



Breeding strategies for improvement of ber (*Ziziphus sp.*)

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Abstract

A significant diversity is available in ber germplasm in India as well in other countries which can be exploited through apposite breeding approaches. There is urgent need to develop varieties which are tolerant to fruit fly and powdery mildew. Earliness is desirable particularly in dry regions for growing ber under rainfed or limited irrigation conditions. There is a need to develop dwarfing, high yielding varieties/rootstocks, varieties suitable for high density planting and early bearing varieties having a better quality of fruits with more storage life. The variety should yield consistently with the local requirements of maturity time, tolerant to biotic and abiotic stresses- resistance to frost, insect pests, diseases, and suitable for post-harvest uses (processing, dehydration, candying). The germplasm suitable for canopy management methods and cultural practices is to be introduced and developed. There are two main bottlenecks in ber breeding programme; polyploidy and incompatibility in its cultivars. Besides these, other constraints in improvement are typical floral morphology, short period of anthesis and stigma receptivity and limited period of fruits availability, owing to these, fruit setting is very less (<10%). The hybridization/crossing protocol need to be standardized, which is also a challenge in ber breeding.

Key words: Ber, germplasm diversity, flower biology, selection, hybridization

Introduction

Ber (*Ziziphus mauritiana* Lamk) is grown in the varying agro-climatic conditions in central Asia, which is the centre of origin of ber (De Candolle, 1886). In India, it has been grown from 4000 years, traditionally from ancient times (Prakash, 1961). However, according to archaeological studies, it is found more than 7000 years ago in China (Qu *et al.*, 1989). It is distributed worldwide in tropical and subtropical regions of south-east Asia, China, Africa, Australia, America and Mediterranean region. Few species are also found in temperate regions. However, it is cultivated in the dried/arid region of the globe. The maximum number of species occurs in Asia, very rare in Oceania and Europe *i.e.* 5.3 and 2.9 per cent, respectively (Liu, 2006). In India, arid part of Rajasthan, Haryana, UP, MP, Gujarat, Maharashtra, Bihar, Andhra Pradesh and Tamil Nadu are major ber growing states (Kumari *et al.*, 2015). It is generally grown in the unproductive, underutilized, inferior soil having pH up to 9.0 in arid and semi-arid regions. The ber plants can be grown in the area where other fruit crops cannot be grown easily. Ber fruits are rich in carbohydrates, minerals, proteins, vitamins and amino acids, aspartic acid, glutamic acid, aserine, asparagine, glycine, and threonine (Bal, 1981). It is richer to apple in nutrients (protein, calcium, phosphorus, vitamin C and carotene) (Bakhshi and Singh, 1974) and oranges in carbohydrates, vitamin C, phosphorus, iron and calorific value. It is a common notion among the people that the ber is a poor man's fruit, but now a days the quality fruits of improved varieties are not in reach of poor people due to its

high market rate. The diploid genotypes were observed resistant to the powdery mildew and octaploid were seedless (Azam-Ali *et al.*, 2006). However, some diploid species were found susceptible to powdery mildew. Diversity in chromosome karyotypes was exhibited higher in Chinese jujube.

Germplasm conservation

The long term conservation of jujube seeds has not given much attention and cross-pollination in this species also reflects higher heterozygosity in seeds. Storage of the *Ziziphus* seeds is not easy to handle and regeneration of seedlings require more time to fruiting. Seeds of *Ziziphus* had orthodox behavior after drying and storage at low temperature. The gene bank of International Center for Underutilized Crops (ICUC) has considered jujube seeds (cultivars, selection and mutants) for collection and maintenance of germplasm to support improvement efforts. These germplasm may be tested at different locations for introduction at new places away from their origin. International Plant Genetic Resource Institute also conserves the germplasm of different species.

In-situ conservation

In *in-situ* conservation, the germplasm is conserved in their natural habitat. The habitats protected from human interference are natural parks, gene sanctuaries, wildlife sanctuaries or biosphere reserve. The areas of the centre of origin or micro centre within the centre of origin preferably the best option for the gene sanctuaries (Azam-Ali *et al.*, 2006). The sanctuary conservation of existing germplasm allows the new germplasm, which appears with the passes of time. But it is very

difficult to maintain and establish new germplasm in the areas of infrastructure development and population pressure areas. It is required to develop the gene sanctuaries of *Z. mauritiana*, *Z. nummularia* and *Z. rotundifolia* in India and *Z. jujuba* in China as a natural habitat or biosphere reserve. In habitat, the targeted species are maintained through natural reserves, wildlife sanctuaries, natural parks, managed forest, protected area, preservation plot and farm conservation through agro-ecosystem.

In-vitro conservation

In this technique, more number of planting material can be preserved in a limited place under controlled conditions using biotechnological tools. Tissue culture methods are suitable for cryopreservation of tissue and/or germplasm. *In-vitro* storage technique for *Z. jujuba* was developed in the Nikitsky Botanical Gardens, Ukraine (Mitrofanova *et al.*, 2002). The explants growth can be retarded by physical (culture condition, light and temperature), chemical (cultural medium) and physiological (crop growth stage, plant age and dormancy) factors.

Germplasm centres

Several ber germplasm including species, cultivars and other types have also been collected at different research stations in the country and are being maintained in the field gene bank centres namely CIAH, Bikaner, NBPGR, Jodhpur, MPKV, Rahuri, CCS HAU, Hisar, CCS HAU, RRS, Bawal, CAZRI, Jodhpur, GAU, SK Nagar. At CIAH, Bikaner highest collections (338) have been made in the National Field Repository (Vashistha, 2006). Most of the leading germplasm in India and China were selected from the heterogeneous population or wild forest. The superior types of germplasm/cultivars were multiplied vegetatively and cultivated on a widespread area e.g. Umran and Gola (Indian jujube) and Sui Men (Chinese jujube). In India, about 300 varieties of ber are being cultivated and few of them become commercially important (Pareek and Nath, 1996), but 180 varieties are mentioned in the literature (Pareek, 2001). In China, about 700 cultivars of jujube are reported by Qu and Wang, 1993. These are divided into two groups- sour and sweet type. Sour type is mostly used as rootstock, animal fodder and medicinal purpose, while sweet type is used as a scion for fruit consumption (Ciminata, 1996).

Resistant germplasm

Powdery mildew: Jamadar *et al.* (2009) studied different germplasm of ber for powdery mildew and reported Mundia and Jogia resistant to powdery mildew, Banarsi Kadaka was moderately resistant, while Umran was reported as susceptible. Godhara *et al.* (2002) studied different germplasm, among them Darakhi-1, Darakhi-2, Safeda Rohtak, Villaiti, Guli and Seedless were reported free from disease. However, Kaithali, Umran, Sandhura Narnaul and Illaichi were susceptible to powdery mildew.

Fruit fly: Thirty five germplasm of ber were screened against

fruit fly. On the basis of per cent infestation these were categorized into four categories, i.e. resistant (infestation less than 1.0 %), less susceptible (infestation from 1 to 10%), moderate susceptible (infestation from 10 to 20 %) and highly susceptible (infestation more than 20%). Among these germplasm, BS 1 was found free from fruit fly infestation whereas Gola, Umran, Mudia Murhara, Laddu and Kaithali were found highly susceptible to fruit fly. Mann and Bindra (1976) reported the damage of fruit fly in cultivars Sanaur-1, Safeda Selected, Illaichi, Mirchia, ZG-3 and Umran. However, Singh (1984) observed that infestation was varied from cultivars to cultivars and reported 6.7% in Tikadi to 73% in Gola.

Genetic erosion

The growing of clonally or vegetatively propagated plants are the main sources of genetic erosion in addition to this the rejuvenation and top working also converted the local germplasm into the improved cultivars (Yadav, 1991). The primary centre of origin becomes the secondary centres (Tropical Africa for *Z. mauritiana*, South-west Asia, Central Asia and parts of Africa for *Z. jujuba*), whilst the population pressure and developmental activities caused the conversion of wildlife sanctuary into the residential area and manufacture unit. Rural community is using the *Ziziphus* for many purposes (windbreak, shelterbelt, fencing, firewood and timber) which caused genetic erosion.

Variability

The physical and morphological variability in germplasm can be studied as recommended in the descriptor of NBPGR (Mahajan *et al.*, 2002) and guidelines for DUS testing of PPV&FRA (Anonymous, 2016). However, the biotechnological tools are the best to find genetic variability.

Genetic variability

Ploidy level: Molecular marker-based study is used to find genetic diversity as compared to conventional/ morphological method. AFLP has been used in limited accessions to study the genetic diversity of different germplasm of *Ziziphus sp.* (Singh *et al.*, 2006). The variability in ploidy level varied from tetraploid to octaploid ($x=12$) and natural allopolyploids also created a large variability (Khoshoo and Singh, 1963). However, Indian jujube usually appears polyploidy, $n = 12, 20, 24, 30, 36, \text{ or } 48$. Khoshoo and Singh (1963) also observed variation in cultivars as $n = 24$ (most of the cultivars), $n = 48$ (two cultivars) and $n = 30$ (one cultivar), however, Nehra *et al.* (1983) observed $n = 4$ (wild material). Only limited wild species have been counted particularly *Z. lotus* ($n=10$), *Z. nummularia* ($n=12$) and *Z. oenoplia* ($n=36$) and *Z. lotus*, *Z. oenoplia* and *Z. nummularia* were observed as diploid, tetraploid and polyploidy, respectively. The possibility of genus exists as tribasic with $x = 10, 12, \text{ or } 13$ (Darlington and Wylie, 1955). Diploid, triploid, tetraploid, pentaploid and octoploid are the range of polyploids observed in Indian jujube, while Chinese represented polyploid series $2n = 45, 60, 90$ (Mehetre and Dahat, 2000).

Morphological variability

A wide variation exhibited in growth, flowering, yield and quality parameters of *Ziziphus* is due to cross-pollination. The variability in morphological and physicochemical traits has also been reported by Shobha *et al.* (2001). As per DUS study conducted by Krishna *et al.* (2006), the maturity of fruits varied as early (Gola), mid season (Banarasi Karaka, Banarasi Pewandi, Chhuhara, Chhuhara Bawal, Illaichi, Kaithali, Mundia, Narma, Reshmi, Safeda Selection, Seb), while (Dharki No.1, Gularivasi, Jogia, Kala Gola, Katha Phal, Lakhan, Mehrun, Safeda Rohtak, Sanaur-5, Tikadi, Umran, ZG-3) were late-maturing varieties. Out of 24 cultivars have anthocyanin blush on immature fruits *i.e.* Katha Phal and Sanaur-5, while no blush on development was observed on other 22 varieties. Vegetative characters such as leaf area and branching habit are the most appropriate characters of classification, while fruit apex, stalk, shape and stylar flesh cavities are dependable characters (Bal, 1992). Some cultivated and wild species have serrated leaf margin *Z. mauritiana*, *Z. nummularia* and *Z. rotundifolia*, except *Jhar ber* and *Desi ber* (Gupta *et al.*, 2003). Higher coefficient of variation was observed in leaf (39.4%) than edible to the inedible portion of fruit (2.7%); variation was also observed in fruit shape, seed and flower bud opening time.

Reproductive variability

Flowering and fruit set: In North Indian conditions the tree shed leaves during March to April and starts vegetative growth from June onwards and flowering on the current season growth during August-September. Flowers are borne on axillary cluster/ cymes. The ber flowers are greenish-yellow, faintly fragrant, pentamerous, hermaphrodite, calyx with deltoid lobed, hairy outside, glabrous within petals 5, sub spatulate, concave, reflexed stamens 5; ovary 2-celled, styles bifid, disc 10-lobed or grooved (Azam-Ali *et al.*, 2006). Flower sepals are dorsally tomentose, disc diameter (3 mm), ovary is 2-celled, disc is immersed, styles are two having 1 mm length. Nehra *et al.* (1984) recorded the initiation of flowering in ber cultivars from September to November under Hisar condition. Kundi *et al.* (1989) observed the time of flowering from 1st week of October to 1st week of November in various cultivars of ber in Pakistan. Flowers emerge from mid-May to late June in northern China (Zeng *et al.*, 1959), however, flowering from June to July in Korea (Cheong and

Kim, 1984), May to August in California, USA (Ackerman, 1961). Flowers bear in the cluster and ranged from 10-14 and 16 to 28, varied with agro-climatic conditions (Josan *et al.*, 1980). Umran had recorded the highest hermaphrodite flower (22.2%), followed by Gurgaon Gola (20.1 %) (Singh and Jindal, 1980).

Flowering duration: The variation in the duration of flowering varied with the cultivars, it ranged from 68 to 94 days (Babu and Kumar, 1998) and 57 to 75 days (Dhaliwal and Bal, 1998). The duration of flowering was observed as 71 ± 5.62 days in Gola, 68 ± 4.49 days in Seb, while shortest flowering duration (47 days) was observed in Tikadi and longest (71 days) in Umran.

Flower order: Flowers on the bearing shoots emerge simultaneously. Flowers emergence on the middle part of the bearing shoot than the upper and middle part of the bearing shoot, fruits also mature early in the middle of the shoot as compared to apex and base (Qu *et al.*, 1989a).

Selection

Most of the planting materials selected and identified during the survey having better yield and quality traits with good economic returns. The identified germplasm is maintained and multiplied vegetatively. Most of the cultivars are being developed by selection. These cultivars have been developed as a result of cross-pollination (entomophilous) or natural hybrids in the different germplasm of wide genetic base available in the locality (Khoshoo and Singh, 1963). The best performing genotypes are propagated vegetatively for multiplication of true to type planting material. Tikadi has been developed as a result of selection form the *Z. rotundifolia* having ovate fruit shape. This selection has a good pulp stone ratio, TSS, shelf life and resistant to fruit fly (*Carpomyia vesuviana*). Artificial cross-breeding is very difficult in the ber therefore most of the cultivars are developed by selection (Zhu *et al.*, 1998). The great variability exists within the leading cultivars (Luo *et al.*, 1997) so the chances to develop new cultivar within the cultivars are more. Gola cultivar has got many variants such as Kala Gola, Kakrola Gola, Gurgaon Gola, Gurgaon Gola-I, II, *etc* (Pareek, 2001). The variety of ber Goma Kirti selected from the population of Umran at CHES, Godhara.

Table 1. Screening of ber germplasm against fruit fly at RRS Bawal (Anonymous, 2020)

S/No.	Varieties/ germplasm	Categories
1	BS-1 (1)	Less than 1.0 % (Resistant)
2	Illaichi, Sanaur No.3, Nauki, Katha Gurgaon, Khathaphal, Banarasi, BS2, Jhajjar, Tasbataso, Reshmi, Narkali, Khatti, Desi Alwar (13)	1-10% (Less susceptible)
3	Sua, Seo, Jhajjar Special, Sandhura Narnaul, Akhrota, Safeda Rohtak, Seo Bhadurgarh, Popular Gola, Nazuk, Kakrola Gola, Katha Rajasthani, Illaichi Jhajjar, Govidgarh Selection, Gola Gurgaon no.2, Bhadurgarhia (15)	10 to 20 % (Moderate susceptible)
4	Gola, Umran, Thornless, Mundia Murhara, Laddu and Kaithali (6)	More than 20% (Highly susceptible)

Pollen viability: Wodehouse (1960) studied pollen of *Ziziphus*. Later on, Rouhaksh *et al.* (2014) studies morphology of different species of *Ziziphus*. The pollen of flowering branches was collected between 6.00-7.00 AM during cool hours and reported the $93 \pm 2.93\%$ at anthesis. 1.0% of 2, 3, 5- triphenyl tetrazolium chloride (TTC) is used to study the viability of pollen by staining and recorded viable pollen after 2 hours (Shivanna and Rangaswamy, 1992). Pollen viability of most of the Chinese jujube was reported 50% to less than 10% (Wang, 2004). The percentage of pollen viability was recorded in five replications and calculated using the following formula:

Pollen germination (%) = (Total number of germinated pollen/ total number of pollens) x 100

Pollen germination: Pollens are yellowish, sticky with fine mass. Sucrose solution was observed the best medium for pollen germination. Pollen grain germination was ranged from 36.47 to 47.66 per cent in different cultivars of ber. The pollen germination of *Z. sativa* cv. Moodeung and Bokjo increased with increase in concentration of sucrose from 1.0 to 10.0 % and thereafter it decreased with increase in the concentration of sucrose (Park and Yu, 1989) and it further increased with the addition of 35 ppm boric acid (Yun *et al.*, 1989). Pollen germination under *in-vitro* conditions was observed optimal in 30% sucrose solution solidified with 1.0% agar (Mchedlidze and Shekiladze, 1986). However, Yun *et al.* (1989) observed 37-39% germination of fresh pollen at 35-30 °C in 15% sucrose solution solidified with 1.0% agar medium by 24 hours, thereafter it decreased and no germination after 24 hours. Pollen germination was observed maximum ($91 \pm 2.65\%$) in 20% sucrose and minimum ($35 \pm 1.61\%$) in 5% sucrose, but observed maximum $48.35 \pm 1.75 \mu\text{m}$ pollen tube length (Dinesh, 2018). The pollen germination (%) was observed using the following formula:

Pollen viability (%) = (No. of stained pollen/ total no. of pollen) x 100

Pollination: Pollination was observed by the honeybee, housefly and ladybird (*Coccinella novemnotata*), however, wind pollination was observed nil in Chinese jujube in California (Ackerman, 1961). The insects remain more active between 11.00 h to 15.00 h. The house fly was observed more efficient and active for a longer period in pollination as compared to the honeybee; both are most active at noon. It is also reported the insect's viz., housefly (*Musca domestica*), honeybee (*Apis sp.*) and the yellow wasp (*Polistes herbarucus*) are the most common pollinating agent for *Ziziphus* (Dhaliwal, 1975).

Size and shape of pollen grain: Nehra *et al.* (1984) observed the variability in pollen grains of *Z. mauritiana* (Illaichi, Umran) and four wild species. Hulwale *et al.* (1995) conducted pollen study in seven cultivars of ber, pollen grain size ranged from 20.05 to 32.04 μm and stain ability ranged from 63.69 to 87.12 per cent. Perveen and Qaiser (2002)

observed the morphology of pollen by light and scanning electron microscope of 5 genera and 11 species of *Rhamnaceae* collected from Pakistan and reported the variability in shape and size from oblate spheroidal and sub-prolate, tricolporate, exine surface sexine thicker than nexine, striate-rugulate and rarely reticulate-rugulate, often psilate in all the species. Pollen grains are monads, small in size with polar axis $22.65 \mu\text{m}$ and equatorial diameter $21.15 \mu\text{m}$ and P:E ratio 1.07, the shape is spheroidal-prolate, tricolporate, isopolar, polar view triangular, operculum irregular and interapertural area are sunken, exine surface regulate in the middle and smooth towards the colpi (Dinesh, 2018).

Fertilization

Chinese jujube has profuse flowering but less than 2 per cent of flowers developed into mature fruits (Qu and Wang, 1993). Heavy fruit drop just after the fruit set due to lack of fertilization and degeneration of ovule. Other biotic (insect-pest and disease) and abiotic reasons for fruit drops are moisture stress, low relative humidity, lack of sunlight and high winds during the initial phase of fruiting (Liu *et al.*, 1997). In self-pollination or cross-pollination, it took at least 4 h to recognize pollen and stigma to each other, 6 h to germinate pollen on the stigma, 12 h to penetrate pollen tube into the mastoid cells and grow into the style, 24 h to reach pollen tube $1/4^{\text{th}}$ of the style (Shao and Wang, 2020). Receptivity of the stigma and viability of pollen are important factors for fertilization. Fertilization was observed 10 days after pollination, proembryo formation after 20 days, globular embryo stage appeared after 30 days, and the embryo could be distinguished after 40 days. The embryo grew rapidly between 45 and 50 days post-anthesis. Two polar nuclei began to fuse to form the secondary nucleus in the embryo sac at 72 h after pollination. After 96 h of pollination, one sperm fused with the secondary nucleus in the embryo sac and formed the primary endosperm nucleus, and the other sperm moved to the vicinity of the egg cell. After pollination for 120 h, another sperm fused with the egg cell, forming a zygote. The zygote did not divide immediately; it began to divide after 4 to 5 days of dormancy (Shao and Wang, 2020). It first divided into a two-cell proembryo, then a three-cell proembryo, then a four-cell proembryo, and formed an early globular embryo after pollination for 10 days. Then 20 days after pollination the embryo body grew in length, width, thickness, and formed into a round shape (a globular embryo).

Hybridization

The flower size of *Ziziphus* is very small and flower emasculation is very difficult without damage to flower, so cross-pollination is difficult. In addition, to this the embryo abortion, self-incompatibility (Godara, 1981) and polyploidy are also serious problems. Better germplasm is identified and screened at different institute/ university because the performance of the germplasm/ cultivars is location-specific. Chundawat and Srivastava (1980) made attempts for inter varietal crosses but obtained seeds of Seb x Umran, Seb x Katha, and Umran x Seb. Vashistha and Pareek (1983) attempted several crosses of Gola, Seb, Sanaur 2, Katha and

Umran and observed maximum fruit set in Umran x Katha and its reciprocal due to isogenic behaviour. The Illaichi had reported 95 per cent pollen sterility due to octaploids ($2n = 96$) genetic makeup (Khoshoo and Singh, 1963). Seb and Gola (tertaploid) are early and commercially accepted varieties included in the hybridization. Seb x Gola with Tikadi was crossed reciprocally, Gola with Tikadi were incompatible, but Seb x Tikadi was compatible and fruit set was hardly one per cent (Singh and Vashishtha, 1993). The successful seeds were raised in the pot and later on budded on rootstock; the plant has resembled with the Tikadi with higher TSS, and resistance to the fruit fly. Tissue culture can be opted to overcome the constraints and rapid multiplication (Sudherson *et al.*, 2001). Singh and Vashishtha (1984) evaluated the ber germplasm at ICAR-CAZRI, Jodhpur to locate the fruit fly resistance germplasm. It was observed that the cultivar Illaichi performed moderately resistance while Tikadi performed resistant to the fruit fly. Thar Sevika (Seb x Katha Phal) hybrid of ber released by ICAR-CIAH, Bikaner.

Embryo abortion and embryo culture

Embryo abortion is common in *Ziziphus* large fruits show less embryo abortion as compared to small fruits. Embryo can be cultured in medium MS + BA 0.1-0.5 mg/l + IBA 0.5-0.1 mg/l + NAA 0.1 mg/l + sucrose 50g/l + agar 7g/l + LH (lactalbumin + hydrolysate) 500 mg/l, then transferred to growing medium MS + sucrose 30g/l + agar 5g/l. The plant can be obtained from the embryo using an immature embryo for direct development, callus formation from the immature embryo and keeping it development from the young embryo (less than 30 days old) (Qi and Liu, 2004). Qi and Liu 2004 also reported that the survival rate is 87-90 and 3.7 per cent for 55 days and 20 days embryo, respectively. For better embryo germination low level of BA and high level of IBA in the proper quantity of luteinizing hormone-induced adventitious bud. However, low temperature (2-4°C) for 44 days favour plantlet formation from poor quality plantlet and darkness of 7-10 days favour rooting of the embryo. Embryo culture can be improved from earlier fruit set with the normal embryo, cutting the tip off main root stimulates the lateral root formation. Qi (2002) reported that the flesh of cultivars (seedless) contains high GA₃ and IAA level than cultivars having seeds. Similarly, high embryo abortion cultivars also having more GA₃ and IAA levels as compared to the flesh of seeded fruits. Wang (2004) reported that the high level of nutrients in flesh leads to low nutrients in the ovule, which cause embryo abortion at stone hardening stage. High ratio of Z/GA and zeatin (Z) caused the seed to shrink at the later stage of embryo development.

Male sterility

Wang (2004) reported two types of male sterility functional pollen sterility (high sterile pollen-pollen germination less than 3 %) and empty anther sacs (empty at yellow bud stage), it varies with the cultivars due to differing in cytological, physiological, and biochemical mechanisms. Pollen fertility is estimated by I₂-IK (Iodine- potassium iodide) staining. Based on the staining, cultivars were divided

into 5 groups, i.e. high fertility (VPR i.e. viable pollen rate $\geq 54\%$), medium-high fertility ($43\% \leq VPR < 54\%$), medium fertility ($28\% \leq VPR < 43\%$), medium sterility ($17\% \leq VPR < 28\%$) and high male sterility (VPR $< 17\%$). The nutrients, enzymes and hormone significantly differ in flowers bud of different cultivars cause variation of male sterility.

Inheritance

Detailed genetic study is yet to be conducted to find the relationship between quantitative and qualitative characters. Some attempts have been made to study the genetic correlation between desirable traits. The estimation of heritability is important for plant breeders to enable the selection programme based on the phenotypic performance of germplasm and predicting the results. Qualitative characters controlled by one or few genes are manipulated in genetic programme; quantitative characters are controlled by many genes (polygenes). The characters which are not affected by the environment are strongly affected as compared to the characters which are environmentally influenced. Genotypic coefficient of variation and phenotypic coefficient of variation was greatest for stomatal frequency while the lowest for relative water content. The high value of genetic gain and heritability was observed for the stomatal index, which is positively correlated with the yield (Praveen and Patil, 1998). High estimates of GCV, PCV, genetic advance and heritability were recorded for fruit weight, stone size, pulp stone ratio and yield indicating the improvement effectiveness through simple selection (Saran, 2005). The heritability values were observed highest for days from fruit set to ripening (99.2%); followed by fruit set (94.7%), days from pruning to sprouting (93.6%), fruit drop (85.0%) and shoot length (82.0%) (Panse, 1957). Heritability in 30 cultivars of ber was observed and the value for total soluble solids 54.2 per cent, for disease intensity 99.63 per cent, and the value for acidity was 91.61 per cent (Bisla and Daulta, 1988a), however, highest genetic gain (142.8%) was recorded for fruit set and lowest (3.5%) for days from pruning to flower initiation. Further, Bisla and Daulta (1988b) studied heritability in *Z. mauritiana*, it was 97.2 per cent for fruit weight, followed by fruit size (87.9%), pulp/stone ratio (87.5%) and seed weight (84.6%) at Hisar.

Anthesis

Anthesis in *Ziziphus* is cultivar specific it occurs in the morning, noon and evening hours. Anthesis in some cultivars is during morning hours (7.30-8.30 AM) like Seb, Jogiya, Illaichi, Ponda and Aliganj, while in Gola and Mundia it occurs between 12.00 noon to 1.00 PM. Vashishtha and Pareek (1983) reported the anthesis time from 7.30 to 8.00 AM in Seb and Sanaur-2, between 1.00 to 2.00 PM Gola, Katha and Umran. While Desai *et al.* (1986) reported anthesis time in Chuhara between 5.30 to 7.30 AM; in Sanaur between 12.30 to 2.45 PM. Kim and Kim (1984) reported that the afternoon flower opening cultivars required a photoperiod of 12 h, while morning anthesis cultivars require a definite dark period for induction of flowering. After completion of anthesis, sepals turn outwards leaving anthers leaned on ovary (Qu *et al.*, 1989a). Anthesis under south western Haryana (RRS, Bawal)

condition takes place from 6.30 to 7.30 AM in Narendra Selection 1, BS 1, BS 2; 6.30 to 8.00 AM in CIAH Selection 1 (Thar Bhuvraj) and CIAH Hybrid-1 (Thar Sevika); 12.00 noon to 1.00 PM in Chhuhara, Kaithali, Umran, Gola, Rohtak Safeda and Narendra Selection 2.

Dehiscence

In most of the cultivars dehiscence starts from the time of anthesis of flowering to 4 to 5 hours of anthesis, it varied with cultivars (Sharma *et al.*, 1990). Vashishtha and Pareek (1979) studied Gola, Seb, Mundia, Illaichi, Ponda, Jogiya and Aliganj cultivars and observed the completion of dehiscence in an hour after anthesis. Dehiscence starts just after the opening of the petal sometimes it may be before the emergence of anther from the sheath (Ackerman, 1961). Pollen dehiscence took place during the first day of flowering and it followed by anthesis from 0.5 h to 2 to 4 h (Dhaliwal and Bal, 1998).

Stigma receptivity

After the rapture of the flower bud/ opening of the flower, the moist and shining (exude nectar) stigma shows the sign of receptivity, it happens just after the opening of the flower (Dhaliwal and Bal, 1998). At the time of anthesis, the stigma look likes minute protuberance. Full development of the stigma takes place after 16-18 hours of anthesis, it indicted as bi or sometimes trifurcation. It remains receptive/ sticky for 13 to 24 h (Desai *et al.*, 1986) and up to 48 h (Godara, 1980). Anthesis and receptivity of the stigma are a cultivar specific (Pareek, 2001). In some cultivars, anthesis and receptivity varied as the morning, noon and evening hours. However, the dehiscence of the anther (separation of petal stamen) occurs in the day time (Qu *et al.*, 1989). The time of anthesis influenced by temperature, rains and clouds (Wang *et al.*, 1989). Ackerman (1961) observed the maximum pollination took place on the date of anthesis.

Marker assisted cross breeding

In a conventional cross-breeding, the varieties/plants are propagated in the same rootstock and cover it with the net house to avoid the pollination from the outside. A box of the honey bee is placed inside the net house for proper cross-pollination. In addition to this embryo rescue, marker-assisted cross breeding has also been carried out by different researchers. Different marker studies such as RAPDs and AFLPs are used for identification of seed obtained as a cross-pollination (hybridization) or self-pollination.

Ploidy manipulation

Cross-pollination in the *Ziziphus* is very difficult, polyploidy breeding is the easy way for breeding in for large fruits and high resistance. Diversity in chromosome number of Chinese ber is very low. Qu *et al.* (1986) studied 117 cultivars and found only one triploid and others were diploid. Jiang (2003) treated the ber shoots cultivars of Dongzao, Linyilzao, and Lijiaozaos with colchicine 0.15%/18hr, 0.1%/30 hr and 0.15%/18hr, and showed induction rate 50, 43.3 and 43.3 per cent, respectively and produced tetraploid and showed

chromosome $2n = 24$ (normal diploid number) and 48. The plants with induced tetraploid showed double chromosome number, large and longer cells and guard cells, more chloroplast and lower density of stomata. The pollen grain is large, deformed and had 4 germination pores. Internodes are shorter but leaves are rounded and thick. Wang, 2004 also treated cluster bud of sour ber and Dongzao with colchicine 50 mg/l for 40 days with a doubling rate of 36.7 and 26.3 per cent, respectively. He also studied the 4 days pre-culture, 15 days dark treatment and addition of 0.5 per cent DMSO and 1.5 mg/l activated carbon improve the doubling effect. Cells of tetraploid shoots were larger than diploid. Tetraploid parts can be purified effectively after 3 or 4 times (at most 8 times) of transplanting.

Biotechnology and mutation

Zhou (2004) observed the most efficient regeneration medium for cultivar Dongzao was MS + TDZ 1.0 mg/l + IBA 1.0-0.5 mg/l (pH 5.8-6.4) during the first 4 weeks followed by medium with CTK (MS + IBA 0.1 mg/l + GA₃ 0.05 mg/l), it achieved 91.3 per cent regeneration. However, for cultivar Lajiaozaos was WPM + TDZ 0.5 mg/l + IBA 0.1 mg/l (pH 5.8-6.4) and MS + IBA 0.1 mg/l + GA₃ 0.05 mg/l, respectively was most suitable medium, achieved 78.9 per cent regeneration rate. Supplementation of 0.1 mg/l AgNO₃ to the medium was beneficial and dark treatment for 14 days increased regeneration rate. Sin'ko and Chemarin (1979) tried gamma irradiation on growth and development of jujube breeding and Sin'ko and Karakhanova (1982) obtained some mutants.

Techniques for improving fruit set

Fruit of jujube is solitary with stony seed and fruit set during November-December. The flowering is very abundant in Chinese jujube but the fruit set is very low (<1.0%) under natural conditions. Improvement in fruit set is mandatory for better fruit production. The marked variation in fruit set was observed among different cultivars. Gupta and Minhas (1991) reported the fruit set under bagging was 8 per cent in Illaichi, followed by Umran (6.0%), whereas fruit set was observed nil in Sanaur-2, Sanaur-3, Sanaur-4, Sanaur-5, Kaithali and Chhuhara. Vashishtha and Pareek (1979) observed self-incompatibility in jujube varieties (Gola, Seb, Jogiya, Aliganj, Ponda, Illaichi and Mundia); Godara (1980) observed in Banarasi Karaka, Illaichi, Karkrola Gola, Kaithali, Kathaphal, Mundia Murhara, Reshmi, Sandhura Narnaul, Safeda Selected and Umran; Mehrotra and Gupta (1985) in ZG-2 and Sanaur-2; Neeraja *et al.* (1995) in Gola, Umran and Seb. Josan *et al.* (1981) did not found any fruit on self-pollinated varieties. However, Illaichi and Umran were observed as self-fruitfulness varieties (Mehrotra and Gupta, 1985). Singh and Vashishtha (1993) also reported cross-incompatible varieties. The crossing of ZG-4, Kala Gola and Sanaur-2 with Umran (male parent) observed no fruit set (Gupta and Minhas, 1991). However, Umran (as female) is cross-compatible with Umran (male parent). But Godara (1980) reported that the Umran is less compatible with other varieties as male as well as the female parent. Mehrotra and Gupta (1985) reported Sanaur-2

as self-incompatible as well as cross incompatible with Umran (female parent). Highest fruit set were observed in Illaichi x Kakrola Gola, while the combined ability of Umran showed best (as male as well as female) (Godara, 1980). Fruit set in open pollination was observed highest in Umran (23.1%); followed by Seb (18.6%) and Gola (13.7%). Highest fruit setting in hand pollination (60%) was recorded in Umran x Seb as compared to open pollination (Neeraja *et al.*, 1995).

Creating optimal pollination conditions

Fruit set can be improved by keeping honey bee in the orchard during flowering. The pollen does not germinate in humidity below 60 per cent. High temperature and drought conditions cause poor pollination and fruit set, spraying of water helps improve the pollination. Physiological and environment conditions are responsible for fruit setting. Fruit drop was observed highest (68.6%) in Illaichi and lowest (24.1%) in Ponda (Vashishtha and Pareek, 1979). Panwar (1980) reported the highest fruit drop (80.6%) in Kakrol Gola than Umran (7.2%) and Kaithali (12.1%). The smaller fruit (<1.0 cm diameter) observed >50 per cent drop and it decreased with increase in size of the fruits.

Spraying growth regulators and chemicals

It is better to improve the fruit regulation and prevent the pre-harvest fruit drop. Fruit setting can be improved by spraying 10-20 ppm GA₃ 3-4 times at 5-6 days interval at full bloom stage or two sprays of borate 0.2 per cent during full bloom stage for rapid fruit growth (Liu, 2004). 10.4 to 12.2 per cent fruit set and 22.1 to 28.8 per cent seed set obtained in pollination during morning hours, followed by the spray of boric acid 100 or 200 ppm in the afternoon (Yun *et al.*, 1995). However, pollination during evening hours followed by a spray of boric acid 200 ppm along with NAA 1 ppm observed 2.0 per cent fruit set and seed set 11.8 per cent. The premature fruit drop can be controlled by the application of NAA 10-20 ppm before the expected fruit drop and 4 weeks before harvest (Yung and Liu, 1990).

Rootstock genetic resources

In addition to the above facts the potential use of rootstock and maintenance in the collection is required. Not much emphasis has been given to the rootstocks only wild species are being used and tested as rootstocks. Bal *et al.* (1997) has reported the rootstocks compatibility species for Indian jujube. They reported that *Z. mauritiana*, *Z. mauritiana* var. *rotundifolia* (wild/naturalised), *Z. Abyssinia* as most successful and widely used rootstocks. Less successful but mostly compatible and often cultivar specific were *Z. nummularia*, *Z. xylopyrus*, *Z. spina-christi*, *Z. mucronata*, *Z. oenoplia* and *Z. jujube*. Chinese jujube rootstocks are most frequently wild materials (especially var. *spinosa*) related to the cultivars, but several other wild species have been tried in areas of China with more extreme climates (Ming and Sun, 1986).

Exploitable attributes of wild species in ber improvement

Z. nummularia and *Z. lotus* are drought tolerance,

having dwarf tree stature and extensive root system and early fruit maturity. *Z. jujuba* found resistance to low-temperature damage with excellent dehydration quality of fruits and high vitamin C and P contents in fruits. *Z. mistol* is resistance to low-temperature damage while *Z. mauritiana* var. *rotundifolia* had vigorous tree frame, wood of marginal timber value (Pareek, 2001).

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Improvement of custard apple (*Annona squamosa* L.)

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Abstract

Immense prospects exist to develop desirable cultivars of annonaceous fruits by conventional breeding techniques. There is greater scope to exploit inter-specific variation than intra-species variation. Edible *Annona* species exhibit morphological affinity to one another but each one is unique and distinct for fruit shape, size, skin surface, pulp colour, texture, flavour and taste. Some species like *Annona squamosa* exhibit narrow genetic variation. However, several interesting traits are available in one or the other allied *Annona* species. Because there are no serious barriers in inter-specific hybridization between *A. squamosa*, *A. cherimola* and *A. reticulata* gene transfer across species boundaries is possible. Gene exchange among them should result in interesting novel recombinants at times most esteemed ones like the popular atemoya.

Key words: *Annona* species, cytogenetics, flower biology, improvement, varieties

Introduction

The Annonaceae or custard apple family comprises about 120 genera and more than 2000 species (Leboeuf *et al.*, 1982). The genus *Annona* is the most economically important one, containing 120 species. The major commercial species throughout the world are: the cherimoya (*Annona cherimola*), sweetsop (*Annona squamosa*) and atemoya (a hybrid of *Annona squamosa* and *Annona cherimola*). The sweetsop species name 'squamosa' refers to the knobby appearance of the fruit. Sweetsop is a small tropical tree originating in the New World tropics, probably Central America. This species is the most widely grown in the tropical regions of the America, Africa, Asia and the Pacific. Sweetsop is also named sugar apple and has many other regional names, such as Custard apple (India), anon (Spanish), ata (Portuguese), noi-na (Thailand), stis (The Philippines) and fan-li-chi (Taiwan). Sweetsop is the mostly grown *Annona* species. The fruit is frequently found in village markets but has not shown much potential for large commercial cultivation due to the small fruit size, frequent cracking at maturity and poor shelf life. The perishable nature and supply shortages make marketing localized or air shipment essential. Fruit is usually harvested from July to October and can be extended to March if summer pruning is conducted. In India, the peak of production occurs later between August to November and in Thailand, Florida and the Caribbean between July and September. Taiwan's peak of production occurs between July and March. Sweetsop is a good source of carbohydrate, potassium, calcium, phosphorus and ascorbic acid. The fruit is usually consumed fresh and also can be used to make juices, shakes and ice creams.

Cytogenetics and breeding

Understanding cytology of a crop is useful in planning breeding programme. The chromosome number of *Annona squamosa* is $2n=14$. Cross-pollination between species is conducted primarily to determine compatibility for increasing fruit set. Inter and intraspecific cross combinations among *Annona squamosa*, *A. atemoya*, *A. reticulata*, *A. glabra*, *A. cherimola* and *A. muricata* were investigated by Kumar and Jalikop (2000). They reported that *A. squamosa* was the most effective pollen parent of *A. atemoya* and *A. cherimola*. However, *A. squamosa* was not an effective female parent with *A. atemoya*, whereas *A. cherimola* was compatible with both *A. squamosa* and *A. cherimola*. *A. atemoya* can be crossed freely with *A. reticulata*, *A. glabra* and *A. cherimola*. *A. atemoya* is the only hybrid that has gained importance and it has inherited the glabrate leaf character of *A. squamosa* and a leaf size almost as large as that of *A. cherimola*. Flowering and fruiting seasons are similar to those of sweetsop. Skin, pulp and seed characters of both parents are inherited in varying degrees by each plant. A desirable hybrid would be between the cherimoya and soursop that combines the larger fruit size and acidity of the soursop and the cherimoya's sweetness, flavour and texture. Attempts to cross the soursop with cherimoya, ilama, bullock's heart or sweetsop have not been successful and may reflect a considerable genetic distance of soursop from the other species (Paull and Duarte, 2011). Jalikop (2010a) investigated the inheritance of foliage characteristics in trispecies hybrids of atemoya (*A. cherimola* x *A. squamosa*) and *A. reticulata*. Segregation for leaf colour (green or dark green), leaf angle (erect or drooping), leaf apex shape (rounded or pointed) and time of leaf fall (early or late or intermediate) into discreet phenotypic classes revealed that their inheritance followed simple Mendelian genetics. Duplicate dominant gene interaction

governed the leaf colour and leaf position. Individuals with single or both the dominant genes (A-B-, A-bb, aaB-) produce green colour leaves and those with recessive genes (aabb) dark colour leaves. Likewise erect leaf individuals are C-D-, C-dd, ccD- and drooping leaves are ccdd. A single gene determined shape of leaf apex that was either rounded (Rr) or pointed (rr). Segregation of progenies for leaf fall into early, intermediate and late suggested that co-dominant alleles were responsible for time of leaf fall. The pattern of segregation of tree and fruit traits in trispecies hybrids (*A. cherimola* Mill. x *A. squamosa* L.) and *A. reticulata* L. have been investigated by Jalikop (2010b) with the objective of salvaging useful genes from the three edible annonas and determining the extent of variation in the progeny. The heterogenous nature of *Annona* species and simultaneous segregation of three distant genomes resulted in a tremendous heterogeneity in the progenies and thus demonstrated that *A. reticulata* is potentially a valuable source of a variety of novel traits. However, the F1 trihybrids exhibited reduced fertility with pronounced undesirable traits of *A. reticulata*, and the survival of F2 trees was poor, with those that did survive being extremely weak and failing to flower or set fruit. Consequently, backcrossing may be more suitable approach than advancing trihybrid generation for transferring desirable genes from *A. reticulata*. Backcrossing F1 progeny of [(*A. cherimola* x *A. squamosa*) x *A. reticulata*] to *A. squamosa*, a highly fertile species, is expected to yield productive introgressions in which the contribution of the *A. squamosa* genome will be extended from 25 to 62.5% in F1BC1 generation.

Problems in breeding

Wester (1913) was the first scientist to realize the possibilities for genetic improvement of annonas and initiated breeding programmes in Florida and in the Philippines. The long reproductive cycles, higher levels of heterozygosity and the costs associated with evaluating large populations of crosses limits breeding programmes. Existing commercial cultivars show considerable variation in growth, fruit set, fruit size and quality. No single variety has all the desirable characteristics. The length of the juvenile period varies, with earliest production occurring in 2 years and full production in 5-6 years. This juvenile period is extremely variable with scions on seedling rootstocks. The seedling rootstocks are derived from extremely heterogeneous, open-pollinated seeds; hence it is difficult to fix specific characters in a short period. Breeding programmes have focused on selections from seedling populations. Seedling rootstocks of annonas are generally derived from heterogeneous open-pollinated plants; hence, it is often difficult to fix specific characters in a short period. Early maturity, better fruit appearance and long post-harvest life for tropical annonas, and in the subtropics, greater cold tolerance, are objectives for cherimoya breeding (Nakasono and Paull, 1998).

Varietal wealth

Arka Sahan

It is a progeny of Island gem (*Annona atemoya* Hort.) x Mammoth (*A. squamosa* L.). Arka Sahan fruits come to harvest in September-October and mature fruits (210 g) take about 6-7 days to ripe. The skin has a waxy bloom, light green in colour, moderately thick (0.5 cm) with large, flat eyes. The creamy white colour flesh is juicy with mild pleasant aroma and tender with scarce seeds (9/100 g) and large segments. The edible pulp is remarkable for its sweetness with 22.8% total sugars and measures more than 30°B as against 24°B in Mammoth. A 100 g pulp of Arka Sahan contains 2.49 g of crude protein, 42.29 mg P and 225 mg Ca against 1.33 g, 17.05 mg and 159 mg respectively in Mammoth. On an average, 12 tonnes of fruits can be harvested/ha and it is resistant to drought.

Balanagar

Tree grows up to 3 m height. Fruits are spherical, pyramidal or cordate in shape; medium to big in size. Average fruit weight is 200 g but recoded up to 640 g; rarely 8.3 cm long and 3.5 cm in diameter. Areoles are tuberculate, very rough, pitted, forming deep furrows; rind greenish, mesocarp white with coarse and medium granules, pulp white, buttery sweet, with moderate to plenty of juice, flavor excellent; seeds 40-80. Highly productive, fruits remain green when ripe; rich in reducing sugars and proteins.

Barbados

Tree grows up to 2.4 m height. Fruits are spherical to cordate in shape; medium in size. Average fruit weight is 230 g. Fruits are 7.0 cm long and 7.7 cm in diameter; areoles tuberculate, very rough; rind fine; mesocarp with medium granules; pulp creamy white, moderately juicy, with agreeable flavor, sweet; seeds 40-60. Flowering late in June to early September and prolific yielder.

British Guinea

Tree grows up to 1.8 to 2.4 m. Fruits are spheroid to cordate in shape; medium in size. Fruit weight ranges from 170 to 335 g. Fruits are generally 6.8 cm long and 6.8 to 7.5 cm in diameter; areoles tuberculate, acute, rough, rind grayish or grayish green; mesocarp white, soft; pulp white, soft buttery, crisp, moderately juicy, sweet, seeds 30-50. Flowering is late in June to mid September. High yielder and fruits remain green at ripening.

Crimson custard apple

Tree grows up to 1.8 to 2.0 m. Fruits are spherical to oval in shape; small to medium in size. Areoles medium-tuberculate, truncate, slightly rough, rind crimson, with grayish blue bloom, mesocarp reddish with medium to big granules, pulp with light red tinge, soft, moderately juicy, sweet, seeds 40-60. Flowering occurs early June to end of August; trunk and branches dark green, new growth pinkish green.

Local custard apple

Tree grows up to 1.8 to 2.4 m. Fruits are spherical or cordate or conical in shape; Fruit weight ranges from 140 to 330

g and recorded up to 615 g. Areoles small to big, smooth to very smooth, round or mamillate; rind green, becoming light yellow on ripening. Mesocarp white, with fine, small to medium granules; pulp dull white, juiciness little to plenty, insipid to very sweet, seeds 30-80. It is an average yielder.

Mammoth

Tree grows up to 1.5 m. Fruits are irregular, triauctrous to spherical in shape; average in size. Fruit weight ranges from 170- 250 g, recorded up to 450 g. Areoles medium to big, very smooth, round, rind light russet; mesocarp white with small to medium granule; pulp white and translucent, soft bright, juicy, sweet, seeds 20-40. It has tendency to branch profusely; prolific bearer; rind becomes wrinkled on ripening; possesses low acidity; fruits have a good keeping quality and stand transport better.

Red Sitaphal

Tree grows up to 1.8 m. Fruits are spherical and cordate in shape. Fruit weight ranges from 170-250 g, recorded up to 450 g; areoles medium to big, tuberculate, truncate, rough and pitted; rind pink; grayish blue; mesocarp pinkish with coarse and big granules; pulp with pink tinge, moderately crisp, juicy, slightly acidic, sweet, seeds 40-60. Trunk and stem dark green; section of the stem shows the presence of pink coloured parenchyma in a circular band; mesocarp becomes deep pink on ripening; seeds small as in *Annona reticulata*. It contains maximum reducing sugars.

Red specked custard apple

Tree grows up to 1.50 to 2.0 m. Fruits are spherical to cordate in shape; small to medium size. Fruit weight ranges from 170-335 g. Areoles medium, tuberculate, truncate, very rough, ridged, pitted; rind light russet-green; splashed with red colour; mesocarp white with red colour; with medium to big granules; pulp dull white, moderately juicy, slightly stringy and just sweet, seeds 40-70. Flowering till the end of August; poor yielder; appears to be a cross between 'Red Custard apple' and Local Custard apple.

Washington 98797

Tree grows up to 1.8 to 3.0 m. Fruits are spheroid to cordate in shape, medium to big size. Average fruit weight is 690 g, areoles medium, truncate, tuberculate, ridged, rough, rind light russet-green; mesocarp with medium to big granules; pulp creamy-white, soft, moderately juicy, pleasant, moderately sweet. Seeds 50-60. Flowering occurs till early September and it is heavy yielder.

Washington 107005

Tree grows up to 1.8 to 2.4 m. Fruits are spherical to short conical in shape. Average in size; fruit weight ranges from 170 to 335 g, recorded up to 560 g. Areoles tuberculate, with small pits; rind grayish green, mesocarp white with small to medium granules ; pulp soft, bright white, buttery;

moderately to very juicy, sweet, flavor, delightful, seeds 30-50. Rich in reducing sugars and also in total acidity and protein.

APK-1

It is a clonal selection from a high yielding type in the State Horticultural farm, Courtallam. It bears higher yield in rainfed vertisol (black soil). It is a drought tolerant variety which bears sweet fruits (TSS of 24.5 Brix with an acidity of 0.2 per cent). The Fruit weigh ranges about 207.5 g with a mean of 72 fruits per tree per year. The first bearing commences in a graft/budded plant at 3-3 ½ years. The Optimum productive life is 25 yrs. The best season for planting is May-June/August-September. It yields about 7300 kg fruits/ha (14.90 kg/tree which is 30.7 per cent higher than Balanagar). It is suitable for cultivation in plains of Tamil Nadu especially in semi arid regions and marginal soils of both vertisol and alfisol in dry tracts. It is suitable for both rainfed and irrigated conditions.

Phule Janaki

It is hybrid between atemoya x custard apple. Trees are spreading in nature with dark green foliage. Average fruit weight: 392.7g; Fruit surface is rough with yellowish green colour. Fruit shape is oval and areoles are mammal in shape. Pulp colour is milky white with soft texture. Less seed content. Fruits are having better sugar acid blend

Phule Purandar

It is a clonal selection from Purandar Tahsil in Pune district of Maharashtra. Average fruit weight (366.17 g) and yield plant per plant is 50.90 kg. TSS - 23.60B), pulp - 47.82 % , better Shelf life (6 days).

GJCA-1

Gujarat Junagadh Custard apple-1 (GJCA-1) was developed from Madhadibag farm, Department of Horticulture, JAU, Junagadh. It requires 62.92 days to maturity, fruit weight 139.89 g, fruit length 6.80 cm, fruit girth 7.06 cm. Less number of seed per fruit as compared to check. It is recommended for Saurashtra region.

Sindhan

Sindhan is a local variety found on large area in Girmar hills of Junagadh district in Gujarat state.

Dharur-6

It has average fruit weight 386.0 g; TSS 25.0 °B; pulp recovery 47.5% and yield is 11.4 kg per plant.

TP-7

It has average fruit weight is 400-500 g, TSS 28.0 °B and yield 8.89 t/ha.

NMK-1 Golden

This variety has developed by the farmer Shri Kaspete of Garmele Village in Barshi Taluks of Solapur district in Maharashtra. Average fruit weight is 430.0 g; TSS 22.0 to 24.0 °B, less seeded 10-12 seeds /100g pulp. This variety has protected under PPV & FRA act.

Saraswati – 7 / Saraswati Saat

This variety also developed by the farmer Mr. Suresh Patil Jam on Wardha road in Nagpur. The fruit of Saraswati Saat is very big, more pulp, fewer seeds, thin skin and less prominent eyes.

Other custard apple varieties

Some cultivars were identified based on colour of the fruit, its origin and plant part: yellow custard apple named after the colour of the fruit. Cultivars like Kakarlapahad, Mahaboobnagar, Local Hyderabad and Saharanpur Local named after the place of origin; white stemmed custard apple named after the part of plant.

Cultivars from Alexandria and Egypt

Beni Mazar

Round, large, fruit weight ranges from 150 to 180 g; 56-60% flesh; 15-30 seeds per fruit (Morton, 1987).

Abd El Razik

Light-green or reddish rind; nearly round, large, average fruit weight is 236.3 g; 69.5% flesh; 14 seeds per fruit (Morton, 1987).

Cuban Seedless and Brazilian Seedless

One is a seedless form ('Seedless') with seemingly identical selections from Brazil and Cuba ('Cuban Seedless' and 'Brazilian Seedless'). This form is not likely to be widely grown because the fruit splits very badly as it matures on the tree and fruit quality appears to be slightly inferior to most-seedling fruit. It is not as productive as the seeded types, is nearly identical in quality and flavor. Another "seedless" sugar apple was introduced from Brazil, which appeared to be identical to the Cuban variety (<http://university.uog.edu/cals/people/PUBS/Sweetsop/MG33000.pdf>). Some selected cultivars of sweetsop are

presented in Table 1 and germplasm conserved at different centres are given in Table 2.

Flower biology

The flowers of sweetsop are hermaphrodite and are produced singly or in small clusters on the current season's growth. The flower buds start appearing on new shoots in the spring, immediately after the commencement of the vegetative growth. The flowering period in sweetsop was from the middle of April to end of June. The average time from visible flower initiation to full flowering was 30.8 days (Nalawadi *et al.*, 1975). Anthesis took place continuously throughout the day and night. Anthesis commenced at 6.00 AM and continued up to 6.00 PM, with its peak at 6.00 AM under Dharwar condition, between 5.30 and 6.30 AM under Bhubaneswar (Sahoo *et al.*, 2000) whereas anthesis occurs at 5.00 AM in Brazil (Ribeiro *et al.*, 2007). Kiill and Costa (2003) reported from Brazil that the anthesis takes place around 5.00 PM, the flowers last for approximately two days, and show female phase in the first twenty hours and male phase in the following twenty hours, characterizing dichogamy. Anther dehiscence commenced at 12.00 PM and was completed by 4.00 AM, with a peak at 2.00 AM (Nalawadi *et al.*, 1975). The flower exhibits a protogynous dichogamy nature that limits self-pollination and cross-pollination can increase fruit set. Pollen grains appearing early in a flowering season have lower germination rates than the pollen from late flowers (Chen and Paull, 2008). The highest pollen germination was recorded between 18.9 and 20.4% in 20% sucrose for green and red type, respectively. The stigmas were receptive from one day prior to anthesis till 2-3 days after anthesis indicating a protogynous condition (Thakur and Singh, 1965; Sahoo *et al.*, 2000). Nitidulid beetles, *Carpophilus domidiahus* and *Carpophilus hemipterous* were identified as pollinators in terms of visitation frequency, pollination potential score and pollination efficiency. However, *Carpophilus hemipterous* was relatively effective pollinator than *Carpophilus domidiahus*. Sweetsop clearly

Table 1. Some selected cultivars of sweetsop (Chen and Paull, 2008)

Country/region	Cultivars
Taiwan	Ruan-zhi, Cu-lin, Da-mu, Xi-lin and Tai-nong no.1
India	Balanagar, Mammoth, Arka sahan, Barbados, Washington and Red Sitaphal
Thailand	Fai Kaew, Fai Krung, Nang kaew, Nang Sir Krung and Nang Thong
Florida	Lessard, kampong Mauve, Red Sugar, Cuban seedless
Egypt	Abd El-Razik

Table 2. Custard apple germplasm conservation under AICRP on Arid Zone Fruits

Sl.No	Centre	No. of collections
1	Ambajogai	28
2	Anantapur	72
3	Aruppukottai	14
4	Jadhawadi	30
5	Jhalawar	23
6	Rahuri	20
7	SK Nagar	40
8	IIHR, Bengaluru	20

exhibit obligate specialization by filtering only *Carpophilus* hemipterous and *Carpophilus domidiahus* as pollinators and thereby explicitly indicating canthrophilous pollination syndrome (Kundan *et al.*, 2012).

Artificial pollination is frequently practiced to ensure pollination and good fruit shape. Hand pollination is normally carried out before 8.00 AM using a small brush. Pollen can be collected in the morning between 5.00 and 8.00 AM from fully open flowers, when the sacs have turned from white to cream. The collected pollen is used to pollinate half-open flowers whose pistils are already receptive (Jalikop and Ravindra, 2007).

Varietal evaluation

Several varietal evaluation studies have been carried out in various regions of India using different cultivars. Evaluation of sweetsop genotypes (APK-1, Mammoth, Balanagar) under sodic soil at Trichy, Tamil Nadu by Krishnamurthy (2009) showed superiority of APK-1 with regard to yield in nine years old trees which produced 47.78 kg per plant, followed by Balanagar (27.05 kg/plant). Thirty five germplasm of custard apple have been evaluated for scarce rainfall zone under rainfed at Anantapur, Andhra Pradesh by Dhanumjaya Rao and Subramanyam (2011) in 10 years old trees and the maximum yield have been recorded from MMR-10 (15.0 kg/plant). Girwani *et al.*, 2011 evaluated sweetsop hybrids under Sangareddy condition and revealed that All the hybrids varied in fruit shape (round, conical and cordate), fruit colour (yellowish green, grayish green, light green and red), pulp colour (creamy white, light pink and white), areole shape (tuberculate, hexagonal) and texture (course, soft and meaty). Time of fruit maturity varied from September 2nd fortnight and lasted till the end of December. Hybrid-1 (17/4 *Atemoya* x *Balanagar*) was earliest to mature. Maximum fruit weight (250 g) was recorded in Hybrid-1 (17/4 *Atemoya* x *Balanagar*) followed by Hybrid-6 (15/3 *Red Sitaphal* x *Atemoya*) (225 g) and Hybrid-4 (1/6 *British Guinea* x *Atemoya*) (220 g). Among all the hybrids, maximum number of fruits per tree (94) was recorded in Hybrid-1 (17/4 *Atemoya* x *Balanagar*) followed by Hybrid-6 (15/3 *Red Sitaphal* x *Atemoya*) (67). The TSS ranged from 22 to 28B and was found to be maximum in Hybrid-2 (15/2 *Red Sitaphal* x *Pondapple*), while the seed content per fruit was also minimum (20) in this hybrid. Based on overall performance the Hybrid-1 (17/4 *Atemoya* x *Balanagar*) and Hybrid-3 (15/3 *Red Sitaphal* x *Atemoya*) and Hybrid-2 (15/2 *Red Sitaphal* x *Pondapple*) were found to be excellent in quality with pleasant aroma, smooth pulp texture with less seed, good sugar acid blend and shelf life.

Breeding objectives

The first objective is the determination of the specific characteristics that are important for the new cultivar the ideal-type (Table 3). These characteristics may help a breeder to select parental groups to be used in an annona breeding programme, in order to obtain desirable progenies. These progenies may not have all desirable

characteristics, but at least will have those most important to growers, retailers and consumers. For instance, a sweet sugar apple cultivar with long shelf life fruits (>5 days), which is important from a consumer's viewpoint, may not be selected, if it presents low yield (<20 kg/tree/year) and fruit weight lower than 400 g. Genetic improvement for yield is the most difficult and expensive of all breeding objectives, due to the complex nature of its inheritance and the numerous environmental factors influencing the trait. Quality is another important characteristic for the improvement of annonas, as important or sometimes more so than yield, since market value is based on the fruit's appearance and its organoleptic characteristics (Pinto *et al.*, 2005).

Breeding strategies

Most *Annona* species and cultivars differ in environmental adaptation, productivity and fruit quality. Therefore, different conventional methods can be used in their breeding. According to Fehr (1987), there are three requirements for the development of an asexually propagated cultivar: a) a suitable source of genetic variability; b) evaluation of individuals from the population; c) asexual multiplication of a new cultivar for commercial use. Introduction of superior genotypes and/or cultivars to establish a germplasm collection is, basically, the first requirement of any breeding programme. This can be complemented by the introduction into the collection of some wild *Annona* species with useful genes, mainly for resistance to diseases. All accessions require comprehensive characterization and documentation, followed by evaluation and selection. Several types of populations can be developed by hybridization, from which superior clones are selected.

Selection and cultivar development

India and Taiwan have selected a few named cultivars of sugar apple from seedling population that are propagated vegetatively (Table 4). In Cuba, researchers developed 'Cuban Seedless', which is a seedless cultivar with medium-sized fruits, and another cultivar with low fibre content that is very important for the commercial market (Nakasone and Paull, 1998). In the Philippines, there are 3 forms of sugar apple fruits: (a) a green-fruited seedy form, which is grown in most parts of the country; (b) a purple-fruited seedy form, reportedly introduced from India; (c) and the green-fruited seedless form, which is a recent introduction and whose origin is unknown. The selection of superior strains is aimed in the direction of a green-fruited seedy form (Coronel, 1994).

Hybridization

Tri-species hybrids between *A. atemoya* x *A. squamosa* have been attempted by Jalikop and released one hybrid for commercial cultivation during 1997 in India which is a cross *A. atemoya* cv. *Island gem* x *A. squamosa* cv. *Mammoth* and named as *Arka Sahan* (Jalikop and Ravindra Kumar, 2007). Likewise, Girwani *et al.* (2010) also developed certain sugar apple hybrids at Sangareddy.

Modern biotechnology

The first haploid plants induced by anther culture in

fruit trees were reported by Nair *et al.* (1983) with sugar apple. The availability of haploids is very important for fruit-breeding, because of the long generation intervals, the highly heterozygous nature of most fruit species and the presence of parthenocarpy and self-incompatibility. These researchers obtained callus differentiation, and formation of triploid roots and shoots from sugar apple endosperm (Nair *et al.*, 1986). Their aim was development of seedless fruits,

but a complete plantlet was not obtained.

Future thrust

- Development of seedless sugar apple varieties.
- Development of coloured sugar apple varieties.
- Development of sugar apple varieties resistant to Anthracnose and fruit fly.
- Production of double haploid in sugar apple.

Table 3. Main characteristics of sugar apple ideo-types (adult plants)

Characteristics	Sugar apple
Plant	
Vegetative vigour	Medium to low
Reproductive vigour(Yield)	High (>20 kg per plant)
Bearing	Regular
Rootstock / scion compatibility	High
Flower number	Abundant (> 180 flowers per tree)
Pollen fertility (20°C)	High (>76%)
Fruit	
Size / Weight	
For industry	Large / >400g
For fresh consumption	Medium / 300- 400 g
Shape	Rounded to Heart
Fruit set (naturally)	High (>25%)
Skin	Tuberculate
Pulp	Sweet , low fibre
Flavour	Pleasant acidulous
Seed number per 100g of pulp	Low or absent (<10 seeds)
Shelf life (15 to 30°C)	Long (>5 days)

Table 4. Some selections and cultivars of sugar apple which are currently grown in various countries (Pinto *et al.*, 2005)

Cultivar/Selection	Country of origin	Cultivar/Selection	Country of origin
IPA selections	Brazil	Leone	Italy
Libby	USA	Madeira	Portugal
Lisa	USA	Mateus 1	Portugal
Mossman	Australia	Negrato	Spain
Ott	USA	Reretai	New Zealand
Whaley	Australia	White	USA
Molate	Philippines	Cuban Seedless	Cuba
Lobo	Philippines	Noi	Thailand
Red Sugar Apple	USA/Florida	Mammoth	India
Balanagar	India	Red Sitaphal	India

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Evaluation of pomegranate varieties for growth and fruit quality attributes under Andhra Pradesh condition

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Abstract

Five pomegranate varieties (Ganesh, Mridula, Bhagwa, Ruby and Jalore Seedless) were evaluated for vegetative and quality parameters for consecutive seven years under at Horticulture Research Station, Anantapur. Jalore Seedless (check) recorded significantly highest values for plant height (2.99 m), no. of stems per plant (5.25) and plant spread (2.64 m EW 2.51m NS). Among all the varieties, fruit yield per plant and per hectare was highest in Bhagwa (19.13 kg and 11.96 t) with fruit weight of 305.21g, total aril weight (168.05g) and 100 aril weight (35.35 g) TSS of 17.87° Brix. Bhagwa was best performer as compared to other popular varieties like Ganesh, Mridula, Ruby and Jalore Seedless. Therefore, on the basis of plant growth and fruit quality attributes variety Bhagwa is recommended for arid regions of Andhra Pradesh.

Key words: Pomegranate, varietal evaluation, fruit quality, yield

Introduction

Pomegranate (*Punica granatum* L.) is most popular table fruit of tropical and subtropical regions of the world. It belongs to genera *Punica* and family Punicaceae (Chatterjee and Randhawa, 1952; Joshi, 1956). It is a native fruit of Iran, and is also cultivated extensively in countries like Spain, Morocco, Egypt, Afghanistan and Baluchistan. The cultivation has also been initiated on small scale in countries like USA (California & Florida), Mexico, Palestine, Israel, China, Japan, Burma, the USSR, Pakistan and many parts of India (Singh, 2000). In India, its cultivation is extended from Kashmir to Kanyakumari. It is grown commercially in the states of Gujarat, Rajasthan, Karnataka, Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Punjab and Haryana. In India, it is considered as a crop of the arid and semi-arid regions because it withstands different soil and climatic stresses (Kaulgud, 2001).

The juice is valued for its medicinal properties mainly for leprosy patients. Juice is also used as cooling ingredient refrigerant of mixtures and some medicines for dyspepsia. The bark and rind of the fruits and seeds are used as astringent in cases of diarrhoea and dysentery. In peninsular India, a kind of wine is prepared from pomegranate juice which is considered superior to grape vine. The sweet types of pomegranate are said to be mildly laxative, while the less sweet types are believed to be good in inflammation of stomach and in heart pain. The powdered flower buds are used in bronchitis. The seeds are considered to be stomachic and the

pulp cardiac and stomachic (Anonymous, 1998). For effective utilization, the evaluation of varieties for their performance and quality attributes for table purpose and value addition are the areas of concern.

Materials and Methods

To study the adaptability, performance and potentiality of improved varieties of pomegranate under arid zone of Andhra Pradesh, the experiment was conducted for consecutive seven years at HRS, Anantapuramu under Randomized Block Design with four replications. The vegetative parameters like plant height (m), plant spread (m), stem girth (m), yield per plant and quality parameters *i.e.* fruit weight, peel weight, aril weight, 100 arils weight, TSS, pH, acidity and anthocyanin were evaluated. A total of ten fruits from each variety was analysed for various physical attributes. The arils were first separated manually and then 100 arils weight (g) was recorded. Also, peel weight (g) per fruit were computed. The extracted fruit juice was then utilized in the experiments for the determination of chemical composition of fruits.

A. Titratable acidity

Total titratable acidity (TA) was determined by the method as defined by Ranganna (1986). In this method, 5 ml of water added to 5 ml aril juice and mixed thoroughly. The sample solution was titrated against 0.1 N NaOH using phenolphthalein as indicator. Appearance of light pink colour

denotes the end point. The acidity of aril juice was expressed in per cent and calculated by using the formula.

B. Total soluble solid (°Brix)

The total soluble solid (TSS) content of the pomegranate juice was measured by Digital Refractometer and expressed as °Brix (Ranganna, 1986).

C. pH

The pH measurements were done using a digital pH meter.

D. Anthocyanin content

For estimation of anthocyanin, juice from 1 g arils was macerated in 1 ml of methanol was extracted and mixed with 4 ml 1% HCl and kept overnight at 0°C and the absorbance of diluted solution was measured at 530 nm by Spectrophotometer. The absorbance of diluted juice was used as index for anthocyanin concentration (Harborne, 1973).

Data analysis

All the experiments were performed in triplicate and the recorded data were analysed by using ANOVA.

Results and Discussion

Significant differences were observed among pomegranate varieties for all the growth characters studied (Table 1). Jalore Seedless (check) recorded significantly highest values for plant height (2.99 m), no. of stems per plant (5.25) and plant spread (2.64 m EW 2.51m NS). Significantly more number of harvestable fruits per plant was observed in Bhagwa (87.83) followed by Ganesh (77.59). The pooled yield per plant and per hectare were significantly high in Bhagwa (19.13 kg and 11.96 t) followed by Ganesh (18.29 kg and 11.43t), respectively. Such variations in growth characters are reported by Sharma and Bist (2005). Also, Rao and Subramanyam (2009) reported that among nine years old four varieties of pomegranate Mridula recorded with highest fruit yield/tree (14.1 kg) under scarce rainfall zone. Similar results were reported by Mir *et al.* (2007 a & b) showed significant variations on all the growth and yield parameters due to various cultivars. The highest plant height and spread was recorded in cv. Kabuli Kandhari, whereas maximum number of suckers was recorded in cv. Jyoti.

The data on fruit quality parameters (Table 2) revealed that maximum fruit weight (424.05 g), total aril weight (253.20 g) and 100 aril weight (40.65 g) were recorded in Jalore Seedless compared to other varieties. High TSS was recorded in Bhagwa (17.87°Brix) followed by Ganesh (16.33°Brix), Mridula (15.81°Brix) and Ruby (15.50°Brix). The per cent acidity was high in Jalore Seedless (0.85) whereas, it was low in Mridula (0.27) and Bhagwa (0.31). The anthocyanin content was high in Mridula (19.30 mg/100g) followed by Ruby (17.86 mg/100g) and Bhagwa (17.52 mg/100g). Similar variations in fruit parameters were recorded in the cultivar Chawla which was superior in its nutritive value to Akanar and Nabla (Sood *et al.*, 1982). Malhotra *et al.* (1983) also observed high juice content (62.5%) in various cultivars. Similarly, TSS, sugars (reducing & non-reducing), acids and vitamin C in the seed juice and total phenolics as tannins in the fruit skin revealed great inter-varietal differences. In general, all the cultivars were found to contain high fraction of reducing sugars as part of total sugars. Dhillon and Kumar (2004) studied the biochemical changes in pomegranate and indicated that TSS and vitamin C content increased up to 150 days of anthesis but acidity decreased during fruit development. High total soluble solids and total sugars were recorded in cv. Kandhari. The highest TSS/acid ratio was recorded in cv. G-137. Cultivar Kabuli Kandhari observed the highest ascorbic acid content followed by Bedana. The anthocyanin content was observed higher in Ganesh followed by Kabuli Kandhari and lowest in Chawla. The juice content was found to be highest in Bedana (Mir *et al.*, 2007 a & b). Varasteh *et al.* (2009) evaluated five commercial cultivars in Iran for different fruit characteristics and observed total soluble solids, titrable acidity and anthocyanin index which varied from 16.60-18.26 °Brix), 0.79- 1.35% and 1.04-1.92 mg/100g, respectively. Akbarpour *et al.* (2009) studied 12 pomegranate cultivars for different physical and chemical characters. Their reducing sugars ranged from 13.89 to 29.83 g/100 ml and TSS ranged from 15.17 to 22.03%. Cultivar Syah-e-Saveh had significantly more TSS (22.03°Brix). The maximum acidity was found in Lamsari-e-Behshahr (3.36%) and minimum in Khazar-e-Bardaskan (0.35%). Vitamin C ranged from 9.68-17.45 mg/100 ml and anthocyanin from 225.17 to 705.50 mmol/100 g.

Table 1. Growth, yield parameters of pomegranate varieties (pooled data 2013 to 2020)

Varieties	Plant height (m)	No. of branches/plant	Plant spread (m)		No. of fruits/plant	Yield (kg/plant)	Yield (t/ha)
			EW	NS			
Ganesh	2.25	4.28	2.17	2.27	77.59	18.29	11.43
Mridula	2.03	3.85	1.95	1.67	53.84	11.34	7.09
Bhagwa	2.00	4.61	1.95	1.87	87.83	19.13	11.96
Ruby	2.05	3.80	2.01	1.96	64.40	12.83	8.02
Jalore seedless	2.99	5.25	2.64	2.51	46.00	12.04	7.53
CD	0.238	0.647	0.28	0.22	13.19	3.14	-
SE(m) ±	0.082	0.222	0.11	0.07	4.55	1.08	-
CV	10.214	14.42	12.58	10.54	19.5	20.87	-

Table 2. Fruit quality parameters of pomegranate varieties (pooled data 2013 to 2020)

Varieties	Fruit weight (g)	Peel weight (g)	Aril weight (g)	100 arils weight (g)	TSS (°Brix)	pH	Acidity (%)	Anthocyanin (mg/100g)
Ganesh	381.06	148.71	232.94	43.52	16.33	2.67	0.33	16.40
Mridula	275.64	93.78	180.76	36.56	15.81	2.72	0.27	19.30
Bhagwa	305.21	126.89	168.05	35.35	17.87	2.74	0.31	17.52
Ruby	282.79	99.64	194.46	36.94	15.50	2.73	0.33	17.86
Jalore Seedless	424.05	16.89	253.20	40.65	13.90	2.47	0.85	11.20
CD	61.41	24.45	42.2	5.32	0.96	0.08	0.08	1.24
SE(m)±	20.81	8.29	14.3	1.8	0.33	0.03	0.03	0.42
CV	15.27	16.12	17.02	11.45	5.92	2.87	16.89	6.22

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Diagnosis and recommendation integrated system norms in custard apple

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Abstract

A leaf sampling survey was carried out at 15 villages in states of Gujarat and Rajasthan during 2018-2020 and collected 338 samples in custard apple to develop diagnosis and recommendation integrated system (DRIS) norms. The leaf samples were collected in July month and the leaves present in the middle portion of the recently matured twig were analyzed for the nutrients, and classified based on standard deviation (SD) as deficient ($< \text{mean} - 8/3 \text{ SD}$), low ($\text{mean} - 8/3 \text{ SD}$ to $\text{mean} - 4/3 \text{ SD}$), optimum ($\text{mean} - 4/3 \text{ SD}$ to $\text{mean} + 4/3 \text{ SD}$), high ($\text{mean} + 4/3 \text{ SD}$ to $\text{mean} + 8/3 \text{ SD}$) and very high ($> \text{mean} + 8/3 \text{ SD}$). The optimum concentration of nitrogen in the index leaf ranged from 1.96% to 3.06%, whereas phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, zinc and copper ranged from 0.13 to 0.17%, 0.59 to 0.99 %, 1.48 to 2.26%, 0.69 to 1.64%, 0.29 to 0.45%, 126 to 328 ppm, 243 to 323 ppm, 38 to 56 ppm, and 21 to 36 ppm, respectively. This information may be used for developing DRIS and CND norms and to predict nutrient needs based on DRIS indices in nutrient management of custard apple trees.

Key words: Custard apple, DRIS norms, CND, leaf sampling survey, nutrient management

Introduction

Custard apple (*Annona squamosa* L.) popularly known as sitaphal over India as well as sugar apple in rest of the world because of high sugar content (25-28% TSS), belongs to family Annonaceae. It is a perennial, small, semi-deciduous tree, which can well survive in both tropical and sub-tropical ecological condition, and seen mostly naturally growing in forest areas (Yadav *et al.*, 2017). The leaves of custard apple are not eaten by grazing animals due to *annonin* content which is toxic and it can also be used as botanical pesticide (Monadal *et al.*, 2018). Custard apple is delicious in taste having nutraceutical properties like vitamin K (58 mcg) and ascorbic acid 36.3 mg (44% DV) (Singh *et al.*, 2019), and minerals like potassium 247 mg, manganese 0.42 mg (20% DV) and magnesium (84 mg) per 100 g fresh pulp (Sugar apple:2020). The pulp of custard apple can be preserved and utilized in ice cream industry. In India, custard apple production is 347 thousand tons in 41 thousand hectares area with an average productivity 8.46 t/ha, and contributes 0.35 % in total fruit production (99,069 thousand tons in 6,664 thousand ha area with an average productivity 14.86 tons/ha) (Anonymous, 2020). In order to meet demand of growing population, custard apple may be a key fruit crops in removing malnutrition over the world, its production can be increased by proper nutrient management techniques. In fruit crops because of deep root system, nutrient diagnosis is generally done by

leaf nutrient diagnosis in which DRIS is one of the important diagnostic tool to judge the nutrient needs of the fruit trees. Many scientists already developed DRIS norms for different fruit crops (Bhargava and Chadha, 1993) but so far for custard apple this technique was not developed therefore, an effort was made to develop DRIS norms by conducting leaf sampling survey in Gujarat and Rajasthan states.

Materials and Methods

A leaf sampling survey in custard apple was carried out in states of Gujarat and Rajasthan during the period 2018-2020 and 338 samples were collected in July month to develop DRIS norms and their details are presented in Table 1. Middle leaves of recently developed twigs are used for analysis. Leaf samples were properly washed with 0.1 N HCl, tap water, distilled water and double distilled water and dried at 68°C temperature, then finely powdered and used for analysis. The plant nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, zinc and copper were estimated by using methods as described by Bhargava and Raghupathi (1993). The nutrient concentrations of entire population were divided into two sub populations *i.e.* low-yielding and high-yielding with a cut off value 21.2 kg fruits/tree. Nutrient concentrations derived from high yielding population were statistically analyzed and classified into deficient, low, optimum, high and toxic based on standard

deviation (SD). The nutrient concentrations in the range with mean \pm 4/3 SD are optimum, $<$ (mean - 8/3 SD) are deficient, (mean - 8/3 SD) to (mean -4/3 SD) are low, (mean + 4/3 SD) to (mean + 8/3 SD) are high and $>$ (mean + 8/3 SD) are toxic. DRIS norms were calculated following the methods suggested by Beaufiles (1973), which were clearly explained by Walworth & Sumner (1987) and Bhargava (1996).

The DRIS index for each nutrient was calculated as follows

Nutrient Index (A nutrient index is a mean of functions of all ratios containing a given nutrient)

$$N \text{ Index} = \frac{f(N/P) + f(N/K) + f(N/Ca) + f(N/Mg) + f(N/S) + f(N/Fe) + f(N/Mn) + f(N/Cu) + f(N/Zn) + f(N/Y)}{Z}$$

Where,

When $N/P \geq n/p$,

$$f(N/P) = \{(N/P/n/p) - 1\} 1000/CV$$

When $N/P < n/p$,

$$f(N/P) = \{1 - (n/p/N/P)\} 1000/CV$$

Where

1) N/P is the value of the ratio of two elements in the tissue of the plant being diagnosed.

2) n/p is the optimum value or norm for that ratio.

3) CV is the coefficient of variation associated with the norm.

4) Z is the number of functions comprising the nutrient index.

Results and Discussion

The total population was divided into two sub populations based on a cut off value of 21.2 kg yield per tree. One is high yielding population with trees yielding above 21.2 kg yield per tree and other one as low yielding population with trees yielding less than 21.2 kg per tree. In high yielding population with 183 trees the average concentration of nitrogen (2.51% and CV% 16.54), phosphorus (0.15% and CV% 12.21), potassium (0.79% and CV% 18.93), calcium (1.81% and CV% 15.8), magnesium (1.16% and CV% 30.49), sulphur (0.37% and CV% 16.10), iron (227 ppm and CV% 33.33), manganese (283 ppm CV% 10.54), zinc (47 ppm and CV% 14.09) and copper (29 ppm and CV% 19.84) were estimated. Based on variation the nutrients were classified and presented in Table 2. These nutrient concentrations and variation were used in developing DRIS index for diagnosing the leaf samples (Table 5). A proper concentration and ratio of nutrients are required for getting optimum yields and that

Table 1. Geographical location of leaf samples collected in Gujarat and Rajasthan

S. No	Village	District	State	Geographical Location	Altitude (Feet)
1	Baina (33)	Dahod	Gujarath	22° 39' 06.18" N, 73° 57' 12.24" E	650
2	Bakrol (33)	Pancha Mahals	Gujarath	22° 29' 30.29" N, 73° 42' 39.21" E	567
3	Bhabhar (6)	Chota Udaipur	Gujarath	22° 28' 36.31" N, 73° 44' 40.76" E	679
4	Chittorgarh Fort (50)	Chittorgarh	Rajasthan	24° 53' 12.70" N-74° 38' 41.04" E	1659
5	Hathni Mata (16)	Pancha Mahals	Gujarath	22° 39' 06.18" N, 73° 57' 12.24" E	740
6	Jaisighpur (12)	Chittorgarh	Rajasthan	25° 05' 40.28" N-74° 34' 21.26 E	1414
7	Jesingpur (22)	Mahisagar	Gujarath	23° 20' 17.66" N-73° 28' 26.54" E	595
8	KVK,Chittorgarh(24)	Chittorgarh	Rajasthan	24° 50' 51.18" N-74° 34' 57.99 E	1388
9	Labadadhara(18)	Pancha Mahals	Gujarath	22° 31' 26.28" N, 73° 41' 51.83" E	608
10	Nathpura (9)	Pancha Mahals	Gujarath	22° 28' 19.74" N, 73° 41' 49.99" E	666
11	Poyali (19)	Pancha Mahals	Gujarath	22° 27' 46.26" N, 73° 43' 16.88" E	798
12	Rugnathpur(22)	Mahisagar	Gujarath	23° 20' 36.5" N-73° 26' 08.43" E	437
13	Sarasava (14)	Pancha Mahals	Gujarath	22° 28' 23.86" N, 73° 42' 42.30" E	705
14	Vejalpura(34)	Pancha Mahals	Gujarath	22° 41' 23.98" N, 73° 33' 47.86" E	368
15	Zinzari (26)	Pancha Mahals	Gujarath	22° 31' 36.71" N, 73° 40' 09.19" E	606

Table 2. Nutrients norms of custard apple for macro and micronutrients

Nutrient	Deficient	Low	Optimum	High	Toxic
Nitrogen	<1.40	1.40-1.96	1.96-3.06	3.06-3.62	>3.62
Phosphorus	<0.10	0.10-0.13	0.13-0.17	0.17-0.20	>0.20
Potassium	<0.39	0.39-0.59	0.59-0.99	0.99-1.19	>1.19
Calcium	<1.08	1.08-1.48	1.48-2.26	2.26-2.66	>2.66
Magnesium	<0.22	0.22-0.69	0.69-1.64	1.64-2.11	>2.11
Sulphur	<0.21	0.21-0.29	0.29-0.45	0.45-0.53	>0.53
Iron	<25	25-126	126-327	327-429	>429
Manganese	<204	204-243	243-323	323-363	>363
Zinc	<29	29-38	38-56	56-65	>65
Copper	<14	14-21	21-36	36-44	>44

information is given in the Table 3 & 4 for comparison, which were collected from different DRIS norms from different workers in various fruit crops which were mentioned by Bhargava and Raghupathi (1993) and those optimum nutrients concentrations are compared with the optimum nutrients concentrations of present work of custard apple.

For higher yield, not only optimum nutrient concentration but also nutrient balance is required. Every plant maintains a definite and specific ratio of nutrient composition of its own nature and it is unique character of its species for optimum growth and yield. Table 5 reveals that as the summation of nutrient indices become zero or near to zero, the yield will be maximized, to interpret DRIS indices with elemental composition of leaves, custard apple trees along with average yield (kg/tree) are given in Table 5. These DRIS

Indices indicate the order of deficiency or sufficiency of each element over the other elements. The element having more negative value is more deficient than the other having less negative value for example in tree No. 2 (Table 5) the order of requirement of nutrients for getting higher yield response is Ca>K>Mn>Zn>Cu>N>Fe>P>Mg. This indicates that the Ca is most important and required element and Mg is least required element to improve the yields of that tree. To get profitable response, Ca should be immediately applied as compared to other elements. The total of DRIS indices of various elements should be balanced (total of indices should be zero or nearer to zero) to get higher yield. Table 5 clearly indicates that tree with more balance in DRIS indices (with lower total number) gave higher yield when compared to those orchards having less balance in DRIS indices.

Table 3. Average nutrient concentration from DRIS norms of different fruit crops

Crop	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	Reference
Mango	1.25	0.165	0.65	3.5	0.35	0.4	150	150	110	11	Bhargava and Raghupathi (1993)
Citrus	2.45	0.2	1.5	2.75	0.35	0.825	80	110	35	53	Bhargava and Raghupathi (1993)
Papaya	1.75	0.31	4.4	2	0.95	0.3	63	85	27	7	Bhargava and Raghupathi (1993)
Sapota	1.815	0.11	0.565	1.525	0.7	0.6	83	28	12	5	Appa Rao <i>et al.</i> , (2006)
Aonla	2.085	0.135	0.675	0.98	0.555	0.135	125	33	11	16	Appa Rao <i>et al.</i> , (2006)
Ber	1.895	0.23	1.535	0.335	0.131	0.2	90	39	17	14	Bhargava and Raghupathi (1993)
Banana	2.75	0.29	3.15	1.05	1.05	0.325	200	1100	32	18	Bhargava and Raghupathi (1993)
Custard apple	2.51	0.15	0.79	1.87	1.17	0.37	227	283	47	29	Present paper

Table 4. Nutrient ratios calculated for average values DRIS norms of different crops

Crop	N/P	N/K	N/Ca	N/Mg	N/S	N/Fe	N/Mn	N/Zn	N Cu	Reference
Mango	7.58	1.92	0.36	3.57	3.13	83.33	83.33	113.64	1136.36	Bhargava and Raghupathi (1993)
Citrus	12.25	1.63	0.89	7.00	2.97	306.25	222.73	700.00	462.26	Bhargava and Raghupathi (1993)
Papaya	5.65	0.4	0.88	1.84	5.83	277.78	205.88	648.15	2500.00	Bhargava and Raghupathi (1993)
Sapota	16.50	3.21	1.19	2.59	3.03	218.67	648.21	1512.50	3630.00	Appa Rao <i>et al.</i> , (2006)
Aonla	15.44	3.09	2.13	3.76	15.44	166.80	631.82	1895.45	1303.13	Appa Rao <i>et al.</i> , (2006)
Ber	8.24	1.23	5.66	14.47	9.48	210.56	485.90	1114.71	1353.57	Bhargava and Raghupathi (1993)
Banana	9.48	0.87	2.62	2.62	8.46	137.50	25.00	859.38	1527.78	Bhargava and Raghupathi (1993)
Custard apple	16.73	3.18	1.34	2.15	6.78	110.57	88.69	534.04	865.52	Present paper

Table 5. Nutrient composition and calculated DRIS indices for custard apple trees

S. No.	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Balance	Yield (kg /tree/year)
1 (tree)	1.9	0.14	0.33	0.66	0.19	0.07	135.00	30.1	11.6	7.8	-----	-----
Index	2.67	11.38	4.26	5.53	0.77	-8.06	5.84	2.84	22.77	19.00	58.48	20.50
2 (tree)	2.91	0.16	0.33	0.52	0.32	0.12	121.5	25.7	5.35	7.4	-----	-----
Index	4.67	11.28	10.4	12.44	20.5	10.46	7.7	-8.19	-7.4	-1.56	14.66	25.75

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Quality of pomegranate fruits as influenced by pre harvest bagging under hot arid climate

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Abstract

An experiment was conducted to study the effect of different bagging material on fruit quality and cracking in pomegranate which is severe problem under hot arid climate of Rajasthan. Pomegranate fruits of cv. Bhagwa were covered with different bagging material i.e. white paper bags, brown paper bags, butter paper bags, perforated transparent polyethylene bags, muslin cloth bags, markin cloth bags, non woven fabric bags, shrink wrapping (cling film) and control without bagging. The fruits were covered in each treatment after two month of fruit set during September and data were recorded on different fruit physical and physico-chemical quality attributes. Among the treatments, perforated transparent poly bags were significantly reduced fruit cracking (11.12%) as against control (25.20%). Perforated transparent polyethylene bags also resulted in highest marketable yield (4.72 kg/plant) followed by butter paper bags (4.00 kg/plant) as compared to lowest in control (3.30 kg/plant). Improved bright red colour fruits was obtained in perforated transparent poly bags and shrink wrapping treatments, while in control fruits colour faded and turn light brown red due to sun scald and frost damage. The total soluble solids and TSS/acid ratio were significantly affected by fruit bagging material, while non significant differences were observed in ascorbic acid, total sugar, reducing sugars and acidity of fruits. The maximum maturity index was recorded in perforated transparent polyethylene bags (35.82) followed by butter paper bags (31.91) as compared to minimum observed in control (25.12). Thus, pre harvest fruit bagging of pomegranate not only improved marketable fruit yield and quality of fruits but also significantly reduced fruit cracking under hot arid climatic conditions.

Key words: Fruit bagging, fruit cracking, maturity index and quality

Introduction

Pomegranate (*Punica granatum* L.) is an emerging fruit crop of hot arid region of India. The pomegranate area and production is increasing very fast owing to its hardy nature, wider adaptability and high nutritional and medicinal value, availability of quality planting material, steady demand and remunerative prices. In India, pomegranate is grown commercially in the states of Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh and Rajasthan. The fruit is mainly used for dessert purpose and also processed for making juices, syrup, jelly and anardana. The fruit are rich in Fe, Zn, Ca and antioxidant component like anthocyanins, phenol, flavonoids and tannins. India is one of the leading growers and producers of pomegranate in the world. During 2018-19, pomegranate was cultivated over 2.62 lakh ha with an annual production of 30.34 lakh tonnes and a productivity of 11.58 tonnes/ha in India (Anonymous, 2019). Maharashtra is the leading state in acreage covering 63.23 % of the total area and 62.90 % of total production followed by Gujarat (13.04 % area and 16.23 % production) and Karnataka (11.10 % area and 9.42 % production) under pomegranate. In Rajasthan, it is mainly grown in Barmer, Jalore, Sirohi, Bhilwara, Jaisalmer, Jodhpur, Chittorgarh, Bikaner, Nagaur, Jaipur, Ajmer, Alwar, Sri Ganganagar, Pali, Kota,

Banswara, Sawai Madhopur, Jhunjhunu, and Sikar districts over 7.47 thousand ha area with 13.13 thousand tonnes production (Anonymous, 2020). In Rajasthan pomegranate is harvested in all three seasons during March-April, August-September and November-December. The Bhagwa variety of pomegranate grown extensively in India, has become popular owing to its high yield, big fruit size, dark purple-red rind and aril colour, semi-soft arils and high juice content.

In hot arid region of Rajasthan, fruit cracking, frost damage and sun scald are the major physiological disorders which results in inferior quality fruits and makes them unfit for shipment and marketing. Almost all the varieties cultivated in this region are susceptible to fruit cracking resulting economic loss to the farmers. It may be due to moisture imbalances, temperature variation and deficiency of micro nutrients. By adopting fruit-bagging, growers could minimize losses and get an additional price over unbagged fruits (Asrey *et al.*, 2013). Fruit bagging considerably reduced cracking, scratches, and development of bacterial spots with reduced incidence of sun burning in pomegranate. Fruit bagging not only improves higher marketable fruit yield but also provides protection to fruits from birds and pests. Covering of fruits with bags modify the micro-climate around fruit, which exerts manifold effects on the growth, development and quality of fruits (Guzman, 2004; Son and Lee, 2008; Li *et al.*, 2008). The fruit bagging is

commercially adopted in fruit crops like mango, apple, pear, litchi, guava, grape, longan *etc.* for fruit quality improvement and reducing pesticide residues by minimization of insect or disease incidence and fruit cracking (Wang *et al.*, 2003; Wei *et al.*, 2005). Fruit cracking caused huge loss and it varies from 35 to 75 % in different *bahars* under hot arid conditions. The number of biotic (bacterial blight, anthracnose, fungal spot and mite) and abiotic stress (drought, frost and salinity) along with fruit cracking possess an emerging threat to the pomegranate industry. Therefore, the present study was formulated to improve fruit quality and to minimize fruit cracking, frost damage and sun scald in pomegranate through different bagging material.

Materials and Methods

The present study was carried out during two consecutive years 2018-19 and 2019-20 at ICAR-Central Institute for Arid Horticulture, Bikaner. The experiment was conducted on three years old uniform plants of pomegranate cv. Bhagwa planted at 4x3 m² spacing and irrigated through drip system. The fruits were covered with different bagging material i.e. white paper bags, brown paper bags, butter paper bags, perforated transparent polyethylene (PTP) bags, muslin cloth bags, markin cloth bags, non woven fabric bags, shrink wrapping (cling film) and control without bagging. The experiment was conducted in randomized block design with three replications. The fruits were covered in each treatment after two month of fruit setting during September. The uniform intercultural operations were performed as per the package and practice of the crop. To protect the plants from mite, plants were first sprayed with propargite (57 % EC) 2 ml/l in May and second spray of spiromesifen (240 SC) 0.4 ml/l was done during September. The plants were sprayed twice with mancozeb (75 % WP) 0.2% + carbendazim (50 % WP) 0.2% to control fungal spots disease during rainy season. Data were recorded on yield parameters and quality indices *viz.* fruit weight and diameter, total fruit yield, fruit cracking (%), marketable yield, fruit rind colour, total soluble solids (TSS), acidity, ascorbic acid, total sugar, reducing sugar and maturity index. The total soluble solids of the fruit juice were

determined with digital refractometer Atago PAL II. The acidity of juice was determined by titration with 0.1 N sodium hydroxide using phenolphthalein indicator. The ascorbic acid was determined by titration using 2, 6, dichlorophenol indophenol dye. Total sugar was estimated by the phenol sulphuric acid method (Dubois *et al.*, 1956). Reducing sugar was determined by the Nelson and Somogyi method (Somogyi, 1952). The data were analyzed statistically as per the methods suggested by Gomez and Gomez (1984).

Results and Discussion

The different bagging material significantly influenced fruit physical and yield attributes of pomegranate. Among all the treatments, significantly maximum fruit weight was recorded in perforated transparent poly bags (213.38 g) followed by markin cloth bags (190.95 g) and butter paper bags (190.54 g), whereas minimum fruit weight was recorded in control treatment (182.81 g) which is at par with brown paper bags (183.38 g), non woven fabric bags (185.39) and white paper bags (185.57 g). Similarly, fruit diameter was found highest in perforated transparent poly bags (8.35 cm) which was statistically at par with markin cloth bags (8.19 g) and butter paper bags (8.17 cm). The minimum fruit diameter was recorded in control treatment (7.96 cm) and brown paper bags (7.99 cm). The total fruit yield was recorded maximum in perforated transparent poly bags (5.36 kg/plant) followed by butter paper bags (4.80 kg/plant) as compared to minimum found in control (4.59 kg/plant). In pomegranate, fruit external appearance and quality are important criteria for fetching higher prices in the market as fruit cracking and sun scald along with mite and fungal spot deteriorate fruit quality under hot arid climatic conditions.

The marketable fruit yield was also significantly influenced by different treatments of bagging materials and registered significantly maximum marketable fruit yield in perforated transparent poly bags (4.72 kg/plant) followed by butter paper bags (4.00 kg/plant) as compared to minimum in control (3.30 kg/plant) (Table 1). Fruit rind colour also influenced by different bagging material. The improved bright red colour of fruit was obtained in perforated transparent poly bags and shrink wrapping treatments, whereas in control fruits colour was observed faded light red due to sun scald and frost damage. Xu *et al.* (2008) reported that bagging with plastic bags

Table 1. Effect of different bagging material on fruit and yield attributes of pomegranate

Treatments	Fruit weight (g)	Fruit dia. (cm)	Total yield (kg/plant)	Marketable yield (kg/plant)	Fruit rind colour
White paper bags	185.57	8.10	4.67	3.99	Red
Brown paper bags	183.38	7.99	4.62	3.91	Light Red
Butter paper bags	190.54	8.17	4.80	4.00	Dark Red
Perforated transparent poly bags	213.38	8.35	5.36	4.72	Bright red
Muslin cloth bags	187.84	8.14	4.71	3.64	Red
Markin cloth bags	190.95	8.19	4.79	3.69	Red
Non woven fabric bags	185.39	8.10	4.69	3.88	Red
Shrink wrapping	188.82	8.18	4.75	3.92	Bright red
Control	182.81	7.96	4.59	3.30	Faded light red
SEm±	1.70	0.07	0.11	0.13	–
CD (5%)	5.09	0.23	0.32	0.39	–

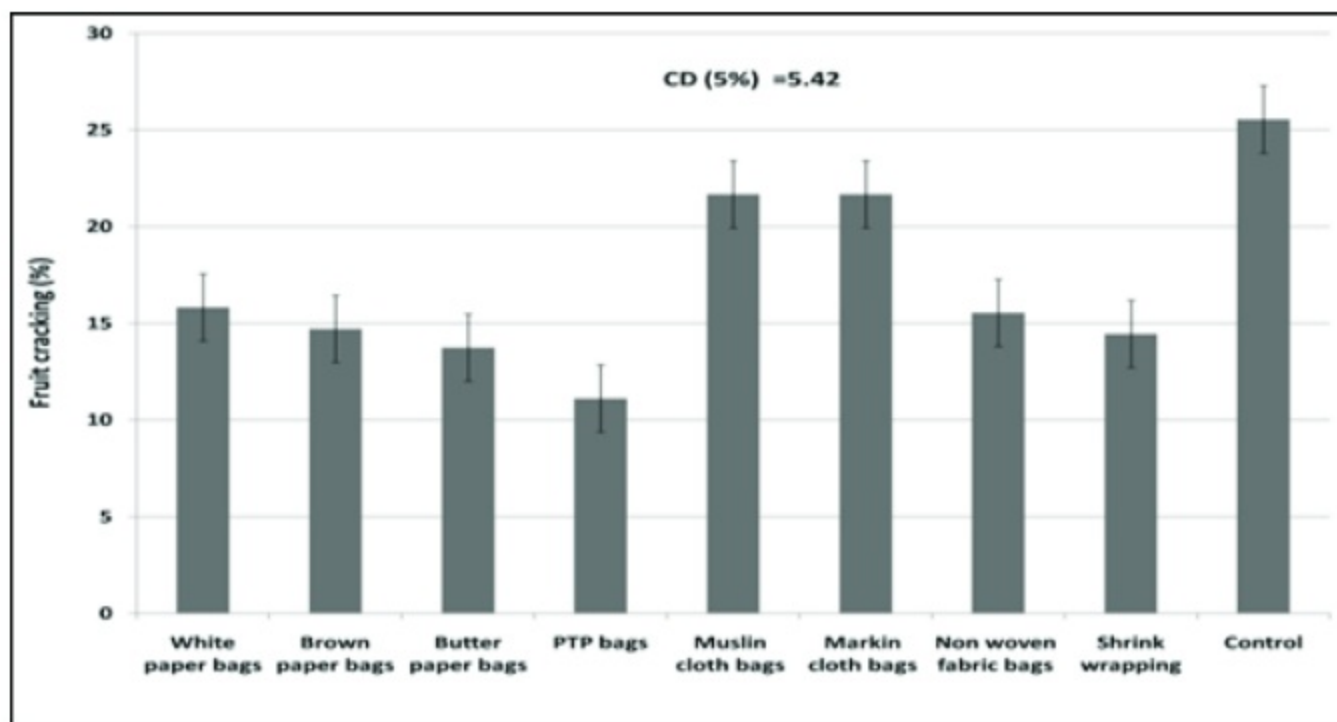


Fig. 1. Effect of different bagging material on fruit cracking of pomegranate

increased fruit weight in carambola. These results are in accordance with those obtained by Abd El-Rhman, (2010), who reported that, the covering of pomegranate fruits with bags resulted in higher fruit weight as compared to control. The different bag types were significantly increased fruit weight in longan (Yang *et al.*, 2009). Bunch bagging increased bunch weight compared to the control (Mohamed *et al.*, 2012). Fruit bagging has increased fruit size probably due to development of optimum micro-climate around fruit. Similarly, Wei *et al.* (2009) and Abd El-Rhman (2010) also reported that, bagging of pomegranate fruit gave higher positive effect on fruit diameter as compared with the control. The higher marketable yield in bagged fruits was possible due to lower incidence of fruit cracking, frost damage, sun scald and improved colour as compared to un-bagged fruits. Fruit cracking was significantly reduced by different bagging material (Fig. 1) and minimum fruit cracking was recorded in perforated transparent poly bags (11.12%) followed by butter paper bags (13.75%) and shrink wrapping (14.45%) as compared to maximum fruit cracking found in control (25.20%) followed by muslin cloth bags (21.67%) and markin cloth bags (20.50%). These results are in agreement with those obtained by Wei *et al.* (2009), who reported that, bagging minimized fruit cracking incidence (5.10%) significantly as compared to the control (32.80%). The berry cracking rate of the non-bagging treatment was higher as compared to berry treated with white paper bag, yellow bag and blue bag (Son and Lee, 2008). The fruit cracking incidence of 'Daqingpitian'

was lower (4.1%) in bagged treatments as compared to the maximum (46%) in un-bagged control (Yuan *et al.*, 2010; Li *et al.*, 2011). Sakineh *et al.* (2015) reported that white bag was the most effective treatment for increasing quality and reducing sunburn in pomegranate fruit cv. Rabab Neiriz.

The total soluble solids and maturity index were significantly influenced by different bagging material while non-significant differences were observed in other fruit physico-chemical quality attributes like acidity, ascorbic acid, total sugar, reducing sugar of fruits. The maximum TSS, total sugar and reducing sugar content were recorded in perforated transparent polyethylene bags (16.07°Brix, 13.11 and 12.10%) followed by muslin cloth bags (15.66°Brix, 12.54 and 11.51%) as compared to minimum TSS, total sugar and reducing sugar content recorded in butter paper bags (14.98°Brix, 11.81 and 10.66%), respectively. The titrable acidity ranged from minimum 0.45% in perforated transparent polyethylene bags to maximum 0.61% in control. The maximum ascorbic acid content was recorded in perforated transparent polyethylene bags (22.73 mg/100 g) as compared to minimum found in brown paper bags (20.35 mg/100 g) (Table 2). The maturity index is an important quality for pomegranate, which varied significantly among different fruit bagging treatments (Fig. 2). The maximum maturity index was recorded in perforated transparent polyethylene bags (35.52) followed by butter paper bags (31.91) as compared to minimum found in control (25.12). Similar results were also obtained by Abou El-Wafa (2014) and Asrey *et al.* (2019) in pomegranate.

Table 2. Effect of different bagging material on physico-chemical quality of pomegranate

Treatments	TSS (°Brix)	Acidity (%)	Ascorbic Acid (mg/100g)	Total sugar (%)	Reducing sugar (%)
White paper bags	15.61	0.502	20.77	12.27	11.12
Brown paper bags	15.11	0.520	20.35	11.82	10.70
Butter paper bags	14.98	0.485	20.81	11.81	10.66
Perforated transparent polybags	16.07	0.453	22.73	13.11	12.10
Muslin cloth bags	15.66	0.503	21.82	12.54	11.51
Markin cloth bags	15.65	0.618	21.09	12.32	11.19
Non woven fabric bags	15.61	0.599	20.72	11.84	10.89
Shrink wrapping	15.42	0.501	22.14	12.09	11.04
Control	15.29	0.610	20.61	11.96	10.91
SEm±	0.11	0.007	0.29	0.05	0.04
CD (5%)	0.31	NS	NS	NS	NS

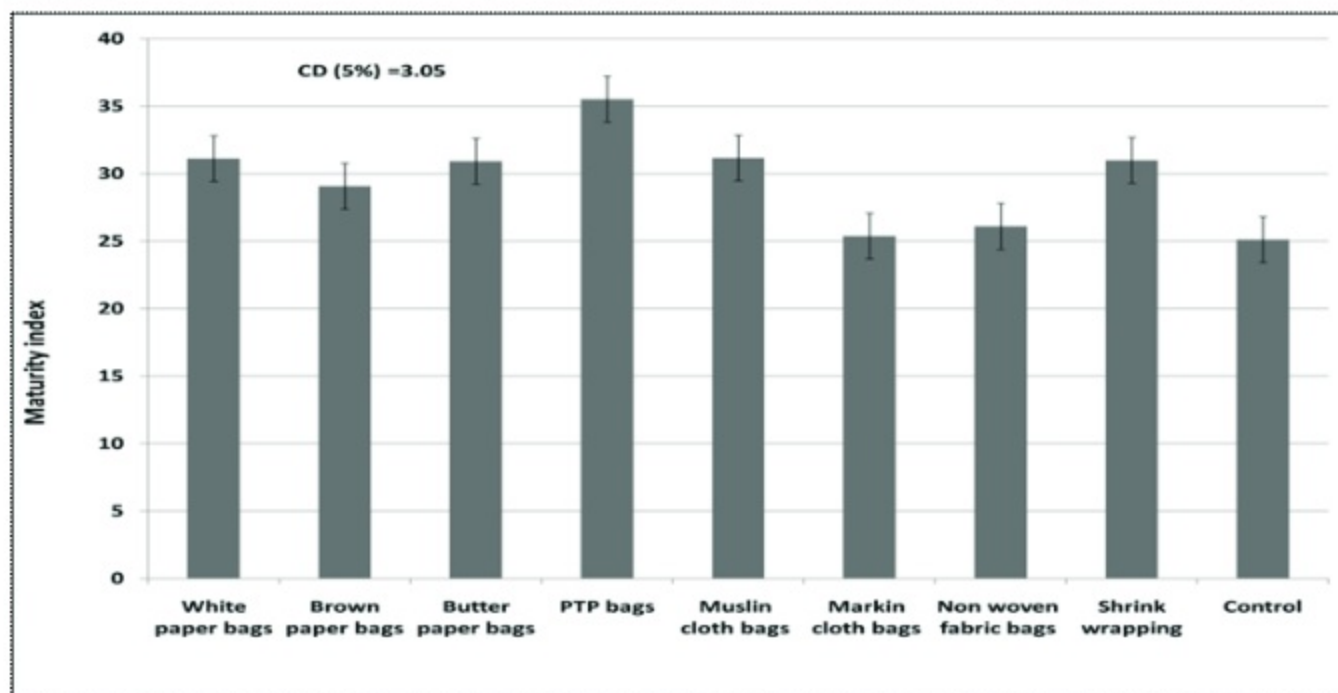


Fig. 2. Effect of different bagging material on maturity index of pomegranate

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Pre-harvest chemical sprays for enhancing shelf life and fruit quality of jamun

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Abstract

An experiment was conducted to study the effect of different pre-harvest sprayed chemicals *i.e.* calcium chloride (1.0, 1.50, 2.0%), GA₃ (50, 100 ppm), potassium sulphate (1.0, 2.0%) and control (water spray) on shelf life and post harvest quality of jamun cv. Goma Priyanka at ambient temperature under semi-arid conditions of western India. Increase in physiological loss in weight (PLW), spoilage percentage and decrease in titratable acidity, ascorbic acid, total sugar and anthocyanin content with advancement of storage period were general phenomena in all the treatments. However, TSS, and TSS: acidity ratio initially increased and thereafter decreased, respectively irrespective of treatments. Minimum spoilage loss was recorded in the fruits treated with CaCl₂ 2.0% (13.33%) closely followed by CaCl₂ 1.50% (17.28%). Same treatment also showed lowest PLW (13.65%) on the last day of storage and exhibited 3.03 days of economic shelf life, while control had 1.68 days of economic shelf life under ambient conditions. Highest PLW (18.17%) and spoilage (25.34%) were recorded in the control on the last day of storage (4th day). In general, shelf life of jamun fruits increased with the increase in concentration of calcium chloride. It may be concluded that CaCl₂ 1.50 to 2.0% can be sprayed before harvest of fruits for enhancing the shelf life and maintaining fruit quality of jamun under ambient conditions.

Key words: Pre-harvest spray, jamun, PLW, spoilage, economic shelf life

Introduction

Jamun (*Syzygium cumini* Skeels) belongs to the family Myrtaceae, highly adapted to diverse environmental conditions, is widely distributed in India up to an altitude of 1600 m. The anthocyanins, fibers and ellagitannins which are present in the pulp are important in reducing the oxidative stress-induced diseases. Jamun berries contain carbohydrates, iron, sugars, minerals, protein and the pharmacologically active phytochemicals like flavonoids, terpenes, and anthocyanins (Singh *et al.*, 2019). The powdered seeds have also reputation of being useful in the treatment of diabetes. These seeds are claimed to contain alkaloid, jambosine, and glycoside jambolin or antimellin, which halts the diastatic conversion of starch into sugar and seed extract has lowered blood pressure. The ripe jamun fruits are consumed fresh and can also be processed into many value added products like jam, jellies, squash, cider, nectar, wine, vinegar, RTS *etc.* Because of its hardy nature and various uses, it has great potential for commercial exploitation in wastelands and dry-land horticulture. Jamun fruits are very perishable in nature, which is a major problem in its marketing (Singh *et al.*, 2019a). Due to increased awareness among masses regarding its nutraceutical value and health benefits resulting in increased demand of jamun fruits day by day. However, due to its perishable nature, the fruit quality deteriorates the very next day of harvesting (Nayak and Panda, 2020). Therefore, there is a need to extend the shelf life of jamun fruits with desirable marketable quality. So this experiment was conducted to study

the effect of pre-harvest chemical sprays on shelf life and fruit quality of jamun fruits.

Materials and Methods

The present investigation was conducted during the year 2016 at experimental farm of CHES, Vejalpur, Godhra. The fruiting trees were sprayed with different concentration of CaCl₂ (T₁-1.0%, T₂-1.50%, T₃-2.0%), GA₃ (T₄-50 ppm, T₅-100 ppm), K₂SO₄ (T₆-1.0%, T₇-2.0 %) and water (T₈ control) twice with the help of foot sprayer. First pre-harvest spray of different chemicals was done on April 05 and second spray was applied after 20 days of first spray. The experiment was conducted under Randomized Block Design which was replicated thrice. The handpicked mature fruits of jamun cv. Goma Priyanka from different treatments having uniform size, undamaged and free from blemishes were collected for the study on post-harvest shelf life and fruit quality. The collected fruits were stored at ambient temperature ranging between 25±2°C. The physiological loss in weight, spoilage loss, total soluble solids and titratable acidity were determined by standard methods. Economic shelf life (in days) of fruits was determined by counting the number of days, on the date after which cumulative spoilage percentage of fruits in particular treatment exceeded 12%, from the date of harvest of the fruits (Singh *et al.*, 2005). Ascorbic acid, total sugar anthocyanin contents were determined by the methods advocated by A.O.A.C. (1990). The collected data were

analyzed statistically and per cent data were angularly transformed and the critical differences (CD) at 0.05 level of probability were worked out for comparing the means.

Results and Discussion

The physiological loss in weight (PLW) gradually increased in all the treatments with the advancement of storage period (Table 1). CaCl₂ 2.0% was the most effective treatment in retaining the PLW during all the days of observations and showed only 13.65% PLW on 4th day of storage followed by CaCl₂ 1.50% (17.38%). The highest PLW (26.47%) was recorded in the control on 4th day of storage. The increased weight loss in untreated jamun fruits might be due to increased storage breakdown associated with higher transpiration and respiration rate compared to treated fruits. The lower weight loss in calcium treated jamun fruits is attributed to membrane functionality and integrity maintenance with lower losses of phospholipids and proteins and reduced ion leakage which could be responsible for lower weight loss (Vandana *et al.*, 2015). Similar results were observed in jamun (Dalvadi *et al.*, 2018, Mishra *et al.*, 2018, Vandana *et al.*, 2015) and guava (Mishra *et al.*, 2003).

Spoilage of jamun fruits started on 3rd day of storage in all the treatments except calcium treated fruits where it started on 4th day of storage (Table 1). The minimum spoilage loss was recorded in CaCl₂ 2.0% (15.08%), which was closely followed by CaCl₂ 1.50% (17.28 %) while the maximum spoilage loss was in the control (31.27 %) on 4th day of storage. The reduction in fruit spoilage calcium treated fruits might be due to its effect on firmness of fruit tissue by retarding rate of respiration and preventing cellular disintegration which leads to delayed senescence (Singh *et al.*, 1993). This is in complete agreement with findings of Dalvadi *et al.*, 2018, Mishra *et al.*, 2018, Vandana *et al.*, 2015 in jamun. On the basis of spoilage within 12%, the maximum economic shelf life (3.03 days) was recorded by CaCl₂ 2.0%, however the control recorded 1.68 days only. Total soluble solids (TSS) increased in all the treatments during 3rd day storage and then decreased (Table 2). It was found to be maximum (20.57°B) in the control and minimum (16.33°B) in the fruits treated with CaCl₂ 2.0% followed by CaCl₂ 1.50% on the 3rd day of storage. Increase in TSS during storage might be associated with the

transformation of pectic substances, starch, hemi-cellulose or other polysaccharides in soluble sugar and also with the dehydration of fruits (Nayak and Panda *et al.*, 2020). Similar results were obtained by Vandana *et al.* (2015) during storage of jamun fruits. During storage, the titratable acidity gradually decreased in all the treatments (Table 3). The minimum acidity (0.31%) was recorded in the control on the last day of storage, while the maximum was observed in CaCl₂ 2.0% (0.45%) closely followed by CaCl₂ 1.50%. Fruits treated with GA₃ also retained more acidity on the last day of storage in comparison to control. This could be due to retarding of ripening by calcium treated fruits as a result of reduced ethylene activity that could delay in the utilization of organic acids in the enzymatic reactions of respiration. The maintenance of higher level of titratable acidity by calcium treated fruits is in conformity with the findings of Vandana *et al.* (2015) in jamun and Mishra *et al.* (2003) in guava. The balance ratio between TSS and acidity is a basic to the judgment of the quality of fruits (Table 3). The TSS (°Brix) and acidity are usually satisfactory indices in many fruits, wherein increasing sugar concentration and decreasing titratable acidity occurs in the ripening processes. The results of this experiment also followed the same pattern of change in TSS: acidity ratio *i.e.* the TSS: acid increased with advancement of storage up to 3rd day and the next day all fruits were spoiled (Table 3). The maximum TSS: acid ratio found in K₂SO₄ 2.0% (49.12) on 3rd while the minimum TSS: acid ratio on 3rd day was observed in CaCl₂ 2.0% (32.73). This could be due to retarding of ripening by calcium treated fruits as a result of reduced ethylene activity resulting in slow rate of degradation while higher increase in sugar concentration and decrease in acid content of fruits day by day in other treatments may be due higher rate of degradation. This type of result was also found by Nayak and Panda (2020).

Total sugar gradually decreased in all the treatments which continued until the end of the storage period (Table 3). It was found to be maximum (3.17%) in the CaCl₂ (2.0%) and minimum in control fruits (2.29%) on the last day of storage (4th day). Reduced increment in sugars during storage in the treated fruits was due to less weight loss that caused less dehydration of the fruits. These findings are in agreement with the findings of Nayak and Panda (2020) in jamun.

Table 1. Effect of treatments on PLW and spoilage of jamun during ambient storage

Treatment	PLW (%)			Economic shelf-life (days)	Spoilage (%)		
	Days after harvest				Days after harvest		
	2	3	4		2	3	4
T ₁	6.74	11.63	17.94	2.57	5.08	11.58	19.21
T ₂	6.20	11.38	17.38	2.63	4.92	10.69	18.87
T ₃	6.09	9.89	13.65	3.03	3.88	9.19	15.08
T ₄	8.43	14.45	19.20	2.08	7.05	12.15	26.85
T ₅	7.71	14.05	18.69	2.13	6.84	12.30	23.92
T ₆	6.82	14.94	21.59	2.00	6.91	12.05	26.10
T ₇	6.36	14.58	22.14	2.06	7.17	12.09	25.41
T ₈	10.22	17.82	26.47	1.68	9.83	14.20	31.27
Mean	7.32	13.59	19.63	-	6.46	10.41	23.34
CD (p= 0.05)	T= 0.26, D= 0.18, D x T= 0.52			0.10	T= 0.34, D= 0.24, D x T= 0.68		

Table 2. Effect of treatments on TSS and acidity of jamun during ambient storage

Treatment	TSS (*B)				Acidity (%)			
	Days after harvest				Days after harvest			
	1	2	3	4	1	2	3	4
T ₁	13.20	14.67	17.44	12.14	0.67	0.57	0.45	0.36
T ₂	13.05	14.13	17.18	12.33	0.65	0.59	0.45	0.41
T ₃	13.23	13.88	16.33	14.73	0.66	0.63	0.50	0.45
T ₄	13.35	14.85	19.24	13.44	0.74	0.61	0.48	0.36
T ₅	13.29	14.44	18.76	13.36	0.74	0.62	0.50	0.38
T ₆	13.59	14.79	20.37	11.80	0.70	0.56	0.43	0.29
T ₇	13.34	14.95	20.14	11.34	0.72	0.54	0.41	0.31
T ₈	13.45	15.15	20.57	11.32	0.75	0.60	0.46	0.27
Mean	13.31	14.61	18.75	12.56	0.704	0.590	0.46	0.35
CD (p= 0.05)	T= 0.19, D= 0.14, D x T= 0.39				T= 0.007, D= 0.005, D x T= 0.015			

Table 3. Effect of treatments on TSS: acidity and total sugar of jamun during ambient storage

Treatment	TSS: acidity				Total sugar (%)			
	Days after harvest				Days after harvest			
	1	2	3	4	1	2	3	4
T ₁	19.70	25.73	38.75	33.72	10.26	8.11	5.73	2.48
T ₂	20.07	23.94	38.17	30.12	10.29	8.15	5.77	2.49
T ₃	20.04	22.03	32.66	32.73	10.30	8.25	6.05	3.17
T ₄	18.04	24.34	40.08	37.33	10.25	8.05	5.15	2.35
T ₅	17.95	23.29	37.52	35.15	9.87	8.13	5.23	2.42
T ₆	19.41	26.41	47.37	40.68	10.16	8.06	5.20	2.40
T ₇	18.52	27.68	49.12	36.58	10.20	8.09	5.18	2.40
T ₈	17.93	25.25	44.71	41.92	10.25	7.80	5.19	2.29
Mean	18.96	24.83	41.05	36.03	10.19	8.08	5.438	2.50
CD(p= 0.05)	T= 0.37, D= 0.26, D x T= 0.74				T= 0.13, D= 0.09, D x T= 0.26			

The ascorbic acid content of fruits decreased progressively during storage in all the treatments (Table 4). The maximum ascorbic acid content (19.42 mg/100 g) was retained by CaCl₂ (2.0%) closely followed by GA₃ (100 ppm) on last day of storage (16.28 mg/100 g), while it was least in the control (12.35 mg/100g). Activities of oxidizing enzymes might be reduced due to binding activity of calcium treated fruits that might have been resulted the higher level of ascorbic acid content up to last day of storage. This finding is in agreement with those of Gol *et al.* (2015) in jamun and Mishra *et al.* (2003) in guava. Data presented in Table 4 revealed a significant reduction in the anthocyanin content at all the storage intervals in all the treatments. The maximum

anthocyanin content (4.36 mg/100 g) was retained by CaCl₂ (2.0%) closely followed by CaCl₂ (1.50 %) on last day of storage (4.33 mg/100 g), while it was recorded the least in the control (3.47 mg/100g) on 4th day of storage. In comparison to the control fruits, all of the treated fruits maintained their anthocyanin concentration at a higher level which might be due to the inhibition of the polyphenol oxidase enzyme activity in treated fruits (Gol *et al.*, 2015).

On the basis of spoilage loss and fruit quality attributes of treated fruits, it may be concluded that fruits treated with CaCl₂ 2.0% could be stored up to day 3 during storage at ambient temperature under semi arid ecosystem of Gujarat.

Table 4. Effect of treatments on ascorbic acid and anthocyanin content during ambient storage

Treatment	Ascorbic acid (mg/100 g)				Anthocyanin (mg/100g)			
	Days after harvest				Days after harvest			
	1	2	3	4	1	2	3	4
T ₁	41.72	32.71	26.66	14.63	7.02	6.45	4.78	4.31
T ₂	43.81	34.57	28.24	15.25	7.11	6.58	4.89	4.33
T ₃	45.53	38.03	31.36	19.42	7.16	6.76	5.37	4.36
T ₄	43.35	34.02	27.44	15.36	7.05	6.33	4.58	4.29
T ₅	44.23	35.20	27.58	16.28	7.08	6.61	4.62	4.33
T ₆	43.55	34.44	26.63	14.30	7.01	6.28	4.42	4.27
T ₇	43.40	34.33	27.05	14.83	7.04	6.30	4.45	4.30
T ₈	41.50	31.60	25.89	12.35	7.02	6.39	4.64	3.47
CD (p= 0.05)	T= 0.31, D= 0.22, D x T= 0.62				T= 0.09, D= 0.07, D x T= 0.19			

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Response of pruning intensity and time on growth, yield and quality attributes of phalsa under hot arid condition

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Abstract

Recently phalsa is gaining popularity in arid and semi-arid regions due to drought tolerance, nutritional and medicinal value; and can be grown successfully in adverse climatic conditions of arid regions with limited supplemental irrigations and fertilizer application. Pruning is an essential cultural operation in phalsa for good flowering and fruiting. Therefore, present experiment was carried out during 2017 to 2019 to study the response of different pruning intensities and timings on vegetative growth, yield and quality attributes of phalsa 'CIAH-P-1'. The phalsa bushes were pruned on four dates *viz.*, 30th November, 15th December, 30th December and 15th January at four intensities, *i.e.* 0.00 cm, 20 cm and 40 cm, and 60 cm height from ground level. It was observed that pruning timings and intensities had significant effect on sprouting period, bush height, number of twigs, number of fruiting clusters, number of fruits per cluster, fruits weight, total soluble solids and fruit yield per plant. Maximum average fruit yield (4.91 kg/plant), average fruit weight and diameter (1.14 g and 1.26 cm) and total soluble solids (25.02°Brix) were obtained when pruned the bushes at 20 cm from ground level on 15th of January, which was significantly higher from rest of the treatment combinations. On the findings of the study, it may be concluded that pruning in phalsa should be done on 15 to 20th of January at 20 cm height from ground level under Bikaner agro-climatic conditions of western Rajasthan.

Key words: Phalsa, pruning intensity, pruning time, yield, quality attributes

Introduction

Phalsa is a crop of hot arid and semi-arid regions. For fruit and colour development, fruit ripening and quality it requires optimum sunlight and warm temperatures. It can be grown in various types of soils. However, sandy loam soil having good drainage facility is ideal for good growth and development of the plant. In India, it is grown commercially in states like Punjab, Uttar Pradesh, Madhya Pradesh, Haryana, Rajasthan and the Himalayan regions, and is found up to 3,000 feet above sea level and also grown on smaller scale in Karnataka, Maharashtra, Andhra Pradesh, Gujarat, West Bengal and Bihar. Traditionally, it is cultivated as subsistence farming and hence it is mostly consumed in fresh fruits and juices. In India, ripen fresh fruits consumed during summer months and also preparation of refreshing cool beverage (Sarolia *et al.*, 2019). Ripe fruits are sour-sweet in taste and good source of vitamin A and C. Fruits rich in antioxidants and are good source of iron and phosphorus. It comes under underutilized fruit crops but have nutritional and medicinal value. The nutritional and medicinal value of phalsa is due to its high phenolic compounds, organic acids, tannins, anthocyanins, and flavonoids. Despite the highly nutritional value of the fruit, it is not cultivated commercial scale. It is an ideal plant for multi-story cropping. However, its popularity is restricted owing to highly perishable nature, small size of fruit and non-synchronous maturity, which necessitates repeated

harvesting. Therefore, the plantation is mainly confined to the surroundings of big cities. Its cultivation is also possible with the minimum or no use of synthetic chemical nutrients that also has a sustainable effect on environment and the soil. Due to this reason, organic production is also possible with excellent quality fruits (Kumar and Haldhar, 2019).

Successful phalsa production is mainly depends upon training and pruning operations. This crop is trained in such a way that it can take the shape of a bush. Because, bush gives more fruiting branches, which results in the higher yield. It is pruned once in North India and twice in South Indian conditions (Kumar and Haldhar, 2020). Pruning is an essential cultural operation since flowers are borne as axillary cyme on new growth, which is induced by pruning. The presence of mature leaves inhibit axillary bud sprouting in un-pruned shoots. The flowering and fruiting is confined to 15-20 nodes from the base depending on vigour (Meghwal, 2006). Pruning and plant growth regulators have been commonly used in modifying various physiological processes with advantage in plant growth, flowering, fruit yield and other attributes in several horticultural crops. Right time pruning and at optimum level in phalsa gives the significant results like increasing the yield and quality of fruits. In addition to manures and fertilizers, pruning has also been reported to manage plant canopy and enhance the flowering, fruiting, yield and quality of many fruit crops (Lakra *et al.*, 2018). Pruning in phalsa is considered as an essential operation since the fruit buds are

found on current season's growth to get good yield. Besides, severity of pruning, the optimum time of pruning, may also be very important for improving yield and quality of fruits. It has also been reported that the time of pruning may regulate fruit maturity in phalsa which ultimately result into orderly marketing of this perishable fruit, which can prove to be advantageous to both the fruit growers and consumers (Abid *et al.*, 2012).

In recent years, phalsa is becoming popular in arid and semi-arid regions due to drought tolerance, high returns and live fence cheep material. Side by side the optimum intensity of pruning and time has not been well established under Bikaner condition of western Rajasthan. Therefore, present experiment was carried out to study the optimum time and severity of pruning on vegetative growth, yield and quality attributes of phalsa 'CIAH-P-1'. In the present study, the pruning time and intensity of pruning was standardized at ICAR-Central Institute for Arid Horticulture, Bikaner.

Materials and Methods

Pruning intensity and right time of pruning are necessary practices for getting optimum yield in phalsa. For the standardization of pruning intensity and pruning time of phalsa 'CIAH-P-1'; an experiment was conducted during 2017 to 2019 in Entomology Block of ICAR-CIAH, Bikaner. The institute is located on 28° N latitude, 73°18' E longitude and at altitude of 234.84 m above sea level. The location of experimental site is very hot and dry and receiving scanty rains. There were four intensities of pruning viz., H₁-0, H₂-20, H₃-40 and H₄-60 cm height from ground level and four time of pruning such as T₁-30th November, T₂-15th December, T₃-30th December and T₄-15th January (Table 1). The field experiment was conducted in randomized block design and data were analyzed using online software developed by Sheoran *et al.*, 1998.

The observations were recorded with respect to bush sprouting, flower bud initiation/flowering, fruiting, yield and quality parameters. The uniform five years old phalsa bushes

were selected for recording bush height, canopy spread, sprouting period (days), required days for pruning to flowering, required days for harvesting, length of harvesting period, number of twigs per bush, length of twigs (cm), number of fruiting clusters per twig, number of fruits per cluster, yield per bush (kg), fruit weight (g), fruit diameter (mm), total soluble solids (°Brix). The selected phalsa bushes were pruned on 30th November, 15th December, 30th December and 15th January during 2017-18 and 2018-19. There were sixteen treatments having two bushes in each treatment. Fruits were harvested from April to June during both the years for recording yield and quality parameters.

Results and Discussion

All the vegetative growth parameters were significantly influenced by pruning intensity and timing. Minimum average period (15 and 21 days) taken for sprouting was observed in treatment T₁H₁ during 2018 and 2019, respectively followed by in T₃H₄ (34 days) while maximum average days taken (87.50 days) for sprouting bushes was noted in treatment T₁H₁ (Table 2). Maximum average bush height (1.48 and 1.65 m) was measured in T₁H₂ during both the years of study with pooled height of 1.57 m followed by T₄H₁ and minimum bush height (1.18, 1.16 and pooled 1.17 m) recorded in treatment T₁H₂. Maximum fruiting twigs per bush (206 and 198) was observed in treatment T₃H₄ followed by T₄H₄ (199 and 193) during both years of experimentation, respectively while in pooled data it was noted 202. Minimum average number of twigs was found in treatment T₁H₁ (120 and 126) with pooled data 112. In 2018, highest twig length was measured 122 cm in T₄H₁ which is at par with T₄H₂ (121 cm) followed by T₁H₁ (112 cm) while in 2019, it was noted maximum (124 cm) in T₄H₂ followed by T₂H₁ (119 cm). In pooled data, maximum twig length was recorded 122.50 cm in T₄H₁ followed by T₄H₁ (120.50 cm). Least average length of fruiting twigs per bush (86 cm) in first year was observed in T₁H₄ which is at par with T₃H₄ (87 cm) followed by T₃H₄ (92

Table 1. Treatment combinations, dates and intensities of pruning of phalsa

Treatment combinations	Pruning Time		Pruning intensity (cm)
	First year	Second year	
T ₁ H ₁	30.11.2017	30.11.2018	0
T ₁ H ₂	30.11.2017	30.11.2018	20
T ₁ H ₃	30.11.2017	30.11.2018	40
T ₁ H ₄	30.11.2017	30.11.2018	60
T ₂ H ₁	15.12.2017	15.12.2018	0
T ₂ H ₂	15.12.2017	15.12.2018	20
T ₂ H ₃	15.12.2017	15.12.2018	40
T ₂ H ₄	15.12.2017	15.12.2018	60
T ₃ H ₁	30.12.2017	30.12.2018	0
T ₃ H ₂	30.12.2017	30.12.2018	20
T ₃ H ₃	30.12.2017	30.12.2018	40
T ₃ H ₄	30.12.2017	30.12.2018	60
T ₄ H ₁	15.01.2018	15.01.2019	0
T ₄ H ₂	15.01.2018	15.01.2019	20
T ₄ H ₃	15.01.2018	15.01.2019	40
T ₄ H ₄	15.01.2018	15.01.2019	60

cm). During 2019, minimum twigs per bush (92 cm) were noted in T₃H₄ followed by T₁H₄ (94 cm) while in pooled data it was 89.50 cm in T₃H₄ which is at par with T₁H₄ (90.00 cm) followed by 94.50 cm in T₃H₃.

Effect of intensity of pruning and time on flowering and fruiting attributes

Intensity of pruning and time had significant effect on flowering and fruiting parameters. During both the years of experimentation, treatment T₁H₁ had taken minimum average number of days (45 and 51 days) for flowering after pruning and in pooled data it was noted 48 days followed by in T₄H₃ (50.50 days) which was at par (equal) with T₄H₂ and T₄H₄ (51 days). On the other side, maximum period had been taken for flowering in T₁H₃ and T₁H₄ (equal days) which were 94 days during 2018 while second year it was observed maximum (equal days) in treatment T₁H₂ and T₁H₃ (106 days) followed by T₁H₁ (100 days). In pooled data, maximum mean flowering time (100 days) was recorded in T₁H₃ followed by (91.50 days) T₁H₁. Similarly, harvesting period had also affected significantly due to pruning intensity and time of pruning. During first year of study, 15th January pruned bushes had taken minimum number of days (equal) for harvesting (104 days) in all four treatment combination *i.e.* T₄H₁, T₄H₂, T₄H₃ and T₄H₄ followed by T₃H₂ and T₃H₃ (112 days) which was equal period while maximum period was taken for picking of fruits in treatment T₁H₄ (148 days). In second year, Minimum time (120 days) for harvesting was recorded in treatment T₄H₄ followed by T₄H₁ (126) and maximum period was taken in T₁H₄ (168 days). In pooled data, minimum harvesting time (112 days) was observed in T₁H₄ followed by T₄H₁ (115 days) which was at par with T₄H₂ and T₄H₃. Likewise, length of harvesting period was also noted in all treatment combinations. During both the years of pooled data, longest

harvesting period (27.50 days) was observed in treatment T₁H₃ which was at par with T₄H₄ and shortest period was found in treatment T₁H₃ (13.50 days) which was also at par with T₁H₄ (14.00 days).

During both the years of study, 15th January pruned bushes at 20 cm from ground level (T₄H₂) were observed with maximum number of fruiting clusters per twig (12.20 and 13.60, respectively) which were at par with T₄H₁ followed by in treatment T₄H₃ (11.50 and 12.40, respectively) while minimum fruit clusters per twig (10.10 and 10.60) were recorded in treatment T₂H₄ which was at par with T₂H₃ (10.20 and 10.80) followed by in T₂H₂ (10.60 and 11.10). In pooled data, maximum fruit clusters per twig (12.90) were found in T₄H₂ which was at par with T₄H₁ (12.30) and T₃H₁ (12.40) while minimum clusters (10.35) were recorded in treatment T₂H₄ which was at par with T₂H₃ (10.50). During 2018, highest numbers of fruits per cluster (19.80) were observed when bushes pruned on 15th January at 20 cm from ground level (T₄H₂) which was at par with T₄H₁ and T₄H₄ (19.50). Minimum numbers of fruits (15.20) were found when bushes pruned on 15th December and 30th November during both the years of experimentation. During 2019 also, maximum fruits per clusters (18.40) were recorded when bushes pruned on 15th January (T₄H₂) which was at par with all three treatments (18.10, 18.00 and 18.00) pruned on 15th January at 0, 40 and 60 cm from ground level. In pooled data of both years, highest numbers of fruits per cluster (19.10) were noted in T₄H₂ and lowest in T₂H₃ (14.95) which were at par with T₁H₂ (15.00) (Table 3).

Yield and quality attributes were significantly affected by pruning time and severity of pruning during both the years of study (Table 4). During 2018, maximum average fresh fruit yield (4.89 kg/ bush) was recorded in treatment T₄H₂ followed by T₄H₃ (4.19 kg/ bush) and minimum in T₁H₄ (2.17

Table 2. Effect of pruning intensity and time on different characteristics of phalsa under hot arid ecosystem

Treatments	Sprouting period (days)			Required days from pruning to flowering			Required days for harvesting (days)			Length of harvesting period (days)			Bush height (m)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T1H1	63	80	71.50	83	100	91.50	135	156	145.50	23	25	24.0	1.23	1.27	1.25
T1H2	68	83	75.50	91	106	98.50	141	159	150.00	16	19	17.5	1.18	1.16	1.17
T1H3	74	86	80.00	94	106	100.00	146	159	152.50	11	16	13.5	1.18	1.19	1.19
T1H4	85	90	87.50	94	99	96.50	148	168	158.00	10	18	14.0	1.33	1.36	1.35
T2H1	34	43	38.50	70	79	74.50	126	144	135.00	16	21	18.5	1.18	1.20	1.19
T2H2	29	41	35.00	70	82	76.00	126	138	132.00	22	23	22.5	2.37	1.43	1.90
T2H3	46	52	49.00	73	79	76.00	128	150	139.00	27	25	26.0	1.32	1.26	1.29
T2H4	46	54	50.00	78	86	82.00	128	148	138.00	27	25	26.0	1.50	1.42	1.46
T3H1	31	40	35.50	67	76	71.50	122	140	131.00	21	23	22.0	1.13	1.18	1.16
T3H2	37	44	40.50	72	80	76.00	122	140	131.00	28	23	25.5	1.27	1.40	1.34
T3H3	41	45	43.00	67	71	69.00	112	132	122.00	31	24	27.5	1.28	1.38	1.33
T3H4	31	37	34.00	67	63	65.00	112	132	122.00	25	24	24.5	1.35	1.41	1.38
T4H1	15	21	18.00	45	51	48.00	104	126	115.00	17	23	20.0	1.37	1.50	1.44
T4H2	33	37	35.00	49	53	51.00	104	128	116.00	29	21	25.0	1.48	1.65	1.57
T4H3	39	42	40.50	49	52	50.50	104	128	116.00	24	21	22.5	1.36	1.48	1.42
T4H4	33	37	35.00	49	53	51.00	104	120	112.00	29	24	26.5	1.39	1.54	1.47
SEm±	2.07			2.55			1.70			2.41			1.30		
CD (5%)	6.31			7.77			5.17			7.33			N/A		

kg/ bush) followed by T₁H₃ (2.67 kg/ bush). In 2019 also, highest yield per bush (4.93 kg/ bush) was obtained in T₄H₂ followed by T₄H₃ (4.32 kg/ bush) and lowest (equal) was found in T₁H₁ and T₃H₁ (2.84 kg/ bush). In pooled data, yield was recorded maximum (4.91 kg/ bush) in T₄H₂ treatment followed by T₄H₃ (4.26 kg/ bush) and minimum in T₁H₄ (2.53 kg/ bush) followed by T₁H₃ (2.83 kg/ bush).

The vegetative growth, flowering, yield and quality attributes were significantly affected by pruning intensities and time. The results of this study are in close conformity with the findings of Mishra and Deen (2015) in phalsa. The phalsa twigs (shoots) lengths and numbers were observed variably in different pruning intensities. Sprouting response of pruned bushes was significant increasing and decreasing in different time and intensities. Maximum number and length of twigs per bush was recorded when phalsa pruned on 15th of January

and 30th of December. Similar results on vegetative growth parameters were also reported by Basith *et al.* (2018) in phalsa. The number of fruit clusters and fruits per cluster per bush were found to be significantly higher when pruning performed on 15th of January at 20 cm height from ground level as compared to other three dates and intensities of pruning during both the years. The results of the present experiment also confirm the findings of Basith *et al.*, (2018) in phalsa. Similarly, the fruit yield per bush, fruit weight, fruit diameter and TSS content were found significantly higher when bushes pruned on 15th of January at 20 cm height as compared to other treatments (Table 2). Increase in TSS content in January pruned bushes might be due to stimulatory effect of essential plant nutrients which increases the photosynthetic rate and metabolic activity in plant system, which might have helped in the translocation and

Table 3. Response of pruning intensity and timings on different characteristics of phalsa under hot arid ecosystem

Treatment	Number of twigs/ bush			Length of twig (cm)			Number of fruit clusters/ twig			Number of fruits / cluster		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
T1H1	120	126	123.0	112	119	115.50	11.30	11.60	11.45	16.20	15.30	15.75
T1H2	135	141	138.0	110	108	109.00	12.00	11.80	11.90	15.20	14.80	15.00
T1H3	149	146	147.5	105	101	103.00	11.10	11.20	11.15	15.80	15.00	15.40
T1H4	171	168	169.5	86	94	90.00	10.70	11.00	10.85	16.60	15.50	16.05
T2H1	140	152	146.0	107	110	108.50	10.90	11.70	11.30	16.80	16.20	16.50
T2H2	167.5	170	168.8	105	103	104.00	10.60	11.10	10.85	16.70	15.30	16.00
T2H3	177	174	175.5	103	98	100.50	10.20	10.80	10.50	15.20	14.70	14.95
T2H4	196	189	192.5	98	105	101.50	10.10	10.60	10.35	16.50	15.20	15.85
T3H1	162.5	165	163.8	111	115	113.00	12.20	12.60	12.40	18.10	17.50	17.80
T3H2	178	172	175.0	106	111	108.50	11.30	12.40	11.85	18.50	17.60	18.05
T3H3	192.5	190	191.3	92	97	94.50	11.70	12.60	12.15	18.20	17.30	17.75
T3H4	206	198	202.0	87	92	89.50	10.60	11.00	10.80	18.20	17.10	17.65
T4H1	165	173	169.0	122	119	120.50	11.90	12.70	12.30	19.50	18.00	18.75
T4H2	170	177	173.5	121	124	122.50	12.20	13.60	12.90	19.80	18.40	19.10
T4H3	189	188	188.5	104	99	101.50	11.50	12.40	11.95	19.30	18.00	18.65
T4H4	199	193	196.0	94	98	96.00	10.50	11.80	11.15	19.50	18.10	18.80
SEm±	3.05			2.28			0.21			0.17		
CD at 5%	9.28			6.95			0.65			0.54		

Table 4. Response of pruning intensity and timings on yield and quality attributes of phalsa

Treatment	Yield/ bush (kg)			Fruit weight (g)			Fruit diameter (mm)			Total soluble solids (^o Brix)		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
T1H1	2.88	2.84	2.86	0.82	0.83	0.83	10.83	10.65	10.74	19.95	19.78	19.87
T1H2	3.08	3.08	3.15	0.92	0.91	0.92	10.97	10.90	10.94	20.86	20.64	20.75
T1H3	2.67	2.99	2.83	0.62	0.60	0.61	10.70	10.66	10.68	20.58	20.82	20.70
T1H4	2.17	2.88	2.53	0.53	0.45	0.49	10.61	10.59	10.60	19.20	19.40	19.30
T2H1	2.99	3.10	3.05	0.93	0.88	0.91	10.96	10.83	10.90	20.36	20.44	20.40
T2H2	3.26	2.87	2.88	0.96	0.97	0.97	11.02	11.05	11.04	21.12	21.24	21.18
T2H3	2.9	2.98	2.94	0.94	0.97	0.96	10.88	10.97	10.93	20.82	21.02	20.92
T2H4	2.87	2.90	2.89	0.90	0.88	0.89	10.86	10.79	10.83	20.72	20.52	20.62
T3H1	2.69	2.84	2.77	0.80	0.79	0.80	10.71	10.41	10.56	21.88	21.59	21.74
T3H2	3.82	3.94	3.88	0.97	0.95	0.96	11.92	11.86	11.89	22.20	21.76	21.98
T3H3	3.74	3.34	3.54	0.83	0.84	0.84	11.69	11.81	11.75	21.48	21.08	21.28
T3H4	2.9	3.41	3.16	0.76	0.73	0.75	10.91	10.71	10.81	22.06	21.77	21.92
T4H1	3.46	3.96	3.71	0.83	0.82	0.83	11.09	11.01	11.05	23.10	22.90	23.00
T4H2	4.89	4.93	4.91	1.13	1.14	1.14	12.62	12.75	12.69	25.42	24.62	25.02
T4H3	4.19	4.32	4.26	1.01	1.02	1.02	12.15	12.30	12.23	22.63	22.23	22.43
T4H4	3.52	4.04	3.78	0.85	0.83	0.84	11.23	11.02	11.13	22.78	22.58	22.68
SEm±	0.06	0.03	0.15	0.03	0.04	0.01	0.17	0.25	0.06	0.62	0.51	0.14
CD at 5%	0.19	0.09	0.45	0.09	0.11	0.04	0.50	0.73	0.20	1.77	1.45	0.43

accumulation of more chemical metabolites in mature fruits. Similar kinds of results on yield and quality parameters were also reported by Ali *et al.* (2001) and Basith *et al.* (2018) in phalsa when pruning performed after 20 December to 20 January. The optimum weather conditions prevailing during last week of December to first fortnight of January as a result pruning might have assisted the phalsa bushes to produce early and more number of sprouts, flowers and fruiting clusters which have significant positive response in giving higher yield with better quality fruits.

The pruning intensity at 20 cm height from ground level on 15th of January had significantly maximum bush height (1.57 m), length of twigs/ shoots (122.50 cm), number of fruit clusters /shoot (12.90), number of fruits/ cluster (19.10), which ultimately yields to maximum fruit weight (1.14 g), fruit diameter (12.69 mm), fruit yield (4.91 kg/ bush) and total soluble solids (25.02 Brix). On the findings of the present study, it may be recommended that to obtain highest yield of good quality fruits, phalsa bushes should be pruned at 20 cm height from above ground level between 15 to 20 January every year under Bikaner agro-climatic conditions. However, response of pruning intensity and different dates of pruning may vary to change in agro-climatic zones and thus, result may differ accordingly

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Effect of foliar application of micronutrients on yield of date palm cv. Halawy

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Abstract

An experiment was carried out to study the effect of foliar application of micronutrients on yield and quality of date palm. The applied treatments were arranged in a randomized block design (RBD) with three replications viz. T₁ Control, T₂ ZnSO₄ (0.5%), T₃ Borax (0.25 %), T₄ FeSO₄ (0.5 %), T₅ Thiourea (0.1 %), T₆ ZnSO₄ (0.5 %) + Thiourea (0.1%), T₇ Borax (0.25%) + Thiourea (0.1%) and T₈ FeSO₄ (0.5 %) + Thiourea (0.1%). Application of different micronutrients affects the yield, fruit weight and quality of date palm cv. Halawy. The maximum fruit yield (121.27 kg/palm) and fruit weight (7.81g/ berry) were recorded in treatment T₈ (FeSO₄ 0.5 % + Thiourea 0.1%) while highest TSS (35.42%) was recorded in treatment T₇ (Borax 0.25% + Thiourea 0.1%) followed by treatment T₈ (FeSO₄ 0.5 % + Thiourea 0.1%).

Key words: Micronutrients, foliar application, yield, fruit weight, TSS

Introduction

Date palm (*Phoenix dactylifera* L.) is a monocotyledonous, dioecious, perennial tree that belongs to the family Arecaceae. The latin name *Phoenix dactylifera* is derived from "Phoenix", which means date palm and *dactylifera* derived from a Greek word "daktulos" means a finger. Major date palm producing countries in world are Iraq, Saudi Arabia, Iran, United Arab Emirates, Egypt, Pakistan, Morocco and Algeria. Besides these countries, Libya, Tunisia, Sudan, Muscat, Oman, the Aden, United States of America and Bahrain also produce dates in substantial quantities. Middle East and North Africa produce 60% of the processed dates in the world (Sivalingum *et al.*, 2014). In India, generally two species of *Phoenix* viz., *dactylifera* and *sylvestris* are found. The *Phoenix sylvestris* Roxb or "desi khajoor" is found throughout the country but it produces inferior quality fruits while commercially *dactylifera* is cultivated in Gujarat, Rajasthan, Punjab, Tamil Nadu, Maharashtra etc. states. Date is a highly nutritious and favourite fruit throughout world. Fresh 100g date fruit contains 59.2g moisture, 1.2g protein, 0.4g fat, 1.7g minerals, 3.7g fibre, 33.8g carbohydrates, 22.0 mg calcium, 38.0 mg phosphorus while 100g dry dates (*chhuhara*) provides 2.5g protein, 2.1g minerals, 3.9g fibres, 75.8g carbohydrates, 120 mg calcium, 50 mg phosphorus, 7.30 mg iron, 0.02 mg riboflavin, 0.9 mg Niacin, 3.0 mg vitamin C (Gopalan *et al.*, 1985). Date palm has provided food, ornamentals material for shelter, fiber, and fuel. In India, it is believed that date palm has been introduced by the soldiers of Alexander in the 4th century B.C. in Indus valley. A large number of seedling date palm groves exist in the western part of the India and Kachchh region of Gujarat state (Johnson *et*

al., 2013). In Rajasthan, date cultivation was first introduced by the ruler Ganga Singh Ji of the Bikaner state.

Micronutrients are essentially as important as macronutrients to have better growth, yield and quality in plants. The requirement of micronutrients is only in traces, which is partly met from the soil or through chemical fertilizer or through other sources. Micronutrients are involved in metabolic and cellular functions in the fruits plants. The sufficient amount of micronutrients necessary for better plant growth which resulted in higher yield due to increased growth, better flowering and higher fruit set (Ram and Bose, 2000). In date palm, very few study are undertaken to assess the effect of micronutrients. Therefore, present study is conducted to study the effect of micronutrients on yield and quality of date palm cv. Halawy.

Materials and Methods

The experiment was conducted at All India Coordinated Research Project on Arid Zone Fruits, Date Palm Research Centre, S.K. Rajasthan Agricultural University, Bikaner. The experiment site was situated an altitude of 234.7 m above mean sea level at latitude 28° 01' N and longitude 73° 22' E. The soil of experimental field was loamy-sand, alkaline in reaction (pH 8.6) having 120 kg ha⁻¹ available N (Alkaline permanganate method), low level of available phosphorus (15.0 kg ha⁻¹, Olsen's method) and medium in available potassium (175.4 kg ha⁻¹, Flame photometric method). The uniform date palm plants spaced at 6 x 6 meters apart and irrigated by drip irrigation were selected. The treatments were applied after fruit set at pea sized fruit and second repeated after one month. The applied treatments were arranged in a

randomized block design (RBD) with three replicates (three trees) for each treatments viz. T₁ Control, T₂ ZnSO₄ (0.5%), T₃ Borax (0.25 %), T₄ FeSO₄ (0.5 %), T₅ Thiourea (0.1 %), T₆ ZnSO₄ (0.5%) + Thiourea (0.1%), T₇ Borax (0.25%) + Thiourea (0.1%) and T₈ FeSO₄ (0.5 %)+ Thiourea (0.1%).

The yield was recorded and data were statistically analyzed for estimation of analysis of variance as per method suggested by (Panse and Sukhatme, 1985). Fruit weight was measured with the help of electronic balance and average fruit weight was recorded in gram. Total soluble solids percentage in fruit juice (TSS) was determined using hand refractometer. The critical differences between the observed values under different treatment combinations were also estimated to understand the significant effects of different Treatments.

Results and Discussion

The six year data (2014-2019) of yield of date palm are presented in Table 1. On pooled analysis basis, the maximum fruit yield (121.27 kg/palm) was recorded in treatment T₈ (FeSO₄ 0.5 % + Thiourea 0.1 %) at *doka* stage followed by treatment T₇ (Borax 0.25% + Thiourea 0.1%) i.e., 114.78 kg/palm and minimum in control (82.29 kg/palm). However, treatment T₁₀ and T₈ were statistically at par with each other in pooled basis. The observed results were in accordance with Ahamad *et al.* (1998). He found that maximum yield (37.2 kg/plant) was recorded with 0.5 per cent ferrous sulfate foliar application in guava. Alila *et al.*, (2004) reported that the foliar application of micronutrients i.e.,

FeSO₄ (0.2%) and boric acid (0.1%) on papaya cv. Ranchi significantly increased growth parameters in comparison to the control. Pathak *et al.* (2011) reported that combined application of Fe (0.5%) and Zn (0.5%) showed the best response on plant growth in terms of plant height, basal girth of pseudostem, number of leaves produced per plant and minimum duration between emergences of two successive leaves in banana. Ferrous sulphate acted as catalyst in formation of chlorophyll and several enzymes which accelerate the yield. The low level of thiourea (sulfhydryl compound) facilitated nutrient acquisition and transport (Garg *et al.*, 2006; Anjum *et al.*, 2011). It may act either as a nutritional supplement due to having nitrogen and sulphur or as biostimulator of cell growth.

The six year data (2014-19) were presented in Table 2 on the pooled basis revealed that maximum fruit weight (7.81 g/ berry) was observed in treatment T₈ (FeSO₄ 0.5% + Thiourea 0.1 %) at *doka* stage followed by 7.68 g berry⁻¹ in treatment T₇ (Borax 0.25% + Thiourea 0.1%) and minimum in control (6.68 g/berry). Similar findings was also reported by Meena *et al.* (2008) and they stated that foliar application of ferrous sulphate and borax at 0.6 per cent produced maximum average fruit weight, fruit length, fruit breadth, pulp weight, stone weight, pulp to stone weight ratio compared than the control and 0.3 per cent spray in ber trees.

As far as total soluble solids is concerned from the year 2014 to 2019, the maximum TSS content was registered in treatment T₇ followed by T₈ and minimum in control. On pooled analysis basis maximum TSS content (35.42%) was

Table 1. Effect of different micronutrients on yield of date palm (pooled from 2014 to 2019)

Treatments	Average yield/palm (kg)						Pooled data
	2014	2015	2016	2017	2018	2019	
Control (T ₁)	102.00	91.00	87.67	69.60	72.27	71.17	82.29
ZnSO ₄ (0.5%) (T ₂)	106.00	103.33	101.00	86.33	83.53	84.53	94.12
Borax (0.25 %) (T ₃)	108.00	102.00	99.00	89.00	86.37	85.70	95.01
FeSO ₄ (0.5 %) (T ₄)	108.60	110.33	108.33	96.53	93.60	97.27	102.44
Thiourea (0.1 %) (T ₅)	112.00	116.67	115.67	104.67	102.67	101.33	108.84
ZnSO ₄ (0.5%) + Thiourea (0.1%) (T ₆)	115.30	118.33	119.00	110.33	107.83	111.17	113.66
Borax (0.25%) + Thiourea (0.1 %) (T ₇)	116.60	117.67	118.33	112.00	110.67	113.40	114.78
FeSO ₄ (0.5 %) + Thiourea (0.1 %) (T ₈)	118.00	124.33	125.00	120.57	118.57	121.14	121.27
S.Em.+	4.23	6.029	5.946	3.56	4.32	5.34	2.26
CD (5%)	12.26	18.287	18.037	10.81	13.09	16.20	6.895

Table 2. Effect of different micronutrients on fruit weight of date palm (pooled from 2014 to 2019)

Treatments	Average fruit weight (g)						Pooled data
	2014	2015	2016	2017	2018	2019	
Control (T ₁)	6.73	6.83	6.63	6.63	6.60	6.65	6.68
ZnSO ₄ (0.5%) (T ₂)	6.80	6.87	6.87	6.87	6.83	6.83	6.85
Borax (0.25 %) (T ₃)	6.80	6.87	6.77	6.80	6.79	6.73	6.79
FeSO ₄ (0.5 %) (T ₄)	6.86	6.97	6.97	6.96	6.91	6.98	6.94
Thiourea (0.1 %) (T ₅)	7.03	7.13	7.13	7.16	7.13	7.05	7.11
ZnSO ₄ (0.5%) + Thiourea (0.1%) (T ₆)	7.13	7.13	7.20	7.33	7.30	7.43	7.25
Borax (0.25%) + Thiourea (0.1 %) (T ₇)	7.56	7.57	7.67	7.67	7.63	7.95	7.68
FeSO ₄ (0.5 %) + Thiourea (0.1 %) (T ₈)	7.66	7.80	7.80	7.80	7.80	8.02	7.81
S.Em.+	0.14	0.07	0.321	0.24	0.37	0.36	0.124
CD (5%)	0.39	0.21	0.974	0.71	1.11	1.10	0.381

recorded in T₇ (Borax 0.25% + Thiourea 0.1%) treatment closely followed by 35.33 % in treatment T₈ (FeSO₄ 0.5 % + Thiourea 0.1 %). Similar findings were reported by Pant and Lavania (1989) in papaya. They noticed that the foliar application of FeSO₄ (0.15%) was gave maximum TSS (14.3%) while maximum sugars (12.5%), highest sugar: acid ratio (49.2) and lowest acidity (0.25%) observed in borax 0.15% in papaya fruit.

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Effect of integrated nutrient management on physico-chemical attributes of ber fruit cv. Banarasi Karaka

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Abstract

An experiment was conducted during 2016-17 at Main Experiment Station, N.D. University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) to study the physico-chemical attributes of ber fruit cv. Banarasi Karaka. The experiment comprised of three replications with seven treatments in RBD viz. T₁ (Control), T₂ (100% RDF through NPK), T₃ (100% FYM), T₄ (50% FYM + 50% RDF through NPK), T₅ (50% FYM + 50% (PSB + Azotobacter)), T₆ (75% FYM + 25% RDF through NPK), T₇ (75% FYM + 25% RDF through NPK + 25% (PSB + Azotobacter)). Therefore, it may be recommended application of treatment T₇ is (75% FYM + 25% RDF through NPK + each 25% PSB + Azotobacter) to ber growers for obtaining larger and heavier ber fruit followed by application of 50% RDF through FYM + 50% RDF through NPK.

Key words: Ber, nutrient management, bio-fertilizers

Introduction

Ber (*Zizyphus mauritiana* Lamk.) is one of the most ancient and common fruit indigenous to India and belong to family Rhamnaceae. It is also known as Chinese date or Chinese fig and commonly consider as poor man's fruit. It is reported to grow in other countries like Iran, Syria, Australia, USA, France and certain parts of Italy, Spain, and Africa etc. Precisely, it is seen to grow under tropical and sub-tropical as well as mediterranean region of the world. The ber tree is drought hardy and can grow under the most hazardous condition of soil, water and climate. Ripe ber fruits are eaten fresh. Fruits are also dried and used as dessert purpose. It gives an excellent product when candied. Other processed products made are ber butter, ber juice or squash, ready to serve (RTS), beverage, jam, murabba and ber pickles. Besides fruit different part of tree like root bark, leaves, flower and seed are being used in Ayurvedic and Unani medicines for treatment of headache, bleeding, gums and asthma. The powder and decoction prepared from the roots are effective in case of fever, ulcers and old wounds. The stem bark is considered to be a remedy for diarrhoea; it is also blood purifier and appetizer. The leaves are used as fodder for the animal (Bakshi and Singh, 1974) and it became hardy nature and prolific bearer. The stem gives a quality wood which is used for making various agricultural implements.

It is one of the most nutritious fruit and good source of vitamin A, B and C. The ripe ber fruits have high nutritive values and conventionally. The ber fruit is richer than apple in protein, phosphorus, calcium and vitamin 'C' (Bakshi and Singh, 1974) and one hundred gram of edible ber fruit contains moisture (85.9%), protein (0.8g), fat (0.1g), carbohydrate (12.88%), calcium (0.03g), phosphorus (0.03g), iron (0.8g),

carotene (70 IU) and vitamin 'C' (50-100 mg), TSS (°Brix) 12.21, total sugars 3.1-14.5%, reducing sugars 1.4-2.4%, non reducing sugar 4.3-9.7%, pH 4.2-4.8% acidity 0.13-1.42%, total ash 0.34-0.45% and ascorbic acid 73-103 mg/100g of pulp. The farm yard manure (FYM) seems to be directly responsible in increasing crop yields either by accelerating the respiratory process by increasing cell permeability by hormone growth action or by combination of all these processes. The farm yard manure contains 0.5-1.5% nitrogen, 0.4-0.8% phosphorus and 0.5-0.9% potassium. Biofertilizers are substance which contains living micro-organisms, which when applied to soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant. Biofertilizers are also able to fix 20200 kg N/ha/year, solubilize P in the range of 3050 kg P₂O₅ ha/year and mobilizes P, Zn, Fe, Mo to varying extent and help to build up the lost micro-flora and play important role in increasing crop productivity (Hazarika and Ansari, 2007). *Azotobacter* is an aerobic, free living nitrogen fixer. When applied to soil, they multiply rapidly and develop a thick population in rhizosphere. PSB is the effective strain of phosphate solubilizing bacteria used in increasing the level of available P in the soil. It is a phosphate solubilizing bio-fertilizer. The present investigation was, undertaken to evaluate the "Studies on integrated nutrient management on physico-chemical attributes of ber fruit (*Zizyphus mauritiana* L.) cv. Banarasi Karaka".

Material and Methods

In the investigation, 27 years old plants of ber cv. Banarasi Karaka having uniform vigour and productivity were selected as experimental material to find out yield and quality

of ber fruits. The present investigation was carried out at the main experimental station, Department of Horticulture, A.N.D.U.A.&T, Ayodhya (U.P.) during the year 2016-2017. The experiment was laid out in Factorial Randomized Block Design with 12 treatments and 3 replications. There were seven treatment combinations viz. T₁ (Control), T₂ (100% RDF through NPK), T₃ (100% FYM), T₄ (50% FYM + 50% RDF through NPK), T₅ (50% FYM + 50% (PSB + *Azotobacter*)), T₆ (75% FYM + 25% RDF through NPK) and T₇ (75% FYM + 25% RDF through NPK + 25% (PSB + *Azotobacter*)).

Results and Discussion

The important results obtained have been discussed in the light of available literature in succeeding heads.

Physical parameters

Result showed that maximum fruit length (4.18 cm), fruit width (3.8 cm) and fruit weight (20.27) at harvest with the application of T₇ (75% FYM + 25% RDF through NPK + 25% (PSB + *Azotobacter*)) was significantly superior to T₁, T₂, T₃, T₄, T₅, and T₆. The increase in fruit length and width by the application of integrated nutrient treatments might be due to optimum supply of plant nutrients and growth hormones in right amount during the entire crop period causing vigorous vegetative development of the plants and ultimately production of more photosynthetic material. Improvement in physical character of fruits on account of FYM application might have been attributed to the translocation of nutrients

from soil to the plants and enhanced supply of macro and micro-nutrients during entire growing season. The various positive effects of biofertilizers on physical parameter like fruit length and diameter may be due to the fact that biofertilizers encouraged better growth and accumulates optimum dry matter with induction of growth hormones, which stimulated cell division, cell elongation, activate the photosynthesis process, enhances translocation of water and nutrients, growth and development of roots as well as energy transformation which in turn causes increase in number and weight of the fruits and other physical characters. The maximum average fruit weight (20.27 g) was recorded in application of T₇ (75% FYM + 25% RDF through NPK + 25% (PSB + *Azotobacter*)) which is followed by T₄ (78.13 kg) were significantly superior to control, T₂, T₃, T₅, and T₆ (Table 1). The enhancement in yield by these treatments was mainly due to proper supply of nutrients and induction of growth hormones, which stimulated cell division, cell elongation, increase in number and weight of the fruits, better root development, and better translocation of water uptake and deposition of nutrients.

Chemical parameters

Application of organics and chemical fertilizers along with biofertilizers not only increased the yield but also improved the fruit quality (Table 2). Their application significantly influenced the chemical constituents viz. TSS, reducing, non-reducing and total sugars, ascorbic acid of the

Table 1. Effect of intergrated nutrient management on physical attributes of ber fruits

Treatments	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)
T ₁	3.26	2.60	16.18
T ₂	3.94	2.92	18.26
T ₃	3.56	2.76	17.12
T ₄	4.07	3.02	18.84
T ₅	3.72	2.78	17.28
T ₆	3.83	2.87	17.85
T ₇	4.18	3.78	20.27
SEm±	0.13	0.10	0.75
CD at 5%	0.39	0.30	2.08

Table 2. Effect of intergrated nutrient management on bio-chemical attributes of ber fruits

Treatments	T.S.S. (°Brix)	Titration acidity (%)	Ascorbic acid (mg/100g pulp)	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)
T ₁	13.32	0.24	65.20	3.25	4.26	7.51
T ₂	15.19	0.20	70.18	4.38	4.56	8.94
T ₃	14.04	0.22	65.95	4.17	4.38	8.55
T ₄	16.09	0.18	72.45	4.33	4.54	8.87
T ₅	16.61	0.18	68.41	4.21	4.45	8.66
T ₆	15.19	0.21	71.53	4.57	4.68	9.25
T ₇	17.40	0.17	74.63	4.70	4.81	9.51
SEm±	0.70	0.01	1.13	0.09	0.07	0.12
CD at 5%	2.16	0.03	3.48	0.29	0.21	0.37

fruit over the control. The minimum acidity (0.17%) and maximum ascorbic acid (74.63 mg), total soluble solids (17.40 °Brix), reducing sugars (4.70%) and non-reducing sugar (4.81%) total sugars (9.51) were recorded in application of T₇ (75% FYM + 25% RDF through NPK + 25% (PSB + *Azotobacter*) which were significantly superior to control. The improvement in various chemical characteristics by application of optimum dose of NPK may be explained by the fact that phosphorus enters into the composition of phospholipids and nucleic acids, the latter combines with proteins and result in the formation of nucleus proteins which are important constituents of the nuclei of the cells. Potassium acts as a catalyst in the formation of more complex substances and in the acceleration of enzyme activity. These carbohydrates and coenzymes are beneficial in the improvement of fruit quality and nitrogen enhances the uptake of phosphorus and potassium. The chain reactions in these components might have possibly been reasons for the improvement in quality of the fruit. Similar results have also been reported by Yadav *et al.* (2007) in aonla and Bohne & Tiwari (2014).

Azotobacter and PSB inoculation resulted in overall increase in plant growth, fruit yield and quality which can be explained in a way that *Azotobacter* and PSB contribute up to 20-30% N and 25-50% P₂O₅ in soil, respectively. Ber responds well to the application of manures and fertilizers, hence biofertilizers application improved plant growth, fruit yield and chemical composition through rapid mineralization and transformation of plant nutrients in soil and also through the exertion of plant growth promoting substances mainly IAA, gibberellic acid and cytokinins like substances, vitamins and amino acid by microorganism. These results are in accordance with the findings of Shukla *et al.* (2009) in guava, Singh *et al.* (2011) in mango, Lesha *et al.* (2016) in ber and Singh *et al.* (2017) in strawberry.

Results of present study indicated that the application of 75% FYM + 25% RDF through NPK + each 25% PSB + *Azotobacter* gave better quantitative and qualitative trades *viz.*, fruit length (cm), fruit weight (g), fruit width (cm), TSS (°Brix), acidity (%), ascorbic acid, Total sugar (%), reducing and non-reducing sugar (%) of ber fruit followed by application of 50% RDF through FYM + 50% RDF through NPK. Therefore, the application of 75% FYM + 25% RDF through NPK + each 25% PSB + *Azotobacter* may be recommended to ber growers for obtaining better yield and quality of ber fruit.

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Vegetable based intercropping system in pomegranate under hot arid region

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Abstract

Field experiments were conducted at farmer's field in Charanwala branch of IGNP stage-II in Bikaner district of Rajasthan during rabi and kharif seasons of 2015-16 and 2016-17, respectively to study the productivity and economic returns of pomegranate based intercropping systems in one and half year old pre-bearing orchard of pomegranate (*Punica granatum* var. Bhagwa). There were five treatment combinations i.e. (i) Pomegranate + onion (*Allium cepa*)- Indian squash (*Citrullus lanatus* var. *fistulosus*), (ii) Pomegranate + radish (*Raphanus sativus*)- cowpea (*Vigna unguiculata*), (iii) Sole onion- Indian squash, (iv) Sole radish- cowpea and (v) Sole pomegranate. Intercropping has positive effect on height, girth and canopy spread of pomegranate tree over its sole plantation. The annual system productivity in terms of onion equivalent yield (OEY) was maximum in sole onion-Indian squash system which was at par with inter-cropping system of pomegranate + onion-Indian squash. Water productivity can be improved to 2.87 and 6.71 kg m⁻³ in terms of economic yield (WP_{EV}) and 130.5 and 378.6 Rs ha⁻¹mm⁻¹ in terms of gross return (WP_{GR}) with intercropping system of pomegranate + radish- cowpea and pomegranate + onion- Indian squash, respectively as compared to sole pomegranate plantations. An additional income of Rs. 2.36 lakhs/ha/year can be obtained with intercropping system of pomegranate + onion- Indian squash and 0.49 lakhs/ha/year with pomegranate + radish-cowpea intercropping system over sole plantations of pomegranate.

Key words: Economics, pomegranate, intercropping system, water productivity, yield

Introduction

Thar desert of Rajasthan occupies about 62% of the total arid region of India. The region is characterised by extremes of climatic conditions with low rainfall and high temperature. The greater proportion of agriculture in this region is resource constrained, subsistence and practiced under rainfed conditions. Yield losses associated with water stress and soil erosion are common in this zone (Soni *et al.*, 2013; Soni *et al.*, 2017 and Santra *et al.*, 2017). With the advancement of irrigation facility through IGNP, growing of suitable horticultural crops *viz.* pomegranate, kinnow, karonda, acid lime, mosambi *etc.* are now becoming popular and their area is increasing day by day.

Pomegranate is an important crop of arid region. The farmers grow pomegranate as sole crop and the interspaces are left unused. Suitable crop combinations in the inter-space of orchard during initial years can generate extra income (Ghosh and Pal, 2010), kinnow (Bhatnagar *et al.*, 2007) and ber (Birbal *et al.*, 2013), enhance productivity, ameliorate and improve ecological situation in a sustainable manner (Awasthi *et al.*, 2009). Though intercropping of fruit trees with suitable vegetables seems remunerative, yet meager scientific information is available regarding production, water productivity and economics of vegetable based intercropping systems with pomegranate in

arid region of Rajasthan. Hence, the present experiment was conducted to assess the yield, water productivity and economic performance of vegetable based intercropping system during establishment phase of pomegranate in light textured soil of arid region of western Rajasthan.

Materials and Methods

Field experiment was carried out at farmer's field located at RD-33 of Charanwala branch of IGNP stage-II (72° 25' E longitude and 27° 51' N latitude) during *rabi* and *kharif* season of 2015-16 and 2016-17, respectively in Bikaner district of Rajasthan. The region is characterised by arid climatic conditions with undulating topography and low to medium height sand dunes. The soil of the experimental site was sandy in texture with low soil organic carbon, alkaline in reaction and non-saline in nature. The bulk density (BD), cation exchange capacity (CEC), pH, permanent wilting point (PWP) and field capacity (FC) ranged between 1.52 to 1.57 Mg/m³, 4.5 to 5.6 cmol (p⁺)/kg, 7.9 to 8.3, 0.04 to 0.06 m³m⁻³ and 0.11 to 0.14 m³m⁻³, respectively depending upon soil depth. The CEC, pH, PWP, FC and soil water content increased with increase in soil depth, whereas BD, soil organic carbon, available N and EC decreased with increase in soil depth.

The experiment was conducted in one and half year old pre-bearing orchard of pomegranate (variety Bhagwa) spaced at

4 m x 3 m apart. In the inter-space of pomegranate, intercrops were sown 0.5 m away from pomegranate tree in either side of the trunk in a plot size of 3 m x 12 m in randomized block design with five treatments and four replications. The treatment combinations were as follows: T₁: Pomegranate + onion (*Allium cepa*) - Indian squash (*Citrullus lanatus* var. *fistulosus*), T₂: Pomegranate + radish (*Raphanus sativus*)- cowpea (*Vigna unguiculata*), T₃: Sole onion- Indian squash, T₄: Sole radish- cowpea and T₅: Sole pomegranate. The recommended packages of practices were followed for pomegranate and intercrops. Pomegranate plants were maintained with drip irrigation during dry periods (4 litre/tree/day for sole tree and 4 litre/tree at every 3rd day for trees in intercropping system). Intercrops were irrigated with mini-sprinkler irrigation. The total amount of irrigation water applied in the system (irrigation + rainfall) has been shown in Fig. 2. Plant protection measures and intercultural operations were done as and when required for both the components. Physico-chemical properties of the soil were analyzed by standard procedures (Jackson, 1973). The growth and yield data were recorded and system productivity was calculated in terms of onion equivalent yields (OEY). The OEY for different intercrops (both *kharif* and *rabi* season crops including fruit crop) was calculated based on selling price of the produce and yield of intercrops using Eq-1. The OEY of individual intercrops of both seasons was summed up to obtain overall system productivity of individual treatments.

$$OEY (kg ha^{-1}) = \frac{Yield\ of\ intercrops\ (kg\ ha^{-1}) \times Selling\ price\ (Rs\ kg^{-1})}{Selling\ price\ of\ Onion\ (Rs\ kg^{-1})} \dots Eq\ 1$$

Water productivity (kg m⁻³) was calculated as water quantity applied (rainfall + irrigation) in each treatment divided by the obtained yield (Eq.2).

$$Water\ productivity\ (WP) = \frac{Yield(kg\ ha^{-1})}{Water\ applied\ (m^3\ ha^{-1})} \dots Eq\ 2$$

The economic analysis was carried out by considering the actual expenditure incurred on various operations, labour charges, prevailing market price of inputs and crop produce. The benefit: cost ratio was calculated dividing net returns by the cost of cultivation of

individual treatment. The data recorded on various attributes were subjected to Fisher's method of analysis of variance and interpretation of data was taken up as per Sukhatme and Amble (1995).

Results and Discussion

Growth of pomegranate

Intercropping has positive effect on pomegranate plants as it improved the height, girth and canopy spread over sole plantation (Table 1). Average increase in height of pomegranate with radish-cowpea and onion-Indian squash cropping system was 37.1 and 46.6 %, respectively as compared to 21.3 % in sole pomegranate. Similarly, percent increase in girth and canopy spread of pomegranate was 65.0 and 20.2 % with radish-cowpea and 81.9 and 32.2 % with onion-Indian squash cropping system as compared to 45.5 and 8.8 %, respectively in sole pomegranate. The intercropping systems in pomegranate helps in improving microclimatic conditions, receiving the additional inputs, increase their use efficiency and improve soil environment through soil cover as compared to sole plantations in which the interspaces were left uncultivated and did not receive any additional inputs in terms of fertilizer, supplemental irrigation, additional biomass, etc. (Panda *et al.*, 2003). The intercropping of the system becomes more useful in arid region with poor soil texture, low in soil organic carbon and available nutrients. Under such conditions, a minimal amount of additional nutrients through fertilizers, biomass return and irrigation help in better growth and development of associated plants. The positive effects of intercrops on vegetative growth of fruit trees have been reported by other workers in citrus (Yadava *et al.*, 2013; Yadava *et al.*, 2017), in sweet orange (Pal and Tarai, 2015), in aonla (Awasthi *et al.*, 2009), in ber (Saroj *et al.*, 2003; Yaragattikar and Itnal 2003; Birbal *et al.*, 2013) and pomegranate (Soni *et al.*, 2020).

Yield of intercrops

Productivity (yield per unit area) of both *rabi* and *kharif* season crops increased with pomegranate as compared to their sole cropping (Table 2). But due to the sacrifice of the area covered with canopy of trees, it resulted in overall decline in yield on hectare basis. The yield of crops *viz.* onion (32900 kg/ha) and radish (21900 kg/ha) in *rabi* season and cowpea (391 kg/ha in *kharif* season) was less in intercropping systems as

Table 1. Growth of pomegranate in pomegranate based agri-horti system (values are ± standard error)

	Nov., 2015	Nov., 2016	% increase
	Height (cm)		
Sole pomegranate	122 ± 1.01	148 ± 0.97	21.3
Pomegranate + radish -cowpea	124 ± 0.93	170 ± 0.81	37.1
Pomegranate + onion -Indian squash	120 ± 1.46	176 ± .41	46.6
	Girth (cm)		
Sole pomegranate	10.17 ± 0.13	14.8 ± 0.11	45.5
Pomegranate + radish -cowpea	10.42 ± 0.12	17.2 ± 0.09	65.0
Pomegranate + onion -Indian squash	9.95 ± 0.15	18.1 ± 0.10	81.9
	Average canopy spread (cm)		
Sole pomegranate	113.7 ± 1.41	123.8 ± 1.37	8.8
Pomegranate + radish -cowpea	118.6 ± 0.95	142.6 ± 0.92	20.2
Pomegranate + onion -Indian squash	112.8 ± 1.14	149.2 ± 1.08	32.2

Table 2. Yield of different vegetable crops grown as sole and in association with pomegranate

Treatments	Yield (kg/ha)			
	Rabi		Kharif	
	Veg. / Grain yield	Straw yield	Veg. / Grain yield	Straw yield
Pomegranate + onion - Indian squash	32900 ± 872	--	25500 ± 813	--
Pomegranate + radish - cowpea	21900 ± 558	--	391 ± 14	574 ± 19
Sole onion - Indian squash	34200 ± 1010	--	24500 ± 714	--
Sole radish - cowpea	25300 ± 843	--	435 ± 12	655 ± 22
Sole pomegranate	--	--	--	--

System productivity

The system productivity was calculated in terms of onion equivalent yield (OEY). The maximum OEY (63.6 t ha⁻¹) was observed in sole onion-Indian squash system which was at par with pomegranate + onion-Indian squash inter-cropping system (Fig 1). However, OEY of pomegranate + radish-

cowpea intercropping was lower (20.2 t ha⁻¹) as compared to sole plantations (23.1 t ha⁻¹) with a reduction in total productivity of the system by 12.4 per cent. This shows that during establishment phase of pomegranate orchard, onion-Indian squash can be a better option than sole plantations.

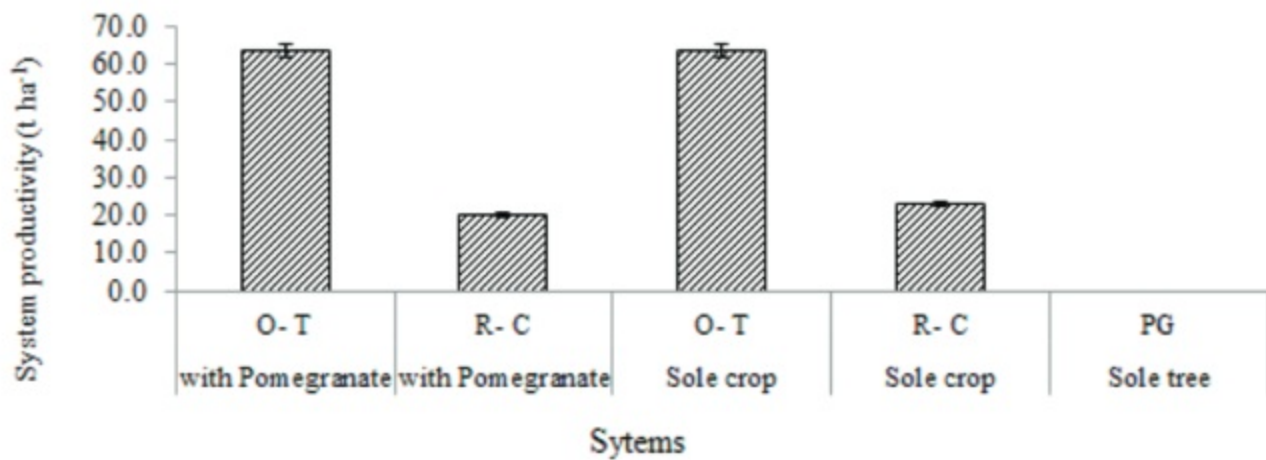


Fig. 1. System productivity (annual) of different systems in terms of onion equivalent yield (OEY, t ha⁻¹) (O= onion; T=Indian squash; R=radish; C=cowpea)

Water use and water productivity

Being long duration crop, maximum amount of water was applied in onion. Pomegranate + onion-Indian squash intercropping system consumed maximum amount of water followed by pomegranate + radish-cowpea intercrops system (Fig 2). Sole pomegranate received least amount of water. In pomegranate based intercropping systems water productivity in terms of economic yield (WP_{EV}) varied from 2.87-8.33 kg m⁻³, respectively (Fig 3). In sole pomegranate, water productivity remained zero during its establishment phase because no economic yield was obtained, which can be improved to 2.87 and 6.71 kg m⁻³ in terms of WP_{EV} by

incorporating intercrops of radish- cowpea and onion- Indian squash, respectively. Among all the systems, sole onion-Indian squash system showed highest WP_{EV} (8.33 kg m⁻³). The water productivity in terms of gross return (WP_{GR}) varied from 130.5 to 452.7 Rs. ha⁻¹ mm⁻¹ (Fig 4). The Sole Onion-Indian squash cropping system registered maximum WP_{GR} (452.7 Rs. ha⁻¹ mm⁻¹). During establishment phase of pomegranate orchard, the water productivity of sole pomegranate remained zero because no economic yield was obtained, which can be improved to 130.5 and 378.6 Rs. ha⁻¹ mm⁻¹ by incorporating intercrops of radish- cowpea and onion- Indian squash, respectively.

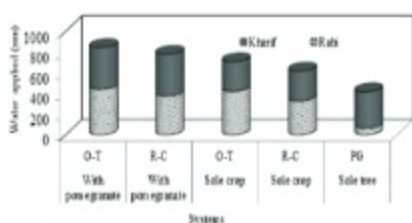


Fig. 2. Water applied in sole and intercropping systems with pomegranate

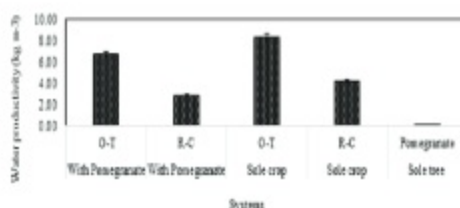


Fig. 3. Water productivity of different systems in terms of economic yield (WP_{EY})

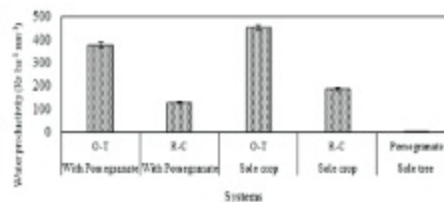


Fig. 4. Water productivity of different systems in terms of gross return (WP_{GR})

Where O=onion; T=Indian squash; R=radish; C=cowpea; PG=pomegranate

Economic analysis

The economic analysis of different intercropping systems showed that onion- Indian squash produced higher gross return, net return and B:C ratio in both sole crops as well as in intercropping systems with pomegranate (Table 3). If we compare the sole pomegranate and intercropping system with pomegranate, an additional income of Rs. 2.36 lakhs ha⁻¹ yr⁻¹ can be obtained with pomegranate + onion- Indian squash and 0.49 lakhs ha⁻¹ yr⁻¹ with pomegranate + radish- cowpea intercropping system.

It could be concluded that intercrops promote the growth of pomegranate. Onion- Indian squash and Radish-

Cowpea can profitably be cultivated in the inter space of pomegranate during establishment phase of orchard. Water productivity of sole orchard can be improved to 2.87 and 6.71 kg m⁻³ in terms of economic yield (WP_{EY}) and 3.05 and 6.71 kg m⁻³ in terms of biological yield (WP_{BY}) by pomegranate + Radish- Cowpea and pomegranate + Onion- Indian squash intercropping systems, respectively. The farmers can get additional income during the gestation period of fruit trees till they come in fruiting. However, the system needs to be assessed for longer term sustainability, productivity, profitability and soil health improvement.

Table 3. Economic performance of different systems grown as sole and in olieri-horti system

Treatments	*Cost of production (Rs./ ha)	Gross return (Rs./ ha)	Net return (Rs./ ha)	B:C ratio
Pomegranate + onion - Indian squash	81180	318000	236820	2.92
Pomegranate + radish - cowpea	51380	101200	49820	0.97
Sole onion - Indian squash	58700	318900	260200	4.43
Sole radish - cowpea	28900	115285	86385	2.99
Sole pomegranate	22480	-	-	-

*Cost of production includes only operational cost and does not include rental value of land, interest on working capital etc.

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Effect of IBA concentrations on semi-hard wood cuttings of phalsa cv. Thar Pragati

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Abstract

An experiment was conducted at Central Horticultural Experiment Station (ICAR-CIAH), Vejalpur on vegetative propagation of phalsa through semi hardwood stem cuttings in the month of July. The cuttings were treated with different concentrations of IBA (100, 150, 500, 1000, 2000, 3000, 4000 and 5000 ppm) along with control and the experiment was replicated thrice. Treated cuttings were planted in poly bags containing soil, sand and FYM in equal proportion and kept in open conditions. Semi hardwood cuttings when treated with IBA 2000 ppm resulted in the highest survival percentage (50.20 %), length of sprout (76.30 cm), number of primary roots (16.30) number of secondary roots (32.20), number of leaves/plant (15.21), number of sprout/plant (3.90) and girth of sprout (1.90 cm) 150 days after treatment, it was followed by IBA 1000 ppm. Whereas control recorded the minimum survival percentage (22.12 %), length of sprout (40.20 cm), number of primary roots (6.20) and number of secondary roots (17.00), number of leaves/plant (7.0), number of sprout/plant (1.70) and girth of sprout (1.20 cm) 150 days after treatment.

Key words: Phalsa, semi hard wood cutting, IBA concentration, sprout

Introduction

Phalsa (*Grewia subinaequalis* D.C.), a member of family Tiliaceae, is one of the oldest fruits of India. Phalsa has been mentioned in Vedic literature as having certain medicinal properties. It is capable of growing under neglected and water scarce conditions. Besides, it is an important arid fruit crop in commercial orcharding (Mishra *et al.*, 2016). The mildly acidic fruits are rich in vitamin A, C and minerals. It is mainly propagated by seeds, which leads a different degree of variation among the population. Seeds have less viability too when stored under ambient condition (90-120 days). However, stem cuttings and air layers which are means of clonal multiplication of phalsa did not root easily. However, treatments with auxins like IBA and NAA may improve rooting of difficult-to-root hardwood cuttings of phalsa (Mishra *et al.*, 2019). Effect of auxins has been found to be positive for induction of rooting and for longer roots in phalsa stem cuttings. A treatment with auxins like IAA, IBA and NAA improve rooting of difficult-to-root hardwood cuttings of phalsa (Joshi *et al.*, 2020), ground layering and air-layering (Mohammed and Chauhan, 1970) and stooling (Singh and Kumar, 1967). Srivastava *et al.* (1994) reported that 2000 ppm IBA gave best results for growth and survival of phalsa cutting. However, Kathrotia and Singh (1995) obtained the best rooting (82.5%) when they treated hardwood cuttings with IBA at 200 ppm. However, studies on effect IBA concentrations on rooting and survival of semi-hardwood cutting are lacking under semi-arid ecosystem of western India. Therefore, the present experiment was undertaken to study the effect of IBA on semi-hardwood cuttings.

Materials and Methods

The present work was carried out at Central Horticultural Experiment Station (ICAR-CIAH), Vejalpur during 2020. The experiment was laid out under CRD with 9 treatments and 3 replications. The experimental material consisted of 20 cm long stem cuttings with three nodes obtained from the middle portion of six months old shoots for semi-hardwood cuttings. The cuttings were collected during the month of July from three year old healthy mother plant of phalsa cv Thar Pragati. The cuttings were treated with different concentrations of IBA (100, 150, 500, 1000, 2000, 3000, 4000 and 5000 ppm) through quick dip method along with untreated control. Treated cuttings were planted in 1.5 kg capacity poly-bags containing growing media of soil, FYM and sand in equal proportion. Overhead water sprinkling over the cuttings was done daily in the morning hours. Subsequently, the stem cuttings were carefully maintained and examined during the experimental period. There were 40 cuttings per treatment per replication. The different root and shoot growth parameters were measured 90 and 150 days after treatment. Further, survival percentage, length of sprouts, number of sprouts and leaves/plant, and root length were also recorded. The data were statistically analyzed as per method suggested by Gomez and Gomez (1984).

Results and Discussion

Different root, shoot growth characters and survival percentage of phalsa semi-hardwood cuttings were significantly influenced by IBA concentrations. Significantly higher number of sprouts/plant (3.0), sprout length (62.30

cm), girth of sprout (1.70 cm) and number of leaves (12.10) were observed with 2000 ppm IBA closely followed by 1000 ppm, 500 ppm and 150 ppm concentrations of IBA 90 days after treatment of cuttings. However, untreated cuttings recorded the minimum length of sprout (28.21 cm), number of leaves/plant (5.20), number of sprout/plant (1.60) and girth of sprout (1.0 cm) 90 days after treatment of cuttings. In case of 150 days after treatment of cuttings, IBA 2000 ppm recorded the highest sprouts/plant (3.90), sprout length (76.30 cm), girth of sprout (1.90 cm) and number of leaves (15.21) while control cuttings recorded the minimum length of sprout (40.20 cm), number of leaves/plant (7.0), number of sprout/plant (1.70) and girth of sprout (1.20 cm). (Singh and Tomar (2015) also observed the highest length of sprout, diameter of sprout, number of leaves and number of sprout per cutting in phalsa cuttings treated with IBA 2000 ppm concentration. Similar kind of observations were made by Singh *et al.* (2015) in phalsa. Application of auxin which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings and resulted in accelerated cell division and cell elongation in suitable environment (Singh *et al.*, 2015). Whereas 150 days after treatment, survival percentage decreased in all the treatments but there

was increase in all vegetative and root growth characters irrespective of treatments. The highest survival percentage of cutting (50.20), number of primary (15.30) and secondary roots (28.10) were observed in phalsa semi-hardwood cuttings treated with 2000 ppm IBA solution 90 days after treatment of cuttings. Whereas control recorded the minimum survival percentage (24.20 %) number of primary (5.12) and secondary roots (15.00). However, in case of 150 days after treatment of cuttings, the maximum survival percentage of cutting (50.10), number of primary (16.30) and secondary roots (32.20) were observed in phalsa semi-hardwood cuttings treated with 2000 ppm IBA solution while control cuttings recorded the minimum survival percentage (22.12 %), number of primary (6.20) and secondary roots (17.00). Rooting and survival of cutting in phalsa depends on various factors such as type of cutting, pre-treatment of cutting, environmental factors, time of planting, method of planting etc. which effects on survival ability of cuttings (Joshi *et al.*, 2020). These findings are in complete agreement with the findings of Singh and Tomar (2015) and Singh *et al.* (2015) in phalsa. In conclusion, phalsa can be successfully propagated through semi-hardwood cuttings in the month of July by treating them with IBA 2000 ppm through quick deep methods.

Table 1. Effect of IBA concentrations on semi hard wood cutting of Phalsa Cv. Thar Pragati

Treatments *	Survival (%)	Length of sprout (cm)	No. of leaves per plant	No of sprouts per plant	Girth of sprout (cm)	No. of primary roots	No. of secondary roots
100 ppm	38.10	55.12	10.20	2.00	1.30	10.10	25.00
150 ppm	40.30	57.10	11.40	2.50	1.40	11.20	26.10
500 ppm	42.20	58.23	10.42	2.68	1.50	12.00	26.50
1000 ppm	44.20	59.20	10.20	2.80	1.55	12.50	27.20
2000 ppm	52.10	62.30	12.10	3.00	1.70	15.30	28.10
3000 ppm	32.21	42.30	8.30	2.00	1.30	8.20	22.10
4000 ppm	30.11	37.10	7.10	1.90	1.20	7.10	18.00
5000 ppm	28.30	31.00	7.00	1.80	1.15	7.00	17.00
Control	24.20	28.21	5.20	1.60	1.00	5.12	15.00
CD (P=0.05)	1.20	1.10	0.51	0.11	0.10	0.53	1.11

*Data recorded 90 days after treatment

Table 2. Effect of IBA concentrations on semi hard wood cutting of Phalsa Cv. Thar Pragati

Treatments #	Survival (%)	Length of sprout (cm)	No. of leaves per plant	No. of sprouts per plant	Girth of sprout (cm)	No. of primary roots	No. of secondary roots
100 ppm	37.00	68.20	12.12	2.00	1.50	12.00	27.10
150 ppm	38.34	70.11	13.00	2.50	1.60	12.50	28.30
500 ppm	39.21	72.32	13.20	2.80	1.65	13.00	28.60
1000 ppm	40.12	73.14	14.32	2.90	1.70	13.50	29.30
2000 ppm	50.20	76.30	15.21	3.90	1.90	16.30	32.20
3000 ppm	30.12	55.30	10.23	2.20	1.45	9.60	24.50
4000 ppm	28.00	50.10	9.12	2.10	1.40	8.50	21.00
5000 ppm	26.00	42.31	9.00	2.00	1.30	8.20	20.11
Control	22.12	40.20	7.00	1.70	1.20	6.20	17.00
CD (P=0.05)	1.21	1.11	0.50	0.12	0.11	0.54	1.12

#Data recorded 150 days after treatment

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Evaluation of mango varieties for pulp processing suitability

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Abstract

Thirty mango varieties were evaluated for pulp processing suitability. Fruit weight of mango varieties ranged from 122.67 to 583.34 g (CV=10.02%), measured maximum for Sonia Malda (583.34 g) followed by Malda (572.34 g) and minimum fruit weight was noticed in Gourjeet (122.67 g). Pulp percentage varied from 53.96 to 75.28%, observed maximum in Sonia Malda (75.28%) followed by Malda (74.11%) and minimum pulp content was recorded in Gourjeet (52.85%) trailed by Cylone (53.96%). Sonia Malda (75.28%), Malda (74.11%), Mallika (72.00%) and Hybrid 18-8 (72.47%) were possessed more than 70% pulp content while 7 varieties (Amin Tehsilwala, Benzeer, Bombay Bottle, Creeping, Kharuspatti, Amrapali and Nisar Pasand) had pulp percentage between 65-70%. The stone percentage was considerably differed in mango genotypes (CV=10.03%) and varied from 10.97 to 21.71%; maximum in Mithua and minimum in Mallika. Similarly, peel percentage ranged from 11.32 to 19.56%, minimum was observed in Sonia Malda (11.32%) followed by Malda (11.76%), Bombay Bottle (11.90%) and Amin Tehsilwala (11.77%) and maximum peel per cent was reported in Gourjeet (19.56%), Santra (19.23%) and Himsagar (18.73%). The varieties having high pulp content also showed high pulp/stone ratio and pulp/peel ratio. The highest pulp/stone ratio was noticed in Mallika (6.56), Malda (6.18) and Sonia Malda (5.37) and lowest was found in Gourjeet (2.09). Pulp TSS of most of the varieties was recorded between 15-20°Brix which was in line with the mango pulp industry standards (16°Brix). Maximum pulp TSS was observed in Amrapali (20.83°Brix) followed by Bombay (20.80°Brix), Mallika and Nisar Pasand (20.50°Brix) and Dashehari (20.13°Brix) while minimum TSS was noticed in Shere-a-Hayat (12.90°Brix) followed by Kalapahar (13.96°Brix). Based on pulp quantity it may be concluded that; Malda, Sonia Malda, Mallika, Hybrid 18-8, Amin Tehsilwala, Benzeer, Creeping, Kharuspatti, Amrapali, Dashehari, Nisar Pasand and Bombay Bottle were found suitable for pulp processing.

Key words: Mango, pulp, evaluation, processing suitability, heirloom varieties

Introduction

India harbours more than 1000 mango varieties/landraces in different agro-ecological regions and represents the largest mango germplasm in the world (Singh *et al.*, 2012). Mango has been cultivated and conserved in different agro-ecological regions including Malihabad area of Lucknow-Saharanpur mango belt of the country (Prakash and Dinesh, 2007). This region is known for old mango plantations predominantly originated from seedling population which were established naturally or propagated through selected stones from elite indigenous mango plants on the basis of fruit quality characteristics and maintained by local fruit lovers since decades. Traditional mango varieties of Malihabad are recognized for their unique characteristics and many of them have originated as open pollinated seedlings from the varieties introduced from different parts of country as, well as, selection of superior seedlings (Ram and Rajan, 2003).

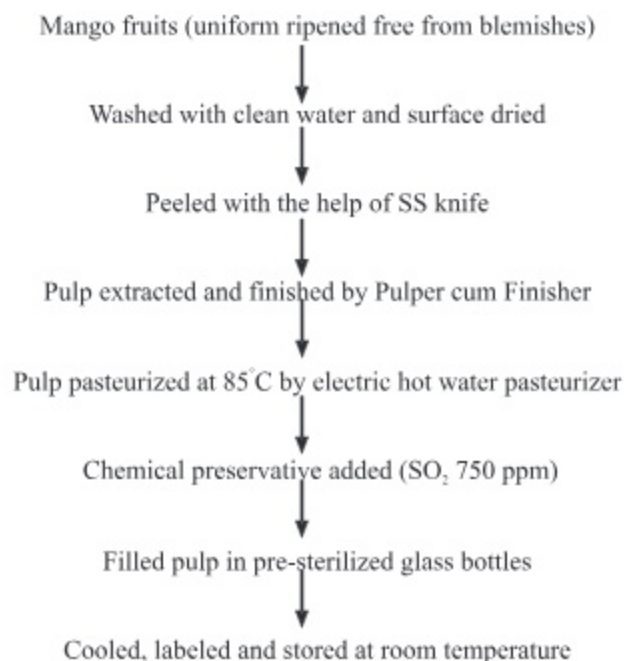
Heirloom varieties are defined as local or regional varieties, passed down from generation to generation of gardeners/farmers, maintained by asexual means, also include old commercial varieties/antiques, presently not grown on commercial scale and limited to few in orchards. Pre-occupation of the agricultural research sector, mango

growers and market sector, which are mainly concerned with few established commercial varieties might overlook and underestimate the potential of heirloom varieties (Rajan *et al.*, 2014). Rapid loss of diversity due to urbanization, industrialization and resultant felling of trees has been well documented (Khan *et al.*, 2015), highlighting the need for collection, conservation and evaluation of processing suitability of non-commercial, heirloom varieties. Mango fruits are used as dessert as a table fruit and are also processed into pulp. Mango pulp is the basic material for preparation of number of other mango based value added products such as juice, squash, RTS, nectar, jam, ice cream, *etc.* The demand for mango fruits and its pulp in the country and abroad is continuously increasing over the years. On farm conservation of these varieties can be encouraged through making economic use of fruits of such varieties. Non commercial, heirloom varieties may be used for pulp processing and other value added product development for additional income generation to the custodian farmers. Therefore, present study was carried out to screen the heirloom and some commercial varieties of Malihabd region for pulp processing suitability.

Materials and Methods

The fruits of 30 heirloom and commercial mango

varieties (Amin Tehsilwala, Amrapali, Benzeer, Benzeer Sandila, Bombay, Bombay Bottle, Creeping, Cylone, Dashchhari, Digambar, Eldon, Gourjeet, Gulab Khas, Himsagar, Hybrid 18-8, Inayat Pasand, Kala Pahar, Kharus Patti, Kichnar, Kohitoor, Madhavrao Pasand, Malda, Mallika, Mithua, Nisar Pasand, Santra, Sharda Bhog, Sherehayat, Sonia Malda and Surkha Verma) were procured from the mango field gene bank of ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow and farmers field. After fruit ripening pulp was extracted through electric pulper cum finisher machine and pasteurized by electric pasteurizer. Complete process of pulp extraction is given in flowchart below.



Average fruit weight was measured by electronic balance and fruit peel thickness was measured by electronic vernier caliper. Total soluble solids (TSS) of pulp was recorded by using ERMA hand refractometer and reading were expressed as degree Brix (°B). The titrable acidity of fruit pulp was estimated by titrating it against 0.1N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator (A.O.A.C., 1984). Ascorbic acid in pulp is estimated by visual titrimetric method using 2,6-dichlorophenol indophenols dye solution as indicator (Rangana, 1986). Pulp, stone, peel and fibre percentage was measured by using standard formulas.

Results and Discussion

Thirty varieties were evaluated for their physical attributes and parameters pertaining to processing suitability (Table 1). Fruit weight ranged from 122.67 g to 583.34 g (CV=10.02%). The maximum fruit weight was noted in Sonia Malda (583.34 g) followed by Malda (572.34 g) and minimum fruit weight was observed in Gourjeet (122.67 g). Mango varieties also showed considerable variation with respect to

peel thickness and showed maximum variation (CV=19.15%) among all the characters studied. Wide variation was recorded with respect to peel thickness which varied from 1.10 to 2.40 mm. The lowest peel thickness was reported in Madhavrao Pasand (1.10 mm) followed by Amrapali (1.40 mm) and thickest peel was noticed in Banzeer Sandila (2.40 mm) followed by Amin Tehsilwala (2.37 mm). Sharma (2007) evaluated sucking types mangoes under sub mountane zone of eastern Punjab conditions and reported a wide variation in respect of fruit shape, size and weight. Kishore *et al.* (2015) also observed more than 400 g fruit weight in Alfazli, Arka Anmol, Neeluddin and Totapari, whereas Dashchhari, Prabha Sankar, AU Ruman and Arunika had small fruits of less than 200 g grown under eastern coast conditions of India.

Pulp percentage is extremely important character with respect to suitability of mango variety for processing and value addition. High pulp yield is crucial for functioning of mango pulp industry in sustainable and economical manner. Substantial variation (CV=3.34%) was reported among mango varieties with respect to pulp quantity. The pulp percentage varied from 53.96 to 75.28%. The highest pulp percentage was measured in Sonia Malda (75.28%) followed by Malda (74.11%) and minimum pulp quantity was recorded in Gourjeet (52.85%) trailed by Cylone (53.96%) (Table 1). Low pulp content was also reported in Gourjeet and Mithua by previous workers (Pandey *et al.*, 2018). Four varieties namely; Sonia Malda (75.28%), Malda (74.11%), Mallika (72.00%) and Hybrid 18-8 (72.47%) were possessed more than 70% pulp content while 7 varieties (Amin Tehsilwala, Benzeer, Bombay Bottle, Creeping, Kharauspati, Amrapali and Nisar Pasand) having pulp percentage between 65-70%. Therefore, these varieties may be considered suitable for pulp processing and further value addition of pulp. The pulp percentage of mango varieties varied with the climatic conditions, fruit size and horticulture practices during production (Anil and Radha, 2003; Padhiar *et al.*, 2011). High pulp content and pulp/stone ratio was also recorded in Langra, Mallika, Pusa Arunima and Pusa Surya by Kishore *et al.* (2015).

The stone percentage was also considerably differed in mango genotypes (CV=10.03%) and varied from 10.97 to 21.71%; being maximum in Mithua and minimum in Mallika (Table 1). Significant variation (CV=9.87%) was found in mango genotypes with respect to peel per cent and it ranged from 11.32 to 19.56%. The lowest peel percentage was found in Sonia Malda (11.32%), Malda (11.76%), Bombay Bottle (11.90%) and Amin Tehsilwala (11.77%) and maximum peel percentage was reported in Gourjeet (19.56%), Santra (19.23%) and Himsagar (18.73%). Fibre content in mango pulp is also an important attribute with regard to processing suitability of mango variety. Presence of fibers are a necessity to protect the interior of a fruit from bruising and internal collapse during handling and shipping, however, abundance of fibre content are not suitable for processing purpose and reduce the consumer acceptability (Iyer, 1991). Noteworthy disparity was observed among mango genotypes with respect to fibre percentage. Fibre percentage in pulp ranged from 1.14 to 3.77%. The lowest fibre content was measured in Benzeer (1.14%), Kichnar (1.20%) Amrapali (1.24%) and Dashchhari

(1.48%) and maximum fibre (%) was found in Eldon (3.77%) and Creeping (3.52%). Ara *et al.* (2014) found significant variation in fibre content in mango varieties grown in Bangladesh. They found maximum amount of fibre in Langra (4.78 g/100 g) followed by Khirsapat (3.16 g/100 g) and Himsagar (2.72 g/100g). Lowest amount of crude fiber was found in Guti (1.08 g/100 g). The varieties having high pulp content were also showed high pulp/stone ratio. The highest pulp/stone ratio was noticed in Mallika (6.56), Malda (6.18) and Sonia Malda (5.37) and lowest was found in Gourjeet (2.09). Same trend was observed among mango varieties in case of pulp/peel ratio.

Evaluation of biochemical parameters revealed that mango genotypes possessed wide variability with respect to total soluble solids (TSS), titrable acidity, ascorbic acid and TSS/acid ratio. The highest total soluble solids in pulp were observed in Amrapali (20.83°Brix), Bombay (20.80°Brix), Mallika, Nisar Pasand (20.50°Brix) and Dashehari (20.13°Brix) while minimum TSS were noticed in Shere-a-Hayat (12.90°Brix) followed by Kalapahar (13.96°Brix) (Table 2). Pulp TSS of most of the varieties was recorded

between 15-20°Brix which was in line with the mango pulp industry standard (16°Brix). TSS of the 31 north Kerala mango genotypes ranged between 12.7 and 25.2°Brix and 'Heralappa'(25.2°Brix) and 'Kalapady' (24.7°Brix) were the two top genotypes in this respect (Pradeepkumar *et al.*, 2006). TSS/acid ratio was also considerably differed (CV=10%) among mango genotypes and ranged between 10.16 to 65.91. The highest TSS/acid blend was observed in Amrapali (65.91) and lowest was found in Shere-a-Hayat. TSS/acid ratio more than 45 was observed in Amrapali, Dashehari and Nisar Pasand while less than 15 were noticed in Shere-a-Hayat, Shardabhog, Madhavrao Pasand and Kalapahar (Table 2). Kishore *et al.* (2015) also reported high TSS (21.9°Brix) and TSS/acid ratio (72.3) in Amrapali mango pulp. Significant variation (CV=10.68%) was recorded for pulp titrable acidity (%) among mango genotypes and it was ranged from 0.31 to 1.31%. Maximum acidity was witnessed in Madhavrao Pasand (1.31%) followed by Shere-a-Hayat (1.29%), Shardabhog (1.07%) and Kalapahar (1.03%) and minimum acidity were found in commercial varieties such as Amrapali (0.42%), Dashehari (0.43%) and in Gourjeet (0.49%), a

Table 1. Physical attributes and pulp per cent of some commercial and heirloom mango varieties

Variety	Fruit weight (g)	Peel thickness (mm)	Pulp (%)	Stone (%)	Peel (%)	Fibre (%)	Pulp/stone ratio	Pulp/peel ratio
Amin Tehsilwala	349.67	2.37	69.70	16.26	11.77	2.35	4.28	5.92
Amrapali	138.34	1.30	65.45	19.76	13.53	1.24	3.31	5.22
Benzeer	383.00	1.40	66.86	16.46	15.53	1.14	4.06	4.30
Benzeer Sandila	236.34	2.43	64.58	18.50	14.53	2.35	3.49	4.44
Bombay	190.67	1.80	58.39	15.53	18.10	1.98	3.75	3.22
Bombay Bottle	314.33	2.13	69.27	15.76	11.90	2.94	4.39	5.82
Creeping	291.35	2.10	66.30	13.52	16.66	3.52	4.90	3.97
Cylone	186.34	1.76	53.96	17.40	18.46	2.49	3.10	2.92
Dashehari	200.39	1.43	64.13	16.30	18.03	1.48	3.93	3.55
Digambar	192.53	1.93	57.30	21.33	19.10	3.11	2.81	3.35
Eldon	225.67	2.26	60.83	21.00	17.20	3.77	2.89	3.53
Gourjeet	122.67	1.66	52.85	25.20	19.56	2.46	2.09	2.70
Gulab Khas	211.25	1.53	57.69	23.03	17.38	1.86	2.50	3.31
Himsagar	225.00	2.16	59.19	20.60	18.73	1.37	2.87	3.15
Hybrid 18-8	283.41	1.50	72.47	12.76	12.76	1.91	5.67	5.67
Inayat Pasand	204.34	1.70	62.31	18.16	17.46	2.03	3.42	3.56
KalaPahar	193.00	1.43	63.13	20.36	15.46	2.67	3.09	4.08
Kharus Patti	195.67	1.90	66.58	17.56	12.83	2.92	3.79	5.18
Kichnar	226.00	2.26	63.18	21.36	14.20	1.20	2.95	4.44
Kohitoor	299.00	1.73	62.25	16.37	17.58	3.30	3.80	3.53
Madhavrao Pasand	134.00	1.10	64.36	17.92	15.70	1.98	3.59	4.09
Malda	572.34	1.83	74.11	13.9	11.76	2.04	6.18	6.29
Mallika	387.34	2.06	72.00	10.97	15.11	1.87	6.56	4.76
Mithua	164.00	1.83	58.49	21.71	18.06	1.69	2.69	3.23
Nisar Pasand	268.33	1.90	66.20	17.96	12.60	3.04	3.68	5.25
Santra	164.67	1.76	60.76	17.62	19.23	2.29	3.44	3.15
Sharda Bhog	165.70	1.50	61.60	20.30	16.23	2.28	3.03	3.79
Sherehayat	212.67	1.93	62.18	19.42	15.09	3.07	3.20	4.11
Sonia Malda	583.34	1.92	75.28	14.00	10.72	2.46	5.37	6.65
Surkha Verma	240.00	1.56	62.73	18.69	16.57	1.95	3.35	3.78
C.D.	41.40	0.56	3.34	2.94	2.53	0.33	-	-
SEm±	14.58	0.20	1.18	1.037	0.89	0.11	-	-
SE(d)	20.63	0.28	1.67	1.46	1.26	0.16	-	-
C.V.	10.02	19.15	3.19	10.03	9.87	8.63	-	-

sucking type variety. Ascorbic acid is an important character particularly with respect to nutritional value of the mango pulp. Considerable amount of vitamin C content is lost during pasteurization of pulp due to its heat labile nature. Highest variation (CV=14.33%) was observed for ascorbic acid content among biochemical parameters in mango varieties. Amount of ascorbic acid varied from 11.90 to 27.33 mg/100 g and observed maximum in Gourjeet (27.33 g/100g) followed by Creeping (24.86 g/100g) and Dashehari (24.80 g/100g) and minimum in Madhavrao Pasand (11.90 g/100g) and Digambar (12.60 g/100g). Pulp content (%) showed significant positive correlation with fruit weight (0.770), pulp/stone (0.868) and pulp/peel ratio (0.911) whereas significant negative

correlation was noticed with stone (-0.757) and peel (-0.852) percentage. No significant relation was noticed between pulp, fibre per cent and fruit peel thickness (Table 3).

Four varieties namely; Sonia Malda (75.28%), Malda (74.11%), Mallika (72.00%) and Hybrid 18-8 (72.47%) were possessed more than 70% pulp content while 7 varieties (Amin Tehsilwala, Benzeer, Bombay Bottle, Creeping, Kharaspati, Amrapali, Dashehari and Nisar Pasand) having pulp % between 65-70%. These varieties may be considered suitable for pulp processing and value addition.

Table 2. Biochemical attributes of some commercial and heirloom mango varieties

Variety	TSS (°Brix)	Titration acidity (%)	Ascorbic acid (mg/100g)	TSS/acid ratio
Amin Tehsilwala	14.500	0.617	13.267	23.567
Amrapali	20.833	0.316	20.833	65.91
Benzeer	14.733	0.720	18.667	20.483
Benzeer Sandila	16.567	0.643	23.833	25.797
Bombay	20.800	0.487	17.967	42.873
Bombay Bottle	18.533	0.523	23.433	35.687
Creeping	19.167	0.457	24.867	42.277
Cylone	15.700	0.757	14.633	20.820
Dashehari	20.133	0.313	24.800	64.31
Digambar	14.700	0.563	12.600	26.343
Eldon	16.567	0.823	21.000	20.163
Gourjeet	18.267	0.497	27.333	36.767
Gulab Khas	14.600	0.713	22.433	20.507
Himsagar	18.400	0.653	13.667	28.233
Hybrid 18-8	16.600	0.523	22.267	31.763
Inayat Pasand	16.133	0.797	13.433	20.257
KalaPahar	13.967	1.030	16.667	13.703
Kharas Patti	18.000	0.540	23.433	33.457
Kichnar	14.933	0.683	15.167	21.940
Kohitoor	14.733	0.760	18.600	19.497
Madhavrao Pasand	15.233	1.317	11.900	11.753
Malda	15.06	0.540	20.733	37.963
Mallika	20.50	0.450	15.833	45.55
Mithua	18.367	0.480	18.933	38.25
Nisar Pasand	20.500	0.453	17.300	45.403
Santra	15.900	0.807	16.667	19.767
Sharda Bhog	15.000	1.070	22.867	14.173
Sherehayat	12.900	1.290	14.433	10.167
Sonia Malda	14.567	0.887	29.283	16.473
Surkha Verma	17.933	0.737	20.800	24.387
C.D.	1.326	0.123	4.522	4.448
SEm±	0.467	0.043	1.593	1.567
SE(d)	0.661	0.061	2.253	2.216
C.V.	4.819	10.684	14.333	10.009

Table 3. Correlation of different parameters with pulp percentage in mango genotypes

	Pulp (%)	Fruit weight	Peel thickness	Stone (%)	Peel (%)	Fiber (%)	Pulp/stone	Pulp/peel
Pulp (%)	1.000							
Fruit weight	0.770*	1.000						
Peel thickness	0.117	0.275	1.000					
Stone (%)	-0.757*	-0.643	-0.085	1.000				
Peel (%)	-0.852*	-0.617	-0.185	0.469	1.000			
Fibre (%)	-0.053	0.025	0.351	-0.032	-0.017	1.000		
Pulp/stone	0.868*	0.778	0.112	-0.928	-0.592	-0.0191	1.000	
Pulp/peel	0.911*	0.708	0.178	-0.560	-0.973*	0.002	0.698*	1.000

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Response of mango cultivars to agro-chemicals in relation to yield attributes

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Abstract

Mango has wide adaptability, high nutritive value, richness in variety, delicious taste, pleasant flavour, attractive appearance and it enjoys the unique popularity among the masses and classes. Mango fruits are rich in vitamin A and C. Application of agro-chemicals alter the behavior of trees for the economic benefit of the fruit growers. In this regard an experiment was conducted at Agriculture Research Station, Banswara district of Rajasthan to find out the response of different agro-chemicals. The experiment consisted of thirteen treatments along with control and replicated thrice in a Randomized Block Design. Fifteen years old mango orchard was selected for experiment which has Dashehari, Langra and Kesar. Plants were planted with square system of planting at 10 m x 10 m spacing. Agro-chemicals viz., calcium chloride (0.3, 0.6 & 0.9%), potassium nitrate (1, 2 & 3%), paclobutrazol (500, 1000 & 1500 ppm), sorbitol (1.5, 2.0 & 2.5%) and control-water spray were used at different stages and time. Among alternate bearing mango cultivars (Dashehari, Langra and Kesar), cultivar Kesar recorded higher fruit weight while Langra recorded higher fruit yield over Dashehari. Fruit diameter significantly influenced by agro-chemicals. Yield per tree and estimated yield per hectare were enhanced by application of paclobutrazol 1500 ppm.

Key words: *Mango, calcium chloride, potassium nitrate, paclobutrazol, sorbitol, yield*

Introduction

Mango is one of the oldest and choicest tropical fruit of the world and is rightly designated as "King" of fruits in India. It belongs to family Anacardiaceae and indigenous to Indo-Burma region (Mukherjee, 1951) and most outstanding among the tropical fruits of India. Fruits are rich in vitamin A (1082 IU/100g) and also vitamin C (36.4 mg/100 g) (Anonymous, 2011). It is grown in almost all the states in India. In Rajasthan, mango is commonly cultivated in Banswara, Dungarpur, Chittorgarh, Pratapgarh, Udaipur, Bhilwara, Dhaulpur and Dausa districts. The mango tree is long-lived, medium to large (10 to 40 m in height) with profuse, wide-spreading feeder roots, the tree also sends down many anchor roots, which penetrate several feet of soil (6 m). The inflorescence is a many branched panicle borne at shoot terminals, possessing from 550 to more than 4,000 flowers. Flowers are monoecious, polygamous and small. Both male and perfect flowers are found within a single inflorescence the pistil aborts in male flowers. The fruit takes three to six months to ripen from fruit set.

Application of agro-chemicals (for regular flowering and improve fruit set) alter the behaviour of trees for the economic benefit of the fruit growers. Control of vegetative vigour, stimulation of flowering, regulation of crop load, reduction of fruit drop, delay or stimulation of fruit maturity and ripening are important horticultural processes in fruit trees that can be regulated with exogenous applications of agro-

chemicals. Yield enhancement of mango by agro-chemicals like sorbitol and potassium nitrate help in pollen tube growth which facilitates better fertilization and fruit set. Besides, KNO₃ has been shown to stimulate flowering under tropical condition in number of mango cultivars. As KNO₃ is suggested to induce ethylene production and efficacy of KNO₃ is suppressed by ethylene biosynthesis inhibitors, the involvement of ethylene appear an important factor in mango flower process (Upreti *et al.*, 2014). Calcium compound improve firmness, delay fruit ripening, storability, better skin and pulp colour (Anjum and Ali, 2004) and paclobutrazol help for regular bearing in biennial habits of mango cultivars. The effect of paclobutrazol in improving flowering per cent was due to its anti-gibberellins activity. Paclobutrazol helps in getting more number of reproductive shoots (Muhammad *et al.*, 2010) and also increase the perfect flowers per panicle in mango (Kumar *et al.*, 2005). Paclobutrazol is a broad spectrum plant growth retardant that selectively controls tree vigour without marked effect on the size of fruit. The cropping manipulations possible with paclobutrazol ranges from off-season or early season to simply increased yield.

Materials and Methods

Experiment was conducted in Banswara district of Rajasthan. The region comes under agro-climatic zone IV b "Humid Southern Plain Zones of Rajasthan" at an altitude of 302 metre above mean sea level and lies between 23°11' N to

23°56' N latitude and 73°58' E to 74°49' E longitude. This region has a typical sub-tropical climate, characterized by mild winters and summers. Soils predominantly reddish medium textured well drained calcareous, shallow on hills and deep soils in valleys. The following treatment combinations were applied control-water spray (T_0), calcium chloride 0.3% (T_1), calcium chloride 0.6% (T_2) & calcium chloride 0.9% (T_3) potassium nitrate 1% (T_4), potassium nitrate 2% (T_5) & potassium nitrate 3% (T_6), paclobutrazol 500 ppm (T_7), paclobutrazol 1000 ppm (T_8) & paclobutrazol 1500 ppm (T_9), sorbitol 1.5% (T_{10}), sorbitol 2.0% (T_{11}) & sorbitol 2.5% (T_{12}). There were three varieties Dashehari (V_1), Langra (V_2) and Kesar (V_3). Stage and time of applications of different agro-chemicals were calcium chloride at one month prior to harvesting (May, 7-8), potassium nitrate at marble size stage (February, 27- March, 1), paclobutrazol at fruit bud differentiation stage (October, 11) and sorbitol at pea nut size (January, 19). Yield and yield attributes such as fruit weight, fruit diameter, yield per tree and estimated yield per hectare were recorded as per the standard methods.

Results and Discussion

Fruit weights of different cultivars were influenced during both the year of investigation as well as in pooled analysis (Table-1). On pooled data basis, the maximum fruit weight 204.87 g was recorded with treatment V_3 (Kesar) followed by 199.15 g with the treatment V_2 (Langra) and lowest fruit weight 181.92 g was recorded in treatment V_1 (Dashehari). Cultivar Kesar recorded 10 per cent higher fruit weight over Dashehari. Fruit weight was affected by various agro-chemicals. The highest fruit weight 211.33 g was observed in T_0 and lowest fruit weight 187.83 g was obtained under T_1 (PBZ 500 ppm). The application of PBZ (500 ppm) reduced about 23.5 g weight over control. The combination of cultivars and agro-chemicals had no significant effect on fruit weight. Fruit diameter as affected by different cultivars and agro-chemicals. The maximum polar diameter (9.60 cm) was recorded in Dashehari followed by Langra (9.00 cm) and Kesar resulted minimum polar diameter (8.54 cm). Different agro-chemicals also had significant effect on polar diameter. The lowest polar diameter recorded under T_1 (8.83 cm). Whereas, treatment T_0 resulted in maximum (9.32 cm) polar diameter followed by T_5 (9.22 cm). Interaction of different cultivars and agro-chemicals resulted in non-significant effect on polar diameter during both the years of experimentation.

A reference of data reveals that the equatorial diameter showed the significant difference in cultivars of mango. The maximum equatorial diameter was recorded in Langra (5.26 cm) followed by Kesar (5.04 cm). Further, the minimum equatorial diameter was registered in Dashehari (4.70 cm). Agro-chemicals significantly influenced equatorial diameter of fruit. The minimum equatorial diameter (4.83 cm) recorded in T_1 (CaCl₂ 0.3%), which was at par with treatment T_2 (4.84 cm), T_3 (4.85 cm), T_{10} (4.88 cm), T_{11} (4.92 cm) and T_{12} (4.94 cm) as compared to maximum equatorial diameter (5.26 cm) in T_0 (water spray) followed by T_6 (5.21 cm) and T_5 (5.14 cm),

which were at par with each other. The interaction effect of cultivars and agro-chemicals on equatorial diameter of mango was found non-significant.

Fruit yield was significantly higher in cultivar Langra as compared to Dashehari and Kesar. The values of fruit yield under V_2 were 103.74, 68.09 and 85.92 kg tree⁻¹, respectively against the corresponding values of 83.56, 49.31 and 66.44 kg tree⁻¹ under V_3 . The maximum fruit yield during first, second year and pooled was found under treatment T_9 (PBZ 1500 ppm) i.e., 100.67, 72.56 and 86.61 kg tree⁻¹, respectively (Table 1). Whereas, minimum fruit yield (71.00, 46.36 and 58.68 kg tree⁻¹) was recorded in T_0 , respectively. During second year, the maximum yield per tree (83.58 kg) was recorded in the treatment V_2T_9 (Langra + PBZ 1500 ppm) followed by V_2T_8 (Langra + PBZ 1000 ppm) which was statistically at par (80.01 kg) with treatment V_2T_9 and minimum (42.24 kg) was observed in Dashehari + water spray. On the basis of pooled analysis, the mean maximum (99.29 kg) yield per tree was registered in treatment V_2T_9 and minimum (54.12 kg) was obtained in V_1T_0 treatment combination. The significantly higher yield (10.32, 6.81 and 8.56 t ha⁻¹, respectively) was recorded with treatment V_2 (Langra) during both the years, while, lowest (8.26, 4.93 and 6.60 t ha⁻¹, respectively) in Kesar. Among the different agro-chemicals T_9 (PBZ 1500 ppm) registered significantly higher yield (8.66 t ha⁻¹) followed by T_8 (8.48 t ha⁻¹) as compared to rest of treatments. Where, the lowest yield (5.38 t ha⁻¹) was registered in treatment T_0 (Water spray).

Interaction effect of cultivars and agro-chemicals was found significant. During second year, the maximum yield (8.36 t ha⁻¹) was recorded under Langra + PBZ 1500 ppm followed by Langra + PBZ 1000 ppm which was statistically at par (8.00 t ha⁻¹) with treatment V_2T_9 and minimum (4.22 t ha⁻¹) was observed under V_1T_0 (Dashehari + water spray). On the basis of pooled analysis, the mean maximum yield (9.93 t ha⁻¹) was registered in treatment V_2T_9 and minimum (4.91 t ha⁻¹) was obtained in V_1T_0 treatment combination. Among alternate bearing mango cultivars (Dashehari, Langra and Kesar), cultivar Langra recorded higher economic trait like yield (85.92 kg tree⁻¹ & 8.56 t ha⁻¹) over Dashehari and Kesar (Table 1). With respect to compact growth (short shoot length, diameter and canopy volume), early flowering (but not regular) and good fruit quality (peel & pulp colour, pulp recovery and shelf life) were observed in Kesar, but poor yielder. Thus, Langra and Dashehari cultivars are promising in this region. Agro-chemicals affected the yield significantly. Paclobutrazol (1500 ppm) treated trees were found better with respect to yield (yield 86.61 kg tree⁻¹ & 8.66 t ha⁻¹). The present results are also supported by the finding of Sergeant *et al.* (1993) and Bally *et al.* (2000). Interaction between cultivars and agro-chemicals showed significant effect on growth parameters with yield attributes maximum recorded under combination V_2T_9 (Langra + PBZ 1500 ppm) with respect to yield (99.29 kg tree⁻¹ & 9.93 t ha⁻¹). Thus, cultivar Langra and agro-chemical paclobutrazol 1500 ppm were found better for yield and return in mango crop

production. Patel and Patel (1998) reported that the increase in yield was mainly because of better growth of the plant under optimum amount of nutrients.

Based on the above findings, it is concluded that

supplementation of paclobutrazol 1500 ppm as foliar spray in the month of October in biennial bearing cultivar Langra resulted in higher yield and net return to the farmers.

Table 1. Response of mango cultivars to agro-chemicals with respect to yield attributes

Treatments/ varieties	Fruit weight (g)	Fruit diameter (cm)		Yield/tree (kg)	Estimated yield/ha (t)
		Polar	Equatorial		
V ₁ (Dashehari)	181.92	9.60	4.70	70.13	6.97
V ₂ (Langra)	199.15	9.00	5.26	85.92	8.56
V ₃ (Kesar)	204.87	8.54	5.04	66.44	6.60
SEm+	0.95	0.05	0.03	0.549	0.055
CD at 5%	2.66	0.13	0.07	1.533	0.153
Agro-chemicals					
T ₀ (Control) WS	211.33	9.32	5.26	58.68	5.38
T ₁ (CaCl ₂ 0.3%)	189.67	8.83	4.83	69.47	6.95
T ₂ (CaCl ₂ 0.6%)	190.48	8.84	4.84	70.43	7.04
T ₃ (CaCl ₂ 0.9%)	191.05	8.85	4.85	70.70	7.07
T ₄ (KNO ₃ 1%)	194.42	9.11	5.02	71.10	7.11
T ₅ (KNO ₃ 2%)	195.45	9.22	5.14	72.37	7.23
T ₆ (KNO ₃ 3%)	196.65	9.26	5.21	73.24	7.32
T ₇ (PBZ 500ppm)	187.83	9.08	5.01	82.52	8.25
T ₈ (PBZ 1000ppm)	188.40	9.12	5.04	84.77	8.48
T ₉ (PBZ 1500ppm)	189.05	9.16	5.07	86.61	8.66
T ₁₀ (Sorbitol 1.5%)	199.97	8.90	4.88	73.19	7.32
T ₁₁ (Sorbitol 2.0%)	201.73	8.94	4.92	74.87	7.49
T ₁₂ (Sorbitol 2.5%)	203.00	8.97	4.94	76.17	7.62
SEm+	1.979	0.096	0.053	1.142	0.114
CD at 5%	5.528	0.269	0.148	3.191	0.319

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Studies on sun burn and fruit cracking in litchi cultivars under Bihar condition

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Abstract

An experiment was conducted at ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar during 2017 and 2018 to assess the response of twenty cultivars of litchi to sun burn and fruit cracking. Result revealed that sun burn and fruit cracking varied from 0 to 13.61% and 0 to 14.57%, respectively. CSL-16 exhibited maximum sun burning (13.61%) and fruit cracking (14.57%) whereas ten cultivars viz., CHL-4, CHL-5, CSL-1, CSL-2, CSL-4, CSL-5, CSL-10, CSL-11, CSL-12 and CSL-18 were found free from sun burn and fruit cracking. Sun burn and fruit cracking started in all susceptible cultivars during 51-56 days after fruit set. Sun burn and fruit cracking in different cultivars were found maximum in last ten to fifteen days of fruit growth and development. Sun burn and fruit cracking were not significantly influenced by orientation of fruits on the tree. All the early ripening cultivars were susceptible to sun burn and fruit cracking while late ripening cultivars exhibited tolerance. Tolerant cultivars can be used in breeding programme for further improvement.

Key words: Litchi, cultivars, sun burn, fruit cracking, susceptible, tolerance

Introduction

Litchi (*Litchi chinensis* Sonn.) is an evergreen subtropical fruit tree and important member of family Sapindaceae which has strong mycorrhizal association (Lal and Nath, 2020a). Litchi has high nutritive and medicinal values. It is good source of vitamin-C and phenolics (Lal *et al.*, 2018a). Litchi is highly specific to its climatic requirements particularly low temperature for bumper flowering and fruiting and this is the reason of its restricted cultivation in few countries and limited states in India. Total by-product in litchi is found to the tune of 19.85 to 59.54 per cent in different genotypes fractioning with 6.96 to 22.58 per cent seed and 12.89 to 36.96 per cent pericarp. Litchi pericarp and seed are good source of total phenol with 7.5-62.2 mg GAE/g and 23.01-85.57 mg GAE/g, respectively (Lal *et al.*, 2018b). It produces inflorescence called panicle which is the fruiting body for ensuring the final yield of litchi and emergence and size of panicle is also influenced by phenol content in the tree (Lal *et al.*, 2019a). Many genotypes bear loose or compact panicle which also depends on climatic condition. However, any cultivar of litchi does not follow regular pattern of flowering during young stages (Lal *et al.*, 2019b). There are three types of flower on the inflorescence in litchi: male (M₁), pseudo-hermaphrodite male (M₂) and pseudo-hermaphrodite female (F) flowers. Male flowers bloom first followed by an overlapping successions of female flowers with pseudo-hermaphrodite male and flowers bloom for 7-10 days and the number of flowers on a single inflorescence vary from hundreds to several thousand (Lal, 2018). Pollen grains of M₂ flowers are more viable and fruit set depends on the sources of

pollen grains (Lal *et al.*, 2019c and 2019d). However, fluctuation in temperature significantly affects fruit retention (Lal *et al.*, 2017a). Litchi suffers from many problems viz., fruit drop (Lal *et al.*, 2017b, c), seed and fruit borer, sun burn and fruit cracking (Lal *et al.*, 2018c), pericarp browning (Purbey *et al.*, 2019) but sun burn and fruit cracking is very important which directly heat to economic parts (fruits). Aberrant weather also influences the productivity and quality of litchi (Lal and Nath, 2020b). Fruit set vary with cultivars grown in the same condition and nutritional condition of plants as highest fruit set (23.96%) and lowest fruit drop (13.06%) was recorded in trees fertilized with calcium nitrate+urea (Jeet *et al.*, 2016). The availability of limited number of litchi cultivars restricts the choices of cultivars, therefore, the assessment of genotypes of litchi become very much essential. Thus, present investigation was conducted to assess the response of genotypes to sun burn and fruit cracking in litchi.

Materials and Methods

The experiment was carried out at the farm of ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar during 2017-18. The research farm is situated at 26°5'87"N latitude, 85°26'64" E longitude at an elevation of 210 m above msl to assess the response of litchi cultivars to sun burn and fruit cracking. The soil type of the site was alluvial with sandy loam texture having calcareous in nature with pH ranging from 7.5-8.0. The temperature varied from 30°C to 43 °C in summer and 5°C to 10°C in winter. The region was characterized by dry and hot summer and cold winter with

heavy rainfall during rainy season. The fifteen years old litchi plants of twenty cultivars viz. 'Bombai-II, CHL-4, CHL-5, CHL-8, CSL-1, CSL-2, CSL-3, CSL-4, CSL-5, CSL-6, CSL-7, CSL-9, CSL-10, CSL-11, CSL-12, CSL-13, CSL-15, CSL-16, CSL-18, CSL-19 were planted at 8 m × 8 m spacing in randomized block design with three replications, were used for the experiment. The observations made for this experiment were percentage of sun burn and fruit cracking at harvest; relationship between panicle direction (east, west, north and south) and percentage of sun burning and fruit cracking at different stages of fruit growth and development. The data was subjected to statistical analysis by using analysis of variance (Burton, 1952). Critical difference values at $p < 0.05$ were used to determine the significance of difference between treatment means.

Results and Discussion

The different cultivars showed significant variation in sun burning and fruit cracking at harvest (Tables 1 and 2). Sun burning varied from 0 to 13.61% and fruit cracking varied from 0 to 14.57% among the twenty studied cultivars. Cultivar CSL-16 exhibited maximum sun burning (13.61%) and fruit cracking (14.57%) and ten cultivars namely CHL-4, CHL-5, CSL-1, CSL-2, CSL-4, CSL-5, CSL-10, CSL-11, CSL-12 and CSL-18 were found free from sun burn and fruit cracking. It seems that there is strong correlation between sun burn and fruit cracking. The cultivars which were free from sun burn were also free from fruit cracking. Similarly, cultivars affected with sun burn were also affected from fruit cracking. Sun burn is a predisposed to the fruit cracking in litchi. It has been also observed that all early ripening cultivars were susceptible to

sun burn and fruit cracking while late ripening cultivars were free from sun burn and fruit cracking. Mitra *et al.* (2014) reported 10-25% crop loss due to fruit cracking and sun-burning in West Bengal condition. The variation in sun burn and fruit cracking among the cultivars were reported by earlier workers (Pereira *et al.*, 2005 and Sanyal *et al.*, 1990). It is clear from the Table 1 & 2 that sun burn and fruit cracking was recorded maximum on the southern side of the tree canopy. In southern direction of tree, sun burn varied from 0 to 19.86% and fruit cracking varied 0 to 20.88%. The maximum sun burn and fruit cracking on southern side were due to more light intensity, high temperature and longer duration of light exposure on this side. However, minimum sun burn and fruit cracking were observed either in north side followed by west side. Kumar *et al.* (2001) found higher sun burn and fruit cracking on south side of the tree canopy.

It is clear from the table 3 that sun burn started between 46 to 50 days after fruit set in CSL-1, CSL-6, CHL-8 and CSL-16 but it started in all susceptible cultivars during 51-56 days after fruit set. The cultivars CSL-3, CSL-6, CHL-8, CSL-9, CSL-13, CSL-15, CSL-16 and CSL-19 showed maximum sun burn between 61 to 65 days after fruit set, whereas, in CSL-1 and CSL-7, it was between 66 and 70 days after fruit set. Similarly, fruit cracking started between 51-56 days after fruit set in all susceptible cultivars (Table 4). The cultivars CSL-3, CSL-6, CHL-8, CSL-9, CSL-13, CSL-15 and CSL-19 exhibited maximum fruit cracking between 61 to 65 days after fruit set whereas CSL-1, CSL-7 and CSL-16 exhibited between 66 to 70 days after fruit set. Sun burn and fruit cracking were also influenced by orientation of fruits on the tree (Table 5) but not significantly (Fig. 1).

Table 1. Incidence of sun-burning of fruits in different directions

Cultivars	Directional variation in sun burn (%)				Sun burn (%)
	North	South	East	West	
Bombai-II	0.00	0.00	0.00	0.00	0.00
CHL-4	0.00	0.00	0.00	0.00	0.00
CHL-5	0.00	0.00	0.00	0.00	0.00
CSL-1	7.15	18.65	12.24	10.56	12.15
CSL-2	0.00	0.00	0.00	0.00	0.00
CSL-3	4.75	16.33	11.84	9.68	10.65
CSL-4	0.00	0.00	0.00	0.00	0.00
CSL-5	0.00	0.00	0.00	0.00	0.00
CSL-6	6.75	14.89	12.76	9.86	11.07
CSL-7	5.75	13.89	11.76	8.86	10.07
CHL-8	5.35	14.00	10.36	8.35	9.52
CSL-9	3.76	12.35	8.26	5.68	7.51
CSL-10	0.00	0.00	0.00	0.00	0.00
CSL-11	0.00	0.00	0.00	0.00	0.00
CSL-12	0.00	0.00	0.00	0.00	0.00
CSL-13	6.86	15.12	10.56	9.13	10.42
CSL-15	5.38	14.12	10.39	8.37	9.57
CSL-16	8.78	19.86	14.53	11.26	13.61
CSL-18	0.00	0.00	0.00	0.00	0.00
CSL-19	7.65	16.85	12.60	10.76	11.97
SE(d)	0.098	0.18	0.175	0.135	0.212
CD (0.05)	0.2	0.365	0.356	0.275	0.432

Thus, it may be concluded that the sun burn and fruit cracking in different cultivars started in last thirty days of fruit growth and were found maximum in last ten to fifteen days of fruit growth and development. During 15 to 31 May (last 15

days of fruit growth) atmospheric temperature was high (38 to 40°C) and relative humidity was low (50% to 60%) which triggered sun burn and fruit cracking.

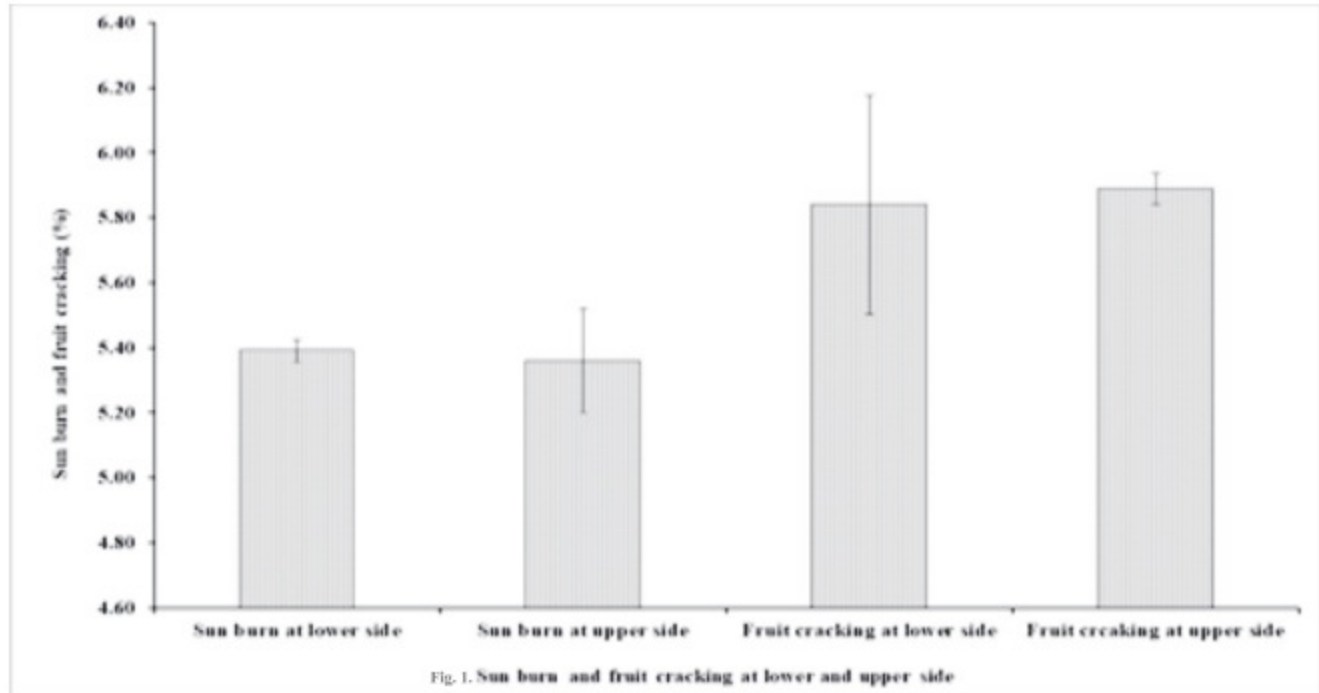


Fig. 1. Sun burn and fruit cracking at lower and upper side

Table 2. Incidence of cracking of fruits in different directions

Cultivars	Directional variation in fruit cracking (%)				Fruit cracking (%)
	North	South	East	West	
Bombai-II	0.00	0.00	0.00	0.00	0.00
CHL-4	0.00	0.00	0.00	0.00	0.00
CHL-5	0.00	0.00	0.00	0.00	0.00
CSL-1	8.45	19.65	12.73	11.49	13.08
CSL-2	0.00	0.00	0.00	0.00	0.00
CSL-3	5.84	17.67	12.67	10.12	11.58
CSL-4	0.00	0.00	0.00	0.00	0.00
CSL-5	0.00	0.00	0.00	0.00	0.00
CSL-6	7.94	15.94	13.03	10.96	11.97
CSL-7	6.46	14.88	12.68	10.28	11.08
CHL-8	6.25	15.68	11.24	9.12	10.57
CSL-9	4.38	13.56	9.86	6.48	8.57
CSL-10	0.00	0.00	0.00	0.00	0.00
CSL-11	0.00	0.00	0.00	0.00	0.00
CSL-12	0.00	0.00	0.00	0.00	0.00
CSL-13	8.64	16.48	12.80	10.76	12.17
CSL-15	6.38	15.68	11.12	9.62	10.70
CSL-16	9.78	20.88	15.46	12.14	14.57
CSL-18	0.00	0.00	0.00	0.00	0.00
CSL-19	9.30	17.95	13.58	11.35	13.05
SE(d)	0.112	0.256	0.215	0.174	0.178
CD (0.05)	0.227	0.52	0.437	0.354	0.361

Table 3. Sun-burning of fruit (%) at different stages of fruit growth and development

Cultivars	Days after fruit set						Sun burn (%)
	Between 40-45	Between 46-50	Between 51-55	Between 56-60	Between 61-65	Between 66-70	
Bombai-II	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHL-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHL-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-1	0.00	1.25	1.59	2.57	3.00	3.74	12.15
CSL-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-3	0.00	0.00	1.56	2.75	5.35	1.00	10.66
CSL-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-6	0.15	0.86	2.68	2.75	4.24	0.39	11.07
CSL-7	0.00	0.00	0.52	1.75	3.75	4.05	10.07
CHL-8	0.00	0.56	0.00	0.45	5.68	2.83	9.52
CSL-9	0.00	0.00	0.24	0.46	3.45	3.36	7.51
CSL-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-13	0.00	0.00	2.56	1.56	5.75	1.55	11.42
CSL-15	0.00	0.00	0.24	1.26	4.56	3.51	9.57
CSL-16	0.00	0.68	1.56	3.56	3.46	4.35	13.61
CSL-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-19	0.00	0.00	1.53	2.68	6.48	1.28	11.97
SE(d)	-	0.004	0.021	0.019	0.088	0.034	0.212
CD (0.05)	-	0.009	0.042	0.038	0.179	0.069	0.432

Table 4. Percentage of fruit cracking at different stages of fruit growth and development

Cultivars	Days after fruit set						Fruit cracking (%)
	Between 40-45	Between 46-50	Between 51-55	Between 56-60	Between 61-65	Between 66-70	
Bombai-II	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHL-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHL-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-1	0.00	1.28	1.63	2.63	3.14	4.40	13.08
CSL-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-3	0.00	0.00	1.83	2.35	5.62	1.78	11.58
CSL-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-6	0.00	0.76	2.67	2.83	4.82	0.89	11.97
CSL-7	0.00	0.00	0.52	1.75	3.75	5.06	11.08
CHL-8	0.00	0.62	0.00	0.48	5.84	3.63	10.57
CSL-9	0.00	0.00	0.63	0.52	3.96	3.46	8.57
CSL-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-13	0.00	0.00	2.35	1.45	5.86	2.51	12.17
CSL-15	0.00	0.00	0.18	2.54	5.60	2.38	10.70
CSL-16	0.00	0.68	2.14	3.28	3.86	4.61	14.57
CSL-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSL-19	0.00	0.00	1.75	2.84	7.15	1.31	13.05
SE(d)	-	0.005	0.025	0.031	0.065	0.044	0.178
CD (0.05)	-	0.011	0.05	0.064	0.133	0.089	0.361

Table 5. Sun burn and fruit cracking influenced by orientation of fruit on the tree

Cultivars	Sun burn (%)		Fruit cracking (%)	
	Lower	Upper	Lower	Upper
Bombai-II	0.00	0.00	0.00	0.00
CHL-4	0.00	0.00	0.00	0.00
CHL-5	0.00	0.00	0.00	0.00
CSL-1	12.43	11.86	13.00	13.16
CSL-2	0.00	0.00	0.00	0.00
CSL-3	11.00	10.32	11.54	11.62

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Evaluation of pomegranate varieties under semi-arid environment of central Gujarat

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Pomegranate (*Punica granatum* L.) belongs to the family *Punicaceae*, widely grown in the moderate climate of the Mediterranean region and it is well adapted to arid and semi-arid soils, and their trees grow successfully under unfavorable climatic and soil conditions and considered as salinity resistant plant (Ibrahim, 2016). Owing to its high nutritive value, wider adaptability to diverse agro-climatic conditions, early and prolific bearing with a high monetary return, pomegranate is becoming popular as a commercial crop in western part of India. In Gujarat, it occupies an area of 30.51 thousand ha with an annual production of 0.46 MT and it is mainly grown in Kachchh, Banaskantha and Mehsana districts; the average productivity is 15.13t/ha (Anonymous, 2018). Pomegranate is grown in many states of India like Maharashtra, Gujarat, Rajasthan, Uttar Pradesh, Haryana, Andhra Pradesh, Karnataka and Tamil Nadu and to a limited extent in Jammu and Kashmir, Himachal and Uttarakhand. Pomegranate possesses drought hardiness, offers immense potential to grow under marginal lands. As a result it is gaining popularity among farmers all over the country particularly in rain-fed areas (Verma *et al.*, 2013). Several old varieties are under cultivation in this region but evaluation and recommendation regarding their suitability for this region has not been done. In this regard present work was carried out to know the plant growth and physico-chemical properties of different important varieties in this region.

Fifteen genetically diverse genotypes including varieties were evaluated for growth, yield and fruit quality attributes at the ICAR-CIAH, Bikaner regional station CHES, Vejalpur; planted during August, 2016 at a spacing of 5 m x 5 m in randomized block design with three replications. *Hasta bahar* crop 2017-18 in which flowering commences during Sept.-Oct. was taken for recording the data on fruit yield and quality attributing characters on one year old plants. Three uniform trees of each genotype/cultivar was selected for recording observations on growth in terms of plant height (cm), stem diameter (cm), plant spread (cm), number of stems and suckers. Average fruit weight (g) was calculated by weighing the fruits in an electronic balance. The yield (kg/tree) was obtained through the weighing the harvested fruits. However, for measuring physical parameters like fruit weight, seed weight and fruit size were recorded as per standard procedures with the help of an electronic balance and

vernier caliper, respectively. The total soluble solids (TSS) were determined with hand refractometer (0-32°Brix). The titratable acidity (%) was determined by method of A.O.A.C. (1980). The average data were subjected to statistical analysis as per the method outlined by Gomez and Gomez (1984). Least significant difference at 5% level was used for testing the significant differences.

The maximum plant height was recorded in Ramnagram (243.33 cm) followed by Jyoti (215.10 cm) and P-16 (211.70 cm) while the minimum plant height was noted in Goma Khatta (145.0 cm). However, Jyoti recorded the maximum plant spread in north-south direction (217.33 cm) while Ramnagram in east-west direction (116.70 cm). The minimum plant spread in both the directions was observed in Goma Khatta (131.67 & 133.33 cm). The maximum stem girth was recorded in Muscat (3.77 cm) followed by Kandhari (3.51 cm) while the minimum stem girth was measured in Gul-e-shah Rose (2.08 cm). P-16 recorded the highest number of stems (5) while Mridula recorded the highest number of suckers (25). Whereas the minimum numbers of stems (1) and suckers (2.67) were recorded in Goma Khatta (Table 1). Genetic makeup of the plants and adaptability of diverse genotypes under different climatic conditions could be the possible reason for the wide variation with respect to growth and plant spread. The results of present findings are in agreement with Verma *et al.* (2013) and Rao and Subramanyam (2010) in pomegranate. Significantly, the maximum number of fruits/plant was observed in Goma Khatta (85) followed by Super Bhagwa (18.33) and Mridula (15.70) and same found minimum in Gul-e-shah Rose (4.66). Whereas, the maximum fruit yield/plant was recorded in Super Bhagwa (3.39 kg) followed by Bhagwa (2.82 kg) while the minimum fruit yield was found in P-16 (0.60 kg). The rich diversity in these characters may be due to highly heterozygous and diverse genetic background of parents (Verma *et al.*, 2013; Rao and Subramanyam, 2010).

Physico-chemical characters of all the evaluated germplasm are presented in Table 2. The maximum fruit weight was observed in Muscat (200.30 g) followed by Ramnagram (198.49 g) and Jyoti (195.19 g). Although, fruit weight \geq 180 g was recorded in Ganesh, Kandhari, Super Bhagwa and Bhagwa. However, the minimum fruit weight was recorded in P-16 (112.37 g) followed by Sinduri (120.50

g) and Goma Khatta (138.57 g). The maximum fruit length was recorded in S-1 (7.77 cm) followed by Muscat (7.56 cm) while the highest width was observed in S-1 (7.52 cm) followed by Ruby (7.49 cm). However, Goma Khatta recorded the minimum fruit length (5.73 cm) while width was observed in P-16 (5.76 cm). Muscat recorded the maximum juice percentage (73.89%) and the lowest 100 seed weight (1.53 g) while the lowest juice content was recorded in Goma Khatta (47.61%). The highest 100 seed weight was noted in Ramnagram (4.80 g) followed by Goma Khatta (4.79 g) and Gul-e-shah Rose (2.99 g). Similar variations in fruit size, juice percentage and 100 seed weight among pomegranate genotypes were reported by Prasad *et al.* (2012) in pomegranate and Mishra *et al.* (2019) in guava.

There were significant difference among the

varieties with regard to chemical quality attributes of pomegranate (Table 2). The highest TSS was recorded in Super Bhagwa (17.20 °Brix) followed by Kandhari (16.42 °Brix) while the minimum TSS was observed in Ramnagram (9.51 °Brix) followed by Goma Khatta (13.20 °Brix). The maximum acidity (1.35%) and lowest TSS: acidity ratio (9.77) were recorded in Goma Khatta while the minimum acidity (0.38%) and highest TSS:acidity (37.39) were found in Mridula and Super Bhagwa, respectively. Similar kind of variation was recorded by Verma *et al.* (2013), Prasad *et al.* (2012) in pomegranate and Mishra *et al.* (2019) in guava. Based on the present findings, pomegranate varieties like Super Bhagwa and Bhagwa were found better in terms of yield and fruit quality parameters. The above findings are preliminary and needs to be studied further.

Table 1. Different vegetative growth characters and average number of fruits in pomegranate genotypes

Germplasm	Height (cm)	Canopy spread (cm)		Stem girth (cm)	No. of stems	No. of suckers	No. of fruits/plant	Yield/plant (kg)
		N-S	E-W					
Gul-e-shah Rose	165.00	108.33	102.10	2.08	3.00	11.66	4.66	0.83
Muscat	206.67	200.33	238.33	3.77	3.66	4.66	14.00	2.80
Ramnagram	243.33	204.08	216.70	3.43	2.33	2.00	12.00	2.40
Jyoti	215.10	217.33	207.20	3.02	3.00	3.66	9.00	1.76
Ganesh	185.00	143.33	150.05	2.49	4.66	16.33	6.33	1.20
Kandhari	185.20	185.00	175.00	3.51	2.66	2.00	12.33	2.27
Appuli	196.70	146.70	141.67	2.32	3.00	18.00	7.70	1.28
P-16	211.70	200.15	218.33	3.02	5.00	7.67	5.00	0.60
Goma Khatta	145.00	131.67	133.33	3.12	1.00	2.67	19.33	2.67
Super Bhagwa	166.70	175.12	156.70	2.82	3.66	12.33	18.33	3.39
Bhagwa	188.33	168.33	186.66	2.85	4.03	13.67	15.67	2.82
Mridula	186.70	173.33	163.33	3.12	4.00	25.00	15.70	2.73
Sinduri	161.70	142.67	161.67	2.94	3.00	9.00	13.66	1.64
S-1	175.00	168.33	183.33	3.11	1.67	9.33	15.00	2.70
Ruby	165.00	145.10	145.05	2.78	2.67	11.00	17.00	2.99
CD (0.05)	37.01	45.09	48.07	0.92	1.75	7.66	9.28	0.46

Table 2. Physico-chemical characters of pomegranate genotypes

Germplasm	Fruit weight (g)	Length (cm)	Width (cm)	Juice (%)	TSS (°B)	Acidity (%)	TSS: acidity	100 seed weight (g)
Gul-e-shah Rose	178.25	5.65	6.50	72.75	13.55	0.91	14.89	2.99
Muscat	200.30	7.56	7.43	73.89	14.27	0.45	31.71	1.53
Ramnagram	198.49	7.22	7.18	57.87	9.51	0.64	14.85	4.80
Jyoti	195.19	7.44	7.38	72.70	13.95	0.38	36.71	1.88
Ganesh	189.17	6.82	6.98	76.71	16.37	0.46	35.58	1.52
Kandhari	184.25	7.35	7.15	73.33	16.42	0.38	43.21	1.65
Appuli	166.69	5.88	6.38	62.30	16.25	0.49	33.16	2.91
P-16	112.37	6.19	5.76	67.30	13.36	0.47	28.43	1.97
Goma Khatta	138.57	5.73	6.34	47.61	13.20	1.35	9.77	4.89
Super Bhagwa	185.15	7.16	6.87	62.30	17.20	0.46	37.39	1.73
Bhagwa	180.25	6.55	6.66	61.20	14.21	0.48	29.60	1.74
Mridula	174.47	6.88	6.41	61.68	11.21	0.38	29.50	1.77
Sinduri	120.50	6.07	6.31	61.25	17.05	0.45	37.88	1.79
S-1	180.08	7.77	7.52	70.45	16.38	0.40	40.95	1.82
Ruby	176.13	7.66	7.49	72.33	13.75	0.39	35.26	1.85
CD _(0.05)	1.83	0.60	0.11	0.92	0.56	0.09	0.34	0.16

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Evaluation of ber cultivars against bark eating caterpillar (*Indarbela sp.*) under field condition

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Ber (*Zizyphus mauritiana* L.) is an important fruit crop cultivated under arid and semi-arid climatic conditions. The importance of bark eating caterpillar, *Indarbela sp.* infesting to this crop has been recognized since many years. It is most devastating pest in ber growing areas. Plants frequently display genetic variation within and between population for traits that influence the preference and non-preference of insects on their hosts that are resistance traits (Johnson and Agrawal, 2005; Haldhar *et al.*, 2017; Samadia and Haldhar, 2017; Muthusamy *et al.*, 2017). Least susceptible cultivar is an economical and environment-friendly, farmer friendly and do not need much financial investment for insect management. Host plants play an important role in determining insect populations in respect to concentrations and proportions of nutrients, which differ among species (Schoonhoven *et al.*, 2005). Direct defenses are mediated by plant characteristics that affect the herbivore's biology such as mechanical protection on the surface of the plants (e.g., hairs, trichomes, thorns, spines, and thicker leaves) that retard the development of herbivores (Hanley *et al.*, 2007). *Zizyphus nummularia* provides a nutritious leaf fodder for the animals. The leaves contain 5.56 per cent DCP and 49.7 per cent TDN and are rich in protein and mineral matter. The fruits are believed to purify blood and to help in digestion. The bark is said to be a remedy in diarrhea. The root is used as decoction in fever and as powder applied to ulcer and wounds. The leaves form a plaster in strangury and are used in conjunctivitis. Besides providing the nutritious fruits, various parts of the ber tree are also known to have medicinal value (Bhandari, 1969; Kirtikar and Basu, 1975).

Bark eating caterpillar, *Indarbela sp.* (Metarbelidae-Lepidoptera) is the most destructive and polyphagous pest of fruits in India. Among them Bark eating caterpillar, (*Indarbela tetraonis* Moore) is now-a-days becoming one of the serious production constraint (Dharam, 2012). Besides, pest is also known to infest other crops *viz.*, ber, citrus, jack-fruit, jamun, loquat, pomegranate, mango, aonla, rose, mulberry, phalsa, rambutan and logan (Dharam, 2012). The total duration of the fruit fly life cycle varies with respect to environmental condition. The female of this pest is active from June to August and deposit their egg on branches and stems on which cracks or the junction of branch in 15 to 20 clusters. A females deposit 300 to 400 egg. Caterpillar after hatching enter the junction of branch, making galleries and start feeding. The egg stage 8-10

days, the larval period 8-10 month, pupal period from May-June about four week and the adult moth emerging from these pupa mate and lay egg again and adult survive 3-4 days. The caterpillar remains concealed in the stem during the day time but eat away the bark in the night. Heavy infestation by this pest retards the growth ultimately affecting the fruit yield adversely. Cultivation of resistant cultivars to bark eating caterpillar is a major component of integrated pest management programmes and therefore this work was taken under field conditions. No holistic information is available regarding varietal screening against bark eating caterpillar. Hence, an investigation was undertaken to generate the data and document results regarding the resistant cultivar to bark eating caterpillar.

A field experiment was conducted in a Randomized Block Design (RBD) with four replication from 2013 to 2020. The eight year data of 12 ber cultivars were screened against bark eating caterpillar is presented in Table-1. Twelve cultivars of ber grown in gene bank trail namely Gola, Umran, Chomu local, Kaithli, Chandi Supari, Ilaichi, Pathani, Ashapuri-II, Saphar Chandni, Lakhani, Chhuara and Pusa Prolific were kept under observations to find out their relative susceptibility to bark eating caterpillar. The cultural practices except recording the bark eating caterpillar infestation were followed as per the crop production guide for horticultural crops. The plant established in 8x8 metre distance and each treatment had four plants (each plant considered as a one replication). The observations recorded at fortnightly intervals starting from August to November month (peak activity of this pest). The presence of frass ribbon on trees with freshly eaten bark was considered as the sign of infestation. In order to determine the resistant ber cultivar, the live hole made by bark eating caterpillar per plant was recorded. The cessations of ribbon elongation were fixed as the criteria for active holes. The established twelve ber cultivar of *Z. mauritiana* at the field gene bank at experimental farm of Asalpur farm, SKN College of Agriculture, Jobner were used for preliminary resistance study (Table 1). Three branches were randomly selected from each plants and average incidence of active holes/ plant was recorded. Twenty ber cultivars were evaluated against bark eating caterpillar in field condition during eight years (2013-14 & 2020-21). The cultivars were categorized on the basis of eight year pooled data on active hole / plant: least susceptible (1.70 to 4.44 active

holes/plant), moderately susceptible (5.53 to 6.67 active holes/plant), highly susceptible (7.10 to 9.27 active holes/plant). Transformations (Values in parenthesis are $\sqrt{X+0.5}$ transformed values) were used to achieve normality in the data before analysis.

All the screened ber cultivars were prone to the attack by *Indarbela sp.* Among 12 cultivar of ber tested, none of them was immune to bark eating caterpillar (Table 1). Twelve cultivars of ber grown in gene bank trail namely Gola, Umran, Chomu local, Kaithali, Chandni Supari, Ilaichi, Pathani, Ashapuri-II, Saphar Chandni, Lakhani, Chhuara and Pusa Prolific were kept under observations to find out their relative susceptibility to bark eating caterpillar. On the basis of eight year pooled data given in Table -1 revealed that the maximum infestation of bark eating caterpillar was observed in cultivar Gola (9.27 active hole/plant), Kaithli (7.91 active hole/plant), Umran (7.10 active hole/plant) and Ilaichi (7.08 active

hole/plant) whereas, it was minimum in Pusa Prolific (1.70 active hole/plant), Ashapuri-II (1.89 active hole/plant) and Chandni Supari (2.52 active hole/plant). The cultivar Pusa Prolific, Ashapuri-II, and Chandni Supari, were statistically at par in their susceptibility to bark eating caterpillar. The cultivar Chomu Local (6.67 active hole/plant), Lakhani (6.04 active hole/plant), Chhuara (5.56 active hole/plant), Saphar Chandni (5.53 active hole/plant), and Pathani (4.44 active hole/plant), were moderately susceptible to bark eating caterpillar. The results of the present investigation show the overall effect of ber resistance traits against the bark eating caterpillar, *Indarbela sp.* While bark eating caterpillar, *Indarbela sp.* infestation in different cultivars of ber showed significant differences. The present finding were also in favour of Verma and Singh (1974) observed that Ilaichi, Dandan, Gola and Kaithli were susceptible the bark eating caterpillar.

Table 1. Incidence of bark eating caterpillar, *Inderbella sp.* on different ber cultivars

Sr. No.	Varieties	Average active hole per plant								
		2013	2014	2015	2016	2017	2018	2019	2020	Pooled
1	Gola	4.70 (2.28)	7.50 (2.87)	13.75 (3.67)	15.71 (3.92)	9.00 (3.07)	8.25 (2.83)	7.75 (2.86)	7.50 (2.82)	9.27 (3.04)
2	Umran	1.50 (1.41)	2.75 (1.79)	8.75 (3.01)	14.08 (3.52)	8.25 (2.96)	7.25 (2.67)	7.25 (2.76)	7.00 (2.74)	7.10 (2.61)
3	Chomu Local	2.50 (1.73)	4.50 (2.19)	5.50 (2.40)	12.37 (3.09)	8.00 (2.91)	7.50 (2.82)	6.75 (2.68)	6.25 (2.58)	6.67 (2.55)
4	Kaithli	4.50 (2.24)	7.25 (2.78)	9.75 (3.19)	14.53 (3.63)	7.75 (2.87)	6.75 (2.52)	6.75 (2.68)	6.00 (2.53)	7.91 (2.81)
5	Chandni Supari	0.00 (0.71)	0.00 (0.70)	1.0 (1.19)	5.89 (1.47)	3.00 (1.86)	3.50 (1.85)	3.25 (1.93)	3.50 (1.98)	2.52 (1.46)
6	Ilaichi	4.00 (2.12)	6.75 (2.68)	6.75 (2.68)	12.64 (3.16)	7.75 (2.87)	6.50 (2.50)	6.5 (2.62)	5.75 (2.49)	7.08 (2.64)
7	Pathani	1.70 (1.35)	3.25 (1.67)	3.75 (2.09)	9.07 (2.26)	4.75 (2.28)	4.25 (2.06)	4.5 (2.23)	4.25 (2.17)	4.44 (2.01)
8	Ashapuri-II	0.00 (0.71)	0.00 (0.70)	0.50 (0.97)	4.36 (1.09)	2.50 (1.63)	2.75 (1.61)	2.75 (1.80)	2.25 (1.61)	1.89 (1.27)
9	Saphar Chandni	3.00 (1.63)	4.50 (1.89)	5.25 (2.39)	11.27 (2.81)	5.50 (2.42)	5.00 (2.33)	5.25 (2.37)	4.50 (2.20)	5.53 (2.26)
10	Lakhani	3.75 (1.93)	6.00 (2.36)	5.75 (2.49)	11.57 (2.89)	5.75 (2.49)	5.25 (2.22)	5.5 (2.41)	4.75 (2.28)	6.04 (2.38)
11	Chhuara	2.25 (1.47)	3.75 (1.93)	4.25 (2.16)	11.98 (2.99)	5.50 (2.40)	5.50 (2.25)	6 (2.54)	5.25 (2.39)	5.56 (2.27)
12	Pusa Prolific	0.00 (0.71)	0.00 (0.70)	0.25 (0.83)	3.84 (0.96)	2.25 (1.57)	2.75 (1.35)	2.5 (1.73)	2.00 (1.48)	1.70 (1.17)
S.E.M. \pm		0.25	0.33	0.15	0.14	0.20	0.41	0.14	0.14	0.44
C.D. at 5%		0.76	1.00	0.46	0.43	0.59	1.24	0.43	0.41	1.22

Values in parenthesis are $\sqrt{X+0.5}$ transformed values.

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Assessment of on-farm trial for improved nursery raising technique in chilli

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Chilli is an important vegetable crop which is grown for green fruits and dry chilli powder as spice. The total production of chilli in India is about 3851 thousand MT in 364 thousand ha area (Anonymous, 2019). India is the largest producer of the chilli in the world followed by China and Pakistan. In India, it has huge demand of green and dry fruits of chilli for aroma, pungency and taste for cooking the vegetables. Biotic factors (sucking pest and soil born diseases) and abiotic factors (temperature, moisture, etc.) are the challenges to the farmers. Therefore, improve nursery raising technique is the only option for regular supply, higher yield and better productivity of chilli to raise healthy, vigorous and disease free especially virus free seedlings. Sharmila *et al.* (2014) and Chatterjee and Mal (2016) confirm that it also reduce the quantity of the seeds, cost, labour, money, time etc. Pro-tray technology is better for raising seedling, as each seedling grows in cavity allows proper nourishment of seedlings through proper utilization of nutrients; space and sun light (Singh *et al.*, 2010). Soilless media is free from microorganism for raising disease free seedlings (Levnish, 2011). It provides adequate space for each seedling to grow, uniform germination, low quantity of seeds, vigorous and healthy seedling, easy in handling, friendly transportation, better root development and early transplant and establishment into the main field. Keeping these facts in view, present on-farm trial was carried out to compare the method being practiced by the local farmers and the improved method.

An on-farm trial was conducted at farmer's field of Dausa district in two consecutive years 2014-15 and 2015-16. The experiment were comprised of three treatments *i.e.* T₁-Farmer's Practices (Use broadcast method in nursery bed), T₂-Recommended Practices (Raised nursery bed + line sowing of seeds), T₃-Raising of seedling in protray using soilless media (Cocopeat : vermiculite: Perlite :: 3:1:1) and 2-3 spray of water

soluble fertilizers N:P:K (19:19:19) during seedling stage. Total number of replications were 10 and each treatment has 1250 m² area. All the observations were recorded on seedling survival (%), fruit yield (q/ha) and economics. The findings (Table 1) revealed that protray with soilless media (T₃) gives maximum survival (96%), green chilli yield (289 q/ha and 210 q/ha) during the year 2014-15 and 2015-16, respectively followed by recommended practices (T₂) and farmers practices (T₁). The maximum per cent increase in green chilli yield (31.66 and 58.49) was recorded in T₃ followed by recommended practices T₂ (9.56 and 14.83) over farmers practices during the year 2014-15 and 2015-16, respectively (Table 1). These findings are in agreement with the results as reported by Kushwah and Dwivedi (2013); Vivek and Duraisamy (2017). Farmer appreciated the result of on-farm trial in term of productivity and profitability and they adopted and disseminated the technology.

The data in Table 2 showed that economic analysis of the green chilli yield performance under OFT's treatment T₃ - Protray with soilless media gives higher gross returns (Rs. 375700/ha and Rs. 630000/ha) with the net returns (Rs.285124 /ha and Rs. 539695/ha) in the year 2014-15 and 2015-16, respectively followed by recommended practices and minimum in farmer's practices. The maximum B: C ratio (4.15 and 6.98 during 2014-15 and 2015-16) was observed in T₃ followed by recommended practices and minimum in farmer's practices. T₃ treatment showed better effect on production of higher number of healthy seedlings, higher survival per cent, higher yield, net return with higher B:C ratio in comparison to T₂ and T₁. Similar results have also been reported by Pandey *et al.* (2004).

The study demonstrated that chilli seedling raised in soil less media is effective and superior than recommended practices of nursery raising and the farmer's practices. Raising

Table 1. Survival and yield of on-farm trial in chilli

Treatment	Survival (%)			Green fruit yield (q/ha)			% increase in green chilli yield/ha		
	2014-15	2015-16	Pooled Mean	2014-15	2015-16	Pooled Mean	2014-15	2015-16	Pooled Mean
T ₁	63	64	63.5	219.5	132.45	175.97	-	-	-
T ₂	70	78	74	240.5	152.1	196.3	9.56	14.83	12.19
T ₃	95	97	96	289	210	249.5	31.66	58.49	45.07

Table 2. Economics of on-farm trial in chilli

Treatments	Gross return* (Rs./ha)			Net Returns* (Rs./ha)			B:C ratio		
	2014-15	2015-16	Pooled Mean	2014-15	2015-16	Pooled Mean	2014-15	2015-16	Mean
T ₁	285350	397350	341350	195200	311250	253225	3.17	4.61	3.89
T ₂	312650	456300	384475	225475	371400	298437.50	3.59	5.37	4.48
T ₃	375700	630000	502850	285124	539695	412409.50	4.15	6.98	5.56

*Green chilli market price 2014-15 and 2015-16 @ Rs. 1300 /q and Rs. 3000 /q

of seedling in protray using soilless media (Cocopeat: vermiculite: Perlite :: 3:1:1) and 2-3 spray of water soluble fertilizers N:P:K (19:19:19) during seedling stage have great potential for healthy and vigorous seedlings production in chilli. Besides it also resulted in improved vigour in seedlings as reflected through virus free seedlings.

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Quality of underground irrigation water of Bikaner district of Rajasthan

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The soils of arid region are very poor in macro and micronutrients as well as physical properties of soil. The proper soil depth, hard layer/pan are also a problem in some parts for better orchard establishment. The soils of the north-western arid region is known as 'desert soils' and 'grey brown soils' comes in the order of Aridisols which is light textured. The soils often have high salinity. The ground water resource is not only inadequate due to poor surface and sub-surface drainage but is also saline in nature. The irrigation water resources in the region are seasonal rivers and rivulets, surface wells and some runoff water storage devices (e.g. *nadi, tanka, khadins*) and canal irrigation in arid region. Thus, the water resources in arid region are inadequate and can irrigate only just 4% of the area. The annual average rainfall in arid region is very low, varies from 100 mm in north-western sector of Jaisalmer to 450 mm in the eastern boundary or arid zone of Rajasthan. Most of the rainfall occurs during July-September in about 19-21 rain spells. Due to low and unpredictable rainfall pattern in arid region, suitable technology is required to increase productivity. Water is precious input in hot arid region of the country therefore, adoption of micro-irrigation system is advantageous to save water and enhance productivity. For arid environment, the variety is needed which are resistant to biotic and abiotic stresses for sustainable production.

Saline or alkali waters constitute an important source of irrigation for agricultural production in water scares of arid region. Soil salinity and alkalinity problems in Rajasthan are primarily due to irrigation of crops with poor quality waters which are further accentuated by the aridity of the state. Ground water in Rajasthan has diversity of quality problems (Lal *et al.*, 1998). As regards the distribution of quality of under-ground water in the Rajasthan state, only 16% is good, 16% is marginal and rest 68% underground water is poor quality. Further, under poor quality water category, distribution of saline, sodic and saline sodic waters are about 16, 35 and 49%, respectively (Yadav and Kumar, 1995). Unavailability of good quality water for irrigation purposes has deteriorated the soil properties, reduced crop yields and qualities. Low rainfall and poor quality Rajasthan state has developed several water projects for drinking and irrigation purposes since ancient. Several times water projects fail to supply water for irrigation in field crops due to low rainfall, high evaporation losses, over irrigation and higher infiltration rate of soil. In these situations,

farmers use underground poor quality water for irrigation resulting in salt accumulation on surface soil resulting in deterioration of soil conditions and consequently low crop-yields. Development of salinity, sodicity and toxicity problems of salts in soils not only reduces crop productivity, quality and limited scope of the choice of the crops. In addition, in dry-hot areas, the availability of good quality water is very limited by low rainfall and high evapotranspiration (El Mahmoudi *et al.*, 2011) and is exacerbated under current global climate change, with severe weather events accompanied by long dry periods (Sietz *et al.*, 2015). The increasing of the population needs more and more food, but at the same time, the consequences of global climate change are compromising crops production (Lesk *et al.*, 2016). In order to reach reasonable and stable crop yields, irrigation can be vital. The agriculture sector is the largest consumer of water, especially in the arid and semi-arid regions, where irrigation water represents from 50% up to almost 90% of total used water (FAO, 2017). Irrigation systems with advanced technologies along with good practices can increase irrigation effectiveness and decrease the water wastage (Levidow, 2014; Tromboni, 2014 and Bortolini, 2016). Appraisal of irrigation water quality based on only a few vital parameters, which consider the crop species to be irrigated and the type of irrigation system and management adopted, can be an easy and flexible method for maximizing the reuse of low-quality water for agricultural purposes (Bortolini *et al.*, 2018). The detailed in sequence is lacking as regard of quality of underground waters of areas of Badrasar district of Bikaner. Therefore, it is very indispensable to categorize the underground waters use for irrigation with respect to their fittingness for crops and soils.

The study was carried out in areas of Badrasar district of Bikaner situated in North-western of part of Rajasthan state of India. Soil of the district falls under category of coarse grain sandy soils of arid region. The colour of soils ranges from grayish brown to brown and textures of soil are sandy and sandy loam in texture (Dhir and Singh, 1985). The climate of this area is arid type. Erratic rainfall (100-420 mm/year), high evapo-transpiration (1500-2000 mm/year) and poor soil physical and fertility conditions is found in the arid region. Pearl millet, groundnut, cluster bean, sesame, green gram are grown in kharif and mustard, wheat and chickpea crops are dominant crops in *rabi* season. The major sources of irrigation

are canals, seepage water from canal in dug well, tubewell, bore wells, pond, etc.

Representative ground water samples were collected from areas of Badrasar district of Bikaner situated in North-western part of Rajasthan state of India and analyzed for pH, EC, cationic and anionic composition according to methods as outlined by Richards (1954). Sulphate was determined by using Chesnin and Yien's (1950) method. Water table was measured by using portable water level meter. Ground waters were categorized on the basis of availability of EC, SAR, and RSC values as suggested by Gupta *et al.* (1994). Soil pH, electrical conductivity and sodium adsorption ratio of soil samples were determined as per U.S.D.A. Hand book 60 (Richards, 1954).

Sodium adsorption ratio (SAR):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

Residual sodium carbonate: It was calculated from the analysis data for carbonates, bicarbonates and Ca plus Mg as follows (all expressed in me/litre):

$$RSC \text{ (me/litre)} = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Maximum concentration of Na^+ , K^+ , Ca^{++} , Mg^{++} , CO_3^- , HCO_3^- , Cl^- and SO_4^- was 101.10, 0.13, 14.44, 20.03, 1.74, 51.02, 74.09, 4.50, 21.94, 0.13, 2.64, 2.97, 1.74, 5.24, 20.33 and 4.50 me L⁻¹ and minimum concentration was 11.67, 0.09, 0.77, 1.40, 0.82, 2.78, 8.17, and 2.01 me L⁻¹ with mean value 24.45, 0.12, 2.87, 4.00, 1.86, 9.13, 18.18 and 3.30, respectively. The sources of major cations, such as Ca^{2+} and

Mg^{2+} , in groundwater can be the weathering of calcium and magnesium minerals (Kumar *et al.*, 2009). In the areas of increased clay rich soil dispersed and where Na^+ concentration is higher (Yousaf *et al.*, 1987), the Mg^{2+} concentration is relatively higher than that of Ca^{2+} . The ratio $HCO_3^- : Na^+$ can also be used to assess the weathering process (Kumar *et al.*, 2009) that occurs in groundwater. When the $HCO_3^- : Na^+$ ratio is greater than 1, carbonate weathering occurs, while a ratio of $Na^+ / (Na^+ + Cl^-)$ higher than 0.5 had only one samples, suggesting that ion exchange process is very low. On the whole, the groundwater samples have the concentration of Na^+ higher than that of K^+ , because of the greater resistance of K^+ to chemical weathering and its adsorption on clay minerals (Rao, 2008). This suggests that when there is lack of rain, the decomposition of organic matter by bacterial organisms in the soil would not provide the appropriate CO_2 to the rock/ water interaction in dry season. The Na concentration in soil layers can influence the scattering of clay particles, the soil water characteristics, soil aggregate stability, and the formation of soil crusts. Dispersion of soil particles may cause clogging of soil pores, which reduces the soil permeability, soil porosity, and soil water conductivity (Bresler, 1970; Greene *et al.*, 1988; He *et al.*, 2013; He *et al.*, 2015; Tedeschi *et al.* 2005).

Sodium hazard index used is the Sodium Adsorption Ratio (SAR) that expresses the comparative activity of sodium ions in the exchange reactions with the soil. This ratio measures the relative concentration of sodium to calcium and Magnesium. SAR of irrigation water was varied from location to location. The classification of irrigation waters with respect to sodic hazard on the basis of SAR is based primarily on the increase of exchangeable sodium and its effect on the physical conditions of soils. On the basis of SAR, irrigation water may be classified into six classes as proposed by Gupta (1986).

S ₀	Non sodic waters: (SAR < 5)	Can be used for irrigation on almost all soils for all crops even those sensitive to sodium.
S ₁	Normal waters: (SAR 5 - 10)	Can be used for irrigation on almost all soils with little danger of development of harmful levels of exchangeable sodium for growing all crops except sensitive to sodium.
S ₂	Low sodic waters: (SAR 10 - 20)	Can be used for crops, which are semi tolerant or tolerant to sodium on almost all soils such that leaching fraction (LF) is around 0.3. If there is a presence of gypsum or calcium carbonate in soil, these waters can be used more successfully.
S ₃	Medium sodic waters: (SAR 20 - 30)	Can be used only for crops which are tolerant to sodium on soils provided with good drainage such that leaching fraction is always greater than 0.3.
S ₄	High sodic waters: (SAR 30 - 40)	These waters are directly not suitable for irrigation but may be used in cycle or conjunction with low sodicity waters or with the use of amendments such as gypsum.
S ₅	Very high sodic waters: (SAR >40)	These waters are directly not suitable for irrigation without drastic treatment.

Alkali hazard (RSC)

The carbonate or bicarbonate (alkali) hazard on the basis of RSC is primarily based on the precipitation of calcium and/or magnesium and pairing of residual carbonate (CO_3^-) or bicarbonate (HCO_3^-) with sodium and formation of sodium carbonate (Na_2CO_3) in the soil and increasing SAR/ESP characterizing it as alkali soil. RSC should be calculated for high pH (> 8.5) waters. On the basis of RSC, irrigation waters may be classified into six classes as proposed by Gupta (1986).

Based on above said classification (Fig. 2), 50% of irrigation water was low alkali waters (RSC < 2.5 me L⁻¹) followed by 31.25 % medium alkali waters (RSC 2.5 - 5.0 me L⁻¹), 12.50% high alkali waters (RSC 5.0-10 me L⁻¹) and 6.25 % high alkali waters (RSC >10.0 me L⁻¹). The relative abundance of sodium with respect to alkaline earths, and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation. This excess is denoted by 'Residual sodium carbonate' (RSC). A negative RSC value indicates that the total concentration of

A ₀	Non-alkali waters: (RSC Negative)	Can be used for irrigation on almost all soils for all crops for indefinitely long periods without any problem.
A ₁	Normal waters: (RSC 0 me L ⁻¹)	can be used for irrigation on almost all soils for all crops even those are sensitive to carbonates or bicarbonates
A ₂	Low alkali waters: (RSC < 2.5 me L ⁻¹)	Can be used for irrigation on almost all soils for all crops.
A ₃	Medium alkali waters: (RSC 2.5 - 5.0 me L ⁻¹)	Can be used for irrigation on almost all soils with little danger of the development of harmful levels of alkali conditions for growing all crops except sensitive to carbonates or bicarbonates.
A ₄	High alkali waters: (RSC 5.0 - 10.0 me L ⁻¹)	Can be used for irrigation on soils provided with good drainage such that leaching fraction is not less than 0.3 for growing semi-tolerant and tolerant crops to sodium. EC should be < 3.0 dS m ⁻¹ and SAR should be <10.0
A ₅	Very high alkali waters: (RSC > 10.0 me L ⁻¹)	These waters are directly not suitable for irrigation but may be used in conjunction with low alkalinity waters or with the use of amendments.

CO₃²⁻ and HCO₃⁻ is lower than the sum of the Ca²⁺ and Mg²⁺ concentrations, reflecting that there is no residual carbonate to react with Na⁺ to increase the Na hazard in the soil. Trace metals including Cu²⁺, Zn²⁺, Fe³⁺, As³⁺, Mn²⁺ were concentrations were low and considered to be suitable for crop production and the soil environment (Ayers and Westcot, 1985). There are situations where canal good quality water is available for irrigation but not in adequate quantities to meet the evapotranspirational needs of crops. Under these conditions, the strategies for obtaining maximum crop production could include mixing of high salinity water with good quality water to obtain irrigation water of medium salinity for use throughout the cropping season. Alternatively, good quality water might be used for irrigation at the more critical stages of growth, e.g. germination, and therefore the saline water at the stages where the crop has relatively more

tolerance. Further research is needed to define the best options considering the tolerance of crops at different growth stages, critical stages of growth *vis-a-vis* soil salinity, etc (Bortolini *et al.*, 2018).

Problematic soil in semi arid region is formed because of indiscriminate application of irrigation with poor quality under-ground water. The water falling under good quality category can be used safely for groundnut, wheat and leguminous crops whereas water which is marginally saline can be used for pearl millet and mustard crops in area having coarse textured soil. Ground water rated as marginally alkali can be used effectively with gypsum application for mustard and barley. The water rated as saline, alkali and highly alkali soils are unfit for irrigation and their indiscriminate use caused secondary salinization and sodication to the extent that growth of the crop may be adversely affected.

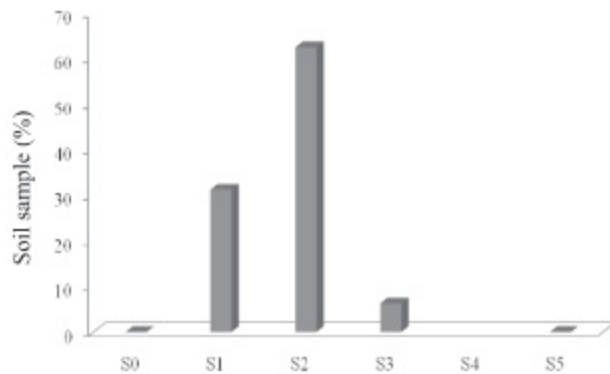


Fig. 1. Classification of irrigation waters with respect to sodic (SAR) hazard on the basis of SAR

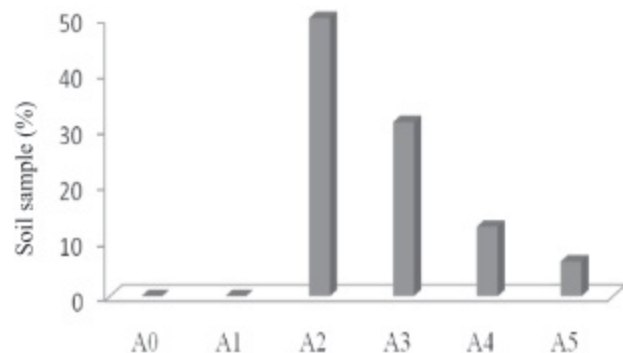


Fig. 2 Classification of irrigation waters with respect to alkali (RSC) hazard on the basis of SAR

Table 1. Quality of underground irrigation water of Badrasar of Bikaner district of Rajasthan

	Cationic conc. (me L ⁻¹)				Anionic conc. (me L ⁻¹)			
	Na ⁺	K ⁺	Ca ⁺⁺	Mg ⁺⁺	CO ₃ ⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻
Badrasar								
Mean	24.45	0.12	2.87	4.00	1.86	9.13	18.18	3.30
Minimum	11.67	0.09	0.77	1.40	0.82	2.78	8.17	2.01
Maximum	101.10	0.13	14.44	20.03	1.74	51.02	74.09	4.50
Median	19.19	0.12	2.09	2.87	1.23	4.96	13.25	3.25
Standard Deviation	21.09	0.01	3.26	4.47	0.25	11.82	15.54	0.74

Table 2. SAR and RSC of underground irrigation water of Badrasar of Bikaner district of Rajasthan

Badrasar	SAR	RSC
Mean	11.99	4.12
Minimum	9.20	0.12
Maximum	24.35	24.65
Median	10.88	2.60
Standard Deviation	3.71	5.93

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Tephrosia pentaphylla (Roxb.) G. Don: Recollection from Todgarh-Raoli Wildlife Sanctuary, Rajasthan

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The occurrence of *Tephrosia pentaphylla* (Roxb.) G. Don from Todgarh-Raoli Wildlife Sanctuary show its extended distribution from South India to Rajasthan and recollected after 126 years from India. Description and photo plates are provided here to facilitate its easy identification. The genus *Tephrosia* Persoon (1807: 328) is belonging to family Fabaceae mainly distributed in tropical and subtropical regions of the world with highest concentration in Africa (Cowie 2004; Schrire 2005; Mabberley 2008). Total 350 species reported so far, of which 29 taxa (27 species, 1 subspecies and 1 variety) reported from India (Kumar and Sane, 2003). Out of which 7 taxa are endemic to India (Sanjappa, 2010) and 11 taxa are reported from Rajasthan (Shetty and Singh, 1987).

Tephrosia pentaphylla was first time collected in India by Cooke's (*l.c.*) sheet from Gulbarga district probably existed in BSI collected during September, 1892, but under *T. senticosa* Pers. only and on its scrutiny, though the pods are very young, it is definitely *T. pentaphylla* and later included in other publications (FBI; Wight and Arnott, 1834; Saldanha 1984; Singh, 1988; Sanjappa, 2010) based on Cooke's collections made on 1892 and housed in BSI herbarium. Thereafter no record was available either from Karnataka or from any other state of India. Thus, it is worthwhile to mention that this species is extremely rare in our country and confined only to state of Karnataka. It is interesting to note that present report corroborate the plant material available in any Indian herbaria for the first time and also it is recollected after a lapse of about 126 years from Indian region.

During floristic exploration of Todgarh-Raoli Wildlife Sanctuary, Rajasthan during August, 2018, one of the author observed one interesting population of 90-95 individuals of *Tephrosia* were collected from core zone area Jhamuda, Raoli range of Todgarh-Raoli wildlife sanctuary. After critical study of herbarium specimens housed at BSJO, BLAT, RuBL, DCH, JAC, CAL, BSI and scrutiny of pertinent literature (Blatter & Hallberg, 1918-21; Bhandari 1990; Singh and Shetty, 1987; Singh and Singh, 2006; Sanjappa, 2010;

Sharma, 2014; Kumar and Purohit, 2015) revealed that this species is *Tephrosia pentaphylla* and has not been collected after Cooke's collections from Karnataka in September, 1892.

The occurrence of *Tephrosia pentaphylla* (Roxb.) G. Don in typical rocky areas of core zone of Todgarh-Raoli wildlife sanctuary, after a lapse of nearly 126 years, with a very small population (90-95 individuals) indicates that this species is rare in India and also its extended distribution from Karnataka to Rajasthan. The herbarium specimens are deposited in herbarium of Botanical Survey of India, Arid Zone Regional Circle, Jodhpur (BSJO). This paper deals with detailed description, notes on habitat, distribution and photo plates for their easy identification.

Tephrosia pentaphylla (Roxb.) G. Don in Sweet, Hort. Brid. ed 3, 170. 1839; Gamble, Fl. Madras 318 (225). 1918; Brummit, Soc. Brot. Bol. Ser. 2, 271. 1968; Singh, Fl. Eastern Karnataka 1, 258. 1988. *Galega pentaphylla* Roxb., Fl. Ind. 3: 384. 1832. Annual or short-lived perennial, up to 80 cm tall. Young stems densely covered with silvery-grey or rarely brown, appressed or ascending hairs. Leaf-rhachis, including a petiole up to 1.2 cm long, petiole 1-4 mm long. Leaflets 37, usually 5, strongly oblanceolate, up to 22(45) x 7(11) mm, cuneate at base, broadly rounded to slightly emarginated at the apex; glabrous above, silvery-grey hairs beneath. Stipules 37 x 0.20.4 mm, subulate Flowers mauve colour, sometime reddish, 13 together in cluster in the leaf-axils, pedicels 37 mm long. Calyx 3.55.5 mm long, covered with grey appressed hairs; calyx lobes 34 mm long, triangular-acuminate; teeth usually approximately equalling the tube. Standard fulvous-silvery, c. 6 mm long. Staminal tube joined above. Ovary pubescent; Style glabrous, not twisted, c. 2 mm long. Pod 44.5 x 0.4 cm, pubescent, somewhat up curved towards the tip, brownish on the sutures. Seeds 78, 34 x 22.5 mm, oblongoid, the hilum and very small aril towards one end of one of the longer sides.

Flowering: August-September; *Fruiting:* August-September. *Ecology:* It is growing in core zone of forest between 300-400m altitudes.

Specimen examined: Rajasthan: TodgarhRaoli Wildlife Sanctuary, Jhamuda (Raoli Range, Ajmer district) 25°43.633' N; 73°54.747' E, 31.08.2018, C.S. Purohit 33511 (BSJO).

Distribution: India: Karnataka and Rajasthan (Present study). Arabia, Ethiopia, Iran, Kenya, Somalia, Sudan, Tanzania, Uganda.

Note: Parmar (2006) reported *Tephrosia pentaphylla* from Narayan Sarovar, Kutch, Gujarat on the basis of V. Singh 15871 collection on 26 Sept. 2000 and deposited at BSJO, Jodhpur. But after critical study of this herbarium, it is *Tephrosia purpurea*, on the basis of fruit not recurved upper side, fruits turns reddish after maturity, leaf apex truncate, flower red in colour. So, it is excluded from Gujarat state, India.

This plant is recollected after 126 years and also its range extension from Karnataka to Rajasthan. Though about 95 individuals have been estimated from the new locality the population is under threat as the population is very less and anthropogenic & grazing pressure on the locality.

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