



Nutritional and medicinal value of some important arid zone fruits of Rajasthan

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Abstract

Arid fruits are the special gifts of nature to the human being grown in the arid climatic conditions. Arid fruits have very good nutritional values and survive in very adverse climatic condition. Protein, fat, fibers, vitamins, mineral *etc.* are found in greater amount in arid fruits as compared to tropical and sub-tropical fruits. Still very less studies has been conducted on arid fruit especially nutritional aspects. Various fruit plants found in Rajasthan having high medicinal properties. Underutilized fruits provide food, nutrition and health promoting substances to native communities and are an additional source of income. To achieve nutrition and income security for the people, particularly in arid region, suitable species are of vital importance. Arid fruits *viz.* aonla (*Emblica officinalis*), bael (*Aegle marmelos*), jamun (*Syzygium cumini*), pomegranate (*Punica granatum*), custard apple (*Annona squamosa*), karonda (*Carrisa carandus*), phalsa (*Grewia subinequalis*), lahsua/lasora (*Cordia myxa*), *etc.* possess high nutritional values. Hence, research and development work, farmers awareness and feasibility for cultivation of these less known fruits are to be given due consideration. The objective of this review article is to concisely summarize the information about the important and underutilized arid fruits of Rajasthan with reference to their nutritional values and medicinal uses.

Key words: Arid zone fruits, medicinal properties, nutritional value, underutilized fruits

Introduction

Arid zone of India covers about 12% of the country's geographical area and occupies over 31.70 m ha of hot desert. This region is characterized by low and erratic precipitation (100-450 mm), high evapotranspiration (1500-2000 mm), and poor soil physical and fertility conditions. These conditions limit the scope of crop production but favour the arid fruit production. However, most of the arid fruits are underutilized. These underutilized fruits have great nutritional and medicinal properties. These day's consumers are becoming health and nutrition conscious, thereby developing tendency to avoid chemicals and synthetic foods and choosing natural foods. Thus, the underutilized fruits have high potential for their therapeutic, medicinal and nutritive values. Some of the underutilized fruits are rich sources of vitamin C, proteins and vitamin A. However, the potential of most of the arid fruits are not be exploited due to narrow genetic pool, limited knowledge sharing on their uses, limited income generation, improper marketing and demand limitation. The unavailability of standard varieties/planting material and lack of technical knowledge further limited the production potential of arid fruits. Thus, the use of underutilized fruits has a vital role in imparting nutritional security to society. Research on nutritional and medicinal aspects of arid fruits is scattered and therefore, the objective of this review is to summarize information on underutilized arid fruits of

Rajasthan with reference to their nutritional values and medicinal uses.

1. Date palm (*Phoenix dactylifera*)

Date palm is a monocotyledonous and dioecious species belonging to Arecaceae (Palmaceae) family. It is an important crop of arid and semi-arid regions of the world. It is one of oldest cultivated plants and has more than 6000 year's history. In India, date palm plantation mostly exist in the western part such as Kachchh region of Gujarat state (Johnson *et al.*, 2013), Rajasthan (Jaisalmer, Barmer, Bikaner, Jodhpur and some parts of Churu, Sri Ganganagar, Hanumangarh, Nagaur *etc.*), Haryana and some parts of Tamil Nadu. Date palm requires high temperature (25-40°C), fertile deep (at least 2 meter) sandy loam soil with good water holding capacity. It plays an important role in the economic as well as social life of the people of arid region. Fruits are eaten as fresh fruits (hard ripe stage), dry dates (Chhuhara) and soft dates (pind khajoor) and also used in different processed products like sugar, starch, vinegar, juice, toffees, wine, chutney, jam, pickles *etc.* (Choudhary *et al.*, 2018). Date fruits are highly nutritious and contain high calorific value (3150 calories/kg of fresh fruits), 60-65% sugar, fair amount of fibre (2.5%), protein (2%), less than 2 per cent fat, minerals up to 2 per cent like iron, potassium, calcium, copper, magnesium, chloride, sulphur and phosphorus *etc.* (Gopalan *et al.*, 1985).

Internationally, there is an increasing demand for excellent quality dates (Awad, 2007). Fruit weight and size are also critical quality parameters that affect dates marketing (Al-Qurashi and Awad, 2011). Now a day, researchers more emphasize to increase the size of fruit, yield and fruit quality of date palm under hot arid conditions of western Rajasthan.

Nutritional value

Date fruit is also a good source of fiber. Date fruits contain 52-88 % carbohydrates (including 13.6-36.8 g fructose, 17.6-41.4 g glucose and 0.05-3.4 g sucrose per 100 g), 3.5-10.9 % total fibres, 0.1-1.4% fat, 1.1-2.6 % protein, 0.4-2.0 % minerals and 0.002-0.02 % vitamins (Baliga *et al.*, 2011). Date fruit is considered as a good source of dietary fiber such as cellulose, hemicellulose, lignin and pectin *etc.* (Biglari, 2009). Many minerals such as boron, calcium, cobalt, copper, fluorine, iron, magnesium, manganese, potassium, phosphorous, sodium and zinc *etc.* are also found in date fruit (Khan *et al.*, 2008; Hasnaoui *et al.*, 2011). The potassium content in date palm is very high and can reach up to 0.9%. Date fruit has reasonable amounts of vitamins including vitamin A, B₁, B₃, niacin (nicotinic acid), C and folic acid (Biglari, 2009). The carbohydrates content, fibre content and mineral concentration in date fruit is influenced by soil fertility, cultivar and ripening stages of date palm. Date seed oil is also used for edible purpose and has nutritional value (Abdul Afiq *et al.*, 2013).

Medicinal value

Date fruit is traditionally used to protect gastric mucosa from the damaging effects of the gastric acid. It is very important for human health to control excess generation of free radicals generated from inflammatory leukocytes. Date fruits are considered as an appropriate substrate for manufacturing value-added products such as organic acids, exopolysaccharide, antibiotics, date flavored probiotic fermented dairy, bakery yeast *etc.* (Aleid, 2011). Recent studies have shown that date fruit and its aqueous extract have the free radical scavenging activity, anti-mutagenic and immune-modulatory activities (Allaith, 2008). The antioxidant activity of date fruit is attributed to the phytochemical compounds such as phenolic acids, flavonoids, anthocyanins *etc.* and mineral selenium. Selenium can contribute to the antioxidant effect because it may play an important role in activating many enzymes related to Reactive Oxygen Species (ROS)-detoxification (Steinbrønner and Sies, 2009). Saafi *et al.* (2011) reported date fruit extract could decrease the levels of the hepatic markers enzymes (transaminases, alkaline phosphatase, gammaglutamyl transferase and lactate dehydrogenase) and hepatic levels of malondialdehyde, and concomitantly increase the levels of antioxidant enzymes (Saafi *et al.*, 2011).

2. Ber/Indian jujube (*Zizyphus mauritiana* Lamk.)

Ber is also known as desert apple or Indian plum. Chinese jujube (*Zizyphus jujuba* Mill.) is grown in temperate regions while Indian jujube (*Zizyphus mauritiana* Lamk.) is cultivated in hot arid regions of India. It belongs to the family

Rhamnaceae. It is an ideal fruit tree for arid and semi-arid regions in tropical and subtropical climate where most of the fruit crops cannot be grown either due to adverse climatic or soil conditions. Fully ripened fruits are gathered in the beginning of the winter months, dried, ground and sieved. The fruits can also be used for making several products like chutney, dried ber, murabba, jelly, squash, jam, ber powder *etc.* Honey can be obtained from the flower nectar. It is also reported that the cotyledons are removed from the seeds, fried and eaten separately or mixed with bajra (Tiwari, 2016). Wines can also be prepared from the ber fruits.

Nutritional value

Ber fruits are rich in nutritive value. Vitamin C content is very high in Chinese jujube and fairly high in Indian jujube (Pareek, 2013). Besides, it also has vitamin A, B-complex, protein, calcium and phosphorus. In general, the fruit contains 81-83% moisture, 17.0% carbohydrates, 0.8% protein, 0.07% fats, 0.76-1.8% iron, 0.03% each of calcium and phosphorus, 0.02 mg/100g carotene and thiamine, 0.020-0.038 mg/100g riboflavin, 0.7-0.9 mg/100g niacin, 0.2-1.1mg/100g citric acid, 65-76 mg/100g ascorbic acid, about 22 g/100g sugar, about 1.3 g/100g fiber, about 0.2 g/100g fat with a calorific value of 104/100g (Mortan, 1987). Galactose, fructose and glucose are the major sugars found in ber fruit (Muchuweti *et al.*, 2005).

Medicinal value

Despite its high nutritional value and its biological properties, ber is considered among underutilized fruit. The decoction from root and bark is good for dysentery and diarrhoea and leaf decoction is useful for gargle in sore throat and in bleeding gums. The seed kernels are aphrodisiac. The powder of ber roots has medicinal properties for curing ulcer, fever and wounds. Polysaccharides extracted from plants and fungi have been identified for their anti-oxidative and hepatoprotective effect (Wang *et al.*, 2012) and also for their immune-biological, anti-viral, anti-tumor and other biological activities (Gonzalez *et al.*, 2011).

3. Aonla (*Emblica officinalis* Gaertn.)

Aonla is a deciduous fruiting plant of family Euphorbiaceae cultivated in India since Vedic Era. The tree is hardy, prolific bearer and a suitable choice for arid regions (Mitra, 1999). The fruit is highly nutritious and is a rich source of pectin and polyphenols apart from ascorbic acid. Aonla fruits are sour and tangy and popularly used to prepare juices, jams and pie-fillings for centuries. It is an important ingredient in the chyavanprash, and a constituent of triphala powder (Boora and Bons, 2015). These days, aonla fruits are becoming popular to prepare food products like preserve, candy, jam, toffee, pickle, sauce, squash, juice, RTS beverage, cider, shreds, dried powder, laddoo *etc.* (Bhattacharjee *et al.*, 2011; Pandita *et al.*, 2017).

Nutritional value

Aonla is a rich source of ascorbic acid and due to high vitamin C content of fruit makes its wide use in Ayurvedic medicine. It has also a good source of nutrients like calcium,

phosphorus and iron as well as proteins and vitamins such as thiamine, riboflavin, niacin *etc.* (Boora and Bons, 2015). The calorific value of aonla is 59 cal with 0.03 mg vitamin B, 0.2 mg nicotinic acid and 700 mg vitamin C per 100 g of fruit. The vitamin C content found in aonla is easily assimilated by the human body and has been found to have great antioxidant properties (Reddy, 2016) It also contains proteins and minerals like calcium, phosphorus and iron.

Medicinal value

The nutritional values of aonla are numerous and is recommended to be included as part of the daily diet. The fruit is the richest source of vitamin C and has diuretic, aperients and laxative properties. It is used for treating ailments like common cold, gastric troubles, chronic diarrhea, dysentery, headache, constipation, enlarged liver, diabetics, bronchitis, jaundice and fever *etc.* (Chadha, 2003; Agarwal and Chopra, 2004). It also cures insomnia, constipation, as well as used as a cooling agent to reduce the effects of sun strokes. It is also useful for haemorrhage, leucorrhoea and discharge of blood from uterus (Hasan *et al.*, 2010). As an anti-oxidant, it prevents premature ageing. Aonla stimulate the isolated group of cells that secrete the hormone insulin, which reduces blood sugar in diabetic patient (Iyer *et al.*, 2009). Aonla is also used in many hair tonics as it enriches the growth and hair pigmentation. It also strengthens roots of hair, maintains colour and shine. It is the main ingredient used in the shampoo and hair dye.

4. Bael (*Aegle marmelos* L.)

Bael is an important indigenous fruit of India and belongs to Rutaceae family. It is a useful medicinal fruit known to Indian population since time immemorial and has also religious value in Hindu dharma for Shiva's devotees (Boora and Bons, 2015). It is native to India and found throughout south-east Asia. In India this fruit is grown in Indo-Gangetic plains and sub-Himalayan tracts up to the height of 500 m, north-east India and dry and deciduous forests of central and southern India. Fruit contain soft yellow or orange coloured mucilaginous pulp with numerous seed. The seeds are densely covered with fibrous hairs and embedded in a thick, gluey aromatic pulp (Kaushik *et al.*, 2002). Gehlot and Dhawan (2005) reported about all parts of the trees *viz.*, root, bark, leaves, flowers or fruits are used for curing one or other human ailments. Bael is used in the preparation of chutneys and for making jelly and jam (Srivastava *et al.*, 2014).

Nutritional value

Fruit of bael are very nutritious and contains 61.5 g of water, 31.8 g of carbohydrates, 1.8 g of protein, 3 mg of fat, 1.7 g of minerals, 2.9 g of fibre and 1.19 mg of riboflavin/100 g edible portion. No other fruit has as high content of riboflavin as bael fruit (Singh *et al.*, 2009). It also contains vitamins and minerals including calcium, phosphorus, iron, carotene, thiamine, riboflavin, niacin and vitamin C (Hasan *et al.*, 2010). Various phyto-constituents have been isolated from different parts of bael plant, namely alkaloids, coumarin and steroid (Meity *et al.*, 2009). The fatty acid composition of the oil is palmitic 16.6; stearic 8.8%; Oleic 30.5%; linoleic 36.0% and linolenic 8.1%.

Medicinal value

Bael is useful in curing dyspepsia, dysentery, diarrhea, vitiated condition of vata, vomiting, cardio palmus, stomach algia, intermittent fever, seminal weakness, swelling, uropathy and gastric irritability in infants. Bael is much used in India as a liver and cardiac tonic and when unripe as a mean of halting diarrhea and dysentery as well as for effective treatment for hiccough, sore throat and diseases of the gums. The medicinal value of bael fruit is enhanced due to presence of tannin, the evaporating substance in its rind. The rind contains 20% tannin while its pulp has only 9% of tannin. The fruit is aromatic, cooling and laxative. It arrests secretion or bleeding. It is also useful in preventing scurvy and strengthens the stomach and promotes its actions (Joshi, 2004). The unripe fruit is good for digestion and is perhaps the most effective remedy for chronic diarrhoea and dysentery where there is no fever (Bakhru, 1997). The ripe fruit of bael contains marmelosin (C₁₃H₁₂O₃) which has cardioprotective, antihelminthic, antibacterial and antiulcer properties. Oxidative stress induced hyperglycemia or diabetes can be reduced to a great extent by extracts of scopoletin (7-hydroxy-6-methoxy coumarin) (Panda & Kar, 2006). Bael is rich in laxatives which makes it useful in controlling the blood sugar levels. This is because it energizes the pancreas and makes it produce enough amount of insulin necessary to control sugar level in the blood.

5. Jamun (*Syzygium cumini* L.)

Jamun is an important indigenous fruit of commercial value in the country. It belongs to the family Myrtaceae. The tree is ideally suited for wind break and roadside plantations. Its fruits are highly perishable in nature and have short life; it deteriorates at a very faster rate if proper post harvest handling practices and processing techniques are not adopted. The storage life of jamun fruits restricted to only 24 hrs at room temperature and 12 days at cool temperature *i.e.* 3 to 4°C (Ramanjaneya, 1985). Apart from eating fresh, it can also be used for making delicious beverages, juice, jam, squash, wine, vinegar and pickles. Seed contain an alkaloid jambosin and a glycoside, jambolin or antimallin, which reduces or stop diastatic conversion of starch into sugars. The anthocyanin content in jamun fruits which attributes to its antioxidant activity is also a good source of natural food colourants for the food processing industries (Namasivayam *et al.*, 2008). The fruits and leaves extract of jamun showed good efficacy to control nematode infestation in plants.

Nutritional value

Jamun is an underutilized fruit crop, gaining popularity among the consumers due to its high neutro-clinical values in rural as well as in urban masses. In addition, the ripe berries are good source of anthocyanins, vitamins, minerals, iron and pectin with fair amount of ascorbic acid. Fruit juice and preserve also hold an important position due to their richness in essential minerals, vitamins and other nutritive constituents (Bukya and Madane, 2018). The freshly picked fruits per 100 g of edible portion contains moisture 85.8 g, ether extract 0.15 g, crude fiber- 0.3 g, nitrogen 0.129 g, ash 0.32 g, calcium 8.3 mg, phosphorus 16.2 mg, iron 1.62 mg,

carotene 0.004 mg, thiamine 0.008 mg, riboflavin 0.009 mg, niacin 0.290 mg and total ascorbic acid 5.7 mg (Munsell *et al.*, 1949). Some other reported constituents of the fruit are specific gravity 1.0184, total acidity (as acetic acid) 5.33 per 100 cc; total solids 4.12 per 100 cc, ash 0.42, alkalinity of ash 32.5 (N/10 alkali), nitrogen 0.66131, total sugar 0.995, reducing sugars 0.995, non volatile reducing sugars 0.995, alcohol 0.159% by weight, oxidation value (KMnO₄, 186.4), iodine value 183.7 and ester value 40.42.

Medicinal value

Traditionally the jamun fruits, leaves, seeds as well as bark are used in ayurvedic medicine. The bark contains tannins and carbohydrates, accounting for its long-term use as an astringent to combat ailments like dysentery (Giri *et al.*, 1985). Jamun fruit reduces the sugar in the blood and is very good in the control of diabetes. All parts of the jamun can be used medicinally and it has a long tradition in alternative medicine. The plant has been viewed as an anti-diabetic plant since it became commercially available several decades ago. The fruits have been used for a wide variety of ailments, including cough, diabetes, dysentery, inflammation and ringworm (Quisumbing, 1951). Water diluted juice is used as a gargle for sore throat and as a lotion for ringworm of the scalp (Gordon and Jungfer, 2011; Shrikant *et al.*, 2012). In India the juice of the ripe fruit or a decoction of the fruit or jamun vinegar is used in cases of enlargement of the spleen, chronic diarrhea and urine retention. With regard to the antineoplastic activities studies suggest that jamun is selective in its action in breast cancer cells. Jamun reduces the tumor incidence, tumor burden and cumulative number of gastric carcinomas. Reports also suggest that ellagic acid, gallic acid, and anthocyanins present in jamun are reported to prevent experimental carcinogenesis in various organs and may have contributed to the anti-carcinogenesis (Shrikant *et al.*, 2012).

6. Pomegranate (*Punica granatum L.*)

Pomegranate xerophytic characteristics and hardy nature makes it suitable for dry, rainfed, pasture and undulating land, where other fruit crops cannot grow successfully. Commercial plantations of pomegranate exist in Maharashtra, Gujarat, Rajasthan, Madhya Pradesh, Andhra Pradesh and Karnataka owing to its preference for arid climate. Besides, being a favourite table fruit it is also used for preparation of juice and squash. Dried seeds give an important condiment coined as *Anardana*. It also has medicinal value and rind is being used for dyeing cloths. It helps in preventing the harmful effects of radioactive substances by producing biologically active substances (Bhowmik *et al.*, 2013). Pomegranate is a poly-vitamin, a unique fruit plant producing a wide spectrum of biologically active substances especially important in our present-day polluted environment.

Nutritional value

The fruit is moderate in calories, holds about 83 calories per 100 g; slightly more than that of the apples. It contains potassium, carbohydrates, protein, fat, fibre and other

vitamins and minerals. It contains no cholesterol or saturated fats. Food value, minerals and vitamins per 100 g of edible portion of pomegranate is moisture-78.0%, carbohydrates-14.5%, calcium 10 mg, protein 1.6%, phosphorus 70 mg, fat-0.1%, iron 0.3 mg, minerals 0.7%, vitamin C 16 mg, small amount of vitamin B complex and fibre 5.1%. Further, it is also good source of many vital B complex groups of vitamins such as pantothenic acid (vitamin B-5), folates, pyridoxine and vitamin-K, and minerals like copper, potassium, and manganese (Jochle, 1971). It also contains phenolic compounds like gallic acid, protocatechuic acid, chlorogenic acid, caffeic acid, ferulic acid, o- and p- coumaric acids, catechin, phloridzin and quercetin (Bhowmik *et al.*, 2013).

Medicinal value

Pomegranate is natural blood thinners. It prevents blood clots in the heart and arteries also. Dietary fibre helps in smooth digestion and bowel movements. Certain ellagitannin compounds such as granatin B, and punicalagin are found abundantly in the pomegranate juice. Consumption of fruits rich in vitamin-C helps the body to develop resistance against infectious agents by boosting immunity. The seeds prevent blood platelets from coagulating and forming clots. Studies suggest that punicalagin and tannins can be effective in reducing heart-disease risk factors by scavenging harmful free radicals from the human body. The rind of the fruit and the bark of the pomegranate tree are used as a traditional remedy against diarrhea, dysentery and intestinal parasites. Drinking pomegranate juice has been shown to have antimicrobial properties against harmful bacteria that can exist in the stomach, such as *Escherichia coli* (*E. coli*) or *Bacillus subtilis*, both of which can cause painful infections and serious stomach conditions. Pomegranate juices is remarkably rich in antioxidants *viz.*, poly phenols, tannins and anthocyanins, thereby acting as scavengers and prevent DNA damage. The seeds and juice are considered a tonic for the heart, throat, eyes and for a variety of purposes, such as stopping nose bleeds and gum bleeds, toning skin, firming-up sagging breasts and treating haemorrhoids. Pomegranate hull and/or root extract are used both orally and intra-vaginally in preventing fertility (Razzak, 1980; Goh *et al.*, 1984), abortion and to ameliorate assorted gynaecological problems (Chaudhary and Mukkopadhyay, 2012).

7. Karonda (*Carrisa carandus L.*)

Karonda is a native plant of India belonging to family Apocynaceae and popularly known as Christ's thorn. In India, it is grown on a limited scale in Rajasthan, Gujarat, Bihar, West Bengal and Uttar Pradesh. Fruits are sour and astringent in taste. It is rich in vitamin C content and good source of iron apart from the usual contents of minerals, protein, sugar *etc.* Some of its species have economic importance and well known as a protective hedge plant yielding berry like fruits, which are edible, attractive in colour and also used as ornamental plant (Misra, 2009). Karonda is an indigenous protective fruit held in high esteem in Indian dietary. Therefore, it is also used in making jelly, jam, squash, syrup,

tarts and chutney which are of great demand in international market (Wani *et al.*, 2013). It is also used for making pickles, coloured wine and candy. Ripe fruits are eaten as raw and use for making jelly of excellent quality, which resemble to gooseberry in flavour.

Nutritional value

It is one of the richest source of iron and contains a fair amount of vitamin C and, therefore, very useful for curing of anaemia and has anti-ascorbic properties. Usually, the dry fruits contain 264 calories, 2.3 per cent protein, 2.8 per cent minerals, 9.6 per cent fats, 67.1 per cent carbohydrates and 3.9 per cent iron. Karonda fruit is rich in iron and contains a fair amount of vitamin C besides being a good appetizer (Boora and Bons, 2015). Ripe karonda fruits contain high amount of pectin.

Medicinal value

It is a popular Indian medicinal plant. It is widely used for medicinal purpose by tribals throughout India and popular in various indigenous system of medicine like Unani, Ayurveda and Homoeopathy (Wani *et al.*, 2013). Enthomediically, fruits are used as astringent, antiascorbutic and as a remedy for biliousness (Jadhav *et al.*, 2004). Traditionally the plant has been used in the treatment of scabies, intestinal worms, diarrhoea, intermittent fever and reputed for its aphrodisiac, antipyretic, appetizer, antiscorbutic, anthelmintic, and astringent and useful for cure of anaemia. Fruits are useful in treatment against anorexia and insanity. The ripe fruit is cooling and acidic; used to treat sore throat, mouth ulcer and skin disorders (Sheela *et al.*, 2015 & Jayakumar *et al.*, 2015). The fruits have antimicrobial and anti-fungal properties and its juice is used to wounds healing properties. The fruit have an analgesic action as well as an anti-inflammatory property. The traditional medicinal value of karonda fruit is used to improve female libido and to remove worms from the intestinal tract. The juice can be applied to the skin to relieve the skin problems.

8. Custard apple (*Annona squamosa* L.)

Custard apple is also known as sharifa, sitaphal and sugar apple. It is one of the most delicious arid regions fruit plant and belongs to Annonaceae family. The fruit has pleasant texture and flavour. The fruit is sweet with slight acidity and delicious hence is used for table purpose. It is a subtropical small deciduous spreading tree of height 5-9 feet, with large green dropping leaves and light yellow trumpet shaped flowers, emitting pungent sweet smell during late afternoon. It starts bearing at the age of 4 to 6 years and the bearing declines after 12 to 15 years. Custard apple prefers dry climate and can withstand mild frost. The root system is confined to relatively shallow layers and therefore, these do not require deep soils. The trees withstand high amounts of lime found in calcareous soils. The fruit has the tendency to burst open if kept on the tree for a long time. To increase nutritional value and accelerate its value addition, several products have been prepared *viz.*, ice cream, carbonated beverages smoothies, cheese cakes *etc.* Often it is pressed through sieve and added to milk shakes,

custards or ice-creams. Custard apple can be made into shakes or smoothies or even into natural ice creams (Vishnupriya and Dhandapani, 2015). A delicious sauce for cake and puddings can be made by blending the seeded flesh with mashed banana and a little cream (Singh *et al.*, 2009). The fruit pulp has numerous medicinal properties which include antioxidant, anti-diabetic, anti-infective and anti dyslipidemic properties.

Nutritive value

Custard apples are usually consumed as dessert fruit. It has high calorific value, able to provide sustained energy and delicious in nature. Custard apple is full of antioxidants, which helps to combat many diseases and also enhances the immune system. It is an abundant source of dietary fibre, vitamin C, vitamin A, potassium, magnesium, calcium, iron, vitamin B6, copper and low fat levels (Geng *et al.*, 2005). The ripe custard apple fruit contains about 104 kcal per 100g of pulp, 70 % moisture, 14.5 % sugars, 3.1% of fibre, 1.6 % protein, 0.3 % fat, 1.0 % iron, calcium (0.02 %), phosphorus (0.04 %) and 0.7 % mineral matter (Nair and Agarwal, 2017). The main sugars are glucose and fructose (80-90%). Potassium removes the lethargies and helps to fight muscle weakness. The vitamin A keeps skin and hair healthy, very important for the eyes, and cures indigestion. As the fruit is high in magnesium, it maintains the water balance in our body, which helps in removing acids from the joints and reduces the symptoms of rheumatism and arthritis (Hundal and Khurana, 1993). Custard apple contains natural sugar, and hence makes a great nutritious snack and can even be added to desserts especially for children.

Medicinal value

The various chemical constituents isolated from leaves, stems, and roots of the custard apple plant include anonaine, aporphine, coryline, isocorydine, norcorydine, and glaucine (Anonymous, 2013). One class of chemicals which sets custard apple apart from other fruit species is the presence of acetogenins, which are very long chain fatty acids and only found in Annonaceous species (Johns and Clarke, 1943). Custard apple is used for treatment of malaria. Three known aporphine alkaloids were isolated from the bark. Structures of compounds were identified as N-Nitrosoxylophine, Roemerolidine and Duguevalline. The *in vitro* and *in vivo* studies revealed its anti-cancer properties and anti-hypertensive properties, which are mainly due to presence of acetogenins. The fruit has antioxidant activity making it suitable even for diabetic patients (Dickson, 1975). Despite its high sugar content the glycemic index of custard apple is low (54). Fruits have anti-microbial activities due to presence of compounds like ent-kauranes, acetogenins, essential oils and Benzylisoquinolines alkaloids (Kitagawa *et al.*, 1994). Two acetogenins, annoreticuin and isoannoreticuin isolated from the leaves, were found to be selectively cytotoxic to certain human tumours. It also possesses anti HIV properties. Among the 14 isolated compounds in a study, 16, 17-dihydroxy-entkauran-19-oicacid showed significant activity against HIV replication in H9 lymphocyte cells with an EC₅₀ value of 0.8 µg/MI (Kumar *et al.*, 2007).

9. Phalsa (*Grewia subinequalis* L.)

Phalsa belongs to Tiliaceae family and native to India. Fruits of phalsa are acidic and are good source of vitamin A and various other nutrients. Generally, its fruits are consumed fresh (Boora and Bons, 2015). Being highly perishable, the fruit must be utilized within 24 hours after picking. The popularity of phalsa fruit is due to its attractive colour ranging from crimson red to dark purple and its pleasing taste. The juice when extracted gives a deep crimson red to dark purple colour and is very popular. In addition, fruits are used for making excellent juice, squash, syrup and crush having cooling effect on the body (Boora and Bons, 2015; Pangotra *et al.*, 2018). Fruits contain 50-60 per cent juice and edible part of the fruits varies from 69-93 per cent. The juice is extremely refreshing and is considered to have a cooling effect especially in hot summer. The fruit is astringent and stomachic. It has been reported that when unripe, phalsa fruit alleviates inflammation and is administered respiratory, cardiac and blood disorders, as well as in fever reduction (Singh *et al.*, 2009).

Nutritional value

Fruits are low in calories and fat, and high in vitamins, minerals, fiber, antioxidants total phenolics, flavonoids, tannins and anthocyanins (Asghar *et al.*, 2008). The 100 g of phalsa fruit contains carbohydrate (21.1 g), fibre (5.53 g), protein (1.57 g), fat (<0.1 g), calcium (136 mg), iron (1.08 mg), phosphorus (24.2 mg), potassium (372 mg), sodium (17.3 mg), vitamin A (16.11 mg), vitamin B₁ (0.02 mg), vitamin B₂ (0.264 mg), vitamin B₃ (0.825 mg) and vitamin C (4.385 mg) (Yadav, 1999). Essential amino acids such as threonine and methionine are present in pulp and seeds, respectively, whereas phosphoserine, serine and taurine are the dominant amino acids in juice. The pulp contains higher concentrations of phosphoserine as compared to other free amino acids, while the hydrolyzed product contains aspartic acid, glycine, and tyrosine in large amount (Hasnain and Ali, 1988). Threonine has been found in pulp but was missing in seed extract, whereas methionine was present only in seeds, indicating that the presence of methionine in fruit juice would be the result of adulteration. Phosphoserine, serine, and taurine were the dominant amino acids in juice (Hasnain and Ali, 1992).

Medicinal value

Aqueous extracts of fruits showed significant anticancer activity against liver cancer and breast cancer. In traditional folklore medicine, the fruit has been used as astringent, stomachic and cooling agent. When unripe, it has been reported to alleviate inflammation and was administered in respiratory, cardiac and blood disorders, as well as in fever. Root and bark has been prescribed for rheumatism and its infusion is used as a demulcent. The leaves can be applied on skin eruptions. The plant has been reported to possess antioxidant, antidiabetic, antihyperglycaemic, radio-protective, antimicrobial, hepatoprotective, antifertility, antifungal, analgesic, antipyretic and antiviral activities (Sinha *et al.*, 2015). Medicinal values of phalsa are due to the

presence of different metabolites like saponins, coumarins and anthraquinone (Sharma and Patni, 2013). Phalsa is reputed to cure upset of stomachs, some skin and intestinal infections, cough, fever, diarrhoea, dysentery, jaundice, rheumatism and have mild antibiotic properties. The plant preparations are used for the treatment of bone fracture and for bone strengthening. Their root and fruits are well known household remedy for the treatment of osteoporosis, tissue and wound healing (Sharma and Patni, 2013). They have free radical scavenging activities which may be responsible for the therapeutic action against tissue damage (Kshirsagar and Upadhyay, 2009).

10. Lasora (*Cordia myxa* L.)

Lasora is locally known as gonda, lasora or lehsua and belongs to family Boraginaceae. It is widely distributed in arid zone, mostly cultivated. It is a perennial, medium sized deciduous tree a short bole and spreading dense crown. Fruits are harvested at tender green immature stage for vegetable and are also used in pickles. Ripe fruits are also consumed. The floral buds and flowers are cooked as vegetable. It bears small sized fruits in bunches, used in traditional vegetable and pickles. Immature green fruits are used as vegetable and pickles. Sometime fruits are dehydrated after blanching to use as vegetable during off season (Singh, 2001). Being a multipurpose plant, it has long been associated with health, nutrition and other diversified uses in curing certain human ailments (Chandra and Pareek, 1992).

Nutritional value

The most important nutrients present in plants are carbohydrates, oils, proteins, minerals, ascorbic acid, and the antioxidants phenols, such as chlorogenic acid and its polymers (Spiller, 2001). Its fruit contains protein (2%), carbohydrates (92%), fat (2%), fibre (2%), phosphorous (275 mg/100g), calcium (55 mg/100g), iron (6 mg/100g), zinc (2 mg/100g), manganese (2 mg/100g) and energy (394 Kcal/100g) (Chandra *et al.*, 1994). Fruits are considered as one of richest natural sources of antioxidants *i.e.* carotenoids, ascorbic acid, phenols *etc.* Fruits are important sources of minerals, fiber and vitamins, which provides essential nutrients for the human health (Mala, 2009).

Medicinal value

Numerous natural substances existing in lasora have demonstrated promising roles in treatment and management of various forms of cancer, diabetes, degenerative disorder, and ulcerative colitis. They have activities of antimicrobial and antifungal, analgesic, antibacterial and cytotoxic, anthelmintic, gastroprotective and antiulcer, anti-inflammatory, anti-implantation, and wound healing (Inas *et al.*, 2011; Prasad *et al.*, 2013). Fruits are used for the treatment of infections of urinary tract, diseases of the lung and spleen, and as an astringent, anthelmintic, diuretic, and demulcent agent (Farida *et al.*, 2001). Because of its mucilage content, the plant fruits have been used as expectorant and emollient in treatment of cough and some respiratory problems (Rechinger *et al.*, 1997).

Promotion of arid zone fruits

A great deal is known about the virtues of the underutilized fruits of Rajasthan, but unfortunately very few of these fruit crops have ended up in farmer's orchards. They can contribute to food security, health or energy needs of people. Promotion of their cultivation and conservation is hence essential. Being local crops and harvested from the wild or found in the home gardens, they are easily available and thereby provide food security to the people.

Conclusion

Arid zone fruits play an important role in the food and nutritional security and possess medicinal properties. These fruits are the future for horticulture of 21st century as this offer a variety of potential benefits in profitability, productivity, sustainability, crop quality, food safety, environmental protection and rural economic development. A large proportion of rural population depends on locally available fruits to meet their dietary requirements. These fruits are known for their typical flavour and taste. These fruit crops have their own history of consumption. Local people are well aware of their nutritional and medicinal properties. Consumers today are increasingly conscious of health and nutrition, and there is a tendency to avoid chemicals and synthetic foods, thereby choosing natural foods. In this context, arid fruits have unlimited potential in their processed form. Most of the indigenous fruits have only a few specified varieties. Therefore, their improvement and development of ideal propagation methods and agro-techniques should also be adopted. Appropriate process technology needs to be developed to popularise these fruits. The promotion for setting up of processing industries (jams, jellies, fermented products etc.) for manufacturing of resins, gums etc. and lifestyle (e.g. cosmetics) should also be encouraged. Most of them can be grown even in wastelands without much care. Therefore, it is worthwhile to look into the organized cultivation and improvement of under-utilized crops, so that their utilization can be maximized and variety of value added products can also be prepared from them as explained above. These neglected and underutilized crops are essential to the livelihoods of millions of poor farmers throughout the world.

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Effect of partial root zone drying in fruit crops

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Abstract

Partial root zone drying (PRZD) is an advancement over traditional irrigation system. It is the process of irrigating the surface area of the plant sequentially one side after another side. In agriculture where 83 per cent of the total available water is used, adoption of such kind of technique is sure to curtail the requirement of water which is getting scarce day by day. PRZD in fruit crops can reduce irrigation water requirement up to 50 per cent and increase WUE to the extent of 90 per cent. Its usefulness has been proven in grapes, orange, pomegranate and apple. Having gone through literature, it vividly appeared that PRZD technique is worth adoption in view of better WUE. It has all merit of higher yield and quality per unit water consumed. Thus, it is environment friendly too which is much concerned in current day agriculture/horticulture production.

Key words: Deficit irrigation, fruit quality, PRZD mechanism, regulated deficit irrigation, WU

Introduction

Water is a limiting resource in the fruit production. The major challenge is to produce more and more produce of higher quality with limited use of water to feed the increasing population of the country. The highest proportion of water is consumed by agricultural crops which is called as blue water footprint and it is assumed that the water scarcity will increase in future in view of changing climate (Mancosu *et al.*, 2015). So, the efficient use of water without affecting crop productivity and its quality by adopting water saving irrigation techniques is the foremost need.

Generally, full irrigation is provided by farmers in crop production. Now-a-days, the use of full irrigation can be reduced without affecting the crop yield (Kang and Zhang, 2004) by the use of water saving irrigation techniques. These techniques are of different types such as regulated deficit irrigation and partial root zone drying which reduces the amount of irrigation water as compared to the full water requirement of crops. The amount of deficit irrigation depends upon crop, soil type, climate *etc.* and it is accompanied by without yield losses or a minor yield loss with increasing water use efficiency of crop (Ahmadi *et al.*, 2010).

Availability of water

Ground water is an important component of water availability. It is a major source of drinking water and also irrigation water. Ground water supplies about 80% of water for domestic purpose and 50% for industrial purposes. The irrigated agriculture depends on ground water, it has a significant role in food security of India. The availability of fresh water is decreasing day by day due to frequent climate changes and drought conditions. In year 1951, the availability of water per capita was 5177 m³, but it is depleting

continuously and up to 2025 it will be only 1341 m³ per capita. The water level in wells has been deepened to 200 per cent. In year 2016, about 33 crores peoples of 9 states of the country gone through the water crises (Rajasthan Patrika, 10 July, 2018).

Water status of India

The average annual water generated mostly from rainfall and by snow melt in India is about 1869 billion cubic meters, whereas it is estimated that a little amount of this surface water (only 690 billion cubic meters) can actually be deployed. The reasons responsible for this are such as maximum flow of the Himalayas river takes place in a short duration and the storage reservoirs are also limited or not have that much potential to capture such resources. The average rainfall of India is 1170 mm. It varies from region to region such as in western desert region it is only 100 mm, whereas in Meghalaya in North-Eastern India it is about 11000 mm. Most of it falls in the June-September (rainy season), so it is necessary to create sufficient storage to collect maximum of this rainfall in rainy season. Ground water is the major source of irrigation water and an average 431 billion cubic meters water has been assessed rechargeable in India. About 30% of this ground water potential has been used for irrigation purpose and domestic use. In some states of India such as Punjab and Haryana have been exploited their 94% of ground water resources. Areas with depleting ground water table in India are Rajasthan, Gujarat, parts of western Uttar Pradesh and all Deccan states (Chatterjee, 2015). In India in year 2001, only 3% of tube-well owners used micro-irrigation or sprinkler irrigation and about 88% irrigated their crops through open channels by flooding irrigation method (according to India's third Minor Irrigation Census).

According to the Central Ground Water Board (CGWB), in India about 39% of the wells are showing a decline in groundwater level and out of 6,607 assessment units in about 1,071 units of 15 states and 2 union territories have been categorized under “over exploited” on the basis of the stage of groundwater withdrawal and long term decline in groundwater level (Dhawan, 2017).

Drought and drought prone regions in India

The period without effective rainfall, unavailability of proper soil water and in which atmospheric conditions also causes continuous loss of water through transpiration is called as drought stress. In India due to lack of monsoon rains water shortage is faced which results lower crop yield. The major drought prone regions in India are western Rajasthan, Southern and Eastern Maharashtra, Andhra Pradesh, Odisha (Eastern coast of India) and Telangana (South-eastern coast of India) (Fig. 1).

Some positive responses of plant by little drought stress

In the drought stress condition plant produces some

symptoms that make it adaptable to adverse condition. Drought stress in plants helps in efficient use of water and nutrients and alters physiology of plants. Stress results in poor growth but increases quality (TSS, sweetness) and shorten juvenile phase, make them adaptable to semi-arid and dry areas. Thus, a little water stress may helpful in plants. Water stresses trigger a wide variety of plant responses, ranging from altered gene expression and cellular metabolism to changes in plant growth, leaf morphology and movement and root development and finally productivity (Kumar *et al.*, 2019). Table 1 depicts the effect of water stress on plants at physiological, biochemical and molecular level, which are as follows:

Deficit irrigation techniques

Deficit irrigation techniques are the irrigation techniques which involves application of reduced amount of water to the crop as compared to the full irrigation. In these techniques the irrigation water is provided to the crop in a controlled manner at critical stages of crop growth and development such as at flowering stage, at fruit set stage, at

Water status of India

Particulars	Quantity
Geographical area	329 million ha.
Flood prone area	40 million ha.
Ultimate irrigation potential	140 million ha.
Total cultivable land area	184 million ha.
Net irrigated area	50 million ha
Natural runoff (surface water and ground water)	1869 Cubic km.
Estimated utilisable surface water potential	690 Cubic km.
Groundwater resource	432 Cubic km.
Available groundwater resource for irrigation	361 Cubic km.
Net utilisable groundwater resource for irrigation	325 Cubic km.

Source: Chatterjee, 2015.

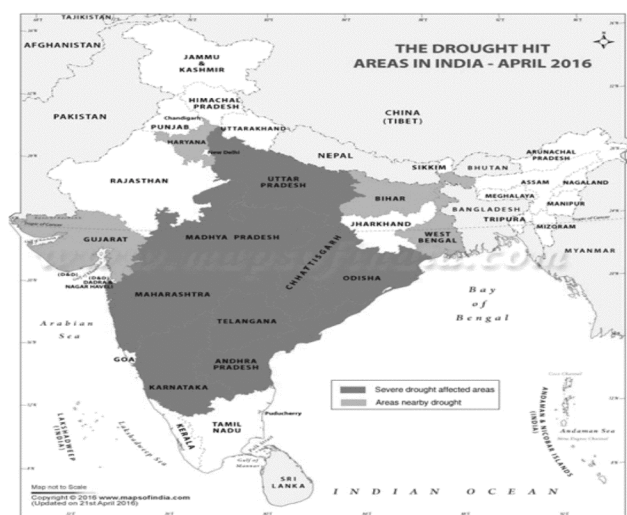


Fig. 1. Drought affected areas in India (Source: Dhawan, 2017)

Table 1. Responses of plant to drought condition

Drought stress		
Physiological responses	Biochemical responses	Molecular responses
Reorganization of root signals	Decrease in photochemical efficiency	Increased expression in ABA biosynthesis
Decrease in stomata conductance and reduced transpiration	Decrease in efficiency of Rubisco enzyme	Expression of ABA responsive genes
Decrease in photosynthesis rate	Accumulation of stress metabolites	Synthesis of specific proteins such as LEA, dehydrins <i>etc.</i>
Reduced growth rate	Increase in antioxidants	Drought stress tolerance

Sources: Sepaskhah and Ahmadi (2010)

fruit maturity *etc.* in different fruit crops. The techniques of deficit irrigation are as follows:

1. Regulated deficit irrigation (RDI) and
2. Partial root-zone drying (PRZD).

Regulated deficit irrigation (RDI)

The term was first coined as a term during 1970s at Tatura in Victoria, and it was applied in the 1980s in peaches and pears which are mainly grown for canning in high density orchards in the Goulburn Valley. In regulated deficit irrigation technique a water deficit is applied to the plants to maintain water status in a closely controlled way over a critical period, *i.e.* at flowering stage, after fruit set, at fruit ripening *etc.* in this technique the water application is manipulated over time (Fig. 2). The main objective of this irrigation technique is to control vegetative growth and development with the reproductive growth of plant with improved water use efficiency. In regulated deficit irrigation the frequency of re-wetting should be determined by the prediction of a decrease in plant water potential below a certain level. The frequency of re-wetting should be based on plant water potential but it can also be measured from soil moisture depletion or estimates of water used by plants based on evaporative conditions and on the basis of sap flow of plant.

Partial root zone drying (PRZD)

Partial root zone drying (PRZD) technique was introduced as a new irrigation strategy which can increase water use efficiency (WUE) and reduce vegetative growth without affecting the yield but improve quality in grapevines (Dry and Loveys, 1999). Partial root zone drying is a type of deficit irrigation technique in which irrigation is provided to the half root system of plant, while the other half is left dry. In

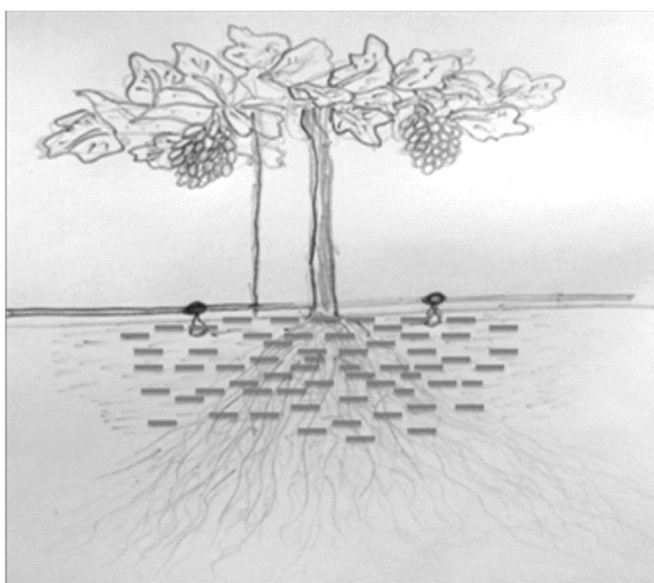


Fig. 2. Regulated deficit irrigation

this the wetted and dried sides of the root system of plant are alternated in different irrigation cycles. In this technique the shifting of irrigation is followed on the basis of soil, type of crop, stage of growing crop and soil water content. The main aim of this practice is to balance the vegetative and reproductive plant growth by improving the water use efficiency. In PRZD the alternate wetting and drying sides of root system is to done on a 10-14 days interval. Regulated deficit irrigation (RDI) and partial root zone drying (PRZD) are techniques jointly designed to increase the water use efficiency, improve quality of fruits and control the vegetative vigour of perennial plants such as grapevines and other fruit trees

RDI Versus PRZD

The basic differences in regulated deficit irrigation and partial root zone drying irrigation techniques are as follows in Table 2.

Types of partial root zone drying (PRZD)

Partial root zone drying is of two types:

1. Fixed partial root zone drying, in which the one half zone of root system is irrigated and another half is left for drying throughout the growing season.
2. Alternate partial root zone drying is another practice in which the irrigated and drying parts of root zone are changed. In alternate PRZD first irrigation is provided to half zone of root system and in next irrigation cycle the irrigation is shifted to the dry side of root system (Fig. 3.).

Mechanism involved in increase WUE through PRZD

The term water use efficiency (WUE) is a measure of plant's efficiency to produce maximally at the cost of per unit water.

Table 2. Physiological and molecular bases of drought stress tolerance

Regulated deficit irrigation (RDI)	Partial root zone drying (PRZD)
Deficit irrigation where only uppermost profile is re-wetted	Deficit irrigation where deeper wet/dry zones are spatially separated
Site is not responsive to irrigation	Site must be responsive to irrigation
RDI timing critical	PRD timing flexible
Can be used with furrow irrigation	Drip irrigation preferred, alternate row furrow possible
Potential for yield loss	No loss of yield
Lower root growth	Enhancement of root growth
Marginal water savings	Significant water savings
No irrigation hardware modification	Significant changes required.
Soil water monitoring recommended	High-level management skills required
Regulated deficit irrigation was originally developed on fine textured clay soils that provided a substantial reserve of plant available moisture.	Partial root zone drying technique can perform best in deep porous light sandy loam soil

Source: Shao *et al.*, (2008).

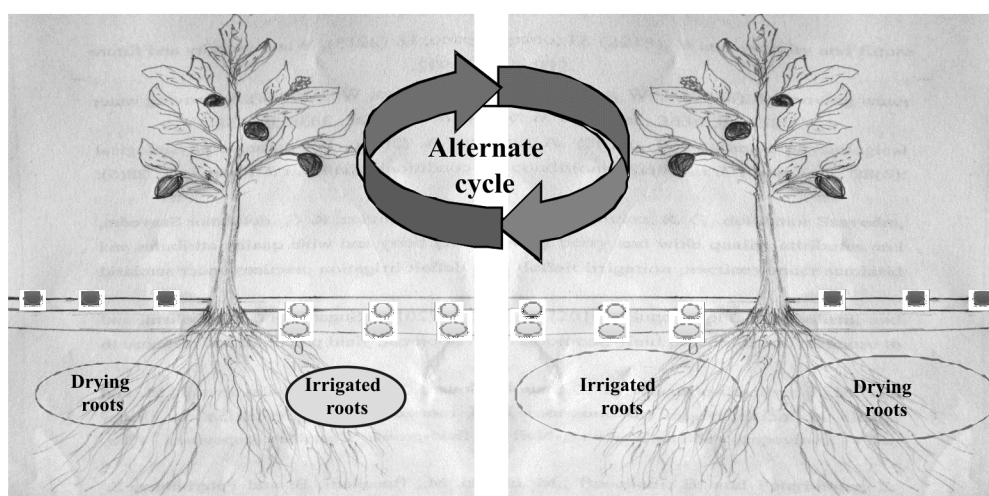


Fig. 3. Partial root zone drying

Basically, it is a ratio between two physiological processes; transpiration and photosynthesis (carbon assimilation). WUE is a complex character related to different physiological and biochemical processes which is involved in carbon-water uptake, in transpiration and controlled by many genes. In different environmental conditions, it is the challenge to balance between crop losses of water in transpiration and the higher efficiency of carbon uptake during photosynthesis, therefore the increase in WUE is not always associated with the increase in yield (Blum, 2009).

In partial root zone drying technique of irrigation, little water stress alter the physiology of plant by the production of ABA, closing the stomata and reducing the stomata conductance which affects the transpiration and increases the water use efficiency (Yan *et al.*, 2012). In the water stress condition given by partial root zone drying, ABA is produced in the dry side of roots and it transported to the leaves through the xylem sap. In the leaves ABA binds with some receptors which are present at the surface of the plasma membrane of the guard cells. These receptors activate many interconnecting pathways which raise the pH of cytosol, transfer the Ca^{2+} from vacuole to the cytosol. These stimulate the loss of NO_3^- , Cl^- and K^+ in the cell. The loss of these solutes in the cytosol reduces the osmotic pressure of the cell and the stomata is closed and finally the transpiration rate is reduced and losses of water is decreased which increase the water use efficiency of the crop.

Mechanism involved in quality improvement through PRZD

The plants in partial root zone drying are exposed to certain degree of water stress; there is the reaction towards the accumulation of stress metabolites. The chemical components which are mainly responsible for improved quality of fruits are primary and secondary metabolites produced during the stress condition in plants. In these sugars, lipids or minerals, proteins etc. are the primary metabolites and carotenoids, flavonoids,

phenols etc. are the secondary metabolites. The water stress condition in plants may influence the secondary metabolism through two interactive mechanisms, which are the change of primary metabolite transport (which is the major sources of carotenoids and ascorbic acid biosynthesis) or by the oxidative stress which could affect the antioxidant compound biosynthesis. In case of the grape, berries responds to drought by altering its physiology and stimulating the production of secondary metabolites such as monoterpenes, phenylpropanoids, zeaxanthin etc. which significantly influence grape berry composition, wine antioxidants and flavour also (Savoi *et al.*, 2016).

The improved colour of peel of apple fruit under partial root zone drying irrigation techniques was also noticed which may be due to the changes in canopy structure and increased WUE and nutrient efficiency. The accumulation of better total soluble solids (TSS) in the fruits may be due to metabolic changes or by the translocation of assimilate from the leaves to fruits (Francaviglia *et al.*, 2013). The increased sugar level of fruits in partial root zone drying irrigation treatments is due to the accumulation of higher amount of ABA in the fruits which stimulates the activity of different enzymes such as enzyme invertase which increases the concentration of sugars hexose in the fruits (Ruan *et al.*, 2010). The change in ABA content under PRD improves the quality of grape berries by increasing anthocyanin content which is induced by the genes responsible for anthocyanin biosynthesis (Jeong *et al.*, 2004). In PRD, the reduced vegetative growth increases the light penetration into the canopy with increased level of ABA and salicylic acid in berries at harvest, which might have effect on production of phenolic compounds. The increased activity of certain antioxidative enzymes like catalase, superoxide dismutase and guaiacol peroxidase in PRD plants (Lei *et al.*, 2009) indicates that certain degree of drought induces oxidative stress under condition of PRZD.

Present status of PRD in fruit crops

Nowadays partial root zone drying technique has been

successfully applied to many horticultural as well as agricultural crops. This technique can save water up to 50% without much affecting the crop yield, increases crop water use efficiency as compared to full irrigation and also improves the quality of different fruits. Effect of partial root zone drying in different fruit crops is as follows:

Grape

In grape, there is increasing global demand of high quality produce such as raisins, wine etc. So, it is the challenge for grape growers to produce higher quality produce without yield loss. It maintains the appropriate balance between vegetative and reproductive growth of grapevine. A little water stress can reduce the vegetative growth and improve the quality of berries, because the vegetative growth of vine is more sensitive to water stress condition than the fruit growth. In case of wine grape cultivars it is important to control the berry size. Some grape growing countries are also facing the problem of water scarcity or drought condition. In such situations the application of irrigation water through partial root zone drying (PRZD) technique is the better option which increases water use efficiency and improves the quality of produce without affecting the yield of crop. The technique of PRZD can reduce 50% amount of irrigation water without any significant yield loss. The water use efficiency in partial root zone drying can be doubled as comparison to full irrigation to the crop (Santos *et al.*, 2005). It improves the quality of berries in the terms of higher concentration of anthocynins, total soluble solids and total phenol content

Citrus

Citrus is an evergreen plant of tropical and sub-tropical regions which requires sufficient amount of water all round the year. In the condition of water stress, it can trigger some physiological responses in the plant that allows the plant to survive with reduced water availability (Hutton *et al.*, 2007) without affecting its productivity. Irrigation through partial root zone drying techniques can be effective to the crop which increases the water use efficiency. Consoli *et al.* (2016) reported that the partial root zone drying with 50% of crop demand (crop evapo-transpiration) can increase 10-20% of crop yield as compared to the full irrigation treatment. The application of deficit irrigation by PRD with 60% of crop evapo-transpiration in citrus cv. Navel orange can save 25 to 40% of water and it increases the yield significantly (Lovatt and Faber, 2007).

Pomegranate

Pomegranate (*Punica granatum* L.) is one of the oldest known edible fruits, cultivated extensively in arid and semi-arid regions of the world. There is a major problem in pomegranate of fruit cracking which takes place due to moisture stress and after exposure of fruit to intense sunlight occurrence of sudden rainfall. Noitsakis *et al.* (2016) studied that the irrigation treatment of partial root drying (PRD₁) with 100% irrigation water of the demand of plant which was given to the half of the root system of each plant and another half

zone of root system was exposed to soil drying. They found minimum fruit cracking of fruits were noticed in the treatment of PRD₁ with other parameters of yield and quality such as maximum fruit weight, fruit diameter, aril weight, juice percentage, TSS, and minimum titratable acid as compared to control irrigation treatment.

Apple

The apple growing areas is the temperate zones of India and other countries are situated at the high altitude which helps to meet the sufficient chilling hours during winter season (extending from Dec. to March). In such condition the measure problem is application of irrigation water, to maintain its yield and quality which can be overcome by applying partial root zone drying technique (PRZD) which can save up to 50% of irrigation water. Durovic *et al.* (2015) found that partial root zone drying technique has a positive effect on fruit firmness and weight loss during storage. It was also effective after 6 months of cold storage. The maximum flesh firmness was found in fruits from partial root zone drying treatment. PRD showed good effect on the fruit size and yield, compared with controlled irrigation and deficit irrigation treatment. The irrigation treatment with partial root zone drying can increase fruit quality. PRD application can save irrigation water up to 52% and it may improve FMA (Zegbe *et al.*, 2016).

Advantages

1. Plants under mild water stress condition, increase root growth (Liu *et al.*, 2011), which facilitate nutrient uptake.
2. The alternate wetting and drying cycles of root zones with partial root-zone irrigation method improve the ability of plants to acquire nutrients from the soil; the cycles facilitate the mineralization of soil organic nitrogen, which increases mineral nitrogen available to the plants.
3. The wetting and drying cycles with partial root zone irrigation method also enhance the activity of microorganisms with high microbial substrate availability that is partly responsible for the improvement of nitrogen mineralization in plants (Wang *et al.*, 2010).

Limitations

There are some limitations of partial root zone drying technique of irrigation such as PRZD systems which are more costly irrigation systems which allowed interchangeable wetting and drying of the root-zone part and the time of switching required in operating PRZD irrigation. In partial root zone drying there is the accumulation of certain reactive oxygen species (ROS) which causes cell damage in plants.

Application of deficit irrigation like partial root-zone drying with drip irrigation method in fruit crops can reduce irrigation water and increase water use efficiency. The challenge is also to understand hormonal signalling under changes of nutrient and water resources and particularly that of cytokinins. Because of limited available data, further research is needed to understand complex biosynthetic pathway and synthesis of nutritive and health-related metabolites and antioxidants in PRZD treated plants. Practical

application and promotion of this knowledge will allow farmers in water scarce areas to adapt PRZD not only as a strategy for saving water, improving nutrient use, and increasing/sustaining yield but also for producing food with enhanced nutritive and health characteristics.

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Leaf morphology, floral biology, pollination behaviour of elite bael accessions under rainfed semi-arid conditions

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Abstract

The knowledge of floral biology, pollination behaviour and reproduction biology is important for improvement and also to enhance productivity. A study was conducted on nine elite bael germplasm which were collected from Rajasthan, Uttar Pradesh and Gujarat, established through in-situ patch budding at Experimental farm of CHES, Godhra. There was variability in leaf characters i.e., leaflet shape, leaf margin, leaf apex, leaf base and leaf surface among the accessions. Variation in bark colour and bark splitting pattern was also observed. Phyllotaxy in different genotypes was observed tristichous and pentastichous. Inflorescence consists of 2-31 lower buds and also single flowers. Flowers possess 4-5 petals within same accession, but 4 followed by 5 petals were found to be common in almost all studied accessions; however 3 and 6 sepals may be seen rarely in few accession. Considerable variations in size of bud, flower, petal, pedicel, stamen, filament, anther, pistil, ovary style, stigma and number of stamens/flower and pollen viability were recorded among the studied accessions. The maximum anthesis was observed between 6.31-8.30 am in all the varieties and it was continued up to 12.30 pm.

Key words: Floral biology, leaf morphology, pollination behaviour, bael

Introduction

Bael is an important sub tropical fruit tree indigenous to India. It belongs to family Rutaceae (Stone, 1985) which is widely distributed in India. It can also be cultivated in arid and semi-arid region successfully (Saroj *et al.*, 2006; Singh *et al.*, 2019). It has great mythological and religious significance in Indian history and culture, and is one of the underutilized fruits known from pre-historic times finding its mention in Hindu mythology. All the parts of tree, whether stem, root, bark, leaves or fruits at different maturity stages have been traditionally identified to contain medicinal properties which have been described in ancient treatise such as Charak Samhita, Sushrut Samhita, Upvan vinod, and Jain and Budhisht literature (Singh *et al.*, 2019). The ripe fruits are laxative and unripe fruits are prescribed for diarrhea and dysentery, and have a great demand in Ayurvedic system of medicine. In India, it is found in wild form in sub-Himalayan tract and in dry deciduous forest of central and southern Indian region (Singh *et al.*, 2018a and 2019). It is very hardy and has capacity to adapt successfully to a wide range of habitat (Singh *et al.*, 2016a). Bael, owing to its environmental friendly nature, is being placed among plant species group called 'climate purifiers' as it emits a greater percentage of oxygen as compared to other plants (Anurag *et al.*, 2014). A large number of land races are available in the different diversity regions in India (Saroj *et al.*, 2006). A wide range of diversity of bael has been noticed in dry sub-tropical, tropical, arid and semi-arid regions of the country (Singh *et al.*, 2019 a). The plains of U.P., and Gujarat and Rajasthan also have wide distribution of bael genotypes with great diversity particularly in dry climate,

undulating terrains, forest and wastelands (Singh *et al.*, 2019). The genotypes of bael found in different parts of the country have enormous variability with regard to their morphological characters (Singh *et al.*, 1989). Some superior genotypes identified by local people are on the verge of extinction owing to extensive urbanization, and hence, there is an urgent need to conserve them for the use of posterity (Singh *et al.*, 2018). Keeping these points in view, large number of germplasm were established *ex-situ* (199) out of which, 9 genotypes were utilized for present study.

Materials and Methods

Nine accessions established through *in-situ* patch budding at Experimental Farm of CHES, Godhra were utilized for study. All trees were established in Randomized Block Design which was replicated thrice. Accessions used in the experiment were CHESB-1(IC.0629381), CHESB-5 (IC.0629382), CHESB-8 (IC.0629383), CHESB-11(IC.0629384), CHESB-16 (IC.0629385), CHESB-21 (IC.0629386), CHESB-27 (IC.0629387), CHESB-29 (IC.0629388) and CHESB-31 (IC.0629389). The different morphological and qualitative growth characters in leaf (base, apex and margin), bark (colour, splitting and thickness) and spine were observed visually in the field, as illustrated by Wilde *et al.* (1972) and Simpson (2006). Studies were conducted during flowering seasons; April-May in the year 2016 and 2017. Basic floral biological data were collected from nine accessions. Flowering period, flower opening time days taken to flower opening, stigma receptivity anther dehiscence and opening pattern were also studied. Sixty

flowers from each accession were subjected to study and data collection was continued in consecutive seasons of each year. Data were recorded in two hour interval starting from 4.30 am to 12 noon to study anthesis and anthesis dehiscence. Pollen viability percentage was studied using 15 of acetocarmin stain test. Anthesis and dehiscence was studied in Goma Yashi, Thar Divya and Thel Nelkanth varieties of bael only. Statistical analysis was followed as per methods outlined by Gomez and Gomez (1984).

Results and Discussion

Flowering period in bael was observed from March to August. It depends upon the variety, soil moisture regime and climatic conditions of particular locality. Under dryland conditions, some of the germplasm flower at their routine period but few the flowers may appear after rain, however peak period of flowering was observed in almost all germplasm after rain, if rainfall is less than 400 mm in previous season resulting into late fruit setting with reduced fruit size.

Leaf morphology

There was variability in the morphological vegetative growth characteristics among the different bael

accessions. The data pertaining to morphological attributes of bael and its leaves showed significant differences and high degree of variability for all the characters were observed (Table 1). The growth habit included tree with upright, spreading, semi spreading and drooping type and foliage with compact, dense and sparse type among all the characterized accessions (Singh *et al.*, 2011). Tree shapes of different genotypes are dome, irregular, semi circular, broad vase and elliptical types among all the genotypes (Singh *et al.*, 2014, 2018a). There were variability in the several leaf characters *i.e.* leaflet shape (ovate, broadly lanceolate to ovate, broadly ovate, elliptical and elliptical to lanceolate), leaf margin (superficially, prominent, crenate and crenulate), leaf apex (acute, acuminate, slightly aristate and sub acute), leaf base (broadly cuneate, round, narrowly cuneate and truncate) and leaf surface (dull rough and shiny smooth) in rainfed semi-arid ecosystem of western India (Singh *et al.*, 2012, 2015) (Table 2). The bark colour was yellowish grey, grayish yellow, blackish grey, dark grey and light whereas splitting pattern was irregular intersecting striations having small rectangular blocks (Singh *et al.*, 2011b). Phyllotaxy in different genotypes was observed Tristichous and Pentastichous (Singh *et al.*, 2019) (Table 1).

Table 1. Morphological variability in leaf characters of bael accessions

Genotypes	Central leaf shape	Lateral leaf let shape	Leaf apex	Leaf base	Leaf margin	Phyllotaxy
CHESB -1	Ovate	Ovate	Aristate	Narrowly cuneate	Superficially crenulate	Tristichous
CHESB -5	Ovate	Ovate	Acute	Broadly cuneate in central oblique cuneate in laterals	Big dentate crenate but depressed at one side	Pentastichous
CHESB -8	Ovate	Ovate	Acute	Rounded	Big dentate crenate superficially	Pentastichous
CHESB -11	Elliptical to lanceolate	Ovate	Central acuminate, laterals acute	Narrowly cuneate, laterals had rounded	Crenate superficially	Tristichous
CHESB -16	Broadly lanceolate	Ovate	Acuminate	Broadly Cuneate but oblique at one side	Small crenulate, superficially	Pentastichous
CHESB -21	Ovate	Ovate	Acute	Rounded	Big dentate crenate superficially	Tristichous
CHESB -27	Elliptical to lanceolate	Elliptical lanceolate	Slightly aristate to acute	Central narrowly cuneate, lateral leaflet rounded	Small crenulate, superficially	Pentastichous
CHESB -29	Ovate	Ovate	Acute	Broadly cuneate in central oblique cuneate in laterals	Crenate but slightly depressed at one side	Tristichous
CHESB -31	Ovate	Ovate	Acute	Rounded	Small crenulate superficially	Trstichous

Table 2. Morphological variability in vegetative characters of bael accessions

Genotypes	Leaf surface	Leaf colour	Growth habit	Foliage	Bark colour	Bark splitting pattern	Thorniness
CHESB-1	Shiny smooth	Dorsal side dark green and ventral side light green	Semi-spreading	Dense	Yellowish grey	Irregular intersecting striations having small rectangular blocks	Thornless
CHESB-5	Shiny, smooth	Dorsal side dark green and ventral side light green	Upright spreading	Compact	Dark grey	Irregular intersecting striations having small rectangular blocks	Very less thorn
CHESB-8	Shiny smooth	Light green at both side	Semi spreading,	Dense	Light grey	Irregular intersecting striations having small rectangular blocks	Less thorn
CHESB-11	Shiny Smooth	Dark green at both side	Semi spreading drooping	Sparse	Light grey	Irregular intersecting striations having small rectangular blocks	Thorny (Thin and small)
CHESB-16	Dull rough	Dark green at both side	Semi spreading, drooping	Sparse	Greyish Yellow	Irregular intersecting striations having small rectangular blocks	Thorny (small)
CHESB-21	Dull rough	Light green at both side	Semi spreading	Dense	Light grey	Irregular intersecting striations having small rectangular blocks	Thorny (very bold)
CHESB-27	Dull smooth	Dorsal side dark Green and light green ventral side	Spreading	Compact	Dark grey	Irregular intersecting striations having small rectangular blocks	Thornless
CHESB-29	Shiny, smooth	Dorsal dark green, ventral side light green	Semi spreading	Dense	Light grey	Irregular intersecting striations having small rectangular blocks	Thorny
CHESB-31	Shiny smooth	Light green at both side	Semi-spreading	Dense	Yellowish	Irregular intersecting striations having small rectangular blocks	Thorny

Flower events

Though flower showed a slight change in colour, majority were dull greenish white with appealing fragrance. Even in the same accessions number of petals may be varied from 4 to 6 (Fig. 1). Flower initiation could be observed 9-15 days after emergence of new flush and flower bud appeared in axillary cymose (Fig. 2). Flower bud appeared as minute swollen structure on inflorescence peduncles and developed into flower between 21-30 days after initiation. All the flowers in a penicle opened with in 7-10 days. Flower open from top to bottom of the penicle. Anthers and petals turn brownish in colour after 8-12 hours of anthesis (Fig. 3). Stigma also turned slightly brownish in colour after 8-10 hours of flower opening though wet surface observed. Anthers attached longitudinally

to the style and after dehiscence of anthers (Fig.3), diverted to outside of the stigma this may be the one of the avoidance mechanism of self pollination. Anthers change to dull brownish colour after 2-3 hours of direct sun light exposure became more side tracked outside of the stigma. Purple colour stigma in CHESB-29 (Fig.5) and curved petals in CHESB-16 (Fig.4) were found as distinct characters of these accessions. Flowers were protogynous and dichogamy (Fig. 6).

Floral biology

The data on the morpho-metrics of flower of bael accessions depicted in Table 4, 5 and 6 showed considerable differences for all the floral characters studied. Flower characters with respect to bud size in terms of bud length

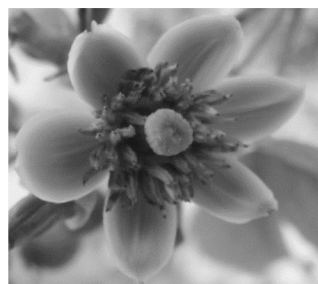
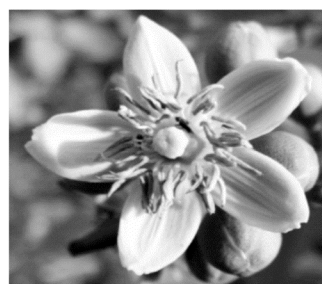
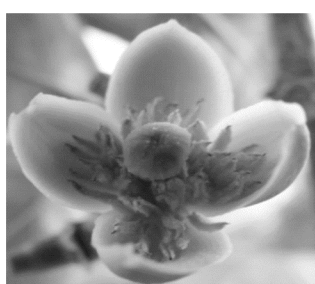


Fig. 1. Variation in number of petals in same accession

Fig. 2. Flower buds arrangement

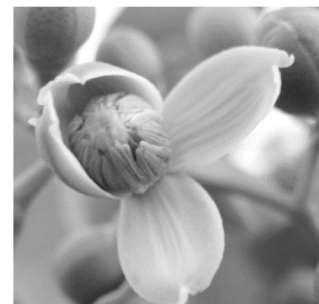
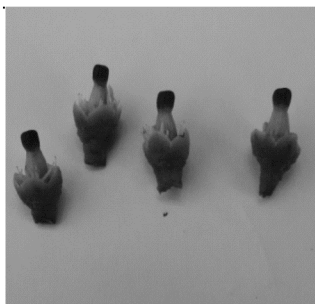
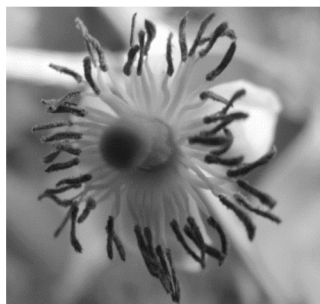


Fig. 3. Dehisced anthers

Fig. 4. Flower on trunk with curved petal while dehiscence

Fig. 5. Purple colour stigma

Fig. 6. Herkogamy

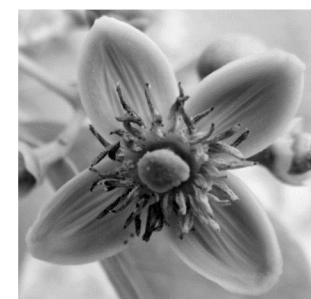
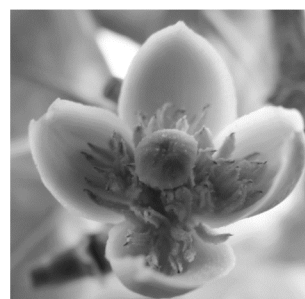
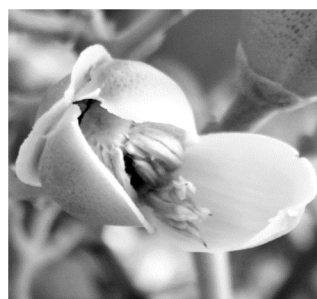


Fig. 7 a. Initiation of petals loosening

b. Opening of petals

c. Complete opened flower and

d. Initiation of dehiscence

(10.0-13 mm), bud breadth (6.84-9.53 mm), flower length (12.05-117.00 mm), flower breadth (23.05-35.17 mm), pedicel length (7.00-9.00 mm), pedicel breadth (1.94-2.50 mm), petal length (11.95-16.54 mm), petal breadth (7.00-9.50 mm), stamen length (6.50-8.61 mm), filament length (5.00-6.90 mm), breadth (0.47-0.73 mm), anther length (4.33-8.00 mm), breadth (0.62-0.84 mm), pollen diameter (40.51-45.53 micron), ovary length (4.33-8.00 mm), diameter (3.00-5.55), style length (1.00-1.50 mm), width (2.00-2.50 mm), stigma length (2.63-3.53 mm), breadth (2.07-3.00 mm) and pistil length (7.29-10.45 mm) exhibited wide variations in their floral organs. Size and shape of flower buds varied in different accessions possibly owing to genetic variation. More or less similar findings for variability in flower organs has been reported in jamun (Singh *et al.*, 2016 b), tamarind (Singh and Singh, 2005, Singh *et al.*, 2008, 2010), chironji (Singh *et al.*, 2010), khirni (Singh *et al.*, 2016), wood apple (Yadav *et al.*, 2017; Singh *et al.*, 2016 c), custard apple (Yadav *et al.*, 2017),

bael (Singh *et al.*, 2014b, 2018b, 2019b) and wild noni (Singh *et al.*, 2014a). Pollen viability was found to be significantly highest in CHESB-5 (95.67%), whereas it was recorded least B-21 (90.17%) among the accessions. Bud length was the minimum in CHESB-16 (13.47 mm) and same was recorded lowest in CHESB-29 (10.02 mm) whereas flower length was recorded the highest in CHESB-21 (17.00 mm) and it was CHESB-29 (12.02 mm). Similar finding for variation in flower organs in bael varieties has been reported by Singh *et al.* (2018a). Bud and flower breadth were recorded the minimum value in CHESB-29, whereas bud and flower breadth were recorded the maximum in CHESB-5 (9.53mm) and in CHESB-21 (35.17), respectively. Number of stamens per flower was recorded the highest in CHESB-8 (43.35) and lowest value of the same was recorded in CHESB-29 (37.25) among the accessions. Among the accession, pedicel size (7.00x1.94mm), stamen size (6.50mm), filament size (6.90x0.47mm), anther size (2.50x0.62 mm), pollen diameter

(40. 51 micron), pistil length (7.29 mm), ovary size (4.33x3.00mm), style size (1.00x2.00mm) and stigma size (2.63x2.07 mm) was recorded the minimum value in CHESB-29, whereas these values were recorded the highest in different accessions. The maximum breadth of petal, anther, filament, ovary, style and stigma was recorded 9.50, 0.84, 0.73, 4.55, 2.50, 1.50 and 3.53 mm in CHESB-11, CHESB-1, CHESB-11, CHESB-1, CHESB-27, CHESB-16 and CHESB-31, respectively. These findings are in agreement with the results reported by Singh *et al.*, (2014a, 2014b, 2014c, 2014d) in bael varieties under rainfed semi-arid conditions. In different accessions, types of flowers were observed axillary biparous, axillary multiparous and compound cyme (Singh *et al.* 2018a, 2018b, 2019a). Commencement of bud emergence was observed from 20th April and lasted up to 05th July whereas

flowering started from 14th May and lasted up to 25th July. The maximum flowering duration was observed in CHESB-1 (Singh *et al.*, 2014e and 2014f) (Table 3).

Anthesis and dehiscence

Under hot semi-arid climatic conditions, there was no anthesis before dehiscence in any accession, whereas anthesis in bael started from 4.30 am and continued up to 12.30 pm. Some flowers opened all petals at a time while in other petals start opening one by one which takes 45 to 60 minutes in complete opening which may vary flower to flower. In the inflorescence, centrally located buds open first as compared to lateral buds. After anthesis, the hint of the anthers dehiscence started which continued till noon (Fig. 7). Among the varieties, the maximum anthesis was observed in

Table 3. Morphological variability in phenological characters in bael accessions

Genotypes	Type of inflorescence	Flower bud emergence			Flowering period			Number of petals	
		Start	Peak period	End	Start	Peak period	End	Common	Rare
CHESB-1	Axillary multiparous cyme	30 April	24-25 May	05 July	14 May	20-30 June	25 July	4,5	6
CHESB-5	Compound cyme	20 April	23-28 May	20 June	16 May	9-19 June	23 June	4,5	6
CHESB-8	Axillary cyme	8 May	23-28 May	22 June	26 May	7-18 June	24 June	4,5	5
CHESB-11	Axillary multiparous cyme	3 May	24-25 May	20 June	24 May	9-16 June	23 June	4,5	---
CHESB-16	Axillary cyme	1 May	23-28 May	16 June	26 May	10-18 June	19 June	4	5
CHESB-21	Axillary biparous cyme	20 April	24-29 May	16 June	15 May	7-19 June	28 June	4,5	---
CHESB-27	Axillary biparous cyme	1 May	25-30 May	19 June	21 May	9-16 June	27 June	4,5	6
CHESB-29	Axillary multiparous cyme	21 April	23-28 May	24 June	15 May	9-16 June	25 June	4	5
CHESB-31	Axillary biparous cyme	20 April	24-29 May	20 June	16 May	10-20 June	24 June	4	----

Table 4. Morphological variability in flower characters in bael accessions

Genotypes	Bud size (mm)		Flower size (mm)		Petal size (mm)		Pedicel size (mm)	
	Length	Breadth	Length	Breadth	Length	Breadth	Length	Thickness
CHESB-1	12.05	8.48	13.43	27.10	14.34	9.05	7.40	2.07
CHESB-5	12.14	9.53	14.53	35.20	15.24	7.50	7.25	2.20
CHESB-8	11.25	8.57	14.47	25.07	14.17	8.00	4.78	2.00
CHESB-11	10.48	7.25	16.57	32.13	16.54	9.50	8.33	2.50
CHESB-16	13.47	9.73	14.07	24.27	15.00	8.50	6.23	2.00
CHESB-21	13.00	8.50	17.00	32.31	16.00	7.53	9.00	2.00
CHESB-27	13.00	8.51	12.30	35.17	12.08	9.59	5.70	2.40
CHESB-29	10.02	6.84	12.05	23.05	11.95	7.00	4.58	1.94
CHESB-31	12.00	9.50	18.00	26.08	18.45	8.50	7.00	2.13
C.D. at 5%	1.21	0.41	0.75	1.42	0.72	0.81	0.70	0.17

Table 5. Variability in flower characters in bael accessions

Genotypes	Number of stamens/ flower	Stamen size (mm)	Filament size (mm)		Anther size (mm)		Pollen diameter (micron)
		Length	Length	Breadth	Length	Breadth	
CHESB -1	42.19	6.50	3.50	0.50	3.00	0.62	42.53
CHESB -5	38.97	7.00	3.53	0.72	3.54	0.70	45.00
CHESB -8	43.35	8.60	5.00	0.50	3.05	0.81	43.74
CHESB -11	43.30	7.78	4.07	0.73	3.75	0.84	41.28
CHESB -16	38.25	7.50	4.76	0.54	2.75	0.70	41.27
CHESB -21	39.00	7.43	4.00	0.70	3.55	0.77	43.03
CHESB -27	38.25	8.61	3.20	0.60	5.26	0.72	43.07
CHESB -29	37.25	6.90	3.00	0.47	2.52	0.70	40.51
CHESB -31	39.68	7.53	3.45	0.70	4.50	0.75	42.47
C.D. at 5%	--	0.31	0.22	0.04	0.23	0.04	2.17

Table 6. Variability in floral organs in bael accessions

Genotypes	Pistil length (mm)	Ovary size (mm)		Style size (mm)		Stigma size (mm)		Pollen viability (%)
		Length	Breadth	Length	Breadth	Length	Breadth	
CHESB -1	10.44	7.57	4.55	1.50	2.50	3.20	2.50	94.10
CHESB -5	09.27	5.54	4.00	1.00	2.50	3.40	2.50	95.67
CHESB -8	10.35	6.52	4.49	1.10	2.05	3.12	2.20	94.27
CHESB -11	09.00	4.07	4.37	1.53	2.50	3.53	2.07	95.17
CHESB -16	09.57	4.28	3.03	1.00	1.55	3.00	2.51	92.05
CHESB -21	07.00	4.50	2.50	1.05	2.31	3.08	2.32	90.17
CHESB -27	10.45	5.50	3.51	1.10	2.50	3.10	2.50	93.22
CHESB -29	07.29	4.33	3.00	1.00	2.00	2.63	2.40	91.35
CHESB -31	07.75	8.00	3.53	1.05	2.10	3.50	3.00	95.22
C.D. at 5%	0.53	0.33	0.21	0.15	0.13	0.11	0.33	4.94

Goma Yashi between 6.31 am to 8.30 am, whereas in all the varieties, maximum anthesis was observed during this period. Among the varieties, the highest anthesis was observed in Thar Neelkanth between 8.31am -10.30 am. In all the varieties, maximum anthesis between 8.31am - 12.30 pm was observed in Thar Divya (Fig 8). Early anthesis was observed in eastward branches compared to rest of the branches owing early exposure of branches to sunlight. Generally, anther dehiscence was synchronous with anthesis and all the anthers in the flower in flower dehisced synchronously presenting the

pollen mass. More or less similar pattern of anthesis was observed by Singh *et al.*, (2009) and Singh *et al.*, (2014e, 2014f & 2019b).

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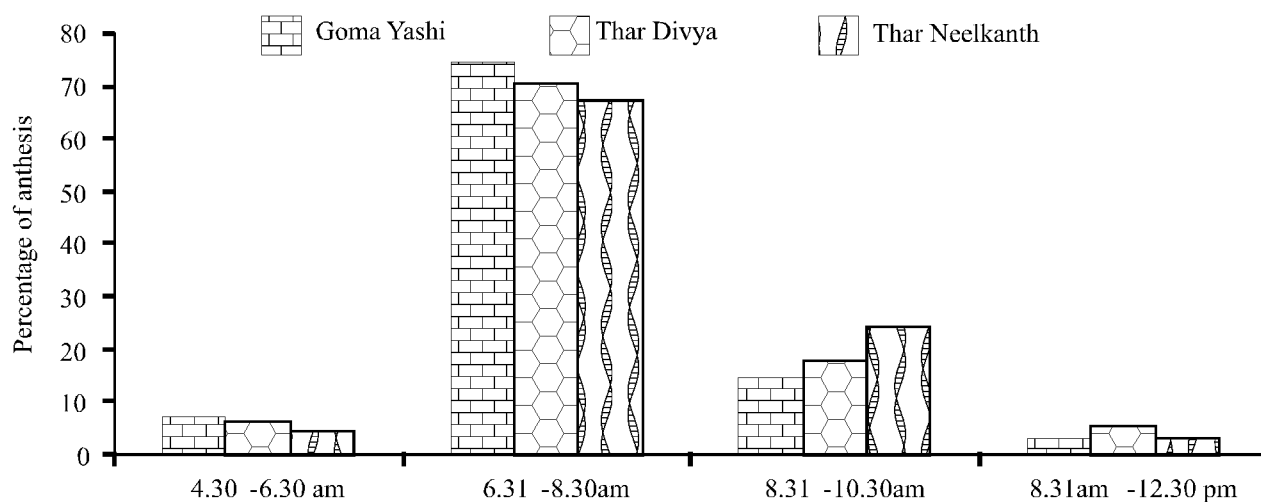


Fig 8. Percentage of dehiscence with the time in bael varieties

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Yield and economics of pomegranate as influenced by flower regulation under hot arid climate

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Abstract

The present study was carried out to improve the marketable yield of pomegranate by flower regulation through withholding of irrigation at different time, pruning and ethrel application. Pooled data revealed that horticultural interventions, chemical applications and their interactions significantly affected total fruit yield, marketable fruit yield, gross return, net return and B:C ratio of pomegranate under hot arid climate. Among horticultural interventions, significantly highest marketable fruit yield, net return and B:C ratio (9.27 t/ha, 194881 Rs./ha and 2.34) were registered in withholding of irrigation during June + pruning and thinning as against minimum recorded in control *i.e.* natural flowering (7.32 t/ha, 138553 Rs./ha and 1.70), respectively. Among chemical applications, significantly highest marketable fruit yield, net return, B:C ratio (9.52 t/ha, 202268 Rs./ha and 2.42) were registered in application of ethrel 2 ml/l + DAP 5 g/l as compared to control without chemicals. Among interactions, significantly highest marketable fruit yield, net return and B:C ratio (10.90 t/ha, 242627 Rs./ha and 2.87) were registered in treatment withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l treatment as compared to minimum recorded in absolute control treatment *i.e.* natural flowering without chemicals (6.64 t/ha, 121644 Rs./ha and 1.57), respectively. In conclusion, withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l treatment combination was found significantly superior over other treatments with highest marketable yield, net return and B:C ratio under hot arid climate.

Key words: Ethrel, flower regulation, marketable yield, net return, water stress

Introduction

Pomegranate (*Punica granatum* L.) is an emerging fruit crop of hot arid regions originated from Iran. In India, pomegranate is cultivated on large scale in the states of Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh and Rajasthan. India is one of the largest producers of pomegranate in the world. During 2018-19, pomegranate was grown over 2.62 lakh ha area with an annual production of 30.34 lakh tonnes and a productivity of 11.58 tonnes/ha in India (Anonymous, 2019). In India, pomegranate is available throughout the year from January to December owing to varied climatic conditions. Maharashtra is the major pomegranate growing state covering 63.23% of the total area and 62.90% of total production followed by Gujarat with 13.04% area and 16.23% production; and Karnataka with 11.10% area and 9.42% production (Anonymous, 2018). Pomegranate has ability to tolerate abiotic stresses *i.e.* heat, drought and saline conditions prevailing in hot arid regions. The area under pomegranate cultivation in hot arid region is increasing continuously owing to its high demand, hardy nature, better storage quality and nutritional value. It has enormous medicinal, therapeutic values and one of the richest sources of antioxidants. A large number of value added products are developed by processing the fruit such as juices, squash, jelly, wine, seed oil, mouth freshener, *etc.* In

Rajasthan, it is commercially grown in Jaipur, Ajmer, Alwar, Tonk, Sri Ganganagar, Pali, Kota, Jalore, Barmer, Jodhpur, Jaisalmer, Sawai Madhopur, Bhilwara, Jhunjhunu and Sirohi districts over 12,000 ha area and acreage in Thar desert particularly Barmer, Jodhpur and Jaisalmer is increasing at faster rate. Under arid and semi-arid regions, about 25-60% fruit cracking has been reported during maturity in different bahars which varies with variety, season and climate. The cracked fruits are sweeter with low shelf life; highly liable to fruit rot and are unsuitable for transport (Saroj and Kumar, 2019). Pomegranate flowers continuously under hot arid climatic conditions and bear small crop irregularly at different period of the year, which may not be desirable commercially. To avoid this, plants are subjected to flower regulation/bahar treatment. In this treatment, the irrigation is withheld one to two months prior to the bahar followed by light earthing up in the basin. This facilitates the shedding of leaves, induction of profuse flowering and fruiting. The availability of irrigation water/rainfall, climatic condition, insect-pests, diseases, and market demand are major considerations for flower regulation (Kumar *et al.*, 2018a). Moisture stress, plant bio-regulators, defoliant, nutrient and canopy management including training, pruning and thinning are major horticultural interventions that influence flowering and fruit quality in pomegranate (Kumar *et al.*, 2019a). Water stresses trigger a

wide variety of plant responses, ranging from altered gene expression and cellular metabolism to changes in plant growth, leaf morphology and movement and root development and finally productivity (Kumar *et al.*, 2019b). In pomegranate cultivation, economics or net return mainly depends on marketable yield and fruit quality. Fruit cracking is major problem under hot arid climate which deteriorate fruit quality and reduce marketable yield. Therefore, the present study was conducted to induce flowering by withholding of irrigation, pruning and ethrel application in desired period to produce improved quality and higher yield with minimum incidence of fruit cracking.

Materials and Methods

The present investigation was carried out during two consecutive years 2017-18 and 2018-19 at ICAR-Central Institute for Arid Horticulture, Bikaner. The experiment was conducted in Factorial Randomized Block Design with three replications comprising 20 treatment combinations. There were two factors *i.e.* horticulture interventions and chemical applications. The horticulture interventions (P) have five levels *i.e.* P₀-control natural flowering, P₁-withholding of irrigation during March, P₂-withholding of irrigation during March + pruning and thinning, P₃- withholding of irrigation during June and P₄- withholding of irrigation during June + pruning and thinning; while chemical applications (C) have four levels *i.e.* C₀-control without chemicals, C₁-ethrel 1 ml/l + DAP 5 g/l, C₂-ethrel 2 ml/l + DAP 5 g/l and C₃-ethrel 3 ml/l + DAP 5 g/l. Pruning of 20 cm growth was carried out after withholding of irrigation period. In thinning, flowers were removed manually before and during water stress period and only flowers produced after flower treatment were retained and allowed to set fruits. Ethrel (40%) and DAP (18:46 grade) were applied as foliar spray after withholding of irrigation period and pruning, while in control (P₀) treatments, chemicals were applied in last week of May. The experiment was conducted on eight years old orchard of pomegranate cv. Jalore Seedless planted at 5x2.5 m² spacing under drip irrigation. The soil of pomegranate orchard was loamy sand with pH of 8.32 and electrical conductivity of 0.27 dSm⁻¹. It had 0.15% organic carbon, 106.4 kg/ha available nitrogen, 11.51 kg/ha available phosphorus and 214.5 kg/ha available potassium content. Data were recorded on yield and economic attributes *viz.*, total fruit yield, marketable fruit yield, gross return, net return and B:C ratio. The data were analyzed statistically as per the methods suggested by Gomez and Gomez (1984).

Results and Discussion

The perusal of data presented in Table 1 divulged that horticultural interventions, chemical applications and their interaction significantly improved total fruit yield of pomegranate. Among different horticultural interventions, during 2017-18 and pooled basis, significantly maximum total fruit yield (10.72 and 10.67 t/ha) was recorded in withholding of irrigation during June (P₃) treatment which was followed by total fruit yield (10.24 and 10.60 t/ha) in withholding of

irrigation during June + pruning and thinning (P₄) treatment, respectively. During 2018-19, significantly maximum fruit yield (10.96 t/ha) was recorded in withholding of irrigation during June + pruning and thinning (P₄) treatment which was statistically at par with withholding of irrigation during June (P₃) treatment (10.61 t/ha). The minimum fruit yield (9.30, 9.41 and 9.35 t/ha) was recorded in control natural flowering (P₀) treatment in the years 2017-18, 2018-19 and pooled basis, correspondingly.

Among different chemical applications, significantly maximum total fruit yield (10.90, 11.39 and 11.15 t/ha) was recorded in application of ethrel 2 ml/l + DAP 5 g/l (C₂) treatment which was followed by ethrel 1 ml/l + DAP 5 g/l (C₁) treatment (10.22, 10.66 and 10.44 t/ha) as against minimum fruit yield recorded in control without chemicals (C₀) treatment (9.22, 9.21 and 9.22 t/ha) in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, maximum total fruit yield (11.89, 12.92 and 12.40 t/ha) was recorded in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P₄C₂) treatment which was followed by withholding of irrigation during June + ethrel 2 ml/l + DAP 5 g/l (P₃C₂) treatment (11.69, 11.88 and 11.79 t/ha) in the years 2017-18, 2018-19 and pooled basis, respectively. The minimum fruit yield (8.56, 8.57 and 8.57 t/ha) was recorded in absolute control *i.e.* control natural flowering without chemical (P₀C₀) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

The higher total fruit yield in withholding of irrigation during June with/without pruning and thinning + ethrel 2 ml/l + DAP 5 g/l treatments might be due to favourable growth condition which improved fruit weight/number while ethrel increased the numbers of bisexual flowers with high fruit set and retention. These results in accordance with Pawar *et al.* (1994), Sheikh and Rao (2002), Ustad (2011) and Chakma (2014) who observed that fruit yield significantly influenced by pruning intensity. Similarly, Goswami *et al.* (2013), Korde (2015), Kumar *et al.* (2018b) reported that application of ethrel improved fruit yield of pomegranate as compared to minimum in control. Murthy (2014) and Supe *et al.* (2015) reported that spraying of ethrel 2 ml/l mixed with DAP 5 g/l and ethrel (2 ml/l) increased fruit yield in pomegranate, respectively.

The perusal of data (Table 2) revealed that horticultural interventions, chemical applications and their interaction significantly improved marketable yield of pomegranate. Among horticultural interventions, during 2017-18, significantly maximum marketable yield (8.99 t/ha) was registered in withholding of irrigation during June + pruning and thinning (P₄) treatment which was followed by withholding of irrigation during March + pruning and thinning (P₂) treatment (8.80 t/ha). During 2018-19 and pooled basis significantly maximum marketable yield (9.56 and 9.27 t/ha) was registered in the withholding of irrigation during June + pruning and thinning (P₄) treatment which was followed by withholding of irrigation during June (P₃) treatment (8.84 and 8.80 t/ha), respectively. The minimum marketable yield (7.61,

Table 1. Effect of flower regulation treatments on yield attributes of pomegranate

Treatment	Total fruit yield (t/ha)			Marketable fruit yield (t/ha)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
	Horticultural interventions (P)			Horticultural interventions (P)		
P ₀	9.30	9.41	9.35	7.61	7.04	7.32
P ₁	9.92	10.10	10.01	8.08	7.81	7.94
P ₂	9.99	10.29	10.14	8.80	8.01	8.40
P ₃	10.72	10.61	10.67	8.77	8.84	8.80
P ₄	10.24	10.96	10.60	8.99	9.56	9.27
SEm ±	0.11	0.13	0.09	0.07	0.11	0.07
CD (5 %)	0.31	0.38	0.24	0.20	0.33	0.19
	Chemical applications (C)			Chemical applications (C)		
C ₀	9.22	9.21	9.22	7.56	7.09	7.32
C ₁	10.22	10.66	10.44	8.62	8.64	8.63
C ₂	10.90	11.39	11.15	9.46	9.57	9.52
C ₃	9.79	9.83	9.81	8.16	7.70	7.93
SEm ±	0.10	0.12	0.08	0.06	0.10	0.06
CD (5 %)	0.28	0.34	0.21	0.18	0.29	0.17
	Interaction (PxC)			Interaction (PxC)		
P ₀ C ₀	8.56	8.57	8.57	6.88	6.40	6.64
P ₀ C ₁	9.51	9.62	9.57	7.74	7.11	7.42
P ₀ C ₂	9.79	10.10	9.94	8.30	7.97	8.14
P ₀ C ₃	9.33	9.33	9.33	7.5 2	6.66	7.09
P ₁ C ₀	9.30	9.17	9.23	7.29	6.58	6.93
P ₁ C ₁	10.08	10.54	10.31	8.30	8.29	8.29
P ₁ C ₂	10.56	10.87	10.71	9.01	8.90	8.96
P ₁ C ₃	9.75	9.83	9.79	7.73	7.46	7.60
P ₂ C ₀	9.23	9.22	9.22	7.87	6.77	7.32
P ₂ C ₁	10.28	10.88	10.58	9.08	8.65	8.87
P ₂ C ₂	10.60	11.19	10.89	9.65	9.21	9.43
P ₂ C ₃	9.86	9.87	9.86	8.59	7.39	7.99
P ₃ C ₀	9.87	9.55	9.71	7.81	7.60	7.71
P ₃ C ₁	10.84	10.92	10.88	8.76	9.08	8.92
P ₃ C ₂	11.69	11.88	11.79	9.90	10.42	10.16
P ₃ C ₃	10.48	10.10	10.29	8.59	8.25	8.42
P ₄ C ₀	9.14	9.55	9.35	7.94	8.08	8.01
P ₄ C ₁	10. 38	11.36	10.87	9.20	10.08	9.64
P ₄ C ₂	11.89	12.92	12.40	10.44	11.36	10.90
P ₄ C ₃	9.53	10.02	9.77	8.37	8.70	8.54
SEm ±	0.22	0.26	0.17	0.14	0.23	0.13
CD (5 %)	0.62	0.76	0.48	0.39	0.66	0.38

Table 2. Effect of flower regulation treatments on economics of pomegranate

Treatment	Gross return (Rs./ ha)			Net return (Rs./ha)		
	2017-18	2018-19	Pooled	2017-18	2018-19	Pooled
	Horticultural interventions (P)			Horticultural interventions (P)		
P ₀	228213	211102	219657	147108	129997	138553
P ₁	242419	234277	238348	161117	152975	157046
P ₂	263969	240182	252076	180698	156910	168804
P ₃	263051	265178	264114	181749	183876	182812
P ₄	269651	286654	278153	186379	203383	194881
SEm±	2065	3436	2005	2065	3436	2005
CD (5 %)	5913	9838	5646	5913	9838	5646
	Chemical applications (C)			Chemical applications (C)		
C ₀	226734	212565	219649	148296	134126	141211
C ₁	258472	259289	258881	177066	177883	177475
C ₂	283846	287199	285523	200592	203945	202268
C ₃	244789	230861	237825	159687	145759	152723
SEm±	1847	3074	1793	1847	3074	1793
CD (5 %)	5288	8800	5050	5288	8800	5050
	Interaction (PxC)			Interaction (PxC)		
P ₀ C ₀	206265	192008	199137	128773	114515	121644
P ₀ C ₁	232177	213298	222738	151716	132838	142277
P ₀ C ₂	248958	239169	244064	166650	156860	161755
P ₀ C ₃	225450	199934	212692	141293	115777	128535
P ₁ C ₀	218653	197430	208041	140963	119740	130351
P ₁ C ₁	248878	248747	248813	168221	168090	168155
P ₁ C ₂	270372	266996	268684	187866	184490	186178
P ₁ C ₃	231773	223935	227854	147419	139581	143500
P ₂ C ₀	236133	202978	219556	156473	123319	139896
P ₂ C ₁	272421	259620	266021	189794	176992	183393
P ₂ C ₂	289533	276394	282964	205058	191918	198488
P ₂ C ₃	257790	221734	239762	171466	135411	153438
P ₃ C ₀	234438	228131	231284	156748	150441	153595
P ₃ C ₁	262888	272478	267683	182231	191820	187025
P ₃ C ₂	297077	312522	304800	214571	230016	222294
P ₃ C ₃	257799	247579	252689	173445	163225	168335
P ₄ C ₀	238183	242276	240229	158523	162616	160570
P ₄ C ₁	275997	302304	289150	193369	219676	206522
P ₄ C ₂	313291	340915	327103	228816	256439	242627
P ₄ C ₃	251134	261124	256129	164810	174800	169805
SEm±	4130	6873	4009	2417	5047	2798
CD (5 %)	11825	19677	11293	6921	14450	7882

7.04 and 7.32 t/ha) was registered in control natural flowering (P₀) treatment during 2017-18, 2018-19 and pooled basis, respectively. Among different chemical applications, maximum marketable yield (9.46, 9.57 and 9.52 t/ha) was registered in ethrel 2 ml/l + DAP 5 g/l (C₂) treatment followed by marketable yield (8.62, 8.64 and 8.63 t/ha) in ethrel 1 ml/l + DAP 5 g/l (C₁) treatment while minimum marketable yield (7.56, 7.09 and 7.32 t/ha) was registered in control without

chemicals (C₀) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. Among interaction treatments, significantly maximum marketable yield (10.44, 11.36 and 10.90 t/ha) was registered in withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P₄C₂) treatment which was followed by marketable yield (9.90, 10.42 and 10.16 t/ha) in withholding of irrigation during June with ethrel 2 ml/l + DAP 5 g/l (P₃C₂) treatment as against

minimum marketable yield (6.88, 6.40 and 6.64 t/ha) was recorded in absolute control (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively.

The higher marketable yield in treatment withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) might be due to favourable growth condition which resulted in higher fruit set and weight, higher photosynthetic efficiency; pruning and thinning encouraged more flow of nutrients and water towards fruits while application of ethrel increased numbers of bisexual flowers which improved fruit set and retention. The cumulative effect of season, pruning, thinning and ethrel application have improved marketable fruit yield and reduced fruit cracking. Similar results were also obtained by Goswami *et al.* (2013) and Kumar *et al.* (2018b) with ethrel application in pomegranate. These findings are in accordance to Pawar *et al.* (1994), Sheikh and Rao (2002) and Ustad (2011) who observed maximum better grade/size fruits in higher pruning intensity. Korde (2015) reported that ethrel application significantly improved fruit size, yield and reduced fruit cracking in pomegranate. Murthy (2014) and Supe *et al.* (2015) reported that ethrel application increased fruit size and thereby increased marketable yield in pomegranate.

The data presented in Table 2 divulged that there was significant effect of horticultural interventions on gross return. During 2017-18, significantly maximum gross return (269651 Rs./ha) was recorded in treatment of withholding of irrigation during June + pruning and thinning (P_4) which was followed by withholding of irrigation during March + pruning and thinning (P_2) treatment (263969 Rs./ha) and withholding of irrigation during June (P_1) treatment (263051 Rs./ha). During 2018-19, and pooled basis significantly maximum gross return (286654 and 278153 Rs./ha) was recorded in treatment withholding of irrigation during June + pruning and thinning (P_4) which was followed by withholding of irrigation during June (P_3) treatment (265178 and 264114 Rs./ha), respectively. The minimum gross return (228213, 211102 and 219657 Rs./ha) was recorded in control natural flowering (P_0) treatment in the years 2017-18, 2018-19 and pooled basis, correspondingly. The gross return was significantly affected by different chemical applications. The maximum gross return (283846, 287199 and 285523 Rs./ha) was recorded in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment which was followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (258472, 259289 and 258881 Rs./ha) as compared to minimum gross return recorded in control without chemicals (C_0) treatment (226734, 212565 and 219649 Rs./ha) in the years 2017-18, 2018-19 and pooled basis, respectively.

The interaction of horticultural interventions (P) and chemical applications (C) was found significant in both the years and also pooled basis. The maximum gross return (313291, 340915 and 327103 Rs./ha) was recorded in treatment withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) which was followed by withholding of irrigation during June with ethrel 2 ml/l + DAP 5 g/l (P_3C_2) treatment (297077, 312522 and 304800

Rs./ha) in the years 2017-18, 2018-19 and pooled basis, respectively. The minimum gross return (206265, 192008 and 199137 Rs./ha) was recorded in absolute control (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. The combined effect of season, pruning, thinning and ethrel application have improved marketable fruit yield and thereby increased gross return. These results are in accordance with Goswami *et al.* (2013), Korde (2015) and Kumar *et al.* (2018b) with ethrel application in pomegranate. Murthy (2014) and Supe *et al.* (2015) reported that ethrel application increased fruit size and thus increased marketable yield and gross return of pomegranate.

The data presented in Table 2 revealed that there was significant effect of horticultural interventions on net return. Among different horticultural interventions, significantly maximum net return (186379, 203383 and 194881 Rs./ha) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by withholding of irrigation during June (P_3) treatment (181749, 183876 and 182812 Rs./ha) in the years 2017-18, 2018-19 and pooled basis, respectively. The minimum net return (147108, 129997 and 138553 Rs./ha) was recorded in control natural flowering (P_0) treatment in the years 2017-18, 2018-19 and pooled basis, correspondingly. The net return was significantly affected by different chemical applications. The maximum net return (200592, 203945 and 202268 Rs./ha) was recorded in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment which was followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (177066, 177883 and 177475 Rs./ha) as against minimum net return recorded in control without chemicals (C_0) treatment (148296, 134126 and 141211 Rs./ha) in the years 2017-18, 2018-19 and pooled basis, respectively. The data divulged that interaction of horticultural interventions (P) and chemical treatments (C) was found significant in both the years and pooled basis. The maximum net return (228816, 256439 and 242627 Rs./ha) was recorded in withholding of irrigation during June + pruning and thinning with ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment which was followed by withholding of irrigation during June with ethrel 2 ml/l + DAP 5 g/l (P_3C_2) treatment (214571, 230016 and 222294 Rs./ha) in the years 2017-18, 2018-19 and pooled basis, respectively. The minimum net return was recorded (128773, 114515 and 121644 Rs./ha) in absolute control (P_0C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. In pomegranate cultivation, fruit yield, quality and cost of cultivation are major factors which determine net returns. Higher net return in treatment withholding of irrigation during June + pruning and thinning + ethrel 2 ml/l + DAP 5 g/l (P_4C_2) might be due to higher yield, improved fruit quality with minimum fruit cracking incidence caused by the cumulative effect of season, pruning, thinning and ethrel application. These results are in close conformity with Goswami *et al.* (2013), Murthy (2014), Supe *et al.* (2015) Korde (2015) and Kumar *et al.* (2018b) with ethrel application in pomegranate.

There was significant effect of horticultural interventions on B:C ratio of pomegranate (Fig. 1). Among

different horticultural interventions, significantly maximum B:C ratio (2.25, 2.44 and 2.34) was recorded in withholding of irrigation during June + pruning and thinning (P_4) treatment which was followed by withholding of irrigation during June (P_3) treatment (2.23, 2.26 and 2.25) in the years 2017-18, 2018-19 and pooled basis, respectively. The minimum B:C ratio (1.80, 1.60 and 1.70) was recorded in control (P_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. The B:C ratio was significantly affected by different chemical applications. The maximum B:C ratio (2.40, 2.45 and 2.42) was recorded in ethrel 2 ml/l + DAP 5 g/l (C_2) treatment which was followed by ethrel 1 ml/l + DAP 5 g/l (C_1) treatment (2.17, 2.18 and 2.18) in comparison to minimum B:C ratio (1.89, 1.71 and 1.80) recorded in control without chemicals (C_0) treatment in the years 2017-18, 2018-19 and pooled basis, respectively. The interaction of horticultural interventions (P) and chemical applications (C) was found significant in both the years and also pooled basis.

The maximum B:C ratio (2.71, 3.04 and 2.87) was registered in withholding of irrigation during June + pruning and thinning with ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment which was followed by withholding of irrigation during June with ethrel 2 ml/l + DAP 5 g/l (P_3C_2) treatment (2.60, 2.79 and 2.69) in the years 2017-18, 2018-19 and pooled basis, respectively. During 2017-18, minimum B:C ratio (1.66) was recorded in absolute control (P_0C_0) treatment which was at par with natural flowering with ethrel 3 ml/l + DAP 5 g/l (P_0C_3) treatment (1.68). During 2018-19 and pooled basis, minimum B:C ratio (1.38 and 1.53) was registered in natural flowering with 3 ml/l + DAP 5 g/l (P_0C_3) treatment which was at par with absolute control (P_0C_0) treatment (1.48 and 1.57), respectively. Higher B:C ratio in withholding of irrigation during June + pruning and thinning with ethrel 2 ml/l + DAP 5 g/l (P_4C_2) treatment could be attributed to higher marketable yield and low cost of cultivation. Similarly, Kumar *et al.* (2018b) obtained highest B:C ratio with ethrel application in pomegranate while

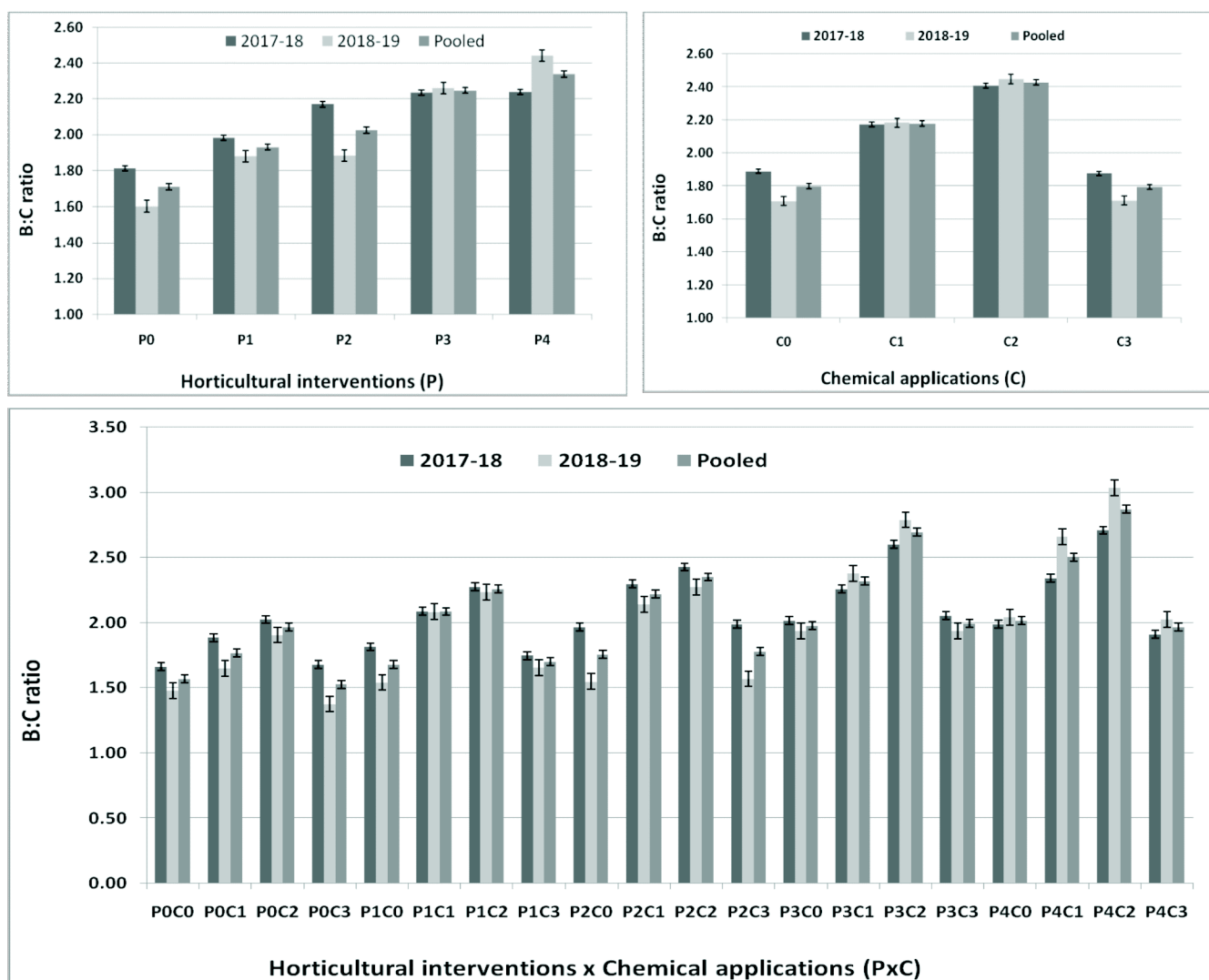


Fig. 1. Effect of flower regulation on benefit cost ratio of pomegranate

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Effect of irrigation levels and methods on yield and water use efficiency of marigold (*Tagetes erecta* L.)

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Abstract

The field experiment was conducted for consecutive two seasons during rabi 2017-18 and 2018-19 at Instructional Farm, College of Agriculture, S.K. Rajasthan Agricultural University, Bikaner (Rajasthan) to study the effect levels and methods of irrigation on yield and water use efficiency of marigold (*Tagetes erecta* L.). The experimental layout was carried out in randomized block design with four replications and treatments included three irrigation levels and three irrigation methods. Irrigation was given based on pan evaporation values following alternate day irrigation schedule for drip irrigation while, surface irrigation was given according to the locally adopted frequency. Results showed that IW/CPE ratio 1.0 recorded significantly higher flower yield (145.4 and 140.2 q ha⁻¹) in 2017-18 and 2018-19, respectively. Maximum water use (721.73 and 606.43 mm) was observed with same irrigation treatment in 2017-18 and 2018-19, respectively. Although, high water use efficiency (WUE) of 25.91 and 27.37 kg ha⁻¹ mm⁻¹ was observed at IW/CPE ratio 0.6 in 2017-18 and 2018-19, respectively. Under different irrigation methods, maximum flower yield (150.6 and 144.6 q ha⁻¹) and high WUE (26.43 and 29.31 kg ha⁻¹ mm⁻¹) was recorded under drip irrigation treatment in 2017-18 and 2018-19 respectively.

Key words: Irrigation level, marigold, WUE, yield

Introduction

Marigold (*Tagetes erecta* L.) is an annual plant, erect and fast-growing with dark green, glossy and aromatic leaves which have deep recesses, grows up-to one meter and above, bears single or fully double large sized globular heads of yellow, orange and white shades. It belongs to the family of *Asteraceae*. Marigold is grown as loose flower in bulk which is sold in the market for decoration of homes, temples, offices, marriage gardens *etc.* and making garlands and worshipping God. It is in great demand as loose flower throughout year and commonly used for decoration, making garlands for religious and social functions (Kumar *et al.*, 2010). Demand of marigold as cut flower or as extracted products is also high in many countries (Spain, Mexico, UK, United States, Italy, South Korea, Taiwan, Japan *etc.*). Hence, export of marigold will increase the economic level of farmers (Luis *et al.*, 2009). Marigold is one of the most commonly grown commercial flowers in India. It occupies an important place among loose flowers. It has nearly two third of total loose flower growing area in India.

In India, flowers cover an area of 339 thousand ha with a total production of 1991 thousand tonnes (loose flowers). Tamil Nadu is leading loose flower producing state followed by Karnataka, Andhra Pradesh *etc.* In Rajasthan, it covers an area of 4.0 thousand ha and the total production is 7.5 thousand tonnes (loose flowers) only (Anonymous, 2018). Marigold is contributing its highest portion as loose flower in Rajasthan.

Irrigation improves the water regime of soil creating

favorable conditions for growing plants. Frequent oscillations of weather conditions in the region, first of all the amount and distribution of precipitation, are the reason why irrigation is needed in crop production. Water is becoming an increasingly scarce resource in many areas of the world, especially in arid and semi-arid regions (Bosma *et al.*, 2003). Proper irrigation scheduling results in increasing water use efficiency (WUE) and yield of crop. WUE relates to how much yield is obtained per unit of applied water. Scheduling of water application is very critical, as excessive irrigations reduce yield, while inadequate irrigation also causes water stress (Sujatha and Shanmuga, 2017). Drip irrigation is very important and efficient method of irrigation when compared to other conventional method of irrigation. Drip irrigation method plays very important role as it uses less water and gives more yield due to precise and direct application of water in root zone as per crop water requirement. A considerably saving in irrigation water, increased growth and development and yield under drip irrigation has been reported by Imtiyaz *et al.*, (2000) and Rajbir Singh *et al.*, (2009).

Material and Methods

The field experiments to study the effect of irrigation levels and methods on marigold were conducted for two consecutive years of *rabi* 2017-18 and 2018-19 at Instructional farm, College of Agriculture, S.K. Rajasthan Agricultural University, Bikaner (Rajasthan) on light textured soil. The experimental layout was carried out in randomized block design and replicated four times. Treatments included

three irrigation levels (main treatments) viz., IW/CPE ratio 0.6 (M₁), IW/CPE ratio 0.8 (M₂), IW/CPE 1.0 ratio (M₃) and three irrigation methods (sub treatments) viz., Check basin method (I₁), Furrow method (I₂), Drip irrigation method (I₃). The weather condition was dry and rainfall during period of experimentation during crop growing period was 6.6 mm and 37.1 mm in 2017-18 and 2018-19, respectively. Total pan evaporation during crop growing period was 731.09 mm and 656.1 mm of 2017-18 and 2018-19, respectively.

Thirty five days old seedlings of marigold var. *Pusa Narangi Gainda* were transplanted on 10th December, 2017 and 23rd November, 2018 at row spacing of 50 cm using seed rate 1-1.5 kg ha⁻¹ (nursery). FYM @ 25 q/ha was applied to the experimental area during field preparation. The recommended fertilizers i.e. N (200 kg ha⁻¹), P₂O₅ (100 kg ha⁻¹) and K₂O (100 kg ha⁻¹) was applied to raise the crop. Half dose of nitrogen along with the full dose of phosphorus and potassium were given at the time of field preparation and half dose of nitrogen was applied in two splits after 30 days and 50 days of transplanting. Dry transplanting was done. Immediately after

transplanting, irrigation was applied to ensure proper crop establishment. There after surface irrigations were applied as per treatment. Drip irrigations were given in alternate days. The irrigation events and irrigation water applied (mm) in experiments is given in Table 1. All other packages of practices were adopted as recommended for this region.

Irrigation was applied on the basis of pan evaporation values following alternate day irrigation schedule for drip irrigation, while for surface irrigation water was given according to treatment. The daily evaporation reading was recorded by USWB class A Pan Evaporimeter.

All the parameters i.e. water use (mm), yield (q ha⁻¹) and WUE (kg ha⁻¹ mm⁻¹) determined using standard procedure. Ten plants from each plot were selected randomly and tagged for recording yield parameters. The water use efficiency was calculated by dividing yield (kg ha⁻¹) with total depth of the water applied (mm) including effective rainfall. In the check basin and furrow method, irrigation water given was quantified after knowing the discharge rate and irrigation time. Then at the end of the season total irrigation water applied was worked out. The analysis and interpretation of

Table 1. Irrigation events and irrigation water applied (mm)

Treatments	Check basin method				Furrow method				Drip irrigation (mm)	
	No. of irrigation		Delta (mm)		No. of irrigation		Delta (mm)		2017-18	2018-19
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19		
IW/CPE ratio 0.6	8	7	406.6	387.1	10	8	406.6	357.1	441	395.9
IW/CPE ratio 0.8	11	9	556.6	487.1	14	11	566.6	477.1	586	515.5
IW/CPE ratio 1.0	14	11	706.6	587.1	18	14	726.6	597.1	732	635.1

Data includes rainfall of 6.6 mm (2017-18) and 37.1 mm (2018-19)

Table 2. Effect of irrigation methods and levels on yield water use efficiency of marigold

Treatments	Flower Yield (qha ⁻¹)		Water use (mm)		WUE (kg ha ⁻¹ mm ⁻¹)	
	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
Irrigation levels						
IW/CPE ratio 0.6	108.3	104	418.07	380.03	25.91	27.37
IW/CPE ratio 0.8	139.2	133.2	569.73	493.23	24.43	27
IW/CPE ratio 1.0	145.4	140.2	721.73	606.43	20.15	23.12
Sem±	1.8	1.84				
CD at 5%	5.24	5.35				
Irrigation methods						
Check basin method	116.7	112	569.84	493.23	20.48	22.7
Furrow method	125.6	120.9	569.84	493.23	22.05	24.5
Drip irrigation	150.6	144.6	569.84	493.23	26.43	29.31
Sem±	1.8	1.84				
CD at 5%	5.24	5.35				

data were done using the Fisher's method of analysis of variance technique as described by Gomez and Gomez (1984).

Result and Discussion

The data presented in Table 2 revealed that increase in IW/CPE ratio from 0.6 to 1.0 increased flower yield. Drip irrigation level of IW/CPE ratio 1.0 gave maximum flower yield (145.4 and 140.2 q ha⁻¹, respectively) over IW/CPE ratio 0.6 and 0.8. Further, highest (721.73 and 606.43 mm) and lowest (418.07 mm and 380.03) water use was recorded at drip irrigation level of IW/CPE ratio 1.0 and IW/CPE ratio 0.6 in 2017-18 and 2018-19 respectively. Higher irrigation level maintains soil physical conditions in congenial condition for growth and yield by maintaining optimum soil-moisture-balance around plant base. Probably, this may be reason for increasing flower yield with increased IW/CPE ratio. Similar results were also obtained by Ayyanna *et al.* (2014). Highest WUE (25.91 and 27.37 kg ha⁻¹ mm⁻¹, respectively) was recorded with drip irrigated crop at IW/CPE ratio 0.6 and lowest with IW/CPE ratio 1.0 (20.15 kg ha⁻¹ mm⁻¹ and 27.37, respectively). These results were similar to the findings of Sujatha and Shanmuga, (2017).

Irrigation methods had significant influence on flower yield and was maximum (150.6 and 144.6 q ha⁻¹) under drip irrigation followed by furrow method (125.6 and 120.9 q ha⁻¹) and check basin method (116.7 and 112.0 q ha⁻¹) in 2017-18 and 2018-19, respectively. In furrow and check basin method where the soil moisture fluctuates from excess or saturation on the day of irrigation to field capacity to different degree of dryness and virtually plant suffers due to moisture stress just before the next irrigation. Because of this reason, crop performance was comparatively poor in furrow and check basin method of irrigation as compared to drip irrigation. Irrigation method also had a significant influence on WUE. However, maximum WUE (26.43 and 29.31 kg ha⁻¹ mm⁻¹) was recorded with drip irrigation followed by furrow method. Minimum WUE (20.48 and 22.70 kg ha⁻¹ mm⁻¹) was recorded under check basin method.

Among the irrigation levels IW/CPE ratio of 0.8 was found optimum for marigold. Drip irrigation gave higher flower yield followed by furrow and check basin method of irrigation. Drip irrigation level recorded higher water use

efficiency in comparison to surface methods of irrigation.

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Genetic diversity in jamun under semi-arid ecosystem of western India

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Abstract

An investigation was undertaken to evaluate the performance of 14 genotypes of jamun at Experimental Farm of Central Horticultural Experiment Station (ICAR-CIAH), Vejalpur, Panchmahals (Godhra), Gujarat under rainfed hot semi-arid ecosystem of western India during the years 2015 and 2016. These genotypes were studied to determine the variability with regards to vegetative growth, flowering and fruit quality attributes under hot semi-arid conditions. The results of study showed considerable variation with respect to vegetative, floral, yield and physico-chemical characters of fruit. The vegetative growth in terms of annual extension growth varied between 34.15 to 58.00 cm being the lowest in CHESJ-28 and the highest in CHESJ-32. The period of panicle emergence and flowering was recorded in February in almost all the genotypes. Panicle length ranged from 10.00 to 14.50 cm. The peak period of fruit set was noticed in the month of March, whereas fruit ripening started from 4th week of May and continued up to 4th week of June in different genotypes. Considerable variation in different flower organs was also observed amongst the genotypes. Flower length, breadth, calyx length, breadth ranged between 09.20-13.28 mm, 09.11-10.29 mm, 7.50-9.00 mm and 4.21-5.18 mm respectively. The maximum fruit yield (30.28 kg/ plant), fruit weight (18.00 g), pulp content (84.44%), TSS (17.42°Brix), total sugar (10.60%) was recorded in CHESJ-30. Based on the various desired traits, the genotypes, CHESJ-30 was found to be promising.

Key words: Diversity, flower length, fruit yield, ovary, panicle length, ripening time

Introduction

The jamun, botanically known as *Syzygium cumini* Skeels, is an economically multipurpose tree of the family Myrtaceae which is one of the important rainfed semi-arid fruit crops, rich in nutrients, hardy in nature, having good processing quality with wider adaptability to varied edapho-climatic conditions. Gradually, it is attaining its position among the important fruits of India. The tree is medium size, evergreen with semi-spreading growth habit. It produces purple delicious fruits with prominent seeds.

Jamun is a heterozygous, cross-pollinated fruit crop and as such existing seedling population exhibit a wide range of diversity, which aids in the selection of the superior desirable genotypes. Elite genotypes were collected from diversity rich areas based on the horticultural traits and evaluated under field condition to identify elite genotypes having earliness, short stature, precocious bearer, high yielder, high pulp content and suitable for commercial cultivation in closer spacing. Such variations were observed in terms of flowering, fruiting, yield and fruit quality attributes in jamun, chironji, mahua, tamarind, bael, custard apple, khirmi and phalsa in different agro-climatic conditions (Patel *et al.*, 2005; Singh *et al.*, 2006; Singh and Singh, 2005; Singh *et al.*, 2008; Singh *et al.*, 2014; Yadav *et al.*, 2017; Malik *et al.*, 2012; Malik *et al.*, 2013 and Singh *et al.*, 2019c). The fruit is good source of iron, sugars, minerals, protein, carbohydrate *etc.*

Fully ripe fruits are eaten fresh and can be processed into beverages like jelly, jam, squash, wine, vinegar and pickles. Fruits are used as an effective medicine against diabetes, heart and liver trouble (Singh *et al.*, 2019 a,b). The seed powder has also reputation of being useful in the treatment of diabetes. The plant can tolerate drought conditions, if occurs for some time as well as heavy rainfall conditions. Present investigation was carried out to find out variability in plant growth, flowering, fruiting and fruit quality attributes of different genotypes of jamun, so that the suitable genotype could be identified for commercial exploitation.

Materials and Methods

The location of the experiment is 113 m above MSL on latitude 22°41' 38" N and longitude 73° 33' 22" E and is characterized by hot semi-arid climate. The annual rainfall is mainly confined to three months (July-September) and actual mean precipitation is about 750 mm with number of rainy days average to about 32. The mean summer temperature is 32.9°C while the mean winter temperature is 21.3°C indicating that the area falls under hyperthermic soil regime. The mean annual maximum and minimum temperatures vary from 42-44°C (May) and 6-9°C (January), respectively. The experimental soil type was characterized with available N (151.25 kg/ha), P (8.22 kg/ha) and K (143.50 kg/ha) and organic carbon (0.33%), while EC and pH, bulk density and

hydraulic conductivity of soil were 0.14 dSm^{-1} , 8.25 , 1.42 g/cc and 0.29 cm/hr , respectively. The soil depth of experimental field ranged from 0.65 to 1.0 m derived from mixed alluvial basalt, quartzite, granite and layers of limestone which falls under semi-arid hot climate.

A total of 14 genotypes, established through *in-situ* softwood grafting, was laid out in randomized block design with 3 replications. Observations on plant growth, flowering, fruiting and fruit quality attributes were observed during two consecutive years 2015 and 2016, and mean data were subjected to statistical analysis. Twenty shoots spread over four directions on each tree were tagged and detail observations on floral traits were recorded. Forty fruits were randomly selected from all the directions of the plant for fruit quality attributes. Total soluble solids, acidity, vitamin C and sugars were analyzed by the methods as outlined by A.O.A.C. (1980). The mean data were statistically analyzed as per

method demonstrated by Gomez and Gomez (1984).

Results and Discussion

The data on vegetative growth of different genotypes depicted in Table 1 showed significant differences in respect of their vegetative characters. The vegetative growth in terms of annual extension growth varied between 34.15 to 58.00 cm being the lowest in CHESJ-28 and the highest in CHESJ-32. Among the genotypes, growth habit was observed as spreading, upright and semi-spreading. The difference in vegetative growth of different genotypes may be due to their inherent characters under varied agro-climatic conditions. Similar results with respect to vegetative characters have been reported by Singh *et al.* (2006) in chironji, Singh *et al.* (2016b) in khirni and Singh *et al.* (2014) in bael under hot semi-arid conditions of western India.

In general, peak period of panicle emergence was

Table 1. Plant growth, flowering and fruiting pattern of jamun genotypes (Mean data 2015 and 2016)

Genotype	Annual extension growth (cm)	Growth habit	Peak period of panicle emergence	Peak period of flowering	Peak period of fruit set	Panicle length (cm)	Ripening time
CHESJ -27	43.70	Spreading	2 nd week Feb	4 th week Feb	1 st week March	10.45	3 rd week June
CHESJ -28	34.15	Spreading	3 rd week Feb	4 th week Feb	2 nd week March	14.50	4 th week May
CHESJ -29	45.10	Semi - spreading	2 nd week Feb	4 th week Feb.	2 nd week March	12.17	4 th week May
CHESJ -30	46.21	Semi - spreading	2 nd week Feb	4 th week Feb.	2 nd week March	11.32	4 th week June
CHESJ -31	54.50	Upright	3 rd week Feb	1 st week March	3 rd week March	10.00	4 th week May
CHESJ -32	58.00	Semi - spreading	2 nd week Feb	4 th week Feb	2 nd week March	12.50	4 th week May
CHESJ -33	55.89	Semi - spreading	3 rd week Feb	1 st Week March	3 rd week March	14.00	3 rd week June
CHESJ -34	42.12	Semi - spreading	2 nd week Feb	4 th week Feb	1 st week March	13.12	4 th week June
CHESJ -35	56.40	Upright	2 nd week Feb	4 th week Feb	2 nd week March	11.20	4 th week June
CHESJ -36	53.10	Spreading	1 st week Feb	4 th week Feb	1 st week March	12.25	3 rd week June
CHESJ -37	52.10	Semi - spread ing	3 rd week Feb	1 st week March	3 rd week March	10.24	3 rd week June
CHESJ -38	43.80	Upright	2 nd week Feb	4 th week Feb	2 nd week March	12.50	4 th week May
CHESJ -39	46.10	Upright	2 nd week Feb	4 th week Feb	1 st week March	14.00	4 th week June
CHESJ -40	47.20	Sp reading	2 nd week Feb	4 th week Feb	3 rd week March	11.13	4 th week May
CD (5%)	1.23	-----	----	-----	----	-----	----

observed in the month of February in all the genotypes and these genotypes exhibited considerable variations. Panicle initiation starts from 1st week of February and continued up to 3rd week of February. The peak period of flowering was recorded in February and March in all genotypes. Flowering was noted in 4th week of February in CHESJ-27, CHES-28, CHES-29, CHESJ-30, CHESJ-32, CHESJ-34, CHESJ-35, CHESJ-36, CHESJ-39 and CHESJ-40. It was recorded in 1st week of March in CHESJ-31, CHESJ-33 and CHESJ-37 (Table 1). Flower bud differentiation is influenced by the prevailing agro-climatic conditions of the area. More or less similar findings have been reported by earlier workers in different fruit crops *viz.*, jamun (Patel *et al.*, 2005, Singh *et al.*, 2007), tamarind (Singh *et al.*, 2008), bael (Singh *et al.*, 2014),

khirni (Singh *et al.*, 2016b), mahua (Singh and Singh, 2005) under different climatic conditions.

The length of panicle directly associated with the number of flowers and fruit setting. Table 1 clearly indicates the significant variation in the length of panicle which varied from 10.00 to 14.50 cm among different genotypes of jamun. The maximum length was observed in CHESJ-28 (14.50 cm) followed by CHESJ-39 (14.00 cm) and CHESJ-33 (14.00 cm), while it was recorded minimum in CHESJ-31 (10.00 cm). Variation in the length of panicle may be due to genetic makeup and their adaptability to varied climatic conditions. These findings are in accordance with results as reported by Singh *et al.* (2008) in tamarind. Wide variability in respect to flowering was recorded in jamun and chironji under different

Table 2. Floral traits in different jamun genotypes (Mean data 2015 and 2016)

Genotypes	Flower length (mm)	Flower breadth (mm)	Length of calyx tube (mm)	Breadth of calyx tube (mm)	Petal length (mm)	Petal breadth (mm)	Stamen length (mm)	Ovary length (mm)	Ovary breadth (mm)	Style length (mm)
CHESJ-27	12.10	10.12	8.22	4.22	4.21	3.02	5.20	3.10	2.15	8.20
CHESJ-28	12.32	10.20	8.93	4.53	4.23	3.20	6.55	3.22	2.10	7.57
CHESJ-29	11.20	9.20	7.93	4.52	4.22	3.50	6.02	3.10	2.50	7.23
CHESJ-30	12.30	9.52	7.50	4.15	4.10	4.00	8.93	3.50	2.75	8.28
CHESJ-31	10.20	9.80	7.82	4.22	4.22	3.50	9.00	3.50	2.54	8.91
CHESJ-32	11.22	10.21	8.23	4.60	4.56	3.21	8.23	3.63	2.55	8.62
CHESJ-33	10.30	10.00	8.42	4.52	4.53	3.53	7.50	3.05	2.52	8.20
CHESJ-34	9.20	9.11	8.90	5.00	5.30	3.60	7.00	3.11	2.50	7.55
CHESJ-35	13.23	9.34	9.10	5.18	5.20	3.52	8.53	3.50	2.72	7.63
CHESJ-36	13.10	9.80	8.52	4.52	5.13	3.63	8.23	3.00	2.52	7.53
CHESJ-37	13.28	10.33	9.00	5.12	5.19	3.50	8.58	3.50	2.70	7.63
CHESJ-38	12.10	10.13	8.20	4.21	4.00	3.11	5.20	3.10	2.00	8.20
CHESJ-39	12.33	10.29	8.90	4.58	4.23	3.22	6.55	3.20	2.12	7.50
CHESJ-40	11.23	9.23	7.93	4.53	4.20	3.50	6.00	3.07	2.53	7.20
CD (5%)	0.10	0.08	0.06	0.05	0.07	NS	0.05	NS	NS	0.03

Table 3. Fruit quality attributes of jamun genotypes (Mean data 2015 and 2016)

Genotype	Fruit yield/Plant (kg)	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Pulp weight (g)	Pulp percent	TSS (%)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Vitamin C (mg/100g)
CHESJ27	20.32	16.72	3.00	2.13	13.00	77.75	14.10	0.35	9.80	3.99	42.56
CHESJ28	23.50	17.00	3.10	2.20	14.10	82.94	16.68	0.39	9.00	3.85	43.43
CHESJ29	28.65	16.20	2.80	2.20	13.30	82.09	13.29	0.38	9.00	3.84	42.13
CHESJ30	30.28	18.00	3.20	2.40	15.20	84.44	17.42	0.37	10.60	5.95	45.07
CHESJ31	27.20	15.00	2.50	2.12	12.34	82.26	14.57	0.40	8.90	3.59	43.00
CHESJ32	28.42	13.00	2.50	2.06	10.16	78.15	13.19	0.42	8.80	3.66	42.00
CHESJ33	21.95	13.90	2.19	2.10	10.70	76.97	15.00	0.42	8.85	3.70	40.11
CHESJ34	23.65	17.77	3.09	2.13	14.48	81.48	15.50	0.40	10.0	3.80	42.60
CHESJ35	20.43	15.24	2.93	2.02	12.20	80.05	14.10	0.42	9.70	3.90	42.12
CHESJ36	23.28	17.40	2.70	2.03	13.20	75.86	13.00	0.38	8.76	3.54	41.05
CHESJ37	25.70	09.14	1.98	2.01	07.28	79.64	13.14	0.35	9.44	3.95	40.45
CHESJ38	19.50	17.00	2.70	2.10	13.35	78.52	14.58	0.39	9.60	4.53	39.00
CHESJ39	18.00	16.00	2.66	2.09	13.20	82.50	14.00	0.45	9.80	3.90	40.00
CHESJ40	18.51	14.00	2.60	2.00	11.60	82.85	13.10	0.43	8.93	3.74	38.67
CD (5%)	1.12	1.14	0.31	0.08	1.10	2.00	0.21	0.01	0.40	0.32	1.11

climatic conditions (Singh and Singh, 2012; Singh *et al.*, 2006; Singh *et al.*, 2010).

Peak period of fruit setting took place from 1st week of March and lasted up to 3rd week of March. However, it may differ in different agro-climatic condition. Variability in fruit set was also recorded in jamun genotypes (Singh *et al.*, 2019 a,b). Fruits ripened in 4th week of May in CHESJ-28, CHESJ-29, CHESJ-30, CHESJ-31, CHESJ-32, CHESJ-34, CHESJ-35, CHESJ-38, CHESJ-39 and CHESJ-40. CHESJ-37, CHESJ-33 and CHESJ-36 ripened in 3rd week of June, while rest of the genotypes ripened in 4th week of June (Table 1). Such variations in fruit ripening have been reported in different fruit crops like chironji (Singh *et al.*, 2016a), bael (Singh *et al.*, 2014) and phalsa (Singh *et al.*, 2019c).

In all the genotypes, significant variation was observed for flower size, calyx tube size, petal size, stamen and style length (Table 2). The minimum flower length and breadth was observed in CHESJ-34 and the maximum length and breadth of the flower was recorded in CHESJ-37. Calyx tube length ranged between 7.50-9.10 mm being the highest in CHESJ-35 and the lowest in CHESJ-30. Breadth of calyx ranged between 4.15-5.18 being highest in CHESJ-35. The maximum petal length was recorded CHESJ-34 and it was minimum in CHESJ-38. Wide variation in stamen length was observed which ranged between 5.20-9.00 mm whereas style length ranged between 7.20-8.91 mm. However differences for ovary size and petal breadth could not reach the level of significance among the genotypes. Such variations in floral organs of fruit crops have been reported by Singh *et al.* (2014) in bael under different agro-climatic conditions.

Variability recorded in yield and fruit weight is presented in Table 3. Results of study revealed significant differences in yield and fruit weight among the genotypes. Yield per plant was recorded the highest in CHESJ-30 (30.28 kg) followed by CHESJ-29 (28.65 kg), CHESJ-32 (28.42 kg) and CHESJ-31 (27.20 kg), and it was recorded the lowest in CHESJ-39 (18.00 kg). The maximum fruit weight was recorded in CHESJ-30 (18.00 g) followed by CHESJ-34 (17.77 g) and CHESJ-36 (17.40 g), while it was recorded the lowest in CHESJ-37 (9.14g). Variation in fruit yield and weight in various fruit crops have been reported by Singh *et al.* (2014) in bael, under rainfed semi-arid conditions of western India.

Pulp content was recorded the maximum in CHESJ-30 (84.44%), closely followed by CHESJ-28 (82.94%), CHESJ-40 (82.85%) and CHESJ-39 (82.50%), it was found to be the minimum in CHESJ-36 (75.86%). Jamun fruits are also rich source of total soluble solids, sugars and vitamin C, and these values varied significantly in different genotypes (Table 3). Total soluble solids and total sugar content of fruits ranged from 13.00 to 17.42 °Brix and 8.76 to 10.60%, respectively in different genotypes. The highest TSS and total sugar was recorded in CHESJ-30, followed by CHESJ-28 and CHESJ-34. Vitamin C content was found to be highest in CHESJ-30 (45.07 mg/100g) closely followed by CHESJ-28 (43.43 mg/100g) and CHESJ-31 (43.00 mg/100g) and the lowest in CHESJ-40 (38.67 mg/100g). Malik *et al.* (2012) and Singh *et*

al. (2016b) have also recorded the remarkable variability in relation to fruit quality attributes of khirni. Based on the horticultural traits studied, the genotype, CHESJ-30 was found to be promising under rainfed hot semi-arid conditions of western India.

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Performance of bael (*Aegle marmelos* Corr.) cultivars under arid condition of Haryana

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Abstract

The study was conducted in the experimental orchard, Regional Research Station, Bawal. Bael varieties viz., NB 5, NB 9, NB 17, CISH 1, CISH 2, NB 16, Pant Aparna and Pant Sujata were evaluated for growth, yield, pulp/seed characteristics and quality parameters and recorded significant variation. Among the growth parameters CISH 2 showed dwarfing plant as compared to other cultivars. Fruit drop, fruit cracking and fruit weight were observed less in NB 5, however, number of fruits and yield were recorded highest in NB 17. Number of seed sacks and seeds per fruit were lowest in NB 16. Test weight and seed weight per fruit were highest in NB 5. TSS was recorded highest in NB 1, ascorbic acid and chlorophyll content was recorded highest in CISH 2, but acidity in Pant Sujata.

Key words: Arid conditions, *Aegle marmelos*, quality parameters, seed, yield attributes

Introduction

Bael (*Aegle marmelos* Corr.) is an indigenous fruit of India belongs to family Rutaceae. Plant of bael held sacred by Hindus and offered in prayers of deities Lord Shiva and Parvati and thus the tree is also known by the name Shivaduma (The Tree of Shiva). The bael plant has found mention in mythological treatise and Indian pharmacopoeia (Singh *et al.*, 2016). All the plant parts of bael like leaves, roots, barks, seeds and fruits are important ingredients of several traditional formulations against various diseases and many bioactive compounds have also been isolated from it (Badam *et al.*, 2002; Gupta and Tondon, 2004). Bael plants have wide range of adaptability to adverse soil and climate. The bael is found as a wild plant, in lower ranges of Himalayas up to an elevation of 500 meters. It is also found growing along foothills of Himalayas, Uttaranchal, Jharkhand, Madhya Pradesh and the Deccan Plateau and along the eastern coast (Sharma *et al.*, 2007). Bael is also cultivated in Nepal, Myanmar, Tibet, Vietnam, Laos, Cambodia, Sri Lanka, Bangladesh, Thailand, Indonesia, Malaysia, Java, Fiji, Surinam and Trinidad; some gardens of Egypt and to a limited extent on Northern Luzon of Philippine Islands. Under hot arid ecosystem the extent of hardiness has been observed and the plants are giving good yield in rainfed conditions (Singh *et al.*, 2017). Owing to its hardy nature, bael plant has a wide range of habitat flexibility to undesirable soil and climatic state even where other crops cannot endure well. However, well drained, sandy loam soils are found suitable for its growth, yield and better quality fruits.

A full grown budded bael tree of about 10-12 years old produces 100-150 fruits under good management

practices, though the seedling trees produce 300-400 fruits of smaller size (Saroj *et al.*, 2004). However, fruit yield depends on age of the tree; cultivar besides management practices. Bael gene pool is stretch over different parts of the country and has colossal inconsistency with respect to qualitative as well as quantitative characters. Apart from the tree morphological characters, ample variability exists in fruit size and shape, bearing habit, flesh colour, texture, sugar content, mucilage content, number of seeds per fruit, gum locules and pericarp thickness (Misra *et al.*, 2000); ascorbic acid content, fruit weight, fruit length, number of seeds and their weight per fruit, fibre content, petiole length (Rai *et al.*, 2002); bark, leaves and fruits (Sharma and Dubey, 2013). Recently, few land races have been developed for commercial cultivation from NDU&T, Faizabad; GBPUAT, Pantnagar; CIAH, Bikaner and CISH, Lucknow. In order to identify distinctive characters of various bael cultivars, the morphological characters are equally important to the fruit characters. In the absence of suitable genotype, desirable growth, flowering and fruit set has not been observed. Characterization and suitability genotypes for the region are necessary for promoting its productivity, production and quality of the fruits under arid conditions of Haryana. It will also help the orchardist in selection of appropriate cultivar(s) of this neglected crop for large scale cultivation to get high yield with good quality fruits. Unproductive/ barren land of this region could be utilized properly by growing such a hardy fruit crop, which holds promise for nutritional security and also helpful in curing the various ailments. The evaluation of cultivars is helpful for researcher to plan their experiment on the basis of

performance of different cultivars under these conditions.

Materials and Methods

The present study was conducted on uniformly grown bael plants in experimental orchard of Regional Research Station, Bawal. Experimental location has typical arid climate with hot dry summer and extremely cold winter. These plants were maintained under same agronomic/cultural operations. The growth parameters were observed at active growth stage of the plant. Plant height was measured from ground level to the tip of the highest shoot with the help of graduated measuring bar. Plant spread was measured as canopy width (average of east-west and north-south dimensions) during active growth period. Stem girth was measured at 15 cm above the graft union in grafted/budded plants. Chlorophyll content was analyzed from the fully grown leaf with the help of chlorophyll meter. The fruit set was calculated on the basis of total number of flowers on tagged branches. Dropped and cracked fruits were counted to calculate per cent drop/crack fruit on the basis fruits set on the tree. Fruits for yield and qualitative characters were collected at harvest maturity after complete litter fall. Randomly selected fruits from different direction of the tree were plucked and weighed on digital electric balance and these fruits were further used for qualitative analysis. The total soluble solids of fruit pulp was determined at room temperature with the help of Abbe's refractometer and the reading was expressed in °Brix. Ascorbic acid and acidity were analyzed by the method prescribed by A.O.A.C. (2000). Seed sacks were counted from horizontally broken fruit; thereafter number of seeds per sack was also counted. These collected seeds were dried in shade and weighed on digital electric balance for seed weight per fruit and test weight (ISTA, 2010). The pulp of horizontally broken fruit was scooped and shell thickness was measured with the help of digital vernier calliper, which was expressed in millimeters (mm). The statistical method described by Panse and Sukhatme (1985) was followed for analysis and interpretation of the experimental results.

Results and Discussion

Growth parameters

The results pertaining to variation in growth

parameters such as plant height, stem girth and plant spread (NS & EW) in respect of various cultivars showed significant difference. Results revealed that the highest plant height (6.50 m) was recorded in NB 17; followed by NB 16 (5.83 m), whereas lowest plant height (3.80 m) was recorded in cv. CISH 2. Maximum trunk girth (63.90 cm) was recorded in cv. Pant Sujata; followed by NB 5 and NB 16 (62.90 cm), whereas minimum plant girth (32.50 cm) was recorded in CISH 2. Plant spread (EW) was highest in NB 17 (6.50 m). However, lowest plant spread EW (4.16 m) was recorded in CISH 2. Plant spread NS was highest in NB 17 (6.40 m). However, lowest plant spread NS (3.90 m) was observed in CISH 2 (Table 1). On the basis of the data, CISH 2 showed dwarfing. Jaiswal *et al.*, (1999) reported that Pant Sujata and Pant Aparna showed dwarf trees, while Pant Bael 3 and Pant Bael 1 showed tall and vigorous growth of trees. Singh *et al.* (2014) reported that variation in vegetative growth among the varieties may be due to inherent characters of individual varieties and their acclimatization to varied agro-climatic conditions. Bael gene pool is operated over different parts of the country and has enormous variability with respect to qualitative as well as quantitative characters (Nagar *et al.*, 2018). The dwarfing is the desirable characters for the high density planting by accommodating more plants per unit area and harvest more sunlight to enhance the productivity. Mishra *et al.* (1999) also reported that the different bael genotypes exhibited variations in their growth behaviour under moist conditions of eastern India. Pandey *et al.* (2013) carried a survey of bael germplasm in different areas of UP and reported variation in fruit circumference from 29.00 cm to 61.00 cm.

Yield attributes

The results pertaining to variation per cent fruit set, fruit drop, fruit cracking, number of fruits, fruit weight and fruit yield in respect of various cultivar varied significantly among different cultivars. The range of fruit set varied from 10.91 to 17.44 per cent. Fruit set per cent was recorded maximum (17.44%) in NB 17 which was statistically at par with CISH 1 (16.71%), while minimum fruit set per cent (10.91%) was observed in Pant Sujata (Table 2). Uniyal and Misra (2013) reported maximum fruit set in Pant Aparna and

Table 1. Growth parameters of bael cultivars under arid conditions of Haryana

Cultivars	Fruit set (%)	Fruit drop (%)	Fruit cracking (%)	Number of fruits/ plant	Fruit weight (g)	Fruit yield/ plant (kg)
NB 5	13.68	89.2	11.2	80	810	64.80
NB 9	15.55	90.2	15.2	56	850	47.60
NB 17	17.44	91.3	20.5	41	1060	43.46
CISH 1	16.71	90.9	42.9	40	1520	60.80
CISH 2	15.62	91.9	35.8	43	1340	57.62
NB 16	14.43	92.5	56.2	53	900	47.70
Pant Aparna	14.89	93.5	17.3	40	972	38.88
Pant Sujata	10.91	91.2	15.5	35	1210	42.35
Range	10.91 - 17.44	89.2 -93.5	11.2 -56.2	35 -80	810 -1520	64.80 -38.88
CD at 5%	1.3	2.2	5.9	3.9	44	6.5

minimum fruit set in Pant Shivani. This variation in fruit set per cent among the various varieties of bael might be due to their inherent characters. Sometimes fruit set per cent may vary due to agronomic practices and local environmental conditions.

Fruit drop per cent in different genotypes varied from 89.20 to 93.5 per cent. Fruit drop per cent was maximum (92.5%) in Pant Aparna (93.5%) and NB 16, these values were statistically at par with CISH 2 (91.9 %), NB 17 (91.3%), however, minimum fruit drop per cent (89.2%) was recorded in NB 5 succeeded by NB-9 (90.2%). Fruit set per cent may directly affect the yield of the plant. Uniyal and Misra (2013) reported fruit drop may be due to embryo abortion. Maximum fruit drop recorded in Pant Sujata followed by Pant Uravshi, while minimum in Pant Shivani. Dropping of fruits due to embryo abortion after fertilization was also reported in litchi by Ray *et al.* (2002). One of the reasons might be due to deficiency of micronutrient especially zinc and boron. This disorder may be due to competition among fruit lets for carbohydrates, water, nutrients, hormones and other metabolites (Uniyal and Misra, 2013).

Fruit cracking in all the genotypes showed

significant variation. Fruit cracking per cent was maximum (56.20%) in NB 16, however, minimum fruit cracking (11.20%) was observed in NB 5. Uniyal and Misra (2013) reported maximum fruit cracking in Pant Sujata followed by Pant Urvashi, while minimum fruit cracking was in Pant Aparna. Boron was helpful in improving the appropriate growth of bael tree and it is constituent of cell membrane and essential for cell division, which reduces disorders like cracking in fruits. Numbers of fruits were recorded highest (80) in NB 5; followed by NB 9 (56). Lowest numbers of fruits (35) were found in Pant Sujata. Similar results have been reported in annual report of AICRP of Arid Zone fruits (Anonymous, 2014). In a different study, Kumar and Nath (2010) reported maximum number of fruits in CHBI 21 genotype followed by CHBI 20 and CHBI 19 under Orissa conditions.

Fruit weight recorded maximum (1520 g) in CISH 1; followed by CISH 2 (1340 g), whereas minimum (810 g) fruit weight was observed in NB 5. Patel *et al.* (1977) reported that increase in fruit weight of some germplasm might be due to more uptake of water, nutrients and also due to the accumulation of photosynthetic assimilates from source to

Table 2. Yield attributes of fruits of bael cultivars under arid conditions of Haryana

Cultivars	Fruit set (%)	Fruit drop (%)	Fruit cracking (%)	Number of fruits/ plant	Fruit weight (g)	Fruit yield/ plant (kg)
NB 5	13.68	89.2	11.2	80	810	64.80
NB 9	15.55	90.2	15.2	56	850	47.60
NB 17	17.44	91.3	20.5	41	1060	43.46
CISH 1	16.71	90.9	42.9	40	1520	60.80
CISH 2	15.62	91.9	35.8	43	1340	57.62
NB 16	14.43	92.5	56.2	53	900	47.70
Pant Aparna	14.89	93.5	17.3	40	972	38.88
Pant Sujata	10.91	91.2	15.5	35	1210	42.35
Range	10.91-17.44	89.2 -93.5	11.2 -56.2	35 -80	810 -1520	64.80 -38.88
CD at 5%	1.3	2.2	5.9	3.9	44	6.5

Table 3. Seed variability in different bael cultivars under arid condition of Haryana

Cultivars	Number of seed sacks/ fruit	Number of seeds /sack	Number of seeds/ fruit	Seed weight / fruit (g)	Test weight of seed (g)	Shell thickness (mm)
NB 5	14.4	7.6	110.8	19.42	15.66	3.99
NB 9	15.8	7.4	116.0	10.91	9.49	2.29
NB 17	11.6	8.6	102.2	10.04	9.93	2.66
CISH 1	14.8	5.0	74.0	5.93	8.09	3.94
CISH 2	13.4	5.6	76.4	5.71	7.55	3.06
NB 16	13.4	5.4	71.8	5.50	7.74	3.10
Pant Aparna	14.8	7.2	108.6	7.78	7.23	2.15
Pant Sujata	14.4	6.0	86.8	6.41	7.46	3.03
Range	13.4 -15.8	5.0 -8.6	71.8 -116.0	5.50 -19.42	7.23 -15.66	2.15 -3.99
CD at 5%	1.1	0.9	9.70	2.3	1.36	0.56

sink. The other probable reason may be due to fertility states of soil, micro-climate and inherent characters of germplasm. Pandey *et al.* (2005) collected the existing diversity and exploration in parts of Bihar and UP conditions and observed range of fruit weight from 1.75 kg per fruit in genotype VN/DP-6/5 to 0.64 kg per fruit in VN/DP-6/8.

Maximum yield per tree (64.80 kg) was recorded in NB 5 and minimum (38.88 kg) in Pant Aparna. A significant difference was also reported in yield per plant among various clones of bael by Jaiswal and Misra (1996). However, Bhawana and Misra (2011) reported maximum yield per plant in Pant Shivani followed by Pant Bael 17, Pant Sujata, Pant Aparna and Pant Urvashi. The variation in yields of different germplasm is more or less in accordance with the findings of Kumar and Nath (2010) and Pandey *et al.* (2013). Fruit yield varied due to variation in fruit weight, number of fruits per plant, fruit drop, fruit cracking and genetic characteristics of germplasm.

Quality parameter

The results pertaining to variation in biochemical characteristics such as TSS, acidity, ascorbic acid, and chlorophyll content in respect of various cultivars varied significantly. Chlorophyll content of the genotypes evaluated under this study ranged from 22.37 spad unit to 39.19 spad unit (Table 4). It was recorded maximum in CISH 2 (39.19 spad

unit), while the minimum in NB 9 (22.37 spad unit), which was at par with NB 5 (23.61 spad unit). Singh and Mishra (2007) reported that chlorophyll-a, chlorophyll-b and total chlorophyll contents were found higher in genotypes PB-3, PB-10, PB-22 and PB-24. TSS values of all the genotypes ranged from 29.00 °B to 40.67 °B. Maximum TSS (40.67 °B) was recorded in NB 17, followed by NB 9 (40.33 °B) and Pant Aparna (40.00 °B), whereas minimum TSS were recorded in Pant Sujata (29.00 °B). Rai *et al.* (2002) reported that TSS ranged from 32.6 °B to 36.20 °B in bael germplasm. Further, Jana *et al.* (2014) recorded variation in TSS of genotype; HABL 1 recorded maximum TSS as 37.00 °B and 39.00 °B in 2008 and 2009, respectively under Ranchi condition. More TSS in a fruit is more useful in medicinal as well as processing industry.

Acidity was noticed minimum (0.29%) in NB 9, which was at par with NB 17 (0.31%), however, maximum (0.39%) value of acidity was recorded in Pant Sujata, which was at par with Pant Aparna and NB 5(0.40 %). Similar range of acidity was also observed by Pandey *et al.* (2013), who observed minimum acidity (0.30 %) in T₁₆ genotype and maximum (0.56 %) in T₄₆ genotype. The variation in acidity among different bael germplasm was also reported by Kumar *et al.* (2008) and Raju *et al.* (2014). Variation in qualitative attributes of different germplasm at different locations might be due to adaptability to varied agro-climatic conditions, root

Table 4. Chlorophyll content and quality parameters of bael cultivars under arid conditions

Cultivars	Chlorophyll content (Spad Unit)	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100g)
NB 5	23.61	39.33	0.36	11.12
NB 9	22.37	40.33	0.29	9.87
NB 17	32.10	40.67	0.31	8.82
CISH 1	30.85	34.67	0.33	10.92
CISH 2	39.19	31.67	0.34	10.51
NB 16	33.56	39.00	0.33	11.96
Pant Aparna	31.66	40.00	0.38	13.01
Pant Sujata	28.29	29.00	0.39	12.35
Range	22.37 -39.19	29.00 -40.67	0.29 -0.39	8.82 -13.01
CD at 5%	1.50	1.50	0.03	0.80

distribution pattern of the crop and genetic make-up of the germplasm (Nagar *et al.*, 2017).

Ascorbic acid was found maximum (13.01 mg/100g) in Pant Aparna, being at par with Pant Sujata (12.35 mg/100g) and minimum ascorbic acid was recorded in NB 17 (8.82mg/100g). The results regarding variation in ascorbic acid among different germplasm are in line with the findings of Pandey *et al.* (2006) and Pandey *et al.* (2013). Singh *et al.* (2014) studied ascorbic acid content in different bael genotypes and reported maximum ascorbic acid in Goma Yashi followed by NB 5 and NB 7 and minimum in Pant Sujata.

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Effect of storage media and period on bare root transplanting of aonla (*Emblica officinalis* Gaertn) budded plants

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Abstract

The present study was carried out to find out appropriate storage medium and period of storage to improve transplanting success of aonla budded plants. There were four storage media (moist gunny bag, sphagnum moss, polythene sheet and polythene sheet + sphagnum moss) and four storage period (control-zero day, 48, 96 and 144 hours). Ten budded plants were transplanted in field at each date at 30 x 30 cm apart replicated thrice. Among different storage media moist gunny bag and sphagnum moss give better performance with respect to budded plants establishment and other growth characters followed by polythene sheet + sphagnum moss equally effective for a period of more than 48 hours in keeping bare rooted budded plants for transplanting success.

Key words: Budded plants, gunny bag, sphagnum moss, transplanting success

Introduction

Aonla or Indian gooseberry is important fruit crop indigenous to India. It can be successfully cultivated in marginal soils and various kinds of wasteland. The poor establishment of budded plants after transplanting is major problem. On other hand transplanting budded plants with earth ball cost heavy loss of fertile nursery soil and increases cost of transport budded plants to distance places. Bare rooted transplanting with growth regulators was also reported by Singh *et al.* (1982); Singh and Pandey (2003) and Sandhu *et al.*, (1983 a). Storage of budded plants often required because of labour problems, unfavorable weather condition, delay in field preparation, transplanting loss and transplanting success owing to excessive loss from budded plants. To overcome these problems of transplanting of bare rooted aonla budded plants success need to find a suitable storage media and period of storage. Media for storage of budded plants for longer period for better transplanting success is required.

Materials and Methods

The experiment was carried out at experimental orchard of Department of Horticulture, A. N. D. University Agriculture & Technology, Kumarganj, Ayodhya (U.P). For the study, single stem defoliated budded plants, uniform in age and vigour were selected for different storage medium and period of storage. There were four storage media including moist, gunny bag, sphagnum moss, polythene sheet and polythene sheet + sphagnum moss; and four storage period *i.e.* control (zero day) 48, 96 and 144 hours. Ten budded plants were transplanted in field at each date at 30 x 30 cm apart, replicated thrice. The observations were recorded on transplanting success and plant growths of budded plants were recorded after 150 day of transplanting. The data was analyzed

as per method given by Panse and Sukhatme (1989).

Results and Discussion

Storage medium and period played vital role in establishment of aonla budded plants (Table 1). Bare rooted budded plants stored in moist gunny bag showed highest success (75.00%) closely followed by sphagnum moss (74.17%) and polythene sheet + sphagnum moss (71.67%). Budded plants establishment decreased during storage but budded plants establishment was not affected up to 48 hrs storage. Data presented in Table 2 indicated sprouting (25.75 days) in polythene sheet + sphagnum moss stored budded plants. Budded plants stored in moist gunny bag (28.42 days) was statistically at par with sphagnum moss stored budded plants. The time taken was significantly less in case of 48 hrs storage (24.50 days) as compared with other storage period.

It is evident from Table 3 and 4 that budded plants height and diameter were influenced by various storage media and period of storage. The plant height was highest (109.25 cm) in moist gunny bag and minimum in polythene sheet stored budded plants. Budded plants diameter ranged between 1.13 cm in polythene sheet to 1.21 cm in moist gunny bag storage media and differed significantly. Budded plants diameter decreased with increase in storage period being (1.25 cm) in immediate transplanting followed by after 48 hrs transplanting moist gunny bag. Storage media and period of storage also influenced number of branchlets per budded plants (Table 5). The highest number of branchlets (154.41) noted in budded plants stored in moist gunny bag which did not differed significantly with other storage media except, polythene sheet however, with increase in storage period it decreased.

Fresh weight of scion shoot and root were also influenced by storage media and period of storage (Table 6). The maximum fresh weight (183.80 g) and root (77.95 g) was recorded with the budded plants stored in moist gunny bag, however, there was no significant difference among budded plants transplanted after storing in moist gunny bag, sphagnum moss or polythene shoot + sphagnum moss.

The present study on storage media and storage period on bare rooted budded plants showed promising results (Table 7). Among different storage media, moist gunny bag and sphagnum moss gave better performance with respect to budded plants establishment and other growth characters

followed by polythene sheet + sphagnum moss. Similar results have been reported by Kanwar and Singh (1981) in ber. On the other hand, increased storage period caused contrary effect on the traits. Similar observations were also in conformity with the findings of Beniwal *et al.* (1984) in ber. The reason seems to be that budded plants polythene sheet media got suffocated due to poor aeration and higher temperature. The budded plants in remaining three media as moist gunny bag, moist sphagnum moss and polythene sheet + sphagnum moss remained in good condition up to 48 hrs of storage due to better aeration and in the storage media.

Table 1. Effect of storage media and period on the establishment of budded plants

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	80.00 (63.93)	80.00 (63.93)	73.33 (59.00)	66.67 (54.78)	75.00 (60.97)
Sphagnum moss	80.00 (63.93)	76.67 (61.22)	73.33 (59.00)	66.67 (54.78)	74.17 (59.73)
Poly. sheet	80.00 (63.93)	70.00 (56.79)	60.00 (50.85)	56.67 (43.08)	64.17 (53.66)
Poly. sheet+ Sphag. moss	80.00 (63.93)	76.67 (61.22)	70.00 (56.79)	60.00 (50.77)	71.67 (58.18)
Mean	80.00 (63.93)	75.84 (60.79)	69.17 (56.41)	60.00 (51.40)	
C.D. (5%): Storage media 0.05, Storage period 0.05, Storage media x storage period NS					

Table 2. Effect of storage media and period on days taken to start sprouting budded plants

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	32.00	25.00	26.67	30.00	28.42
Sphagnum moss	32.00	24.33	26.00	29.00	27.83
Poly. sheet	32.00	26.00	30.00	40.67	32.17
Poly. sheet+ Sphag. moss	32.00	22.67	23.00	25.33	25.75
Mean	32.00	24.50	26.42	31.25	
C.D. (5%): Storage media 0.94, Storage period 0.94, Storage media x storage period 1.88					

Table 3. Effect of storage media and period on diameter of budded plants (cm)

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	1.25	1.22	1.19	1.17	1.21
Sphagnum moss	1.25	1.20	1.17	1.14	1.19
Poly. sheet	1.25	1.15	1.10	1.01	1.13
Poly. sheet+ Sphag. moss	1.25	1.20	1.17	1.12	1.18
Mean	1.25	1.19	1.16	1.11	
C.D (5%): Storage media 0.05 Storage period 0.05 Storage media x storage period NS					

Table 4. Effect of storage media and period on height of scion shoot (cm)

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	115.36	110.85	107.28	103.50	109.25
Sphagnum moss	115.36	108.56	105.50	98.82	107.06
Poly. sheet	115.36	103.72	95.80	91.40	101.57
Poly. sheet+ Sphag. moss	115.36	107.90	104.10	97.25	106.15
Mean	115.36	107.76	103.17	97.74	
C.D. (5%) Storage media 5.05 Storage period 5.05 Storage media x storage period NS					

Table 5. Effect of storage media and period on number of branchlets per budded plants

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	160.33	156.60	153.20	147.50	154.41
Sphagnum moss	160.33	154.40	148.47	138.53	150.43
Polythene sheet	160.33	138.24	126.10	120.30	136.24
Polythene sheet + Sphagnum moss	160.33	150.50	145.27	133.60	147.42
Mean	160.33	149.93	143.26	134.98	
C.D. (5%): Storage media 11.83, Storage period 11.83, Storage media x storage period NS					

Table 6. Effect of storage media and period on fresh of weight scion shoots (g)

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	188.62	184.21	182.56	179.81	183.80
Sphagnum moss	188.62	183.27	179.00	172.35	180.86
Polythene sheet	188.62	175.30	171.42	160.08	173.85
Polythene sheet + Sphagnum moss	188.62	182.50	178.80	171.20	180.28
Mean	188.62	181.37	177.94	170.86	
C.D. (5%): Storage media 7.05, Storage period 7.05, Storage media x storage period NS					

Table 7. Effect of storage media and period on fresh weight of roots (g)

Storage media	Storage period				Mean
	Planting immediately	Planting after 48 hours	Planting after 96 hours	Planting after 144 hours	
Moist gunny bag	82.30	79.46	75.80	74.23	77.95
Sphagnum moss	82.30	78.21	75.36	70.60	76.62
Polythene sheet	82.30	74.27	70.04	63.20	72.45
Polythene sheet + Sphagnum moss	82.30	77.32	75.00	70.20	76.20
Mean	82.30	77.32	74.05	69.56	
C.D. (5%): Storage media 3.72, Storage period 3.72, Storage media x storage period NS					

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Standardisation of juice extraction method from phalsa (*Grewia subinaequalis* L.) fruits

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Abstract

Phalsa fruits are highly perishable in nature resulting in very high amount of postharvest losses. This could be managed only through proper value addition of the ripe fruits. Fruits are often processed into juice due to their pleasant taste and cooling effects. Phalsa juice is very popular due to its pleasing flavour and deep crimson-red colour. However, the process of extraction of juice from the phalsa fruits is highly tedious and complex process due to their minute size and bigger seed size. The recovery of juice from the fruits varies with the method of extractions such as mechanical or manual *etc.* Hence, an attempt was made to standardize the juice extraction methods for achieving greater quantity and quality of phalsa extracts. The methods used include manual crushing, microwave heat application (900 watt) prior to and after crushing, direct heat application (60°C), prior to and after crushing, and freezing followed by thawing. Among various physical extraction methods used for juice extraction from ripe phalsa fruits, the freezing and thawing method was found to be best suitable method in terms of obtaining higher percentage of recovery as well as for recording more sensory score in terms of flavour, taste and overall acceptability.

Key words: Extraction methods, *Grewia subinaequalis*, juice, phalsa, sensory quality

Introduction

Phalsa (*Grewia subinaequalis* L.) is an underexploited minor fruit of Indian origin. The genus *Grewia* belongs to the Tiliaceae family consists of around 150 species of which 40 are available in India. Phalsa plants are small, bushy and highly climate resilient as they could tolerate extreme high temperatures of 45° during summers and freezing temperatures for few days (Khurdiya and Anand, 1981a, b). These plants are often cultivated in marginal lands and peri-urban areas to facilitate timely marketing of the fruits. In India, phalsa is majorly grown in the states of Uttar Pradesh, Rajasthan, Madhya Pradesh, Punjab, Haryana, Maharashtra, Bihar, West Bengal, Gujarat and Andhra Pradesh. The fruits are highly perishable in nature owing to perishability they cannot be exported but their processed products are highly appreciable. Ripe fruits are consumed fresh in desserts, or processed into refreshing soft drinks like squash, RTS, Sherbet *etc.* which are enjoyed during hot summer months in India (Tiwari *et al.*, 2014).

Ripe fruits of phalsa contain high amounts of vitamin A, C, minerals (calcium, phosphorus and iron) and fibre; however, low in calories and fats. Fruit pulp and seeds contain essential amino acids like threonine and methionine, respectively. Phosphoserine, serine and taurine are the dominant amino acids present in fruit juice. The attractive crimson red to dark purple colour of phalsa fruit is due to anthocyanin pigments mainly, delphinidin-3-glucoside, cyanidin-3-glucoside and pelargonidin-3, 5-diglucoside. The major phytochemical compounds present in the fruit of phalsa are triterpenoids, fatty component, flavonoids (quercetin,

quercetin-3-O-β-D-glucoside and naringenin-7-O-β-D-glucoside), steroids, saponins and tannins. The fruit possess very high antioxidant activity due to presence of vitamin C, phenolics, flavonoids, tannins and anthocyanins. In the fruit, highest antioxidant activities are found in fruit peel followed by pulp and seeds. The air-dried phalsa seeds are also rich in linoleic acid, besides containing fair amount of palmitoleic, heptadecanoic, linolenic and arachidic acids (Khurdiya, 2001).

Phalsa is a summer season fruit and are generally harvested during the month of March-April in the South and May-June in the North India. The fruits are highly perishable thus due care must be taken while harvesting to avoid physical injuries such as bruising, skin punctures and cuts. Immediately after harvesting, prompt cooling of fruit is essential for the shelf life of phalsa. Being highly perishable in nature, the fruit cannot be stored for a longer period and must be marketed within 24 hours or used for processing to make stable products. Fruits harvested at unripe mature stage, can be stored up to 48 hours while, fully ripe fruit cannot be stored more than 24 hours at ambient conditions. Fruits harvested at turning stage can be stored for a week at 7°C under cold storage.

Post harvest losses in phalsa are very high and it can be managed by value addition in fruits. Phalsa juice is very popular due to its pleasing flavour and deep crimson-red colour. In addition, due to extremely refreshing quality of phalsa juice, it can be processed into ready-to-serve (RTS) and carbonated beverages. Syrup and squash can also be prepared with phalsa fruit juice after mixing with sugar and preserved

with sodium benzoate. However, extraction of juice from the harvested fruits is a tedious task as the seed portion is relatively more compared to the pulp/ juice content. Thus, it's a great challenge to extract juice from the phalsa fruits with all its bio-active and other health beneficial components. Hence, an experiment was designed to standardise various physical methods for extracting juice from the phalsa fruits.

Materials and Methods

Fully ripe phalsa fruits are freshly harvested from the research farm of CIAH during the early hours of the day and transported to the post harvest laboratory. In the laboratory, the fruits are sorted out to remove any unripe and damaged fruits. Later the fruits are washed under running water to remove surface dirt and other foreign materials. The fruits are then weighed and separated for imposing various treatments viz. T₁ (Control-Mashing/ Manual crushing); T₂ (Mashing followed by Microwaving @ 900 W for 5 min); T₃ (Microwaving @ 900 W for 5 min followed by mashing); T₄ (Heating at 60°C for 5 min followed by mashing); T₅ (Mashing followed by heating at 60°C) and T₆ (Freezing at -20°C followed by thawing). After application of various treatments, the final extraction mixture was passed through double layered muslin cloth for final filtration and squeezing. The amount of juice extracted with each treatment was measured using measuring cylinder replication wise and the pomace left over was weighed separately.

The juice extracted by various methods is subjected to sensory evaluation using 9 point hedonic scale. The sensory data for color/ appearance, taste, flavour, mouth feel and overall acceptance was recorded by using semi-trained panellists of different age groups (20-30; 31-50 and 51-60 years). The significance of various treatments analyzed using analysis of variance (ANOVA) and Fisher's Least Significant Difference at 5% level (p=0.05). The data are represented as mean values ± standard deviation; the alphabet after mean value indicates the significance at 5% level. The entire analysis was performed using online SAS program (version 9.3).

Results and Discussion

Due to high perishability of the phalsa fruits, the surplus production needs to be processed immediately for conversion into stable products such as squash/ powder from.

For processing into various products, juice extraction from the ripe fruits is the basic step and the juice yield recovery varies with the method adopted for extraction. We attempted various physical treatments like application of heat, cold and microwaves (900 watt) for extraction of the juice from the ripe phalsa fruits. The effect of various physical treatments on the juice yield recovery and its sensory quality was studied.

The results of the study (Table 1) indicated that, the juice recovery was significantly high (70.56 %) from the fruits subjected to freezing at -20°C followed by thawing (T₆). This is succeeded by physical treatment of microwaving at 900 watt for 5 min prior to manual crushing (67.49 %)/ maceration (T₃) which is on par with the control treatment (T₁) where juice is extracted by traditional mashing procedure. Higher recovery from the frozen fruits could be due to formation of ice crystals within the cellular fluids resulting in the cell rupturing and release of all fluids from the cell structure during extraction after thawing. Similar reports of using freezing and thawing as pre-treatments for apple pulp prior to main processing by Nadulski *et al.* (2016). The reduction of recovery percentage in other extractions might be due to evaporation of water during heating process. Least per cent of juice recovery (51.44 %) was observed with the treatment of heating-up of macerated pulp to 60°C for 5 min (T₅) followed successively by heating of fruits @ 60°C followed by mashing (T₄) treatment (55.47%).

Among various methods, the leftover pomace percentage was significantly low (20.49 %) in the treatment T₆ (Freezing and Thawing) while it was highest (33.29 %) in the treatment T₅ (Mashing followed by heating at 60°C). Sensory evaluation data has revealed that the scoring for colour/ appearance was more for the juice extracted through microwaving methods (T₂ and T₃). This is clearly evident from the intensity of anthocyanin pigmentation in the extracted juice (Fig. 1). This might be due to rupturing of cells and cellular components like vacuoles where the pigments such as anthocyanins are stored in the cell. Several authors reported on the advantages of microwave-assisted extraction compared to conventional extraction, such as reduced process time, lower solvent and energy demand, and higher yield (Hemwimon *et al.*, 2007; Proestos and Komaitis, 2008; Chen *et al.*, 2008). Also, the water molecule being polar in nature absorbs the applied microwave radiation efficiently. The sensory parameters taste, aroma/ flavour and overall acceptability was

Table 1 . Juice recovery obtained through various extraction methods

Treatment	Method of extraction	Juice recovery (%)	Pomace waste (%)
T1	Mashing (Manual crushing)	67.53 ^b ± 0.86	25.40 ^e ± 1.05
T2	Mashing + Microwaving (5 min)	61.65 ^c ± 1.08	24.76 ^e ± 1.43
T3	Microwaving (5 min) + Manual crushing	67.49 ^b ± 1.21	24.57 ^e ± 1.13
T4	Heating (60°C) for 5 min + Mashing	55.47 ^d ± 1.16	30.72 ^b ± 0.79
T5	Mashing + Heating (60°C) for 5 min	51.44 ^e ± 0.93	33.29 ^a ± 1.12
T6	Freezing (-20°C) + Thawing	70.56 ^a ± 0.69	20.49 ^d ± 0.85
	LSD @ 5 %	1.79	1.93

Values are mean ± standard deviation of three replicates

Values with same letters are not significantly different at 5% level

observed to be high with the juice extracted by freezing and thawing treatment (Fig. 2) which might be due to preservation of the flavour volatiles by frozen fruits and alternatively the heat applied in other treatments could have liberated the flavour volatiles from the juice resulting in their reduced overall acceptability.

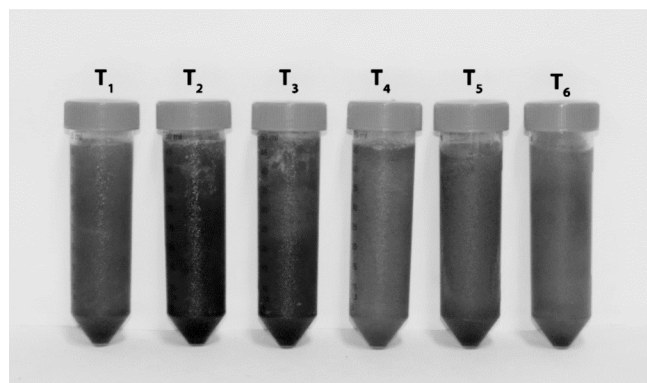


Fig. 1. Variation in the colour and pigmentation of the phalsa extract obtained by different methods

Conclusion

Among various physical extraction methods used for juice extraction from ripe phalsa fruits, the freezing and thawing method was found to be best suitable method in terms of obtaining higher percentage of recovery as well as for recording more sensory score in terms of flavour, taste and overall acceptability.

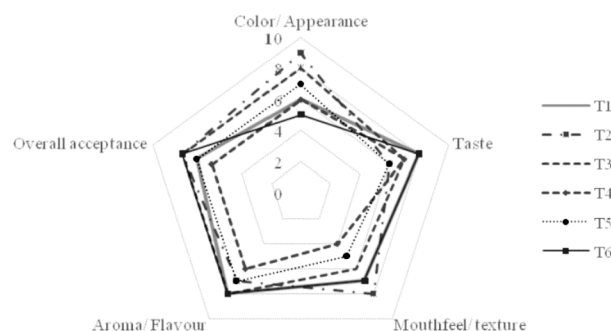


Fig. 2. Sensory acceptability of the phalsa juice extracted by different methods

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Effect of NAA, GA₃ on growth, yield and quality of cluster bean, okra and cowpea in arid condition of south-western Rajasthan

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Abstract

The field experiments were conducted on three different vegetable crops at College of Agriculture, Sumerpur (Rajasthan) during Kharif and Zaid season of 2018-19 continuously to study the effect of plant growth regulators (NAA, GA₃) on growth, yield and quality of cluster bean [*Cyamopsis tetragonoloba* (L) Taub.], okra (*Abelmoschus esculentus* L.) and cowpea (*Vigna unguiculata*). The experiments were laid out in randomized block design with sixteen treatments in three replications. The treatment comprised of three levels of individual growth regulator of GA₃ and NAA (50, 100, 200 ppm) and their nine combinations. Results revealed that the all variables regarding vegetative and reproductive growth were influenced by different concentrations of the growth regulators. Growth regulators were less effective when applied individually as compared to their combined use however, performance of plants treated with individual PGR was better than the untreated plants. In cluster bean, among the different combination of treatments, T₁₂ (GA₃ 100 ppm + NAA 200 ppm) registered the maximum number of pod cluster plant⁻¹ (20.25), number of pods plant⁻¹ (344.71), marketable green pod yield (116.07 q ha⁻¹), highest net return of Rs.265207.50 ha⁻¹ with maximum B:C ratio of 3.23 as compared to rest of the treatment combinations. In okra T₁₅ treatment (GA₃ 200 ppm and NAA 200 ppm) performed better than other treatments with the highest number of fruits plant⁻¹ (12.60), fruit length (10.90 cm), fresh weight of fruit (10.69 g), total fruit yield (67.34 q ha⁻¹) and net return of Rs. 132867.5 ha⁻¹ with maximum B:C ratio of 2.74. Cowpea also performed better when medium dose of growth regulators (100 ppm GA₃ + 100 ppm NAA) were applied under T₁₁ treatment with maximum pod yield plant⁻¹ (198.85 g), marketable green pod yield (99.64 q ha⁻¹), highest net return Rs. 133394.00 ha⁻¹ with maximum B:C ratio of 3.81 as compared to rest of the treatments.

Key words: GA₃, Napthalene-acetic-acid, morpho-physiological traits, plant growth regulator

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench], is an important herbaceous annual plant belongs to family Malvaceae growing in tropical and subtropical parts of the world. India is the global leader in the okra production (Saxena *et al.*, 2016). These green fruits are rich sources of vitamins, calcium, potassium, magnesium, phosphorus, vitamin 'A' and 'C'. The edible fruit of okra (100 g) contains moisture (89.6%), vitamin A (88.01 I.U.), thiamine (0.07 mg), vitamin C (13 mg), riboflavin (0.1 mg) with the little amount of iron (1.5 mg) and other nutrients. Okra is extensively grown in India throughout the year for its tender non-fibrous edible fruit. It is very popular among the farmers because of easy in growing and has wider adaptability range. Besides being a vegetable, it also has medicinal and industrial importance. Cluster bean [*Cyamopsis tetragonoloba* (L) Taub.] and Cowpea [*Vigna unguiculata* (L.) Walp.] belongs to the family leguminosae, both are one of the important summer vegetables. It can be grown on soil of low fertility as well as drought prone arid and semi arid area of Rajasthan. They are a good source of protein,

vitamin A, thiamin, riboflavin, iron, phosphorus, and potassium, and a very good source for vitamin C, folate, magnesium, and manganese. These crops are gaining popularity among vegetable growers due to higher remuneration and steady market demand. A nitrogen-fixing legume, cluster bean and cowpea can be included in crop rotations to build up soil nitrogen. Cluster bean and cowpea is particularly useful for building up fertility in country that has been run down from over-cropping. Provided crop is properly nodulated, cluster bean and cowpea can fix 20 to 140 kg residual nitrogen ha⁻¹ into the soil. This can give a significant bonus to later cereal crops in the rotation. However, poor productivity level with traditional practices impairs wider acceptability of the crop. In crop production plant growth regulators promotes growth along with the longitudinal area, increase number of branches, early flower initiation, fruit set, fruit quality and subsequently contributes towards higher production when applied at various concentrations. There is a tremendous scope to increase the current productivity level by adopting innovative practices. Plant growth regulators

(PGR's) are considered as a new generation of agrochemicals which affect the physiology of plant growth and influence the natural rhythm of a plant when added in small amounts. Different treatments of plant growth regulators were found effective in increasing the growth and yield parameters through enhanced biomass production and translocation of assimilates toward developing sink. In addition, GA₃ and NAA are also emerging as plant booster for improving the physiological efficiency of the crop. GA₃ has been reported beneficial in cluster bean, okra and cowpea because it is involved in the regulation of growth and development of the crop.

The role of GA₃ has been reported to be involved in regulation of growth through cell division and enlargement. NAA is also being used in many vegetable crops at various stages of development for increasing growth and yield by way of cell elongation, enlargement and differentiation. Artificial foliar spray of growth regulators has been found effective in increasing vegetative growth, early fruiting, total yield and quality of fruits in many vegetables (Ibrahim *et al.*, 2007). Plant growth regulators are one of the cheap and widely used physiological manipulators which can be used for productivity enhancement in okra. Although plant growth regulators have great potential for growth improvement but their application has to be planned sensibly in terms of optimal dose, stage of application, crop specificity and seasons (Khan *et al.*, 2006). Even the same growth regulator at different dose can bring about different results. To obtain the precise recommendations regarding growth regulators (GA₃ and NAA) application through foliar spray on cluster bean, okra and cowpea crop during kharif and zaid season, field experiments entitled with the objectives to assess response of foliar application of NAA and GA₃ on growth and yield of cluster bean, okra and cowpea and to evaluate the economic feasibility of the treatments.

Materials and Methods

The present experiments were carried out during kharif and zaid season of 2018-19 at the experimental field of College of Agriculture, Sumerpur (Rajasthan). The experiment was conducted on three different vegetable separately and laid out in randomized block design with three replications which have sixteen treatment combinations. The treatments comprised three levels of GA₃ [T₁ (50 ppm), T₂ (100 ppm) and T₃ (200 ppm)] and NAA [T₄ (50 ppm), T₅ (100 ppm) and T₆ (200 ppm)] and nine combinations of GA₃ and NAA [T₇- 50 ppm GA₃ + 50 ppm NAA, T₈- 50 ppm GA₃ + 100 ppm NAA, T₉- 50 ppm GA₃ + 200 ppm NAA, T₁₀- 100 ppm GA₃ + 50 ppm NAA, T₁₁- 100 ppm GA₃ + 100 ppm NAA, T₁₂- 100 ppm GA₃ + 200 ppm NAA, T₁₃- 200 ppm GA₃ + 50 ppm NAA, T₁₄- 200 ppm GA₃ + 100 ppm NAA, T₁₅- 200 ppm GA₃ + 200 ppm NAA] with untreated [T₀ (distilled water)]. The soil of experimental field was uniform in fertility, sandy loam in texture, low in organic carbon (0.58% and 0.58%), medium in available P (25.5 kg and 24.5 kg ha⁻¹) and high in K (280.0 kg and 285.0 kg ha⁻¹) with saturated extraction electrical

conductance of 2.0 ds.m⁻¹ and slightly alkaline reaction (pH 8.2) during both kharif and zaid season of experimentation, respectively. The abiotic factors *viz.*, average minimum and maximum temperatures were 28.0° ± 5.0°C and 38.0° ± 5.0°C, average relative humidity of 58.0 ± 10.0% and 485.0 mm rainfall per annum were recorded during the experimentation. The experiment field was supplied with well rotten farm yard manure (20 t ha⁻¹) as basal dose at 20 days before seed sowing. Fertilizers (NPK 60:40:40 kg ha⁻¹ for okra, 30:40:40 kg ha⁻¹ for cluster bean and cowpea) were supplied through urea, single super phosphate (SSP) and muriate of potash (MOP), respectively. Basal application of full dose of SSP, MOP and half dose of urea was given at the time of sowing and remaining half dose of urea was given as top dressing at 30 days after sowing. Seeds of okra cv. 'Arka Anamika', clusterbean cv. 'Thar Bhadvi' and cowpea cv. 'Kashi Kanchan' were sown in month of February for zaid season crop and in July for kharif crop at the spacing of 45 cm x 45 cm with a net plot size of 6.0 m². NAA and GA₃ were applied at 4 true-leaf stage with two litre capacity hand sprayer. The crop was raised adopting standard cultural practices and plant protection measures were implemented uniformly in all treatments as and when required. For recording different field observations, five plants of cluster bean, okra and cowpea from each net plot area were selected randomly in the beginning and tagged with the labels.

The data on parameters like plant height at maturity (cm), number of leaves plant⁻¹, number of days taken to first flowering, number of pods/fruits plant⁻¹, fruit quality, yield (q ha⁻¹), net return (Rs) and B:C ratio were recorded. Chlorophyll content of leaves was observed by direct method used by SPAD. The number of cluster per plant was counted at the time of each picking and average was worked out. The number of pods/fruits were counted per cluster at each picking and then averaged to obtained number of pods per cluster. The number of pods/fruits per plant were counted at each picking and then averaged to obtained number of pods/fruits per plant. From the ten randomly selected pods/fruits, the lengths of pod/fruit was measured in centimeter from the stalk to the apex by thread and mean pod length was determined by summing up the length of all ten pods and divided by ten. Ten fresh and marketable pods/fruits from each treatment were selected randomly for weighing and their average value was recorded as pod/fruit weight in gram. Pod/fruit yield was derived by summing up the pod weight of all the pods/fruits harvested from the net plot during all the pickings and then summed to obtain the pod/fruit yield. The values of pod/fruit yield were converted in q ha⁻¹. Furthermore, the net return was calculated by subtracting cost of each treatment from gross return. The gross return was calculated from yield multiplied by average market rate during the period of investigation. The benefit cost ratio was calculated by dividing net return to total cost. The data were analyzed statistically following the standard procedure given by Panse and Sukhatme (1967). Significance of differences among treatment means were calculated at 5 per cent level of significance.

Results and Discussion

The results of the analysis of variance showed that the effects of growth regulators *i.e.* NAA and GA₃ on vegetative and yield parameters were significantly affected by treatments ($P \leq 0.05$) in these experiments (Table 1 to 6).

Effect of GA₃ and NAA on cluster bean

The application of both PGRs (GA₃ and NAA) either alone or in combination significantly improved growth and yield related traits of cluster bean. The maximum plant height (98.72 cm) and number of leaves plant⁻¹ (99.0) were recorded in plants sprayed with solution containing both 50 ppm GA₃ + 200 ppm NAA (T₉ treatment), which was at par with all combined application of both growth regulators. It is clear from the study that exogenous application of plant growth regulators stimulate the effects of enzymatic activities of natural occurring hormones that accelerated and modified the growth and development of plants and hence increased number of leaves and plant height.

The results are in line with the findings of Patel *et al.* (2011) in cowpea, Satodiya *et al.* (2011) and Dholariya *et al.* (2018) in cluster bean. Days to first flower appearance is one of the important parameters attributing yield, treatment combination with NAA 200 ppm + GA₃ 200 ppm (T₁₅) showed the earliest (35.20 days) flower appearance followed by 200 ppm GA₃ + 50 ppm NAA (T₁₃) (35.40 days), whereas the control (44.67 days) was latest for appearance of flowering (Table 1). This might be due to the reason that higher concentration of GA₃ reduced the days required for flowering which ultimately led towards early flower production. These results were supported by Bhagure and Tambe (2013) and Meena *et al.* (2017) in okra. Plant growth regulators were found to have non-significant effect on chlorophyll content of leaves (SPAD value), number of pods cluster⁻¹, pod length and fresh weight of pods. The observation recorded on yield attributes (Table 1 and 2) indicated that all the treatments significantly enhanced the yield parameters as compared to control. The highest number of cluster plant⁻¹ (20.25), maximum number of pods plant⁻¹ (344.71) and marketable green pod yield (116.07 q ha⁻¹) were recorded when GA₃ 100 ppm + NAA 200 ppm (T₁₂ treatment) was sprayed to the plants. This might be due to synergistic effect of GA₃ in stimulation of cell division and cell elongation, which ultimately affect overall growth and yield of the plant. Similar results were also recorded by Dholariya *et al.* (2018) in cluster bean. Pod quality was also significantly influenced by applications of growth regulators and the highest quality score (8.44) observed by the combined application of both regulators with 100 ppm GA₃ + 200 ppm NAA (T₁₂ treatment).

The results are in conformity with Golakiya *et al.* (2017) in cowpea, Patel *et al.* (2015), Dholariya *et al.* (2018) in cluster bean. The data presented in Table 2 revealed that among the different combination of treatments, T₁₂ (GA₃ 100 ppm + NAA 200 ppm) registered the highest net return Rs. 265207.5 ha⁻¹ with maximum B:C ratio value of 3.23:1 as compared to rest of the treatment combinations. Moreover, the

next best treatment was T₁₁ (GA₃ 100 ppm + NAA 100 ppm) registered the net return of Rs. 252771.7 ha⁻¹ with B:C ratio of 3.08:1. Whereas, treatment T₀ (Control) recorded the lowest net return of Rs. 168434 ha⁻¹ with lowest B:C ratio of 2.05:1. This might be due to higher green pod yield registered under T₁₂ treatment. Similar result was also found by Golakiya *et al.* (2017) in cowpea and Dholariya *et al.* (2018) in cluster bean.

Effect of GA₃ and NAA on okra

The plant height recorded at 60 days after sowing showed significant difference with various treatments. The maximum plant height (52.80 cm) was obtained in the treatment T₁₄ (200 ppm GA₃ + 100 ppm NAA). It increased the plant height significantly over control and rest of the treatments. The treatment T₁₄ increased the plant height by 33.67 per cent over control and it was statistically at par with the treatment T₁₅ and T₁₃ (Table 3). It is observed fact, that GA₃ act in cell elongation or cell enlargement resulting in increased in size and number of leaves. Similar result was also reported by Baraskar *et al.* (2018) in okra. The maximum number of leaves plant⁻¹ (45.20) was obtained with the treatment T₁₅ (200 ppm GA₃ + 200 ppm NAA) at the time of last harvesting (cumulative). It significantly increased the number of leaves plant⁻¹ as compared to control. It is well established fact that GA₃ and NAA act by cell elongation resulting in increased number of leaves.

The similar results were also reported by Mandal *et al.* (2012) and Chowdhury *et al.* (2014), Baraskar *et al.* (2018) in okra. It is clear from the data (Table 3) that, days taken to first flowering marginally reduced with the application of GA₃ and NAA as foliar application. Among all the treatments minimum 40.50 days taken to first flowering was recorded under the treatment T₉ (50 ppm GA₃ + 200 ppm NAA) and maximum 45.48 days taken to first flowering was under control. This might be due to NAA 200 ppm which most important primary site of action as the cell division is stimulated in the shoot apex especially more in basal meristematic cells from which large files of cortex and pith cells develop. These results were in conformity with those of Patil and Patel (2010) and Singh *et al.* (2012) in okra. Application of medium dose of GA₃ (100 ppm) was found to have significant effect on chlorophyll content of leaves with highest SPAD value (53.57) in treatment T₂. The treatments T₃, T₄, T₇ and T₁₂ also recorded significantly higher chlorophyll content of leaves than that of control, but these were at par with each other. Earlier results by Chatterjee and Choudhuri (2012) revealed that maximum chlorophyll content (SPAD value 52.30) of leaves was observed in the plots sprayed with GA₃ 150 ppm.

The significant variation in the fruits yield parameters was noted under different treatments (Table 3). The maximum number of fruits per plant (12.60) was recorded under the treatment T₁₅ (200 ppm GA₃ + 200 ppm NAA). Treatment T₁₅ recorded 40.0 per cent increase in number of fruits over control. The treatments T₁₄ and T₁₃ also recorded

significantly higher number of fruits than that of control, but these were at par with T₁₅. There was significant variation in the number of picking due to different treatments. The maximum number of picking (12.49) was recorded in the treatments T₁₅ followed by T₁₄ and T₁₃, respectively. All these treatments showed higher number of pickings than the control but these treatments did not differ significantly from each other. The minimum numbers of picking (9.0) was found in control. The maximum duration of harvesting (47.0 days) was found under the treatment T₆ (NAA 200 ppm), which was found non-significantly higher than control and rest of the treatments. There was significant variation in fruit length, fresh weight of fruits, and quality score of fruits with various treatments (Table 4). The maximum fruit length (10.90 cm) was obtained with T₁₅ (200 ppm GA₃ + 200 ppm NAA) that was significantly higher than all treatment including control. The increase in fruit length could be due to cell elongation. The results were supported by Ravat and Makani (2015) and Meena *et al.* (2017) in okra.

The maximum fresh weight of green fruit (10.69 g) was recorded in T₁₅ (200 ppm GA₃ + 200 ppm NAA), which was closely followed (10.68 g) by the treatment T₁₄ and the minimum (7.89 g) was recorded in control (T₀). The maximum quality score of fruit (8.50) was recorded with the foliar application of T₁₅ (200 ppm GA₃ + 200 ppm NAA) which was found to be significantly higher over rest of the treatments including control but at par with T₁₄, T₁₃, T₁₁, T₁₀ and T₈. The analysis of variance exhibited significant variation among the treatments for yield of fruits per hectare.

All the treatments showed significantly higher yield than control. Treatment T₁₅ (200 ppm GA₃ + 200 ppm NAA) obtained higher yield (67.34 q ha⁻¹) that was at par with T₁₄ in the descending order. Earlier results by Kokare *et al.* (2006) revealed that maximum plant height was observed in the plots sprayed with GA₃ 200 ppm, while spraying the plants with NAA 200 ppm resulted in increase in number of leaves, leaf area, plant dry weight, number of fruits, fruit girth, fruit yield per plant, fruit yield (t/ha) and ascorbic acid content over the control (sprayed with distilled water). Ayyub *et al.* (2013) also reported enhanced vegetative and reproductive growth of okra in response to 100 ppm of GA₃, applied after three weeks of sowing. More or less similar effect of GA₃ and NAA has been obtained on okra crop with respect to variation in yield attributes of various cultivars at different climatic conditions by Meena *et al.* (2017).

The maximum net return (Rs. 132867.5 per hectare) was recorded under the treatment T₁₅ (200 ppm GA₃ + 200 ppm NAA) with benefit cost ratio of 2.74:1 which was very close to T₁₄ and T₁₃ (Table 4). Similarly, from the economics point of view, NAA was found to be profitable as compared to rest of treatments reported by Patil and Patel (2010) in cv. GO-2 with variable concentration. Mandal *et al.* (2012) and Meena *et al.* (2017) earlier found that, concentrations of plant growth regulators caused an increased in net return and B:C ratio over the control, but the differences were much narrower.

Effect of GA₃ and NAA on cowpea

The application of plant hormones (GA₃ and NAA) both alone or in combination significantly improved growth and fruiting related traits. The results (Table 5) indicated that vine length at maturity was greatly increased by the application of NAA 100 ppm (68.85 cm) followed by the application of 100 ppm GA₃ + 100 ppm NAA (68.00 cm), whereas minimum vine length was found in controlled (59.83 cm). Same trends were also found in number of leaves plant⁻¹ as NAA 100 ppm (48.80) showed the highest followed by NAA 100 ppm + GA₃ 100 ppm (47.90) and minimum leaves (41.20) with GA₃ 100 ppm + NAA 100 ppm (T₁₅). Same results were observed by Shahid *et al.* (2013) and Meena *et al.* (2017) in okra. Significantly less number of days was required for days to 1st flowering (42.48) with the treatment 200 ppm GA₃ + 100 ppm NAA (T₁₄) which was at par with (T₁₅) GA₃ 200 ppm + NAA 200 ppm (43.88 days), T₁₃ (42.68 days), T₁₂ (45.28 days), T₁₁ (44.78 days), T₁₀ (43.48 days) and T₇ (44.91 days), as compared to control and rest of the treatments (Table 5). This might be due to the reason that GA₃ reduced the days required for flowering which ultimately led towards early flower production.

These results were supported by Singh and Kumar (2005) and Bhagure and Tambe (2013). Significantly higher chlorophyll content of leaves (61.68 SPAD value) were observed when 100 ppm GA₃ + 100 ppm NAA (T₁₁) was sprayed to plants, which was at par with T₁₄, T₁₃, T₁₂, T₁₀, T₈, T₇, T₆ and T₅. More number of pods gives an idea about yield, here the combination of GA₃ and NAA *i.e.* 200 ppm GA₃ + 50 ppm NAA (T₁₃) showed maximum number of pods per plant (37.44) followed by T₁₄ (24.33), T₁₂ (36.40) and T₁₁ (36.30). This might be due to more number of nodes per plant in case of above said combinations. The result coincides with the findings of Patil and Patel (2010) and Mehraj *et al.* (2015). Mean data revealed that pods yield plant⁻¹ varied from 122.5g to 198.85 g. Maximum pods yield plant⁻¹ (198.85 g) was observed with the application of 100 ppm GA₃ + 100 ppm NAA (T₁₁) and it was significantly superior treatment. The minimum pods yield plant⁻¹ (122.50) was recorded in control. It is amply clear from the study that exogenous application of plant growth regulators stimulate the effects of enzymatic activities of natural occurring hormones that accelerated and modified the growth and development of plants and hence increase pods yield plant⁻¹. The results are in line with the findings of Satodiya *et al.* (2011) in cluster bean, Patel *et al.* (2011) and Golakiya *et al.* (2017) in cowpea.

The highest pod length (31.41 cm) was observed with 100 ppm GA₃ + 200 ppm NAA (T₁₂), which was significantly higher as compared to control (25.18 cm). Treatments T₄ (27.20 cm), T₅ (27.80 cm) and T₆ (27.60 cm) and rest of the treatments were at par with T₁₂ treatment. The increase in fruit length could be due to cell elongation. The results were supported by Kokare *et al.* (2006) and Ravat and Makani (2015) in okra. The highest fresh weight of pod (5.54g) recorded with 100 ppm GA₃ + 50 ppm NAA (T₁₀)

followed by T₁₁ (5.49g), T₁₂ (5.29g) and T₈ (5.25g) was significantly superior over control (4.31g) and rest of the treatments. This might be due to the growth by cell division, cell enlargement and cell expansion which ultimately improved the fruit weight. These results were supported by Singh and Kumar (2005) and Katung *et al.* (2007). The quality score of fruit was recorded highest (8.12) under 100 ppm GA₃ + 100 ppm NAA (T₁₁) followed by 100 ppm GA₃ + 50 ppm NAA (T₁₀) which was non-significant with control. Foliar application of gibberellic acid and NAA had been reported to affect number of pods plant⁻¹, pod yield plant⁻¹ as well as fresh weight of pod. Therefore, impact of PGRs was also assessed on pod yield and quality. Fresh pod yield ha⁻¹ was found maximum (99.64 q ha⁻¹) from plants sprayed with solution containing 100 ppm GA₃ + 100 ppm NAA (T₁₁) followed by T₁₀ treatment (97.28 q ha⁻¹) and statistically it surpassed all other treatments and control (Table 6). While minimum pod yield (61.42 q ha⁻¹) was noted in control (T₀). It is clear from the results that treatments comprising of both GA₃ and NAA at medium concentration improved pod yield significantly as compared to their application alone or in combination at low (50 ppm) as well as higher concentrations (200 ppm). The data presented in Table 6 revealed that among the different combination of treatments T₁₁ (GA₃ 100 ppm + NAA 100 ppm) registered the highest net return Rs. 133394.0 ha⁻¹ with maximum B: C ratio value of 3.81: 1 as compared to rest of the treatment combinations. Moreover, the next best treatment

was T₁₀ (GA₃ 100 ppm + NAA 50 ppm) which registered the net return of Rs. 129380.1 ha⁻¹ with B: C ratio of 3.70: 1. Whereas, treatment T₀ (control) recorded the lowest net return of Rs. 70409.7 ha⁻¹ with lowest B: C ratio of 2.01: 1.

From the above results it may be concluded that plant growth regulators *i.e.* gibberellic acid and naphthalene-acetic-acid have significant effect in increasing growth, development and yield of cluster bean, okra and cowpea with different concentration of both. However, GA₃ is found to be a superior growth regulator as compared to respective doses of NAA. Growth regulators were less effective when applied individually as compared to their combined use, however performance of plants treated with individual growth regulator was better than the untreated plants. The improvement in growth as a result of GA₃ and NAA might be attributed to their function in stimulation of metabolic activities and hormonal regulation. GA₃ and NAA stimulate the growth of plant tissues there by enhancement in cell multiplication and cell elongation resulting increased growth of plant. It could be concluded that among the different combination of treatments in cluster bean GA₃ 100 ppm + NAA 200 ppm, in okra GA₃ 200 ppm + NAA 200 ppm and in cowpea 100 ppm GA₃ + 100 ppm NAA were found the most suitable treatments for maximum production, highest net return with maximum B: C ratio as compared to rest of the treatments.

Table 1. Effect of NAA and GA₃ on different growth and yield attributes of cluster bean

Treatments	Plant height at maturity (cm)	No. of leaves plant ⁻¹	No. of days taken to first flowering	Chl. content (SPAD Value)	No. of cluster plant ⁻¹	No. of pods cluster ⁻¹	Number of pods plant ⁻¹
T ₀	96.23	87	44.67	49.67	16.48	14.68	242.01
T ₁	96.72	90	42.96	51	17.68	15.78	279.08
T ₂	97.3	94	41.25	51.01	18.48	15.88	293.56
T ₃	96.87	88	40.87	53.11	19.08	16.18	308.81
T ₄	97.08	94	40.63	54	17.1	14.11	241.65
T ₅	97.93	99	42.33	54.3	16.5	15.1	249.53
T ₆	98.38	97	42.94	55.5	17.47	15.8	276.35
T ₇	96.9	92	37.9	56.6	19.02	15.76	299.74
T ₈	97.77	94	39.3	57.3	19.82	16.48	326.62
T ₉	98.72	99	39.7	57.7	19.42	16.08	312.26
T ₁₀	96.44	95	36.12	58.1	19.55	16.51	322.83
T ₁₁	96.92	96	37.43	59.9	19.95	16.91	337.41
T ₁₂	97.29	96	37.93	60	20.25	17.02	344.71
T ₁₃	96.85	92	35.4	61.2	18.91	15.91	300.86
T ₁₄	97.64	91	36.6	61.7	18.51	15.81	292.65
T ₁₅	97.95	88	35.2	62.3	18.41	15.51	285.54
SEm	0.774	2.059	1.24		0.7		1.641
CD 5%	2.322	6.179	3.74	NS	2.101	NS	4.925

Table 2. Effect of NAA and GA₃ on yield attributes and economics of cluster bean

Treatments	Pod length (cm)	Fresh weight of pod (g)	Quality score of fruit (10)	Yield (q ha ⁻¹)	Net Return (Rs.)	B: C ratio
T ₀	6.29	0.69	7.02	83.48	168434.1	2.05
T ₁	5.86	0.7	7.55	98.13	211885	2.58
T ₂	5.83	0.69	7.83	100.77	219817.1	2.68
T ₃	6.23	0.69	7.82	106.52	237073.8	2.89
T ₄	5.68	0.63	7.34	76.86	148078.4	1.81
T ₅	5.96	0.64	7.52	80.6	159297.4	1.94
T ₆	5.08	0.65	7.75	90.61	189329.3	2.31
T ₇	6.14	0.68	8.01	101.9	222694.4	2.72
T ₈	5.78	0.63	8.25	102.87	225613.5	2.75
T ₉	5.56	0.62	8.15	96.79	207359.3	2.53
T ₁₀	5.08	0.65	8.32	105.47	233417.4	2.85
T ₁₁	5.86	0.66	8.02	111.92	252771.7	3.08
T ₁₂	6.06	0.67	8.44	116.07	265207.5	3.23
T ₁₃	5.98	0.74	7.55	111.33	250993.6	3.06
T ₁₄	6.58	0.73	7.8	106.83	237485.1	2.9
T ₁₅	5.4	0.71	8	101.38	221139.8	2.7
S. Em ±	-	-	0.85	1.641	-	-
CD 5%	NS	NS	0.253	4.925	-	-

Table 3. Effect of NAA and GA₃ on different growth and yield attributes of okra

Treatments	Plant height at maturity (cm)	No. of leaves plant ⁻¹	No. of days taken to first flowering	No. of fruits plant ⁻¹	No. of picking	Chl. Content (SPAD Value)	Duration of picking (days)
T ₀	39.5	33.5	45.48	9	8.99	46.07	38.5
T ₁	42.3	35.4	42.08	10.3	9.99	49.57	39.1
T ₂	43.5	36	42.48	10.6	10.99	53.57	40
T ₃	42.1	33.5	42.98	10.7	10.49	52.07	42.5
T ₄	47.9	30.7	44.5	10	10	51.23	42.5
T ₅	46.9	36.7	44.5	10.3	10.5	49.23	46.7
T ₆	45.3	32.5	42.5	10.7	11	47.53	47
T ₇	49.5	38.5	41.3	11.5	11	51.6	43.5
T ₈	46.3	39	42.7	11.8	11.5	49.8	44
T ₉	46.7	40.5	40.5	12	11	48.5	45
T ₁₀	49.49	39.59	41.19	11.9	11.5	46.97	45.5
T ₁₁	49.49	41.49	42.69	12	11.5	49.07	46
T ₁₂	47.49	42.09	42.89	12.09	10.99	51.67	44.5
T ₁₃	49.7	43.8	41.3	12.5	11.99	48.67	45.7
T ₁₄	52.8	44.5	42.2	12.5	12.45	46.27	45.5
T ₁₅	50.7	45.2	42.3	12.6	12.49	44.37	45
S Em ±	0.552	0.551	0.66	0.148	0.103	1.413	-
CD 5%	1.597	1.592	1.908	0.429	0.298	4.082	NS

Table 4. Effect of NAA and GA₃ on yield attributes and economics of okra

Treatments	Fruit length (cm)	Fresh weight of fruit (g)	Quality score of fruit (10)	Yield (q.ha ⁻¹)	Net Return (Rs.)	B: C ratio
T ₀	8.5	7.89	7.3	35.52	56300	1.16
T ₁	8.69	7.99	7.49	41.17	68414.2	1.41
T ₂	8.7	8.19	7.7	43.42	74061.7	1.53
T ₃	8.91	8.49	7.75	45.44	79098.3	1.63
T ₄	9.5	8.4	7.3	42	70500	1.45
T ₅	9.71	8.7	7.5	44.81	77512.5	1.6
T ₆	9.8	8.8	7.75	47.08	83200	1.72
T ₇	8.85	9.2	8	52.94	96836.3	2
T ₈	8.9	9.6	8.25	56.68	106189.2	2.19
T ₉	9.3	10	8.1	60.04	114591.7	2.36
T ₁₀	9.4	10.2	8.3	60.73	116317.1	2.4
T ₁₁	9.6	9.8	8.4	58.84	111590.8	2.3
T ₁₂	9.49	10.29	8.05	62.19	120007.6	2.47
T ₁₃	9.95	10.49	8.25	65.55	128406.3	2.65
T ₁₄	10.5	10.68	8.39	66.8	131531.3	2.71
T ₁₅	10.9	10.69	8.5	67.34	132867.5	2.74
S Em ±	0.099	0.901	0.103	0.276	-	-
CD 5%	0.298	0.29	0.297	0.799	-	-

Table 5. Effect of NAA and GA₃ on different growth and yield attributes of cowpea

Treatments	Vine length at maturity (cm)	No. of leaves plant ⁻¹	No. of days taken to first flowering	Chl. content (SPAD value)	Number of pods plant ⁻¹	Pod yield plant ⁻¹ (g)
T ₀	59.83	42.33	51.88	49.67	28.5	122.5
T ₁	65.53	43.13	50.18	50.67	29	131.04
T ₂	67.03	44.03	48.48	52.87	30.1	138.13
T ₃	65.73	44.93	48.08	55.07	27.51	124.84
T ₄	67.8	46.9	48.58	56.57	30.26	136.54
T ₅	68.85	48.8	50.28	57.67	30.81	139.94
T ₆	66.05	46.7	50.88	60.87	32.45	141.85
T ₇	66.28	44.53	44.91	61	34.53	172.48
T ₈	67.73	45.73	46.31	58.2	33.67	176.6
T ₉	66.38	45.13	46.71	56.71	33.57	172.71
T ₁₀	67.05	45.1	43.48	61.28	35.12	194.13
T ₁₁	68	47.9	44.78	61.68	36.3	198.85
T ₁₂	66.17	45.8	45.28	57.98	36.4	192.12
T ₁₃	65.37	42.1	42.68	60.27	37.44	192.48
T ₁₄	64.7	41.5	42.48	61.37	36.54	184.19
T ₁₅	63.1	41.2	43.88	55.27	34.81	170.24
S. Em ±	1.451	1.264	1.175	1.483	1.175	1.42
CD 5%	4.354	3.792	3.527	4.284	3.527	4.102

Table 6. Effect of NAA and GA3 on yield attributes and economics of cowpeap

Treatments	Pod length (cm)	Fresh weight of pod (g)	Quality score of fruit (10)	Production (q.ha ⁻¹)	Net Return (Rs.)	B: C ratio
T ₀	25.18	4.31	6.69	61.42	70409.7	2.01
T ₁	28	4.53	7.22	65.69	76164.5	2.18
T ₂	28.5	4.6	7.5	69.23	82191	2.35
T ₃	28.2	4.55	7.49	62.59	70894.9	2.03
T ₄	27.2	4.5	7.71	68.09	80244.5	2.29
T ₅	27.8	4.53	7.89	69.78	83133.9	2.38
T ₆	27.6	4.36	7.59	70.74	84759.7	2.42
T ₇	29.53	5	7.71	86.39	110864.5	3.17
T ₈	30.13	5.25	7.95	88.45	114362.7	3.27
T ₉	29.73	5.15	7.85	86.51	111062.4	3.17
T ₁₀	31.6	5.54	8.01	97.28	129380.1	3.7
T ₁₁	31	5.49	7.89	99.64	133394	3.81
T ₁₂	31.41	5.29	8.12	96.28	127672.6	3.65
T ₁₃	30.75	5.15	7.22	96.41	127893.6	3.65
T ₁₄	30.1	5.05	7.47	92.26	120848	3.45
T ₁₅	29.51	4.9	7.67	85.28	108983.7	3.11
S. Em ±	1.141	0.095	-	1.024	-	-
CD 5%	3.297	0.287	NS	3.072	-	-

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Effect of thiourea on growth, yield and quality of vegetable cowpea (*Vigna unguiculata* L. Walp)

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Abstract

The field experiment was conducted on "Effect of thiourea on growth, yield and quality of vegetable cowpea (*Vigna unguiculata* L. Walp)" at Horticulture farm, Department of Horticulture, S.K.N. College of Agriculture, Jobner (Rajasthan) during *kharij*, 2018. The experiment consisting six levels of thiourea (control, seed treatment with 500 ppm thiourea, seed treatment with 1000 ppm thiourea, foliar application of 500 ppm thiourea, foliar application of 1000 ppm thiourea and seed treatment with 500 ppm thiourea + foliar application of 500 ppm thiourea) in randomized block design with three replications. Results indicated that application of seed treatment with thiourea 500 ppm and foliar application of thiourea 500 ppm significantly increased the plant height (64.15 cm), branches per plant, chlorophyll content, pods per plant (24.85), pod length, pod yield per per ha (148.67 q), nitrogen, phosphorus, protein content and crude fiber content in green pod over control and other treatments. The seed treatment with thiourea 500 ppm with foliar application of thiourea 500 ppm found significantly superior with net returns (Rs. 212675/ha) and highest B:C ratio (3.51).

Key words: Growth, quality, thiourea, vegetable cowpea, yield

Introduction

Vegetable cowpea (*Vigna unguiculata* L. Walp.) is important leguminous crop originated from central Africa belongs to family Fabaceae. It is widely grown in India in both summer and rainy season as well as all over the world. Cowpea is cosmopolitan and assumes fair degree of importance as pulse as well as vegetable crop. It is also consumed both as green pod and dry seed. Choice of cowpea as vegetable is due to being palatable, highly nutritious and relatively free of metabolites or other toxins.

It is considered inexpensive source of vegetable protein. The green tender pods of vegetable cowpea contain 84.6 % moisture, 4.3 per cent protein, 8.0 % carbohydrates and 0.2 % fats. Cowpea seed contains about 21.2 to 30.6 % protein, 60.3 % carbohydrate, 1.8 % fat and rich source of calcium, phosphorus and iron (Mann, 1975). The protein in the cowpea seeds is rich in amino acids, *viz.*, lysine and tryptophan which are deficient in cereals.

Thiourea is a sulphydryl compound ($\text{NH}_2\text{-CS-NH}_2$) known for breaking dormancy, stimulating germination and has also been reported for significantly improving growth, yield and water use efficiency of field crops under arid and semi-arid conditions (Mathur *et al.*, 2006). Thiourea contains 42.10 % sulfur and 36.80 % nitrogen. Soaking of seeds and foliar spray of thiourea have been reported not only to improve growth and development of plants but also the dry matter partitioning for increased grain yield. Thiourea plays a vital role in the physiology of plants. It promotes growth in cytokinin requiring callus tissues in absence of kinetin in

various crops (Erez, 1978). Among the stress alleviating compounds, thiourea is an important molecule with two functional groups *thiol* is important to oxidative stress response and *imino* partly fulfils the N requirement. Thiourea has the capability to serve as a potential bio-regulatory molecule to impart multi stress tolerance in plants under field conditions (Srivastava *et al.*, 2009).

Materials and Methods

The experiment was conducted at Horticulture Farm, S.K.N. College of Agriculture, Jobner (Jaipur) during *Kharij* 2018. The experiment was laid out in randomized block design with six levels of thiourea (control-T₀, Seed treatment with thiourea 500 ppm-T₁, seed treatment with thiourea 1000 ppm-T₂, foliar application of thiourea 500 ppm-T₃, foliar application of thiourea 1000 ppm-T₄ and seed treatment with thiourea 500 ppm with foliar application of thiourea 500 ppm-T₅) with three replications. Thiourea was used as seed soaking and foliar spray after 50 days of sowing at branching stage and followed by flowering stage as per treatment combinations. Each plot measured 2.0 m x 2.5 m (5 m²) area. The crop geometry was kept at 40 x 10 cm.

The observations like plant height (cm), number of branches per plant, leaf area (cm²), number of green pods per plant, green pod length (cm), green pod yield per plant (g), green pod yield per plot (kg), green pod yield per hectare (q) taken manually. Chlorophyll content was determined using the method of Arnon (1949) with slight modifications. Nitrogen content in the green pods was estimated by using

Nessler's reagent by spectrophotometer method (Snell and Snell, 1949), phosphorus concentration in pod was determined by 'Vanado molybdo' phosphoric acid yellow color method. Digestion of samples was done by tri-acid mixture and the intensity of color was measured by spectrophotometer (Jackson, 1973), protein content in the pods was calculated by multiplying nitrogen concentration (%) by the factor 6.25 (A.O.A.C., 1960). Crude fiber content in pods was determined by the method suggested by A.O.A.C. (1960). The data obtained from the experiment were subjected to statistical analysis and the results were documented, analyzed and presented in tabular form.

Results and Discussion

The data in Table 1 revealed that growth parameters were significantly influenced by the application of thiourea as seed soaking and foliar spray after 50 days of sowing at branching stage of vegetable cowpea crop. The maximum plant height of (47.96 and 64.15 cm) at 30 DAS and at harvesting stage, number of branches per plant (17.89), total chlorophyll content in leaves (2.35 mg/g) and leaf area (429.21 cm²) at 30 DAS were recorded under treatment T₅ (seed treatment with thiourea @ 500 ppm + foliar application of thiourea 500 ppm) and minimum under control. This treatment was observed as significantly superior over control and other treatments. It might be due to changes the metabolites present in the seedlings as a result in change of activity of hydrolytic enzymes or due to the change in the oxidation mechanisms and especially those concerned with electron transport. The significant effect on all growth parameters also provided a possibility that thiourea might have resulted into creation of more photo-synthetically active leaf for longer period during vegetative and reproduction phases, leading to more absorption and utilization of radiant energy which ultimately resulted in higher plant height, number of branches, leaf area, pods per plant and total chlorophyll content. Similar, results were also reported by Singh *et al.* (2012) in okra and Meena *et al.*, (2016) in cluster bean.

It is evident from data (Table 2 and Fig. 1) that thiourea as seed soaking and foliar spray at branching stage of vegetable cowpea crop significantly increased the yield and yield attributing characters. Total number of pods (24.85), green pod yield per plant (64.64 g), green pod yield per plot (7.43 kg) and pod yield per ha (148.67 q) were found maximum under seed treatment with thiourea 500 ppm with foliar application of thiourea 500 ppm significantly while minimum parameters were recorded under control.

The significant variation in yield attributes and yield obtained with thiourea applied through seed soaking and foliar spray was most probably due to increased photosynthetic activities and source to sink relationship. The bio regulatory effect of thiourea, chiefly through mobilization of dry matter and translocation of photosynthates to sink which ultimately improved the yield. The findings of the present investigation is closely supported by Solanki (2002) in cluster bean, Mani *et al.* (2013) in potato and Singh *et al.* (2012) reported that yield of okra increased significantly by foliar application of thiourea (500 ppm).

A perusal of data presented in Table 3 revealed that the application of different levels of thiourea as seed soaking and foliar spray found significantly increased quality parameters of vegetable cowpea. The maximum nitrogen content (0.682%), phosphorus content (0.078), protein content (4.26%) and crude fiber content (15.09%) in green pods were recorded with the application of T₅ treatment where thiourea was applied as seed treatment 500 ppm with foliar application 500 ppm. The increased accumulation of nutrients especially N, P, protein and crude fibre content in vegetative parts concomitant the improved metabolism led to greater translocation of these nutrients to reproductive structure of crop. Application of thiourea resulted in better utilization of nitrogen and phosphorus in soil probably due to the fact that application of thiourea might have helped in improved metabolic process of plants and better growth and development leading to greater absorption of nutrients from rhizosphere. Solanki (2002) reported that thiourea being a sulphhydryl compound significantly improved the root growth

Table 1. Effect of thiourea on growth attributes of vegetable cowpea

Thiourea treatment combinations	Plant height (cm) 30 DAS	Plant height (cm) at harvesting	Number of branches per plant	Total chl. (mg/g)	Leaf area (cm ²)
T ₀ -Control	36.21	49.32	12.11	1.72	365.92
T ₁ - Seed treatment 500 ppm	39.98	54.49	14.21	1.96	396.64
T ₂ - Seed treatment with 1000 ppm	40.25	56.22	14.78	2.06	397.65
T ₃ - Foliar spray with 500 ppm	43.89	58.49	15.25	2.11	399.45
T ₄ - Foliar Spray with 1000 ppm	44.25	59.68	15.94	2.14	401.15
T ₅ - Seed treatment with 500 ppm + foliar spray with 500 ppm	47.96	64.15	17.89	2.35	429.61
SEm ±	1.26	1.41	0.50	0.06	9.67
CD at 5%	3.61	4.06	1.42	0.16	27.80

Table 2. Effect of thiourea on yield and economic attributes of vegetable cowpea

Thiourea treatment combinations	Pod length (cm)	Number of green pods/plant	Pod yield (g/plant)	Pod yield (kg/plot)	Pod yield (q/ha)	Net Returns (Rs./ha)	B:C Ratio
T ₀ . Control	13.84	19.77	49	5.63	112.69	141441	2.68
T ₁ . Seed treatment 500 ppm	15.44	23.22	56.51	6.55	130.9	177488	3.1
T ₂ . Seed treatment with 1000 ppm	15.96	23.27	58.31	6.71	134.1	183537	3.16
T ₃ . Foliar spray with 500 ppm	16.05	23.35	59.07	6.79	135.86	187392	3.22
T ₄ . Foliar Spray with 1000 ppm	16.29	23.54	60.89	7	140.04	195413	3.3
T ₅ . Seed treatment with 500 ppm + foliar spray with 500 ppm	17.34	24.85	64.64	7.43	148.67	212675	3.51
SEm±	0.44	0.39	0.83	0.13	2.38	7147	0.11
CD at 5%	1.27	1.11	2.38	0.36	6.84	20540	0.35

Table 3. Effect of thiourea on quality attributes of vegetable cowpea

Thiourea treatment combinations	Protein content (%)	Crude fibre content (%)	N content (%)	P content (%)
T ₀ . Control	3.4	13.01	0.544	0.056
T ₁ . Seed treatment @ 500 ppm	3.756	13.82	0.601	0.066
T ₂ . Seed treatment with @ ppm	3.844	13.96	0.615	0.068
T ₃ . Foliar spray with @ ppm	3.881	14.06	0.621	0.069
T ₄ . Foliar Spray with @ ppm	3.931	14.16	0.629	0.07
T ₅ . Seed treatment with 500 ppm + foliar spray with 500 ppm	4.263	15.09	0.682	0.078
SEm±	0.103	0.21	0.017	0.002
CD at 5%	0.296	0.61	0.05	0.006

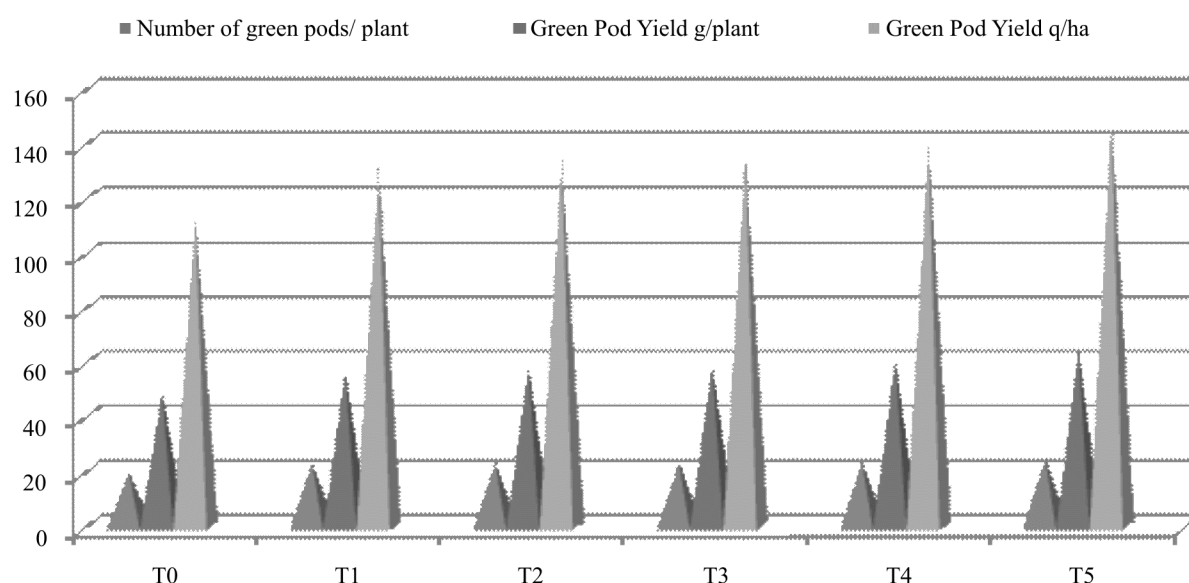


Fig. 1. Effect of thiourea on number of green pods and pod yield of vegetable cowpea

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Effect on system productivity through inter crop diversification in agri-horti system in arid ecosystem of western Rajasthan

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Abstract

An experiment was conducted on the “study of system productivity through intercrop diversification in agri-horti system in arid ecosystem of western Rajasthan” at research farm of ICAR-CAZRI, Regional Research Station, Bikaner on the existing plantation of 10 year old plantation of citrus (*Citrus aurantifolia*), bael (*Aegle marmelose*) and gonda (*Cordia myxa*) planted with drip irrigation system under agri-horti system. The experiment was conducted under factorial Randomized Block design with three replications. The experimental results revealed that the intercropping of legumes (rainfed) has no competition in agri-horti system, showing positive effect on growth and yield of fruit trees. Growth parameters of all the trees were found to be non-significant in intercropping of *Lasiurus indicus* and aloe-vera over no intercropping. Intercropping of mothbean with bael gave highest plant height of bael which was 15.9, 13.05, 4.90 and 10.70 per cent higher over intercropping of clusterbean, aloe-vera, *L. scindicus* and sole, respectively. Yield of intercrops were highest with citrus and lowest with bael during both the years. Highest water use efficiency (0.98 kg/mm) was in intercropping of mothbean with citrus whereas in perennial crops, *L. scindicus* showed highest WUE of 19.4 kg/mm in intercropping with citrus. The CEY was highest in all the crops in intercropping with citrus over rest of the trees under agri-horti system.

Key words: Agri-horti system, arid ecosystem, clusterbean equivalent yield, water use efficiency

Introduction

Intercropping is a technique of crop intensification in both space and time where in the competition between crops may occur during a part or whole of crop growth period. Beets (1982) thought that crop insurance was a major principle of intercropping in that if environmental factors change, some of the intercrop does well when others do poorly. In some related studies, the results indicated that competition for nutrients does not exist in intercropping systems (Jose *et al.*, 2000; Thevathasan *et al.*, 2004). Therefore, it is very important to explore the competitive mechanism in intercropping systems, in order to provide optimum management strategies and technologies for managing intercropping system with high-yield, high-efficiency and stabilization. Within tree-based intercropping systems, a number of factors can influence tree shading of adjoining agricultural crops. Intercropping of different field crops in cassava indicated that all intercropping systems had LER greater than 1 which varied between 1.35 (cassava + upland rice) and 1.6 (cassava + peanut) which showed the profitability of intercropping (Islami *et al.*, 2011). Mahant (2011) inferred that intercropping in banana was more productive and profitable than their sole cultivation without loss in yield.

India is facing a big challenge in balancing its dual objectives of food security and crop diversification to increase

farm income. The India's low crop productivity, limited irrigation facilities and underdeveloped infrastructural support like cold storages, markets, roads, and transportation, which have increased the woes of Indian horticulturists. As India begins to market its agricultural produce across political boundaries, it can add new dimensions to its commercial viability in agriculture. Within the horticulture sector also, besides spices, fruits and vegetables are the major crops where the area under cultivation has increased. This gain in area under horticulture and mainly under fruits and vegetables is a collective impact of diversification of the production pattern of producers and increased demand of the consumers due to shift in their consumption pattern (Mittal, 2009).

Tree-based intercropping one of the excellent farming system and can contribute much to our understanding of sustainable agriculture practices. Our current research goals are to address and quantify the numerous biophysical interactions that occur at the tree-crop interface in order to enhance our understanding of the ecology of tree-based intercropping. Investigations over the last decade have documented several complementary biophysical interactions. Nitrogen (N) transfer from fall-shed leaves to adjacent crops with enhanced soil nitrification as the proposed mechanism was estimated to be 5 kg N ha⁻¹. Soil organic carbon (C) adjacent to tree rows has increased by over 1%, largely as a

result of tree litter fall inputs and fine root turnover (Thevathasan *et al.*, 2008).

It is estimated that intercropping has reduced nitrate loading to adjacent waterways by 50%, a hypothesized function of deep percolate interception by tree roots. Earthworm distribution and abundance was also found to be higher closer to the tree rows when compared to earthworm numbers in the crop alleys. We speculate that these are indicative of major changes in the flow of energy within the trophic structure identified with intercropping systems (Thevathasan *et al.*, 2008). Tree-based intercropping is considered an excellent farming system and can contribute much to our understanding of sustainable agriculture practices. Therefore, experiments was conducted with the objective of assessment of intercrop productivity and their effect on trees growth, production and quantify the numerous biophysical interactions that occur at the tree-crop interface in order to enhance our understanding of the ecology of tree-based intercropping (a form of agroforestry) in arid zone of western Rajasthan.

The climate during both the years was normal. Total rainfall of 257 mm and 279.9 mm was received which was almost equal to the normal rainfall of the region followed by highest rainfall of 153 mm 128.9 mm was received in month of August during 2012 and 2013, respectively. The highest maximum temperature of 40.3°C and 43°C was recorded in month of May with a minimum mean temperature 4.0 & 4.3°C in January during 2012 and 2013, respectively. The highest evaporation of 12.6 mm/day was recorded in month of May 2012. Highest evaporation was recorded in month of May during both the years. The soil of the experimental site contains 83-87% sand, 8-9% clay and 5-7 % clay content. The bulk density of soil varies from 1.52 to 1.55 g cm⁻³ and alkaline in chemical reaction having pH 7.8 to 8.1. The moisture content at field capacity and permanent wilting point varied from 15.4- 16.8% and 7.7-8.6%, respectively. The soil was low in organic carbon (0.09%) and available N (135 kg ha⁻¹), medium in available P (38.31 kg ha⁻¹) and high in available potassium (356- 375 kg ha⁻¹).

Materials and Methods

The present investigation was conducted for two consecutive years 2012 and 2013 at Research farm of Central Arid Zone Research Institute, Regional Research Station Bikaner which falls in Zone-I (1c) defined as partially irrigated hyper arid zone of western Rajasthan. The intercropping of arable crops like mothbean and clusterbean, sewan grass (*Lasiurus scindicus*) as rainfed and aloe-vera (drip irrigation) were taken under agri-horti system in between the sows of fruit trees (10 year old) of lime (*Citrus aurantifolia*), bael (*Aegle marmelose*) and gonda (*Cordia myxa*) which were grown under drip irrigation system. The irrigation of fruit trees were done as per the requirement and recommendation of fruit trees. The *sewan* grass (*Lasiurus scindicus*) and aloe-vera were planted during 2009 as perennial component in agri-horti system. All the treatments

were laid under randomized block design with three replications. The growth data of trees were taken each year in month of November whereas the arable crops growth and yield data were taken as per their schedule. No irrigation was given to any intercrop except aloe-vera which was grown with drip irrigation system.

Results and Discussion

Growth of trees

All the fruit trees under drip irrigation system showed significantly higher plant height, stem girth and tree canopy with the intercropping of mothbean. Regarding the plant height of fruit trees which was highest with mothbean intercropping and 5.5% higher over sole citrus (without intercrop) but found at par with intercropping of rest of the crops. The data showed that citrus plant height was unaffected significantly by intercropping. Mothbean intercropping with bael gave highest plant height of bael which was 15.9, 13.05, 4.9 and 10.7 per cent higher over intercropping of clusterbean, aloe-vera, *L. scindicus* and sole, respectively. The plant height of *gonda* was not significantly affected by any intercrop (Table 1). The variation in different growth parameters of trees were found to be non-significant in intercropping of *L. scindicus* and aloe-vera over no intercropping because of being the perennial nature of these crops.

The collar diameter of all the trees were not affected significantly and found to be at par with intercropping of annual (mothbean and clusterbean) or perennial crops (*L. scindicus* and aloe-vera). The canopy was highest with intercropping of mothbean but in case of citrus the canopy was non-significant with all the intercrops. The canopy cover of bael and *gonda* was significantly affected and 38.5, and 47.3 per cent higher in mothbean intercropping over their sole plantations (Table 1). This shows that the intercropping have a positive effect on tree growth. This may be due to more inter culture and other operation going on with intercropping system providing more favorable conditions than the sole plantations. In different studies it was found that the leguminous plants, soybean and peanut could fix nitrogen from the air *via* a symbiotic relationship with rhizobium bacteria and increase the mineral soil nitrogen content (Cheng 1994; Wani *et al.*, 1995).

Fruit yield

The highest fruit yield of all the trees were highest with intercropping of mothbean during both the years. Highest citrus fruit yield (1197.9 kg/ha) was recorded with mothbean intercropping which was 55.13 per cent higher over sole planting. The yield was 38 and 54 per cent higher with perennial intercrops of *L. scindicus* and aloe-vera, respectively. The lower yield with the system was due to perennial nature of intercrop giving completion for year round for moisture and nutrient (Fig. 1). Many researchers have supported that as one of the main reasons leading to the reduction of crop yield, the competition for soil nutrients does exist in the interface of trees and crops and has a negative impact (Newman and

Bennett, 1979; Yun *et al.*, 2012).

Yield of intercrops

In different agri-horti system the highest total dry matter yield and grain yield of annual crops (mothbean and clusterbean) and intercropping of *L. sindicus* (perennial) were recorded in intercropping with citrus. In mothbean and aloevera the effect on yield was found to be non-significant (Table 2). *Lasiurus sindicus* grown as intercrop (rainfed) gave highest total dry matter (TDM) yield of 64.20 q/ha in intercropping with citrus which was 73.0, 50.9 per cent higher over intercropping with bael and gonda, respectively (Table 2). Aloe vera gave highest green pad yield of 611q/ha which was at par in intercropping with bael and gonda. This showed that bael has heavy competition and affecting adversely on growth of *L. sindicus* but no adverse effect on growth of aloevera. Aiyer (1949) also showed that the increase in yield was the better utilizing of resources because the crops with varying root depth, tap different layers of soil for plant nutrients and moisture. The periodical return and distribution of labour requirements throughout the year is of great help to the resource poor cultivators.

Water Use Efficiency (WUE)

Among the intercropping of annual crops mothbean

showed the highest water use efficiency (0.98 kg/mm) in intercropping with citrus which was 43.8, 21.48 and 39.7 per cent higher over intercropping with bael, *gonda* and sole, respectively (Table 3). In perennial intercrops, *L. sindicus* showed highest WUE of 19.4 kg/mm in intercropping with citrus which was 55.67, 12.86 and 23.7 per cent higher over bael, *gonda* and sole cropping, respectively.

Water use efficiency of agri-horti system was highest with mothbean intercropping which was at par with clusterbean but significantly higher over rest of the intercrops. The system WUE by intercropping of perennials also were highest in intercropping with citrus over rest of trees which showed that citrus has very less competition with intercrops than bael and *gonda* (Table 3).

Clusterbean equivalent yield (kg/ha) of agri-horti system

Clusterbean equivalent yield in all the intercrops was highest in intercropping with citrus. In citrus+ mothbean agri-horti system highest CEY was 265.5 which was 44.16, 21.88 and 40.33 per cent higher over bael + mothbean, *gonda* + mothbean and sole, respectively (Table 4). Citrus + *L. sindicus* intercropping gave 31.2 per cent higher CEY over citrus + aloevera system. All the intercropping system gave higher CEY in agri-horti system than their sole cropping.

Table 1. Growth of trees affected by different intercrops agri-horti system (Mean of 2012 and 2013)

Fruit trees	Tree height (cm)					Tree Collar diameter (cm)					Tree canopy (m ²)					
	Moth bean	Cluster bean	Aloevera	<i>L. sindicus</i>	Sole	Moth bean	Cluster bean	Aloevera	<i>L. sindicus</i>	Sole	Moth bean	Cluster bean	Aloevera	<i>L. sindicus</i>	Sole	
Citrus	348.35	315	331.65	322	330.8	18.16	14.86	14.32	14.07	13.52	17.9	16.3	13.10	15.65	13.3	
Bael	521.7	438.35	453.65	495	456.65	17.61	14.62	15.68	15.77	15.69	20.5	13.15	18.85	15.5	12.6	
<i>Gonda</i>	385.85	385.3	346.65	353.3	320.35	18.20	14.92	14.12	16.58	14.82	19.3	15.95	11.75	13.35	10.9	
Mean	418.63	379.55	377.32	390.10	369.27	17.66	14.80	14.71	15.47	14.68	19.23	15.13	14.57	14.83	12.27	
CD 5%	T=34.89	C=59.03	TXC=64.05			T=4.87	C=6.29			TXC=10.9		T=3.11	C=5.345			TXC=5.62

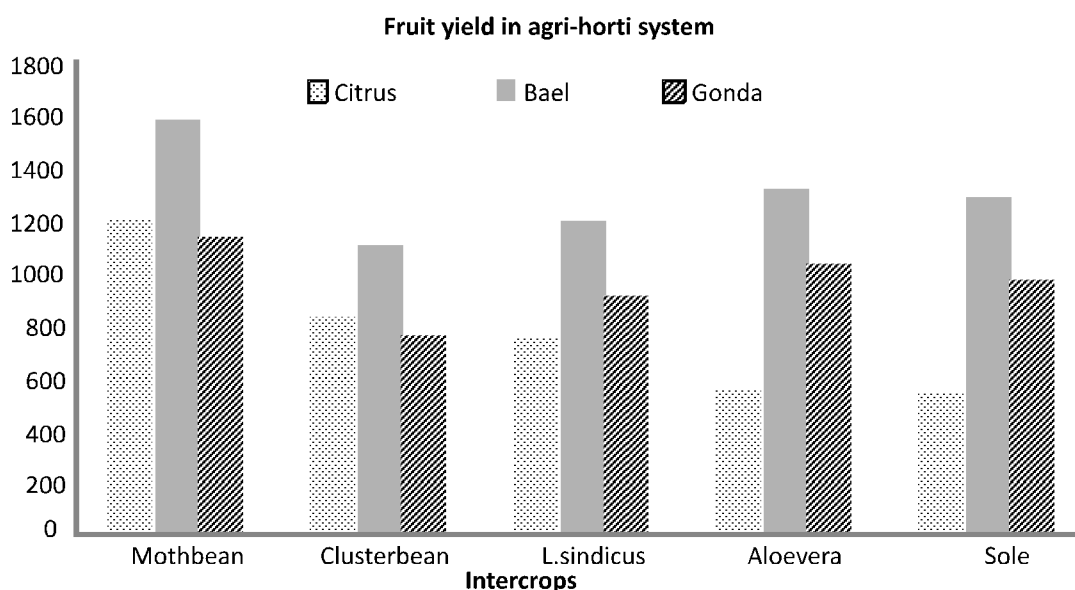


Fig. 1. Fruit yield under agri-horti system in drip irrigation

Table 2. Growth and yield of intercrops under agri-horti system (mean of 2012 and 2013)

Fruit trees	Dry matter production (kg/ha)		Seed yield		Dry matter yield (q/ha)	Green Pad yield (q/ha)
	Moth bean	Clusterbean	Mothbean	Clusterbean	<i>L. indicus</i>	Aloe-vera
Citrus	660.85	3014.15	240.4	1001.6	64.2	584
Bael	506.25	1865.85	192.5	732.85	17.3	611
Gonda	506.25	2032.9	211.25	841.9	31.5	404
sole	629	3018.95	247.5	1035	31.02	394
Mean	575.59	2482.9	222.91	902.84	36	498
CD 5%	419.3	526	NS	198.3	1.19	NS

Table 2. Growth and yield of intercrops under agri-horti system (mean of 2012 and 2013)

Trees/ Intercrops	Inter Crop WUE (kg/mm)				Agri-horti System WUE (kg/mm)			
	Moth bean	Cluster bean	Aloe- vera	<i>L. indicus</i>	Moth bean	Cluster bean	Aloe vera	<i>L. indicus</i>
Citrus	0.989	0.682	4.498	19.423	2.511	2.257	5.929	19.5
Bael	0.557	0.461	4.814	8.635	0.557	0.461	4.814	8.635
Gonda	0.778	0.509	3.919	16.994	0.778	0.509	3.919	16.994
Sole	0.595	0.485	3.2	14.8	0.595	0.485	3.5	14.8

Table 3. Water use efficiency (WUE) of intercrops and agri-horti system

Trees/ Intercrops	Inter Crop WUE (kg/mm)				Agri-horti System WUE (kg/mm)			
	Moth bean	Cluster bean	Aloe- vera	<i>L. indicus</i>	Moth bean	Cluster bean	Aloe vera	<i>L. indicus</i>
Citrus	0.989	0.682	4.498	19.423	2.511	2.257	5.929	19.5
Bael	0.557	0.461	4.814	8.635	0.557	0.461	4.814	8.635
Gonda	0.778	0.509	3.919	16.994	0.778	0.509	3.919	16.994
Sole	0.595	0.485	3.2	14.8	0.595	0.485	3.5	14.8

Table 4. Clusterbean equivalent yield of agri-horti system

Trees/ Intercrops	Clusterbean equivalent yield (kg/ha) agri-hotri system 2012-13			
	Mothbean	Clusterbean	Aloe-vera	<i>L. indicus</i>
Citrus	265.59	179.95	516.41	749.67
Bael	148.22	120	550.02	299.6
Gonda	207	132.5	447.8	589.6
Sole	158.44	220	3.5	14.8

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Standardization of seed and seedling standards of phalsa (*Grewia subinaequalis* L.)

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Abstract

Phalsa multiplication through seeds requires certain prerequisites *i.e.* fully ripened fruits and freshly extracted seeds for seedling raising, portrays for maximum seed germination per cent, germination more than 80 % from fresh seeds and completed within 25 days after sowing with 60-90 per cent plant survival rate, during seedlings shifting in polybags require minimum 3-4 weeks period with height of about 4-5 cm, seedlings of about 3-4 months age group attaining height and diameter 35-40 and 0.25-0.35 cm, respectively ready for sale or field planting. The developed standards would be highly useful for conservation of elite type germplasm and large scale multiplication of seedlings of phalsa.

Key words: Phalsa, seed propagation, seed standards, seedling standards

Introduction

Phalsa (*Grewia subinaequalis* L.) is known to be one of the oldest indigenous fruits in country. It is widely distributed in tropical and subtropical regions of India, Pakistan and Bangladesh. Phalsa is grown commercially in several states *i.e.* Punjab, Uttar Pradesh, Madhya Pradesh, Haryana, Rajasthan and the Himalayan regions, and at smaller scale in Karnataka, Maharashtra, Andhra Pradesh, Gujarat, West Bengal and Bihar. It is found up to 3,000 feet above sea level. Phalsa is drought-hardy crop and thus suitable for arid and semi-arid zones. 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, antioxidants, organic acids, tannins, anthocyanins, and flavonoids present in it (Kumar and Haldhar, 2020). Phalsa fruits have several traditional health benefits. It is an astringent, coolant and stomachic in nature. During Vedic period, the bark was used as a demulcent and serves as a treatment for rheumatism. Ground leaves is used to treat pustular infections and possess strong antimicrobial and antibacterial properties capable of remedying *Escherichia coli*. Its fruit and leaves exhibited significant anticancer activities against breast cancer cells and liver cancer cells (Kumar and Saravanan, 2017). Despite the highly nutritional value of the fruit, its commercial scale cultivation and production did not receive a fair response from the industry. 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 (Kumar and Haldhar, 2019). For fruit and colour development, fruit ripening and quality it requires optimum sunlight and warm temperatures.

Phalsa can grow and thrive well in different types of

soils. However, sandy loam soil having good drainage facility is ideal for good growth and development of the plant. 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. Good quality and healthy planting materials is the key of a successful orcharding which is lacking in phalsa. The demand for quality planting material of phalsa is increased throughout the country in the recent years. However, the greatest bottleneck in the expansion of area under it is the non-availability of genuine and named plants of released variety in adequate quantity from reliable government nurseries. The ICAR-CIAH, Bikaner has identified Thar Pragati an improved of phalsa for cultivation in arid and semi-arid region. More often farmers have to get the plants from unreliable sources and this practice is causing great harm to the fruit industry. The maintenance of purity is easy in vegetatively propagated plants as compared to seed propagated ones, still it requires a close monitoring at different stages in the nursery to produce disease and pest free planting material. (Anonymous, 2019). For improving this crop, selection of high yielding genotypes with desirable characters from seedling population and perpetuation by vegetative means is the best strategy.

There is not much attention given to the phalsa improvement by research institutes and state agricultural universities. Thus, there is no better variety available for commercial cultivation of phalsa. From last twenty years at ICAR-CIAH, Bikaner collection, conservation and evaluation of several genotypes under field condition have been done.

These genotypes have variations in plant, stem, leaf, flower, fruit size and color *etc.* which have collected from different states of the country and on which continuous research and evaluation was done for good quality and high yield production (Kamlesh and Haldhar, 2019). Results of several years of continuous study one elite genotype 'CIAH-P-1' was identified at institute level based on big fruit size, high fruit yield potential and other desirable attributes for commercial exploitation which is capable of producing high yields in limited resources in hot dry climate. Propagation of phalsa by seeds and cuttings has been practiced since long time, but till date this crop commercially multiplying through seeds (Sarolia *et al.*, 2018) only due to easy in propagation and short juvenility. General practice for seed propagation, seeds should be sown in June month at 1.5-2.0 cm deep in poly bags filled with equal proportion of FYM and soil. Success of germination depends on number of factors *i.e.*, water management, plant protection and bird-pest management *etc.* In summer, these are very difficult and reduce the success rate drastically. In place of this portray with soil less media provide the better option and ensure success as compared to direct polybags sowing. This fruit crop has good production potential but still underutilized and yet requires commercial exploitation. Additionally, meagre information are available on seed/ planting material standards till date in most of the underutilized fruit crops and no commercial exploitation for value added products for consumer preference.

Thus, keeping of above points in mind present study was undertaken to develop seed and seedling material standards of phalsa for high quality production. Seed and seedling material standards of phalsa cultivar 'CIAH-P-1' were standardized in the present study. The developed standards would be highly useful for conservation of elite type and large scale multiplication of quality planting material of phalsa for commercial orcharding in the country.

Materials and Methods

The experiment was conducted during 2019 at nursery unit, ICAR-Central Institute for arid Horticulture, Bikaner which is located at 28° N latitude, 73° 18' E longitude and at altitude of 234.84 m above sea level. Phalsa mature fruits have attractive and red to dark purple in colour were plucked manually from elite genotype CIAH-P-1 (IC No. 0628132) during May month and categorized on the basis of size (<8.5, 8.6-9.8 & >9.9 cm) and weight (<0.4, 0.41-0.49 & ≥0.5 g) in A, B and C grades, respectively then removed pulp by gently messing in water dip. Immature, undersized, shriveled and off type seeds removed and minimum of 400 seeds were taken and treated with carbendazim 3g per kg of seeds and sown in ten plug trays containing 40 cells (100 cc) in each in June month. Protray containing media mixture of vermiculite, perlite and cocopeat in the ratio of 1:1:2, respectively. These portrays were kept under agro-shed net (50% intensity) conditions and followed uniform management practices *viz.*, watering, plant protection, nutrition's management *etc.* Similarly, in polybags directly sown seed containing media of FYM, pond silts and soil in

ratio of 1:1:2, respectively. Observations were recorded pre germination as fruit size, weight, seed size, seed weight, seed number per gram, test weight (1000 seed weight), per cent germination. Post emergence of seedling picked at four leaf stage and shifted in poly bags containing media FYM: pond silt and soil in the ratio of 1:1:2, respectively. Seedling parameters *viz.*, seedling height, seedling diameter, leaf number, internodal length, root length, seedling vigour, biomass of seedlings were observed at 25 days interval up to 100 days after sowing as per standard methodology. Further, seedling vigour index was calculated by the formula proposed by Abdul and Anderson (1973) *i.e.* averaged root length (cm) + averaged shoot length (cm) x survival percentage in polybags conditions. Data were analysed with one factors analysis using statistical online OPSTAT software developed by Sheoran *et al.* (1998).

Results and Discussion

Fruit and seed attributes

Data revealed that mature fruits (diameter and weight), seed parameters (size, weight g⁻¹ and test weight) and germination parameters (per cent and span) significantly varied with grade of fruits and growing conditions. General fruit diameter ranges from 8.03-9.98 mm polar to 8.44-10.78 mm equatorial whereas, seed length slightly bigger 4.94-5.84 mm than breadth 3.61-4.38 mm. Seed weight in all categories recorded about 0.04-0.05 g weight of individual fruit. Per gram of weight counted seed 18 in A-grade and 22 in C grade fruits further, test weight varies with 48.8 to 52.6 g. Germination of seed initiation starts within fortnight after seed sowing observed *i.e.*, on 15th day and 50 % germination achieved on 20th day of sowing and final count was recorded on 25th days after sowing in both the conditions. Protray sown seeds germinated somewhat earlier than polybags might be due to cocopeat based media containing good water holding capacity and aeration that favoured better air exchange to faster germination. Additionally fresh seed sown were recorded maximum seed germination (> 80-90 %) over stored (one year) one (≤ 50 %) at ambient temperature. Stored fruit highly damaged by mould growth and quickly shriveled pulp on seed or hard seediness cause poor germination within a month period. This probably due to seed moisture, storage temperature and viability has a strong relationship, seed maintain moisture more than 12 per cent (12-16%) during the defined storage environment have considerable viability (Table 1).

Seedlings attributes under portrays grown than shifted to polybags

Seedlings have four leaf stage, 5-6 cm length and 20-25 days old, ready for shifting for secondary hardening in polybags. Seedlings parameters gradually showed increasing trend with the advancement of the days after shifting or sowing (DAS) in polybag. An interesting trend was observed when compared the seedling parameters over successive days of seedling growth. The minimum per cent increase was

observed during 0 to 25 days after shifting over rest of the segments in plant height, diameter, root length, seedling vigour etc. As far as seedling parameters under polybags seed sowing is concerned recorded same trend but lower incremental rate over portrays conditions. In present study 0-25 DAS showed low incremental might be due to changing of media (portray to polybags) and little damage of roots during handling and shifting, but after that shifted seedlings got required environment for accelerating growth and development of seedlings over polybags conditions. These results are in accordance with the findings of Davis and Hartmann (1984) and Hartmann *et al.* (2002). In present study maximum seedling height (40.17 cm), diameter (2.9 mm) and inter nodal length (3.4 cm) at 100th DAS might be due to better uptake of moisture which played key role in enhancement of vigour index in poly bag shifted seedlings from portray conditions (Table 2). This is in line with the results of Jabbar *et al.* (2010).

Seedlings parameters directly sown under polybags conditions

Seedling parameters in directly seed sown in polybags conditions were shown significantly with advancement of DAS. The initial observations (25 DAS) were recorded on seedling height 2.46 cm, diameter 0.34 mm, number of leaves 3.4, internodal length 1.15 cm, root length 4.11 cm and survivability 67 per cent. At 100th DAS the respective values were, 35.2 cm, 2.51 mm, 11.0, 3.30 cm, 28.60 and 62.3 %, respectively.

Seedling parameters between both the conditions

(portray sown and then shifted in polybags and directly seed sown in polybags), portray to polybags shifted seedlings were better with regards to growth, vigour and survivability during different days after sowing. At 100th DAS the portray sown seed shifted in polybags treatment recorded higher plant height 14.12 %, seedling diameter 15.54 %, seedling vigour 25.16 % and survivability 30.82 % over direct seed sown in polybags condition. This early attainment in portray sown and shifting seedlings polybags might be due to favourable growing conditions, better aeration and optimum moisture retention during experimental period. It is proved that portray seedlings are more stout and vigorous due to easy management and produce more volume of roots and less chance of soil born diseases as well as can be harvest the benefit of secondary nursery (Anonymous, 2019).

Therefore, on the findings from the study seed and seedlings standards have developed and phalsa requires prerequisites for quality production such as (1) seeds should have test weight around 50 g (20 seeds per gram), (2) seed germination should be more than 80 per cent with 60-90 percent plant survival rate, (3) seedlings should be ready for shifting in polybags within 20-25 days from seed sowing, and (4) seedlings of about 3-4 months age group attaining height and diameter 35-40 and 0.25-0.35 cm respectively ready for sale or field planting (Fig. 1).

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Table 1. Fruit/seed parameters and germination status of phalsa

Grades	Fruit diameter (mm)		Seed size (mm)		Fruit weight (g)	Seed weight (g)	Number of seed (g ⁻¹)	Test weight (g)	Germination (%)		Germination span (days)	
	Polar	Equatorial	Length	Breadth					PT	PB	PT	PB
A	9.98	10.78	5.84	4.38	0.50	0.05	18	52.6	95.6	84.5	14.0	18.0
B	9.06	9.67	4.96	4.40	0.44	0.05	20	51.5	95.0	85.0	14.3	18.3
C	8.03	8.44	4.94	3.61	0.35	0.04	22	48.8	93.3	82.7	16.0	21.0
SEm±	0.14	0.15	0.13	0.18	0.13	0.01	0.79	1.90	0.93	0.57	0.31	0.58
CD at 5%	0.43	0.44	0.40	0.54	0.40	NS	2.38	NS	NS	1.72	0.92	1.72

Where, PT:Protray and PB:Polybag

Table 2. Seedling parameters of phalsa sown in portrays conditions

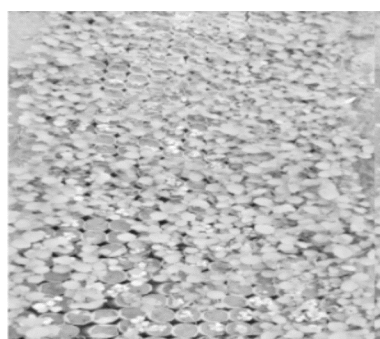
Days after Sowing	Plant height (cm)	Seedling diameter (mm)	Number of leaves	Inter-nodal length (cm)	Root length (cm)	Root: Shoot	Seedling vigour index	Seedling biomass (g)	Survival (%)
25	5.23	0.78	4	1.3	8.11	1.55	631	3.50	87.5
50	8.55	1.16	6	1.4	9.00	1.05	830	4.88	83.0
75	27.33	2.15	10	2.6	18.11	0.66	2149	12.77	82.3
100	40.17	2.90	12.4	3.4	30.80	0.77	3358	20.10	81.5
SEm±	2.22	0.28	0.53	0.19	1.44	0.01	38.65	0.36	0.61
CD at 5%	6.72	0.86	1.59	0.59	4.34	0.28	117.78	1.10	1.85

Table 3. Seedling parameters of phalsa sown in polybags conditions

Days after sowing	Plant height (cm)	Seedling diameter (mm)	Number of leaves	Inter-nodal length (cm)	Root length (cm)	Root: Shoot	Seedling vigour index	Seedling biomass (g)	Survival (%)
25	2.46	0.34	3.4	1.15	4.11	1.67	276	2.24	67.0
50	7.72	0.68	5.5	1.50	7.51	0.97	497	5.54	65.3
75	16.05	1.57	8.0	1.70	11.35	0.71	1152	9.15	64.0
100	35.20	2.51	11.0	3.30	28.60	0.81	2683	14.00	62.3
SEm±	0.49	0.09	0.60	0.10	1.19	0.07	56.18	0.63	1.23
CD 5%	1.50	0.26	1.79	0.31	3.57	0.21	168.21	1.88	3.69

Seed and seedling standard of phalsa

S. No.	Character	Standard
1.	Stage of fruit	Fully ripe
2.	Period of fruit ripening	May
3.	Fruit condition for seedling raising	Fresh and stored seed
4.	Seed extraction	Manually by running water
5.	Seed storage condition	Cool and dry place
6.	Seed viability during storage (month)	12-14
7.	Test weight (g)	49- 53
8.	Seed sowing	Protray
9.	Germination media	Cocopeat and FYM based
10.	Protray/ root trainer media mixture	Cocopeat: vermiculite (2:1) in protray and soil:pond silt : FYM (2:1:1) in polybags
11.	Germination initiation after sowing	12-15 days
12.	Germination 50%	18-20 days
13.	Germination > 95%	21-25 days
14.	Germination (%)	80-95
15.	Age of seedling suitable for shifting	3- 4 weeks
16.	Height and stage of seedling suitable for shifting	4-5 cm at four leaf stage
17.	Seedlings ready for sale/ f ield planting	3-4 months from seed sowing
18.	Height of standard seedlings at 3 -4 months (cm)	35-40
19.	Diameter of standard seedlings 3 -4 months (cm)	0.25-0.35



Direct polybag sown



Protray sown



Seedlings ready for sale

Fig. 1. Experimental view of phalsa and saplings ready for plantation

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Impact of FLD on vegetable pigeonpea (*Cajanus cajan*) variety 'Vaishali' under rainfed condition of central Gujarat

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Abstract

Traditionally, pigeonpea [*Cajanus cajan* (L.) Millsp.] cultivated for grain seed but for vegetable purpose, pods are harvested when it is immature. In Gujarat, it is used as substitute of green pea [*Pisum sativum* (L.)]. Pigeonpea is as one of the most important pulse crops of the Panchmahals district of Gujarat. However, productivity of pigeonpea in this district is very low. Attempts were made to improve productivity and to increase area under pigeonpea by adopting high yielding variety (Vaishali). In order to compare conventional pigeonpea with HYVs, 75 front line demonstrations were carried out in systematic manner on farmers' field to show the worth of a new varieties in comparison to local check and thereby convincing farmers about potentialities of improved variety and advance production management practices for adoption. The yield (green pod) in HYVs was recorded 80q/ha whereas it was 45q/ha in local check. Similarly, the benefit cost ratio for HYVs was estimated to 3.9 as compared to local check (2.5). The impact of FLDs was standardized which showed improvement in knowledge of pigeonpea cultivation and higher level of satisfaction in terms of its culinary uses and economic gain resulted into mass scale adoption of HYVs in Panchmahal district (Gujarat).

Key words: Frontline demonstration, pigeonpea, production technology

Introduction

Among sub-tropical legumes, pigeonpea or red gram [*Cajanus cajan* (L.) Millsp.] occupies an important place in rainfed agriculture. Globally, it is cultivated over 4.67 million ha, out of which; 3.30 million ha is confined to India alone. Though, it is mainly consumed as pulse, and also has a wide range of uses including as fresh or canned green pigeonpea vegetable purpose which is quite common in many parts of India including Gujarat. Vegetable pigeonpea is characterized by large pods and seeds are easy to shell. Vegetable pigeonpea can also be grown in slightly degraded soil, backyards, field bunds land with undulating topography *etc.* The fresh seeds (green seeds) can be frozen and canned for commercialization and export. It is more easily digested when cooked. It is a good source of protein, vitamins (A, C, B complex), minerals (Ca, Fe, Zn, Cu), carbohydrates and dietary fibers, *etc.* Compared to pulse, it has five times more β -carotene content, three times more thiamine, riboflavin and niacin content and has double amount vitamin C content. Besides it has higher shelling per cent (edible grains) (70%) than that of green peas (52%). These all factors indicate that pigeonpea is nutritionally rich vegetable and it can be used in daily cuisine. Even after this, the farmers' adoption rate for vegetable pigeonpea is poor, owing to inferior pod and seed characteristics of traditional strain of pulses. A survey was conducted to find out the liking of farmers about the qualities of pigeonpea, it was found that the farmers prefer pigeonpea which is having more number of pod, bold seed, and good taste, these physical characteristics

indicate that green pods are also liked for harvesting pigeonpea for vegetable purpose. The consumers preferred long (5-7 cm), wide (1.5-2.0 cm), pods with high numbers of seeds per pod (4-7). In view of this preference, the varieties which were bred or are cultivated mainly for vegetables (pod) purpose should be recommended for sowing in the area where pigeonpea is used as culinary purpose. Consequently, varieties Shavani, Vaishali, Mahima, Ganesh, *etc.* has been recommended for commercial cultivation in Central Gujarat.

Materials and Methods

An extensive survey was conducted to collect information pertaining to various usage of vegetable pigeonpea in the Panchmahals District of Gujarat. Seventy five farm families each from seven pigeonpea growing villages were selected from three Talukas *viz.*, Goghamba, Kalol, and Godhra for gathering the information. A questionnaire containing (10) questions were put to the respondents and data were analyzed. To popularize the improved vegetable pigeonpea production practices, constraints in vegetable pigeonpea production were identified through participatory approach. Preferential ranking technique was utilized to identify the constraints faced by the respondent farmers in vegetable pigeonpea production. Farmers were also asked to rank the constraints they perceive as limiting factors for vegetable pigeonpea production in order of preference. The quantification of data was done by first ranking the constraints and then calculating the Rank Based

Quotient (RBQ) as given by Sabarathnam (1988), which is as follows:

$$R.B.Q. = \sum_{i=1}^n f_i \times 100 / N \times n$$

Wherein,

f_i = Number of farmers reporting a particular problem under i^{th} rank

N = number of farmers

n = number of problems identified

Based on top rank farmers problems identified, front line demonstrations were planned and conducted at the farmers' field under technology demonstration for harnessing pulses production programme. In all, 150 full package frontline demonstrations were conducted to convince them about potentialities of improved variety of pigeonpea 'Vaishali' during the years 2015, 2016 and 2017. All the participating farmers were trained on all aspects of pigeonpea production management. Recommended agronomic practices and genuine seeds were used for FLDs in 0.5 ha area in each demonstration. A one fifth area was also devoted to grow local standard check. To study the impact of front line demonstrations, out of 75 participating farmers, a total of 50 farmers were selected as respondent through proportionate sampling. Production and economic data for FLDs and local practices were collected and analyzed. The technology gap and technology index were calculated using the following formulas as given by Samui *et al.* (2000):

Potential gap = Potential yield - Demonstration yield

Technology index = (Potential yield - Demonstration yield) \times 100 / Potential yield

Results and Discussion

Constraints in pigeonpea production

Farmers' pigeonpea production problems were documented in this study. Preferential ranking technique was utilized to identify the constraints faced by the respondent farmers in pigeonpea production. The ranking given by the different farmers are presented in Table 1. A perusal of Table indicates that lack of suitable HYVs was given the top most rank by 29 respondent farmers. The FLD participants were provided HYVs seeds as critical inputs. Based on the ranks given by the respondent farmers for the different constraints listed out in Table 1, the rank based quotients were calculated and presented in Table 2.

The analysis of data presented in the Table 2 revealed that lack of suitable HYVs, low soil fertility, weed infestation and followed by leaf hopper infestation were the major constraints to pigeonpea production. Other constraints such low technical knowledge, wilt, pod fly infestation, pod borer infestation, intercropping, wild animals and erratic rainfall were also found to reduce pigeonpea production. Earlier workers Saxena *et al.*, (2010); Ouma *et al.*, (2002); Joshi *et al.*, (2005) have reported similar problems in maize production.

Performance of FLD

A comparison of productivity levels between demonstrated variety and local check is shown in Table 3. During the period under study it was observed that in front line demonstrations, the improved pigeonpea variety Vaishali recorded the higher green pod yield (80 qha⁻¹) compared to local check (45 qha⁻¹). The percentage increase in the yield over local check was 77.7. Similar yield enhancement in different crops in front line demonstration has amply been documented by Haque Mishra *et al.* (2009), Kumar *et al.* (2010) and Dhaka (2010). From these results, it is evident that the performance of only improved variety was found better than the local check under local conditions. Farmers were motivated by results of agro technologies applied in the FLDs trials in also to adopt improved variety. Yield of the front line demonstration trials and potential yield of the crop was compared to estimate the yield gaps which were further categorized into technology index. The technology gap showed that the gap in the demonstration yield over potential yield 35.00 qha⁻¹. The best potential yield comes from the demonstration field where all inputs are given at optimum level. The observed technology gap may be attributed to dissimilarities in soil fertility, salinity and erratic rainfall and other vagaries of weather conditions in the area. Hence, to narrow down the gap between the yields of different varieties, location specific recommendation appears to be necessary. Technology index showed the feasibility of the variety at the farmer's field. The lower the value of technology index more is the feasibility. Table 3 revealed that the technology index values were 36%. The finding of the present study is in consonance with the findings of Hiremath and Nagaraju (2009) in case of onion crop.

The economics of pigeonpea production under front line demonstrations were estimated and the results have been presented in Table 4. Economic analysis of the yield performance revealed that front line demonstrations recorded higher gross returns (Rs. 120000 ha⁻¹) and net return (Rs. 87400 ha⁻¹) with higher benefit cost ratio (3.7) compared to local checks. These results are in line with the findings of Gurumukhi and Mishra (2003) and Hiremath *et al.* (2007)

Conclusion

The study undertaken with the help of 75 FLD participants at KVK, Panchmahals to know the economics of pigeonpea production using HYV and adoption level and constraint influencing the adoption of HYV. The results revealed that lack of knowledge of suitable HYV, soil fertility; weed infestation, wilt and low technological knowledge were the five most important factors which limits the adoption of HYVs of pigeonpea in Panchmahals. The yield of pigeonpea in demonstration was 80 q/ha as compared local check (45q/ha) has change the mindset of farmers at present, they are adopting the improved production technologies as demonstrated through FLDs.

Table 1. Ranks given by farmers for different constraints (n=75)

S. No.	Constraints	Ranks									
		I	II	III	IV	V	VI	VII	VIII	IX	X
1.	Lack of suitable HYVs	29	16	12	08	05	05	00	00	00	00
2.	Low technical knowledge	14	08	16	10	08	05	02	06	04	02
3.	Low soil fertility	13	12	16	17	05	06	03	03	00	00
4.	Weed infestation	18	15	11	07	03	06	07	08	00	00
5.	Intercropping	00	00	05	08	05	10	20	35	00	00
6.	Wild animals	05	05	04	07	07	02	10	13	10	12
7.	Wilt	06	04	15	11	13	26	00	00	00	00
8.	Pod borer infestation	10	10	09	06	07	05	08	10	05	05
9.	Pod fly infestation	09	14	10	11	09	07	04	06	05	00
10.	Leaf hopper infestation	08	14	17	15	13	00	05	00	00	03

Table 2. Frequency distribution of RBQ values given by farmers (n=75)

S. No.	Problems	R.B.Q	Overall rank
1.	Lack of suitable HYVs	85.46	I
2.	Low technical knowledge	69.2	V
3.	Low soil fertility	74.26	II
4.	Weed infestation	73.6	III
5.	Intercropping	48.13	IX
6.	Wild animals	45.2	X
7.	Wilt	66.8	VI
8.	Pod borer infestation	59.73	VIII
9.	Pod fly infestation	67.46	VII
10.	Leaf hopper infestation	73.06	IV

Table 3. Yield, technology gap and technology index of demonstration

Variables	Yield (q ha ⁻¹)	Increase (%) over Local check	Technology gap (qha ⁻¹)	Technology index (%)
Local check	45.00	-	-	-
Demonstration (Vaishali)	80.00	77.7	35.00	36

Table 4. Economics of frontline demonstrations

Variables	Cost of cultivation (Rs ha ⁻¹)	Gross return (Rs ha ⁻¹)	Net return (Rs ha ⁻¹)	Benefit cost ratio
Local check	26500	67500	41000	2.5
Demonstration	32600	120000	87400	3.7

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Performance of colocasia in hot arid region of western Rajasthan

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Abstract

The present study was conducted to evaluate the performance of colocasia under full shade, partial shade and open conditions of hot arid region of western Rajasthan. Result revealed that the vegetative growth characteristics *i.e.* plant height (31.20 cm), numbers of leaves/plant (2.70), leave length (21.60 cm) and leave width (20.20 cm) and yield attributes and quality attributes like dry matter percentage were recorded highest when colocasia was grown under aonla plantation (8 x 8 m) followed by colocasia grown under 100% shade condition and lower yield was observed under open conditions. Maximum numbers of cormels/plant (5.60), corm length (6.20 cm), corm diameter (9.20 cm), average corm weight (32.00 g), cormel length (4.30 mm), cormel diameter (8.10 mm) and cormel weight (18.90 g) were recorded when colocasia was grown in aonla plantation followed by colocasia grown under fully shade condition and lower values for yield attributes of colocasia was recorded under open field condition in the arid region.

Key words: *Colocasia esculenta* L., open condition, shade condition, yield attributes

Introduction

Colocasia (*Colocasia esculenta* L. Schott) is an important staple food crop grown throughout many Pacific island countries, parts of Africa, Asia and the Caribbean for its fleshy corms and nutritious leaves. The corm is an excellent source of carbohydrate, the majority being starch of which 17-28% is amylose, and the remaining is amylopectin. All parts of the colocasia are consumed, *viz.*, the leaves, petioles, corm and cormels used for curry preparation, corms utilized for snacks, baby feed, pig feed, *etc.* Colocasia (Taro) is thought to have originated in North Eastern India and Asia (Kuruville and Singh, 1981; Ivancic, 1992; Kolchar, 2006). Globally, it is grown in an area of 1.60 million ha producing 11.66 million t with an average productivity of 7.25 t/ha (FAO, 2009) and gradually spread worldwide by settlers. It is widely grown as a rainfed crop in the valley and *Jhum* area in entire North Eastern States of India. In Rajasthan, it is an important bulbous crop grown by both tribals and non-tribal populations. Previously it was grown in surroundings of major cities and National Capital Territory region of the state. However, due to the industrialization and urbanization, its area was reduced in these places (Alwar, Bharatpur and Jaipur region). At present, colocasia is the choicest tuber crop in *Hadoti* region *i.e.* eastern Rajasthan in Jhalawar, Kota, Bundi, Baran districts (Rathore *et al.*, 2016).

In the last few years, area under fruit crops has increased drastically in the state. Tuber crops are most suitable for intercrop in the fruit orchards. Colocasia are recommended as intercrop in new as well as old orchards. Rajasthan state is having highest rainfall variation in the country. It experience drought in every three years. Temperature also varied very

much, in summers temperature reaches as much as 47-48°C and in winters it is around -1 to -3°C. Frost is also occurred during severe winter. Extreme weather conditions can adversely affect corm production. The information regarding growing of colocasia crop is very scanty for arid region. To improve the yield and quality of colocasia, there is a need to standardize the conditions of growing in the arid region. Therefore, the present investigation has been carried out to study the response of the colocasia crop to full shade, partially shade and open field conditions.

Materials and Methods

The present investigation was conducted at ICAR-CIAH, Bikaner from 2017-2018 under aonla based cropping system (8 x 8 m) conditions as well as open condition (Fig. 1). The climate of the region is hot arid with a maximum temperature range from 39 to 45° C during May-June and minimum from subzero to 20° C during December-January. The average rainfall of Bikaner is 250 mm (average of 1998 to 2016) and most of rainy days occur during July to September with high evapo-transpiration that ranges from 1500 to 2000 mm per year.

Colocasia cv. local procured from the All India Coordinated Research Project on Tuber Crops Centre at MPUAT, Udaipur, was used for the study. The soil type is sandy texture and neutral to saline in reaction (pH 8.2). The experiment was carried out under three conditions *i.e.* between aonla plantation (8 x 8 m), fully shade condition and open condition with six replications under Randomized Complete Block Design. The sprouted cormels were planted at 45 x 45 cm spacing. After a month, gap filling was done for

maintaining uniform plant stand. Subsequent irrigations, weeding, intercultural operations and suitable plant protection measures were employed as and when required as per the recommended package of practices. Vermicompost @ 1.5 t/ha and NPK @ 80:60:80 kg/ha were applied. Phosphorus was given as basal dose. Nitrogen and potash were applied in four equal splits at 3rd, 4th, 5th and 6th months after planting. The observations were recorded for growth, yield and quality related traits.

Results and Discussion

The observations for growth and yield related traits were recorded like petiole length (cm), number of petioles, number of side shoots, number of cormels and yield per plant, length (cm), diameter (cm) and weight (g) of corm and cormels and yield (t/ha) (Table 1 to 3). The dry matter (%) was estimated based on fresh and dry weight basis. Maximum plant height (31.20 cm), numbers of leaves (2.70), leaf length (21.60 cm) and leaf width (20.20 cm) were recorded when colocasia was planted between aonla plantation (8 x 8 m) followed by colocasia grown under fully shade condition (31.10 cm, 2.50, 17.40 cm and 13.10 cm) and minimum was recorded when colocasia grown under open field condition (12.50 cm, 1.10, 7.00 cm and 5.30 cm). Colocasia are heavy feeders and for best performance required organic fertilizers and rich organic soil with plenty of composted material. A pH from 5.5 to 7.5 is found suitable for colocasia. Most colocasia prefer bright sunlight, unless grown in extremely hot, low humidity climates, where some light shade was necessary as reported by Cao and Long (2003), Long and Liu (2001), Misra *et al.* (2005), Tao *et al.* (2004) and Whitney *et al.* (1939).

Similar trends were observed for yield attributes of colocasia in the arid region. Higher value of numbers of cormels/plant (5.60), corm length (6.20 cm), corm diameter (9.20 cm), average corm weight (32.00 g), cormel length (4.30 mm), cormel diameter (8.10 mm) and cormel weight (18.90 g) followed by colocasia grown under fully shade condition and lowest yield attributes of colocasia were recorded in the arid was recorded under open field condition (Table 1).

Yield and quality of colocasia in the arid region varied significantly in different growing condition. Higher value of numbers of corms/plant, yield/plant (g), yield (t/ha) and dry matter (%) were obtained in partially shade condition followed by full shade condition and minimum was obtained under open field condition (Table 3). Crop when grown in open condition there is lower leaf number, leaf area index, chlorophyll content, dry matter accumulation, bulking rate, yield as compared to shade. Shade levels favoured for obtaining higher dry matter (Kumar and Jayachandran, 2003). It suggested that canopy temperature around the crop have been reduced by shading and this favours improved growth of colocasia in partial shade condition.

From the present study, it can be concluded that there is a good scope for cultivation of colocasia in hot arid region of north-western Rajasthan as intercrop in orchard. If good quality planting material and micro-irrigation facilities are made available, definitely the prospect of colocasia will be bright in this region as an intercrop with drip irrigation which enables high frequency application of water in and around root zone of the plants. This micro-irrigation methods of irrigation/fertigation economize on water (about 40-70% saving) at the same time giving 20-35 higher yield with up to 30-35% saving on fertilizers.

Table 1. Growth attributes of colocasia in the arid region at 45 days after planting

Growing conditions	Plant height (cm)	Numbers of leaves	Leaf length (cm)	Leaf width (cm)
Between aonla plantation (8x8m)	31.20	2.70	21.60	20.20
Grown under fully shade condition	31.10	2.50	17.40	13.10
Open field condition	12.50	1.10	7.00	5.30
Mean	24.90	2.10	15.30	12.80
CD at 5%	6.14	0.98	4.89	3.84

Table 2. Performance of yield attributes of colocasia in the arid region

Colocasia grown in different conditions	Number of cormels/plant	Corm length (cm)	Corm diameter (cm)	Corm weight (g)	Cormel length (mm)	Cormel diameter (mm)	Cormel weight (g)
Between aonla plantation (8 x 8 m)	5.60	6.20	9.20	32.00	4.30	8.10	18.90
Grown under fully shade condition	3.40	3.70	5.50	19.20	2.60	4.90	11.30
Open field condition	1.30	1.50	2.20	7.70	1.00	1.90	4.50
Mean	3.40	3.80	5.60	19.60	2.60	5.00	11.60

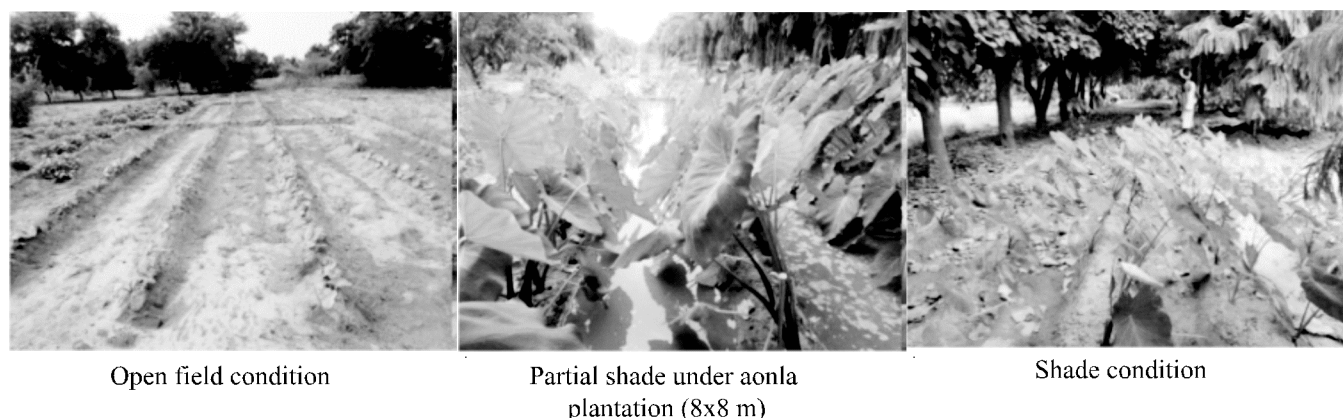


Fig. 1. Colocasia performance under different growing conditions

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An impact of COVID-19 on Indian Agriculture

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India is currently confronting its most noteworthy emergency since its freedom. There is a two months lockdown to authorize self-separating to forestall the spread of COVID-19 and straighten its development bend. It is regular that all the while, the economy is on finished bed rest. The activity is to discover the expense of this lockdown. Internationally, the Food and Agriculture Organization (FAO) expects moves in the inventory of and interest for nourishment. It cautions of a world "nourishment emergency" if nations don't shield defenceless individuals from craving and malnourishment, and de-stop up nourishment supply chains. Thus, the India has cautioned that the COVID-19 emergency could trigger "nutritional deficiencies" around the globe. The World Food Program (WFP) has noticed that the COVID-19 emergency is taking steps to influence a large number of individuals previously made defenceless by nourishment frailty or lack of healthy sustenance. Little and negligible ranchers will likewise be severely influenced on the off chance that they can't keep working their territory, win profitable item costs, and access markets for purchase or sale.

As can be seen, aside from basic administrations, power, gas, water supply and part identifying with broadcasting, money related administrations (banking) and, open organization, safeguard, and so forth, all different segments have been totally closed. The effect on horticulture, which is regular in nature, can't be discovered precisely. Our survival is dependent on agriculture and a good harvest depends on quality seeds delivered to farmers by the seed sector, both public and private. As we are in the corona virus crisis, it is imperative that good seeds and other farm inputs reach farmers in time for the *kharij* season.

During these difficult occasions, how does Indian agriculture react to the emergency and how do government estimates influence 140 million ranch family units the nation over and from that point sway the economy of a significant nation in the creating scene. We evaluate the quick difficulties that COVID-19 has presented to the homestead division and recommend alleviation measures to guarantee a feasible nourishment framework in the post-emergency period. In this informational review, we will discuss the impact of COVID-19 in Indian agriculture industry. The problems in agriculture at the moment are primarily related to (a) labour availability and, (b) inability to access markets for produce due to issues in transportation as well operation of markets.

The non-accessibility of work has harmed tasks in numerous parts. A few pieces of farming that have the advantage of conveying innovation for gathering, similar to

paddy and wheat, are generally more protected since they frequently don't need to rely upon huge number of work. The expanding utilization of mechanical gatherers for paddy has helped in the current conditions, however their between state development has been seriously shortened. In any case, business crops are definitely hit as they will in general be progressively subject to transient work. Thus, the deficiency of vagrant work has brought about a sharp increment in day by day compensation for reaping crops. In numerous territories, the ascent is as high as 50 per cent, making it unprofitable at makers since costs have crumpled due to either absence of market get to including the stoppage of transportation and conclusion of outskirts.

Agriculture producers are especially hard hit with returns on produce shifting from 33% the standard or a total misfortune. In various locals, between state exchange business yields or nearness to urban zones gives advertise access and better costs. These are frequently because of activities of individual ranchers as opposed to coordinate state support. This is frequently the situation of yields like onions, cotton, mango, inland fisheries, blossoms and vegetables. The ascent in labour expenses and absence of access implies that ranchers are gazing at immense misfortunes and henceforth permitting harvests to spoil in the fields, a superior 'stop-misfortune's system. The individuals who have kept away from a total misfortune scarcely squeeze out any cash to take care of the expense not to mention family support or land rent rates. If we bifurcate the impacts of COVID-19 in some areas we can understand the current situation:

Economic impact

Let us first beginning with the topic of costs. It is critical to take note of that even before the COVID-19 pandemic started, Indian economy was confronting an ascent in food costs. Information shows that food swelling had started to ascend from the center of 2019, coming to, by January, 2020, and levels recently achieved in 2013-14 (Fig. 1). Information on the discount value files (WPI) for chose crop gatherers, accessible just till February, 2020, show that while WPI for food articles has been ascending from August, 2019 onwards, the ascent was driven by an ascent in the costs of vegetables; inside vegetables, the cost of onions, trailed by potato and tomato, drove the WPI up (Fig. 2). While onion costs have descended, vegetable costs stayed high even in February, 2020.

The RBI's appraisal is that food swelling weights will fall, since total interest is probably going to debilitate on

account of the COVID-19 emergency. Buyer value lists (CPI) for food additionally show a comparable pattern of an ascent after August, 2019 with some debilitating in January and February, 2020 (Fig. 3)



Fig. 1. Food inflation rates in India (Source: Trading economics)

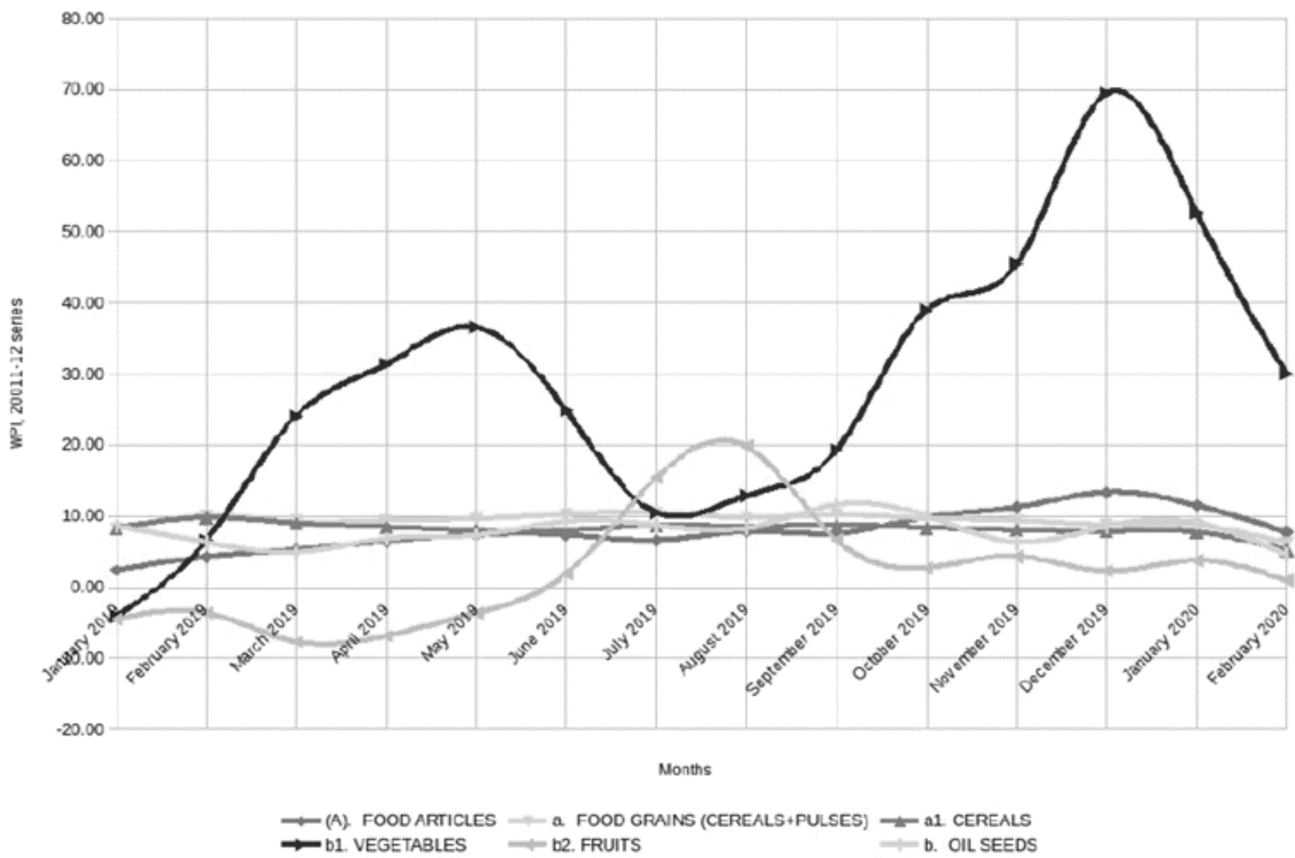


Fig. 2 Percentage change in the WPI of important agricultural commodities, y-o-y (Source: MOSPI)

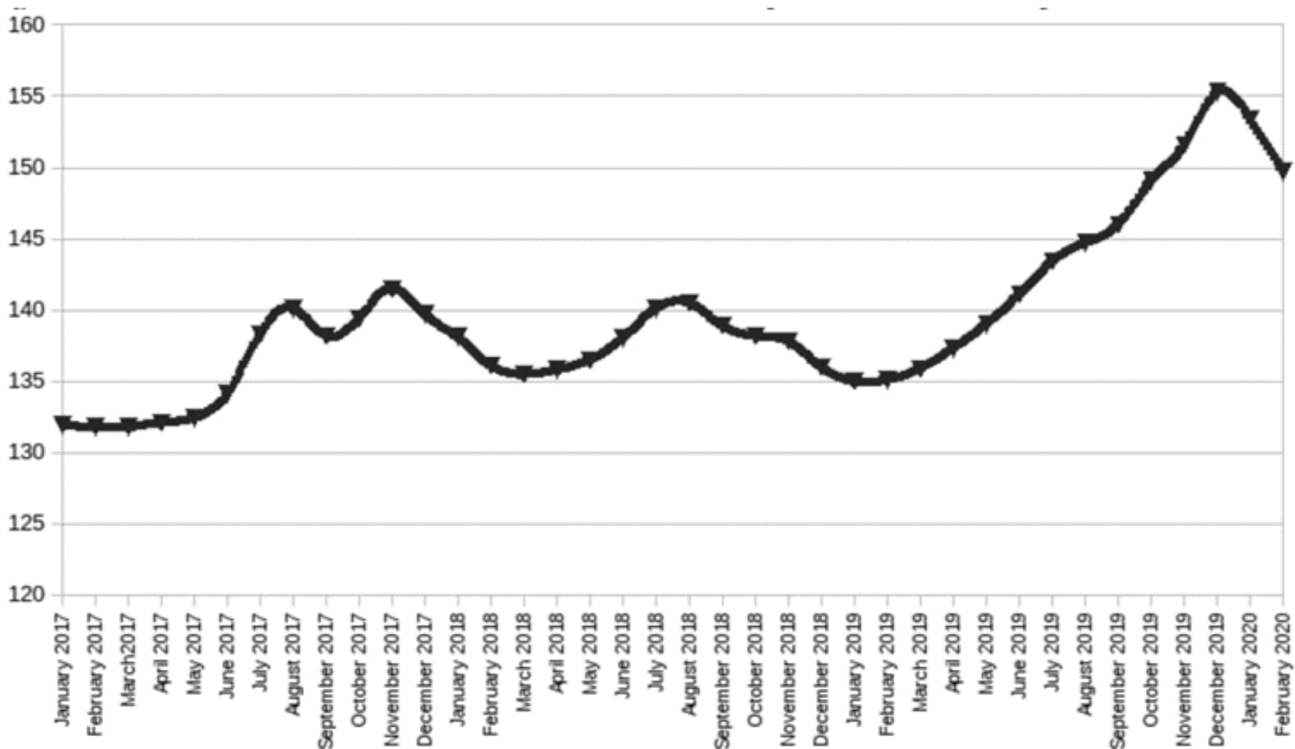


Fig. 3. Consumer Food Price Index, India, January 2017 to February, 2020 (Source: MOSPI)

Harvesting and marketing

Reaping and showcasing crops at the ranch level is in emergency the nation over, in light of the fact that are (a) interruptions in the acquirement of food grains by government organizations; (b) disturbances in the assortment of harvests from the homesteads by private merchants; (c) a lack of laborers to collect the *rabi* crop; (d) a deficiency of drivers in the transportation division; (e) bars in the development of horticultural wares over the significant interstates; (f) constrained tasks of APMC *mandis*; and (g) shutdowns in the retail farming markets. These variables have prompted an emergency in a scope of harvests as well: wheat, grapes, watermelons, bananas, muskmelon, cotton, chillies, turmeric, cumin, coriander, onion, and potato. These bottlenecks have led to a fall in the farm prices of a range of commodities in agriculture. Tomato growers in Maharashtra are reported to be receiving not even Rs. 2 per kg. Grape growers are reported to be facing an aggregate loss of Rs. 1000 crore because of the crisis, as demand has fallen. Wheat prices in Madhya Pradesh are reported to have fallen from Rs 2200/Q to about Rs. 1600/Q by March 25, 2020. For many crops, these prices are also below the Minimum Support Prices (MSP) announced. In Punjab, vegetables that were sold at Rs. 15/kg are reportedly being sold at a mere Rs. 1/kg. In Delhi's *mandis*, the price of broiler chicken has fallen from Rs. 55/kg in January 2020 to Rs. 24/kg in March 2020. In Tamil Nadu, egg prices are reported to have fallen from Rs. 4/egg to Rs. 1.95/egg over the same period.

As the lockdown continues, these costs can be relied

upon to rise, similarly as in the Western economies, the ascent driven by alarm purchasing and flexibly bottlenecks. In spite of such value rises, ranchers are probably not going to be the recipients; most advantages are relied upon to stream to discount and retail dealers just as other go between.

Migration of workers

The arrival of numerous vagrant laborers to their homes has implied that collect activities are not occurring easily, and numerous ranchers are being driven away from the yield in the field. Misfortunes to ranchers will be the most elevated in such cases. While mechanical reapers can be utilized, lockdown guidelines disturb their free development. Further, in certain spots, a lack of drivers/administrators for these reapers has additionally been accounted for. As machine fix shops are shut and mechanics become inaccessible for work, save parts are not effectively accessible, prompting numerous machines being left unused. In the rice plants of Kerala, reports show a lack of transient laborers, which has prompted these factories not securing sufficient supplies of paddy from ranchers. Ranchers have either not reaped by any means, or have collected and left the item close to the fields. Work deficiencies are additionally being knowledgeable about most milk handling plants, cold stockpiling units, and distribution centers. As indicated by the chairperson of AMUL, most milk preparing plants are right now working with half of the work power. Numerous specialists are not revealing for work or have get back additionally on account of the dread of police outrages.

Supply chain

Supply chains have been upset the nation over for a scope of products. The primary authority warning on lockdowns seems to have been poorly considered; prompting the prohibition of various exercises from the rundown of fundamental things (this included even cleanser and sterile cushions till March 28, 2020). A subsequent warning has adjusted this, at any rate incompletely. However, significant thruways and section focuses to states are seeing a heap up of trucks unfit to push ahead. Bus transport is in significant lack at numerous spots, prompting the incredibly sluggish development of products the nation over. APMC *mandis* are not working each day; while some have shut down, others are working just twice or threefold every week. The bottlenecks because of the lockdown are set apart as crosses at the fitting areas. The data for this reason has been sourced from news reports and are thus to be viewed as primer. Likewise, the nearness of bottlenecks may contrast broadly across States/districts.

Shortage of livestock feed

The lack of domesticated animals feed and their accessibility is raising the expenses of creation in numerous creature farming units. This is in spite of the way that poultry has been proclaimed as a fundamental thing. This is prompting the demise of numerous flying creatures at the homestead, or ranchers undertaking alarm selling at exceptionally low costs.

Possible shortages ahead

An immediate consequence of this should make the government weary and alert to a possible sharp spike in the price of vegetables and other commercial crops due to large scale changes in cropping patterns. Large buffer stocks in paddy and wheat mean that food grains shortage due to poor harvest is unlikely, at least this year. The case of commercial crops and vegetables is more complex. The decision to plant, these are largely dependent on realization price in the preceding season. A collapse in returns means that farmers are likely to shift to another crop thereby substantially altering supply dynamics and with it prices. This, in turn, may have a bearing on food inflation.

This is the pinnacle of *rabi* season in India and yields like wheat, chickpea, lentil, mustard, and so forth (remembering paddy for flooded tracts) are at harvestable stage or nearly arriving at development. This is additionally when the homestead harvests come to the *mandis* (showcase yards) for guaranteed acquisition activities by assigned government organizations. In addition, any serious interruption to the flexibility of transient leafy foods, dairy items, fish, and so forth having activated to satisfy the expanding need from a protruding white collar class just as urban and country purchasers, may make unsalvageable harm to all on-screen characters in the gracefully chain. The relocation of laborers from scarcely any parts to their local spots has likewise activated emergency signals, as they are significant for both gathering tasks and post-collect treatment of produce away and showcasing focuses. The Union Home

Ministry, in an extremely noteworthy move, has told to prohibit development of ranchers, ranch workers and collecting and planting related machines from the domain of lockdown.

As the progressing lockdown harmonizes with the *rabi* collecting season, ranchers the nation over admire the government to guarantee continuous gathering of the harvests just as smooth acquirement activities. The Union Home Ministry's roundabout deferring limitations on the between and intra-state developments of ranchers/workers, just as collecting and related homestead machines, is for sure a stage right way. While guaranteeing accessibility of workers for basic ranch tasks, their wellbeing (from any COVID contamination) and government assistance must be organized by the Government frameworks. The offer of dairy items; fish; poultry, and so forth has likewise been hit during the lockdown time frame as the take-up by the composed business players have been influenced because of lack of workforce and transport issues. As climate has been flighty over recent months in numerous parts, gathered produce should likewise be shielded from such dangers.

Need for possible plan

The finish of the lockdown won't end the issues. Actually, they are probably going to be exacerbated at the beginning of the new planting season. The most significant issue that ranchers need to overcome is the issue of reimbursing their yield advance and gold advances at any rate for the individuals who have acquired from the proper financial part. Yield credits are reimbursed among April and May and a new advance is allowed at the beginning of another season. Ongoing value breakdown implies that ranchers are gazing at enormous misfortunes and the vast majority of them are as of now exceptionally obliged and henceforth improbable to have the way to reimburse their credits.

Any inability to do so will imply that they will be compelled to get cash from the casual area at high paces of enthusiasm for the new season. Henceforth, the administration will be all around instructed to think with respect to a rescheduling of credits wherein existing advances are changed over to long haul advances payable over a multiyear time span. There is requirement for government support as help for other rural sources of info. Absence of any help will just exacerbate the farming emergency.

India needs to make more collaboration in food innovation, farming, and biotechnology. Organizing and adaption of development should go about as primary drivers of profitability development and improved manageability. We ought not to neglect to use accessible assets in the correct way. The sufficient, suitable and accessible assets should stream the correct way. The progressing across the country lockdown should be checked on and supplanted with group indicated limitations (as required) in view of epidemiological evaluation, as there is no possible situation of control or end in a brief period. An interdisciplinary group of general wellbeing authorities and social researchers, alongside grassroots political and social initiatives and volunteers, should keep

bringing issues to light about the COVID-19 methods of transmission and strategies for anticipation in the network. Assistance of vagrant specialists to come back to employments after the lockdown in any case staple food creation can be influenced prompting a grave effect on food security. There ought to be an arrangement of value seeds to ranchers by the seed area - both open and private.

Conclusion

The episode of Corona infection began in Wuhan region in China in December 2019 has now gotten a worldwide pandemic influencing about 15 lakh populace with a demise cost of about 1 lakh individuals. In spite of the fact that the greater part of the individuals are recuperating every day, this organic fiasco has seriously shaken the world economy and has had an enormous negative ramifications on the equivalent. The most touchy agribusiness segment which is the foundation of our nation is additionally hit with the externalities of COVID-19 flare-up. Despite the fact that not straightforwardly, yet in a roundabout way the fallout of crown infection spreading impact for example lockdown the nation over has ended up being a dark opening for the cultivating network. The ranchers are probably going to feel a plunge in their pay. For the most part because of lockdown the limitations on the development of agribusiness products from its place of creation to a definitive customer has been hampered. Another issue lies with the deficiency of work power due to the dread of viral transmission which at last prompts the wastage of gathered items, chiefly foods grown from the ground vegetables which are transitory in nature, in the rancher's field itself. The Corona infection pandemic has

put a potential sway on the farming item flexibly chain which is a complex trap of maker, transporter, distributor, retailer lastly the shopper. Likewise the arranging of the *kharif* and *rabi* crops has been placed into an end which will cause a significant halt in the up and coming rural seasons. In any case, it can be battled with the incorporated endeavors of the focal what's more, state governments alongside the exploration foundations what's more, expansion administrations. To keep away from the unfavorable effect of COVID-19 episode and to keep the farming division unaffected the legislature should give specific rules for agribusiness activity, the value structure ought to be taken into thought and changed such that the ranchers are not under any sort of budgetary misfortunes, the cultivating network alongside the workers ought to be ensured from Corona infection by keeping up social separating along with help with managing the frenzy and mental misfortunes during this time and obviously giving the ranchers a stage for direct showcasing to satisfy the need of the buyers by home conveyance of the agrarian create and stay away from any sort of wastages in the gathered items.

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Short Communication

Variability in date palm fruits (*Phoenix dactylifera* L.) collected from Kachchh region of Gujarat

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Date palm (*Phoenix dactylifera* L.; family-Arecaceae) is one of the most important fruit trees for semi arid and hot arid regions of the country. It is an ancient fruit and believed to be indigenous to countries around Persian Gulf. Date palm groves in coastal region of Kachchh from Anjar to Mandvi have developed naturally through seeds, which probably brought by Turk settlers, traders, gardeners and Haj pilgrims. The seedlings are very old in Kachchh region and some new systematic plantations of date palm have also been developed either through suckers or tissue culture plants of cv. Barhee. Moreover, seedling populations of date palm are not found in other parts of country. The ripe fruits (*doka* or *khalal*) are used for fresh consumption and processing. Every part of the date palm plant is useful since its history of cultivation and utilization. Dried fruit pulp is used for flavoring the bakery products. Date palm leaves are also used for making handicraft items *viz.*, broom, hand-fan, mat, rope *etc.* Date is nutritious fruit having high calorific value in the form of sugar, minerals and vitamins (Zaid, 1999; Singh, 2018). It has high market potential for the production of soft dates (*pind khajoor*) and dry dates (*chhuvara*). However, processing is very less in our country. Presently, India imports about 3,11,575 MT dates every year from Gulf countries to meet out the domestic requirement.

At present, about 18,847 ha area is under date palm cultivation in the coastal region of Kachchh with estimated annual fresh fruit production 173997.60 MT (2017-18). Variability in date palm exists through out Kachchh region because the date groves have originated from seeds. The entire region exhibits great variability and diversity in many phenotypic characters *viz.*, colour, shape, size and taste of fruits. The climatic conditions of Kachchh region is also suitable for date production in India. It is a dioecious and monocotyledonous plant. The soil of the region is sandy loam and average annual rainfall is 425 mm. All fruit from Kachchh palms are harvested during mid June to July at *doka* or *khalal* stage (hard ripe yellow, red or dark red colour) of maturity because of early rains. Intercrops *viz.* pearl millet, cluster bean, forage and small fruit plants are grown in association with date palm in Kachchh region (Muralidharan *et al.*, 2008). Date palm plantations are economically important because it requires minimum care and has vast potential of cultivation arid regions in Rajasthan, Punjab and Haryana as well as in coastal belt of Gujarat. Limited work has been conducted on

post harvest management for proper utilization of fruits. Therefore, major emphasis should be given on processing and value addition in date palm (Sharma *et al.*, 2010). Now a days, consumer's preferred red colour fruit of date palm whereas these genotype/cultivars are limited in date palm repository at ICAR-CIAH, Bikaner.

Keeping in view, a survey was conducted to exploit genetic diversity in the country in date palm and to identify superior plus trees having early maturity, better quality of fruits at *doka* stage, good fruits yield, medium to heavy bearing types, suitability for processing, rain and *Graphiola* leaf spot disease tolerance, the details of survey, identification of elite type, fruiting and quality characters have been discussed in this paper.

A survey of date palm orchards was conducted during the year 2019 in Kachchh region of Gujarat to identify genotypes having early maturity, better quality and yield of fruits and also having rain tolerance characters. The orchards surveyed in villages near by Mundra, Anjar taluka of Bhuj district. Kachchh region of Gujarat, spread over 45,652 sq. km lies between 22° 5' to 24° 4' N latitude and 68° 9' to 71° 5' E longitude which is highly suitable for date palm cultivation in India. Palms having prolific bearing, attractive colour of fruit, sweet in taste and disease free were identified and marked. Plant population, fruiting behavior, number of bunch/palm and fruit characters along with status of uses, marketing *etc.* were recorded to assess date palm production and utilization. Nineteen fruit samples were collected from elite trees. Data on important fruit characters were assessed the extent of variability and compared over better palm for further multiplication and evaluation through clonally and raising seedling progenies.

The data pertaining to physico-chemical characters of date palm fruits are presented in Table 1. The date palm orchards were surveyed nearby Mundra, Kachchh region to identify elite type germplasm. The maximum seedling population exists on field or farm boundary, road side, river belt and depressions. The seedling palms are natural and very old, which are estimated to be around 1.9 million in Kachchh region. However, some seedlings have been planted at close spacing at farmer's field. The palm trees are having good

potential in natural population which should be multiplied. Among dates groves some palms are high yielding while others are unproductive because of high palm height, improper pollination, small size inferior quality fruits and poor management.

The plant characters basically depend upon genetic composition as well as soil and climate condition of the growing site. In general, 15-20 feet trees height was observed while some old date groves are very high and naturally grown. The palm had good foliage, vigorous growth and 5-10 offshoots per palm. However, some date groves are well managed by removing suckers for new plantations or better fruiting. But the maximum date groves are in natural condition. Now tissue culture plantations of cv. Barhee have been done in which suckers has not been allowed to grow for early fruiting. The tissue culture plantations are under drip system and spaced at 8 x 8 and 9 x 9 m. Branching in date palm is rare (Zaid, 1999) but at a place 3-4 palms were growing in groves. Some times the growth of aerial suckers also looks like branch in date palm. The maturity and ripening in local genotype is early in Kachchh region in comparison to other parts of the country.

The fruit yield in date palm is directly depends upon size of bunch and berry, number of bunches/palm and number of fruits/strand. Variation in number of bunches from 4 to 10 per tree was observed. Variation in number of bunches, size of

bunches and berries might be due to genetic features of the type, soil types, plant density per unit area and management practices employed. Genetic diversity in date palm has also been reported by Jain (2018) under climate change scenario. The bunch weight also varies from 5-10 kg depending on size of berries and thinning practices. Fruit thinning improves the size of berry in date palm is known practice to growers. However, all the growers do not practice thinning of fruits. From perusal of data, a significant variation (8-34 fruits/strand) in number of fruits per strand was observed. Variation in number of fruits, bunches and yield has also reported by Murlidharan *et al.* (2008).

The significant variation was observed in date palm fruits with respect to weight of berry (4.59 to 15.4 g), fruit size (2.65-4.62 cm length and 1.52-2.83 cm width) and pulp content (3.61-14.5 g) besides stone weight and size. Variations in size, berry colour, length of bunch, weight and yield have also been described by Muralidharan *et al.* (2008). As far as fruit weight is concerned, DP-06, DP-09 and DP-12 were found superior in size and quality characters in comparison to other germplasm. The maximum fruit weight (15.39 g) was recorded in DP-19 but TSS was very low possibly due to improper maturity and ripening. The TSS of fruits was greatly varied from 14.8 to 36.69 °Brix. The variations in colour of fruits at *doka* stage of maturity from yellow to light, dark red were observed, which is very useful to popularize date for

Table 1. Physico-chemical characters of fruits of date palm germplasm

Germplasm	Fruit colour at doka stage	No. of fruit/ strands	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Pulp weight (g)	Stone weight (g)	Stone length (cm)	Stone width (cm)	TSS (° Brix)
DP-1	Red	34	3.75	1.81	7.40	6.35	1.08	2.40	0.80	18.48
DP-2	Dark red	24	3.46	1.52	4.92	3.62	0.52	2.32	0.74	31.43
DP-3	Yellow	16	4.26	1.85	10.13	9.46	1.06	2.79	0.75	23.55
DP-4	Dark red	18	3.11	2.35	9.77	8.03	1.31	2.17	0.94	24.25
DP-5	Reddish green	8	3.38	2.46	12.83	11.90	1.30	2.11	1.09	23.65
DP-6	Red	10	3.89	2.18	12.06	10.87	1.13	2.33	0.94	36.69
DP-7	Dark red	27	3.10	1.92	7.52	6.45	1.05	2.09	0.92	28.55
DP-8	Light red	8	4.63	2.30	12.54	11.82	1.14	2.70	0.82	14.80
DP-9	Red	20	4.13	2.25	12.79	12.40	0.90	2.23	0.88	25.31
DP-10	Red	28	3.46	2.04	7.85	7.30	1.51	2.67	0.92	17.48
DP-11	Dark red	10	3.27	1.84	8.52	7.64	1.30	2.28	0.88	28.90
DP-12	Light red	11	3.65	2.29	13.42	12.02	1.04	2.26	0.85	20.48
DP-13	Green	11	3.28	2.34	11.60	10.51	1.18	2.11	0.93	21.81
DP-14	Dark red	22	3.06	1.79	6.46	5.82	1.01	2.12	0.85	19.52
DP-15	Dark red	19	3.57	2.24	11.56	10.12	1.27	2.39	0.91	21.51
DP-16	Yellow	18	3.42	1.94	7.87	6.43	1.05	2.27	0.89	20.55
DP-17	Dark red	12	2.71	2.03	6.38	5.11	0.99	1.64	0.96	23.51
DP-18	Dark red	14	3.50	1.70	6.97	6.04	0.88	2.29	0.77	35.65
DP-19	Greenish red	09	3.73	2.83	15.39	14.50	1.04	2.03	0.94	16.54
SEm+	---	2.02	0.21	0.16	0.41	0.34	0.06	0.13	0.05	0.84
CD (5%)	---	5.82	0.63	0.48	1.16	0.97	0.17	0.38	0.15	2.41

fresh consumption. Early maturity was noted maximum in red colour type. A perusal of data presented in Table 1 revealed that the difference between the genotypes in fruit size, pulp weight, pulp stone ratio and seed size were varied. Fruit characters vary greatly depending on variety, environmental conditions and technical care given like fertilization, pollination, etc. (Zaid, 1999). The palm bearing big size dark red colour sweet in taste fruits were considered promising. The fruit yield vary from 50-100 kg per tree which depends upon the age of tree, extents and pattern of rainfall, pollination, number of bunches/tree, number of berries/strand, management practices besides soil and climatic conditions. In general, 50-60 kg fruits/palm is harvested at *doka* stage by the farmers. The quality of *doka* fruits varied greatly because of genetic variability in seedling palms. The elite palms, which bear good quality, sweet fruits fetches good price in the market. In Mundra area, fruit bunches were harvested and packed with berry strand in carton for sale in local market. The wholesale price of *doka* fruits varied and depends upon quality of fruits, grading, packing, etc. Use of date fruits for processing and value addition is very less as told by the date palm growers of the region.

The seedling populations are abundantly found in Kachchh region of Gujarat showing variability with respect to berry shape, colour, weight, pulp content, fruit size, taste, bunch size and yield potential in date palm. The genotypes showed significant variation in morphological and physico-chemical characters of fruits. The colour of berry at *doka* stage

was yellow, red to dark red and greenish red. The significant differences were noted in number of berries/strand, fruit weight from 4.92 to 15.40 g, stone weight 0.52-1.30 g and TSS 14.8 -36.8 Brix. The seeds of collected material have been used for raising seedlings for further evaluation. The suckers of marked genotypes DP-06, DP-09 and DP-12 would be procured for multiplication and evaluation under hot arid region and it can be further utilized for date palm improvement programme.

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Site specific agriculture

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An agricultural production system is the consequence of a complex interaction of seed, water and agro-chemicals together with fertilizers and pesticides. Therefore, careful management of all inputs is imperative for the sustainability of such complicated system. The focal point on enhancing the productiveness barring thinking about the ecological impacts of the enter resources has resulted into environmental degradation. Increasing environmental cognizance of the widespread public is necessitating us to regulate agricultural management practices for sustainable conservation of natural sources such as water, air and soil quality, whilst staying economically profitable. The productivity can be elevated except any detrimental effect by using maximizing the aid enters efficiency. It is also certain that availability of labour for agricultural recreation is going to be in quick grant in future. The time has now arrived to carry statistics technology and agricultural science together for extended financial and environmentally sustainable crop production. This offers start to Precision Agriculture or Precision Farming or we also coined this as Site Specific Agriculture. In precision agriculture well timed collection and analysis of the spatial and temporal variant data of crops, soils and surroundings is important. This can be finished by means of new emerging statistics applied sciences such as Global Positioning System (GPS), Geographical Information System (GIS), remote sensing, yield monitors, IOT based totally gadget *etc.*

What is precision farming ?

Precision farming refers to the precise application of agricultural inputs with appreciate to soil; weather and crop need in order to enhance productivity, quality, profitability in agriculture. It is a complete system designed to optimize manufacturing by the use of a key factor of information, technology, and management, so as to increase manufacturing efficiency, improves product quality, enhance the efficiency of crop chemical use, preserve strength and protect environment. Thus, precision farming is an appealing thought and its principles quite naturally lead to the expectation that farming inputs can be used greater effectively, with subsequent upgrades in earnings and environmentally less burdensome manufacturing (Nandurkar *et al.*, 2014).

Need of precision farming

The international food gadget faces bold challenges today that will amplify markedly over the subsequent 40

years. Much can be executed at once with contemporary applied sciences and knowledge, given adequate will and investment. But coping with future challenges will require extra radical modifications to the meals machine and funding in lookup to grant new solutions to novel problems. The decline in the total productivity, diminishing and degrading natural resources, stagnating farm incomes, lack of eco-regional approach, declining and fragmented land holdings, alternate liberalization on agriculture, confined employment opportunities in non-farm sector, and world climatic variation have emerge as primary concerns in agricultural boom and development. Therefore, the use of newly emerged technological know-how adoption is seen as one key to amplify agriculture productivity in the future. Instead of managing an entire discipline based totally upon some hypothetical common condition, which might also not exist somewhere in the field, a precision farming strategy acknowledges site-specific differences inside fields and adjusts management moves accordingly. Farmers typically are conscious that their fields have variable yields throughout the landscape.

Tools of precision parming

Global positioning system (GPS)

Global Positioning System satellites broadcast signals that allow GPS receivers to calculate their position. This information is provided in real time, meaning that continuous position information is provided while in motion. Having precise location information at any time allows soil and crop measurements to be mapped (Kim *et al.*, 2008). GPS receivers, either carried to the field or mounted on implements allow users to return to specific locations to sample or treat those areas. Uncorrected GPS signals have an accuracy of about 300 feet. To be useful in agriculture, the uncorrected GPS signals must be compared to a land-based or satellite-based signal that provides a position correction called a differential correction. The corrected position accuracy is typically 63-10 feet. In Missouri, the Coast Guard provides differential correction beacons that are available to most areas free of charge (Suma *et al.*, 2017). When purchasing a GPS receiver, the type of differential correction and its coverage relative to use area should be considered.

GPS is a navigation gadget based totally on a community of satellites that helps users to file positional records (latitude, longitude and elevation) with an accuracy of

between one hundred and 0.01 m. GPS lets in farmers to hit upon the actual position of discipline information, such as soil type, pest occurrence, weed invasion, water holes, boundaries and obstructions. There is an automatic controlling system, with light or sound guiding panel (DGPS), antenna and receiver. GPS satellites broadcast signals that enable GPS receivers to calculate their position. The gadget approves farmers to reliably become aware of area places so that inputs (seeds, fertilizers, pesticides, herbicides and irrigation water) can be utilized to an character field, primarily based on performance criteria and preceding enter applications.

Geographic information system (GIS)

GIS utility in agriculture such as agricultural mapping plays an important role in monitoring and administration of soil and irrigation of any given farm land. This agriculture and agricultural mapping act as a necessary device for administration of agricultural quarter *via* obtaining and implementing the correct statistics into a mapping environment (Vidya *et al.*, 2013). The utility in agriculture also helps in administration and manipulate of agricultural resources. GIS agriculture technology helps in improvement of the present systems in following areas:

- Irrigated landscape mapping
- Application development for GIS agriculture
- Soil and irrigation amendment analysis
- Suitability assessment studies
- Erosion identification and remediation
- Agricultural mapping for detailed vegetation cover and monitoring
- Change detection studies and developing crop models
- Damage and land degradation assessment studies
- Elevation models for efficient drainage

Agricultural drones

Drones are being used in agriculture in order to beautify number of agricultural practices. The methods ground-based and aerial primarily based drones are being used in agriculture are crop fitness assessment, irrigation, crop monitoring, crop spraying, planting, and soil and area analysis (Wang *et al.*, 2010). From the drone data, we can draw insights regarding plant fitness indices, plant counting and yield prediction, plant peak measurement, cover mapping, subject water posing mapping, scouting reports, stockpile measuring, chlorophyll measurement, nitrogen content in wheat, drainage mapping, weed stress mapping, and so on. The drone collects multispectral, thermal, and visual imagery for the duration of the flight and then lands in the same area it took off.

Smart greenhouses

In precision farming, protected cultivation is additionally region for enhancing yield and best and growth. Greenhouses manipulate the environmental parameters through manual intervention or a proportional control mechanism. As guide intervention consequences in

manufacturing loss, energy loss, and labor cost, these strategies are less effective (Nalajala *et al.*, 2017). A smart greenhouse can be designed with the assist of IoT; this format intelligently video display units as properly as controls the climate, disposing of the want for manual intervention.

Greenhouse automation

In addition to sourcing environmental data, weather stations can automatically alter the stipulations to in shape the given parameters. Specifically, greenhouse automation systems use a comparable principle. For instance, Farmapp and Growlink are also IoT agriculture merchandise providing such skills amongst others. GreenIQ is also an interesting product that makes use of clever agriculture sensors (Lakshmisudha *et al.*, 2011). It is a clever sprinklers controller that approves you to control your irrigation and lighting systems remotely.

Predictive analytics for smart farming

Crop predication performs a key role. It helps the farmer to figure out future sketch concerning the manufacturing of the crop, its storage, advertising strategies and hazard management. To predict production charge of the crop synthetic network use information gathered *via* sensors from the farm. This statistics consists of parameters such as soil, temperature, pressure, rainfall, and humidity. The farmers can get a correct soil data either by the dashboard or a personalized cellular application (Bhatia *et al.*, 2015). In precision farming, smart agriculture gadgets are weather stations, combining various smart farming sensors. Located across the field, they collect various data from the environment and send it to the cloud. The provided measurements can be used to map the climate conditions, choose the appropriate crops, and take the required measures to improve their capacity (*i.e.* precision farming).

Grid soil sampling and variable-rate fertilizer (VRT) application

Variable-rate advances (VRT) are programmed and may be applied to various cultivating tasks. VRT frameworks set the pace of conveyance of homestead inputs relying upon the dirt kind noted in a dirt guide. Data extrapolated from the GIS can control forms, for example, seeding, manure and pesticide application, herbicide choice and application at a variable rate justified place at the perfect time. VRT is may be

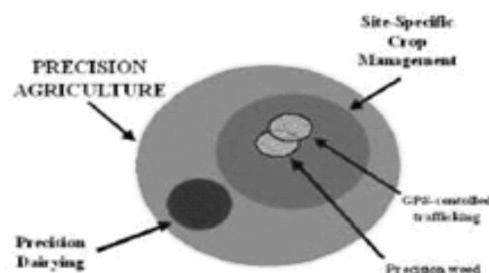


Fig.1. Precision agriculture and its application areas

the most generally utilized PFS innovation in the United States. Matrix soil testing utilizes the same standards of soil examining however builds the force of examining. Soil tests gathered in an orderly framework likewise have area data that permits the information to be mapped. The objective of matrix soil testing is a guide of supplement needs, called an application map. Tests might be gathered for more than one territory of a field which falls in to a similar scope of yield, soil shading, and so forth. Furthermore, along these lines a similar zone. Framework soil tests are examined in the research facility, and a translation of harvest supplement needs is made for each dirt example. At that point the compost application map is plotted utilizing the whole arrangement of soil tests. The application map is stacked into a PC mounted on a variable-rate manure spreader. The PC utilizes the application map and a GPS beneficiary to coordinate a item conveyance controller that changes the sum or potentially sort of compost item, as per the application map.

Cattle monitoring and management

Just like crop monitoring, there are IoT agriculture sensors that can be attached to the animals on a farm to monitor their health and log performance (Gutiérrez *et al.*, 2013). This works similarly to IoT devices for pet car. For example, SCR by Allflex and Cowlar use smart agriculture sensors to deliver temperature, health, activity and nutrition insights on each individual cow, as well as collective information.

Crop management

One more type of IoT product in agriculture and another element of precision farming are crop management devices. Just like weather stations, they should be placed in the field to collect data specific to crop farming; from temperature and precipitation to leaf water potential and overall crop health, these can all be used to readily collect data and information for improved farming practices (Yoo *et al.*, 2010). Thus, can monitor crop growth and any anomalies to effectively prevent diseases or infestations that could harm yield. Arable and Semios can serve as good representations of how this use case can be applied in real life.

Financial aspects

PA applications are viewed as proficient when the extra continues realized through reserve funds in capital and more significant returns surpass the extra consumption fundamental for the procurement and utilization of the PA innovation. While the expenses for the assortment of information and choice models just as the application and route innovation are known and can be generally precisely calculated, the advantages of PA techniques must be generally assessed, as they are de-swinging upon different elements, some of which can't be impacted (for example climate designs) and the impacts not out of the ordinary turn out diversely as indicated by the development step, the field inside

site heterogeneity, the harvest developed and the power of generation. Through site explicit nitrogen treating, the mineral manure cost on heterogeneous fields can be decreased by about 7% or 14 kg N/ha by and large, with yields staying steady or up to 6% higher. Investment funds in the utilization of manure are likewise conceivable in the region of basal dressing and liming, anyway the impacts on yield are not deserving of notice. The use of PA additionally achieves positive outcomes in plant insurance: When applying herbicides an affirm period of about half of the sum spread (a range of 10 to 90%) can be spared. Moreover while applying fungicides utilizing the CROP Meter, reserve funds of the request for 10 to 20% appear to be attainable; comparative figures remain constant for the use of development controllers. There indicate extensive reserve funds to be made in fuel utilization with site explicit soil treatment. Site explicit planting can genius duce constructive outcomes (same yield with a decreased planting force) with push crops (for example maize). There are no outcomes so far accessible with regards to the monetary impacts of an outwardly supporting or programmed direction framework. It can anyway be expected, that capital reserve funds are conceivable through the decrease of regularly happening covers while developing the dirt and applying natural manure.

Conclusion

Therefore, the paper proposes a thought of consolidating the most recent innovation into the agrarian subject to turn the regularly occurring methods for farming device to contemporary techniques in this way making simple profitable and temperate trimming. Some diploma of mechanization is presented empowering the thinking of gazing the subject and the product stipulations inner some long-separate extents making use of cloud administrations. The factors of activity like water sparing and work sparing are commenced using sensors that work therefore as they are modified. This concept of modernization of farming is straightforward, realistic and operable. As relying upon these parameter esteems rancher can barring tons of a stretch pick which fungicides and pesticides are utilized for enhancing crop creation. The paper pursuits at making agriculture clever using automation and IoT technologies. The highlighting aspects of this paper consists of smart GPS primarily based far off controlled robot to perform tasks like; weeding, spraying, moisture sensing, chicken and animal scaring, preserving vigilance, *etc.* Secondly, it includes clever irrigation with smart manipulate based totally on real time area data. Thirdly, clever warehouse administration which includes; temperature maintenance, humidity upkeep and theft detection in the warehouse. Controlling of all these operations will be through any far flung clever system or laptop related to Internet and the operations will be carried out through interfacing sensors, Wi-Fi or ZigBee modules, digicam and actuators with micro-controller and raspberry pi.

Table 1. Table of sensor name with parameters are using in precision farming

S.No.	Sensor Name	Parameters Captured
1	ECH2O soil moisture sensor	Soil temperature, soil moisture, conductivity
2	Hydra probe II soil sensor	Soil temperature, salinity level, soil moisture, conductivity
3	MP406 Soil moisture sensor	Soil temperature, soil moisture
4	4 EC sensor (EC250)	Soil temperature, salinity level, soil moisture, conductivity
5	Pogo portable soil sensor	Soil temperature, soil moisture
6	107-L temperature Sensor	(Beta Therm 100K6A1B Plant Temperature Thermistor)
7	237 leaf wetness sensor	Plant moisture, plant wetness, plant temperature
8	SenseH2TM hydrogen sensor	Hydrogen, plant wetness, CO ₂ , plant temperature
9	Field scout CM1000TM	Photosynthesis
10	YSI 6025 chlorophyll sensor	Photosynthesis
11	LW100, leaf wetness sensor	Plant moisture, plant wetness, plant temperature
12	TT4 multi -sensor	Thermocouple Plant Moisture, Plant temperature
13	13 TPS -2 portable	Photosynthesis, plant moisture, CO ₂
14	LT -2 M (leaf temperature sensor)	Plant temperature
15	CI-340 hand -held	Photosynthesis air temperature, air humidity

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Short Communication

Seven families addition under class Polypetalae for flora of Todgarh-Raoli wildlife sanctuary, Rajasthan

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Todgarh-Raoli wildlife sanctuary is one of the protected areas expressing full range of habitat of Aravalli ecosystem. It is important from bio-geographical point of view the patches of Dhok and Salar forests. It has exceptional diversity and interspersed habitat which includes areas of Dhok, Salar, dryland, seasonal streams, cascading mountains and newly formed sand dunes, formed on western hill aspects and fine grooves of mixed wood lands. This sanctuary makes an ecotone between hilly forests of Aravallis and Thar desert situated in the north-west. The hills of this sanctuary acts like a barrier, checking eastward extension of desert. Because this sanctuary has potential to rich plant wealth, which attracts botanist. Rajasthan is endowed with a wealth of a wide range of vegetation. It represents 1910 plant species belonging to 779 genera and 153 families. Out of these, 624 species belonging to 257 genera and 68 families under Polypetalae class in Rajasthan (Shetty & Singh, 1987). In the Aravalli range, Polypetalae represents 445 species belonging to 213 genera and 62 families (Otaghvari *et al.*, 2015).

Todgarh-Raoli wildlife sanctuary is situated in most fragile ecosystem of Aravallis, is just 110 kms in the south-west of Ajmer. Geographically this sanctuary is situated between 73°40' – 74°10' east longitudes and 25°20' – 26°0' north latitudes, covers an area of 495.27 km² and extended in three districts viz., Rajsamand, Pali and Ajmer in the south-western part of Rajasthan state. It is one of the protected areas expressing full range of habitat of Aravalli ecosystem. The climate of this sanctuary is dryness, uncertainty of rainfall and great variation in temperature during different season in the year. The major tribal inhabiting in or around the sanctuary are Bhil, Meena, Garasiya *etc.*

Many researcher (Sharma *et al.*, 2005; Sharma and Katewa, 2007; Jain *et al.*, 2011; Kanther and Gena, 2012; Kanther 2018; Purohit, 2019; Purohit 2020a; Purohit 2020b; Purohit *et al.*, 2020; Sharma, 2019; Sharma and Khandal, 2019; Tomar and Sharma, 2019;) have been reported few plants from Todgarh-Raoli wildlife sanctuary and nearby area but some workers have done remarkable works *i.e.* Jain *et al.* (2007) have done work on ethno-medicinal plant of this sanctuary and reported 45 ethno-medicinal plant species belonging to 28 families. Galav *et al.* (2013) reported 54 species belonging to 34 families used by tribals as ethnoveterinary medicines in the sanctuary. Singh and Yadav

(2018) extensive work on medicinal important cucurbits of this sanctuary and reported medicinal importance of 5 species belonging to 5 genera. Kanther (2019) have done extensive work extensive vegetation of Todgarh-Raoli wildlife sanctuary and reported 301 species belonging to 84 families including with 141 species belonging to 107 genera and 41 families under class Polypetalae.

While working on the floristic diversity of the Todgarh-Raoli wildlife sanctuary (Rajasthan) during 2015 to 2019, author collected 11 plant samples from different locations of this sanctuary. These collected herbarium samples deposited at Botanical Survey of India, Jodhpur (BSJO). After critical study, scrutiny of literature (Blatter and Hallberg, 1920; Sharma and Tiagi, 1979; Chakravarty, 1982; Bhandari, 1990; Shetty and Singh, 1987; Tiagi and Aery, 2007; Datar *et al.*, 2013; Otaghvari *et al.*, 2015) and herbaria (BSJO, BSA, RUBL, JAC, BLAT, DCH, CAL), these plant samples identified under seven families *i.e.* Balsaminaceae, Caryophyllaceae, Elatinaceae, Geraniaceae, Polygalaceae, Ranunculaceae and Tamaricaceae. These families listed here alphabetically including plant species.

[I] Family: BALSAMINACEAE

1. *Impatiens balsamina* L. var. *balsamina* [Fig. 1]

Fl. & Fr.: Aug. – Nov.

Distribution: Bhilwara (Gangapur); Jhalawar (Sarhod); Pali (Paras Ram mahadev temple); Sirohi (Mount Abu); Udaipur (Kewada forest); Todgarh-Raoli Wildlife Sanctuary (Goramghat khai, Dewiar, Satpalia forest, Goramghat top).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bhim Range, Goramghat Khai, Rajsamand, 04-Aug-16, 25°38.120'N & 73°46.758'E, 476m, C.S. Purohit 33026 (BSJO 40727, 40728); Bhim Range, Dewair, Rajsamand, 15-Aug-16, 25°25.884'N and 73°48.017'E, 636m, C.S. Purohit 33222 (BSJO 41192, 41193); Todgarh-Raoli wildlife sanctuary, Bhim Range, Goramghat Top, 05-Sep-18, 25°39.994'N & 73°52.130'E, 943m, C.S. Purohit 33598.

[II] Family: CARYOPHYLLACEAE

2. *Polycarpea corymbosa* (L.) Lam.

Fl. & Fr.: Aug. – Dec.

Local name: Dholiphuli.

Distribution: Barmer (Tapara village); Bhilwara (Banas river bed); Bikaner (Rawla); Bundi (Kota dam); Dungarpur; Nagaur (Thanwla); Sirohi (Mount Abu); Tonk (Rajmahal R.F.); Todgarh-Raoli Wildlife Sanctuary (Khodiya Naka).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bijajiguda Range, Khodiya Naka, Pali, 08-Aug-16, 25°54.234'N & 74°00.159'E, 397m, C.S. Purohit 33138 (BSJO 40862, 40863).

3. *Silene conoidea* L.

Fl. & Fr.: February - April.

Local name: Gidarkanno

Distribution: Bhilwara (Kharidam); Bikaner (Khara); Ganganagar (Kumbhalgarh); Jaipur (on Tonk road); Kota (Sitabari); Todgarh-Raoli wildlife sanctuary (Pachanpura).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bijajiguda Range, Pachanpura, 25-Feb-19, 25°57.677'N and 74°03.420'E, 377m, C.S. Purohit 31089;

4. *Spergula arvensis* L.

Fl. & Fr.: July – Nov.

Distribution: Todgarh-Raoli wildlife sanctuary (Pachanpura village).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bijajiguda Range, Pachanpura, 25-Feb-19, 25°57.677'N and 74°03.420'E, 377m, C.S. Purohit 31088;

5. *Spergula fallax* (Lowe) Krause

Fl. & Fr.: December - March.

Local name: Khandidal.

Distribution: Banswara (Ghatol); Barmer (Piplum); Bikaner (College campus); Kota; Sawaimadhopur; Todgarh-Raoli wildlife sanctuary (Aasan).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bijajiguda Range, Aasan-Mata Temple, 23-Feb-19, 25°57.117'N and 74°07.938'E, 442m, C.S. Purohit 31066;

[III] Family: ELATINACEAE

6. *Bergia aestivosa* (Wight & Arn.) Steud.

Fl. & Fr.: Oct. – Feb.

Distribution: Barmer; Jaipur (Gujar ki Dhani, Amer, Bhandana); Todgarh-Raoli Wildlife Sanctuary (Modia village).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Raoli Range, Modia village, 12 Nov. 2017, 25°46.396'N and 73°57.060'E, 457m, C.S. Purohit 33305;

7. *Bergia ammannioides* Roth.

Fl. & Fr.: Throughout the year.

Local name: Jalbhagara.

Distribution: Banswara; Bikaner (Sagar pond); Chittorgarh (Bassi); Ganganagar (79 GB); Jaipur (Bhandana); Jaisalmer (Bendalai tank); Kota (Baran); Nagaur (Harsolav pond); Sirohi (Mount Abu); Todgarh-Raoli wildlife sanctuary (Modia village, Sarkaniya beri, Jamun mata temple, Dodiyo ka kheda, Halela);

Specimen examined: Todgarh-Raoli wildlife sanctuary, Raoli Range, Modia village, 12 Nov. 2017, 25°46.396'N & 73°57.060'E, 457m, C.S. Purohit 33304 (BSJO 39893, 39894); Todgarh-Raoli wildlife sanctuary, Jojawar Range, Sarkaniya Beri, 25-Nov-17, 25°45.729'N & 73°54.944'E, 451m, C.S. Purohit 33468; Todgarh-Raoli wildlife sanctuary, Bhim Range, Jamun mata temple, 10-Sep-18, 25°25.381'N & 73°45.588'E, 443m, C.S. Purohit 31038; Todgarh-Raoli wildlife sanctuary, Bhim Range, Dodiyo ka kheda, Halela, 07-Mar-19, 25°22.685'N and 73°48.007'E, 739m, C.S. Purohit

38050;

[IV] Family: GERANIACEAE

8. *Monsonia senegalensis* Guill. & Perr. [Fig. 2]

Fl. & Fr.: July. – Oct.

Distribution: Ajmer; Bhilwara (Kotra village); Jaisalmer (Miajlar); Jodhpur (Kailana); Pali (Piprol R.F.); Todgarh-Raoli Wildlife Sanctuary (Modia, Kundal).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Raoli Range, Modia, Ajmer, 29-Jul-16, 25°46.396'N & 73°57.060'E, 457m, C.S. Purohit 32890 (BSJO 40566, 40567); Bijajiguda Range, Kundal, 07-Aug-16, 26°00.140'N & 74°10.175'E, 441m, C.S. Purohit 33107 (BSJO 40915).

[V] Family: POLYGALACEAE

9. *Polygala erioptera* DC.

Fl. & Fr.: Throughout the year.

Local name: Sarbhagolia.

Distribution: Banswara (Dagia-Bowji, Ghatol); Bikaner (Panchu); Ganganagar (Pallu); Jaisalmer (Sam); Jhunjhunu (Pilani); Kota (Shahabad); Nagaur (Vishnu Pond, Merta City); Sirohi (Mount Abu); Tonk (Kachhabundh); Todgarh-Raoli Wildlife Sanctuary (Taheshwar Mahadev).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bijajiguda Range, Taheshwar Mahadev, Pali, 29-Jul-16, 25°49.954'N and 73°56.474'E, 426m, C.S. Purohit 32902 (BSJO 40598, 40599);

[VI] Family: RANUNCULACEAE

10. *Ranunculus muricatus* L. [Fig. 2, Fig. 3]

Fl. & Fr.: Feb. – May.

Distribution: Sirohi (Mount Abu); Jhunjhunu (Pilani); Todgarh-Raoli wildlife sanctuary (Wakali kui).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Bhim Range, wakali kui, Tegi, 05-Mar-19, 25°26.249'N and 73°52.964'E, 677m, C.S. Purohit 38041.

[VII] Family: TAMARICACEAE

11. *Tamarix aphylla* (L.) Karst.

Fl. & Fr.: Aug. – Sept.

Local name: Fransh.

Distribution: Ajmer (Govindgarh); Bikaner (Ghoghra); Churu (Sujangarh); Jaipur (Chaksu); Jaisalmer (Ramgarh); Jhalawar; Nagaur (Nagaur); Pali (Guda); Todgarh-Raoli Wildlife Sanctuary (Kabradata).

Specimen examined: Todgarh-Raoli wildlife sanctuary, Raoli Range, Kabradata, 10 Nov. 2017, 25°42.736'N & 73°55.517'E, 445m, C.S. Purohit 33236 (BSJO 41217, 41218).

During the course of field exploration of Todgarh-Raoli wildlife sanctuary during 2015 to 2019, authors demarcated and collected 19 plant samples and identified with the help of literature. Results are in following points *i.e.*

[1]. Family addition for Flora of Todgarh-Raoli wildlife sanctuary

Kanther (2019) have done extensive work extensive vegetation of Todgarh-Raoli wildlife sanctuary and reported 301 species belonging to 84 families including with 141 species belonging to 107 genera and 41 families under Class Polypetalae. But in addition with these seven families *i.e.* Balsaminaceae, Caryophyllaceae, Elatinaceae, Geraniaceae,

Polygalaceae, Ranunculaceae and Tamaricaceae are first time reported from this sanctuary. These seven families in addition under class polypetalae for Flora of Todgarh-Raoli wildlife sanctuary.

[2]. Addition for Flora of Aravalli Range

Otaghvari *et al.* (2015) have done extensive work on flora of Aravalli range and reported 445 species belonging to 213 genera and 62 families under Class polypetalae. In this paper, *Spergula arvensis* L. is first time report from Aravalli range and addition for flora of Aravalli range.

[3]. Generic addition for Flora of Todgarh-Raoli wildlife sanctuary

Kantr (2019) reported 107 genera under Class Polypetalae from this sanctuary. In this paper, Nine genera i.e. *Bergia*, *Impatiens*, *Monsonia*, *Polycarpaea*, *Polygala*, *Ranunculus*, *Silene*, *Spergula* and *Tamarix* are first time report and generic addition under class polypetalae for flora of Todgarh-Raoli wildlife sanctuary.

[4]. Species addition for Flora of Todgarh-Raoli wildlife sanctuary

Kantr (2019) reported 141 species under Class Polypetalae from this sanctuary. In this paper, eleven species i.e. *Bergia aestivosa* (Wight & Arn.) Steud.; *Bergia ammannioides* Roth.; *Impatiens balsamina* L. var. *balsamina*; *Monsonia senegalensis* Guill. & Perr.; *Polycarpaea corymbosa* (L.) Lam.; *Polygala erioptera* DC.; *Ranunculus muricatus* L.; *Silene conoidea* L.; *Spergula arvensis* L.; *Spergula fallax* (Lowe) Krause and *Tamarix aphylla* (L.) Karst. are first time report and addition under class polypetalae

for flora of Todgarh-Raoli wildlife sanctuary.

Present paper deals with seven families i.e. Balsaminaceae, Caryophyllaceae, Elatinaceae, Geraniaceae, Polygalaceae, Ranunculaceae and Tamaricaceae are first time reported from this sanctuary. one species *Spergula arvensis* L. is first time report from Aravalli range and addition for flora of Aravalli range. Nine genera i.e. *Bergia*, *Impatiens*, *Monsonia*, *Polycarpaea*, *Polygala*, *Ranunculus*, *Silene*, *Spergula* and *Tamarix* are first time report and generic addition under class polypetalae for flora of Todgarh-Raoli wildlife sanctuary and eleven species i.e. *Bergia aestivosa* (Wight & Arn.) Steud.; *Bergia ammannioides* Roth.; *Impatiens balsamina* L. var. *balsamina*; *Monsonia senegalensis* Guill. & Perr.; *Polycarpaea corymbosa* (L.) Lam.; *Polygala erioptera* DC.; *Ranunculus muricatus* L.; *Silene conoidea* L.; *Spergula arvensis* L.; *Spergula fallax* (Lowe) Krause and *Tamarix aphylla* (L.) Karst. are first time report and addition under class polypetalae for flora of Todgarh-Raoli wildlife sanctuary.

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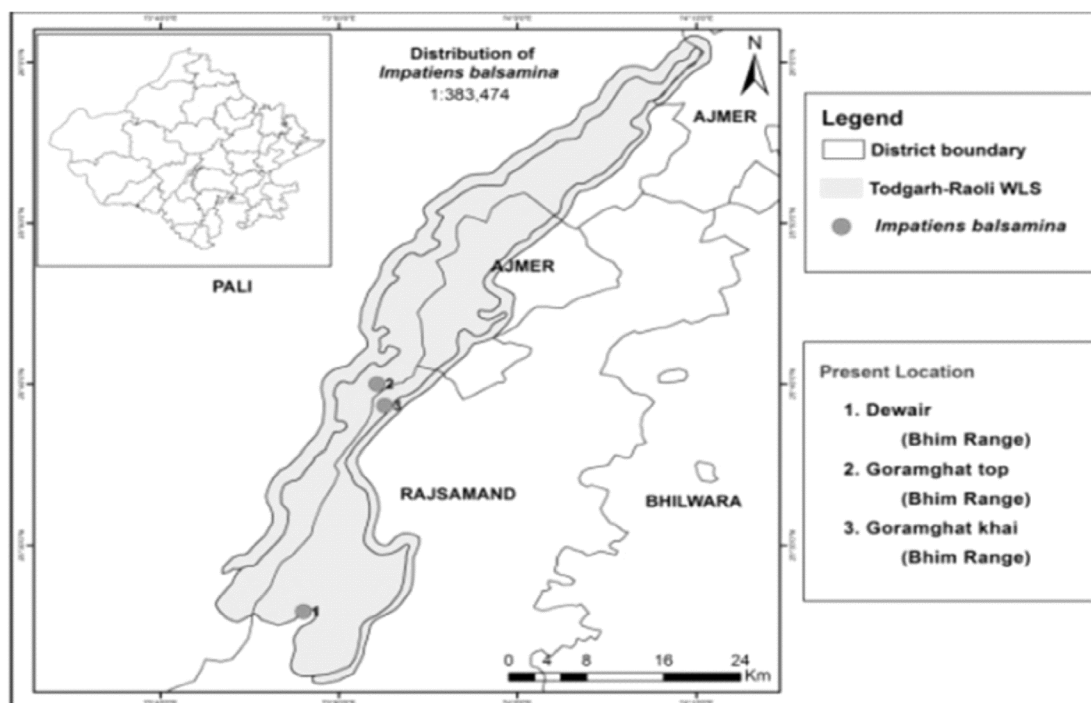


Fig.1. Map of *Impatiens balsamina*

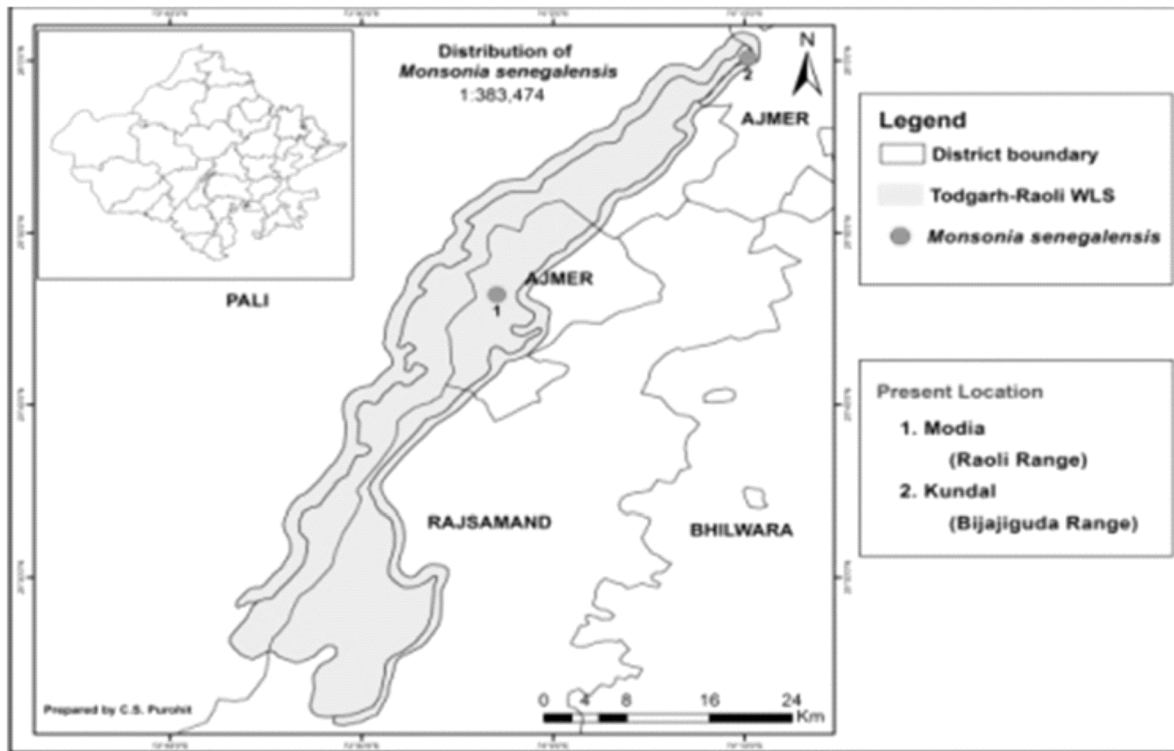


Fig.3. Map of *Monsonia senegalensis*

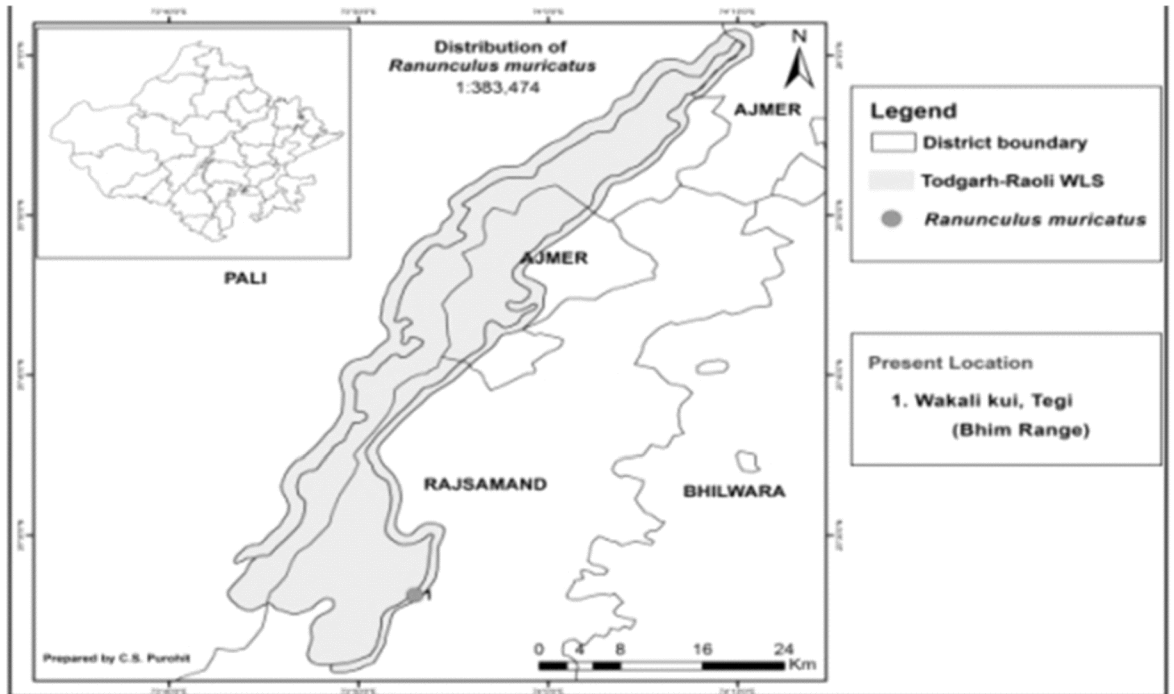


Fig. 3. Map of *Ranunculus muricatus*

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Short Communication

Multiplication of mulberry varieties through semi hard wood cuttings in arid region

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Mulberry (*Morus sp.*) is an underutilized fruit plant of tropical to subtropical province and native to south west Asia to China. Genus *Morus* comprises about sixteen species of deciduous nature. This fruit plant is fast-growing when young, but soon become slow-growing. The leaves are alternately arranged, simple and often lobed and serrated on the margin. Inflorescence catkin and fruit type is a multiple, immature fruits are green or pale yellow. The fruits of the species *alba* are greenish yellow when ripe and *nigra/rubra*, turn dark purple or black and have a sweet flavour when fully ripe.

Mostly this crop is being cultivated for rearing of silkworm and wind break rather than fruit crop. This crop not specific with climatic requirement so can be grown in arid, marginal soil, barren land without much care. Fruits use as fresh desert and in processing for making of different products like jam, beverages *etc.* Root has high medicinal properties and wood for sports article preparation and twigs for making baskets of packaging. In order to meet out planting material requirement, development of an easier, quicker and economic method of propagation is required. The raising of mulberry plants by cuttings has been found to best as it is quick, less expensive and requires less space and skill. The higher rooting potential of semi hardwood cuttings has been attributed to endogenous auxin in tender vegetative growth of such cuttings (Hartmann and Kester, 1983). It is a well known fact that physiological status of the plant exerts a strong influence on the root initiation. The involvement of root metabolites and rooting promoters/ inhibitors has been reported to play a significant role. ICAR-Central Institute for Arid Horticulture has identified two varieties of mulberry namely Thar Harit (a short stature and spreading growth habit, green white colour, pendulus shape fruits, fruits ripens in 38-42 days from set and suited for table & processing purposes) from *Morus alba* group and Thar Lohit (Spreading growth habit skin colour red fruit ripens 32-36 days from fruit set, TSS 20.8^o B and acidity 1.6 % with ascorbic acid 11.2 mg 100g⁻¹ edible pulp) from *Morus rubra* group (Anon., 2017) used as experimental material with the aim to produce true to type planting material of these varieties through cuttings.

The experiment was conducted during 2017-18 at nursery unit, ICAR-Central Institute for Arid Horticulture,

Bikaner is located on 28° N latitude, 73° 18' E longitude and at altitude of 234.84 m above sea level. The semi hard wood cuttings of mulberry varieties Thar Harit and Thar Lohit were planted on pro trays and polybags conditions (Fig 1a & 1b). Stem cuttings were prepared during late January month about 20-25 cm long, 1.5-2.5 cm diameter and containing 3-4 nodes per cutting (Pathak, 1996). After IBA (1000 ppm) treatment planted in slanting position in pro trays containing media mixture of vermiculite, perlite and cocopeat in the ratio of 1:1:2, respectively. Further successful cuttings were shifted in polybags containing mixture of pond silt, FYM and soil (1:1:2). From each variety prepared 100 cuttings and two sets of the experiment kept in green agro-shed net of 50 % light intensity conditions. Uniform nursery practices were followed during the experimentation. Observations on cuttings survivability shoot growth, root: shoot, success per cent *etc.* were recorded up to 6 month after planting as per standard methodology. Further, vigour index was calculated by the formula proposed by Abdul and Anderson (1973) *i.e.* averaged root length (cm) + averaged shoot length (cm) x survival percentage in polybags conditions. Data were analysed with t-test and two factors (varieties and months) analysis using statistical online OPSTAT software developed by Sheoran *et al.* (1998)

Results revealed that both the varieties were showed initiation of sprouts about a month after planting; however Thar Harit took six days more compared to Thar Lohit. Initial sprout and survivability observed higher in Thar Lohit and maximum survivability (85 %) in pro tray condition. After sprout maximum drying of shoot was observed in Thar Harit and because of that received only 35 per cent survivability. The possible reason for the better survivability was due to difference in genetic makeup of the both the varieties either alone or in combination with environmental factors, that might contributed to the higher carbohydrate supply to root resulting in better sprout growth and initial survivability as evident in the present study. These results are in accordance with the findings of Davis and Hartmann (1984) and Hartmann *et al.* (2002)

Further in polybag (containing mixture of pond silt, FYM and soil) conditions at 4 month after shifting maximum shoot length (22.4 cm) and inter nodal length (3.8 cm) in Thar

Harit and other parameters namely, nodes number (10.2), root length (15.6 cm), root: shoot (0.82), vigour index (2760) and success per cent (80 %) were higher in Thar Lohit. It might be due to difference in nature of varieties with respect to growth, development, survivability, root/shoot ratio and uptake of moisture play key role in enhancement of vigour index of poly bag shifted plants. These results are in accordance with the results of Maynard and Bassuk (1988). The variety Thar Lohit recorded early root initiation, higher root/ shoot ratio and vigour index provides higher survival percentage of rooted air layers after shifting. Thus, Mulberry variety Thar Lohit was found to be easy-to-root and registered higher success rate compared to the variety Thar Harit in irrigated hot arid

conditions.

Results revealed that both the varieties have showed initiation of sprouts about a month after planting and maximum survivability (85%) was recorded in variety Thar Lohit in protray condition. Further in polybags condition maximum shoot length and inter nodal length was observed at 4 month after shifting in Thar Harit and other parameters namely, nodes number, root length, root: shoot, vigour index and success per cent (80%) were higher in Thar Lohit. Thus, mulberry variety Thar Lohit was found to be easy-to-root and registered 31.25% higher success rate compared to the variety Thar Harit

Table 1. Performance of stem cuttings in pro tray conditions

S. No.	Particulars	Mulberry varieties		SEm±	T cal
		Thar Harit	Thar Lohit		
1	Days to sprout	36	29	1.15	31.18
2	Sprout (%)	69	90	1.37	50.50
3	Survivability (2MAP)	30	85	0.58	51.96

MAP=months after planting and t tab value=2.57 at 5 % level

Table 2. Performance of mulberry varieties in polybags conditions at 2 and 4 month after shifting

S.No.	Parameters	Thar Harit		Thar Lohit		SEm±	CD (5%)
		2 month	4 month	2 month	4 month		
1	Shoot length (cm)	10.63	22.4	12.6	18.92	0.24	0.71
2	Number of leaves	5.46	8.53	7.16	10.20	0.12	NS
3	Internodal length (cm)	2.52	3.84	2.20	3.11	0.04	0.13
4	Root length (cm)	5.66	10.2	8.19	15.59	0.15	0.45
5	Root: shoot	0.53	0.46	0.65	0.82	0.01	0.03
6	Shoot: root	1.88	2.19	1.54	1.21	0.02	0.07
7	Success (%)	30.0	24.6	85.0	80.0	0.89	NS
8	Vigour index	486	815	1768	2760	24.61	72.25



Cuttings in protray

Thar Harit

Polybags shifting

Saplings

Fig. 1a. Mulberry propagation through semi hard wood cuttings



Thar Lohit

Fig. 1b. Mulberry propagation through semi hard wood cuttings

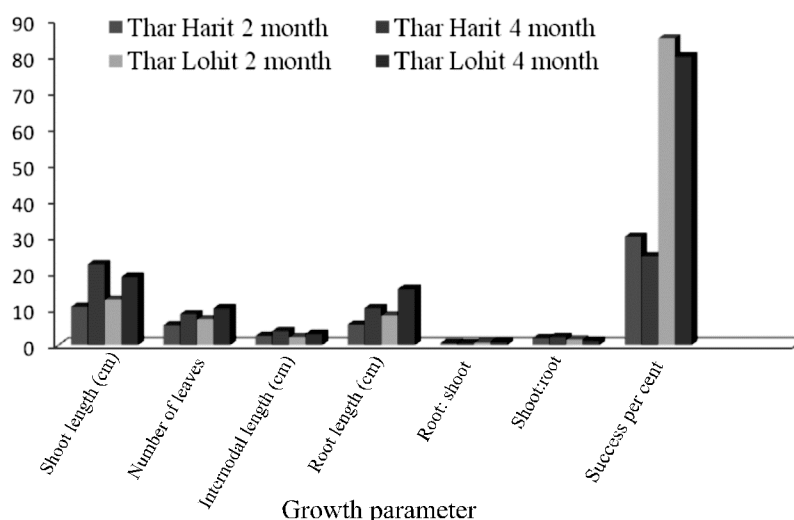


Fig. 2. Performance of semi hard wood cuttings of mulberry in polybags

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Short Communication

Effect of pruning intensity and foliar feeding of nutrients on growth, yield and quality of phalsa (*Grewia subinaeqalis* D.C.)

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Phalsa also known as star apple is subtropical fruit cultivated commercially in Punjab, Haryana, Uttar Pradesh, and Madhya Pradesh. It is also cultivated in limited scale in the states of Maharashtra, Gujarat, Andhra Pradesh, Bihar and West Bengal. Fruits are eaten fresh and juice is used for making squash and syrup, on other hand wood is used for fuel to rural people and used for basket making which income generating entrepreneurship to the rural formers and poor people. It is quick growing, hardy shrub thrive well in wide range of soils even on salt affected wastelands. Phalsa can also be grown as intercrop in mango, aonla, bael and ber orchards. Little information is available on pruning combined with foliar feeding of phalsa for better plant health and higher production of quality fruits which has good medicinal properties known since Vedic times.

Field experiment was conducted at main experiment station (Horticulture) N. D. U. A. & T., Kumarganj, Ayodhya (U P). Forty five plants of eighteen years old phalsa cv. Sharbati, uniform in size and vigour planted at distance at 3x2 m were selected. The experiment was laid out in Factorial R B D with three replications having 15 treatment combination including 3 levels of pruning viz., pruned at 25 cm, 50 cm and 75 cm above ground level and 5 chemical treatment viz., control (water) ZnSO₄ 0.4%, CuSO₄ 0.4%, K₂SO₄ 0.2% and Urea 2% solution.

Pruning of phalsa bushes was done in first week of February and spray of nutrients solution was done in 2nd fourth night of March (pre 100 m stage) while second spray was done after fruit setting. Observation were recorded on number of shoot/fruitlet nodes/shoot, fruits /node, fruits yield/plant, weight of 50- fruits, juice percent and quality of juice in terms of TSS, acidity ascorbic acid and sugar contents per methods given in A.O.A.C (1996).

Perusal of data presented in Table 1 revealed that shoot per plant fruiting node per shoot fruits/node and fruit yield was influenced significantly by node. Pruning intensity and flower foliar feeding of nutrients influenced all yield characters significantly. The highest numbers of shoots (300), nodes/shoot (18.08), and fruit number per node were recorded with pruning 50 cm above ground level. Same level of pruning and foliar feeding of ZnSO₄ 0.4% for followed by Urea 2.0%.

The increase in growth parameters in might be due to the fact that potash, zinc and Cu activate many enzymes required for photosynthesis and play role in metabolism and same time spray of urea is constituent of protein essential for formation of protoplasm, influence cell division, elongation and causes better plant growth. The finding is in line with the findings in litchi (Kumar *et al.*, 2004) phalsa (Pankaj *et al.*, 2004; Rathore, 2010)

It is also clear from the data (Table 2) that response of pruning and nutrients also increased fruit yield being highest (4.10 kg/plant) with pruning 50 cm above ground level combined with ZnSO₄ 0.4% foliar feeding follow by same level of pruning follow by spray of Urea 2.0%. Similar were the finding of Tiwari *et al.* (2011) in aonla and Mishra and Pathak (1998) in Guava.

A perusal of data presented in Table 2 that weight of 50 fruit and juice per cent were influence by pruning intensity and feeding of nutrients. The highest 50 fruits was recorded (47.67 g) pruning at 50 cm above ground level with ZnSO₄ 0.4% followed by same level of pruning sprayed with 2.0% urea foliar feeding followed by K₂SO₄ 0.2% foliar feeding (49.67) and pruning at 50 cm above ground level. The present findings are in close agreement with Arora and Yamdagni (1985) in fruiting of sweet lime, Singh and Singh (2008) in cv. NA-7 and Singh *et al.* (2001) in aonla cv. Francis. The juice content was increased due to fact that nutrients (N, K, Zn and Cu) application result in more up take of nutrients in plant and absorption of more water with minerals because of increase turgor pressure resulting increase in juice content. The present findings are in also agreement with Kumar (2004) in litchi.

Pruning intensity and foliar feeding of nutrients influenced the TSS, acidity and ascorbic acid content in juice (Table 2 and 3) and chemical. The interaction effect between pruning levels and chemicals on TSS was found significant and noted highest (28.40) with combined effect of ZnSO₄ 0.4% along with pruning at 50 cm above ground level and effect was significant than rest of the combination. The increase in TSS content may be explained by the fact that applied nutrients are helpful to photosynthesis which ultimately led to the accumulation of carbohydrate which helps to increase TSS content of juice. The acid content in

juice decreased significantly with foliar feeding, while non significant effect was observed with pruning levels. The reason for decreased in acidity due to nutrients (N, K, Zn and Cu) might be due to increase translocation of carbohydrates due to conversion of acid to sugar. The finding is in agreement to Joon *et al.*, (1984). The highest ascorbic acid content (37.28 mg /100g juice) was recorded with combined effect of ZnSO₄ 0.4% closely followed by spray of K₂SO₄ 0.2% (36.63 mg/100 g juice) along with pruning at 50 cm above ground level. Similar response has also been reported by Singh *et al.*, (2009) in aonla and Singh *et al.*, (1995) in ber. The increase in ascorbic acid content may be attributed to quality improving properties of N, K, Zn and Cu. The increase in ascorbic acid content in potassium treated fruits might be due to the stimulated function of enzymes which participate in the synthesis of ascorbic acid. The reducing sugars and total sugars in fruits juice of phalsa have also been increased as influenced by pruning levels and spray of

nutrients (Table 3).

The highest level of reducing sugars (13.76), non reducing sugar (3.77%) and total sugars (17.53) were found with foliar spray of ZnSO₄ (0.4%) closely followed by K₂SO₄ (0.2%) along with pruning at 50 cm above ground level. The significant increase in sugar contents might be due to accumulation of carbohydrates in fruits as a result of N, K, Zn and Cu application and also the role played by regular pruning of phalsa as phalsa needs regular pruning of previous season shoots. Similar finding are also reported, Singh *et al.*, (1979) in grapes, and Bhatia and Yadav (2005) in ber. It can be concluded that pruning of phalsa at 50 cm above ground level combined with ZnSO₄ (0.4%) increased number of shoot, and fruiting nodes closely followed by urea 2% and K₂SO₄ (0.2%) with pruning at 50 cm above ground level. Better response was obtained with fruit yield attributing attributes. The fruit quality in terms of TSS, acidity, ascorbic acid content, juice

Table 1. Effect of pruning intensity and foliar feeding of nutrients on vegetative and yield attributes of phalsa

Treatments	Number of shoots per plant				Number of fruiting nodes per shoots				Number of fruits per nodes				Fruit yield (kg/plant)			
	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean
	25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)	
Control (C ₀)	22.67	26.67	21.00	23.44	15.67	16.40	14.67	15.58	14.00	14.70	14.33	14.34	2.84	3.10	2.83	2.92
ZnSO ₄ 0.4% (C ₁)	32.00	33.33	31.33	32.22	18.67	19.80	18.33	18.93	16.33	17.15	16.00	16.49	3.70	4.10	3.67	3.82
CuSO ₄ 0.4% (C ₂)	29.00	29.67	28.67	29.11	17.00	17.60	16.67	17.09	15.33	16.10	15.00	15.48	3.60	3.95	3.63	3.73
K ₂ SO ₄ 0.4% (C ₃)	30.00	30.33	29.67	30.00	16.67	18.00	17.33	17.33	15.67	16.40	14.67	15.58	3.56	3.90	3.79	3.81
Urea 2.0% (C ₄)	32.67	33.00	30.67	32.11	17.67	18.60	16.00	17.42	16.33	17.10	15.00	16.14	3.68	4.05	3.71	
Mean	29.27	30.60	28.27		17.14	18.08	16.60		15.53	16.29	15.00		3.48	3.82	3.53	
	P	C		PxC	P	C		PxC	P	C		PxC	P	C		PxC
SEm±	0.40	0.51		0.89	0.31	0.40		0.70	0.28	0.37		0.63	0.07	0.08		0.15
CD at 5%	1.15	1.48		NS	0.90	1.17		2.02	0.82	1.06		1.84	0.19	0.25		0.43

Table 2. Effect of pruning intensity and foliar feeding of nutrients on fruit quality attributes of phalsa

Treatments	Weight of 50 fruits (g)				Juice content (%)				TSS (° Brix)				Acidity (%)			
	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean
	25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)	
Control (C ₀)	42.67	43.00	42.33	42.67	37.00	37.00	36.33	36.78	19.22	21.23	18.38	19.61	2.35	2.20	2.30	2.28
ZnSO ₄ 0.4% (C ₁)	47.00	47.67	42.00	45.56	47.67	48.67	44.67	47.00	27.65	28.40	26.76	27.87	1.83	1.80	1.88	1.84
CuSO ₄ 0.4% (C ₂)	40.33	42.00	41.00	41.11	46.67	50.33	43.33	46.78	26.12	26.34	25.16	25.87	2.25	2.32	2.27	2.28
K ₂ SO ₄ 0.4% (C ₃)	43.00	44.33	41.33	42.89	50.00	51.00	48.00	49.67	26.91	27.62	25.82	26.78	1.96	2.02	2.05	2.01
Urea 2.0% (C ₄)	43.33	44.00	43.00	43.44	49.33	52.00	49.00	50.11	26.13	27.13	25.87	26.38	2.22	2.13	2.35	2.23
Mean	29.27	30.60	28.27		46.13	47.80	44.27		25.20	26.15	24.40		2.12	2.09	2.17	
	P	C		PxC	P	C		PxC	P	C		PxC	P	C		PxC
SEm±	0.27	0.35		0.61	0.47	0.61		1.05	0.19	0.25		0.43	0.03	0.04		0.06
CD at 5%	0.79	1.01		1.76	1.36	1.76		3.04	0.56	0.72		1.25	NS	0.10		NS

Table 3. Effect of pruning intensity and foliar feeding of nutrients on ascorbic acid and sugar content of phalsa fruits

Treatments	Ascorbic acid (mg/100g pulp)				Reducing sugar (%)				Non reducing sugar (%)				Total sugar (%)			
	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean	Pruning (Above ground level)			Mean
	25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)		25 cm (P ₁)	50 cm (P ₂)	75 cm (P ₃)	
Control (water) C ₀	27.03	27.81	26.65	27.16	11.52	11.93	10.57	11.52	3.16	3.27	2.9	3.11	14.68	15.2	13.47	14.45
ZnSO ₄ 0.4% (C ₁)	36.5	37.28	35.98	36.59	13.29	13.76	13.25	13.29	3.65	3.77	3.63	3.69	16.94	17.53	16.88	17.12
CuSO ₄ 0.4% (C ₂)	34.86	35.58	33.97	34.8	12.88	13.07	12.48	12.88	3.53	3.58	3.42	3.51	16.42	16.65	15.9	16.32
K ₂ SO 0.4% (C ₃)	35.9	36.63	35.05	35.86	12.92	13.13	12.73	12.92	3.54	3.6	3.49	3.55	16.46	16.73	16.22	16.47
Urea 2.0% (C ₄)	35.21	35.91	34.86	35.32	12.8	12.87	12.86	12.8	3.51	3.53	3.53	3.52	16.32	16.4	16.38	16.37
Mean	33.9	34.64	33.3		12.68	12.95	12.37	12.68	3.48	3.55	3.4		16.16	16.5	15.77	
	P	C	PxC		P	C	PxC		P	C	PxC		P	C	PxC	
SEm±	0.22	0.29		0.49	0.15	0.19		0.33	0.04	0.05		0.09	0.19	0.25		0.43
CD at 5%	0.64	0.83	NS		0.43	0.56	NS		0.12	0.15	NS		0.56	0.71		1.25

per cent and sugar contents were better with ZnSO₄ (0.4%) combined with pruning at 50 cm above ground level closely followed by K₂SO₄ (0.2%) with pruning at 50 cm above ground level.

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Physical and qualitative characters of date palm (*Phoenix dactylifera* L.) fruits stored under freeze condition

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Date palm (*Phoenix dactylifera* L.) is a nutrient rich fruit crop. Iraq is the center of origin of date palm and it is reported that it is cultivated from more than 6000 years ago. Date palm fruit rich in essential nutrients, vitamins, and minerals which help in enhance the growth and development of human body. It contains 70–80% carbohydrates (fructose and glucose) and minerals like calcium, iron, magnesium, phosphorus, potassium, zinc, selenium and manganese which enhance their nutritional values. Aqueous extracts of date have a potential antioxidant and anti-mutagenic property (Saafi *et al.*, 2009). It is rich source of vitamins, especially β -carotene, thiamine, riboflavin, niacin, ascorbic acid and folic acid (El Hadrami *et al.*, 2011). The major date palm growing areas in India are Kutch (Gujarat), western part of Rajasthan, and certain parts of the Punjab, as well as Tamil Nadu. Area of date palm in Rajasthan is 850 ha with production of 800 tonnes (Singh, 2018). It is well known fact that quality deteriorates at ambient temperature after some days of harvesting. However, frozen storage can be utilized in some fruits and vegetables for long time storage. It enhances the shelf life of produce by decreasing the water activity, inhibits microorganism growth and reduces enzymatic activity (Fellows, 2000). Therefore, present study was planned to evaluate the impact of freeze storage on fruit quality characters of date palm and compare the quality parameter of fresh and stored fruits.

The experiment was conducted during July 2019 to July 2020 at College of Agriculture, SKRAU, Bikaner on “Halawy” cultivar of date palm. Fruits were harvested at doka stage. For each observation 30 random fruits were taken. At the time of harvesting, fruits were taken from uniform bunches. Fruits were packed in net bags and stored in deep freeze at -20°C temperature for period of 12 months. Fruits were thawed before taking observations; fruits were taken from the freeze and leave them for 2 hours at room temperature for thawing. Fruits weight, pulp weight and stone weight of fresh and stored fruit at doka stage were recorded. Fruit length and diameter were observed by using vernier caliper and then mean values calculated. Total soluble solids (TSS) were determined by using digital hand refractometer ($0-50^{\circ}$ Brix). The value was corrected at 20°C and expressed as $^{\circ}$ Brix (A.O.A.C., 2007). The titrable acidity of the juice was determined by titrating it against 0.1 N NaOH, using

phenolphthalein indicator and it was expressed in % malic acid (A.O.A.C., 2007). However, ascorbic acid content was determined by the method reported earlier by Ruck (1969). Ten ml of juice was diluted with 0.4% oxalic acid solution and 5 ml of filtered aliquot was titrated against 2, 6-dichlorophenol indophenol dye to light pink colour end point and were determined as mg 100 ml⁻¹ FW. The total sugar contain determine by Anthrone reagent method (Hedge, 1962). Reducing sugar content was measured by following “Nelson's modification” of “Somogyi method” (Somogyi, 1952) using arsenomolybdate colour forming reagent and two copper reagent “A” and “B”. The non-reducing sugars were calculated by the deducting the reducing sugar content from the total sugar content and multiplied by the factor 0.95.

Physical parameters

The data obtained on physical parameters are presented in Table 1. The average fruit weight of 30 fresh fruits was found 7.42 g. The weight of fruits decreases after 12 months in deep freeze storage at -20°C temperature. Initial weight of fresh date fruits at doka stage found 6.20 g and it is also reduces from 6.20 to 3.99 g after 12 months. Stone weight of fruit initially observed 1.22 g and after deep freeze storage slightly loss in weight was found from 1.22 to 1.19 g. Reduction in the weight occurs due to chemical reaction and water loss during storage period. This finding supported by the work of Yousef *et al.*, (2012) in mango and they found rapid moisture loss in mango during storage. Length and diameter of the fresh fruit observed 3.87 and 1.92 cm which reduced after storage period to 2.98 and 1.33 cm, respectively. Reduction in the length and diameter occurs due to shrinkage in fruit skin. This result confirm with the finding of Al- Yahyai and Al-Kharus (2012).

Quality parameters

The data observed on quality parameters are given in Table 1. Total soluble solids in fresh fruit of Halawy cultivar found 47.52 B $^{\circ}$ and it was increase in storage condition up to 52.62 B $^{\circ}$. The similar trends were observed by Yousef and Labib (2007) on apricot and Zina (2000) and Shatta (2006) on lime. TSS increased in mango irrespective to storage period (Islam, et al., 2013). Acidity of the date palm fruits were

decreased from 0.42% to 0.34% during storage. It is commonly attributed to consumption of organic acids for energy production (Cohen *et al.*, 1990). Previous studies also get similar results, where temperature and storage reduced the acidity (Porat *et al.*, 2000). Fresh fruit contain high ascorbic acid and it was reduced with the storage period from 6.41 to 4.21 mg/100g. Loss in ascorbic acid carried out by the oxidation process (El-Ishaq, and Obirinakem, 2015) and vitamin C also reduced at 4°C temperature in 14 days storage of orange (Galani *et al.*, 2017).

Total, reducing and non reducing sugars were enhance at -20°C after 12 months storage which is 32.79%, 29.64% and 3.15%, respectively as compared to fresh fruit that was 28.42%, 25.47% and 2.95%, respectively. This phenomenon occurs due to slow rate of respiration metabolism in date fruit. Invertase enzyme play major role in changing the amount of sugars in date palm under freeze storage condition. Al- Redhaiman (2005) also reported that under storage total sugar was increased in cv. Barhee. In date

palm Barhee cultivar at -40 °C, the glucose and fructose percentages increased at slow and regular rate under storage (Alhamdan *et al.*, 2018). Increase in the reducing sugars (fructose and glucose) was also observed by Al-Mashhadi *et al.* (1993). Sugars were increased in stored fruits of mango (Islam *et al.*, 2013).

Date palm fruit contain high amount of sugars (30 to 44% at doka stage) therefore, spoiled due to fermentation process at room temperature. The shelf life of date fruits can be enhanced by stored fruits under low temperature. Amount of sugar and TSS were enhanced in storage however, acidity and ascorbic acid were reduced. Texture of the fruit somewhat changed due to water loss and shrinkage but these fruits contain good amount of TSS, ascorbic acid, sugars and acidity. These fruits remain consumable after 12 months storage and these are used as preparation of value added products like jam, biscuits, dry dates and soft dates *etc.* and other date based products.

Table 1. Physical and quality characters of date palm cv. Halawy cultivar at Doka stage

Characters	Fresh fruits	Stored fruits (-20°C)
Fruit weight (g)	7.42	5.18
Pulp weight (g)	6.20	3.99
Stone weight (g)	1.22	1.19
Diameter(cm)	1.92	1.33
Length (cm)	3.87	2.98
TSS B°	47.52	52.62
Acidity %	0.42	0.34
Ascorbic acid (mg/ 100g)	6.41	4.21
Total sugar %	28.42	32.79
Reducing sugar %	25.47	29.64
Non reducing sugar %	2.95	3.15

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