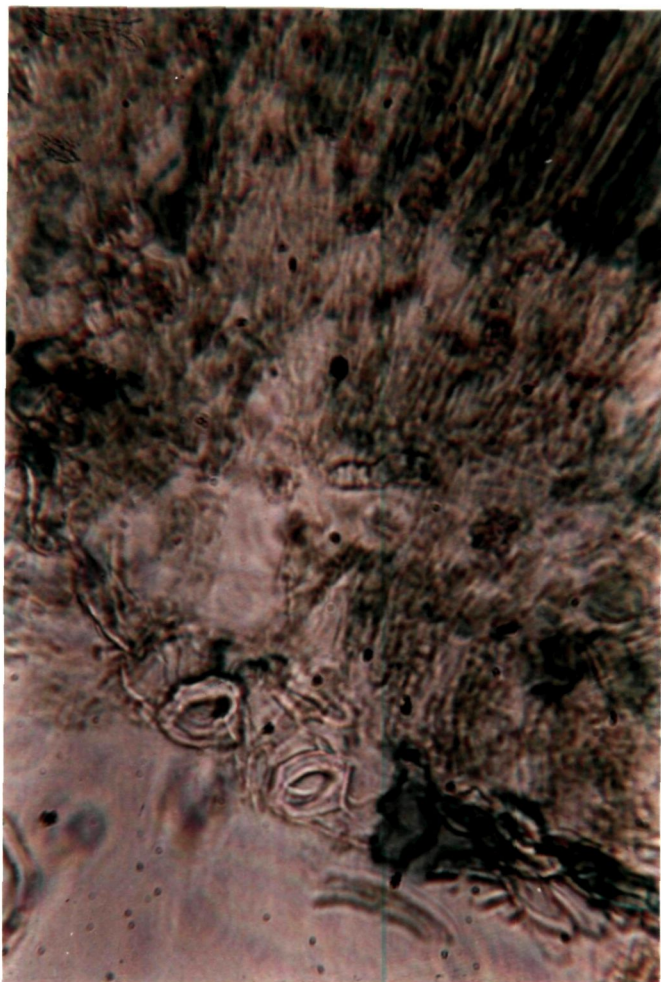
The data pertaining to diameter of stomata was found significantly differing between the cultivars. Significantly highest measurements of stomatal diameter was recorded in Sanaur-2 (18.80 μ) followed by Umran (17.67 μ). Kadaka (17.67 μ), Sanaur-6 (17.66 μ), Seb (16.53 μ) and Chuhhara (16.50 μ) which were found statically on par with each other. However, a significantly low stomatal diameter was observed in Rambore (12.54 μ) followed by Manuki (13.11 μ) and Mehroon (13.11 μ), which were statistically on par with each other.

4.2.3.2 Length of guard cell

The observation recorded on length of guard cell in different ber cultivars depicted statistically more of uniformity. However, numerically highest measurement of guard cell length was found in Umran (19.95 μ) followed by Sanaur-2 (19.38 μ). Lowest guard cell length was recorded in Manuki (15.39 μ).

4.2.3.3 Breadth of guard cell

The data pertaining to measurement of breadth of guard cell, showed significant difference among the cultivars under study. Significantly superior value was recorded in Sanaur-2 (9.12 μ) followed by Seb (7.41 μ). However, significantly lowest measurements of guard cell breadth was found in Rambore (3.42 μ) which was found on par with the values of Manuki and Mehroon, respectively (Table 4).



Plates 4&5. Microphotograph showing stomatal features (10x X 100x)

4.2.3.4 Size of stomatal

The stomatal size measurement were found significantly differing between the cultivars of ber. Significantly superior value of stomatal size was found in Sanaur-2 ($365.21 \mu^2$) over all other cultivars followed by Umran, Sanaur-6 and Kadaka which were found on par with Sanaur-2. Significantly low values were measured in Manuki ($202.73 \mu^2$).

4.2.3.5 Length of pore opening

The data pertaining to pore length revealed significant differences among the cultivars of ber. Maximum length of stomatal pore was recorded in Mehroon (12.54μ) followed by Rambore (11.40μ) and Jogia (10.83μ) which were statistically on par with each other. Significantly lowest pore length was recorded in Seb (5.70μ).

4.2.3.6 Breadth of pore opening

The root stock plant showed significantly highest (7.98μ) breadth of pore opening when compared to all other cultivars under study. However, significantly lowest breadth of pore was recorded in Chuhhara (1.80μ) followed by Manuki which were on par with each other.

4.2.3.7 Size of stomatal pore

The maximum pore size was observed in Mehroon ($42.88 \mu^2$) followed by Umran (34.10μ), minimum stomatal pore size was noticed in seb ($18.02 \mu^2$) followed by Chuhhara ($18.03 \mu^2$) and Manuki ($18.49 \mu^2$), respectively (Table 4).

Table 5. Content of chlorophyll in leaves of ber cultivars at two stages

| Genotypes | Chlorophyll-A (mg g^{-1}) | | Chlorophyll-B (mg g^{-1}) | | Total chlorophyll (mg g^{-1}) | |
|-----------|--------------------------------------|----------|--------------------------------------|----------|--|----------|
| | Stage-I | Stage-II | Stage-I | Stage-II | Stage-I | Stage-II |
| | Umran | 0.593 | 0.533 | 0.412 | 0.317 | 1.007 |
| Kadaka | 0.602 | 0.593 | 0.430 | 0.371 | 1.032 | 0.964 |
| Chuhhara | 0.561 | 0.440 | 0.372 | 0.302 | 0.933 | 0.742 |
| Dandan | 0.758 | 0.650 | 0.465 | 0.446 | 1.222 | 1.057 |
| Sanaur-2 | 0.675 | 0.584 | 0.419 | 0.361 | 1.095 | 0.945 |
| Illaiichi | 0.753 | 0.643 | 0.422 | 0.344 | 1.169 | 0.987 |
| Sanaur-6 | 0.707 | 0.642 | 0.400 | 0.389 | 1.107 | 0.982 |
| Rambore | 0.535 | 0.506 | 0.305 | 0.290 | 0.811 | 0.785 |
| Manuki | 0.644 | 0.517 | 0.430 | 0.412 | 1.074 | 0.930 |
| Mehroon | 0.528 | 0.478 | 0.332 | 0.302 | 0.862 | 0.780 |
| Jogia | 0.240 | 0.351 | 0.305 | 0.187 | 0.656 | 0.611 |
| Seb | 0.335 | 0.308 | 0.164 | 0.114 | 0.472 | 0.449 |
| Cv(%) | 5.37 | 2.02 | 13.91 | 12.97 | 6.45 | 6.86 |
| SEm± | 0.018 | 0.015 | 0.030 | 0.024 | 0.035 | 0.033 |
| CD at 5% | 0.053 | 0.045 | 0.087 | 0.070 | 0.104 | 0.098 |
| CD at 1% | 0.072 | 0.061 | 0.119 | 0.095 | 0.141 | 0.133 |

4.3 Biochemical changes in leaf

4.3.1 Chlorophyll pigment changes

Table 5, depicts the tabulated values of chlorophyll-a, chlorophyll-b and total chlorophyll during two stages of plant growth. The results revealed that there was a reduction in the levels of a, b and total chlorophyll from Stage-I to Stage-II. Significant differences among the cultivars in both the stages for a, b and total chlorophyll were existed. Further, it was observed that the cultivars Dandan registered significantly highest values of chlorophyll-a (0.758 mg g^{-1} and 0.650 mg g^{-1}), chlorophyll-b (0.465 mg g^{-1} and 0.446 mg g^{-1}) and total chlorophyll (1.222 mg g^{-1} and 1.057 mg g^{-1}) at first and second stage respectively. However, significantly lowest values of chlorophyll-a (0.335 mg g^{-1} and 0.308 mg g^{-1}), chlorophyll-b (0.164 mg g^{-1} and 0.114 mg g^{-1}) during first and second stage were registered in Seb cultivar .

The cultivar Sanaur-2 registered moderate to high values of chlorophyll-a (0.675 mg g^{-1} and 0.584 mg g^{-1}), chlorophyll-b (0.419 mg g^{-1} and 0.316 mg g^{-1}) and total chlorophyll (1.095 mg g^{-1} and 0.945 mg g^{-1}) during first and second stage of plant growth.

4.3.2 Total free amino acids

The total free amino acid concentration in leaf of two different stages of plant growth are presented in Table 6.

The persual of data pertaining to total free amino acids in Stage-I revealed significantly highest concentration in Seb (0.990 mg g^{-1}) followed by Kadaka (0.969 mg g^{-1}) which were on par with each other. The lowest values were

Table 6. Total amino acid content in leaf of different ber cultivars

| Genotypes | Amino acids (mg g ⁻¹) | | Proline (mg g ⁻¹) | |
|-----------|-----------------------------------|----------|-------------------------------|----------|
| | Stage-I | Stage-II | Stage-I | Stage-II |
| Umrán | 0.757 | 1.006 | 0.416 | 0.469 |
| Kadaka | 0.969 | 1.064 | 0.313 | 0.519 |
| Chuhhara | 0.707 | 0.938 | 0.283 | 0.371 |
| Dandan | 0.843 | 1.015 | 0.240 | 0.402 |
| Sanaur-2 | 0.828 | 0.979 | 0.286 | 0.423 |
| Illaichi | 0.737 | 1.013 | 0.319 | 0.483 |
| Sanaur-6 | 0.916 | 0.969 | 0.286 | 0.557 |
| Rambore | 0.834 | 0.876 | 0.176 | 0.452 |
| Manuki | 0.973 | 1.012 | 0.285 | 0.356 |
| Mehroon | 0.889 | 0.993 | 0.266 | 0.358 |
| Jogia | 0.828 | 0.873 | 0.202 | 0.270 |
| Seb | 0.990 | 1.057 | 0.441 | 0.510 |
| Cv(%) | 6.18 | 2.42 | 6.20 | 8.84 |
| SEm± | 0.03 | 0.014 | 0.010 | 0.022 |
| CD at 5% | 0.090 | 0.040 | 0.031 | 0.065 |
| CD at 1% | 0.112 | 0.055 | 0.042 | 0.088 |

found in Chuhhara (0.707 mg g^{-1}), while in second stage significantly highest value of total free amino acid was noticed in Kadaka (1.064 mg g^{-1}) followed by Seb (1.057 mg g^{-1}) which were on par with each other. The lowest concentration was noticed in Jogia. However, Sanaur-2 and Dandan registered moderate values.

4.3.3 Proline accumulation

The study of data (Table 6) on proline accumulation in leaf revealed that in both the stages of plant growth the cultivars showed significant differences between them. In Stage-I the cultivar seb (0.442 mg g^{-1}) showed significantly highest accumulation of proline followed by Umran (0.417 mg g^{-1}) which were statistically on par with each other. However, significantly lowest proline accumulation was observed in Rambore (0.176 mg g^{-1}) followed by Jogia (0.202 mg g^{-1}) which was on par with Rambore. In second stage Sanaur-6 recorded highest proline accumulation (0.557 mg g^{-1}) followed by Seb, lowest proline accumulation was recorded in Jogia (0.270 mg g^{-1}).

4.3.4 Carbohydrate changes in leaf

The data pertaining to carbohydrate changes in leaf during first and second stage of plant growth are presented in Table 7.

The results indicated that there was an increase in the content of total, reducing and non reducing sugar from Stage-I to Stage-II while a decreasing trend was noticed in starch content.

4.3.4.1 Reducing sugar

The data analysed for reducing sugars at both stages showed significant difference between the cultivars. The data of Stage-I indicated that

Table 7. Leaf carbohydrate content of different ber cultivars

| Genotypes | Reducing sugar (mg/g) | | Non-reducing sugar (mg/g) | | Total sugar (mg/g) | | Starch (mg/g) | |
|------------------|-----------------------|----------|---------------------------|----------|--------------------|----------|---------------|----------|
| | Stage-I | Stage-II | Stage-I | Stage-II | Stage-I | Stage-II | Stage-I | Stage-II |
| | Umrani | 4.14 | 5.21 | 6.20 | 7.18 | 10.34 | 12.39 | 29.25 |
| Kadaka | 4.41 | 4.91 | 6.21 | 12.28 | 10.73 | 17.20 | 40.12 | 29.62 |
| Chuhhara | 2.19 | 3.57 | 2.04 | 6.86 | 4.23 | 10.43 | 34.28 | 28.29 |
| Dandan | 3.31 | 4.34 | 10.86 | 15.54 | 14.17 | 19.88 | 33.42 | 26.72 |
| Sanaur-2 | 3.92 | 4.85 | 6.20 | 19.16 | 10.13 | 24.01 | 24.41 | 19.68 |
| Illaichi | 4.50 | 5.47 | 9.20 | 12.95 | 13.70 | 18.42 | 31.88 | 27.00 |
| Sanaur-6 | 4.64 | 5.14 | 7.85 | 12.07 | 12.49 | 17.22 | 28.73 | 23.24 |
| Rambore | 3.42 | 4.42 | 7.45 | 12.29 | 10.87 | 16.71 | 25.13 | 24.23 |
| Manuki | 2.79 | 5.17 | 4.75 | 9.03 | 7.54 | 14.20 | 28.13 | 19.00 |
| Mehroon | 3.98 | 4.74 | 6.23 | 8.06 | 10.21 | 12.80 | 32.28 | 25.68 |
| Jogia | 2.17 | 4.11 | 3.13 | 5.85 | 5.27 | 9.96 | 36.18 | 24.56 |
| Seb | 3.87 | 4.87 | 6.39 | 8.98 | 10.26 | 13.88 | 44.10 | 35.85 |
| Cv (%) | 5.58 | 5.30 | 12.89 | 18.87 | 7.92 | 12.85 | 8.40 | 11.01 |
| SE _{mi} | 0.116 | 0.145 | 0.475 | 1.092 | 0.457 | 1.095 | 1.567 | 1.640 |
| CD at 5% | 0.341 | 0.425 | 1.392 | 3.202 | 1.340 | 3.210 | 4.595 | 4.808 |
| CD at 1% | 0.463 | 0.577 | 1.892 | 4.351 | 1.821 | 4.362 | 6.244 | 6.534 |

significantly highest reducing sugar level was found in Sanaur-6 (4.637 mg g^{-1}) followed by Illaichi (4.50 mg g^{-1}) which were statistically on par with each other. The lowest reducing sugars were recorded in Jogia (2.17 mg g^{-1}) followed Chuhhara (2.19 mg g^{-1}) which were statistically on par with each other. The cultivars Sanaur-2 and Dandan were found having intermediate values.

In Stage-II highest reducing sugar concentration was registered in Illaichi (5.47 mg g^{-1}) followed by Umran (5.21 mg g^{-1}), Manuki (5.17 mg g^{-1}) and Sanaur-6 (5.14 mg g^{-1}) which were found to be on par with each other. The lowest reducing sugar accumulation was observed in Chuhhara (3.57 mg g^{-1}). The intermediate values were recorded in Sanaur-2 and Dandan.

4.3.4.2 Non reducing sugar

The analysis of data in table 7 showed significant differences between the treatments during both stages. The data pertaining to Stage-I indicates a significantly higher values of non reducing sugar in Dandan (10.86 mg g^{-1}), whereas Jogia (3.13 mg g^{-1}) recorded significantly lowest value. In Stage-II significantly highest non reducing sugar was recorded in Sanaur-2 (19.16 mg g^{-1}) which was almost three folds to that of Stage-I. The lowest concentration was found in Jogia (5.85 mg g^{-1}) which was found on par with Chuhhara (6.86 mg g^{-1}), Umran (7.18 mg g^{-1}) and Mehroon (8.06 mg g^{-1}).

4.3.4.3 Total sugar

The persual of data exemplified a significant difference among the different cultivars. Significantly highest total sugars were registered in Dandan (14.17 mg g^{-1}) followed by Illaichi (13.70 mg g^{-1}) which was statistically on par with Dandan. Jogia (5.207 mg g^{-1}), recorded significantly lowest total sugars. The

Stage-II data reveals that highest total sugar concentration was noticed in Sanaur-2 whereas the lowest concentration was recorded in Jogia (9.96 mg g^{-1}) followed by Chuhhara (10.43 mg g^{-1}) which was statistically on par with each other.

4.3.4.4 Starch

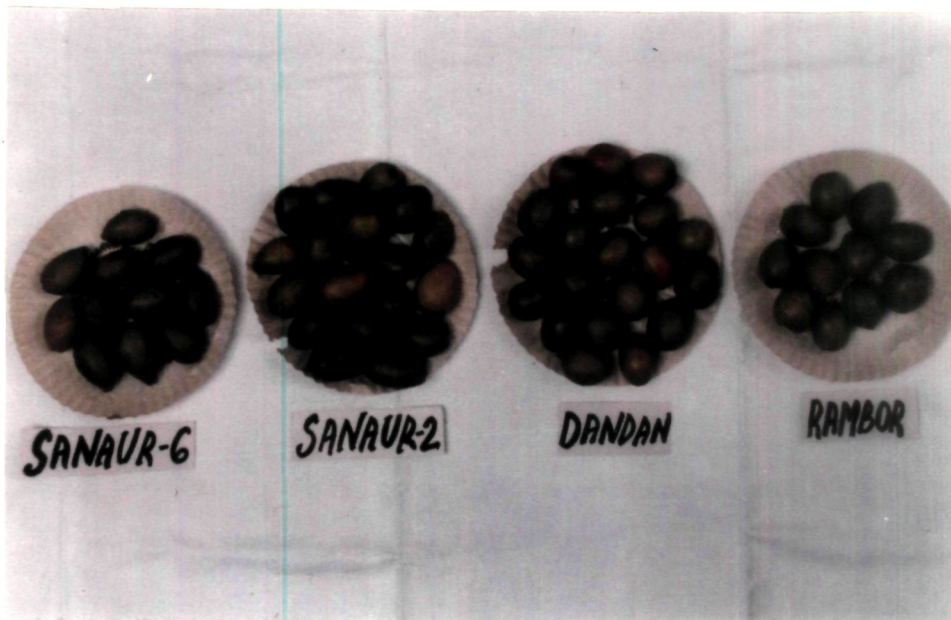
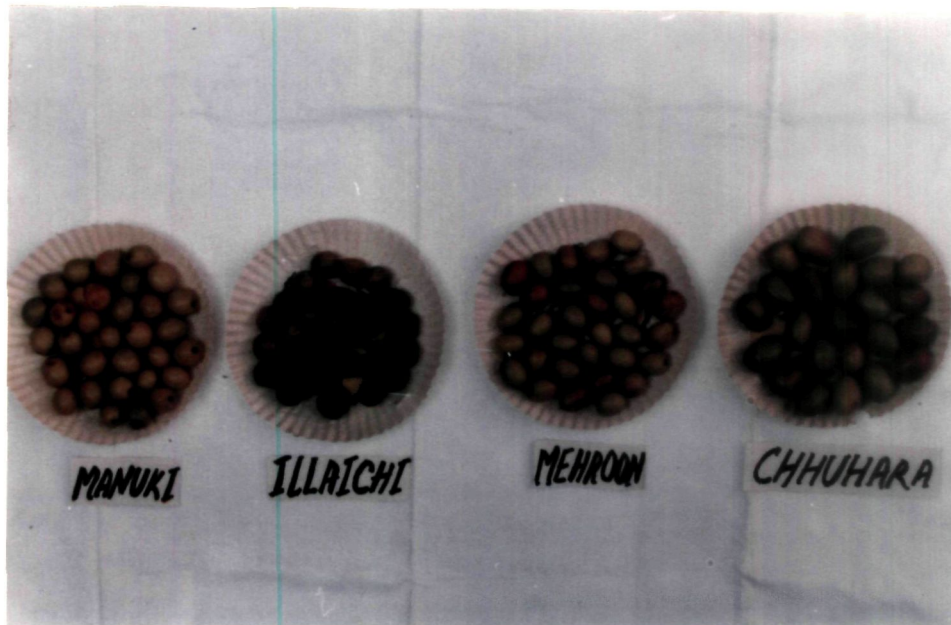
The analysis of data on starch at both stages reveal significant differences between the cultivars under study. Seb (44.10 mg g^{-1}) registered highest starch content in Stage-I followed by Kadaka (40.12 mg g^{-1}) which were on par with each other. The lowest values were recorded in Sanaur-2 (24.41 mg g^{-1}). In Stage-II significantly maximum starch concentration was found in Seb (35.85 mg g^{-1}) followed by Umran (29.62 mg g^{-1}) and significantly lowest value in Manuki (19.0 mg g^{-1}) followed by Sanaur-2 (19.68 mg g^{-1}) which were found statistically on par with each other.

4.4 Physico-chemical studies in fruits

The data pertaining to different physico-chemical characters of fruits are presented in Table 9 and Plates 6, 7, 8 depicts the general appearance of fruits of different cultivars at maturity.

4.4.1 Fruit weight

The statistical analysis of data on fruit weight was found significantly differing between all the cultivars at both maturity and ripe stage. There was a reduction in weight of fruit from maturity to ripe stage. Significantly highest fruit weight was recorded in Umran at both maturity (23.53 g) and ripe stage (16.71 g). Significantly lowest value at maturity was found in Manuki (4.15 g) while Illaichi (2.53 g) recorded lowest weight at ripe stage which was followed by Manuki and Mehroon (3.01 g) which were statistically on par with each other.



Plates 6,7&8. General fruit appearance of different ber cultivars at maturity

Table 9. Physico-chemical characters of fruit in different ber cultivars grown under rainfed conditions

| Genotypes | Fruit weight (g) | | Pulp to stone ratio | | Total soluble solids (%) | | Per cent acidity | |
|------------------|------------------|-----------|---------------------|-----------|--------------------------|-----------|------------------|-----------|
| | At Maturity | Full ripe | At Maturity | Full ripe | At Maturity | Full ripe | At Maturity | Full ripe |
| Umrān | 23.53 | 16.71 | 15.57 | 10.62 | 14.00 | 16.83 | 0.868 | 0.341 |
| Kadaka | 17.27 | 13.09 | 11.82 | 8.74 | 16.87 | 18.67 | 0.491 | 0.277 |
| Chuhhara | 7.03 | 5.16 | 10.32 | 7.43 | 15.33 | 18.67 | 0.579 | 0.332 |
| Dandan | 15.55 | 11.12 | 14.82 | 9.70 | 14.67 | 18.83 | 0.363 | 0.258 |
| Sanaur-2 | 13.17 | 6.72 | 15.76 | 10.53 | 13.17 | 14.83 | 0.725 | 0.469 |
| Illaichi | 5.54 | 2.53 | 13.84 | 5.79 | 16.50 | 19.17 | 0.395 | 0.277 |
| Sanaur-6 | 14.93 | 9.69 | 11.67 | 7.18 | 12.33 | 16.83 | 0.640 | 0.327 |
| Rambore | 13.12 | 9.53 | 8.60 | 5.96 | 14.67 | 18.17 | 0.481 | 0.277 |
| Manuki | 4.15 | 3.01 | 4.39 | 3.06 | 15.67 | 18.00 | 0.523 | 0.405 |
| Mehroon | 4.21 | 3.01 | 5.22 | 3.42 | 17.00 | 18.33 | 0.747 | 0.363 |
| Jogia | 18.65 | 12.00 | 14.43 | 9.45 | 15.83 | 17.17 | 0.577 | 0.448 |
| Seb | 16.45 | 12.00 | 7.21 | 4.83 | 15.67 | 17.50 | 0.491 | 0.384 |
| Cv (%) | 6.70 | 14.16 | 9.33 | 14.81 | 4.38 | 2.56 | 11.13 | 15.71 |
| SEm _t | 0.495 | 0.713 | 0.599 | 0.618 | 0.383 | 0.257 | 0.037 | 0.031 |
| CD at 5% | 1.453 | 2.092 | 1.758 | 1.813 | 1.123 | 0.755 | 0.108 | 0.091 |
| CD at 1% | 1.974 | 0.943 | 2.389 | 2.463 | 1.526 | 1.026 | 0.147 | 0.124 |

4.4.2 Pulp to stone ratio

The data pertaining to pulp to stone ratio was mentioned in two stages. At maturity Sanaur-2 was found with highest pulp to stone ratio (15.76) followed by Umran, Dandan, Jogia and Illaichi which were statistically on par with each other. However, significantly lowest values were found in Manuki (4.39) followed by Mehroon which were on par with each other.

The data at ripe stage revealed that the stone to pulp ratio was significantly highest in Umran (10.62) followed by Sanaur-2 (10.53), Dandan (9.70) and Jogia (9.45) which were on par with each other. However, significantly lowest values were registered in Manuki (3.06).

4.4.3 Total soluble solids (TSS)

The analysis of data on TSS suggest the existence of significant differences among the cultivars at both maturity and ripe stages. Significantly higher TSS was recorded in Mehroon (17%) followed by Kadaka (16.87%) which were on par with each other. However, significantly lowest TSS was recorded in Sanaur-6 (12.33%), Sanaur-2 recorded 13.17 per cent TSS whereas at ripe stage Illaichi (19.17%) recorded highest TSS while lowest TSS was in Sanaur-2 (14.83%).

4.4.4 Per cent acidity

The analysed data on per cent acidity exemplified that there was reduction in acidity from maturity to ripe stage in all cultivars. Significantly highest value was recorded in Umran (0.87%) at maturity followed by Sanaur-2 (0.73%) whereas significantly lowest acidity was recorded in Dandan (0.363%)

followed by Illaichi (0.395%) which were statistically on par with each other. At ripe stage significantly maximum acidity was recorded in Sanaur-2 (0.46%), while lowest acidity was in Dandan (0.26%).

4.5 Yield and related parameters

The data on number of fruits per kg, number of fruits per plant and total yield of fruits per plant are presented in Table 10.

4.5.1 Number of fruits per kg

Significant differences between the cultivars were recorded with significantly highest number of fruits per kg in Manuki (226.6) followed by Mehroon (215.3). However, significantly lowest fruits per kg were recorded in Umran (40.3) followed by Kadaka and Jogia (50.6).

4.5.2 Number of fruits per plant

The persual of data shows that there were significant differences among cultivars. Significantly highest fruit number was recorded in Mehroon (3451 fruits/plant) followed by chuhhara (2466 fruits/plant). Significantly lowest fruit number was recorded in Rambore (85 fruits/number).

4.5.3 Total yield of fruits/plant

The data on yield depicts that significant differences existed among the cultivars under study. Significantly highest yield was recorded in Sanaur-2 (21.0 kg/plant) followed by Dandan (16.19 kg/plant), and chuhhara (15.61 kg/plant). However, significantly lowest yield was recorded in Rambore (1.24 kg/plant) followed by Sanaur-6 (3.88 kg/plant) and Illaichi (3.92 kg/plant).

Table 10. Yield performance of different ber cultivars grown under rainfed conditions

| Genotypes | Number of fruits/kg | Number of fruits/plant | Total yield per plant (kgs) |
|-----------|---------------------|------------------------|-----------------------------|
| Umran | 40.33 | 577.67 | 13.73 |
| Kadaka | 56.67 | 707.33 | 12.39 |
| Chuhhara | 158.00 | 2466.38 | 15.61 |
| Dandan | 64.00 | 1036.20 | 16.19 |
| Sanaur-2 | 46.00 | 1595.20 | 21.00 |
| Illaichi | 187.67 | 761.33 | 3.92 |
| Sanaur-6 | 65.33 | 186.00 | 3.88 |
| Rambore | 81.67 | 85.00 | 1.24 |
| Manuki | 226.67 | 2095.00 | 10.68 |
| Mehroon | 215.33 | 3450.67 | 13.53 |
| Jogia | 56.67 | 662.40 | 11.69 |
| Seb | 59.33 | 353.00 | 6.02 |
| Cv (%) | 2.74 | 26.53 | 13.73 |
| SEm± | 1.695 | 178.37 | 0.858 |
| CD at 5% | 4.921 | 526.09 | 2.515 |
| CD at 1% | 6.755 | 710.81 | 3.418 |

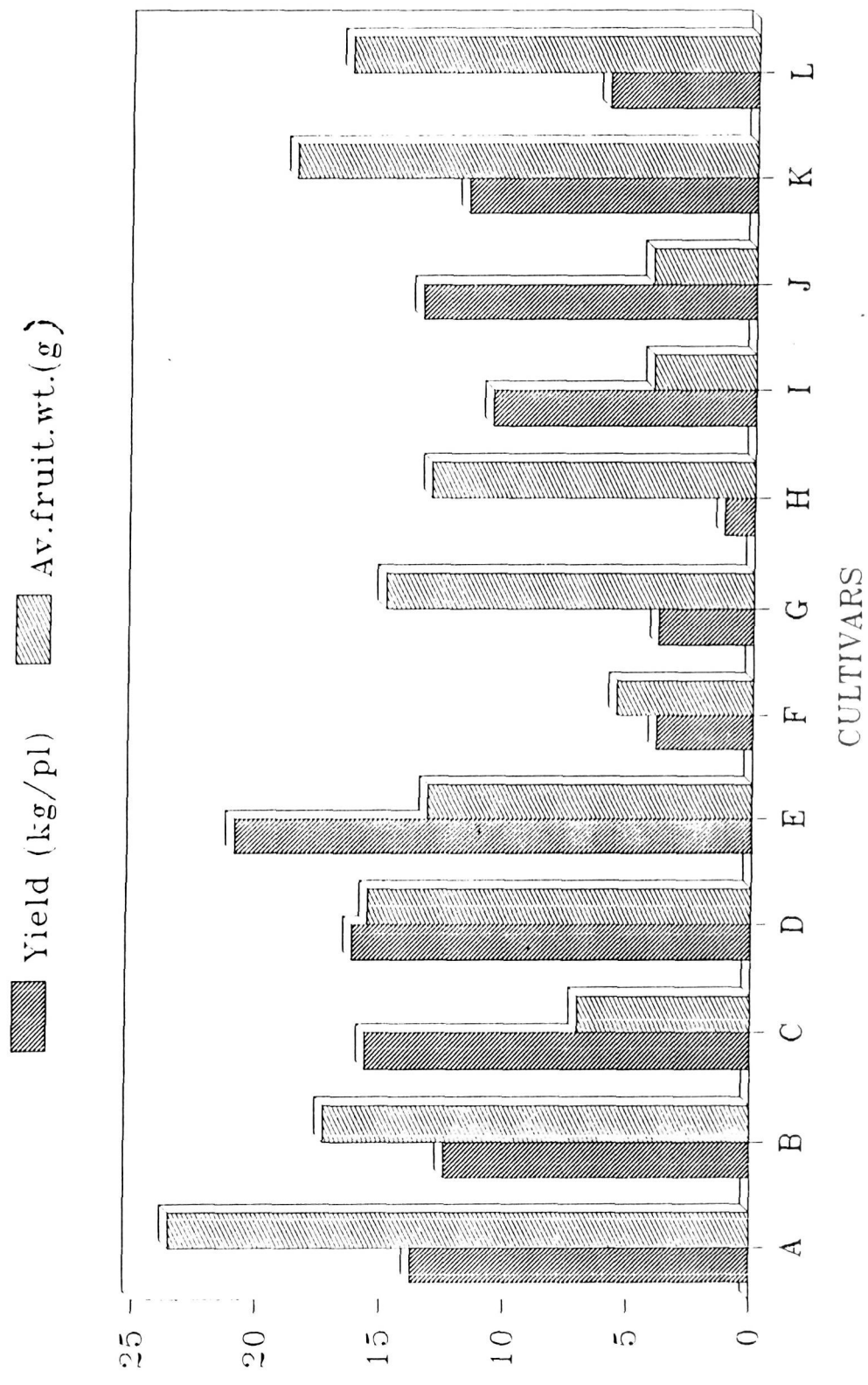


Fig. 1: YIELD PERFORMANCE OF DIFFERENT
 BER CULTIVARS

4.6 Analysis of variance

4.6.1 Physiological characters

The analysis of variance of means representing the physiological characters of 12 ber cultivars is presented in Table 11A.

It is evident from the table that all the cultivars showed significant differences for all the physiological characters except for relative water content.

Analysis of mean performance of different physiological characters represented in table 11B, it is clear that there was a narrow range of difference recorded for relative water content among all the cultivars. However, highest range of variation was recorded in stomatal frequency (114.67-1304 stomata/mm²) in Jogia and Sanaur-2 respectively, followed by stomata index (15.15-44.49%) in Mehroon and Sanaur-2.

4.6.2 Phenological characters

Analysis of variance of means of 12 cultivars of ber representing the phenological traits is presented in Table 12A.

It is clear from the table that all the cultivars showed significant differences in the phenological characters, highest variation in range was recorded in canopy volume (1361.3-4847 sq cm) in Mehroon and Rambore cultivars, respectively followed by plant height which ranged from 168.33 cm in Mehroon to 407.33 cm in Manuki (Table 1). However, a wide range of variations in mean performance was observed for all the characters.

Table 11A. Analysis of variance for different physiological characters in 12 ber cultivars

| Sr. No. | Variance due to freedom | Degree of freedom | Area of leaf St.I | Area of leaf St.II | Relative water content | Stomatal index | Stomatal frequency | Yield/plant |
|---------|-------------------------|-------------------|-------------------|--------------------|------------------------|----------------|--------------------|-------------|
| 1. | Treatment | 11 | 141.7** | 83.79** | 21.55 | 200.42** | 502198.6** | 105.01** |
| 2. | Error | 22 | 18.73 | 2.69 | 11.61 | 1.94 | 19460.0 | 2.14 |
| 3. | F-Value | - | 57.57 | 31.07 | 1.85 | 103.36 | 25.80 | 49.12 |
| 4. | SEm* | - | 2.49 | 0.95 | 1.96 | 0.804 | 80.54 | 0.84 |

(** Significant at 1 and 5% CD)

Table 11B. Genetic variability parameters of different physiological characters in 12 cultivars

| Sr. No. | Character | Range | | Grand mean | Genotypic variation | Phenotypic variation | Coefficient of variance | | Heritability (%) | Genetic advance | Genetic advance % mean |
|---------|------------------------|---------|---------|------------|---------------------|----------------------|-------------------------|------------|------------------|-----------------|------------------------|
| | | Minimum | Maximum | | | | Genotypic | Phenotypic | | | |
| 1. | Leaf area Stage-I | 21.51 | 44.22 | 33.11 | 40.99 | 59.72 | 19.34 | 23.35 | 68.6 | 10.93 | 33.01 |
| 2. | Leaf area Stage-II | 21.16 | 38.64 | 31.42 | 27.03 | 29.72 | 16.55 | 17.35 | 90.9 | 10.21 | 32.49 |
| 3. | Relative water content | 45.92 | 51.61 | 50.17 | 3.31 | 14.92 | 3.63 | 7.70 | 22.2 | 1.77 | 3.53 |
| 4. | Stomatal index | 15.15 | 44.49 | 22.54 | 66.16 | 68.10 | 36.08 | 36.61 | 97.2 | 16.52 | 73.29 |
| 5. | Stomatal frequency | 114.67 | 1304 | 490.14 | 160912.80 | 180372.80 | 81.84 | 86.65 | 89.2 | 780.50 | 159.24 |
| 6. | Yield/plant | 1.24 | 21.00 | 10.83 | 34.29 | 36.43 | 54.09 | 55.75 | 94.1 | 11.70 | 108.03 |

Table 12A. Analysis of variance for different phenological characters in 12 ber cultivars

| Sl. No. | Variance due to | Degree of freedom | Spread of plant | Plant height | Length of sec. br-anch | No. of Teri-ary br-anch | Canopy volume | Average fruit weight | Fruit yield /plant |
|---------|------------------|-------------------|-----------------|--------------|------------------------|-------------------------|---------------|----------------------|--------------------|
| | | | | | | | | | |
| 1. | Treatment | 11 | 1240.50** | 16862.93** | 7830.66** | 29.80** | 3066882.60** | 117.29** | 105.01** |
| 2. | Error | 22 | 340.50 | 5234.31 | 703.05 | 4.63 | 443299.82 | 0.744 | 2.14 |
| 3. | F-value | - | 3.64 | 3.22 | 11.13 | 6.43 | 6.92 | 157.54 | 49.12 |
| 4. | SE _{ME} | - | 10.65 | 41.77 | 15.31 | 1.24 | 384.40 | 0.497 | 0.84 |

(** Significant at 1 and 5% CD)

Table 12B. Genetic variability parameters of different phenological characters in 12 ber cultivars

| Sl. No. | Character | Range | | Grand mean | Genotypic variation | Phenotypic variation | Coefficient of variance | | Heritability (%) | Genetic advance | Genetic advance % mean |
|---------|------------------------|---------|---------|------------|---------------------|----------------------|-------------------------|------------|------------------|-----------------|------------------------|
| | | Minimum | Maximum | | | | Genotypic | Phenotypic | | | |
| 1. | Spread of plant | 251.67 | 325.50 | 292.53 | 300.00 | 640.54 | 5.92 | 8.65 | 46.8 | 24.42 | 8.35 |
| 2. | Plant height | 168.33 | 409.67 | 300.14 | 3876.21 | 9110.50 | 20.74 | 31.80 | 42.5 | 83.66 | 27.87 |
| 3. | Length of sec.branch | 226.00 | 407.33 | 330.94 | 2375.87 | 3078.92 | 14.73 | 16.77 | 77.2 | 88.20 | 26.65 |
| 4. | No. of tertiary branch | 15.33 | 27.00 | 21.94 | 8.39 | 13.02 | 13.20 | 16.45 | 64.4 | 4.79 | 21.83 |
| 5. | Canopy volume | 1361.30 | 4847.00 | 2723.81 | 874527.59 | 1317827.40 | 34.33 | 42.15 | 66.4 | 1569.32 | 57.61 |
| 6. | Average fruit weight | 4.15 | 23.53 | 12.79 | 38.84 | 39.58 | 48.70 | 49.16 | 98.1 | 12.72 | 99.45 |
| 7. | Fruit yield/plant | 1.24 | 21.00 | 10.83 | 34.29 | 36.43 | 54.09 | 55.75 | 94.1 | 11.70 | 108.03 |

4.6.3 Biochemical characters

The analysis of variance of means representing 12 ber cultivars for biochemical characters are depicted in Table 13A.

It was noted from the table that significant differences existed among cultivars for all the biochemical characters. The analysed data for mean performance of all biochemical features of 12 cultivars has been represented in Table 13B. It is clear from data that there were significant variations in all biochemical traits. The highest range of variation was recorded in total sugar content in leaf from 4.23 mg g⁻¹ in Chuhhara to 14.17 mg g⁻¹ in Dandan, followed by the trait total chlorophyll (Stage-I) which was between a range of (0.47-1.22 mg g⁻¹) in Seb and Dandan, respectively. However, it is clear from the table that there was a wide variation in mean performance for all the characters.

4.7 Variability, Heritability and Genetic advance

The genetic parameters were estimated for all traits related to phenological, physiological and biochemical in the 12 cultivars of ber and the results obtained are furnished in Tables 11B, 12B and 13B, respectively.

4.7.1 Yield and its component character

The phenotypic coefficient of variation (PCV) was higher than the respective genotypic coefficient of variation (GCV) for all the characters studied. The genotypic coefficient ranged from 5.92 per cent for spread of plant to 54.09 per cent for fruit yield per plant. Very high GCV was recorded for plant height (20.74%), canopy volume (34.33%) and yield per plant (54.08%). The PCV

Table 13A. Analysis of variance for different biochemical characters in 12 ber cultivars

| Sl. No. | Variance due to | Degrees of freedom | Total chl. | | Proline Stage-I | Proline Stage-II | Total sugar | Reducing sugar | Starch | Amino acid | Yield/plant |
|---------|-----------------|--------------------|------------|----------|-----------------|------------------|-------------|----------------|----------|------------|-------------|
| | | | Stage-I | Stage-II | | | | | | | |
| 1. | Treatment | 11 | 0.146** | 0.097** | 0.017** | 0.207** | 27.40** | 2.19** | 102.01** | 0.026** | 105.01** |
| 2. | Error | 12 | 0.0038 | 0.0034 | 0.00038 | 0.0015 | 0.62 | 0.04 | 7.36 | 0.0029 | 2.14 |
| 3. | F-Value | - | 37.82 | 27.64 | 45.48 | 13.71 | 43.87 | 54.17 | 13.85 | 8.67 | 49.12 |
| 4. | S.E.m \pm | - | 0.035 | 0.034 | 0.011 | 0.022 | 0.45 | 0.115 | 1.57 | 0.031 | 0.844 |

(** Significant at 1 and 5% CD)

Table 13B. Genetic variability parameters of different biochemical characters in 12 cultivars of ber

| Sl. No. | Character | Range | | Grand mean | Genotypic variation | Phenotypic variation | Coefficient of variance | | Heritability (%) | Genetic advance | Genetic advance % mean |
|---------|----------------------------|---------|---------|------------|---------------------|----------------------|-------------------------|------------|------------------|-----------------|------------------------|
| | | Minimum | Maximum | | | | Genotypic | Phenotypic | | | |
| 1. | Total chlorophyll Stage-I | 0.47 | 1.22 | 0.953 | 0.047 | 0.051 | 22.86 | 23.77 | 92.5 | 0.43 | 45.12 |
| 2. | Total chlorophyll Stage-II | 0.45 | 1.06 | 0.839 | 0.030 | 0.034 | 20.71 | 21.85 | 89.9 | 0.34 | 40.52 |
| 3. | Proline Stage-I | 0.18 | 0.44 | 0.292 | 0.0055 | 0.0059 | 25.81 | 26.67 | 93.7 | 0.15 | 51.36 |
| 4. | Proline Stage-II | 0.27 | 0.56 | 0.430 | 0.068 | 0.07 | 18.59 | 20.67 | 80.9 | 0.15 | 34.88 |
| 5. | Total Sugar | 4.23 | 14.17 | 9.99 | 8.93 | 9.55 | 29.89 | 30.92 | 93.5 | 5.95 | 59.56 |
| 6. | Reducing Sugar | 2.17 | 4.64 | 3.61 | 0.72 | 0.76 | 23.49 | 24.15 | 94.7 | 1.70 | 47.09 |
| 7. | Starch | 24.41 | 44.10 | 32.32 | 31.55 | 38.91 | 17.38 | 19.30 | 81.1 | 10.42 | 32.24 |
| 8. | Amino acids | 0.71 | 0.99 | 0.857 | 0.0077 | 0.011 | 10.21 | 12.04 | 71.9 | 0.15 | 17.50 |
| 9. | Yield/plant | 1.24 | 21.00 | 16.83 | 34.29 | 36.49 | 54.09 | 55.75 | 94.1 | 11.70 | 108.03 |

ranged between 8.65 per cent and 55.75 per cent for spread of plant and yield per plant, respectively. However, highest PCV was observed for yield per plant followed by average fruit weight (49.16%), canopy volume (42.15%) and plant height (31.80%).

Heritability (broad sense) varied between 42.5 per cent and 98.1 per cent for plant height and canopy volume, respectively. Heritability was high for all characters except plant height and spread of plant.

Genetic advance

Genetic advance as per cent mean ranged from 8.35 per cent for spread of plant to 108.03 per cent for fruit yield per plant. The characters namely fruit yield per plant, average fruit weight and canopy volume registered high genetic advance as per cent mean (108.3, 99.45 and 57.61, respectively) (Table 11B).

4.7.2 Fruit yield versus Physiological characters

The estimates of phenotypic coefficient of variation were found higher than the respective genotypic coefficient of variation for all the characters studied. The range of GCV was between 3.63 per cent for relative water content and 81.84 per cent for stomatal frequency, high GCV values were recorded for stomatal frequency followed by yield per plant (54.09%) and stomatal index (36.08%).

Highest phenotypic coefficient of variation was observed for stomatal frequency (86.65%) followed by yield/plant (55.75%). Stomatal index (36.61%) and leaf area at Stage-II (23.35%), whereas relative water content (7.70%) exhibited a lowest PCV, among all the cultivars studied.

Heritability in broad sense ranged between 22.2 per cent (RWC) and 97.2 per cent (Stomatal index). However, all characters except RWC showed higher estimates of heritability (Table 12B).

A wide range of genetic advance as per cent mean was observed among the cultivars. However, the range varied between 3.53 per cent for RWC to 154.24 per cent for stomatal frequency.

4.7.3 Fruit yield versus biochemical characters

Genotypic coefficient of variation ranged from 10.21 per cent for amino acid to 29.89 per cent for total sugar. The estimates of GCV were found to be higher for all the characters except for proline content (Stage-II), starch content and total free amino acid profiles.

A narrow range of PCV that is 12.04 per cent (total free amino acid content) to 30.92 per cent (total sugar) was observed for all the cultivars studied. However, the PCV estimates were high for total sugar at Stage-I followed by proline content Stage-I and reducing sugars.

The highest broadsense heritability estimates were recorded for reducing sugars (94.7%) followed by proline (93.71%), total sugars (93.5%) and total chlorophyll at Stage-I (92.5%) while the trait total free amino acid content exhibited the lowest heritability estimates of 71.9 per cent.

Genetic advance as per cent mean ranged from 17.50 per cent for total free amino acid content to 51.36 per cent for proline (Stage-I). All the

characters exhibited high estimates of genetic advance as per cent mean except total amino acid content (Table 13B).

4.9 Correlation coefficient

The characters association for fruit yield versus its phenological, physiological and biochemical characters were estimated and the results are furnished in Tables 14 to 16.

4.8.1 Fruit yield versus its attributing characters

Spread of the plant was found to be positively correlated with canopy volume (0.549), plant height (0.152), length of secondary branch (0.142) and fruit yield (0.069). However, its association with number of tertiary branches was negative (-0.14).

Plant height exhibited positive association with all traits except length of secondary branch and number of tertiary branches, and yield of plant. A strong positive significant association was observed between length of secondary branches and number of tertiary branches (0.686) and its association was positive with fruit yield (0.386). However, its association was found to be negative with canopy volume and average fruit weight.

The characters, number of tertiary branches and canopy volume were found to be negatively correlated with fruit yield. However, a positive relation was recorded between average fruit weight and fruit yield (Table 14).

4.8.2 Fruit yield versus physiological characters

The correlation coefficient for yield per plant showed a positive association with stomatal frequency (0.489), leaf area at Stage-II (0.352) and

Table 14. Phenotypic correlation of phenological characters with yield

| Sl. No. | Characters | Spread of plant | Plant height | Length of Sec. br | No. of Ter.br | Canopy volume | Av. fruit weight | Fruit yield |
|---------|------------------|-----------------|--------------|-------------------|---------------|---------------|------------------|-------------|
| 1. | Spread of plant | 1.000 | 0.152 | 0.142 | -0.014 | 0.569** | -0.077 | 0.069 |
| 2. | Plant height | | 1.000 | -0.480 | -0.539 | 0.450 | 0.266 | -0.141 |
| 3. | Length of Sec.br | | | 1.000 | 0.686** | -0.318 | -0.259 | 0.386 |
| 5. | No. of Ter.br | | | | 1.000 | -0.450 | -0.385 | 0.036 |
| 4. | Canopy volume | | | | | 1.000 | 0.101 | -0.369 |
| 6. | Av. fruit wt. | | | | | | 1.000 | 0.053 |
| 7. | Fruit yield | | | | | | | 1.000 |

(** Significant at 1 per cent level of probability)

sec.br - Secondary branch

Ter.br - Tertiary branch

Table 15. Phenotypic correlation of physiological parameters with yield

| Sl. No. | Characters | Yield/ plant | Area of leaf St. II | Area of leaf St. I | R.W.C. | Stomatal index | Stomatal frequency |
|---------|---------------------|-----------------|------------------------|-----------------------|--------|-------------------|-----------------------|
| 1. | Yield/plant | 1.000 | 0.352 | 0.106 | -0.049 | 0.343 | 0.489 |
| 2. | Area of leaf St. II | | 1.000 | 0.777** | 0.036 | -0.266 | -0.314 |
| 3. | Area of leaf St. I | | | 1.000 | 0.023 | -0.198 | -0.185 |
| 4. | R.W.C. | | | | 1.000 | 0.159 | 0.213 |
| 5. | Stomatal index | | | | | 1.000 | 0.814** |
| 6. | Stomatal frequency | | | | | | 1.000 |

(** Significant at 1 per cent level of probability)

St. I - 165 days after pruning

St. II - 315 days after pruning

RWC - Relative water content

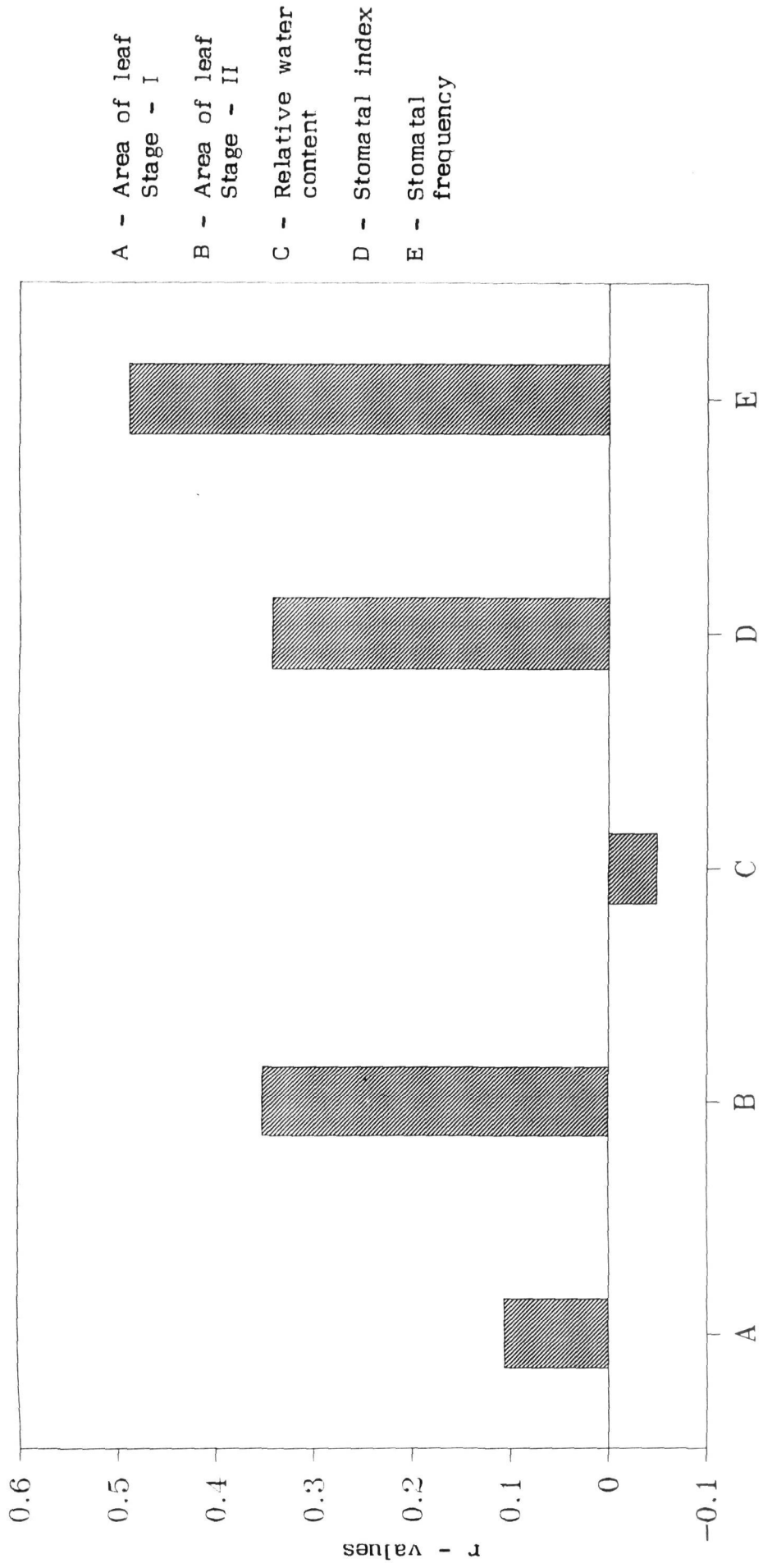


Fig. 2: PHENOTYPIC CORRELATION OF DIFFERENT PHYSIOLOGICAL CHARACTERS WITH YIELD PER PLANT

stomatal index (0.343) while negative association with relative water content (-0.049).

A strong significantly positive association (0.777) was found between leaf area Stage-I and Stage-II. Similarly significant strong association (0.814) was also noticed between stomatal frequency and stomatal index (Table 15). Most of the characters exhibited negative correlation with fruit yield per plant except stomatal index and stomatal frequency (Fig. 2).

4.8.3 Biochemical characters

Most of the biochemical characters were found to be negatively related with fruit yield per plant except total chlorophyll content at both the stages (Stage-I and Stage-II) and total and reducing sugars content. Biochemical characters such as total chlorophyll at both stages, reducing and total sugars showed a positive association with yield per plant whereas, amino acids, proline and starch showed negative association with yield per plant (Fig. 3).

Table 16. Phenotypic correlation of biochemical characters with yield.

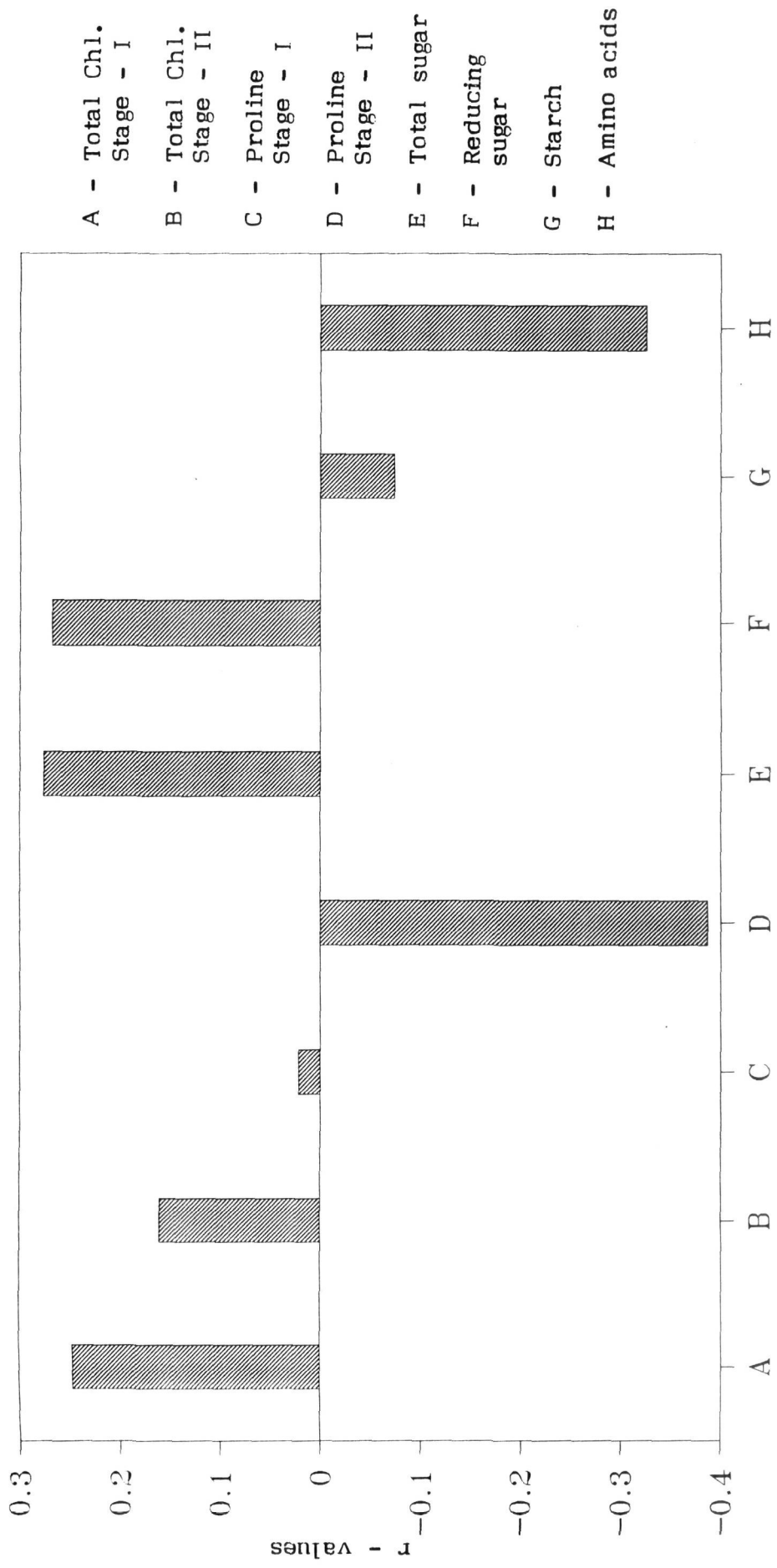
| Sl. No. | Characters | Yield/ plant | Total chl. St.-I | Total chl. St.-II | Proline St.-I | Proline St.-II | Total sugar | Reducing sugar | Starch | Amino acids |
|---------|------------------|-----------------|---------------------|----------------------|------------------|-------------------|----------------|-------------------|--------|----------------|
| 1. | Yield/plant | 1.000 | 0.247 | 0.161 | 0.022 | -0.387 | 0.276 | 0.268 | -0.074 | -0.326 |
| 2. | Total Chl. St-I | | 1.000 | 0.944** | -0.154 | 0.161 | 0.434 | 0.284 | -0.460 | -0.318 |
| 3. | Total Chl. St-II | | | 1.000 | -0.231 | 0.164 | 0.487 | 0.343 | -0.441 | -0.173 |
| 4. | Proline St.-I | | | | 1.000 | 0.510 | 0.158 | 0.422 | 0.355 | 0.023 |
| 5. | Proline St.-II | | | | | 1.000 | 0.616** | 0.772** | 0.016 | 0.350 |
| 6. | Total sugar | | | | | | 1.000 | 0.762** | -0.129 | 0.276 |
| 7. | Reducing sugar | | | | | | | 1.000 | -0.052 | 0.276 |
| 8. | Starch | | | | | | | | 1.000 | 0.247 |
| 9. | Amino acids | | | | | | | | | 1.000 |

(** Significant at 1 per cent level of probability)

Chl. - Chlorophyll

St-I - Stage I (165 days after pruning)

St-II - Stage II (315 days after pruning)



CHARACTERS

Fig. 3: PHENOTYPIC CORRELATION OF DIFFERENT BIOCHEMICAL CHARACTERS WITH YIELD PER PLANT

DISCUSSION

DISCUSSION

Owing to wider adaptability on marginal and waste lands with shallow soils, ber has achieved greater prominence in farming community during recent years. Further, good productivity and its ability to withstand distant transport and storage, besides high nutritive value of fruits and a characteristic drought tolerating ability has added to its popularity for commercial cultivation in vast tracts of arid and semiarid regions. Although, ber cultivation in the country is wide spread, its systematic cultivation is sporadic in Region-I, Zone-II of Karnataka, which is characterised by all the typical features of arid and semiarid regions besides vast area as a waste land.

A rich genetic diversity in cultivated species of *Zizyphus mauritiana* L. has resulted in availability of large variability among different cultivars. The cultivation of ber cultivars in dry regions under rainfed conditions have shown a wider fluctuations in yielding pattern, owing to its differences in adaptability to a particular region having a particular set of agro-ecological conditions. However, the impact of environment expressed in phenological features of cultivars and the need to interpret the complex phenological, biochemical differences to understand the extent of association of these characters, and its impact on yield had necessitated to undertake present investigation. The results obtained from this experiment are discussed under the following heads.

5.1 Phenological features of tree

A specified cultivar does not exhibit the same phenotypic characters including yield in all the environments. The failure of a cultivar to give the same

phenotypic performance when tested under different environments is the reflection of genotype and environment (GxE) interaction (Eberhart and Russel, 1966).

In the present investigation significant variations were exhibited in the phenological characters studied in different ber cultivars (Table 1). These observations are in confirmation with Anonymous (1988) who had reported that there was a wide variation in the phenological characters of different ber cultivars grown in a particular set of agro-climatic conditions.

Maximum phenological characters namely plant spread, height and canopy volume were recorded in Rambore cultivar with minimum yield levels (Table 10). However, the high yielding cultivars like Sanaur-2 and Dandan have shown intermediate values for phenological features. Illaichi with low yield levels showed least phenological values except possession of more number of tertiary branches.

The variation in yield and phenotypical characters of different cultivars raise a question, that wheather the phenological characters are really a yard stick to measure the yield performance of ber cultivars. Since, the maximum yields were recorded in Sanaur-2 and Dandan cultivars while significantly lower yield were recorded in highly vigourous cultivars like Rambore, and very low vigoured cultivars like Illaichi and Mehroon. In contrast to our findings Levy and Shalhavet (1978) and Koo, (1979) demonstrated a positive correlation between canopy size and yields in citrus. However, Spinks (1936) strongly advocated that there is no correlation between the size and vigour of apple cultivars grown in a particular set of agro-ecological conditions which corroborate with present findings.

Similarly Hilgeman and Sharp, (1970) reported that there was no commensurate increase in yield due to large canopy of Valencia Orange. In the present study also yield was not proportional to canopy size.

5.2 Parameters related to drought tolerance

5.2.1 Stomatal and leaf features

Presence of stomata only on abaxial surface of leaf was noticed in all the cultivars and these stomata were sunken in nature in wavy lower epidermis (Plate 6), thus reducing the possible exit of water from leaf. This investigation is in confirmation with Ehrler and Van Bavel (1968) in citrus. The abaxial surface of the leaf being covered with more dense pubescence in Dandan and Illaichi when compared to other cultivars, was the major constraint in getting good section. Therefore, it was impossible to record leaf stomatal observations.

The cultivar Sanaur-2 recorded highest stomatal index and stomatal frequency (Plate 9) which was in conformity with Brainerd *et al.* (1981). However, increased frequency cannot be attributed solely to stress because stress reduced the size of the leaf. In present investigation too the leaf size was reduced (Table 3). Further, the increase in stomatal frequency was proportional to the reduction in leaf area (Table 3). This view gets the support of Monsalisa (1951). Ciha and Brun (1975) and Sapra *et al.* (1975) have also reported that stomatal frequency was inversely correlated with size of the leaf and further, they have stated that water stressed plants had greater stomatal frequency and smaller leaf area.

The highest stomatal measurements such as diameter of stomata, length and breadth of guard cell, stomatal size and medium pore size along with

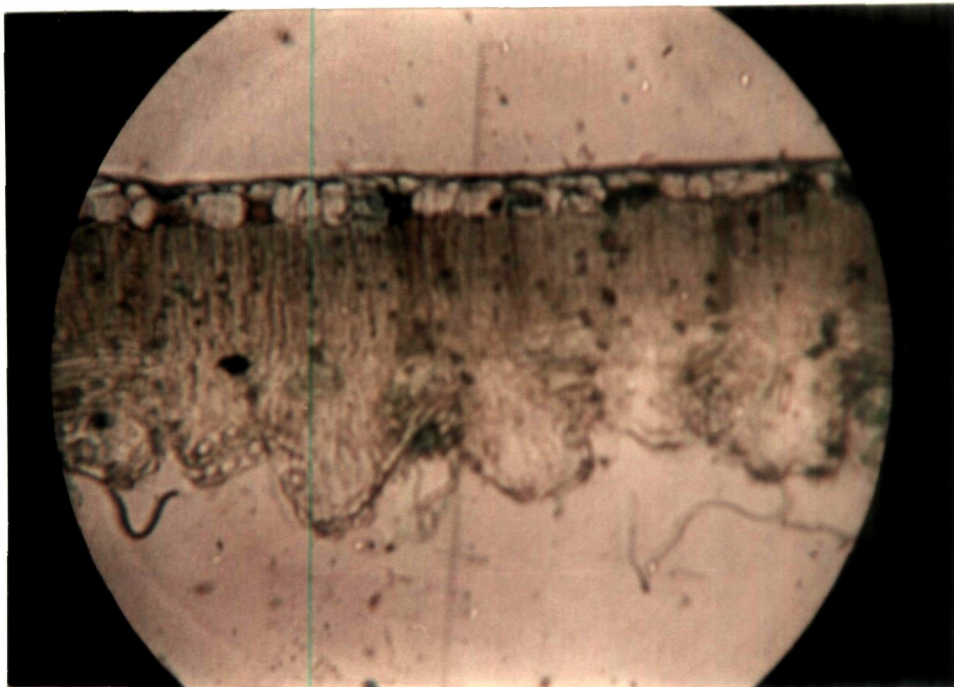


Plate 9. Microphotograph showing high stomatal frequency in Sanaur-2 cultivar (10x X 20x)

reduced leaf area were recorded in high yielding cultivar like Sanaur-2 (Table 3 and 4). From these findings it may be inferred that the reduction in area of leaf may be an adaptive mechanism by which the plant reduces the exposure of leaf surface to desiccating sunlight and perhaps to compensate photosynthetic efficiency by increasing the frequency of stomata. Further, by maintaining larger stomatal size and medium pore opening, the plant may regulate the gaseous exchange which might result in increased efficiency in fixation of dry matter. These findings are in confirmation with Mugnai *et al.* (1995).

The observations on Umran cultivar revealed highest leaf area and lower stomatal frequency with moderate to higher levels of yields. This shows that there is some other factor governing the stress physiology and resultant impact on yields of this cultivar. Other adaptive mechanism like increase in leaf thickness along with thicker upper and lower epidermis which may act as a stress tolerance features. This indicates that under stress conditions more surface wax is deposited which leads to increase in the thickness of stress tolerant leaves. These investigations corroborated with the findings of Singh (1985), in citrus. Similarly the studies of Syvertsen and Smith (1984) envisaged that leaf grown under full light conditions had more cuticular thickness than shade grown leaves which would support the above mentioned findings.

All these anatomical changes have adaptive significance for sustaining drought conditions (Kaufmann, 1977) smaller leaf size more compactness of cells having advantage in high temperature avoidance and fixation of more carbon dioxide per unit loss of water (Hoarse and Barrs, 1974). Increase in cuticular thickness

reduces the epicuticular loss of water along with increase in reflectivity which prevents the leaf from reaching high temperature.

5.2.2 Plant water relations

Whenever plants are subjected to water stress changes in physiological processes of plants occur and these changes are in response to reduction in water content of plant tissue, so the actual water content of the tissue is important in determining the rate of various processes in plant and thus may give an indication of intensity of stress to which a plant has reached (Singh, 1985).

Rao and Reddy (1993) have stated that Rangpur lime and cleopatra mandarin which have better tolerance to water deficits have higher relative water content. However, it is stated that the parameters related to water relations particularly relative water content should be more in resistant cultivars (Voleti, *et al.*, 1990; Wilcox and Ashley, 1982; Lee and Asahira, 1983). In contrast to this in the present investigation the cultivars studied showed non significant low values of relative water content (Table 2).

The moisture status of leaf on fresh weight basis were also non significant and low (Table 2), in contrast to the observation of Gati (1982) where he found that the drought resistant pepper varieties maintained 85 per cent water in the tissue while egg plant maintained 86-88 per cent of moisture.

Although ber is known for its drought tolerance, the relative water content showed reverse values, this may be due to the deciduous nature of ber plant which sheds its leaves with the onset of summer, Probably the water content might have been transported to stem portion for conservation (Kozlowski *et al.*, 1991).

Kozłowski (1968) opined that the water content in the leaf depends on the climatic conditions. In the present investigation the sampling was done at the onset of summer, because of which there may be reduction in the water content of leaf. However, this parameter was not found reliable for proper assessment of genotypic performance under rainfed conditions.

5.3 Biochemical changes

5.3.1 Leaf Pigments

During present investigation it was noticed that there was a significant difference among the cultivars for total 'a' and 'b' chlorophyll and there was a reduction in the levels of total 'a' and 'b' chlorophyll from Stage-I to Stage-II of plant growth. These findings are in confirmation with the findings of Syvertsen and Smith,(1984). They had reported that chlorophyll pigments gets reduced under high light conditions in summer. Similar, observations were also noted by Singh (1985) in citrus.

During the course of investigation cultivar Dandan recorded maximum values of leaf pigments (Total 'a' and 'b' chlorophyll) followed by Illaichi, Sanaur-2 and Sanaur-6 which were statistically on par with each other (Table 5), indicating a better photosynthetic efficiency of plants resulting into higher yields under rainfed conditions. Whereas Seb cultivar recorded the lowest values of total 'a' and 'b' chlorophyll which was also associated with lower levels of yield due to reduced photosynthetic efficiency. This investigation is in confirmation with the observations of Sankhla *et al.* (1989).

However, it is not possible to draw a definite conclusion about its possible direct role in the stress physiology of ber cultivars, as it has been reported by Johanson, *et al.* (1982) that chlorophyll content reduces under stress.

5.3.2 Total free amino acids

In the present findings it was observed that the levels of amino acids particularly proline increased from Stage-I to Stage-II of plant growth in all the cultivars under study. These findings corroborated with the findings of Barnett and Naylor (1966) who reported that the amino acids were continuously synthesized during water stress in Bermuda grass. Similar observations were also reported by Palfi (1969).

Proline accumulation increased with the increase in the stress subjected plants is wide spread noticed in several plant species and it can be used as a parameter for evaluation of sensitivity to drought stress (Aloni and Rosenshtein, 1984; Rajagopal *et al.*, 1977; Barnett and Naylor, 1966; Maestri *et al.*, 1995; Aspinal and Paleg, 1981).

The data obtained in the present investigation are in agreement with the above said workers. However, the accumulation of proline in different ber cultivars significantly varied. Moderate to low levels of proline were accumulated in high yielding cultivars, whereas low yielding cultivar Seb showed highest proline accumulation in leaf, which might be due to its susceptibility to drought conditions. These findings are in confirmity with the findings of Levy (1983), he reported that susceptible cultivars of potato accumulated higher amount of proline

in response to stress. Contradictory to this cultivar Rambore recorded intermediate values of proline content.

5.3.3 Carbohydrates

Reducing sugars in leaf were found to increase in all the cultivars from first stage to second stage with advancement of growing period coupled with the aridity of the environment which was sufficient enough to develop moisture stress in plants, similar findings were reported by Singh (1985). This observation is also in confirmation with the findings of Yelenosky (1979) who found increase in sugars in response to moisture stress in sweet orange.

The relative contribution of reducing and non reducing sugars to the total changes in the sugar and the resulting osmotic adjustments vary between the species and cultivars (Madeline *et al.*, 1980). The present investigation on ber showed a major contribution to the total sugar is from non reducing sugar in all the cultivars which is in confirmation with the observation of Cutler and Rains (1978) in cotton leaves growing under water stress conditions.

However, the mechanism by which soluble sugars are accumulated in water stressed leaves is difficult to establish. Probably the increased concentrations of sugar in leaf may result from increased starch hydrolysis or synthesis by other pathways. Alternatively, increased translocation of carbohydrates into leaves or a decreased translocation of carbohydrates from leaves could also contribute to the observed sugar accumulations (Madeline *et al.*, 1980).

Other probable reason for accumulation of sugar in stressed leaves may also be due to restricted cellular enlargement in leaves subjected to stress, as in

the present investigation it was noticed that, there was a reduction in leaf area from Stage-I to Stage-II (Table 3). Therefore, the effectiveness of cell growth as a carbohydrate sink is similar to the enlargement response, a reduction in growth sink utilization without a parallel reduction in intensity of carbohydrate source could itself account for the sugar accumulation, this was observed by Cutler and Rains (1978).

However, it was observed in the present investigation, that there was a reduction in starch content from Stage-I to Stage-II indicating the applicability of possible above explained mechanism. This findings are in confirmation with Madeline *et al.* (1980) in sorghum.

During the present investigation higher values of total and non reducing sugars with moderate values of reducing sugars and lower values of starch in high yielding cultivars like Sanaur-2 and Dandan were recorded (Table 7). Higher levels of non reducing sugars are the resultant of current assimilation in leaf (Singh, 1985), are readily available for photosynthesis, the higher chlorophyll content in Dandan added to the enhanced photosynthetic activity resulted in probable increment in yield.

5.4 Physico-chemical characters

In the present investigation, it was observed that cultivar Umran had recorded the highest fruit weight, pulp to stone ratio and intermediate acidity and moderate TSS (Table 9). Similar observations were recorded by Room Singh and Tomer, 1988; Reddy *et al.*, 1991; Singh and Jindal, 1980; Gupta, 1977).

Lowest fruit weight, pulp to stone ratio, moderate acidity and TSS were found in Manuki, which is in confirmation with the views of Anonymous (1988). However, the high yielding cultivars like Sanaur-2 and the Dandan showed medium fruit weight but higher pulp to stone ratio indicating higher edible portion. These observations are in confirmation with Anonymous, 1988; Yamadagni *et al.*, 1985; Gupta, 1977 .

5.5 Yields

Results of present trial indicated that Sanaur-2 out yielded all other cultivars followed by Dandan (Table 10). This suggests that even though the plants were high yielding but possessed moderate phenology. Thus it suggests that medium plant canopy is desirable for higher yields in ber under rainfed conditions.

However, this increment in yield levels may be attributed to different set of complex interaction between the biochemical constituents in leaf along with the adaptive mechanism that the plant has developed. High yielding ability of a cultivars itself is an indication of stress resistance which was obtained in Sanaur-2 and Dandan cultivars. These finding are in agreement with the views of Fisher and Wood (1979) and Acevedo *et al.* (1991) who have suggested that stress resistance in cultivar is equated to maintaining higher yields over its contemporary susceptible cultivars.

Levitt (1980) reported that yield potential plus all the adaptive features, of cultivars, whether they are related to a given stress resistance or not influences yield under stress.

However the higher levels of yield in Sanaur-2 and Dandan may be also due to higher values of stomatal features Table (3 and 4) which has increased

the gaseous exchange. This might have resulted in efficient fixation of carbon and nitrogen in the leaf. Higher level of chlorophyll in cultivar Dandan might have also enabled a higher photosynthetic activity in the presence of abundant radiant energy under arid conditions (Table 7). Similar findings were opined by Mugnai *et al.* (1991) in *Nerium oleander*. As there is more accumulation of sugars in leaf during stress (Yelenoski, 1979; Singh, 1985). The accumulated sugars are transported to the sink (fruit) in the plant system and thus increased yield levels. This finding is in confirmation with Acevedo *et al.* (1991) who reported higher rate of photosynthesis is associated with higher yields.

The lowest yield obtained in Rambore in the present investigation (Table 10) may suggest about the complexity of perennial plant phenology. This cultivar having higher values of phenological characters (plant height, spread, canopy volume) showed poor yields, which may be attributed to the fact that most of the energy of the plant might have been diverted towards vegetative growth.

5.6 Crop improvement studies

Improvement through breeding programme in any crop is dependent on the availability of information on genetic variability. As in many other crops, in ber also, fruit yield is very much influenced by yield contributing characters. The information obtained on genetic parameters and correlation coefficient are discussed.

5.6.1 Analysis of variance

The results of the analysis of variance revealed highly significant differences among the cultivars for all the fruit yielding characters studied. The range of variation for these characters was wide except for number of tertiary

branches (15.33 to 27.0). The cultivar exhibited considerable amount of variation for other characters. Similar results were also observed by Bisla and Daulta (1988). This indicates the scope for selection of suitable material for crop improvement.

The range in the values reflect the extent of phenotypic variability in respect to those characters, it includes genotypic, environmental and genotypic x environment interaction components. The estimation of genetic and environmental variations is of great value in the choice of suitable breeding procedure. Johanson, (1909); Nilson Ehle (1909) and East (1916). Power (1942) separated genetic variance from total variance by using environmental variance. The components of variation such as *phenotypic and genotypic coefficients of variability, heritability* and predicted genetic advance as per cent mean were computed in respect to fruit yield and its phenotypic characters, physiological characters and biochemical characters.

Phenotypic variability is not very reliable since it includes both genotypic and environmental effects and does not reveal as to which character is showing higher degree of variability, thus, it is indispensable to split the overall variation into genetic and non genetic components and to standardise there by obtaining the coefficients of genotypic and phenotypic variability. The phenotypic coefficients of variability was higher then the genotypic coefficient of variability for all the characters studied. High genotypic and phenotypic coefficients of variation are found for canopy volume, average fruit weight and fruit yield per plant. These findings corroborated with the findings of Bisla and Daulta (1988). These *observations indicate that substantial variability exist for these characters. Even*

though the differences for PCV and GCV were recorded for length of secondary branch, number of tertiary branches, average fruit weight and fruit yield indicate negligible influence of external factors in the expression of these characters.

The coefficient of variation indicate only the extent of variability present for different character and do not indicate the heritable portion. To obtain the knowledge of heritable portion of the variability it is essential to know the heritability estimates for different characters. The heritable estimate separate the environmental influence from the total variability and indicates the accuracy with which a cultivar can be identified by its phenotypic performance. Thus making the selection more effective, as such the heritability in broad sense is the proportion of genotypic variability to the total variability, its importance has been emphasized by Lush (1949) in animals and Johanson *et al.* (1955) in plants. Very high heritability estimates were obtained for average fruit weight (98.1%) fruit yield (94.1%), length of secondary branch (77.2%), canopy volume (66.4%) and number of tertiary branches (64.4%) of phenological characters. All the physiological and biochemical characters were also found to be highly heritable except for relative water content (22.2%).

Heritability estimates in broadsense alone cannot serve as true indicator for effectiveness of selection for the trait since their scope is restricted by their interaction with the environment (Johanson *et al.*, 1955). Hence heritability values considered along with the predicted genetic gain. It increases the reliability of this parameters as a tool in selection programme.

In case of canopy volume, average fruit weight and fruit yield, Proline (Stage-I) and total sugar (Stage-I) of biochemical characters and stomatal index and stomatal frequency of physiologically related traits, it was observed that high heritability was coupled with high genetic advance as per cent mean. The high heritability coupled with high genetic advance for these characters infer that this observation was not much influenced by environmental factors and is expected to respond to direct selection for improvement.

It is observed that moderate heritability values were associated with low genetic advance as per cent mean for spread of plant and plant height, and low heritability and low genetic advance for relative water content.

Character association

Although variability estimates provides information on the extent of improvement possible in different characters, they donot throw light on the extent and nature of relationship prevalent between the *contributory characters* and economically important characters. This could be obtained from simple association analysis that determines the direction of action of different characters, based on this analysis, the traits that can be selected for improving the desired variables can be ascertained.

Yield is a complex character predominantly governed by a large number of genes and is greatly affected by environmental fluctuations. Therefore, selection based on yield alone is not effective. Therefore, improvement in yield can be brought about by effecting indirect selection for yield contributing components, whose heritability is high and show a strong association with yield.

It is important to understand the relationship between two metric traits in the individuals of a population as it would be possible to bring about genetic improvement in one character through the selection of the other. Grafius (1959) opined that there may not be any gene for yield as such but operate only through its components. Hence, the study of characters association through correlation will surely help to break the genetic barriers of yield.

The direct observable phenotypic correlation does not indicate the magnitude or direction of genetic correlation which present a true genetic picture of relationship between the gene controlling the characters. In the present investigation phenotypic and genotypic correlations between fruit yield and its component characters were studied.

Phenotypic correlation of physiological parameters with yield

In the present investigation a high positive correlation of stomatal frequency and stomatal index with yield per plant was observed, where as RWC showed a very low negative correlation with yield, and a positive correlation was observed between leaf area and yield. However, high negative correlation was noticed between leaf area at both first and second stage with stomatal frequency and stomatal index (Table 15).

High positive correlation indicate a greater association of stomatal frequency and stomatal index with yield per plant and as they have high heritability estimates, therefore selection involving the improvement of stomatal distribution will increase the yield per plant. These findings are in confirmation with Ciha and Brun (1975).

A very low negative correlation shows a very weak association between RWC and yield per plant and as RWC has shown low heritability and per cent genetic advance, which gives an insight that selection involving RWC will not influence yield per plant.

A negative correlation between leaf area and stomatal index, stomatal frequency indicates that simultaneous improvement of these two characters is difficult.

Phenotypic correlation of phenological characters yield

In the present investigation it was observed that length of secondary branch showed high positive correlation with yield. Whereas features like spread of plant, number of tertiary branches and average fruit weight showed low but positive correlation. However, a negative correlation was observed between canopy volume, plant height and yield per plant (Table 14). This indicated selection involving length of secondary branch will improve the yield performance. However, this criteria does not hold good for all cultivars. A high negative correlation existed between canopy volume and yield. The data also indicated that spread of plant is significantly positively correlated with canopy volume. Therefore, by seeing the complexity of phenology of plant it is difficult to improve the crop through selection involving phenological parameters, except for length of secondary branch.

Phenotypic correlation of biochemical features with yield

In present investigation a positive correlation between total chlorophyll (both stage), and yield per plant was observed. Similarly total and

reducing sugars were found in positive association with yield per plant. However, proline showed negative correlation with yield per plant. Similarly the amino acids and starch recorded negative correlation with yield per plant (Table 16). This data indicated that the selection involving high total sugar reducing sugar and chlorophyll content will also improve the crop yield. Significant positive correlation was also observed between chlorophyll values in Stage-I and Stage-II. Similarly high positive correlation between total chlorophyll and sugars indicates the existence of fair association between these traits. It was also found that the chlorophyll content had shown negative correlation with starch and amino acid, indicating their utilization in higher chlorophyll levels.

Proline Stage-I showed significant high positive correlation with reducing and total sugars. Similarly a significant positive correlation was recorded between total and reducing sugars.

Therefore, the selection pressure can be made on the characters which showed high correlation coefficient with yield. In the present investigation the characters related to the yield namely length of secondary branch of phenological character and stomatal index, stomatal frequency, area of leaf of physiological characters and total chlorophyll (both stages), total and reducing sugars of biochemical characters showed their fair association with yield.

SUMMARY

SUMMARY

The present investigation was undertaken with a view to select ideal cultivars having better adaptability to arid and semiarid regions with high yielding ability.

Twelve popular cultivars of ber were studied in an experiment following Randomised Block Design with three replications at Regional Research Station, Raichur, University of Agricultural Sciences, Dharwad during May 1995 to June 1996. The observations were recorded on phenological characters, Biochemical parameters, stomatal features and physico-chemical parameters of fruits. Selected parameters were subjected for analysis of variance, heritability estimates, genetic advance and correlation studies.

The important findings of this investigation are summarised below.

The relationship between phenological features and yield was not clear in ber. High yielding cultivars like Sanaur-2 and Dandan showed moderate phenological features, whereas the low yielder Rambore recorded highest phenological values.

Stomatal observations viz., index, frequency, diameter, size, length and breadth of guard cell, were found highest, along with moderate values for length and breadth of pore and pore size in high yielding cultivar Sanaur-2. While, leaf area was found to be least in the same cultivar.

The plant water status parameters like relative water content, moisture content in leaf and water saturation deficit were found to be non significant. The values of RWC and moisture content were very low with high water saturation deficits and were influenced by environmental conditions. Therefore, these parameters were found irrelevant for assessment of cultivar performance for drought tolerance under rainfed conditions.

Biochemical parameters (leaf pigments, amino acids, proline accumulation, Carbohydrates and phenols) at two stages showed significant differences among the different cultivars of ber under study.

The leaf pigments were reduced from Stage-I to Stage-II. Dandan a high yielding cultivar recorded maximum concentration of these pigments. Whereas, Rambore a low yielder showed intermediate values.

Total free amino acids accumulation increased from Stage-I to Stage-II. Similarly, the Proline levels increased from Stage-I to Stage-II in all the cultivars. However, the high yielders like Dandan and Sanaur-2 showed intermediate values of Proline accumulation. Whereas, low yielding cultivar like Seb recorded higher accumulation of Proline.

Sugars also showed increasing trend from Stage-I to Stage-II with significant differences among all the cultivars. Dandan and Sanaur-2 recorded higher values of non reducing and total sugars, and moderate levels of reducing sugars, along with lower values of starch content in leaf.

The cultivar Sanaur-2 recorded the highest yield followed by Dandan. Whereas, the cultivars like Rambore, Seb, Illaichi, Jogia registered lower yields.

The quality of high yielding cultivars was found poor as indicated by TSS and acidity levels in fruits.

High heritability with high genetic advance as per cent mean were obtained in characters like canopy volume, average fruit weight, fruit yield as phenological parameters, Proline (Stage-I) and total sugar (Stage-I) of biochemical characters and stomatal index stomatal frequency of physiological traits indicating less interference of environment for these characters. Low heritability with least genetic advance as per cent mean was found in relative water content.

Correlation studies revealed that fruit yield was positively correlated with length of secondary branch, average fruit weight, area of leaf (Stage-II), stomatal frequency, stomatal index, total chlorophyll at both stages and Proline at Stage-I.

Salient findings of the investigations

1. Moderate plant canopy in ber was found to be most ideally suited for higher yields, under rainfed conditions.
 2. Plant water status parameters viz., relative water content, leaf moisture content and water saturation deficit values are not reliable parameters for selection in crop improvement programme of ber.
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3. Fruit yield, average fruit weight, canopy volume, total sugar content, Proline (Stage-I), stomatal index and stomatal frequency are parameters expected to respond for direct selection under rainfed conditions.
4. Sanaur-2 and Dandan were found most suitable cultivars having better drought tolerance capacity and higher yielding ability in rainfed regions.

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* Originals are not seen.

APPENDICES

ಕೆ.ಎ. ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಕ್ರೀಡಾಂಗಣ
ಗಾ. ಶ್ರೀ. ಸಿ.ಸಿ., ಬೆಂಗಳೂರು-65
22 MAY 1997
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Appendix I. Climatic condition of experimental site (Monthly Meteorological data for 64 years recorded at Regional Research Station, Raichur)

| Months | Temperature (°C) | | Rainfall (mm) (1930-94) | Relative humidity (%) (1930-94) |
|-----------|----------------------|----------------------|----------------------------|------------------------------------|
| | Maximum (1930-94) | Minimum (1930-94) | | |
| January | 30.53 | 16.20 | 1.87 | 77.05 |
| February | 37.00 | 18.51 | 2.56 | 62.65 |
| March | 38.38 | 21.22 | 6.40 | 53.92 |
| April | 39.85 | 23.97 | 18.09 | 53.96 |
| May | 38.94 | 24.52 | 39.18 | 61.99 |
| June | 35.60 | 22.94 | 34.08 | 75.96 |
| July | 32.77 | 29.74 | 113.85 | 81.39 |
| August | 31.20 | 21.84 | 128.79 | 83.36 |
| September | 32.56 | 22.20 | 154.77 | 82.33 |
| October | 32.20 | 19.07 | 86.35 | 79.70 |
| November | 30.68 | 17.46 | 26.59 | 75.76 |
| December | 29.47 | 10.16 | 8.79 | 77.46 |

Appendix II. Meteorological data during experimental period

| Months | Mean temperature (°C) | | Rainfall (mm) | Mean relative humidity (%) | | Evaporation (mm/day) | Wind speed (km. P.hr.) |
|-----------|-----------------------|---------|---------------|----------------------------|---------|----------------------|------------------------|
| | Maximum | Minimum | | Maximum | Minimum | | |
| 1995 | | | | | | | |
| January | 29.5 | 15.1 | 0.8 | 84.4 | 48.6 | 3.9 | 9.3 |
| February | 34.3 | 19.1 | 0 | 66.8 | 28.8 | 5.6 | 3.8 |
| March | 38.3 | 22.5 | 0 | 66.0 | 23.3 | 7.8 | 5.0 |
| April | 39.8 | 24.7 | 4.2 | 52.0 | 20.0 | 10.4 | 5.4 |
| May | 39.3 | 25.0 | 36.6 | 69.0 | 35.0 | 9.9 | 8.3 |
| June | 37.7 | 23.7 | 292.0 | 76.0 | 38.8 | 9.1 | 10.3 |
| July | 31.6 | 22.9 | 141.6 | 84.0 | 54.0 | 5.0 | 9.2 |
| August | 32.3 | 23.0 | 221.0 | 85.0 | 60.0 | 4.3 | 7.0 |
| September | 32.2 | 22.3 | 146.0 | 86.0 | 59.2 | 4.4 | 5.7 |
| October | 31.2 | 21.8 | 15.6 | 88.2 | 61.4 | 4.1 | 3.9 |
| November | 31.8 | 18.0 | 18.6 | 81.3 | 41.8 | 4.3 | 2.9 |
| December | 30.6 | 16.7 | 0 | 82.6 | 39.3 | 4.4 | 3.8 |
| 1996 | | | | | | | |
| January | 32.0 | 17.4 | 0 | 78.5 | 31.9 | 5.1 | 4.5 |
| February | 33.9 | 18.8 | 0 | 70.9 | 29.2 | 6.4 | 4.9 |
| March | 38.4 | 22.0 | 0 | 58.3 | 22.7 | 8.4 | 4.5 |
| April | 39.6 | 24.6 | 24.5 | 64.6 | 27.8 | 9.0 | 5.6 |
| May | 43.7 | 25.9 | 14.8 | 52.0 | 19.0 | 11.5 | 7.6 |
| June | 35.4 | 23.7 | 23.9 | 80.0 | 46.0 | 6.6 | 9.2 |