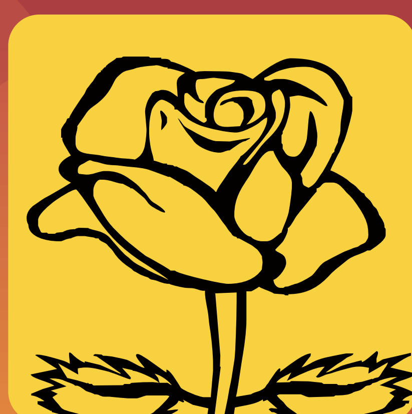
RNI No. UPENGO3865/24/1/2013-TC
ISSN 2347-7377

Current Horticulture

(A Journal Dedicated for the Advancement of Horticultural Science)

Vol. 5 No. 1 January–June 2017



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Current Horticulture

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CURRENT HORTICULTURE

Vol **5**, No. 1, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

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This is indeed a great pleasure and pride for all of us, that the National Academy of Agricultural Sciences (NAAS) has enlisted *Current Horticulture* in its current list of prestigious journals. The NAAS rating of *Current Horticulture* has been given as **3.71**, one of the highest rating of such a new incumbant journal like ours. In such a short time, *Current Horticulture* has achieved this feat, because of your whole-hearted support and stringent efforts to contribute quality papers/articles time- to- time. We sincerely hope, in years to come, you will take this journal to a new height, and we assure you from our side to leave no stone unturned to provide you the best and quickest services at our end.

Thanking you and our best regards.

Editor-in-Chief

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Research Review Article

Current Horticulture **5**(1): 3–14, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Microirrigation in onion *(Allium cepa)* and garlic *(A. sativum)* – a review

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Received: February 2016; **Revised:** January 2017

ABSTRACT

The objective of this paper was to review the microirrigation studies in onion *(Allium cepa* L.*)* and garlic (*A. sativum* L.) carried out in different parts of the world with special reference to India which is largest producer and consumer of the short-day onion and garlic in the world. Despite of leading producer of both onion and garlic, the productivity in our country is lesser than other countries. Water availability is one of the crucial inputs for productivity. The efforts were made by several organizations to develop and evaluate microirrigation methods and systems to increase the production and productivity of both onion and garlic. The experiments showed that drip irrigation increases yield (15-40%), bulb size and storability of bulbs. The drip irrigation was found to be more effective than sprinkler irrigation. The water saving (30-40%) was higher in drip irrigation with higher use efficiency. Besides, drip irrigation was found beneficial in reduction weed population, disease infection and labour requirement.

KEY WORDS: Microirrigation, Yield, Quality, Water-use Efficiency, Bulb size, sprinkler irrigation.

Onion (*Allium cepa* L.) and garlic (*A. sativum* L.) are most important bulbous vegetable crops grown and consumed all over the world. In India, onion is grown in 1.173 million ha, whereas garlic is grown 0.262 million ha, The annual production of onion is about 18.939 million tonnes and that of garlic 1.425 million tonnes. The productivity of onion and garlic are 16.1 and 5.04 tonnes/ha respectively. The highest productivity of onion is in Gujarat (25.43 tonnes/ha), while productivity of garlic is highest in West Bengal (11.94 tonnes/ha) (NHB 2015), (Figs 1 and 2). Onion is grown in 3.0 million ha, in world whereas garlic is grown in 1.0 million ha. The annual production of onion is about 54 million tonnes and that of garlic 14 million tonnes. The major onion-growing countries are China, India and USA, whereas major garlic-growing countries are China and India. The productivity of onion is highest in Republic of Korea (57.03 tonnes/ha), while productivity of garlic is highest in Egypt (24.34 tonnes/ha) (FAO, 2013, Figs 3 and 4).

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The low productivity of onion and garlic in India could be attributed to low inheritance potential of short-day onion and garlic varieties predominately grown in the country, higher disease incidence and shortage of timely inputs, particularly of water (Singh, 2000; Lawande, 2005). Irrigation is one of the most crucial inputs for onion and garlic. The shortage of irrigation at bulb development, which usually coincides with summer season, affect the yield drastically. Water scarcity is an increasingly important issue in many parts of the world. Climate change predictions of increase in temperature and decrease in rainfall may enhance water scarcity. Restricted supply of good quality water is the most important factor limiting their production. Thus, efficient management of water resources is essential to meet the increasing competition for water between agricultural and non-agricultural sectors.

The availability of water has continuously reduced during last five decade from 90% share of water used for agriculture to 75-80% .Ground water in many parts of the country is fast depleting due to over exploitation. Also per hectare investment on irrigation has doubled over the past 50 years. It is also expected that the share of agriculture in total water demand by the year 2025 is expected to be about 75 per cent. The availability of

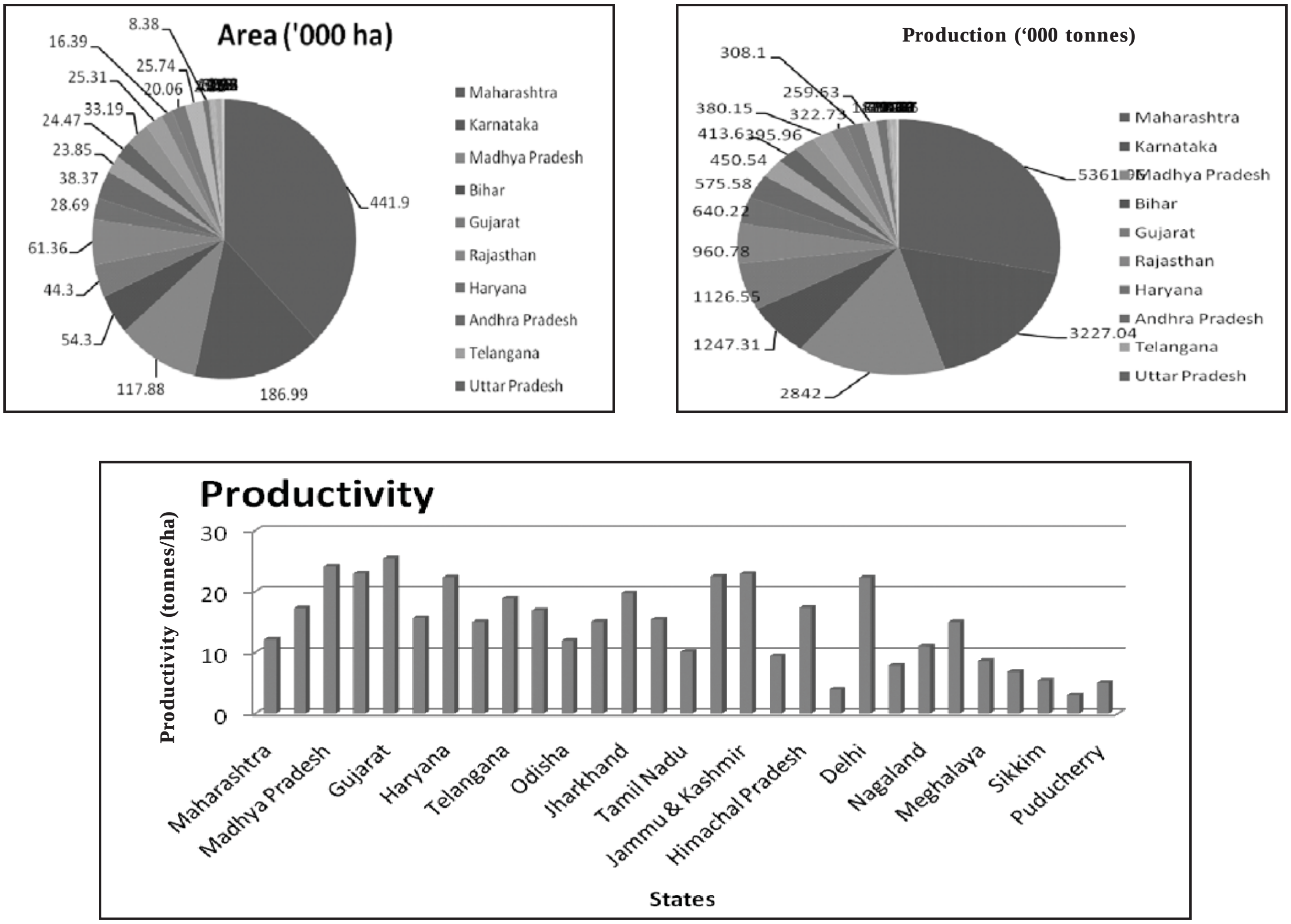

Fig. 1. Area production and productivity of onion in India (2014-15)

water for agriculture is declining since independence and it is expected to decrease further by 2050 (Fig. 5).

Thus, increasing efficiency in irrigation is only option. In last few decades, emphasis has been given in enhancing the productivity of irrigation water. Therefore, efficient use of water by irrigation is becoming increasingly important, and alternative water application method such as microirrigation methods may contribute substantially to attain the twin objectives of higher productivity and optimum use of water. The trend in recent years has been towards conversion of surface to microirrigation because cost of installation has relatively decreased with the easy in access to subsidized drip irrigation equipments.

Water requirement

Water requirement of any crop depends upon the nature of crop, soil, evapotranspiration rate of that particular locality and also stage of growth of plant. Water requirement for onion and garlic would be different in different seasons and localities and therefore water requirement estimated in a particular area would not be exactly applicable in other areas. Onion and garlic are shallow-rooted and frequent irrigation is necessary for their optimum growth and better bulb development. These crops are very sensitive to moisture stress conditions during bulb initiation and development stages. Onion is grown in *kharif* (rainy), late-*kharif* (late-rainy) as well as *rabi* (winter)season in India, while garlic is grown in *rabi* (winter) season except a few exceptions. The active root zone of these crops is between 20 and 30 cm depth.

The important growth stages in onion are initial vegetative growth period, bulb initiation, bulb development and maturity. In garlic, initial vegetative growth period, bulb initiation and bulb development are the most critical stages. Seedling stage can withstand for water stress or fluctuations and water requirement is less at bulb maturity stage but moisture stress during bulb initiation and bulb development may cause drastic reduction in yield and bulb quality. Excess moisture or waterlogged conditions during later stages of bulb

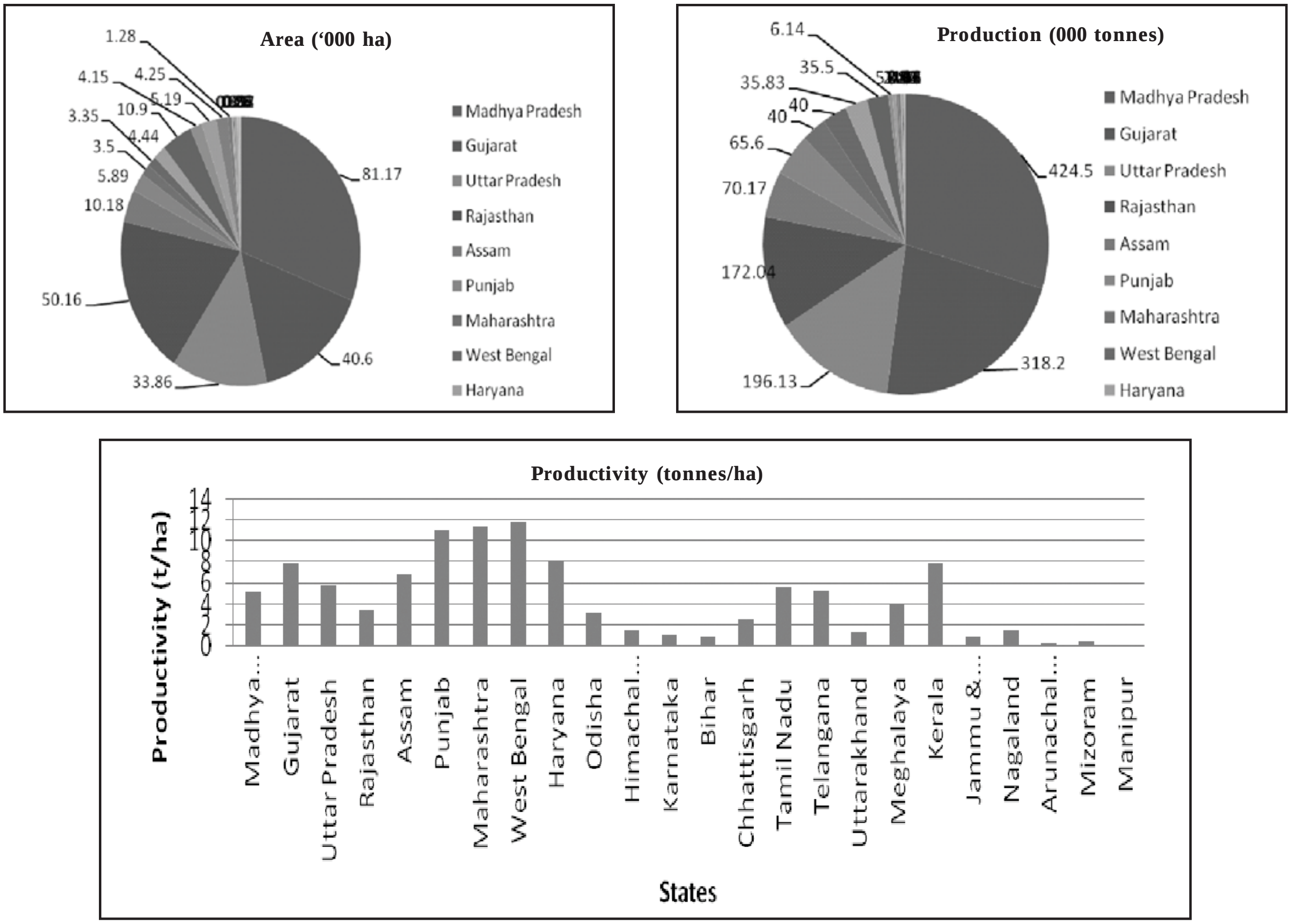

Fig. 2. Area, production and productivity of garlic in India (2014-15)

growth and maturity may lead to higher disease infection, particularly bulb rot, secondary rooting new sprouts *etc.*

Further, losses can be enhanced by the infection of basal rot and purple blotch, withholding of irrigation for 2-3 weeks prior to harvesting in onion is very essential. However, for garlic some amount of moisture is necessary at harvesting for easy lifting of bulbs. The maintenance of soil water potential of -0.85 bar or less either during pre-bulb development (20 - 60 days after transplanting) or bulb development stages (60-110 days after transplanting) significantly reduced onion yield and bulb development stage was found to be to more sensitive to moisture than pre-bulb development.

Onion requires 64-72 cm water during growth and development. This requirement may be as per the climatic conditions and soil type. Joshi (1963) reported 16 irrigations with total 64 cm water are required for onion crop, while Narang and Dastane (1969) reported that 18 irrigations with 72.2 cm water are required for Delhi conditions. Hegde (1986) reported 20 irrigations with 38-39 cm consumptive use of water are required for onion grown under Bengaluru conditions. In field experiment, on two soils of different texture, highest yields of fresh and dry matter of bulbs were obtained at the lowest soil water potential (-0.15 bars). Mandke and Arakeri (1956) reported that onions consume less water immediately after the establishment of the crop but water consumption increases with advance in the season. They found that irrigation application at 13 days interval during November-December, 10 days interval during January and 7 days interval during February was optimum for onion under Pune conditions. In clay soils, irrigation at 5 days interval gave higher yield of winter season crop. Moisture deficit occurring at any period reduces yield but moisture stress occurring early in the season are not as detrimental as those occurring late. Bulb development and enlargement stages are critical in their demand for water (Parashar, 1979, Table 1).

Dimitrov (1974) reported that onion and garlic grow faster and mature early and produced higher yields

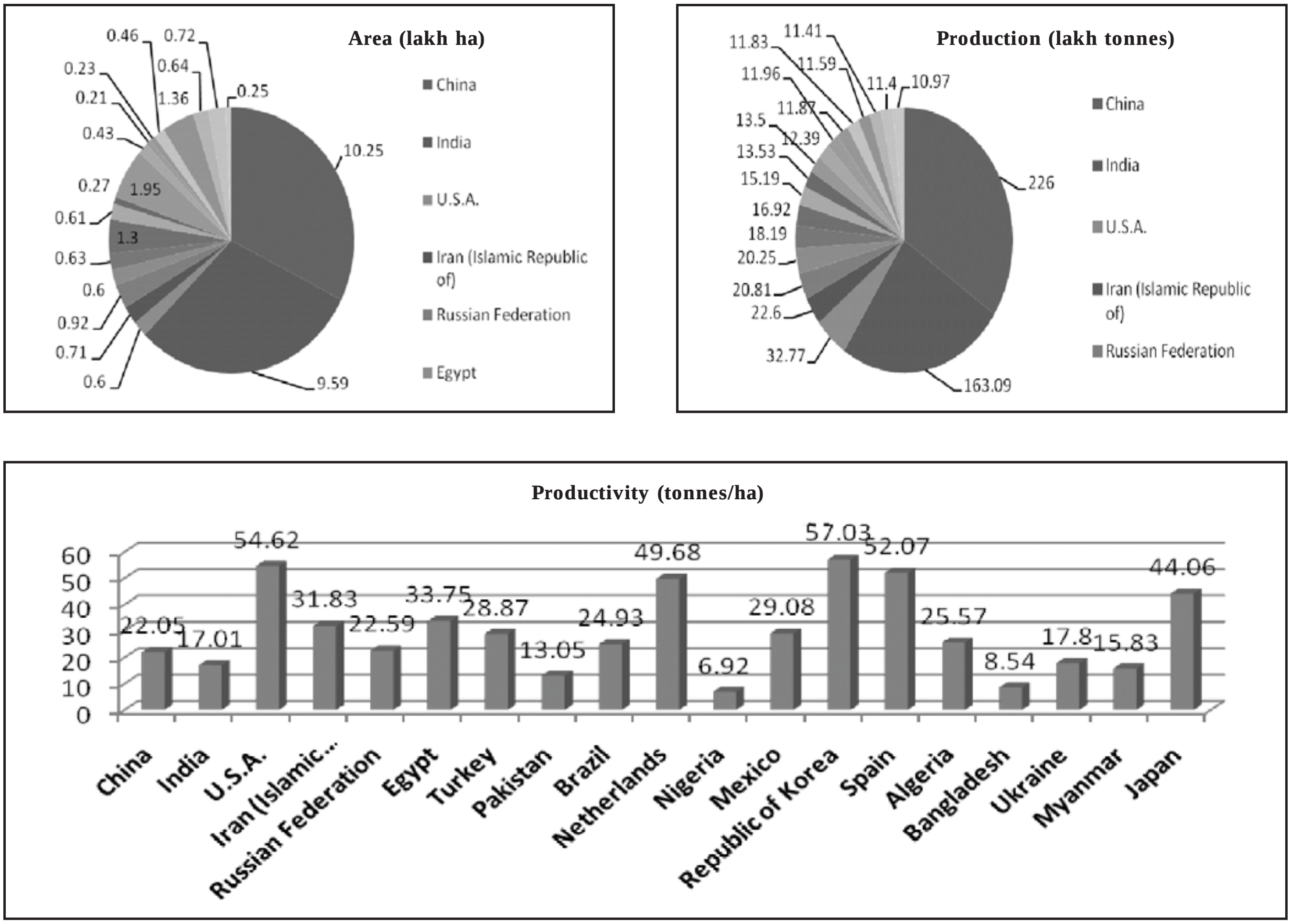

Fig. 3. Area, production and productivity on onion in world (2012-13)

Table 1. Water requirement of onion in locations

Location	Source	Optimum soil moisture	No. of irrigations	Depth of irrigation (cm)	Total water requirement (mm)	Consumptive use of water (mm)
Hyderabad	Rao (1954)	-	5-6 *(kharif)*\12-15 *(rabi)* 1 5 -20 (summer)	-	-	-
Rahuri	Patil *et al.* (1958)	-	13	-	-	-
Delhi	Joshi (1963)	0.65 bar tension	16	8.0	640	464
Delhi	Dastane and Joshi (1964)	-	16 (sandy loam soil) 12 (clay loam soil)	-	-	-
Delhi	Narang and Dastane (1969)	0.6	18	7.5	722	637
Bangalore	Hegde (1986)	-0.65	20	8.0	-	380 - 396
Faizabad	Singh *et al.* (1987)	-	4	5.0		
Nargund	Pallad *et al.* (1988)	0.7IW/CPE	-	6.0	-	-

when moisture was maintained at 80-90% of field capacity. The keeping quality of bulbs was poorer than that of plants grown at lower soil moisture, because the large cells and thinner cuticle led to greater transpiration. Irrigating when soil water potential reached 0.45-0.65 bar resulted in maximum dry matter production,

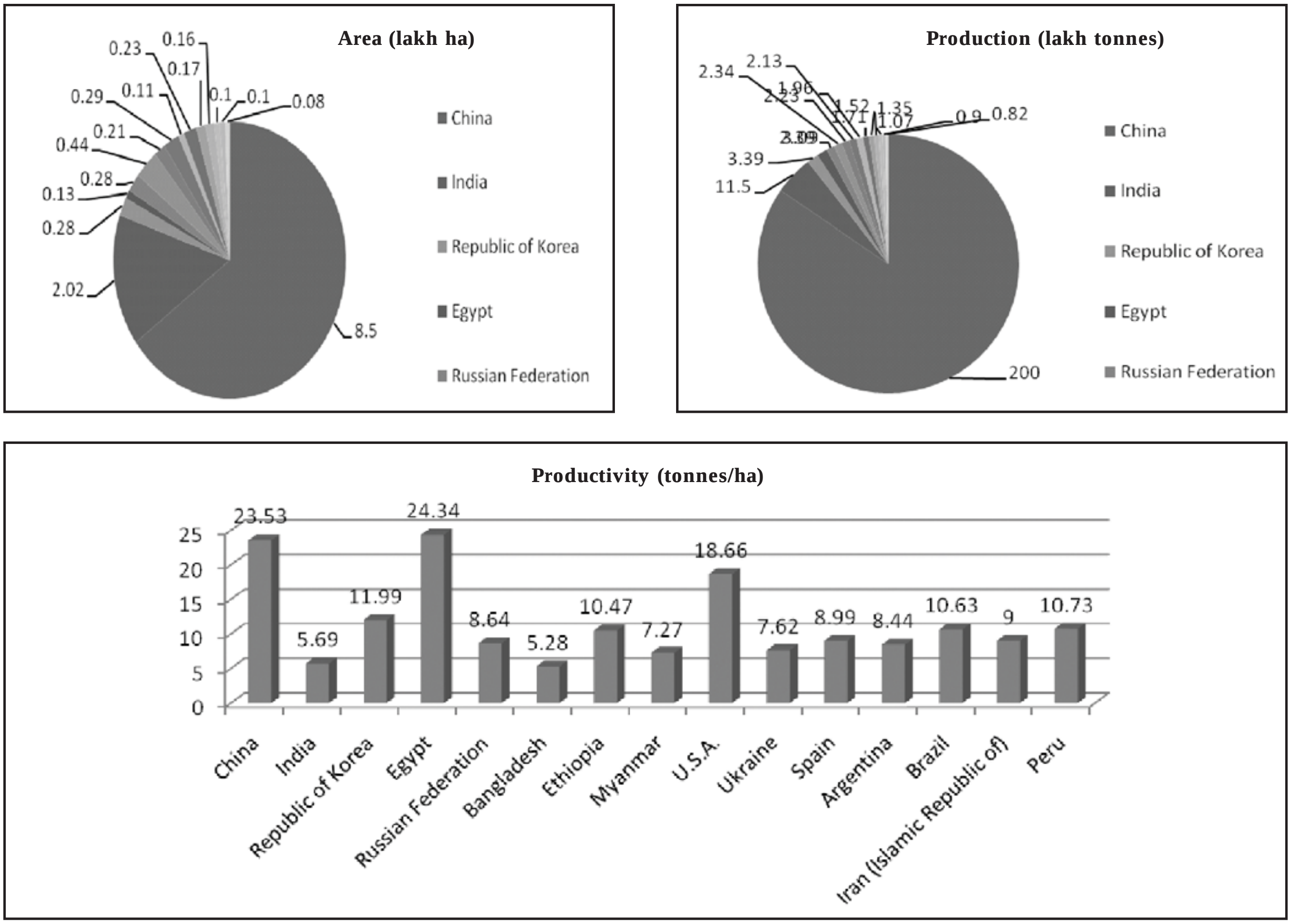

Fig. 4. Area, production and productivity of garlic in world (2012-13)

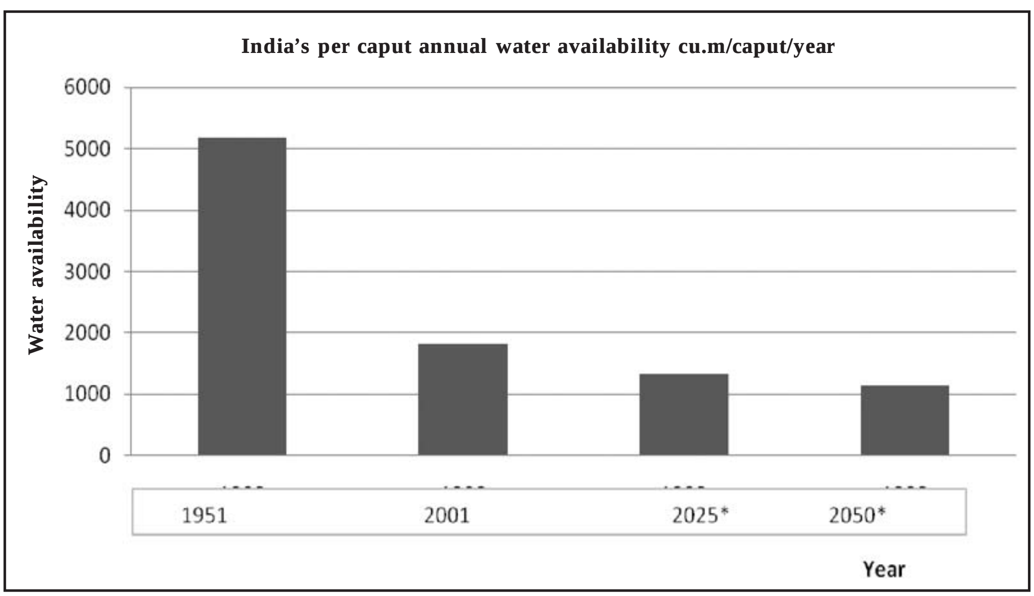

Fig. 5. Per caput water availability in India

nutrient uptake and yield (Hegde, 1986). Pirov (2001) reported that maximum yield of onion can be achieved at 80-90% of field capacity. However, 70% field capacity throughout growing season helped for improving the post-harvest storage life.

Methods of irrigation

Onion and garlic are mostly grown as irrigated crops in India. The most common method of applying water to onion crop is to irrigate it with bed or border strip flooding or furrow method irrigation. The productivity of water in surface irrigation is low due to higher percolation, distribution and evaporation losses. The modern systems of irrigation such as drip, sprinkler ensures higher water-use efficiency. First experimental system of drip irrigation was established in 1959 by Blass who partnered later (1964) with Kibbutz Hatzerim to create an irrigation company and developed first practical surface drip irrigation emitter. Microirrigation methods are found increasing plant growth and yield by increase availability of soil moisture, and better soil consistency. Abrol and Dixit (1972) also obtained higher yield and water-use efficiency under drip irrigation. Two method of microirrigation, *i.e.* drip irrigation and sprinkler irrigation are extensively used for onion and garlic cultivation in India.

Advantages of microirrigation

Microirrigation system water is saved through different ways such as reducing loss of water in conveyance, reducing loss of water through evaporation, run off, and by deep percolation, water supply source with limited flow rates such as small water wells or city / rural water can be used in this type of irrigation system. Microirrigation system requires a smaller power unit and consumes less energy. This is helpful in inhibiting growth of weeds as it keeps limited wet areas. It also reduces the incidence of disease. Fertilizers and chemicals can be applied with water through microirrigation system. This systems can be automated which reduces labour requirements.

It Improves production on marginal land, hilly terrain, and can operate in undulated land with no run off. There are some disadvantages of microirrigation systems such as higher maintenance requirements, clogging of devices, damage by animals, rodents and insects may cause damage to some components. Further, initial investment cost is high. Initially microirrigation systems were used for orchards, vineyards, greenhouses, and nurseries but gradually these were used in vegetable cultivation.

There were several issues of use of microirrigation for onion and garlic such as size, type of beds and method of irrigation. In drip irrigation, thickness of hydrogols, number of drippers, discharge of drippers, number of laterals / bed, distance between two laterals, length of laterals were major issues to be answered, while in sprinkler number of sprinklers, discharge of sprinklers, number of sprinklers / bed, coverage, droplet size, distance between two sprinklers, length of laterals were major concerns. A lot of experiment have been done on various combinations in drip and sprinkler irrigation system during last 20 years all over the onion-and-garlic growing belts of India.

It has been amply proved that even onion and garlic can be taken on drip irrigation system. The results supported drip irrigation and its technical feasibility is an undisputed fact in most of the states.

Crop growth and yield

The production of healthy seedlings is one of the crucial steps of onion cultivation. The nursery production with surface irrigation requires more water, low seed germination and uneven seedling growth. The nursery raising with on drip irrigation under 50% agri shade net or hessian cloth ensures 80-83% of seed germination with 58% final seedling stand in summer against 49% and 27% respectively in surface irrigation with no shade (Tripathi and Lawande, 2011). In late-*kharif* and winter season nurseries on onion, the drip and sprinkler irrigation resulted 90-95 per cent germination with 80-85 percent transplanted seedlings as compared 55-60 per cent transplanted seedlings in surface irrigation (Tripathi *et al.*, 2002).

The trickle irrigation shortened the time of emergence, good seedling growth and uniform crop stand. The growth and diseases incidence are lesser in drip irrigated crop. Other benefits are prevention of soil erosion, feasibility in undulation land, saving fertilizer through fertigation *etc.* There is an ample scope extending are under drip irrigation. Drip irrigation can save up to 50% of water and increase yield by 15- 20%. Dixit *et al.* (1971) reported that drip irrigation significantly increased the yield and diameter of bulbs as compared to surface irrigation. Drip irrigation system has high water-use efficiency and does not require land levelling.

Microirrigation methods are found increasing plant growth and yield by increase availability of soil moisture, and better soil consistency. The crop growth and final stand in onion was higher in all three season under Maharashtra conditions. The plant height was highest in drip irrigation as compared to sprinkler and surface irrigation conditions (Table 1) (Tripathi *et al.*, 2010). Abrol and Dixit (1972) also obtained higher yield and water use efficiency under drip irrigation. Drip irrigation with the recommended rate of solid fertilizer in 2 applications gave the highest bulb yield (496.35 q /

Table 2. Yield of onion (cv. N-2-4-1) as influenced by various systems of irrigation

Treatment	Bulb yield (q/ha)	Water applied (cm)	Water -use efficiency (Q/ha.cm)	Water saving (%)	Yield increase over 75mm CPE
Surface irrigation					
50mm CPE	359.6	108	3.61		9.87
75 mm CPE	334.9	78	4.53	-	-
100mm CPE	274.0	60	4.73	23.08	-
125mm CPE	216.0	54	4.28	30.7	-
Sprinkler irrigation					
75 mm CPE at 40 mm depth	412.7	52	8.47	33.3	24.6
CD (0.05)	31.01				

(Anon, 1986-87)

ha) while drip fertigation at 50% of the recommended rate gave the highest bulb quality.

The annual irrigation water requirement of onion through drip irrigation was 46.27 cm. Field experimentations on drip irrigation at Hissar conditions resulted significantly higher yields of onion. Field experimentations on sprinkler irrigation resulted significantly higher yields of onion (Table 2). The water requirement of onion by drip irrigation method was 45.12 cm as against 60.2 cm in surface irrigation. The water use efficiency was also higher in drip irrigation (63%) compared to 55.5% in surface irrigation treatment. The highest yield (441.76q/ha.), higher water-use efficiency (10.04 q/ha) and bulk density of bulb (10.04 q/ha cm) were obtained with sprinkler irrigation. The yield of onion was higher in drip irrigated plots than furrow irrigated plots. But the increase was non-significant.

Usage of water was low with the drip method stated that onion yields were consistently 35% higher in drip irrigation than regular furrow irrigated onions in a three year trial. Moreover, it saved more 50 % water and 20% fertilizer. Patil *et al.* (2000) reported significant performance with respect to yield and quality of white onion cv.Phule Safed during summer season over the control. Through microirrigation system 53-69% water saving was achieved. Maximum water-use efficiency (0.91 q.ha/mm) was observed through both the micro irrigation system. Balasubrahmanyam *et al* (2000) reported that optimum yield of acceptable quality of bulbs obtained from irrigation through drip system at 60000 litres/ha/day and fertigation using NPK liquid fertilizer at 150:125:200 kg/ha are necessary.

Tripathi and Lawande (2008) reported that planting of onion cv. Baswant-780 on Broad Based Furrows (BBF) with drip resulted in higher yield (31.2 tonnes/ha) as compared to flat bed, raised bed and ridge and furrow planting in *kharif* season under Maharashtra conditions. Studies on microirrigation on growth, yield and yield contributing characters of onion under western Maharashtra conditions revealed that both drip and micro sprinkler irrigation improved growth yield and yield contributing parameters of onion. Among different irrigation methods and levels tested, the drip irrigation at 100% pan evaporation recorded the highest marketable bulb yield onion followed by micro sprinkler irrigation at 100% pan evaporation.

Moreover, it was clearly indicated from the experiment that the saving of irrigation water was to the tune of 37.8% in drip and 32.5% in sprinkler system under best treatment as compared to surface irrigation, when it was scheduled at 50 mm CPE with 7 cm depth (Table 3, NRCOG, 2001, 2002, 2003; Sankar *et al.*, 2008a). According to Tripathi *et al.* (2010) studies on effect of various irrigation methods, *i.e.* drip, mini sprinkler, big sprinkler and surface irrigation on the growth, yield and storage of onion cv. N-2-4-1. The highest yield was recorded in drip irrigation (47.47 tonnes/ha) followed by big sprinkler (31.21 tonnes/ha). The lowest yield was recorded in surface irrigation (22.79 tonnes/ha).

The plant height, percentage of big size bulbs, equatorial and polar diameter of bulbs was higher in drip irrigation method (Table 4). The study of Bagali *et al.* (2012) shown that short interval of irrigation (one day) recorded significantly higher bulb yield (46.93 tonnes/ha). 100 per cent PE recorded significantly higher bulb yield (50.92 tonnes/ha) compared to 80 and 60 per cent PE and flood irrigation Significantly higher bulb yield was recorded in one day interval of irrigation at 100 per cent PE (54.91 tonnes/ha) which was on par with two days interval of irrigation at 100 per cent PE (52.83 tonnes/ha).

Microirrigation is found successful in garlic to increase yield, quality and water use efficiency. A study revealed that there was 28.3% water saving and 4.3 percent increase in yield of Garlic cv. Jamnagar under

Table 3. Effect of irrigation systems on growth and yield of onion cv. N 2-4-1.

Treatment	Plant height (cm)	Marketable yield (tonnes/ha)	Bulb weight (g)
Drip irrigation 50 % PE	55.2	26.1	47.1
Drip irrigation 75 % PE	63.3	33.9	56.6
Drip irrigation 100 % PE	66.9	39.6	56.8
Sprinkler irrigation 50 % PE	55.0	22.8	41.5
Sprinkler irrigation 50 % PE	61.5	25.3	40.2
Sprinkler irrigation 50 % PE	65.2	28.1	46.4
Surface irrigation at 50 mm CPE	62.6	31.8	54.5
CD (0.05)	1.98	0.67	3.41

(Sankar *et al.*, 2008a)

Table 4. Effect of irrigation systems on growth and yield of onion cv. N-2-4-1.

Treatment	Plant height (cm)	Yield (t/ha)	Per cent Bulb grade bulbs		
			A (>60mm ED)	B (50-60mm ED)	C (35 -50mm ED)
Surface irrigation	53.42	22.79	9.05	49.73	37.08
Drip irrigation	58.78	47.47	36.03	50.04	8.75
Sprinkler (big) irrigation	55.24	31.21	15.81	46.22	22.32
Sprinkler (micro) irrigation	54.12	24.74	13.84	44.21	35.38
CD (0.05)	4.70	6.83	7.38	NS	12.64

(Tripathi *et al.*, 2010)

sprinkler irrigation. Patel *et al.* (1996) recorded higher marketable bulb yield of garlic under drip irrigation system. In garlic, clove germination was higher and uniform as compared to surface irrigation. Among the different irrigation methods and levels tested, drip irrigation at 100% PE recorded the highest marketable bulb yield of garlic followed by sprinkler irrigation at 100% PE. The study indicated that in the best treatment compared to surface method of irrigation, a saving of 37.9% irrigation water in drip and 36.4% in sprinkler system can be achieved (Table 5, Sankar *et al.* 2008b). Mohammad Ghanbari *et al.* (2013) indicated that the use of drip irrigation and weed control increased cloves number, cloves weight and bulb yield. Mean comparisons of interaction effects also showed that the highest economical yield was registered in using drip method with manual weed control in garlic cv. China in Turkey. The results revealed that in places with limitation of water, using of drip irrigation causes both decreasing weeds and increasing yield in garlic cultivars.

Quality of bulbs

Microirrigation have influence the size and quality

Table 5. Effect of irrigation systems on growth and yield of garlic cv. G-41.

Treatment	Plant height (cm)	Yield (tonnes/ha)	A-grade bulbs (%)	B-grade bulbs (%)	C-grade bulbs (%)
Drip irrigation 50 % PE	53.9	9.07	40.9	41.9	17.2
Drip irrigation 75 % PE	61.7	11.9	48.8	40.2	11.1
Drip irrigation 100 % PE	62.7	13.2	53.5	39.1	7.3
Sprinkler irrigation 50 % PE	49.5	7.31	30.8	38.2	31.0
Sprinkler irrigation 50 % PE	5.1	10.4	39.9	40.0	19.6
Sprinkler irrigation 50 % PE	58.6	12.3	46.9	40.8	15.6
Surface irrigation at 50 mm CPE	46.7	11.6	46.7	40.2	13.2
CD (0.05)	3.84	0.23	2.97	2.43	1.03

(Sankar *et al.*, 2008b)

of bulb in onion and garlic. Tripathi *et al.* (2010) reported that the percentage of bigger size bulbs of onion were more in drip irrigation than surface and sprinkler irrigation (Table 6). Similar results were reported by Sankar *et al.* (2008 and Table 4). The study also found that the percentage of rooted bulbs were ore under sprinkler irrigation and surface irrigations. Although there was no significant difference in Total soluble solids (TSS) content of bulbs. In almost all the micro irrigation studies in onion and garlic revealed in the bulbs size and percentage of big size bulbs. In fact the yield increase by microirrigation may be attributed to higher plant stand per unit area and higher number of bigger size bulbs.

Weed growth and soil conditions

Weed population in drip irrigated plot was lower than the surface irrigation and sprinkler irrigation. The results revealed that in places with limitation of water, using of drip irrigation causes both decreasing weeds and increasing yield in garlic cultivars (Mohammad Ghanbari *et al.*, 2013). Further, soil of drip and sprinkler irrigated field remains fragile and less compact than field irrigated with surface irrigation. These soil conditions favour easy weeding and harvesting operations. The lower weed population was recorded in drip irrigated onion nursery (Tripathi *et al.*, 2002).

Water saving and water-use efficiency

Higher water saving, water productivity of water in drip irrigation system is due to the reduction of various types of water losses during irrigation. Al-Jamal *et al.* (2000 and 2001) elucidated that maximum irrigation efficiency (100%) obtained with sprinkler irrigation followed by drip irrigation method (79-82%) compared with 54-80% obtained from furrow irrigation at farmers field. Sankar *et al.* (2008a) indicated that the saving of irrigation water was to the tune of 37.8% in drip and 32.5% in sprinkler system under best treatment as compared to surface irrigation, when it was scheduled at 50 mm CPE with 7 cm depth (Table 7).

There was around 30 per cent water saving in drip irrigation system as compared to surface system while it was between 7 and 16 per cent in sprinkler irrigation systems. The highest water use efficiency was recorded in drip irrigation system, which was 770 kg / ha-cm of water (NRCOG, 2001, 2002, 2003 and Table 3). higher water use efficiency in drip irrigation (770 kg / ha-cm) than micro sprinkler(344.6 kg / ha-cm), big sprinkler (386.5 kg / ha-cm) and surface irrigation (252.5 kg / ha-cm) (Tripathi *et al.*, 2010) . Bagali *et al.* (2012) found that both one day (M1) and two days (M2) interval of irrigation and 60 per cent PE (S1) recorded significantly higher WUE, The intervals and levels of irrigation and

Table 6. Effect of irrigation systems on different grades of bulbs in onion

Treatment	Bulb grade bulbs (%)		
	A (>60 mm diameter)	B (50-60 mm diameter)	C (35 to 50 mm diameter)
Surface irrigation	9.05	49.73	37.08
Drip irrigation	36.03	50.04	8.75
Sprinkler (Big) irrigation	15.81	46.22	22.32
Sprinkler (Micro) irrigation	13.84	44.21	35.38
CD (0.05)	7.38	NS	12.64

Tripathi *et al.* (2010)

Table 7. Effect of irrigation systems on water saving and water-use efficiency in onion

Treatment	Water applied (ha cm)	Water saving (%) over surface	Water-use efficiency (kg / ha-cm)
Drip irrigation 50 % PE	29.8	63.6	1080
Drip irrigation 75 % PE	40.4	50.1	959
Drip irrigation 100 % PE	56.0	37.8	867
Sprinkler irrigation 50 % PE	30.0	63.1	828
Sprinkler irrigation 50 % PE	45.7	44.1	615
Sprinkler irrigation 50 % PE	57.3	32.5	525
Surface irrigation at 50 mm CPE	79.3	0	414

(Sankar *et al.* 2008a)

Table 8. Effect of irrigation systems on water saving and water-use efficiency in garlic

Treatment	Water applied (ha cm)	Water saving (%) over surface	Water-use efficiency (kg / ha-cm)
Drip irrigation 50 % PE	28.2	63.7	343.1
Drip irrigation 75 % PE	38.6	50.7	318.8
Drip irrigation 100 % PE	48.7	37.9	274.4
Sprinkler irrigation 50 % PE	28.3	63.6	256.0
Sprinkler irrigation 50 % PE	38.9	50.1	304.8
Sprinkler irrigation 50 % PE	50.0	36.4	248.9
Surface irrigation at 50 mm CPE	78.7	0	145.1

(Sankar *et al.*, 2008b)

their combinations were significantly superior for WUE, compared to flood irrigation.

In garlic , Sankar *et al.* (2008b) reported that among the levels of irrigation evaluated, drip irrigation system at 50% PE recorded the highest water-use efficiency (343.1 kg / ha / cm) but there was a marked reduction in marketable bulb yield at minimum water applied per either through drip or sprinkle irrigation(Table 8).

Microirrigation has another advantage of utilization of saline and brackish water for irrigation. The studies have proved that these irrigation systems can minimized the effect of salinity. The sprinkler irrigation with brackish water reduced onion yields by 60%, compared to fresh water. This reduction was due to reductions in both bulb size and bulb number per unit area. Drip irrigation with brackish water shown yield reduction of 30%, and only the bulb number was affected. With drip irrigation, seedling death occurred in the first 40 days after emergence; yield reduction was eliminated by using fresh water during the establishment phase, changing to brackish water at 45 days after sowing.

Storage losses

Storage losses in the onion bulbs produced under micro irrigation are reported lower than surface irrigation. Tripathi *et al.* (2010) found that total storage losses after three months of storage were lowest in drip irrigation (13.38%) and surface irrigation (17.15%). While higher losses were found in micro-sprinkler irrigation (22.58%) and big sprinkler irrigation (32.25%) systems. Similarly, these losses were 32.72 and 36.18% in drip and surface irrigation, respectively in comparison to 46.18% in micro-sprinkler and 57.73% in big sprinkler after 6 months of storage. The rotting losses were significantly higher in both types of sprinklers than drip and surface irrigation. Brice *et al.* (1997) reported higher storage losses in overhead irrigation. The reason may be due to the fact that the overhead irrigation allows the entry of disease causing microorganisms in the later stage of bulb maturity.

Seed production

Microirrigation system has been found effective in yield enhancement and reduction in water requirement in onion seed crop. Large scale seed production programme carried out at NRC onion and Garlic farms at Rajgurunagar and Manjari showed that higher yield of quality seed of onion can be produced with less use of water (Tripathi *et al.*, 2004). According to Sankar *et al.* (2015) growth, yield and yield contributing characters of onion seed crop as significantly influenced by different methods and levels of irrigation practices. Among the methods and levels of irrigation, drip irrigation at 100% PE daily improved the growth, yield and yield contributing parameters. Higher seed yield was recorded at drip irrigation at 100 PE (582.6 kg / ha) in daily interval followed by drip irrigation at 100% PE at 3 days interval (506.4 kg / ha).

The results indicated saving of irrigation water to the tune of 37.5% in drip system as compared to surface irrigation (Table 9). Dingre *et al.* (2012) also observed that drip irrigation resulted into 41-62% water saving with 4-26% increase in yield of onion seed as compared to surface irrigation. The growth and yield attributes in drip irrigated treatments showed decreasing trend with increase in irrigation interval and CPE. When drip irrigation applied daily at 100% of CPE, the yield increased up to 26% as compared to control. The drip application at every 3 days interval with 75% CPE was found to be optimum and effective for growth, yield, and quality as well as economically viable for onion seed production (Dingre *et al.* 2012).

Economics

The yield of onion was higher in drip irrigated plots than furrow irrigated plots. But the increase was non-significant. Usage of water was low with the drip method. Tripathi *et al.* (2010) reported that the benefit : cost ratio was highest in onion grown under drip irrigation (1.98) followed by big sprinkler (1.50) while it was lowest in surface irrigation. Patel *et al.* (1996)

reported that the benefit: cost ratio was highest in garlic grown under drip irrigation. The higher benefit: cost ratio in drip irrigation suggests that despite of higher initial cost of the system; the drip irrigation is more profitable than sprinklers and surface irrigation.

The microirrigation studies carried out in onion and garlic during last 30 years in various parts of the country revealed that both drip irrigation and sprinkler irrigation system increased yield and quality onion and garlic bulbs with a considerable saving of water. There is variation in yield enhancement and water saving by these systems in different regions and locations. But it is no doubt that these systems have potential to mitigate water scaring without affecting the yield and quality of onion and garlic. Moreover, most of the studies have proved the superiority of drip irrigation over sprinkler irrigation. But in some locations sprinkler system outpassed drip irrigation with respect to yield. The microirrigation systems have been successfully adopted by farmers of major onion-and garlic-growing regions of the country.

REFERENCES

Abbey L and Joyce D C. 2004, Water deficit stress and soil type effects on spring onion growth. *J. Veg. Crop Prod.* **10**(2): 5-18

Abrol I P and Dixit S P. 1972. Studies of the drip method of irrigation. *Expl. Agric.* **8**: 172-75.

Al-Jamal M S, Sammis T W, Ball S and Smeal D. 2000. Computing the crop water production function for onion. *Agricultural Water Management* **46**(1): 29-41.

Al-Jamal M S, Ball, S. and Sammis, T W. 2001. Comparison of sprinkler, trickle and furrow irrigation efficiencies for onion production. *Agricultural Water Management* **46**(3): 253-66.

NHB, Gurgaon. 2015. *Data Book-2015.* National Horticulture Board, Gurgoan, India.

FAO, Rom. 2013. *FAO Year Book-2013*. Food and Agriculture Organization, Rome.

NRCOG, Rajgurunagar. 2001. *Annual Report 2000-01*. NRCOG, Rajgurunagar, Maharashtra, India 60.

NRCOG, Rajgurunagar. 2002. *Annual Report 2001-02*. NRCOG, Rajgurunagar, Maharashtra, India 70.

NRCOG, Rajgurunagar. 2003. *Annual Report 2002-03*. NRCOG, Rajgurunagar, Maharashtra, India 64.

Bagali A N, Patil H B, Guled M B and Patil R V. 2012. Effect of scheduling of drip irrigation on growth, yield and water use efficiency of onion (*Allium cepa* L.). *Karnataka Journal of Agricultural Science* **25**(1): 116-19.

Balasubrahmanyam, V R, Dhake A V and Moitra P. 2001. Micro-irrigation and fertigation in onion. *In: Proceedings of International Conference on Micro and Sprinkler irrigation Systems*, held at Jalgoan, Maharashtra.

Bandyopadhyay P K, Mallick S and Rana S K. 2003. Actual evapotranspiration and crop coefficients of onion (*Allium cepa* L.) under varying soil moisture levels in the humid tropics of India. *Trop. Agric.* **80**(2) : 83-90.

Bose T K and Som M G. 1986. *Vegetable Crops in India*, Nayaprakash, Calcutta, India.

Brice J, Currah L, Malins A and Bancroft R. 1997. *Onion Storage in the Tropics: A Practical Guide to Methods of Storage and their Selection*. Chaltham, UK: Natural Resources Institute.

Carrijio O A, Olitta A F L, Miami K and Menezes A. 1982. Effect of different water quantities on the productivity of two garlic cultivars under drip irrigation. *Pesquisa Agropecuaria Brasileira* **17**: 783-80.

Dingre S K, Pawar D D and Kadam K G. 2012. Productivity, water use and quality of onion *(Allium cepa)* seed production under different irrigation scheduling through drip. *Indian Journal of Agronomy* **57**(2): 186-90.

Dixit S P, Agrawal M C and Singh K. 1971. Studies on subsurface drip irrigation method of irrigation for vegetable onion and sugar beet, *Indian J. Hort*. **28**(30): 221-23.

Gajbhiye K R, Kale M U and Wadatkar S B. 2009. Effect of different irrigation methods on yield of garlic. *Green Farm.* **13**(1): 963-64.

Gethe R M, Pawar V S, Sonawane D A and Kadlag A D. 2006. Infuence of planting layouts, irrigation regimes and fertilizer levels and yield of onion under micro sprinkler. *Journal of Maharashtra Agricultural University* **31**: 272-74.

Hegde D M. 1986. Effect of irrigation regimes on dry matter production, yield nutrient uptake and water use efficiency in onion. *Indian J. Agron.* **31**: 343-48.

Kadam U S, Gorantiwar S D, Kadam S A, Gurav G B and Patil H M. 2006. Effects of different moisture regimes on yield potential of onion (*Allium cepa* L.) under micro sprinkler irrigation system. *J. Maharashtra Agric. Univ.* **31**(3) : 342-45.

Lawande K E. 2005. Onion improvement-Present status and future thrust. *In: National Symposium on Current Trends in Onion, Garlic, Chillies and Seed Spices - Production, Marketing and Utilization*, held at Rajgurunagar, Pune.

Mohammad Ghanbari, Gholam-Reza Zaboli and Behrooz Mir. 2013. Comparing irrigation methods and weed control on yield of garlic (*Allium sativum* L.) cultivars. *World of Science Journal* **3**: 78-78

Patel B G, Khanpara V D, Malavia D D, Maraviya R B and Kaneria B B. 1996. Economic feasibility of drip irrigation in garlic. *Indian Journal of Agronomy* **45**: 143-45.

Patil R S, More S C, Firake N N, Bhalekar M N and Desale M N. 2000. Effect of microirrigation system and nitrogen fertigation levels on yield and quality of white onion (cv. Phule Safed) during summer season. Approaches for sustainable development of onion and garlic. *Proceedings of the National Symposium on Onion-Garlic Production and Post harvest Management – Challenges and Strategies,* held at Nasik, pp. 277-81.

Pawar C Y, Kadam U S, Gorantiwar S D and Pampattiwar S P 1998. Efficacy of the micro sprinkler irrigation method for garlic. *Journal of Maharashtra Agricultural. University*. **23**: 156-59.

Quadir M, Boulton A, Ekman J, Hickey M and Hoogers R. 2005. Influence of drip irrigation on onion yield and quality. *IREC Farmers' Newsletter*, **170**: 29-31.

Saman S. 2002. Microirrigation in onion cultivation. In: *Consultative Meeting on Accelerated Production and Export of Onion and Garlic*, held at New Delhi, during 19-20 April 2002. National Horticultural Research and Development Foundation, Nasik.

Sankar V, Qureshi A A, Tripathi P C and Lawande K E. 2001. Micro irrigation studies in garlic. *South Indian Horticulture* **49**: 379-81.

Sankar V, Lawande K E and Tripathi P C. 2008a. Effect of micro irrigation on growth, yield and water use efficiency of onion *(Allium cepa)* under western Maharashtra conditions. *Indian Journal of Agricultural Science* **78**(7): 584-88.

Sankar V, Lawande K E and Tripathi P C. 2008b. Effect of micro irrigation practices on growth and yield of garlic (*Allium sativum* L.) var. G. 41. *Journal of Spices and Aromatic Crops* **17**(3): 230-34.

Sankar V, Thangasamy A and Lawande K E. 2015. Effect of drip irrigation on onion seed production under western Maharashtra conditions. *International Journal of Tropical Agriculture* **33**(2): 622-25.

Singh Kriti. 2000. Current status of onion and garlic research in India and future prospects: Approaches for sustainable development of onion and garlic. *Proceedings of the National Symposium on Onion–Garlic Production and Post-harvest Management Challenges and Strategies*, held at Nasik, pp. 1-13.

Tripathi P C, Lawande K E and Mahajan V. 2002. Onion Cultivation (in Hindi). *Technical Bulletin No*. 4 Published by NRC Onion and Garlic, Rajgurunagar p. 52.

Tripathi P C and Lawande K E. 2004. Onion seed production (in Hindi). *Technical Bulletin No.* 8 Published by NRC Onion and Garlic, Rajgurunagar p. 20.

Tripathi P C and Lawande K E. 2008. *Kharif* onion production Technology. *Technical Bulletin No.* 18. NRC Onion and Garlic, Rajgurunagar, p. 10.

Tripathi P C, Sankar V and Lawande K E. 2010. Influence of micro-irrigation methods on growth, yield and storage of rabi onion. *Indian J. Hort*. **67**(1): 61-65.

Tripathi P C and Lawande K E. 2011. Evaluation of irrigation and shading methods on nursery production of onion (*Allium cepa* L.). *Vegetable Science* **38**(1): 22-25.

Research Article

Current Horticulture **5**(1): 15–19, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Evaluation of Citrus (*Citrus* spp.) for tolerance to abiotic stresses

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Received: December 2016; **Revised:** March 2017

ABSTRACT

An experiment was conducted to test the potential resistance capacity according to PAL activity and total soluble phenolic, lignin and flavonoid concentration in leaves of Citrus species, *viz. Citrus aurantium, C. grandis, C. junos* and *Poncirus trifoliate* during 2016. The results showed that *C. aurantium* had higher phenylalanine ammonialyase (PAL) activity and total soluble phenolic, lignin and flavoroid concentration in leaves compared with other three species. However, leaf PAL activity and leaf total soluble phenolic and lignin concentration in *C. grandis, C. junos* and *P. trifoliata* varied but had no significant difference among three Citrus plants at 5% level. Leaf flavonoid concentration was significantly higher in *C. junos* than in both *C. grandis* and *P. trifoliata*. These results imply that the resistance capacity was potentially ranked as: *C. aurantium* > *C. junos* ≥ *C. grandis* ≥ *P. trifoliata*.

Key Words: Resistance, Citrus, PAL, Total soluble phenolic, Lignin, Abiotic stress tolerance, Leaf flavoroid

Every plant possess two operational metabolic pathways, *viz.* primary metabolism and secondary metabolism pathways. Phenyl propanoid pathway plays a critical role in secondary metabolism, based on the fact that all products with phenylpropanoid backbone are synthesized by this pathway (Dixon and Pavia, 1995). Phenylalanine ammonialyase (PAL, E.C4.3.1.5) is not only the first and rate-limiting enzyme in phenyl propanoid pathway, but also an important point to connect primary metabolism and phenyl propanoid pathway. Earlier studies showed that PAL took part in resisting various biotic and abiotic stresses such as chilling injury, wounding, and UV lighting (MacDonald and D'Cunha, 2007), and thus its activity is seen as a resistance index.

Many productions of phenyl propanoid pathway regulate plant physiological metabolism including total soluble phenolic, lignin, flavonoid, and so on (Whetten and Sederoff, 1992). Earlier studies proved that total soluble phenolic concentration was linked with resistance. Prusky *et al.* (1988) showed that there was higher epicatechin content in disease resistant avocado plants than susceptible controls. In addition, while pathogen attacked, the former could quickly synthesize more phenolic to enhance resistance. Lignin is a kind of important macromolecular organic material, only behind cellulose. Lignin in cellulose network would improve cytoderm hardness, which acts as mechanical barrier to resist various stresses (Vance *et al.*, 1980; Lewis and Yamamoto, 1990). Flavonoid is a vital secondary metabolite that restrains spore germination of pathogenic fungi and has antibacterial activity to protect plants avoiding infection by pathogens (Fawe *et al.*, 1998).

Therefore, plants of four citrus species were selected and tested their potential resistance capacity according to PAL activity and total soluble phenolic, lignin and flavonoid concentrations in their leaves.

MATERIALS AND METHODS

The experiment was conducted in a completely randomized block design with four citrus plants as single factor: *C. aurantium* L. vardaidai Tanaka, *C. grandis* Osbeck, *C. junos* Sieb.ex Tanaka, and *Poncirus trifoliata* (L.) Raf., respectively during 2016. Each treatment had four replications. Four citrus plants were planted in pots with 4.6 L volume for five years and placed in the campus of Yangtze University, Jingzhou, China (30°36'N, and 112°14'E) under natural conditions. The

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leaves of each plant were collected in October, cleaned by distilled water, and stored at -80 C.

Leaf PAL activity was measured according to the method of Wang (2006). A 0.2 g leaf sample was homogenated with 5 mL 0.05 mM borate buffer containing 5 mM ß-mercaptoethanol and then collected supernates at 10,000×g. The reaction solution consisted of 1 mL supernate, 1 mL 0.02 M phenylalanine and 2 mL distilled water at 30°C for 0.5 h, and then adding 0.5 mL 35% trichloroacetic acid stopped the reaction. The absorbance was measured at 290 nm. One enzyme unit (U) was definited as light absorption value changed 0.01 per h.

Leaf total soluble phenolic and lignin concentrations were followed based on the method of Rodrigues *et al.* (2005). A 0.2 g fresh leaf sample was extracted with 1.5 mL 80% methyl alcohol solution and centrifugated in 12,000×g. The supernants were used to measure the total soluble phenolic concentration, and the centrifugated precipitates were lignin. The absorbance of supernate was determined at 725 nm with catechol as the standard. The precipitates were resuspended in 1.5 mL distilled water, and the absorbance was determined at 280 nm with lignin standards as the control .

Leaf flavonoid was extracted from 0.2 g fresh leaves with 5 mL 70% ethyl alcohol at 90 C for 1 h, filtrated, and then determined at 510 nm for the absorbance with the outin as the standard (Cheng *et al.*, 2004). The Data (means ± SD, $n = 4$) were analyzed with ANOVA (SAS, version 8.1). The significant difference among treatments was compared by the Duncan's multiple range test at $P < 0.05$.

RESULTS AND DISCUSSION

The plant stressed sensitivity was closely related with PAL transcript level and activity, because PAL transcript level and activity increased when plants suffered from stresses such as heat and wounding (Sanchez-Ballesta *et al.*, 2000). The plants of *C. aurantium* species had significantly higher leaf PAL activity compared with all other citrus species. However, there was no significant difference among plants of other three citrus species, though leaf PAL activity was slightly different. The leaf PAL activity was ranked as *C. aurantium* > *C. junos* > *C. grandis* > *P. trifoliata* in the decreasing order (Fig. 1). Thus, resistance capacity was relatively higher in *C. aurantium* than in other three plants in terms of leaf PAL activity.

The salt stress and drought stress are accompanied with oxidative stress and hence antioxidants play an important role in alleviating stresses. Phenolic compounds made the contribution of 71% to antioxidant capacity in plants, such as Ocimum sp. (Javanmardi *et al.*, 2002). So, higher phenolic concentration implies stronger resistance. In this work, leaf total soluble phenolic concentration in plants of all the four citrus species was ranked as: *C. aurantium* > *C. junos* > *P. trifoliata* > *C. grandis* in the decreasing order (Fig. 2). We concluded that the resistance capacity was ranked as: *C. aurantium* > *C. junos* $\geq$ *P. trifoliata* $\geq$ *C. grandis*, based on total soluble phenolic.

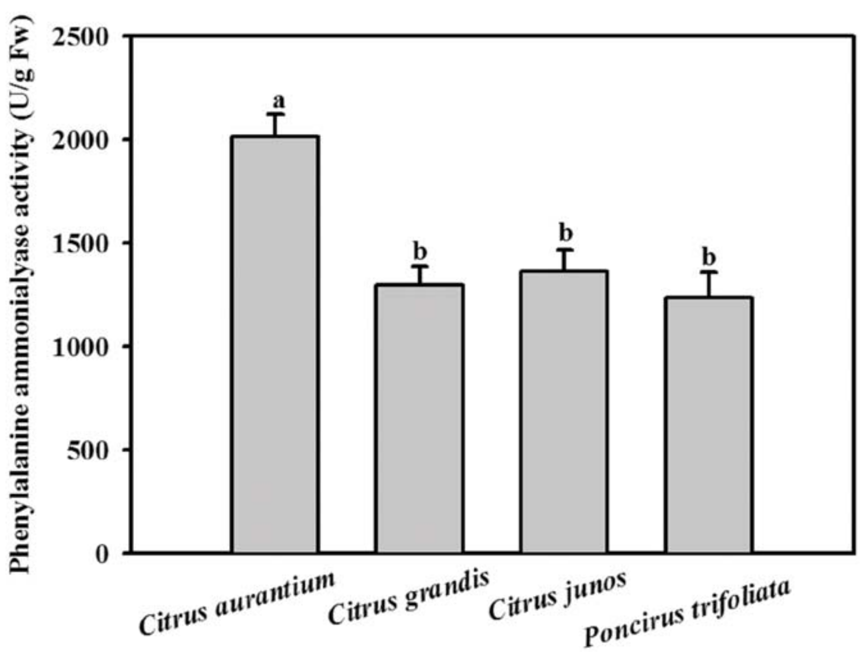

Fig. 1. Leaf phenylalanine ammonialyase (PAL) activity in plants of *C. aurantium, C. grandis, C. junos,* and *P. trifoliata*. Data (means ± SD, $n = 4$) followed by different letters at bar showed significant difference between treatments

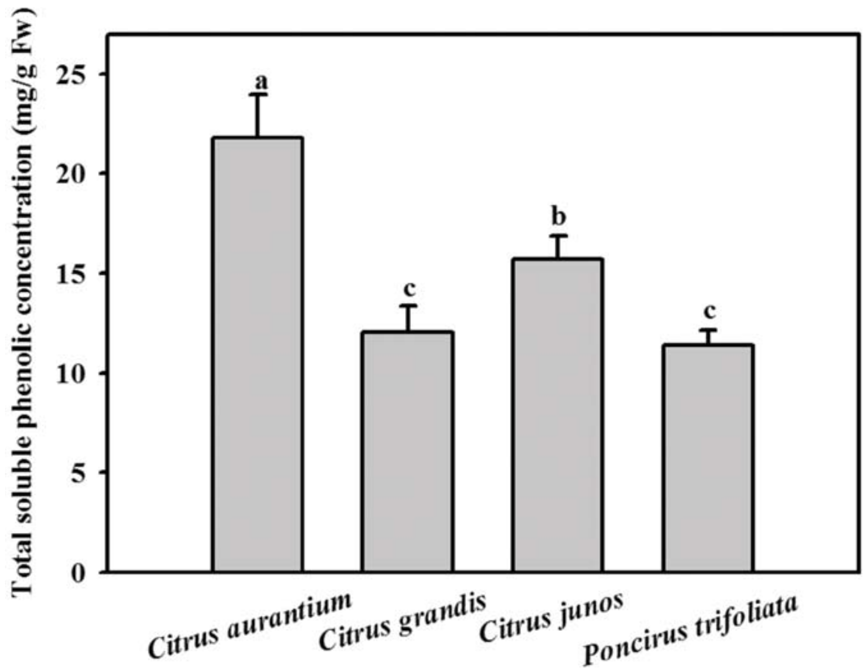

Fig. 2. Leaf total soluble phenolic concentration of *C. aurantium, C. grandis, C. junos,* and *P. trifoliata* plants. Data (means ± SD, *n* = 4) followed by different letters at the bar showed significant difference between treatments

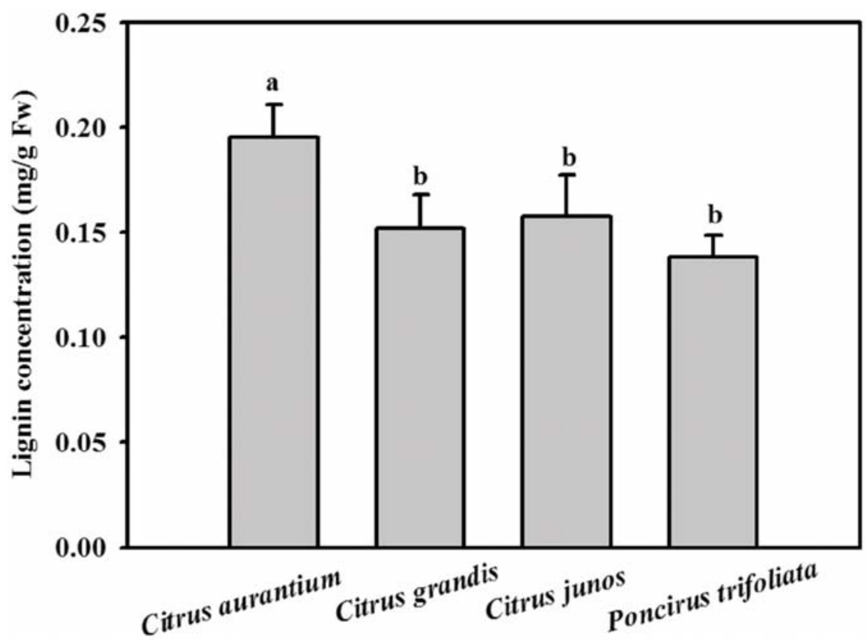

Fig. 3. Leaf lignin concentration of *C. aurantium, C. grandis, C. junos,* and *P. trifoliata* plants. Data (means ± SD, *n* = 4), followed by different letter at the bar showed significant difference between treatments

The lignin can bond with cell wall as a natural barrier to protect plants from disease and insect attacks (Modafar and Boustani, 2001). In present work, plants of *C. aurantium* plants recorded highest leaf lignin concentration among plants of all four citrus species, while other plants showed similar lignin concentration in leaves (Fig. 3). Since lignin can protect plants against stresses, it was concluded that plants of *C. aurantium* possess considerably greater capacity to resist abiotic or biotic stresses than other plants.

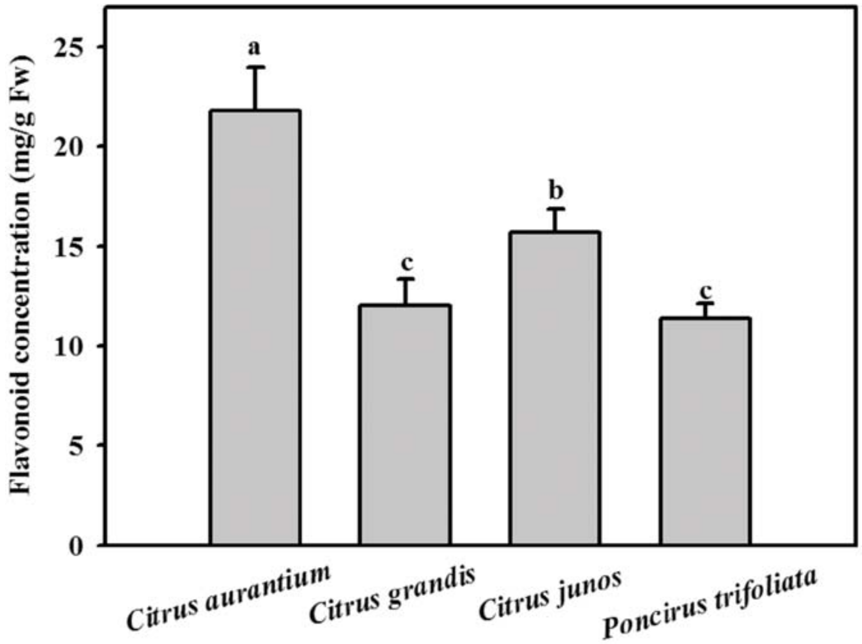

Fig. 4. Leaf flavonoid concentration of *C. aurantium, C. grandis, C. junos,* and *P. trifoliata* plants. Data (means ± SD, *n* = 4) followed by different letters at the bar showed significant difference between treatments

The leaf flavonoid concentration had a significant difference among plants of all the four citrus species. Significantly higher leaf flavonoid concentration was ranked as the trend of *C. aurantium* > *C. junos* > *C. grandis* ≈ *P. trifoliata* in the decreasing order (Fig. 4). Skadhauge *et al.* (1997) reported that Flavonoid could strongly inhibit fusarium growth and macrospore formation. Hence, we concluded that plants of *C. aurantium* plants showed higher resistance to pathogens.

Thus, it can be conclude that the resistance capacity may be ranked as the trend of *C. aurantium* > *C. junos* ≥ *C. grandis* ≥ P. trifoliata in the decreasing order. Such results will provide the highlight to manage trees of citrus species in the field. Further research is required to analyze more citrus plants and determine more biochemical variables or use molecular technique for the evaluation of resistance in citriculture.

ACKNOWLEDGEMENTS

The authors acknowledge the support given by the Plan in Scientific and Technological Innovation Team of Outstanding Young, Hubei Provincial Department of Education (T201604).

REFERENCES

Cheng S Y, Wang Y, Fei Y J and Zhu G C. 2004. Studies on the effects of different treatments on flavonoids concents in Ginkgo biloba leaves and their regulating mechanism. *Journal of Fruit Science* **21**(2): 116-19 (in Chinese with English abstract).

Dixon R A and Lamb C J. 1990. Molecular communication in interactions between plants and microbial pathogens. *Annual Review of Plant Physiology and Plant Molecular Biology* **41** : 369-419.

Fawe A, Abou-zaid M, Meczies J G and Bélanger R R. 1998. Silicon-mediated accumulation of flavonoid phytoalexins in cucumber. *Phytopathology* **88** : 396-401.

Javanmardi J, Stushnoff C, Locke E and Vivanco J M. 2002. Antioxidant activity and total phenolic content of Iranian Ocimun accession. *Food Chemistry* **83** : 547-50.

Lewis N C and Yamamoto E. 1990. Lignin occurr and biodegradation. *Annual Review of Plant Physiology and Plant Molecular Biology* **41** : 455-96.

MacDonald M J and D'Cunha G B. 2007. A modern view of phenylalanine ammonia lyase. *Biochemistry and Cell Biology* **85** : 273-82.

Modafar C E L and Boustani E E L. 2001. Cell wall-bound phenolic acid and lignin concentrations in data palm as related to its resistance to Fusarium oxysporum. *Biologia Plantarum* **44**(1) : 125-30.

Prusky D, Kobiler I and Jacoby B. 1988. Involvement of epicatechin in cultivar susceptibility of avocado fruits to colletotrichum gloeso-prioides after harvest. *Journal of Phytopathology* **183** : 140-45.

Rodrigues F A, Jurick W M, Datnoff L E, Jones J B and Rollins J A. 2005. Silicon influences cytological and molecular events in compatible rice-magnaporthe grisea interactions. *Physiological and Molecular Plant Pathology* **66**: 144-59.

Sanchez-Ballesta M T, Zacarias L, Granell A and Lafuente M T. 2000. Accumulation of Pal transcript and Pal activity as affected by heat-conditioning and low-temperature storage and its relation to chilling sensitivity in mandarin fruits. *Agricultural and Food Chemistry* **48** : 2726-31.

Skadhauge B, Thomsen K K and Wettstein D V. 1997. The role of the barley testa layer and its flavonoid content in resistance to Fusarium infections. *Hereditas* **126** : 147-60.

Vance N C, Kirk T K and Sgerwood R T. 1980. Lignification as a mechanism of disease resistance. *Annual Review of Phytopathology* **18** : 259-88.

Wang X K. 2006. *Principles and Techniques of Plant Physiological Biochemical Experiment* (2nd edn). Higher Education Press, Beijing, pp. 224 (in Chinese).

Whetten R W and Sederoff R R. 1992. Phenylalanine ammonia lyase from loblolly pine: Purification of the enzyme and isolation of complementary DNA clones. *Plant Physiology* **98** : 380-86.

Current Horticulture **5**(1): 20–30, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

On-farm validation of site-specific nutrient management in cassava *(Manihot esculenta)* in Thiruvananthapuram district (Kerala)

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Received: July 2016; **Revised:** March 2017

ABSTRACT

On-farm experiments were conducted to evaluate the performance of site-specific nutrient management (SSNM) of cassava (*Manihot esculenta* Crantz) in five important soil series of Thiruvananthapuram district in Kerala, during 2011-12 and 2012-13. Field and crop-specific NPK rates were calculated using quantitative evaluation of fertility of tropical soils (QUEFTS) model. Tuberous root yield increased significantly in SSNM treatment compared to FFP in all five soil series studied. Above 5 tonnes/ha yield increase was observed in SSNM treatment in all soil series compared to FFP treatment. The nutrient uptake was maximum in Thiruvanathapuram series (22.3 kg/ha, 3.3 kg/ha and 17.9 kg/ha N P and K uptake increase in SSNM treatment than FFP) and minimum nutrient uptake (27.9 kg/ha, 1.9 kg/ha and 8.7 kg/ha N P and K uptake increase in SSNM treatment than FFP) was observed in Vellayani series. Large increase in nutrient-use efficiency parameters like agronomic efficiency (19 kg/kg, 17 kg/kg and 33 kg/kg N, P and K respectively) and recovery efficiency (0.14 kg/kg, 0.06 kg/kg and 0.14 kg/kg N, P and K respectively) was observed in SSNM treatment compared to FFP. The SSNM treatment led to a reduction of average fertilizer cost (₹ 5,240 crop/ha) and an increase in gross return above fertilizer cost (₹ 10,9,880 crop/ha) compared with FFP.

Key Words: Cassava, Site-specific nutrient management, Farmers fertilizer practice, Soil series, On-farm Validation.

Cassava (*Manihot esculenta* Crantz) is a secondary staple food crop grown in India. Tamil Nadu, Kerala, and Andhra Pradesh account for 92 per cent of the total cassava production in India. It is cultivated in varied agroclimatic and pedogenic environments. In Kerala, where it has been introduced into India more than 300 years ago, it is cultivated mostly in laterite soils (Ultisols) (Byju and Varghese 1999 and 2001). Fertilizer recommendation for cassava in India are blanket (100:50:100 kg/ha NPK), without soil testing. These are adjusted to 75, 100 or 125 per cent of blanket recommendations depending on soil test results. In Kerala, table proposed by Aiyer and Nair (1985) is used for the adjustment of blanket recommendation based on soil test data. Differences in soils, plant analysis, crop productivity and site-specific data were not considered in their approach.

It is very clear that nutrient management of cassava by blanket fertilizer recommendations over wide areas and soil types over the past 40 years or so in India have resulted in significant yield increase. But when we extrapolate the results from experimental stations to farmers' fields, the yield cannot be increased beyond a certain level due to high temporal and spatial variability of soil and plant properties. The conventional blanket and injudicious use of fertilizers not only reduces nutrient -use efficiency but also causes nutrient imbalance in soil, resulting in decreased crop yield (Ladha *et al.*, 2005). Further increase in yield and nutrient-use efficiency can be possible only by managing this large spatial and temporal variability existing in soil nutrient supply, nutrient-use efficiency and crop response to nutrients among different farms (Dobermann and White. 1999; Pathak *et al.*, 2003). Results of on-station and on-farm research conducted by Byju *et al.* (2012) revealed large and potentially manageable soil nutrient variability in major cassava-growing environments in southern India.

Site-specific nutrient management (SSNM) is the dynamic, field-specific management of nutrients in a particular cropping season to optimize the supply and demand of nutrients according to their differences in cycling through soil-plant system. The concept of SSNM is based on hypothesis that in high-yielding situations, the ability to predict soil nutrient supply and plant uptake in absolute terms rather than relative yield response is the basis for plant nutrient management (Dobermann and White, 1999). The SSNM provides an approach for need based feeding of crops with nutrients while recognizing the inherent spatial variability. It involves monitoring of all pathways of plant nutrient flows/supply, and calls for judicious combination of fertilizers, biofertilizers, organic manures, crop residues and nutrient efficient genotypes to sustain agricultural productivity.

It avoids indiscriminate use of fertilizers and enables the farmer, to dynamically adjust the fertilizer use to fill the deficit optimally between nutrient needs of the variety and nutrient supply from natural resources, organic sources, irrigation water etc. It aims at nutrient supply at optimal rates and times to achieve high yield and efficiency of nutrient use by the crop. In Kerala, cassava is cultivated of 69,586 ha, of which 20 per cent of the area is in Thiruvananthapuram district (Farm Guide 2015). In Thiruvananthapuram district, we have a cross-section of major soil types of Kerala and out of the seven soil series, *viz.* Amaravila, Nedumangad, Trivandrum, Kazhakuttam, Vellayani, Kallar and Ponmudi series, cassava is cultivated on a large scale in five soil series, *viz.* Amaravila, Nedumangad, Trivandrum, Kazhakuttam and Vellayani series whose physico-chemical and biological properties are quite different (Soil Survey Organisation 2007).

Hence, it is very important to understand whether the envelop functions describing the yield-uptake relationships hold good for different soil series and to know the relationship between indigenous nutrient supply and soil test values. Therefore, studies were undertaken to: (i) determine variation in soil nutrient supply in five major cassava-growing soil series in Thiruvananthapuram district (Kerala), (ii) to evaluate SSNM technology for cassava in all the five soil series of Thiruvananthapuram district, by comparing its cultural and economic performance to farmers and practices of fertilizer rate choice.

MATERIALS AND METHODS

Study Area

The study was carried out in five soil series of Thiruvananthapuram district, *viz.* Amaravila, Nedumangad, Trivandrum, Kazhakuttam and Vellayani series. The soil series map of Thiruvananthapuram district is shown in Fig. 1. In these five soil series, on-farm experiments were conducted during

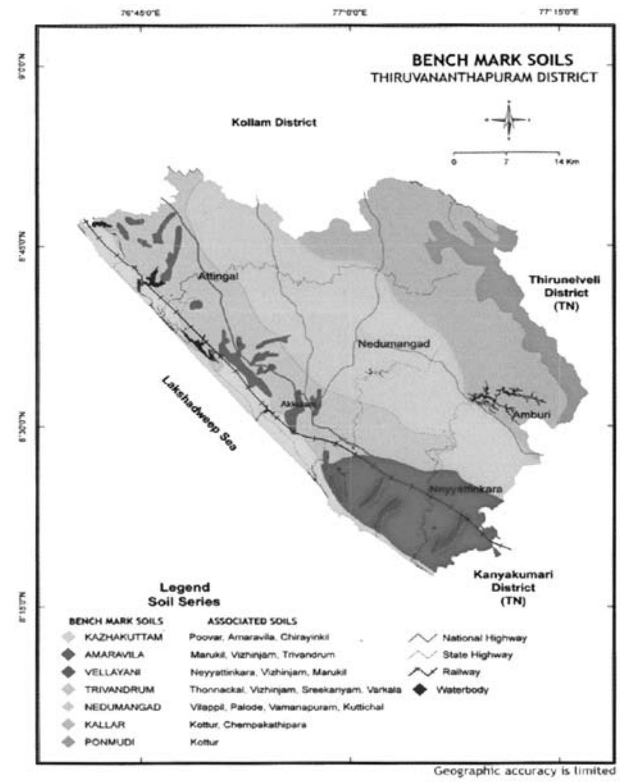

Fig. 1. Soil series map of Thiruvananthapuram district (Soil Survey Organization 2007).

Table 1. General characteristics of experimental sites

Soil series	Location	Soil type	Soil texture
Amaravila	8°22'40" N, 77°08'02" E	Fine, mixed, isohyperthermic, Aquic Ustifluvent	Clay loam
Ntedumangad	8°37'27" N, 77°0' E	Clayey-skeletal, mixed, isohyperthermic, Ustic Haplohumult	Gravelly sandy clay loam
Trivandrum	8°35'10" N, 76°53'10" E	Clayey-skeletal, kaolinitic, isohyperthermic, Typic Plinthustult	Gravelly sandy laom
Kazhakuttam	8°34'34" N, 76°51'50" E	Coarse loamy, mixed, isohyperthermic, Typic Ustifluvent	Sandy loam
Vellayani	8°25'36" N, 76°59'14" E	Clayey, kaolinitic, isohyperthermic, Typic Kandiustult	Sandy clay loam

2011-2012 and 2012-2013 to validate SSNM technology for cassava. The general characteristics of selected five soil series in the district are given in Table 1.

Treatments and Experimental Design

The field experiment was laid out in a randomized complete block design with five treatments and two replications. The treatments in on-farm experiments are explained below.

0N-Nitrogen omission plot : In this plot, no fertilizer nitrogen was applied. Only P and K at 150% recommended NPK rate (Nair *et al.*, 2004) were applied to ensure that macronutrient other than N did not limit plant N uptake from indigenous sources. Half of K fertilizer and entire does of P fertilizer were applied as basal application 10 days after planting the stakes of cassava and the remaining dose of K fertilizer was applied 45 - 60 days after planting. This treatment was sampled at each soil series at harvesting of for each of the two years to estimate the indigenous N supply (INS), defined as total plant N accumulation at maturity. These measurements were used to estimate: (a) N-use efficiencies using the difference method and (b) INS as an input parameter for SSNM.

0P-Phosphorus omission plot : In this plot, no fertilizer phosphorus was applied. Only N and K at 150% recommended NPK rate (Nair *et al.* 2004) were applied to ensure that macronutrient other than P did not limit plant P uptake from indigenous sources. Half of N and K fertilizers were applied as basal application 10 days after planting the stakes of cassava and the remaining dose of N and K fertilizers were applied 45 - 60 days after planting. This treatment was sampled at each soil series at harvesting for each of the two years to estimate the indigenous P supply (IPS), defined as total plant P accumulation at maturity. These measurements were used to estimate: (a) P use efficiencies using the difference method and (b) IPS as an input parameter for SSNM.

0K-Potassium omission plot : In this plot, no fertilizer potassium was applied. Only N and P at 150 per cent recommended NPK rate (Nair *et al.*, 2004) were applied to ensure that macronutrient other than K did not limit plant K uptake from indigenous sources. Half of N fertilizer and entire does of P fertilizer were applied as basal application. 10 days after planting the stakes of cassava and the remaining dose of N fertilizer was applied 45 - 60 days after planting. This treatment was sampled at each soil series at harvesting for each of the two years to estimate the indigenous K supply (IKS), defined as total plant K accumulation at maturity. These measurements were used to estimate (a) K use efficiencies using the difference method and (b) IKS as an input parameter for SSNM.

SSNM-Site-specific nutrient management plot : In SSNM, NPK recommendations were made following the SSNM approach using the modified QUEFTS model for each soil series (Byju *et al.*, 2009 and 2012). The SSNM approach manages spatial variation in indigenous N, P and K supplies. Specific optimal NPK fertilizer rates were predicted using indigenous nutrient supplies and yield in nutrient omission plots. The modified QUEFTS model was used to work out NPK recommendations at the beginning of each growing season. Half of N and K fertilizers and the entire does of P fertilizer were applied as basal application, 10 days after planting the stakes of cassava and the remaining dose of N and K fertilizers were applied 45-60 days after planting.

Information needed for QUEFTS model to estimate the total amount of N, P and K to be applied included: (i) climatic yield potential, (ii) yield goal, (iii) relationship between tuberous root yield and nutrient accumulation, (iv) recovery efficiencies of fertilizer N, P and K, (v) site-specific estimates of indigenous N, P and K supply and (vi) potential constraints to fertilizer use. The climatic yield potential was fixed at 80 tonnes/ha as highest yield ever recorded at that site in an experiment with near optimal growth conditions as suggested by Dobermann and Witt (2004). Yield goals were constrained to a range of 70-80% of the climatic yield potential because beyond that level, internal efficiency of a nutrient (kg tuber per kg plant nutrient accumulation) decreases (Witt *et al.*, 1999). Moreover, results of earlier studies indicated that yields of about 80% of climatic yield potential currently represent a ceiling for achievable farmer yield with the technology and soils available (Cassman and Harwood, 1995; Byju *et al.*, 2009 and 2010).

The general empirical model proposed for cassava (Byju *et al.*, 2012) was used to model the relationship between tuberous root yield and uptake of N, P and K. Using the results of Byju *et al.* (2009, 2010), average crop recovery fractions of 0.5, 0.3 and 0.5 kg/kg were assumed for fertilizer N, P and K respectively. The potential supply of N, P and K from soil and other indigenous sources was estimated as plant nutrient accumulation in nutrient omission plots. A linear optimization procedure was used to find the best combination of N, P and K fertilizer rates to achieve the yield goal under the constraint of optimizing the internal N, P and K efficiencies in plant. The model was constrained to arrive at a solution close to the situation of most balanced nutrition, that is where ratio between accumulation and potential supply of each macronutrient was close to 0.95 (Janssen *et al.*, 1990).

The SSNM treatment was sampled at harvesting of cassava for each of the two years to estimate the tuberous root and above-ground biomass yields and plant nutrient (N, P and K) accumulation. This treatment was used for comparison with farmers, fertilizer practice treatment for yield, nutrient accumulation, fertilizer use, nutrient-use efficiency, total fertilizer cost and gross return above fertilizer cost.

FFP-Farmers' fertilizer practice plot : In all the five soil series, one treatment was farmers' fertilizer practice in which farmers did all cultural practices as well as weed and pest control measures, following the commonly recommended methods. However, where problems were suspected or observed, measures to either control them in advance (prophylactic) or correct them, were implemented under the guidance of the researcher.

Field and Laboratory Measurements

Soil and plant sampling and analysis

Initial soil samples were collected from each soil series before the start of laying out field experiments for characterisation of soil initial nutrient status. The collected soil samples were air dried and sieved through a 2-mm sieve and analyzed for soil pH (1:2.5 soil:water) (Byju, 2001), organic carbon (Walkley and Black, 1934), available N (Page *et al.*, 1982), available P (Page *et al.*, 1982), and exchangeable K (Knudsen *et al.*, 1982). From individual treatment plots, soil samples were collected at the active growth stage of cassava (3 months after planting) and at harvesting. Two replicate samples were collected per treatment from each location.

The soil samples were air dried and sieved to pass through a 2-mm sieve and analyzed for pH, organic C, available N, available P and exchangeable K. Samples of youngest fully expanded leaf (YFEL) blades without petioles were also collected 3 months after planting to assess the crop nutritional status for different treatments. Leaf samples were dried in a hot air oven at 65°C for 48 h until constant weight was attained. Dried plant samples were ground in a stainless steel Wiley Mill to pass a 40-mesh screen. Total N content was determined by digesting the samples in concentrated sulfuric acid (H_2SO_4), followed by analysis of total N by the Kjeldahl method (Page *et al.*, 1982) using a Kjeltec automatic N digestion and distillation system. Tissue P was determined using the vanado-molybdo phosphoric yellow color method after digestion with triple acid (HNO_3: $HClO_4$: H_2SO_4 10:4:1) and tissue K by using a flame photometer using the same digest (Jackson, 1972).

At maturity, crop was harvested manually and leaf, stem, and tuberous root samples (50 g each) were collected separately from three plants of each plot. Number of fallen as well as standing leaves and number of tuberous roots per plant were also counted during sampling. Total weight of leaves, stem, and tuberous roots were measured from three plants of each plot. Total weight of tuberous roots were taken from all the plants in each plot excluding the border row for estimation of tuberous root yield. Leaf, stem and tuberous root samples were dried in a hot air oven at 65°C for 48 h until constant weight was attained and the dry weight of samples was recorded. Then the dried samples were ground in a stainless steel Wiley Mill for estimating the N, P and K contents in leaves, stem and tuberous root. The total N content was determined by digesting the samples in sulfuric acid (H_2SO_4), followed by analysis of total nitrogen by using a Kjeltec automatic N digestion and distillation system (Model: Pelican-Kelplus). Tissue P was determined by the vanado-molybdo phosphoric yellow colour method after digestion with triple acid (HNO_3 : $HClO_4$: H_2SO_4 10:4:1) and tissue K by using a flame photometer using the same digest (Jackson, 1972).

Cultural and Economic Calculation

NPK uptake

Based on dry weight of leaves, stem and tuberous roots, and N, P and K contents of leaves, stem and tuberous root (per cent), total N, P and K uptake at harvesting was estimated in kg/ha.

Indigenous nutrient supply

To estimate the indigenous nutrient supply of soils, the plant NPK uptake from unfertilized plots was used. Indigenous nitrogen supply (INS) was estimated from N omission treatment, whereas indigenous phosphorus supply (IPS) and indigenous potassium supply (IKS) were estimated from P and K omission treatments, respectively.

Nutrient-use efficiency

Nutrient-use efficiencies were estimated using the differences between N, P or K fertilized treatments and the nutrient omission plots (Cassman *et al.*, 1998). Terms used are agronomic efficiency (AE; kg tuberous root yield increase per kg N, P or K applied) and recovery efficiency (RE; kg N, P or K removed from fertilizer per kg N, P or K applied).

Agronomic efficiency = (Y – Y0)/F

Recovery efficiency = (U – U0)/F

where, Y - tuberous root yield (kg/ha) in fertilized field; Y0 - tuberous root yield (kg/ha) in unfertilized field; U - total plant uptake of N/P/K (kg/ha) in fertilized field; U0 - total plant uptake of N/P/K (kg/ha) in unfertilized field; F - rate of application of N/P/K fertilizer (kg/ha).

Economics

Gross return above fertilizer cost (GRF) were calculated according to Wang *et al.* (2001) using the following equation:

$$GRF = PCYC - TFC$$

where, TFC is total fertilizer cost, TFC = PNFN + PPFP + PKFK (₹/ha) and

PN - Price of N fertilizer (₹/kg N)
FN - Amount of N applied (kg/ha N)
Pp - Price of P fertilizer (₹/kg P)
Fp - Amount of P applied (kg/ha P)
PK - Price of K fertilizer (₹/kg K)
FK - Amount of K applied (kg/ha K)
PC - Price of cassava (₹/kg cassava)
YC - Cassava yield (kg/ha)

All prices used were average retail prices at Thiruvananthapuram, Kerala, India. The incremental profitability of SSNM (ΔGRF, ₹/ha) was measured as the difference in gross returns above fertilizer cost for SSNM and farmers fertilizer practice minus the change in total fertilizer costs due to different fertilizer usage in two treatments.

$$\Delta\ GRF = GRF\ SSNM - GRF\ FFP$$

Statistical analysis

Analysis of variance (ANOVA) was used to compare treatment differences for different soil and plant parameters, yield, NPK uptake, nutrient-use efficiency and economic parameters using SAS statistical software (SAS Institute Inc. 2002). The least significant difference (LSD) test was used at the 0.05 level of probability to test differences between treatment means.

RESULTS AND DISCUSSION

Initial Soil Characteristics

Initial soil analysis showed spatial variation in soil properties among five soil series in Thiruvananthapuram district (Table 2). Five soil series differ in soil pH, organic carbon content, available nitrogen, available phosphorus and exchangeable potassium. Soil pH in the study locations ranged from 4.9 (Trivandrum series) to 5.2 (Amaravila series). Organic carbon ranged from 0.48 (Kazhakuttam series) to 0.99% (Nedumangad series). Compared to other soil series, relatively low organic carbon content was observed in Kazhakuttam series (0.48%), followed by Vellayani series (0.53%). Available nitrogen ranged from 138.7 (Kazhakuttam series) to 301.1 ka/ha (Trivandrum series). Available phosphorus ranged from 72.2 (Nedumangad series) to 135 .3 kg/ha (Trivandrum series). Available nitrogen and phosphorus was highest in Trivandrum series compared to other soil series. Exchangeable potassium content in sites ranged from 110.6 (Kazhakuttam series) to 280.5 (Amaravila series).

Indigenous Nutrient Supply

The plant nutrient accumulation in omission plots also known as indigenous nutrient supply was calculated (Table 3). The indigenous nitrogen supply (INS) in all the five soil series ranged from 86.7 kg/ha (Vellayani series) to 119.1 kg/ha (Trivandrum series). In other soil series, INS was in the order of 97 kg/ha (Kazhakuttam series), 112 (Amaravila series) and 117 kg/ha (Nedumangad series). The indigenous P supply (IPS) ranged from 9.2 kg/ha (Vellayani series) to 14.3 kg/ha (Trivandrum series). In other soil series studied, IPS was 10.1 kg/ha (Kazhakuttam series), 12.3 kg/ha

Table 3. Indigenous nutrient supply in five soil series in Thiruvananthapuram district (mean of 2011 and 2012).

Soil series	INS* (Kg/ha)	IPS* (Kg/ha)	IKS* (Kg/ha)
Amaravila	112.0	13..1	109.0
Nedumangad	117.0	12.3	106.0
Trivandrum	119.1	14.3	117.0
Kazhakuttam	97.0	10.1	102.0
Vellayani	86.7	9.2	114.0

*INS, Indigenous nitrogen supply; IPS, indigenous phosphorus supply; IKS, indigenous potassium supply

Table 2. Variations in initial soil fertility characteristics of five soil series selected for study

Soil series	Soil pH	Organic carbon (%)	Available N	Available P Kg/ha	Exchangeable K
Amaravila	5.2	0.62	167.5	85.4	280.5
Nedumangad	5.0	0.99	184.0	72.2	208.3
Trivandrum	4.9	0.94	301.1	135.3	223.9
Kazhakuttam	5.0	0.48	138.7	75.1	110.6
Vellayani	4.9	0.53	165.2	97.1	278.4

(Nedumangad series) and 13.1 kg/ha (Amaravila series). In case of indigenous potassium supply (IKS), maximum IKS was observed in Trivandrum series (117 kg/ha) and minimum IKS was observed in Kazhakuttam series (102 kg/ha). In other soil series like Amaravila, Nedumangad and Vellayani, IKS was 109, 106 and 114 kg/ha respectively.

Among five soil series studied, maximum indigenous nutrient supply (INS, IPS and IKS) was observed in Trivandrum series compared to other soil series. Pathak *et al.* (2003) reported that large variability in indigenous nutrient supply was probably one of the major reasons for the large temporal fluctuations in optimal fertilizer rates observed.

Root Yield and Nutrient Uptake and Fertilizer Use

Compared with FFP treatment, SSNM significantly increased tuberous root yield, and NPK uptake in all soil series during both cropping seasons in 2011 - 2012 and 2012 - 2013 (Table 4). The amount of NPK fertilizers applied for the treatments SSNM and FFP are shown in Table 5. Significant increase in tuberous root yield was observed in Amaravila series with 51.6 tonnes/ha in SSNM compared to FFP (43.5 tonnes/ha). In Nedumangad series, the yield in SSNM treatment (40.22 tonnes/ha) was on par with that of FFP. In Trivandrum series, the SSNM treatment significantly increased tuberous root yield (51.44 tonnes/ha) compared to FFP (45.53 tonnes/ha). In Kazhakuttam series, yield in SSNM treatment was significantly higher (41.42 tonnes/ha) compared to FFP. In Vellayani series also, yield in SSNM treatment was significantly higher (27.78 tonnes/ha) compared to FFP (21.12 tonnes/ha). Comparatively low yield was observed in Vellayani series, although the SSNM practice increases a 6.66 tonnes/ha yield than the farmers' fertilizer practice.

There were significant increases in plant N, P and K uptake in SSNM compared with FFP treatment (Table 4). Total N uptake in SSNM in five soil series ranged from 162.5 (Vellayani series) to 296.8 kg/ha (Trivandrum series) and that in FFP ranged from 134.6 (Vellayani series) to 274.5 kg/ha (Trivandrum series). Total P uptake in SSNM in five soil series ranged from 18.7 (Vellayani series) to 32.6 kg/ha (Trivandrum series) and that in FFP ranged from 16.8 (Vellayani series) to 29.3 kg/ha (Trivandrum series). Total K uptake in SSNM in the five soil series ranged from 143.4 (Vellayani series) to 261.3 kg/ha (Trivandrum series) and that in FFP ranged from 134.7 (Vellayani series) to 243.4 kg/ha (Trivandrum series). Significant increase in plant N, P and K was observed in SSNM treatment in Amaravila, Nedumangad, Trivandrum and Kazhakuttam series.

In Vellayani series, significant difference between SSNM and FFP was observed in plant N uptake and no significant difference was observed in plant P and K uptake. The maximum nutrient uptake was observed in Trivandrum series and minimum nutrient uptake was showed by Vellayani series. The average nutrient removal by cassava/fresh roots are 55, 13.2, and 112 kg/ha N, P and K respectively (Howeler 1991). Cassava removed substantial quantities of nitrogen and potassium from the soil but the removal of phosphorus was relatively low as reported by different authors (Thampan (1979); Howeler (1981); Nair *et al.* (1988).

Table 4. Effect of site-specific nutrient management on tuberous root yield and plant N, P and K uptake in five soil series in Thiruvananthapuram district (mean of 2011 and 2012).

Soil series	Treatment	Tuberous root yield (t/ha)	Total N uptake (kg/ha)	Total P uptake (kg/ha)	Total K uptake (kg/ha)
Amaravila	SSNM*	51.60	285.6	32.5	258.5
	FFP*	43.52	241.3	28.3	233.7
	LSD*	5.21	23.5	2.1	13.5
Nedumangadu	SSNM	40.22	237.5	28.8	218.5
	FFP	33.85	195.3	23.5	168.5
	LSD	NS	21.4	3.1	23.4
Trivandrum	SSNM	51.44	296.8	32.6	261.3
	FFP	45.53	274.5	29.3	243.4
	LSD	1.08	15.2	1.2	6.9
Kazhakuttam	SSNM	41.42	238.6	27.5	237.3
	FFP	32.70	195.4	22.3	172.4
	LSD	4.52	17.4	2.7	27.5
Vellayani	SSNM	27.78	162.5	18.7	143.4
	FFP	21.12	134.6	16.8	134.7
	LSD	1.55	17.3	NS	NS

*SSNM, site-specific nutrient management; FFP, farmers' fertilizer practice; LSD, least significant difference

Table 5. Dose of NPK fertilizer applied in SSNM and FFP treatments

Soil series	Treatment	N fertilizer (kg/ha)	P fertilizer (kg/ha)	K fertilizer (kg/ha)
Amaravila	SSNM	150	80	150
	FFP	155	84	170
Nedumangadu	SSNM	150	80	150
	FFP	120	82	175
Trivandrum	SSNM	25	40	40
	FFP	27	48	55
Kazhakuttam	SSNM	125	40	100
	FFP	100	80	120
Vellayani	SSNM	125	50	50
	FFP	80	80	60

Das *et al.* (2009) reported that the highest N, P and K uptake in rice was observed in the treatment where NPK was applied based on QUEFTS model. Fox *et al.* (1975) reported that application of nitrogen promoted branch production, leaf area and plant height in cassava. Penas (1987) suggested that cassava might uptake phosphorus more than other nutrients to promote early root and leaf formation. Das *et al.* (2009) reported that fertilizer management based on QUEFTS model will be more advantageous for increasing yield compared to conventional blanket and imbalanced fertilizer recommendations. Significant increase in tuberous root yield and NPK uptake in SSNM treatment was also observed in all the major cassava-growing environments of India where on-farm experiments were conducted (Byju *et al.*, 2015).

Nutrient-Use Efficiency

The SSNM led to significant increases in nutrient-use efficiency in all the five soil series studied. The agronomic efficiency of N, P and K was significantly higher in SSNM than FFP (Table 6). The agronomic efficiency of nitrogen in SSNM ranged from 74 kg/kg (Vellayani series) to 78 kg/kg (Amaravila series), whereas in FFP it ranged from 56 kg/kg (Trivandrum series) to 63 kg/kg (Amaravila, Kazhakuttam and Vellayani series). The agronomic efficiency of phosphorus in SSNM ranged from 77 kg/kg (Vellayani series) to 86 kg/kg (Amaravila series), whereas in FFP it ranged from 67 kg/kg (Vellayani series) to 71 kg/kg (Amaravila series). The agronomic efficiency of potassium in SSNM ranged from 99 kg/kg (Trivandrum series) to 112 kg/kg (Nedumangad series), whereas in FFP it ranged from 71 kg/kg (Trivandrum series) to 82 kg/kg (Amaravila series).

The SSNM practice showed significant increase in recovery efficiency of N, P and K compared to FFP (Table 7). The recovery efficiency of nitrogen in SSNM

Table 6. Effect of site-specific nutrient management on agronomic efficiency of N, P and K in five soil series in Thiruvananthapuram district (mean of 2011 and 2012)

Soil series	Treatment	AE_N	AE_P	AE_K
Amaravila	SSNM	79	86	106
	FFP	63	71	82
	LSD	11	12	16
Nedumangadu	SSNM	77	85	112
	FFP	59	68	79
	LSD	9	11	21
Trivandrum	SSNM	75	82	99
	FFP	56	70	71
	LSD	12	10	18
Kazhakuttam	SSNM	78	81	105
	FFP	63	69	73
	LSD	7	9	17
Vellayani	SSNM	74	77	108
	FFP	63	67	81
	LSD	6	6	13

ranged from 0.49 kg / kg (Trivandrum series) to 0.54 kg / kg (Amaravila series), whereas in FFP it ranged from 0.37 kg / kg (Trivandrum series) to 0.41 kg / kg (Kazhakuttam series). The recovery efficiency of phosphorus in SSNM ranged from 0.16 kg / kg (Kazhakuttam and Vellayani series) to 0.19 kg / kg (Trivandrum series), whereas in FFP it ranged from 0.11 kg / kg (Amaravila series) to 0.14 kg / kg (Trivandrum series). The recovery efficiency of potassium in SSNM ranged from 0.38 kg / kg (Nedumangad and Vellayani series) to 0.41 kg / kg (Trivandrum series), whereas in FFP it ranged from 0.26 kg / kg (Kazhakuttam series) to 0.29 kg / kg (Trivandrum series).

Profitability of Site-specific Nutrient Management

The effect of treatments (SSNM and FFP) on differences in total fertilizer cost (TFC) and differences in gross return above fertilizer cost (GRF) (Fig. 2). Site-specific nutrient management led to a reduction of total fertilizer cost and increase in gross return above fertilizer cost compared with FFP in all the soil series. In Amaravila series, SSNM treatment reduced the total fertilizer cost by ₹ 1,220 / crop / ha than in FFP. In Nedumangad series, SSNM reduced the TFC by ₹ 560 / crop / ha, in Trivandrum series, SSNM reduced the TFC by ₹ 3,573 / crop / ha, in Kazhakuttam series, SSNM reduced the TFC by ₹ 5,240 / crop / ha and in Vellayani series, SSNM reduced the TFC by ₹ 3,483 / crop / ha.

Among five soil series studied, the highest reduction in total fertilizer cost in SSNM treatment was observed in Kazhakuttam series because of increased use of P and K fertilizer in FFP in this soil series. The difference in GRF in SSNM and FFP was ₹ 98,180 / crop / ha for Amaravila, ₹ 77,000 / crop / ha for Nedumangad, ₹ 74,493 / crop / ha for Trivandrum, ₹ 10,9,880 / crop / ha for Kazhakuttam and ₹ 83,403 / crop / ha for Vellayani series. The reduced TFC and increased GRF due to SSNM treatment in cassava was also observed by Byju *et al.* (2016) in their study conducted in major cassava growing regions of India. Sharma and Singh (2000) also suggested that fertilizer recommendations based on targeted yield concept were more balanced, profitable and also helpful in controlling soil nutrient mining and was essential for sustainable crop production.

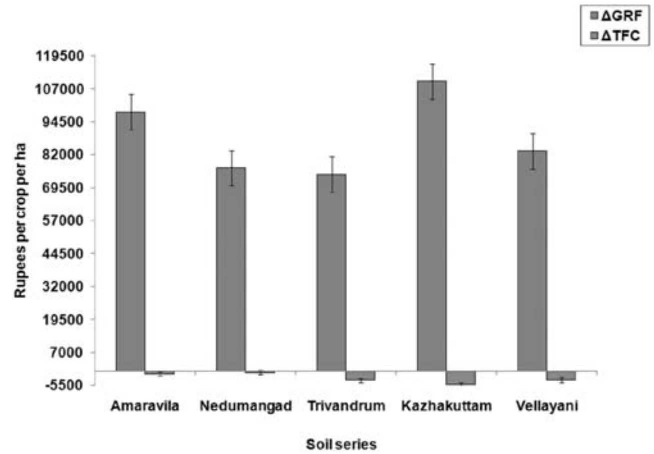

Fig. 2. Difference in gross return above fertilizer cost (ΔGRF) and total fertilizer cost (ΔTFC) between site-specific nutrient management (SSNM) and farmer fertilizer practice (FFP) in the five soil series of Thiruvananthapuram district.

Increased nutrient uptake, yield, nutrient-use efficiency and highest net returns in rice due to SSNM technology was reported by many authors in different parts of the world (Peng *et al.* (2007); Khuong *et al.* (2007); Rao *et al.* (2013). Khurana *et al.* (2008) and Das *et al.* (2009) reported increased yield, NPK uptake and

Table 7. Effect of site-specific nutrient management on recovery efficiency of N, P and K in five soil series in Thiruvananthapuram district (mean of 2011 and 2012)

Soil series	Treatment	RE_N	RE_P	RE_K
Amaravila	SSNM	0.54	0.17	0.40
	FFP	0.40	0.11	0.28
	LSD	0.11	0.03	0.07
Nedumangadu	SSNM	0.52	0.18	0.38
	FFP	0.38	0.13	0.27
	LSD	0.10	0.04	0.08
Trivandrum	SSNM	0.49	0.19	0.41
	FFP	0.37	0.14	0.29
	LSD	0.08	0.03	0.07
Kazhakuttam	SSNM	0.50	0.16	0.40
	FFP	0.41	0.13	0.26
	LSD	0.05	0.02	0.11
Vellayani	SSNM	0.53	0.16	0.38
	FFP	0.39	0.12	0.28
	LSD	0.07	0.03	0.05

GRF in wheat in India due to SSNM technology compared to FFP treatment. Pasuquin (2014) reported that significant increases in grain yields, agronomic efficiency of nitrogen and GRF were achieved over the FFP through field and season-specific management practices in the SSNM treatment in maize crop.

CONCLUSION

The requirement of cassava for NPK fertilizers can vary greatly from field to field, season to season, and year to year because of high variability among fields, seasons and years in soil nutrient supplying capacity and crop growth due to differences in climate factors (Byju and Haripriya Anand, 2011). The majority of cassava farmers in India do not follow balanced fertilization practices and there is an opportunity to increase yield and crop economics through balanced fertilizer use. In this study, site-specific management of NPK for cassava in the five soil series of Thiruvananthapuram district showed that SSNM treatment significantly increased tuberous root yield, NPK uptake and agronomic and recovery efficiencies of NPK in all the soil series studied compared to the current farmers' fertilizer practices.

The initial soil characteristics and indigenous NPK supply was varied among five soil series. The SSNM treatment increased tuber yield in all the soil series. The difference in tuberous root yield between SSNM and FFP in all the soil series was above 5 tonnes / ha. In all the soil series, where on-farm experiments were conducted, SSNM treatment showed higher NPK uptake (total N uptake in SSNM in five soil series ranged from 162.5 to 296.8 kg / ha, total P uptake from 18.7 to 32.6 kg / ha, and total K uptake from 143.4 to 261.3 kg / ha).

The SSNM treatment significantly increased the nutrient-use efficiency parameters like agronomic efficiency and recovery efficiency of NPK in all the soil series compared to FFP treatment. On-farm experiments conducted in major cassava-growing environments of India for the development of SSNM technology for cassava in India showed an increase in agronomic efficiency of N by 35 kg / kg, agronomic efficiency of P by 17 kg / kg and agronomic efficiency of K by 41 kg / kg. There was also an increase in recovery efficiency of N by 0.14 kg / kg, of P by 0.01 kg / kg and of K by 0.13 kg / kg in SSNM treatment compared to FFP. The SSNM treatment reduced total fertilizer cost (TFC) and increased the gross return above fertilizer cost (GRF) than FFP treatment in all the soil series. The SSNM treatment led to a reduction of average fertilizer cost (₹ 5,240 / crop / ha) and an increase in gross return above fertilizer cost (₹ 10,9,880 / crop / ha) compared with FFP.

REFERENCES

Aiyer RS and Nair KH. 1985. Soils of Kerala and their management. *In: Soils of India and their Management*. Biswas BC *et al.* (Eds). Fertilizer Association of India, New Delhi, India.

Byju G and Haripriya Anand M. 2011. Validation of chlorophyll meter and leaf colour chart based nitrogen management in cassava. *Indian Journal of Fertilizers* **7**(12): 94-106.

Byju G and Varghese T. 1999. Soil acidity parameters of three selected laterite soils under cassava from Kerala. *Journal of Root Crops* **25**(2): 179-84.

Byju G and Varghese T. 2001. Influence of land uses on soil acidity parameters in a typical laterite terrain from Kerala. *Journal of Tropical Agriculture* **39**: 124-127.

Byju G, Ravindran C S and Santhosh Mithra V S. 2009. *Precision farming techniques for cassava*. Govindakrishnan PM *et al.* (Ed.) *In: Information Technology Applications in Horticultural Crops*. ICAR-CPRI, Shimla, India, pp. 239-250.

Byju G, Ravindran C S, Haripriya Anand M and Santhosh Mithra V S. 2010. *Balanced fertilizer application to cassava by site specific nutrient management approach for enhanced yield, income and nutrient use efficiency*. International Conference on Balanced Nutrient Management for Tropical Agriculture. Swiss Garden Resort and Spa, Kuantan, Pahang. Organised by The Malaysian Society of Soil Science, pp. 61-65.

Byju G, Nedunchezhiyan M, Ravindran C S, Santhosh Mithra V S, Ravi V and Naskar S K. 2012. Modeling the response of cassava to fertilizers: a site specific nutrient management approach for higher tuberous root yield. *Communications in Soil Science and Plant Analysis* **43**: 1-14.

Byju G, Nedunchezhiyan M, Haripriya Anand M, Suchitra C S, Hridya A C and Sabitha Soman. 2015. *Handbook of Site-specific Nutrient Management of Cassava (CASSNUM)*. Technical Bulletin, Published by ICAR-CTCRI, Sreekariyam, Trivandrum, Kerala, India.

Byju G. 2001. *Soil Analysis - A Laboratory Manual*. Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala, India.

Byju G, Nedunchezhiyan M, Hridya A C and Sabitha Soman. 2016. Site-specific nutrient management for cassava in southern India. *Agronomy Journal* **108**(2): 830-40.

Cassman K G and Harwood R R. 1995. The nature of agricultural systems food security and environmental balance. *Food Policy* **20**: 439-54.

Cassman K G, Peng S, Olk D C, Ladha J K, Reichardt W, Dobermann A and Singh U. 1998. Opportunities for increased nitrogen use efficiency from improved resource management in irrigated rice systems. *Field Crops Research* **56**: 7-38.

Das D K, Maiti D and Pathak H. 2009. Site-specific nutrient management in rice in eastern India using a modeling approach. *Nutrient Cycling in Agroecosystems* **83**: 85-94.

Dobermann A and Witt C. 2004. The evolution of site specific nutrient management in irrigated rice systems of Asia. *In: Increasing Productivity of Intensive Rice Systems through Site Specific Nutrient Management*. Dobermann *et al.* (Eds). The Philippines. Science Publishers, Inc., and IRRI, The Philippines, pp. 75-99.

Dobermann A and White P F. 1999. Strategies for nutrient management in irrigated and rain fed lowland rice systems. *Nutrient Cycling in Agroecosystems* **46**: 1-10.

Farm Guide. 2015. Farm Information Bureau, Goverment of Kerala, Thiruvanathapuram, Kerala, India.

Fox R H, Talleyrand R H and Scott T W. 1975. Effect of nitrogen fertilizer on yields and nitrogen content of cassava, Llanera cultivar. *Journal of Agricultural University PR* **59**: 115-24.

Howeler R H. 1981. *Mineral nutrition and fertilization of cassava.* Series 09EC-4. Centro International de Agriculture Tropical (CIAT). Cali, Colombia.

Howeler R H. 1991. Long-term effect of cassava cultivation on soil productivity. *Field Crops Research* **26**: 1-18.

Jackson M L. 1972. *Soil Chemical Analysis.* Prentice Hall (India) Pvt. Ltd, New Delhi, India.

Janssen B H, Guiking FCT, Van der Ejik D, Smaling EMA, Wolf J, Reuler H. 1990. A system for quantitative evaluation of fertility of tropical soils (QUEFTS). *Geoderma* **46**: 299-318.

Khuong T Q, Huan TTN, Tan P S and Buresh R. 2007. Effect of site specific nutrient management on grain yield, nutrient use efficiency and rice production profit in the Mekong delta. *Omonrice* **15**: 153-158.

Khurana H S, Phillips S B, Singh B, Alley M M, Dobermann A, Sidhu A S, Singh Y and Peng S. 2008. Agronomic and economic evaluation of site-specific nutrient management for irrigated wheat in northwest India. *Nutrient Cycling in Agroecosystems* **82**:15-31.

Knudsen D, Peterson G A and Pratt P F. 1982. *Lithium, sodium and potassium*. Page A L. (ed.) *In: Methods of Soil Analysis*, pp. 225-245, part 2. Chemical and microbiological properties, ASA, SSSA, Madison, WI, USA.

Ladha J K, Pathak H, Krupnik T J, Six J and van Kessel C. 2005. Efficiency of fertilizer nitrogen in cereal production: retrospect and prospects. *Advances in Agronomy* **87**: 85-156.

Nair P G, Mohankumar B, Prabhakar M and Kabeerathumma S. 1988. Response of cassava to graded doses of phosphorus in acid lateritic soils of high and low P status. *Journal of Root Crops* **14**(2): 1-9.

Nair G M, Ramanathan S and Nambiar T A. 2004. Agrotechniques of tuber crops. CTCRI, Kerala, India.

Page A L, Miller R H and Keeney D R. 1982. *Methods of Soil Analysis*, part 2. Chemical and microbiological properties. Agronomy Series No. 9., ASA, SSSA, Madison Winconsin, USA.

Pasuquin J M, Pampolino M F, Witt C, Dobermann A, Oberthür T, Fisher M J and Inubushi K. 2014. Closing yield gaps in maize production in Southeast Asia through site-specific nutrient management. *Field Crops Research* **156**: 219-230.

Pathak H, Aggarwal P K, Roetter R, Kalra N, Bandyopadhaya S K, Prasad S and van Keulen H. 2003. Modelling the quantitative evaluation of soil nutrient supply, nutrient use efficiency, and fertilizer requirements of wheat in India. *Nutrient Cycling in Agroecosystems* **65**: 105-113.

Penas E J and Wiese R A. 1987. *Fertilizer suggestion for soybeans.* NebGuide G87-859. University of Nebraska, Cooperative Extension, Lincoln, NE.

Peng X, Liu Y, Luo S, Fan L, Song T and Guo Y. 2007. Effects of site-specific nitrogen management on yield and dry matter accumulation of rice from cold areas of northeastern China. *Agricultural Sciences in China* **6**(6): 715-723.

Rao A U, Dakshina Murthy K M, Sridhar T V, Tejeswara Rao K and Rajendra Prasad TVP. 2013. Effect of site-specific nutrient management on productivity, profitability and soil N, P and K balance in rice - rice-cropping system. *Progressive Agriculture* **13**(1): 1-6.

SAS Institute Inc. 2002. SAS / STAT software, Version 9, SAS Institute, Inc., Cary, NC, USA.

Sharma B M and Singh R V. 2000. Fertilizer recommendation for wheat based regression and targeted yield approaches a comparison. *Journal of the Indian Society of Soil Science* **48**: 396-397

Soil Survey Organization. 2007. Benchmark soils of Kerala. Department of Agriculture, Government of Kerala, India.

Thampan A K. 1979. Cassava. In: Root Crops, Trichur, Kerala, India, pp 242.

Walkley A and Black I A. 1934. An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Wang G, Dobermann A, Witt C, Sun Q and Fu R. 2001. Performance of site-specific nutrient management for irrigated rice in southeast China. *Agronomy Journal* **93**: 869-78.

Witt C, Dobermann A, Abdulrachman S, Gines G C, Wang G H, Nagarajan R, Satawathananont S, Son TTN, Tan P S, Tiem T V, Simbahan G C and Olk D C. 1999. Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia. *Field Crops Research* **63**: 113-38.

Current Horticulture **5**(1): 30–39, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Selection of tomato *(Solanum lycopersicum)* genotypes for heat stress and analyzing stability in their physio-morphological traits under different seasons

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Received: March 2016; **Revised:** February 2017

ABSTRACT

A field experiment was conducted at ICAR-Indian Institute of Vegetable Research (IIVR), Varanasi, to study the stability in morphological traits of 23 tomato (*Solanum lycopersicum* L.) genotypes for heat stress during 2007-2009. Observations were recorded on low (6.0°C) and high temperature (42.9°C) for vegetative characters of plants, *e.g.* plant height, number of primary branches, days of 50% flowering, number of flowers/cluster, number of fruit set/plant, average fruit weight, fruit length and fruit width. The number of fruits decreased during summer and increased during winter seasons. It was possible by low fertility and pollen viability due to high temperature. In response of stability the genotypes, IIHR-2202 (plant height, number of branches), CH-155 (50% flowering, number of flowers/cluster, number of fruits set), FLA-7421 and Sel-7 (number of fruit set), and EC-538156 (fruit length and width) gave significant value of βi=<1.00, indicating the suitability for high reproducible environment. These genotypes can be utilized for further breeding programme against high temperature.

Key Words: High temperature, Physio-morphological traits, Stability analysis, Primary branches, cluster.

Tomato (*Solanum lycopersicum* L.) is one of the world's most popular vegetable crops and can be grown round the year. Presently high price of tomato in summer created a great demand among the farmers for developing a summer variety (Prasanth and Kumary 2014). It can grow vigorously and is highly productive within the temperature range of 18-28°C and sometime an optimal mean daily temperatures between 21-24°C, depending on developmental stage (Geisenberg and Stewart, 1986; Saeed *et al.*, 2007). A substantial yield losses has been noticed in summer when the extreme temperature range reached at 35°C (Peet *et al.*, 1997; Saeed *et al.*, 2007). The high temperatures may be reduce the flower formation, reproductive procedures (formation of pollen-grains, ovule formation, stigma exertion, pollen tube elongation, pollen germination, fertilization and seed formation) and reduce the yield of tomato (Dane *et al.*, 1991; Kuo *et al.*, 1979; El-Ahmadi and Stevens, 1979; Hanna and Hernandez, 1982). In comparison of heat tolerant varieties, susceptible tomato cultivars faced drastic reductions in vegetave growth and yield of tomato (Kuo and Tsai, 1984; Kuo *et al.*, 1989; Dane *et al.*, 1991).

Day to day environmental condition is changing from year to year/region to region, in such condition tomato genotypes need for stability within phenotypic characters (Singh *et al.*, 2014). Therefore, a few varieties have been recommended for cultivation against heat stress and using for breeding programme (Kalloo *et al.*, 1998). Stability analysis is a good technique for measuring the adaptability of a variety to varying environments (Al-Aysh, 2013). Several Genotype × Environment interaction force can affect the timing of transition from vegetative to reproductive development in tomato (Bernier and Perilleux, 2005; Jinks and Pooni, 1982). Fruit setting in tomato is reportedly completely interrupted and completely arrested at temperatures above 38/27°C day/night and day above 26/20°C day/night, respectively (Golam *et al.*, 2012). Although tomato plants can be grown under a wide range of climatic conditions, they are extremely sensitive to hot and wet conditions (Steven and Rudich 1978, El-Ahmadi and

Stevens 1979, Kuo *et al.*, 1979, Golam *et al.*, 2012). But limited efforts have been made so far to overcome the high temperature barrier which prevents fruit setting in summer season. Hence, an experiment was conducted to evaluate tomato genotypes and analyze the stability in physio-morphological characters and yield potential for high temperature under different seasons.

MATERIALS AND METHODS

A set of 23 tomato genotypes were evaluated at research field of IIVR, Varanasi, for two seasons, summer (January - June) and winter (October - March) during 2007 - 2009, when temperature range was 15°C (minimum) and 42°C (maximum). Nursery was raised for summer and winter seasons in January and October, after that 21 days old seedling were transplanted during February and November in three replications (30 plants in each) with recommended spacing of 45 cm (plant-to-plant) × 60 cm (row-to-row). All cultural practices were followed. Pesticides and insecticides were sprayed timely.

Metrological data (minimum and maximum temperatures and sunshine) were recorded from the weather observatory machine of IIVR, Varanasi for each year (2007, 2008 and 2009) (Table 1).

Horticultural data, *e.g.* plant height (cm), number of primary branches, days of 50% flowering, number of flowers / cluster, number of fruits / plant, average fruit weight (g), fruit length (cm), and width (cm) were recorded from mid row of each replication of each genotypes. After physiological maturity of fruits, plant height was recorded from randomly selected 10 plants of each replication from the base of plants to tip of shoots. The plants used for measuring plant height were also used for counting of number of primary branches per plant at the same time. Days to 50% flowering were recorded from the data of sowing to till 50% plants have to flower. Number of flowers / cluster was counted by tagging of flowers panicle from randomly selected 10 plants of each replication of each genotype.

Total number of fruits / plant was harvested from randomly selected 10 plants of each replication of each genotype, and fruits were counted from each picking. Fruit weight was measured in gram by average 5 fruits from randomly selected 10 plants of each replication of each genotype. Fruit length was measured in centimeters with the help of Vernier Calipers at the time of fruit maturity. The data were recorded by 5 randomly selected fruits of 10 plants from each replication of each genotype. Fruit width was measured in centimeters with the help of Vernier Calipers of the same fruits which were used for measuring fruit length.

Stability analysis was done in 23 genotypes which were evaluated for summer and winter seasons during 2007-2009 for 8 horticultural traits, *viz.* plant height, number of primary branches, days of 50% flowering, number of flowers / cluster, number of fruits / plant, average fruit weight, fruit length and fruit width. The data were tabulated of both summer and winter seasons of all the years (2007-2009). The stability parameters, *i.e.* regression coefficient (b) and deviation from regression (sd^2) were estimated using the model proposed by Eberhart and Russell (1966).

Table 1. Range of minimum and maximum temperature and sunshine status during summer and winter seasons of 2007-2009

Month	Minimum temperatures (°C)			Maximum temperatures (°C)			Sunshine		
	2007	2008	2009	2007	2008	2009	2007	2008	2009
Summer seasons biometric data after days of transplanting									
January	6.0	8.5	10.9	23.4	22.8	24.2	7.1	7.6	6.9
February	12.0	11.2	12.5	24.4	26.3	28.0	6.8	7.7	9.2
March	15.0	17.5	16.3	30.5	34.1	33.7	8.1	8.4	8.8
April	22.6	22.5	22.4	38.6	40.5	39.4	9.6	9.7	9.9
May	25.1	17.5	26.5	40.5	36.1	38.5	9.3	9.1	9.4
June	25.8	26.4	28.2	40.2	38.1	42.9	9.8	9.5	9.1
Winter seasons biometric data after days of transplanting									
October	19.3	20.8	19.7	32.0	33.0	31.6	8.0	2.9	8.2
November	13.1	14.8	15.2	28.1	28.6	28.7	7.4	1.9	6.6
December	9.0	12.2	11.0	25.0	24.4	24.6	6.2	1.1	6.5
January	7.8	9.3	11.1	24.2	22.6	23.6	7.5	6.3	5.9
February	12.0	11.2	12.5	24.4	26.3	28.0	6.8	7.7	9.2
March	15.0	17.5	16.3	30.5	34.1	33.7	8.1	8.4	8.8

RESULTS AND DISCUSSION

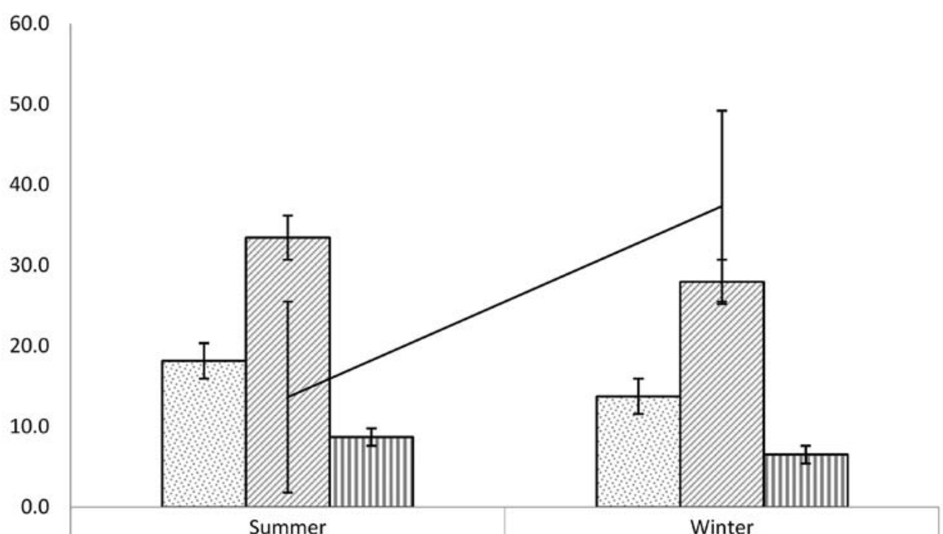
High temperature has been limiting factor for fruit setting in tomato because day-to-day temperature is increasing due to changing in climates (Abdelmageeda *et al.*, 2003; Alam *et al.*, 2010; Golam *et al.*, 2012). In the present study 23 genotypes were evaluated under summer and winter seasons of 2007-2009 and data were recorded on morphological characteristics like plant height, number of branches, days of 50% flowering, number of flowers/cluster, number of fruits/plant, average fruit weight, fruit length and width. Among the genotypes average number of fruits was given significant response in winter season's crops for each year (Fig. 1).

During summer seasons when the average minimum and maximum temperature were 18.2°C and 33.5°C, the average number of fruits were 13.7. Whereas, in winter seasons the average minimum and maximum temperature was 13.8°C and 28.0°C then average number of fruits were 37.3 (Fig. 1). Abdelmageeda *et al.* (2003) stated that tomato is usually produced during the winter periods but low fruit setting is observed during summer due to high temperatures between 31 to 35°C. Similar findings of effect of high temperature on fruit numbers were discussed in many studies of Saeed *et al.* (2007), Alam *et al.* (2010), Golam *et al.* (2012), Jędrszczyk *et al.* (2016). They also stated that number of flowers and fruits was negatively correlated with temperature.

Plant height varied from 76.67 (Money Maker) to 37.22 (FLA-7421) in summer seasons and from 140.11 (Flora-Dade) to 43.89 (EC-501583). Only a genotype, Flora Dade, recorded higher performance relative to the general mean for both seasons; so, this was desirable. But the genotype, Flora-Dade, gave non-significant values for both S^2di and βi, therefore, this was stable and suitable to a wide array of environments. Only three genotypes, EC-501582 (-2.752), IIHR-2202 (-0.721) and EC-501580 (-0.922), had significant value in summer seasons and Sel-7 (-1.44), PS-1 (0.73) and IIHR- 2202 (-1.82) were significant during winter seasons for βi. Out of which a genotype, IIHR- 2202, was common in both seasons with βi > 1*, indicating its suitability for high acceptable environments. Upadhay *et al.* (2001), Al-Aysh (2013) and Singh *et al.* (2014) supported an results.

Number of primary branches ranged from 5.44 (EC-560340) to 3.68 (IIHR-2202) during summer, while in winter season this range was from 9.56 (Flora-Dade) to 4.44 (EC-552140). Coefficient of regression (βi) recorded significant value -1.00 for VRT-2, H-24 and IIHR-2202 during summer crops, while in winter crops this significant value of βi was -1.16 (EC-560340) and -0.68 (Pearson). According to Eberhart and Russell (1966), large variation in values of S^2di and βi indicates large differences in genotype response to different environments.

The mean of 50% flowering ranged in summer from 33.11 (VRT-2) to 25.33 (CH-155) and in winter



	Summer	Winter
Average minimum temperature	18.2	13.8
Average maximum temperature	33.5	28.0
Average sunshine	8.7	6.5
Average number of fruits among genotypes	13.7	37.3

Fig. 1. Effect of temperature on number of fruits in tomato during winter and summer seasons

Table 2. Stability analysis for eight characters of tomato in summer seasons of 2007-2009

Genotype	Plant height			Number of branches			Days of 50% flowering			Number of flowers/cluster		
	μ Mean	βi	σ²di	μ Mean	βi	σ²di	μ Mean	βi	σ²di	μ Mean	βi	σ²di
EC-538138	59.78	4.43	2.02	4.89	-1.43	-0.16	27.56	2.057	0.95	5.11	-0.14	-0.39
EC-560340	51.67	-0.05	-2.49	5.44	-2.37	-0.22	27.56	-0.34	-1.1	4.11	0.55	-0.31
Money Maker	76.67	0.33	3.36	4.67	-2.29	0.38	30.78	-0.90	0.75	5	-1.93	-0.25
EC-501575	56.89	0.69	9.81	4.67	3.12	-0.19	30.44	-1.04	2.56	4.22	0.71	-0.35
EC-501574	59.79	3.28	906.09	4.78	-4.17	-0.08	30.33	-0.69	-0.99	4.56	-2.79	-0.15
Sel-7	40.68	-1.40	-0.24	4.33	3.64	-0.14	31.56	-0.46	-1.17	3.67	-0.30	-0.22
CH-155	54.00	2.47	267.38	5.33	1.32	-0.2	25.33	-0.12	0.45	8	-1.000*	-0.4
PS-1	48.11	3.03	-0.01	4.22	0.37	-0.22	32.33	3.58	3.75	5.22	1.18	0.61
VRT-2	54.67	-0.90	-1.94	4.33	-1.000*	-0.22	33.11	-0.34	-1.1	4.89	-0.92	-0.33
H-24	47.11	2.55	0.98	4.33	-1.000*	-0.22	28.44	1.79	1.5	3.56	-0.46	0.54
Pearson	41.33	-0.83	1.36	4.89	0.37	-0.22	30.33	-1.39	-1.22	4.22	0.48	-0.06
RF-4A	37.68	-1.08	-1.02	5.11	-0.57	-0.16	29.11	-1.6	0.54	4.11	1.25	0.14
EC-501583	60.56	-1.06	-2.25	4.67	-0.48	-0.01	30.67	-0.37	-0.11	5.56	-2.09	3.35
EC-501582	59.66	-2.752*	-2.3	4.56	4.49	-0.17	30.33	1.14	-0.56	4.33	-1.70	-0.22
DVRT-1	43.89	-0.023	-2.48	4.33	-1.51	-0.01	30.78	-0.34	-0.62	4.67	-1.47	1.13
IIHR-2202	45.22	-0.721*	-2.48	3.68	-1.000*	-0.22	29.56	-0.94	-1	3.67	4.83	-0.33
EC-538156	51.33	-1.94	119.42	4.68	-2.80	-0.12	32.11	1.486*	-1.27	4.78	-1.78	-0.38
15-SB	43.33	-0.18	-2.49	3.88	0.37	-0.22	30.11	1.02	1.14	4.67	0.40	0.32
EC-501577	46	-0.42	48.26	4	3.12	-0.19	31.89	-0.15	-1.25	4.33	-0.07	-0.25
FLA-7421	37.22	-1.53	15.48	4.11	1.75	-0.21	29.33	-0.20	-1.02	3.89	-1.85	-0.39
Flora Dade	61.78	-0.99	3.13	4.44	-0.57	-0.16	29.67	-1.78	-0.75	3.78	-1.08	-0.33
EC-501580	49.44	-0.922*	-2.5	4.33	2.60	0.18	29.44	0.37	-1.26	4	4.83	-0.33
EC-552140	43.44	-1.98	50.26	4.22	-1.94	-0.18	31.00	-0.75	0.04	3.78	3.35	0.32
Population mean	50.87	4.52	30.22	4.53								

Table 2 continued

Genotype	Number of fruits/plant			Average fruit weight			Fruit width			Fruit length		
	µ Mean	βi	σ²di	µ Mean	βi	σ²di	µ Mean	βi	σ²di	µ Mean	βi	σ²di
EC-538138	59.78	4.43	2.02	4.89	-1.43	-0.16	27.56	2.057	0.95	5.11	-0.14	-0.39
EC-560340	51.67	-0.05	-2.49	5.44	-2.37	-0.22	27.56	-0.34	-1.1	4.11	0.55	-0.31
Money Maker	76.67	0.33	3.36	4.67	-2.29	0.38	30.78	-0.90	0.75	5	-1.93	-0.25
EC-501575	56.89	0.69	9.81	4.67	3.12	-0.19	30.44	-1.04	2.56	4.22	0.71	-0.35
EC-501574	59.79	3.28	906.09	4.78	-4.17	-0.08	30.33	-0.69	-0.99	4.56	-2.79	-0.15
Sel-7	40.68	-1.40	-0.24	4.33	3.64	-0.14	31.56	-0.46	-1.17	3.67	-0.30	-0.22
CH-155	54.00	2.47	267.38	5.33	1.32	-0.2	25.33	-0.12	0.45	8	-1.000*	-0.4
PS-1	48.11	3.03	-0.01	4.22	0.37	-0.22	32.33	3.58	3.75	5.22	1.18	0.61
VRT-2	54.67	-0.90	-1.94	4.33	-1.000*	-0.22	33.11	-0.34	-1.1	4.89	-0.92	-0.33
H-24	47.11	2.55	0.98	4.33	-1.000*	-0.22	28.44	1.79	1.5	3.56	-0.46	0.54
Pearson	41.33	-0.83	1.36	4.89	0.37	-0.22	30.33	-1.39	-1.22	4.22	0.48	-0.06
RF-4A	37.68	-1.08	-1.02	5.11	-0.57	-0.16	29.11	-1.6	0.54	4.11	1.25	0.14
EC-501583	60.56	-1.06	-2.25	4.67	-0.48	-0.01	30.67	-0.37	-0.11	5.56	-2.09	3.35
EC-501582	59.66	-2.752*	-2.3	4.56	4.49	-0.17	30.33	1.14	-0.56	4.33	-1.70	-0.22
DVRT-1	43.89	-0.023	-2.48	4.33	-1.51	-0.01	30.78	-0.34	-0.62	4.67	-1.47	1.13
IIHR-2202	45.22	-0.721*	-2.48	3.68	-1.000*	-0.22	29.56	-0.94	-1	3.67	4.83	-0.33
EC-538156	51.33	-1.94	119.42	4.68	-2.80	-0.12	32.11	1.486*	-1.27	4.78	-1.78	-0.38
15-SB	43.33	-0.18	-2.49	3.88	0.37	-0.22	30.11	1.02	1.14	4.67	0.40	0.32
EC-501577	46	-0.42	48.26	4	3.12	-0.19	31.89	-0.15	-1.25	4.33	-0.07	-0.25
FLA-7421	37.22	-1.53	15.48	4.11	1.75	-0.21	29.33	-0.20	-1.02	3.89	-1.85	-0.39
Flora Dade	61.78	-0.99	3.13	4.44	-0.57	-0.16	29.67	-1.78	-0.75	3.78	-1.08	-0.33
EC-501580	49.44	-0.922*	-2.5	4.33	2.60	0.18	29.44	0.37	-1.26	4	4.83	-0.33
EC-552140	43.44	-1.98	50.26	4.22	-1.94	-0.18	31.00	-0.75	0.04	3.78	3.35	0.32
Population mean	50.87			4.52			30.22			4.53		

Table 2 continued

Genotype	Number of fruits/plant			Average fruit weight			Fruit width			Fruit length		
	µ Mean	βi	σ²di	µ Mean	βi	σ²di	µ Mean	βi	σ²di	µ Mean	βi	σ²di
EC-538138	30.44	1.69	1.14	201.67	-1.70	-11.25	2.01	0.60	0.13	2.01	0.33	0.11
EC-560340	18.22	-0.31	35.5	111.44	-2.12	379.28	1.78	-0.969*	-0.01	1.61	-0.964*	-0.01
Money Maker	13	0.56	-2.93	317.11	0.17	167.29	2.13	-0.979*	-0.01	2.22	-0.84	0.02
EC-501575	10	0.02	-2.98	101.67	-1.08	3.48	2.33	0.97	0.21	2.37	1.52	0.14
EC-501574	10.78	0.82	-1.67	137.78	9.213*	-18.51	1.82	-0.09	0.29	1.84	-0.07	0.12
Sel-7	13.44	-0.001	-2.57	222.67	-3.77	3.04	2.8	1.67	0.19	3.3	1.54	0.18
CH-155	35.67	-0.70	-2.27	44.44	-3.16	-12.29	1.94	-0.04	0.08	1.9	0.02	0.02
PS-1	22.44	-0.35	-2.61	245.56	10.877*	-12.09	2.58	1.05	0.17	2.43	0.67	0.04
VRT-2	18.22	-1.50	-2.96	366.11	-8.48	219.97	2.44	-0.896*	-0.01	2.19	-1.06	-0.01
H-24	12.67	0.13	-1.17	325.56	-0.045	-10.58	3.28	2.14	0.3	3.57	1.73	0.38
Pearson	14.11	1.94	-2.86	303.44	-0.64	-17.97	2.39	-0.938*	-0.01	2.51	-0.910*	-0.01
RF-4A	5.56	-0.33	-2.88	119.44	26.83	403.93	1.56	-0.959*	-0.01	1.72	-0.981	-0.01
EC-501583	10.67	1.73	-2.91	106.11	-1.56	-3.97	2.6	-0.731*	-0.01	2.67	-0.837*	-0.01
EC-501582	10.44	0.43	-2.11	152.78	-13.42	25.02	1.84	0.02	0.02	2.13	-0.11	0.15
DVRT-1	16.33	2.27	4.88	322.56	-0.30	73.56	2.99	0.41	0.06	2.92	0.39	0.07
IIHR-2202	5.67	-0.17	-2.75	202.22	-1.495*	-18.52	2.37	-0.927*	-0.01	1.86	-0.85	-0.01
EC-538156	11	-1.20	3.15	319.22	-3.01	99.25	2.5	0.01	0.32	2.6	-0.24	0.13
15-SB	19.67	-1.24	-1.55	302.22	-1.495*	-18.52	2.07	-0.04	0.36	1.9	0.061	0.36
EC-501577	7.67	-1.19	-2.84	267.22	-3.78	1911.81	3.6	2.991*	-0.01	3.22	2.13	0.17
FLA-7421	5.33	-1.341*	-2.99	302.22	-0.72	-13.61	3.04	-0.22	0.21	3.01	0.56	0.57
Flora Dade	3.11	-0.84	-2.97	322.22	1.74	213.69	2.52	-0.616*	-0.01	2.33	-0.65	-0.01
EC-501580	10.78	0.72	-2.99	135.56	-2.03	84.39	2.88	-0.64	0.02	3.01	-0.964*	-0.01
EC-552140	9.11	-1.12	1.72	207.22	-0.01	-18.34	3.83	-1.82	0.21	3.87	-0.48	0
Population mean	13.67			223.3			23.35			2.49		

Table 3. Stability analysis for eight characters of tomato in winter seasons of 2007-2009

Genotype	Plant height			Number of branches			Days of 50% flowering			Number of flowers/cluster		
	μ Mean	βi	σ²di	μ Mean	βi	σ²di	μ Mean	βi	σ²di	μ Mean	βi	σ²di
EC-538138	103.22	1.32	42.67	7.11	0.76	-0.25	32.56	5.64	0.58	6.89	0.61	-0.23
EC-560340	62.78	-0.88	-2.37	7.44	-1.16*	-0.37	32.00	2.43	-0.77	5.44	0.87	-0.25
Money Maker	66.22	-0.39	45.77	5.89	-0.33	-0.25	34.67	5.69	-0.89	6.44	1.68	0.58
EC-501575	115.67	1.28	26.61	8.11	1.47	0.15	34.56	2.38*	-0.37	6.33	-7.95	-0.24
EC-501574	106.33	-0.68	89.26	7.44	1.12	1.18	31.22	2.38*	-1.33	5.78	3.55	0.33
Sel-7	44.67	-1.42*	-4.08	6.56	0.32	0.57	28.89	-0.03	-0.89	6.78	-4.74	0.33
CH-155	122.22	1.32	42.88	9.22	1.37	-0.31	27.78	-7.12*	-1.31	10.00	3.82	-0.01
PS-1	74.33	0.73*	-4.09	7.78	1.53	-0.33	31.89	-0.72	-1.26	7.00	-1.00*	-0.26
VRT-2	64.67	-1.07	9.25	5.44	-0.94	-0.31	32.56	2.38*	-1.33	6.56	-2.87	-0.25
H-24	47.78	-0.31	-4.13	5.56	-0.39	-0.02	29.11	-15.02	-0.07	6.56	4.08	-0.21
Pearson	62.56	-0.23	67.56	4.78	-0.68*	-0.37	32.78	-1.80	0.92	6.78	3.01	-0.03
RF-4A	45.00	-0.71	90.92	4.67	-0.81	0.19	41.78	0.77	-0.63	6.56	-4.21	-0.15
EC-501583	43.89	-1.17	0.84	5.44	-0.94	-0.31	34.33	2.60	-0.42	5.78	-2.60	-0.23
EC-501582	89.33	3.62	65.61	7.44	0.64	1.42	36.44	-5.41	0.66	6.44	-2.60	-0.23
DVRT-1	53.33	-0.07	-4.31	6.11	0.06	-0.37	32.44	16.39	-0.13	6.33	5.95	-0.24
IIHR-2202	65.44	-1.82*	-3.56	5.67	-0.26	-0.36	39.67	0.20	-1.23	5.67	-4.48	-0.25
EC-538156	71.33	-3.38	37.97	5.67	0.03	0.19	30.22	-3.12	-1.19	6.22	4.08	-0.21
15-SB	47.11	-0.87	8.45	4.67	-0.74	-0.34	41.11	-0.26	1.37	7.11	-2.60	-0.23
EC-501577	136.89	8.98	240.66	7.44	1.05	-0.28	39.56	-6.21*	-1.32	6.56	-4.21	-0.15
FLA-7421	58.67	-2.60	5.58	5.78	-0.23	0.02	39.44	-0.43	-1.06	5.56	4.08	-0.21
Flora Dade	140.11	0.49	224.18	9.56	-0.07	-0.09	41.78	4.55	-1.19	5.89	0.61	-0.23
EC-501580	89.78	-0.88	-3.85	5.22	-0.87	-0.12	35.11	-0.09	-1.32	8.33	2.48	-0.25
EC-552140	84.00	-1.26	7.38	4.44	-0.94	-0.31	41.78	-1.63	-1.29	5.67	2.48	-0.25
Population mean	78.06			6.41			34.85			6.55		

Table 3 continued

Genotype	Number of fruit/plant			Average fruit weight			Fruit width			Fruit length		
	μ Mean	βi	σ²di	μ Mean	βi	σ²di	μ Mean	βi	σ²di	μ Mean	βi	σ²di
EC-538138	44.22	-7.27	-0.52	308.89	-2.17	-18.56	4.56	23.53	0.00	4.50	-0.01	0.00
EC-560340	31.78	-0.79	-2.21	385.33	-0.92	49.14	4.36	18.60	-0.01	4.18	-1.32	0.00
Money Maker	33.44	3.28	-1.03	516.11	28.39	653.24	4.48	64.60	-0.01	4.64	3.12	0.00
EC-501575	27.11	3.63	3.17	305.56	-2.213*	-49.98	4.29	-198.28	0.00	4.46	-0.53	-0.01
EC-501574	27.89	2.27	21.94	291.11	-1.151*	-50.99	4.29	-84.91	-0.01	4.01	2.23	-0.01
Sel-7	38.44	-15.205*	-2.12	352.22	0.04	-40.67	4.19	-25.76	-0.01	4.58	2.27	-0.01
CH-155	131.11	8.285*	-2.25	58.11	-1.92	-20.83	2.10	141.89	-0.01	1.97	-4.45	-0.01
PS-1	40.56	-0.09	-2.23	259.11	-3.48	155.04	4.02	66.26	0.02	3.97	0.16	0.02
VRT-2	37.11	-2.55	-1.61	481.56	-0.805*	-50.86	2.48	-1.06	-0.01	2.27	-1.02	-0.01
H-24	36.89	-5.23	1.67	375.00	-1.910*	-50.41	3.98	79.41	0.02	3.98	-1.491*	-0.01
Pearson	28.89	2.54	8.19	399.33	-1.38	4.00	4.46	-20.83	-0.01	4.50	0.07	0.11
RF-4A	28.67	2.34	33.84	399.78	-1.77	59.15	4.60	-30.69	0.02	4.33	-1.07	0.01
EC-501583	25.44	-0.71	-1.79	286.78	-1.467*	-50.61	3.57	5.48	-0.01	3.67	0.42	-0.01
EC-501582	34.56	-6.48	-2.18	301.11	-2.37	184.07	4.21	-6.04	-0.01	4.88	-3.93	0.00
DVRT-1	36.89	9.41	-1.73	666.67	3.55	-37.30	4.94	110.59	-0.01	5.46	-0.61	0.04
IIHR-2202	23.44	6.62	7.30	407.78	-0.31	7.72	4.39	-83.27	0.00	4.41	1.99	0.00
EC-538156	38.78	1.89	-2.22	297.45	-11.576*	13.28	4.04	130.332*	-0.01	3.56	3.207*	-0.01
15-SB	36.78	-2.53	5.32	456.22	-0.20	262.17	4.74	2.16	-0.01	4.81	0.39	0.17
EC-501577	29.56	5.73	11.52	457.22	3.89	6.18	2.84	-283.68	0.02	2.82	7.48	0.02
FLA-7421	34.44	-3.53	-2.20	403.33	-1.43	-43.59	4.39	39.95	0.01	4.93	-3.61	0.02
Flora Dade	31.78	-0.30	-2.25	387.22	1.74	761.96	5.09	25.15	0.01	5.11	-1.20	0.01
EC-501580	32.00	1.45	-0.26	545.89	-1.33	-47.27	3.62	21.91	0.01	5.67	-1.411*	-0.01
EC-552140	29.22	-2.73	11.60	301.11	-1.20	-30.13	4.63	2.16	-0.01	5.04	-0.67	-0.01
Population mean	37.35			375.8			4.09			4.25		

μ mean; βi, regression coefficient, and σ²di, mean sum of square deviation from regression lines ranged from 41.78 (RF-4A, Flora Dade, CH-155) to 27.78 (CH-155), hence they showed desirable performance. The significant values of coefficient of regression was 1.486 of EC-583156 in summer, and significant values of coefficient of regression during winter was 2.38 (EC-501575, EC-501574, VRT-2) and -7.12 (CH-155). In present study, CH-155 having high average mean and regression value indicated stability for favourable environments. Our findings corroborate to those of Kalloo *et al.* (1998), Aravindkumar *et al.* (2001) and Prasanna *et al.* (2007).

Number of flower/cluster's average mean value range was 8.0 (CH-155) to 3.56 (H-24) in summer season, while in winter this value range was 10.00 (CH-155) to 5.44 (EC-560340). High mean value of CH-155 was indicated for desirable performance of genotype (Kalloo *et al.* 1998). Whereas, coefficient regression value was -1.00 for CH-155 and PS-1 in summer and winter seasons, respectively. Significant value of βi=1.00 indicated the stability of crops in any suitable environment (Prasanna *et al.* 2007).

Number of fruits/plant varied from 35.67 (CH-155) to 5.33 (FLA-7421) during summer season but in winter season it ranged 44.22 (EC-538138) to 23.44 (EC-IIHR-2202). Mane (2009) noticed that highest mean value for number of fruits/plant in tomato genotypes. Among genotypes, FLA-7421 (1.341) in summer and Sel-7 (-15.205) and CH-155 (8.285) in winter had significant value of βi < 1*, indicating their suitability for high-reproducible environments. Similar studies were done by Upadhay *et al.* (2001) in 30 tomato genotypes during four environments to know the stability behaviour under diverse environmental conditions.

Average fruit weight ranged from 366.11 (VRT-2) to 44.44 (CH-155) in summer but in winter it was 666.67 (DVRT-1) to 58.11 (CH-155). The winter season fruits should higher mean values than summer season, this may be favorable environment of the crop. The significant coefficient of regression (βi) varied from 10.877 (PS-1) to -1.495 (IIHR-2202) for summer but during winter VRT-2 and EC-538156, indicating high and low value -0.805 and -11.576, respectively. According to Eberhart and Russell (1966), the large variation in values of βi indicates large differences in genotype response to different environments. The significant value of these genotypes which had βi > 1*, were sensitive to environmental changes and had greater specificity of adaptability to high-yielding environments. Similarly, Shalini (2009), Al-Aysh *et al.* (2012) and Al-Aysh (2013) observed that significant genotypes recorded βi values more than unity for the average fruit weight.

The mean value of fruit width in summer varied from 3.83 (EC-552140) to 1.78 (EC-560340) and during winter this range from 5.09 (Flora Dade) to 2.48 (VRT-2). The significant coefficient of regression (βi) ranged from -0.805 (VRT-2) to 11.576 (EC-538156) for summer season but during winter the significant value was expressed for only EC-538156 (130.332). Present finding supported to that of Shalini (2009) and Al-Aysh *et al.* (2012).

The average mean value of fruit length ranged from 3.87 cm (EC-552140) to 1.61 (EC-560340) during summer season but in winter 5.67 cm (EC-501580) to 1.97 cm (CH-155), hence, they gave desirable performance. The significant coefficient of regression varied from -0.837 (EC-501583) to -0.964 (EC-560340, EC-501580) during summer but in winter this range was 3.207 (EC-538156) to -1.491 (H-24). The significant value of these genotypes which had βi > 1*, were profound to environmental changes and had greater specificity for fruit length. Kalloo *et al.* (1998), Aravindkumar *et al.* (2001), Prasanna *et al.* (2007), Shalini (2009), Al-Aysh *et al.* (2012), Al-Aysh (2013) reported similar study for fruit length to determine fruit shape.

Thus, these results denoted that significant value of βi=<1.00 indicated the suitability for high reproducible environment. The genotypes, IIHR-2202, CH-155, FLA-7421, Sel-7 and EC-538156, were stable with plant height, number of branches, 50% flowering, number of flowers/cluster, number of fruits set fruit length and width under both summer and winter seasons. These can be utilized for development of tolerant hybrids/varieties for high temperature.

REFERENCES

Abdelmageeda AH, Grudab N and Geyerb B. 2003. Effect of High Temperature and Heat Shock on Tomato (*Lycopersicon esculentum* Mill.) Genotypes under Controlled Conditions. *Conference on International Agricultural Research for Development.* Deutscher Tropentag Göttingen.

Alam MS, Sultana N, Ahmad S, Hossain MM and Islam AKMA. 2010. Performance of heat tolerant tomato hybrid lines under hot, humid conditions. *Bangladesh Journal of Agricultural Research* **35**(3): 367-73.

Al-Aysh FM, Al-Serhan M, Al-Shareef A, Al-Nasser M and Kutma H. 2012. Study of genetic parameters and character interrelationship of yield and some yield components in tomato (*Solanum lycopersicum* L.). *International Journal of Genetics* **2**(2): 29-33.

Al-Aysh FM. 2013. Genotype-environment interaction and phenotypic stability for fruit yield and its components of tomato in Dara'a Governorate, Syria. *Research Journal of Agriculture and Environmental Management* **2**(11): 371-77.

Aravindakumar J S, Mulge R, Madalageri H B, Patil M P, Kulkarni M S and Gangadharappa P M. 2001. Stability differences among tomato genotypes for fruit quality parameters. *Vegetable Science* **28**: 102-105.

Bernier G and Perilleux C. 2005. A physiological overview of the genetics of flowering time control. *Plant Biotechnology Journal* **3**: 3-16.

Dane F, Hunter A G and Chambliss O L. 1991. Fruit set pollen fertility and combining ability of selected tomato genotypes under high-temperature field conditions. *Journal of the American Society for Horticultural Science* **116**: 906-10.

Dane F, Hunter A G and Chambliss O L. 1991. Fruit set pollen fertility and combining ability of selected tomato genotypes under high-temperature field conditions. *Journal of the American Society for Horticultural Science* **116**: 906-10.

Eberhart S A and Russell W A. 1966. Stability parameters for comparing varieties. *Crop Science* **6**: 36-40.

EI-Ahmadi A B and Stevens M A. 1979. Reproductive responses of heat-tolerant tomatoes to high temperatures. *Journal of the American Society for Horticultural Science* **104**: 686-91.

Geisenberg C and Stewart K. 1986. Field crop management. *In: The Tomato Crop*, Atherton J. G. and Rudich J. (Eds). Chapman & Hall, London, pp. 511-57.

Golam F, Prodhan Z H, Nezhadahmadi A and Rahman M. 2012. Heat tolerance in Tomato. *Life Science Journal* **9**(4): 1936-50.

Hanna H Y and Hernandez T P. 1982. Response of six tomato genotypes under summer and spring weather conditions in Louisiana. *Hort Science* **17**: 758-9.

Jędrszczyk E, Skowera B, Gawęda M and Libik A. 2016. The effect of temperature and precipitation conditions on the growth and development dynamics of five cultivars of processing tomato. *Journal of Horticultural Research* **24**(1): 63-72.

Jinks J L and Pooni H S. 1982. Determination of the environmental sensitivity of selection lines of Nicotiana rustica by the selection of environments. *Heredity* **49**: 291-294.

Kalloo G, Chaurasia S N S and Singh M. 1998. Stability analysis in tomato. *Vegetable Science* **25**: 81-84.

Kuo C G and Tsai C T. 1984. Alternation by high temperature of auxin and gibberellins concentrations in the floral buds, flowers, and young fruit of tomato. *Hort Science* **19**: 870-72.

Kuo C G, Chen B W, Chou M H, Tsai C L and Tsay T S. 1979. Tomato fruit-set at high temperatures. In: AVRDC. Proceedings of the Ist International Symposium on Tropical Tomato, Oct. 23-27, 1978 at Shanhua, Taiwan, Republic of China. *Asian Vegetable Research Development Center* Publication No. **78-59**: 94-108.

Kuo C G, Chen H M, Shen B J and Chen H C. 1989. Relationship between hormonal levels in pistils and tomato fruit-set in hot and cool seasons: Green SK, Griggs TD, McLean BT, (Eds). Tomato and Pepper Production in the Tropics.

Mane R S. 2009. Stability analysis in tomato (Solanum lycopersicum Mill.) genotypes. M. Sc. Thesis, Department of Genetics and Plant Breeding, College of Agriculture, University of Agricultural Sciences, Dharwad, India.

Peet M M, Willits D H and Gardner R. 1997. Response of ovule development and post-pollen production processes in male sterile tomato to chronic, sub-acute high temperature stress. *Journal of Experimental Botany* **48**: 101-111.

Prasanna H C, Chaubey T, Kumar R, Rai M, Verma A and Singh S. 2007. Identification of stable variety for yield and quality attributes in tomato. *Vegetable Science* **34**: 131-134.

Prasanth K and Kumary S. 2014. Utilization of male sterility for hybrid seed production in vegetables. *Current Horticulture* **2**(2): 3-14.

Saeed A, Hayat K, Khan A A and Iqbal S. 2007. Heat Tolerance Studies in Tomato (*Lycopersicon esculentum* Mill.). *International Journal of Agriculture and Biology* 1560-8530 / /09-4: 649-652, http://www.fspublishers.org .

Shalini M. 2009. 'Studies on heterosis and combining ability in tomato (*Solanum lycopersicum* L.)'. Ph. D. Thesis, Department of Horticulture, College of Agriculture, University of Agricultural Sciences, Dharwad, India.

Singh AK, Rai N, Singh RK, Singh S and Singh RP. 2014. Evaluation of combiners for resistance to early blight disease using interspecific crosses in tomato *(Solanum lycopersicum)*. *Current Horticulture* **2**(2): 21-26.

Stevens MA and Rudich J. 1978. Genetic potential for overcoming physiological limitations on adaptability, yield and quality in the tomato. *Hort Science* **13**: 673-678.

Upadhay R, Lal G and Ram HH. 2001. Genotype environment interaction and stability analysis in tomato. *Progressive Horticulture* **33**(2): 190-93.

Current Horticulture **5**(1): 40–42, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Evaluation of FLD and existing practices for yield of tomato *(Lycopersicon esculentum)* under semi-arid conditions of middle Gujarat

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Received: October 2015; **Revised:** March 2017

ABSTRACT

The studies were carried out on tomato (*Lycopersicon esculentum* Mill.) to enhance its productivity in Panchmahals district in Gujarat during 2011-12 and 2012-13. The improved production technologies, *viz,* use of improved varieties, seed treatment, raised seed bed preparation, balanced fertilizers application and integrated pest management gave on an average 25.32% more yield of tomato as compared to the existing practices (156.35q/ha). The pooled level extension gap (39.57q/ha), technology gap (15.75%) and technology index (20.19%) were recorded. In subsequent years, the extension gap technology index was reduced thus, the knowledge of farmers about improved production technologies was increased. The frontline demonstrations recorded higher gross returns (₹ 107635/ha), net return (₹ 66,585/ha) with a cost:benefit ratio (2.62) as compared to existing practice ₹ 87,450/ha, ₹ 49,350/ha respectively. Hence, by conducting frontline demonstrations of proven technologies, yield potential of tomato can be increased to great extent. This will subsequently increase the income as well as the livelihood of farming community.

Key Words: FLD, Existing practices, Productivity, Frontline demonstration, Balanced fertilization, Integrated pest management

The area, production and productivity of tomato (*Lycopersicon esculentum* Mill.) is 8.79 lakh ha, 182.26 lakh tonnes and 20.72tonnes/ha, respectively in india, compared to 44.0 lakh ha, 11.56 tonnes and 26.27 tonnes/ha, respectively in Gujarat. The area, production and productivity in major tomato-growing states in India vary (NHB, 2012). The area, production and productivity of Panchmahal district of middle Gujarat is 255 ha, 4200 tonnes and 16.17 tonnes/ha (GSG, 2010). The productivity of tomato is low as compared to the national and state level. The main reasons for low productivity in tomato are low coverage of high-yielding varieties/hybrids, heavy incidence of pest and disease and lack of adoption of scientific package of practices (Indira *et al.*, 2001).

Presently, only about 15% area is under hybrids of vegetables, of which, 36 and 30% area are covered under tomato and cabbage hybrids respectively (Prasanth and Kumary, 2014). There is a need to adoption hybrids and varieties to increase the productivity of tomato. The low productivity of tomato crops is not only threat to economic security of millions of small and marginal farmers but also to the world trade of tomato. Keeping the above points in view, frontline demonstrations (FLD) on tomato was initiated with objectives of showing the productive potential of improved production technologies under real farming situations over locally/traditionally cultivated tomato crop.

MATERIALS AND METHODS

The studies were carried out during *kharif* season of 2011-12 and 2012-13 at 20 farmers' fields by KVK in Panchmahal district. The total 40 frontline demonstrations in 12 ha area in different villages, *viz.* Bukhi, Kharsaliya, Nanderkha, Bediya and Richhiya were conducted. In general, soils of the area under study are medium black to reddish black with medium to low fertility status. The climatic conditions of area are

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characterized as hot semi-arid ecosystem. The average annual rainfall is 800-1450 mm mostly occurring during June- September. The minimum (10-12°C) and maximum (42-45°C) temperature were recorded during January and May respectively. The materials used in the present study with respect to FLDs and farmers practices are given in Table 1. In case of local control plots traditional practices were used.

The data on output of tomato cultivation were collected from FLDs and plots having existing practices. In demonstration plots, quality seed was provided and non-monetary inputs like manures and fertilizers, timely transplanting, plant-protection measures and weeding were also performed as per the recommondations of KVK experts. However,traditional practices were maintained in case of local control (Junagrah Rubi). The demonstrations were facilitated by KVK experts at farmers fields. The operations like weeding, line planting, nutrient management, spraying, weeding and harvesting were adopted as per the guidelines. For technology and extension gap, technology index were calculated as suggested by Samui *et al.* (2000).

$$\text{Average} = \frac{(F1+F2\_\ \_\ \_Fn)}{N}$$

F1 = Farmer

N = No. of farmers

Technology gap = Pi (Potential yield) – Di (Demonstration yield)

$$\text{Technology Index} = \frac{\text{Potential yield} - \text{Demonstration yield}}{\text{Potential yield}} \times 100$$

The collected data were tabulated and statistically analyzed to interpret the results.

RESULTS AND DISCUSSION

A comparison of productivity levels between FLD plots and existing practices (farmers, practices) is shown in Table 1. The improved production technologies, *viz.* use of improved varieties, seed treatment, raised seed bed preparation, balanced fertilizers application and integrated pest management produced on an average 25.32 per cent more yield of tomato compared to existing practices (156.35q/ha). The results indicated that frontline demonstrations have given a good impact over the farming community in Panchmahal district as they were motivated by the new agricultural technologies applied in FLD plots. The poled level the technology gap 15.75 q/ha were recorded. It may be attributed to the dissimilarity in soil fertility status of a particular plot and weather conditions. Hence, variety wise location-specific recommendations appear to be necessary to minimize the technology gap for yield level in different situations.

The similar findings were also reported by Kumar *et al.* (2014) in okra. On pooled basis the extension gap (39.57 q/ha) was recorded, emphasizing the need to educate the farmers through various means for adoption of improved agricultural production technologies. It is clear that the extension gap reduced from 43.90 q/ha (2011-12) to 35.25 q/ha (2012-13). It means the level of knowledge and adoption of improved agricultural production technologies by farmers increased. More and more use of latest production technologies with high-yielding varieties will subsequently change this alarming trend of galloping extension gap.

The new technologies will eventually lead to farmers to discontinue the old varieties/technology and to adopt new good agriculture practices. The technology index shows the feasibility of evolved technology at farmers fields. The lower the value of technology index, more is the feasibility of technology. In present study, it was reducing in sub-sequent year from 22.35% (2011-12) to 18.03% (2012-13), exhibiting the feasibility of technology demonstrated (Table 2) in the FLD. The more or similar findings are also reported by Hiramath

Table 1. Details of tomato growing under front line demonstration and existing practices.

Operation	Existing practices	Improved practices demonstrated
Variety	Local seeds (Junagrah Rubi)	Improved cv. Gujarat Tomato-2, developed by Anand Agricultural University, Anand (Gujarat)
Seed treatment	No seed treatment	Seed treatment with Carbendazim (3 g/kg seeds) or imidacloprid 70WS (10 g/kg seeds)
Raising of seedlings	By flat bed broadcasting	By raised bed line sowing
Fertilizer application	FYM-10 tonnes/ha	FYM-20 tonnes/ha N:P:K@80:40:00 N:P:K@100:50:50 kg/ha
Pest management	Non-adoption of IPM practices	Adoption of IPM practices
Quality improvement	Un-hygienic at farm level	Adoption of improved post-harvest handling practices

Table 2. Exploitable productivity, extension gap, technology gap, technology index of tomato under FLD and existing practices

Year	Area (ha)	No.of FLDs	Yield (q/ha)		Increasein FLD	Extension gap (q/ha)	Technology gap (q/ha)	Technology index (%)
			FLD	Existing practice				
2011-11	2.5	5	196.40	152.50	28.78	43.90	12.10	22.35
2012-13	5.0	10	195.45	160.20	21.87	35.25	19.40	18.03
Poled	3.75	7.5	195.92	156.35	25.32	39.57	15.75	20.19

Table 3. Economics of tomato production under FLD and existing practices

Year	Cost of cultivation		Gross return		Net return		B:C ratio	
	FLD	Existing practice	FLD	Existing practice	FLD	Existing practice	FLD	Existing practice
2011-12	38900	37200	108020	86900	67920	49700	2.69	2.33
2012-13	42000	39000	107250	88000	65250	49000	2.55	2.26
Poled	40450	38100	107635	87450	66585	49350	2.62	2.29

and Nagaraju (2010) in chilli and Hiramath *et al.* (2007).

The comparative economics / profitability, of tomato cultivation with adoption of improved production technology and farmers practices has been presented in Table 3. On pooled basis the cost of cultivation (₹ 40,450), gross return (₹ 107,635/ ha), net return (₹ 66.585 / ha) and benefit : cost ratio (2.62) was recorded by adopting the improved production technology under FLDs as compression to existing practices (₹ 38,100, 87,450 and 2.29 respectively). These results were in conformity with the findings of Hiremath *et al.* (2009) in chilli, Kumar *et al.* (2014) in okra and Mishra *et al.* (2009) in potato. Hence, by conducting frontline demonstrations of proven technologies, yield potential of tomato can be increased to great extent. This will subsequently increase the income as well as the livelihood of farming community.

REFERENCES

GSG, Gandhi Nagar. 2010. Report, Gujarat State Government, Gandhi Nagar, pp. 27.

NHB, Gurgaon. 2012. *Indian Horticulture Detabase*-2012. National Horticulture Board, Ministry of Agriculture, Government of India, Gurgaon.

Hiramath S M and Nagaraju M V. 2010. Evaluation of on-farm frontline demonstrations on yield of chilli. *Karnataka J. Agric. Sci.* **23**(2): 341-42.

Hiremath S M, Nagaraju M V and Shashidhar K K. 2007. Impact of frontline demonstrations on onion productivity in farmers fields. *In: National Seminar on Appropriate Extension strategies and Management of Rural Resources*, Univ. Agric. Sci., Dharwad, 18-20 December, p. 100.

Indira P, Gopalkrishnan T R and Peter P V. 2001. Spices in India. *In: Silver Jubilee Seminar on Spices*, Indian Institute. Spice Research., Calicut, 8-9 October, pp. 143-152.

Kumar R, Khadda, B S, Jadav, J K, Rai, A K and Lata, K. 2014. Impact of front line demonstrations on productivity of Okra cv. Gujarat Okra-2 in Panchmahals district of middle Gujarat. *Indian. J. Arid Hort.* **8**(1-2): 68-70.

Mishra D K, Paliwal D K, Tailor R S and Deshwal A K. 2009. Impact of Frontline Demonstrations on Yield Enhancement of Potato. *Indian Res J. Ext. Edu.* **9**(3): 26-28.

Prasanth K and Kumary S. 2014. Utilization of male sterility for hybrid seed production in vegetables. *Current Horticulture* **2**(2): 3-14.

Samui S K, Maitra S, Roy D K, Mondal A K and Saha D. 2000. Evaluation on front-line demonstration on groundnut (*Arachis hypogea* L.). *J. Indian Soc. Coastal Agric. Res.* **18**: 180-83.

Current Horticulture **5**(1): 43–48, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Determining leaf : fruit ratio for high productivity in apple *(Malus pumila)* under intensive orcharding system

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Received: November 2015; **Revised:** December 2016

ABSTRACT

An experiment was conducted to determine the optimum leaf : to fruit ratio in 8 apple (*Malus pumila* Mill.) cultivars under high-density planting system in Karewa (dry) areas of Jammu and Kashmir. The maximum leaf area per fruit was recorded in Jona Gold, whereas maximum coloured surface were noted in Starkrimson but the size of fruits in terms of fruit weight was less. The maximum leaf area was recorded when leaves were of 35 in number. Thirty-five leaves/fruit provided maximum leaf area (479.75 cm^2/fruit). Irrespective of cultivars, fruit skin colour, fruit weight, fruit length, fruit diameter and TSS were highest in 30 leaves/fruit. Maximum fruit colour was found in Starkrimson, Vista Bella and Red Chiefwith 30 leaves/fruit which had significant influence. Significantly higher fruit weight was observed in Mollies Delicious with 30 leaves/fruit. The maximum fruit polar length (FPL) was recorded in Starkrimson and Mollies Delicious when 30 leaves kept for one fruit. The maximum TSS was observed in 'Vista Bella' and 'Mollies Delicious' with 30 leaves/fruit. The maximum yield/tree was recorded in 'Mollies Delicious' with 30 as well as 35 leaves/fruit. Leaf area had positive correlation with fruit weight, fruit length and yield/tree, while fruit colour had positive significant correlation with acidity and total sugars.

Key Words: Leaf: fruit ratio, Leaf area/fruit, Fruit quality, Fruit skin colour, HDP

Apple, (*Malus pumila* Mill.) an important temperate fruit has been cultivated in Europe and Asia from antiquity. Due to its wider adaptability it is grown in Siberia (-40°C) and in high elevations of Columbia and Indonesia.In India, apple is mainly grown in Jammu and Kashmir, Uttrakhand and Himachal Pradesh commercially. It occupies 2.735 lakh ha area with 25.631 lakh tonnes of production. Jammu and Kashmir records highest productivity (11 tonnes/ha) which is highest as compared Himachal Pradesh and Uttarakhand. Further, existing productivity is far below in comparison to advanced countries like Austria (84.1 tonnes/ha) and Switzerland (62.22 tonnes/ha). Further, India has a huge potential to increase its productivity by 40-50 tonnes/ha through properly addressing the yield constraints by advanced technological interventions.

Among constraints, low-planting density, old and senile orchards and poor canopy and nutrient management, canopy management has emerged as one of the most important aspect to address quality and productivity. On the basis of the bibliometric analysis there are no data about management of cropload in high-density apple orchard by maintenance of leaf : fruit ratio, by altering the fruit number at bold pea stage nor any altering the whole canopy to determine perfect balance of leaf : fruit ratio. The development of novel crop load management techniques will be critical to adopt and successful high- density orcharding system in Karewa (*tarai* areas) belt of India, hence an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted during 2009 - 2010,involving 8 apple varieties, *i.e.* Starkrimson (V1), Mollies Delicious (V2), Super More Gold (V3), Vista Bella (V4), Red Chief (V5), Royal Delicious (V6), Jona Gold (V7) and Ambri (V8). Two-year-old apple varieties grafted on MM 106 rootstock were planted at 3.5 m ×

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3.5 m spacing and trained on modified central leader systems. The experimental site is located at Central Institute of Temperate Horticulture, Srinagar, at Karewa (dry) areas of Jammu and Kashmir situated at 34°, 45 N latitude and of 74°, 50 E longitude and 1640 m above mean sea-level. The area receive average maximum and minimum temperature of 19.63°C and 6.52°C respectively with rainfall of 60.72 cm and relative humidity 58.35%. The experiment was set up in a factorial randomized block design. The treatments were replicated thrice with 2 plants per unit.

The 144 plants having uniform trunk cross sectional area were selected for the experiment. Standard uniform cultural practices were followed in all the trees. After fruit attaining the size (10-15 mm), 30 days after petal fall, total fruits and leaves / tree were counted for determining the 25, 30 and 35 leaves against one fruit (LFR). In order to fix specified leaf : fruit ratio excess leaves as well as fruits were clipped where ever required as per the method of Usenik *et al.* (2010) in sweet cherry. The leaf area was measured by taking 15 representative samples from all the directions, middle, mature leaves between 15 and 30 July. The area was measured using portable leaf area meter.

The fruit weight was recorded using digital electronic balance, while fruit polar length and diameter were measured by digital Vernier Caliper. Total soluble solids content was recorded with the help of digital hand refractometer, whereas acidity and total sugars were estimated as per the method suggested of AOAC and per cent area of skin colour were recorded visually. The two-year data were pooled and analysed using data analyzing statistical software.

RESULTS AND DISCUSSION

Leaf area per fruit had great influence on varietal variation. There was significantly highest leaf area irrespective of number of leaves registered in Jona Gold (327.19 cm^2), followed by Ambri (321.66 cm^2), whereas least LA (263.50 cm^2) recorded in Vista Bella which are statistically at per with Starkrimson, Super More Gold, Red Chief and Royal Delicious (Table 1). Varieties also had significant effect on fruit colour. The greatest colour fruit (86.66%) was noted in Starkrimson, followed by Red Chief and Vista Bella, whereas least specify method of skin colour estimation in M & M was recorded in Mollies Delicious. Significant variation on fruit weight was registered.

Highest weight (158.75g / fruit) was noted in Mollies Delicious, smallest fruit (98.97 g) in Jona Gold which are statistically at par with parameters of external and internal quality. However, fruit polar length registered highest 82.77 (mm) in Starkrimson which was statistically at par to Mollies Delicious, whereas Vista Bella had shortest FPL (61.36 mm). Significantly, highest diameter (59.24 mm) was recorded in Starkrimson which was statistically at par to Mollies Delicious and Royal Delicious and least F D (49.31 mm) was registered in Jona Gold. Highest TSS (14.61 °Brix) was found in Vista Bella, followed by Mollies Delicious (14.26 °Brix), whereas Ambri registered least TSS (11.14 °Brix).

Starkrimson registered highest total sugars (17.83%), followed by Red Chief (16.54%), while lowest total sugars were noted in Vista Bella (11.00%). Significant variation in yield was registered in varieties irrespective of leaf number per fruit. Cultivar Mollies Delicious registered 93.86 kg fruits / tree, followed by 46.22 kg fruits / tree in Red Chief, whereas least yield was noted in Jona Gold (18.26 kg fruit / tree),whereas yield / tree recorded Starkrimson, Super More Gold, Vista Bella and Ambri.

The leaf area / fruit was highest (479.75 cm^2) in L3

Table 1. Effect of variety onleaf : fruit ratio and other quantitative and qualitative characters of fruits

Variety	Leaft area / fruit (cm^2)	Skin colour (%)	Fruit weight (g)	Fruit polar length (FPL) (mm)	Fruit diameter (FD) (mm)	TSS (°Brix)	Total sugars (%)	Yield / tree (kg)
V1 Starkrimson	272.79	86.66	102.51	82.77	59.24	11.62	17.83	20.45
V2 Mollies Delicious	316.39	63.88	158.75	81.73	58.34	14.26	12.16	93.86
V3 Spur More Gold	294.00	76.11	113.18	75.49	56.83	11.22	11.75	25.39
V4 Vesta Bella	263.50	83.88	104.39	61.36	52.11	14.61	11.00	25.68
V5 Red Chief	287.04	84.44	106.05	67.63	51.04	11.41	16.54	46.22
V6 Royal Delicious	273.65	76.66	114.49	77.79	58.47	13.2	14.23	39.76
V7 Jona Gold	327.19	76.11	98.97	71.28	49.31	11.68	13.77	18.26
V8 Ambri	321.66	78.88	102.41	72.07	55.88	11.14	13.07	26.92
LSD (P20.05)	30.10	3.77	15.61	2.97	2.01	0.56	0.45	19.82
SE (Mean)	15.00	1.87	7.75	1.47	1.00	0.28	0.22	9.84

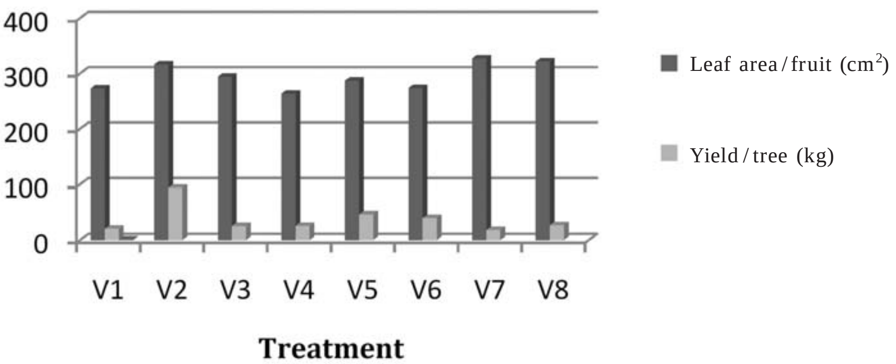

Fig. 1. Effect of variety on leaf area : fruit and yield / tree

(35 leaves), followed by L2 (243.73 cm^2) (30 leaves), whereas very low leaf area (160.1 cm) was noted in L1 (25 leaves). Skin colour, fruit weight, fruit length, fruit diameter, TSS and total sugars were highest with 30 leaves / fruit, irrespective of varieties, whereas fruit colour was statistically at par in L1 (25 leaves) and L3 (35 leaves) leaf numbers. L2 leaf numbers (30 leaves / fruits recorded highest yield 42.84 kg / tree, whereas yield was recorded statistically at par in L1 and L3 leaves number.

Highest leaf area (LA) (546.75 cm^2)was registered in Ambri with in 35 leaves / fruits, followed by 538.23 cm^2 and 538.0 cm^2 in Mollies Delicious and Jona Gold respectively with leaf numbers of 35 leaves, whereas very low (145.09 cm^2) LA registered in Mollies Delicious with 25 leaves.

Interaction effect of variety and leaf number were found significant on skin colour. Greatest color (91.66%) noted in Starkrimson, Vista Bella and Red Chief on 30 leaves / fruit. However, lowest skin colour (61.66%) was noted in Mollies Delicious on 25 leaves / fruit. Fruit weight recorded highest (173.42 g) in Mollies Delicious on 30 leaves / fruit, followed by (167.23 g) with 35 leaves in same varieties, whereas minimum fruit weight (91.51 g) was recorded in Starkrimsonon (25 leaves / fruit).

Fruit polar length (FPL) was highest (85.64 mm)

Table 2. Effect of leaf number onleaf : fruit ratio and other quantitative and qualitative characters

Treatment	Leaf area / fruit (cm^2)	Skin colour (%)	Fruit weight (g)	Fruit polar length (mm)	Fruit diameter (mm)	TSS (°Brix)	Total sugars (%)	Yield / (kg / tree)
25 leaves (L1)	160.1	76.45	103.98	70.61	52.91	11.52	12.87	35.01
30 leaves (L2)	243.73	83.12	120.52	77.46	58.04	13.31	14.96	42.89
35 leaves (L3)	479.75	75.41	113.27	73.22	54.51	12.34	13.55	33.35
LSD	18.43	2.31	9.56	1.82	1.23	0.34	0.27	12.13
SE (mean)	9.15	1.14	4.75	0.90	0.61	0.17	0.13	6.03

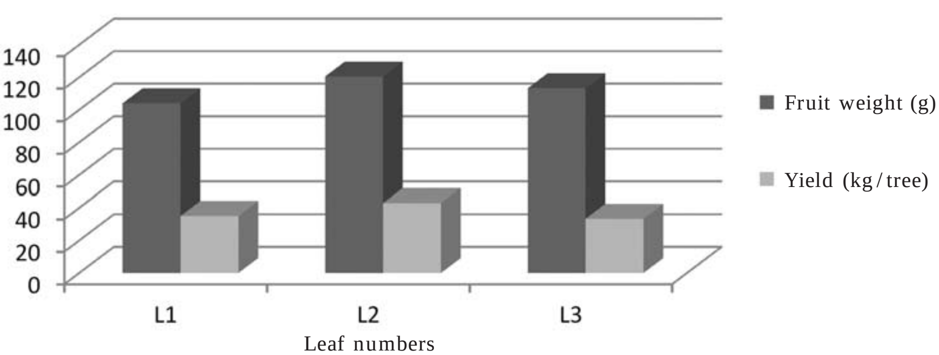

Fig. 2. Effect of leaf numbers on fruit weight and yield / tree.

Table 3. Effect of interaction on variety and leaves number on LA and other quantitative and qualitative characters

Treatment	Leaf area/fruit (cm^2)	Skin colour (%)	Fruit weight (g)	Fruit polar length (FPL) (mm)	Fruit diameter (FD) (mm)	TSS (°Brix)	Total sugars (%)	Yield/ (kg/tree)
V1 L1	160.22	86.66	91.51	80.48	57.12	10.43	16.56	15.1
V1 L2	233.50	91.66	110.61	85.64	62.23	12.7	19.3	23.88
V1 L3	424.65	81.66	101.41	82.19	58.38	11.73	17.63	22.36
V2 L1	145.09	61.66	135.60	77.70	56.00	12.66	11.46	46.64
V2 L2	265.84	66.66	173.42	85.38	61.97	15.86	13.3	147.63
V2 L3	538.23	63.33	167.23	82.11	57.06	14.26	11.73	87.30
V3 L1	179.06	73.33	103.56	72.88	54.97	10.3	11.33	43.65
V3 L2	244.5	81.66	122.51	77.82	58.85	11.93	12.36	15.61
V3 L3	458.45	73.33	113.46	75.79	56.68	11.43	11.56	16.91
V4 L1	147.24	81.66	97.21	58.69	50.91	13.23	10.53	18.91
V4 L2	220.90	91.66	111.20	63.66	53.69	16.06	11.5	26.42
V4 L3	422.35	78.33	104.77	61.72	51.72	14.53	10.96	31.73
V5 L1	167.02	81.66	100.36	62.36	48.69	10.76	15.3	62.32
V5 L2	222.74	91.66	111.36	75.25	53.82	12.13	18.2	52.60
V5 L3	471.38	80.00	106.43	65.28	50.62	11.33	16.13	23.78
V6 L1	151.55	75.00	105.45	72.69	55.12	12.66	12.9	52.25
V6 L2	230.96	81.66	126.66	85.01	62.72	13.83	15.86	19.02
V6 L3	438.45	73.33	111.29	75.68	57.56	13.1	13.93	48.02
V7 L1	178.22	73.33	93.88	67.92	47.23	11.16	12.93	16.39
V7 L2	265.57	78.33	103.47	75.17	52.08	12.4	14.83	23.58
V7 L3	537.77	76.66	99.56	70.74	48.62	11.5	13.56	14.80
V8 L1	152.37	78.33	100.27	72.15	53.25	11.00	12.00	24.83
V8 L2	265.85	81.66	104.95	71.76	58.96	11.56	14.36	33.99
V8 L3	546.75	76.66	102.00	72.28	55.44	10.86	12.89	21.94
LSD (p =0.05)	52.13	6.53	27.05	5.15	3.48	0.98	0.78	34.33
SE (Mean)	25.90	3.24	13.44	2.56	1.73	0.48		17.05s

V1: Starkrimson, V2: Mollies Delicious, V3: Spur More Gold, V4: Vesta Bella, V5: Red Chief, V6: Royal Delicious, V7: Jona Gold and V8: Ambri.

L1: 25 leaves/fruit, L2: 30 leaves/fruit and L3: 35 leaves/fruit

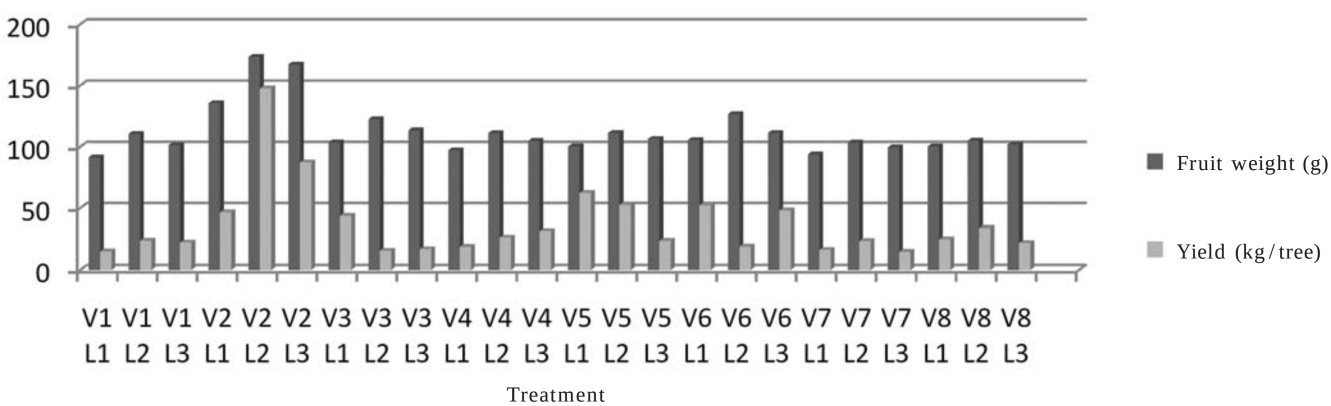

Fig. 3. Combined effect of variety and leaf number on fruit weight and yield/tree

and (85.38 mm) in Starkrimson and Mollies Delicious with 30 leaves respectively, whereas lowest FPL (58.69 mm) was recorded in Vista Bella with 25 leaves / fruit. So far as fruit diameter was concerned highest diameter (62.72 mm) was recorded in Royal Delicious with 30 leaves / fruit, followed by (62.23 mm) in Starkrimson on 30 leaves / fruit. Lowest diameter (47.23 mm) was noted in Jona Gold with 30 leaves / fruit. The TSS were highest 16.06 °Brix and 15.86 °Brix in Vista Bella and Mollies Delicious respectively with 30 leaves / fruit. Whereas lowest TSS (10.3 °Brix) was recorded in Super More Gold with 25 leaves / fruit. Total sugars registered highest 19.3% and 18.2%with 30 leaves / fruit in Starkrimson and Red Chief respectively, and least were (10.53%) recorded in Vista Bella with 25 leaves / fruit. Fruit yield tree was recorded highest 147.63 kg / tree and 87.30 kg / tree in Mollies Delicious at 30 leaves and 35 leaves fruits respectively, whereas lowest yield (14.80 kg / tree) was noted in Jona Gold with 35 leaves (14.80 kg / tree).

Leaf area had positive correlation with fruit weight, fruit length and yield / tree. Fruit colour had significant positive correlation with total sugars. Fruit weight had significantly high degree of positive correlation with fruit yield / tree. Fruit length had significant positive correlation with fruit diameter. The TSS also had positive correlation with fruit yield. Highest positive correlation was recorded between fruit weight and yield / tree (Table 4). These findings are in consonance of the results obtained by Lang (2004), who also observed the decrease in quality with decline leaf area 200 cm^2 / fruit in cherry. Further (Usenik *et al.*, 2010) observed the ripining process was accelerated by the highest leaf : fruit ratio.

To maintain regular cropping, there is a delicate balance between number of leaves and number of fruits / tree. Most apple cultivars require 80-90 sq inches of healthy green leaves to support one, 3 inch diameter apple; this is equivalent to 10 mature leaves / fruit. For a tree grafted onto M-9 dwarfing rootstocks are capable of sending about 70% of carbon to tree to fixes to the crop. In contrast a larger tree on seedling rootstocks puts more than half of the carbon into growing woods so a greater number of leaves are required to support a fruit. According to Michale (2008) in order to obtain a 3 inch diameter apple other fruit lets should be removed from a cluster when they are no larger than a dime.

The variation in fruit yield, fruit weight and quality may be attributed to variation in genetical constituents of varieties and number of leaves. Usenik et al. (2010), reported that high leaf area : fruit ratio influenced significantly darkest fruit color, higher fruit mass, higher TSS content and higher sugar : acid ratio. So for variation in leaves area / fruit might be due to varietal variation and instinct vigour of plants. Der Nan (2006) reported that fruit size, TSS and skin colour were better on high leaf : fruit ratio than low leaf; fruit ratio / tree, and optimized fruit cluster number / tree 200 for 8-10 years old trees and 400 fruits / tree for 20 year old trees. He found 35 to 40 leaf : fruit ratio for getting the best wax-apple fruits.

Harley *et al.* (1932) found that when leaves number was 10 / fruit, no flower bud initiation accured, whereas in case of 70 leaves / fruit all spurs differentiated flower buds.

Haller and Magnese (1925) were among the first to use leaf : fruit ratio (LFR), number of leaves / fruit is an attempt to optimize crop load. They found a strong correlation between increase in fruit volume and leaf area supplying the fruit. They also noted there is a LFR

Table 4. Correlation among various characters in apple cultivars for the leaf fruit ratio.

Character	Leaf area / fruit (cm^2)	Skin colour (%)	Fruit weight (g)	Fruit length (cm)	Fruit diameter (mm)	TSS (°Brix)	Acidity (%)	Fruit yield (kg / tree)
Leaf area / fruit (cm)	I	-599	0.232	0.159	-0.207	-0.318	-0.701	0.222
Fruit colour (%)		I	-0.839	-0.421	-0.262	-0.351	0.773	-0.730
Fruit weight (g)			I	0.488	0.458	0.548	-0.658	0.943
Fruit length (cm)				I	0.804	-0.118	-0.709	0.353
Fruit diameter (mm)					I	0.106	-0.297	0.304
TSS (%)						I	0.150	0.514
Acidity (%)							I	-0.603
Total sugars (%)								-0.170
Fruit yield / tree								I

** Correlation is significant at 0.01 level (2-tailed)
* Correlation is significant at 0.05 level (2-tailed).

at which maximum fruit growth is obtained 30-40 for Grimes and Ben Davis and up to 75 for Delicious. Hansen (1969) calculated the saturation & leaf area / fruit (*i.e.* the point at which all available assimilates are fixed in fruits) as 14-17 leaves / fruit in Golden Delicious. Aldrich and Fletcher (1932) also found that number of leaves / fruit was related positively to percentage blooming and setting the following season.

Shen (1941) found some positive relationship and noted that there is a limit of about 700-1400 cm^2 leaf area / fruit beyond which flower bud differentiation does not increase. Thus, altering the leaf number / fruit at fruit development primarily influenced the fruit quality of apple. In this experiment 30 leaves / fruit resulted in high skin color, fruit weight, fruit diameter and total soluble solids content. Whereas yield / tree was influenced by 35 leaf : fruit ratio. Manually maintaining proper amount of leaf : fruit ratio may not be practical, but in particular years may be necessary for some cultivars, especially in dwarfing rootstocks. Strategies for improving canopy source -sink relation are essential not only for improving fruit quality, but also for proper fruit development and obtaining optimum crop following year.

REFERENCES

Aldrich W W and Fleteher L A. 1932. Relation of foliage system and fruit thinning to biennial bearing in apple. *Proceeding of American Society for Horticultural Science* **29**: 56-61.

Forshey C G and Elfving D C. 1977. Fruit number, fruit size and yield relationships in 'Mclntosh' apples. *Journal of the American Society for Horticultural Science* **102**: 399-402.

Haller M H and Magness J R. 1925. The relation of leaf area to the growth and composition of apples. *Proceeding of American Society for Horticultural Science* **22**: 189-96.

Hansen P. 1969. C-Studies on apple trees: IV. Photosynthates consumption in fruits in relation to the leaf - fruit ratio and to leaf- fruit position. *Physiology* **22**: 186-89.

Harley C P Masure M P and Magness J R. 1932. Effect of leaf area, nitrate of soda and soil moisture on fruit bud formation in the Delicious Apple. *Proceeding of American Society for Horticultural Science* **29**: 193-98.

Michele W. 2008. Leaf to Fruit Ratios: A Balancing Act for Sustained Apple Production. *Environment and Garden* **14**(3): 15-16.

Shen T. 1941. The influence of leaf-fruit ratio o alternate bearing in the apple. *Proceeding of American Society for Horticultural Science* **38**: 127-32.

Usenik Valentina, Orazem P. and Stampar F. 2010. Low leaf to fruit ratio delays fruit maturity of 'Lapins' sweet cherry on Gisela5. *Scientia Horticulturae* **126**: 33-36.

Wang Der Nan and Bi-Jauan L. 2006. Effect of leaf fruit ratio on fruit quality of wax apples. Special publication Taichung District Agricultural Improvement Station *(Youngwu, Chen. and Lin Ren, Chavg)* (Eds).

Whiting M D and Lang G A. 2004. Bing sweet cherry on the dwarfting rootstock. 'Gisela 5': tinning affects fruit quality and vegetative growth but not net CO_2 exchange. *Journal of the American Society for Horticultural Science* **129**: 401-15.

Current Horticulture **5**(1): 49–52, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Effect of foliar spraying of organic liquid fertilizer and micronutrients on flowering, yield-attributing characters and yield of banana *(Musa paradisiaca)* cv. Grand Naine

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Received: September 2016; **Revised:** May 2016

ABSTRACT

A field experiment was conducted to find out the effect of novel organic liquid and combi - F, grade - IV micronutrient on flowering, yield-attributing characters and yield of banana (*Musa paradisiaca* Linn.) cv. Grand Naine during 2014-15 and 2015-16 at Instructional Farm of ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat). The experiment was laid out in a randomized block design with factorial concept comparising two factors, *viz.* different levels of novel organic liquid fertilizer (0, 1 and 2%) and combi - F, grade - IV micronutrient (0, 1, 1.5 and 2%). The treatments were replicated thrice and applied 3, 5 and 7 months after planting. The foliar application of 1% novel organic liquid fertilizer was found better for getting maximum finger girth, length and girth of bunch, weight of third hand, fingers/bunch, number of hands/bunch, bunch weight and yield. While maximum finger length was reported with foliar application of 2% novel organic liquid fertilizer. However in case of micronutrient, foliar application of 1.5% combi - F, grade - IV micronutrient 3, 5 and 7 months after planting (F_3) gave maximum finger length, finger girth, length and girth of bunch, weight of third hand, fingers/bunch, number of hands/bunch, weight of bunch and yield.

Key Words: Novel organic liquid fertilizer, Micronutrient, Yield, Fingers, Bunch, Hands

Banana (*Musa paradisiaca* Linn.) popularly known as Apple of Paradise, is staple food in Uganda, Bakauba and Tanzania and most important traded tropical fruit in the world (Radha and Mathew, 2007). The use of inorganic fertilizers alone may cause problems for human health and the environment (Arisha and Bradisi, 1999). Long-term studies on various crops indicated that the balanced use of NPK fertilizer could not maintain higher yield over the years because of emergence of secondary and micronutrient deficiencies and deterioration in soil physical properties. Use of organic manures alone cannot fulfill the its nutrients requirement (Kondapa *et al.*, 2009). Bokhtiar *et al.* (2008) reported that organic manures when applied with chemical fertilizers gave better yield than individual ones. In recent times, consumers are demanding higher quality and are safer food and highly interested in organic products (Ouda and Mahadeen, 2008). Hence there is an urgent need to improve organic fertilizers with natural minerals through biological processes.

Apart from direct use of sap as liquid fertilizer, an enrichment process was developed (patented) for preparing novel organic liquid fertilizer (NOLF) suitable for foliar and soil application. It was tested in mango, banana, wheat and paddy. The NOLF has been prepared using only organic inputs and hence it is suitable for use in organic farming system as liquid formulation. Organic liquid fertilizer is good source of plant nutrient along with growth-promoting substances like cytokinin, GA_3, *etc.* (NAU., 2014). However, there is very wide information gap on efficiency and utilization of banana pseudostem sap as organic liquid fertilizer in India and abroad. Keeping all these points in view, an experiment

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was conducted to find out the effect of novel organic liquid fertilizer with micro-nutrient application on yield of banana cv. Grand Naine.

MATERIALS AND METHODS

The experiment was conducted at the Instructional Farm of ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Taluka, Jalalpore, district Navsari, during 2014-15 to 2015-16. The experimental plot was prepared by deep ploughing and harrowing. The pits of 30 cm radius were dug out by tractor-drawn digger at a spacing of 2.4 m × 1.2 m and well-decomposed fine-textured farmyard manure @ 10 kg/pit was applied at time of planting. The experiment was laid out in randomized block design with factorial concept comparising two factors, *viz.* different level of novel organic liquid fertilizer (0, 1 and 2%) and Combi - F, Grade - IV micronutrient (0, 1, 1.5 and 2%).

The treatments were replicated thrice.The individual effects of foliar applications were secorded 3, 5 and 7 months after planting of different levels of novel organic liquid fertilizer and micronutrient treatment as well as their interaction on yield. The data on yield per net plot was recorded 3, 5 and 7 months after planting and multiplied by multiple factor computed on area basis to give the final data for total yield.

RESULTS AND DISCUSSION

There were significant increase in length and girth of fingers and bunch (cm) due to 1% novel organic liquid fertilizer (N_2) (Table 1). It might be due to higher carbohydrate accumulation in plant at early stages of growth which resulted in better nutrient supply, increasing fruit and bunch size in terms of length and girth. Similar results were reported by NAU (2011) and NAU. (2014) in banana and Deore *et al.* (2010) in chilli. The foliar application of 1% novel organic liquid fertilizers (N_2) had maximized number of fingers/ bunch, number of hands/bunch, bunch weight, weight of third hand and yield over other treatments.

The lower yield of banana recorded under the control treatment might be due to slow growth of plant, small leaf size, less number of hands and fingers/ bunch. Yield/plant increased with foliar application of novel organic liquid fertilizer due to macro and micronutrients present in novel organic liquid fertilizer. The nutrients, N and K, at higher rate exerted a significant positive effect on bunch weight. The highest bunch weight was recorded in plants treated with 1% novel organic liquid

Table 1. Effect of novel organic liquid fertilizers and micronutrient on yield parameters of banana cv. Grand Nain (mean of two years)

Treatment	Initiation of inflorescence (days)	Finger length (cm)	Finger girth (cm)	Period of fruit maturity (after flowering, days)	Length of bunch (cm)	Girth of bunch (cm)
Novel organic liquid fertilizer (N)						
N_1	264.23	18.23	11.74	124.52	72.60	89.07
N_2	253.14	20.63	12.62	120.09	88.12	102.04
N_3	256.74	20.68	12.46	121.09	82.33	98.62
SEm ±	3.39	0.30	0.20	1.92	1.53	1.98
CD (5%)	NS	0.86	0.57	NS	4.37	5.65
Micronutrient (F)						
F_1	265.54	17.74	11.76	124.82	70.81	87.40
F_2	257.59	19.95	12.14	121.97	81.86	97.60
F_3	253.19	21.02	12.79	120.04	87.07	101.90
F_4	255.83	20.67	12.40	120.79	84.31	99.41
SEm ±	3.88	0.34	0.23	2.19	1.76	2.26
CD (5%)	NS	0.98	0.65	NS	5.00	6.45
Interaction effect (N × F)						
SEm ±	6.53	0.58	0.38	3.69	2.95	3.80
CD at (5%)	NS	NS	NS	NS	NS	NS
CV (%)	6.59	7.60	8.12	7.89	9.49	10.28

fertilizer, which might be due to higher uptake of N and K by plants. Usefulness of nutrients to determine the effect on yield-attributing characters of banana is adequately stressed. Our study also corroborated with the findings of NAU (2011) and NAU (2014) in banana.

The foliar application of combi - F, grade - IV micronutrient increased size of fingers, *i.e.* finger length and diameter 3, 5 and 7 months after planting. This might be directly associated with better vegetative growth, which resulted into increased synthesis of starch food material that was reflected in increased size of fingers in terms of length and girth of finger with micronutrient feeded plants. Similar results were also found by Ghanta and Mitra (1993), Suresh and Savithri (2001), Yadav *et al.* (2009), Patel *et al.* (2010) and Pathak *et al.* (2011) in banana.

The foliar application of 1.5% combi - F, grade - IV micronutrient treatment 3, 5 and 7 months after planting recorded more number of fingers / bunch and number of hands / bunch. Foliar application of micronutrients involved directly in various physiological processes and enzymatic activity. This might have resulted into better photosynthesis, more accumulation of starch in fruits and involvement of Zn in auxin synthesis and B in translocation of starch to fruits. The balance of auxin in plant increased total number fingers / bunch and number of hands / -bunch 3, 5 and 7 months after planting.

The spraying of micronutrients significantly increased length and girth of bunch. Zn plays a vital role to promote starch formation. The possible reason for increase in length and girth of banana bunch is by increased finger length and girth, number of fingers / bunch and number of hands / bunch by micronutrients, might be due to faster loading and mobilization of photo assimilates to fruits and involvement in cell division and cell expansion which ultimately reflected into more length and girth of banana bunch in treated plants (Ghanta and Mitra, 1993).

The yield was signi-ficantly affected by micronutrients. The maximum yield was obtained from plants treated with 1.5% combi-F, grade-IV micronutrient compared to other treatments 3, 5 and 7 months after planting. Iron (Fe) is highly associated with chlorophyll synthesis which later on boosted up to photosynthesis. Promotion of starch formation followed by rapid transportation of carbohydrates in plants is activated by micronutrients like Zn and B which are well established. The most outstanding effect of micronutrients on yield was due to favourable effect on finger size, higher number of fingers / bunch, number of hands / bunch, weight of bunch and weight of third

Table 2. Effect of novel organic liquid fertilizer and micronutrient on yield parameters of banana cv. Grand Naine (mean of two years)

Treatment	Weight of third hand (kg)	Number of fingers / bunch	Number of hands / bunch	Weight of bunch (kg)	Yield (tonnes / ha)
Novel organic liquid fertilizer (N)					
N_1	3.03	161.47	8.31	27.20	94.45
N_2	3.62	171.08	9.63	31.09	107.85
N_3	3.56	168.90	9.25	29.76	103.25
SEm ±	0.06	1.81	0.19	0.61	2.10
CD (5%)	0.18	5.16	0.54	1.73	5.99
Micronutrient (F)					
F_1	2.90	159.65	8.14	26.72	92.72
F_2	3.40	167.25	9.04	29.42	102.19
F_3	3.70	171.44	9.67	31.11	107.93
F_4	3.62	170.28	9.40	30.14	104.57
SEm ±	0.07	2.07	0.21	0.69	2.41
CD (5%)	0.21	5.89	0.61	1.98	6.86
Interaction effect (N × F)					
SEm ±	0.12	3.47	0.36	1.17	4.04
CD (5%)	NS	NS	NS	NS	NS
CV (%)	9.37	5.41	10.42	10.35	10.33

hand attributing characters. These results are in confirmation with those of Ghanta and Mitra (1993) and Anjali *et al.* (2013) in banana.

REFERENCES

Anjali, Lenka P C, Das S N and Das S S. 2013. Effect of micronutrients on growth and yield on banana cv. Grand Naine. *Env. Eco.* **31**(4): 1919-21.

NAV Navsari. 2014. Effect of enriched banana pseudostem sap (injection) at pre-flowering stage on production and quality of banana var. Grand Naine. 10th *AGRESCO Report, S.W.M.R.U., NAU, Navsari,* pp. 115-28.

NUA Navsari. 2011. Evalution of banana pseudostem sap as liquid fertilizer through drip in banana. 7th *AGRESCO Report, S.W.M.R.U., NAU, Navsari,* pp. 75-82.

Arisha H M and Bradisi A. 1999. Effect of mineral fertilizers and organic fertilizers on growth, yield and quality of potato under sandy soil conditions. *Zagazig J. Agric. Res.* **26**: 391-405.

Bokhtiar S M, Paul G C and Alam K M. 2008. Effects of organic and inorganic fertilizer on growth, yield, and juice quality and residual effects on ratoon crops of sugarcane. *Journal of Plant Nutrition* **31**(10): 1832-43.

Deore G B, Limaye A S, Shinde B M and Laware S L. 2010. Effect of novel organic liquid fertilizer on growth and yield in chilli (*Capsicum annum* L.). *Asian J. Exp. BIol. Sci. Spl.* pp. 15-19.

Ghanta P K and Mitra S K. 1993. Effect of micronutrients on growth, flowering, leaf nutrient content and yield of banana cv. Giant Governor. *Crop Res.* **6**(2): 284-87.

Kondapa D, Radde B M, Patil P L, Hebsur N S and Alagundagi S C. 2009. Effect of integrated nutrient management on growth, yield and economics of chilli cv. Byadgi dabbi in a vertisol. *Karnataka J. Agric. Sci.* **22**(2): 438-40.

Ouda B A and Mahadeen A Y. 2008. Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli *(Brassica oleracea var. italica). International. J. Agriculture. Biol.* **10**: 627-32.

Patel A R, Saravaiya S N. Patel A N, Desai K D, Patel, N M and Patel J B. 2010. Effect of micronutrients on yield and fruit quality of banana (*Musa paradisica* L.) cv. Basarai under pair row planting method. *Asian J. Hort.* **5**(1): 245-48.

Pathak M, Bauri F K, Misra D K, Bandyopadhyay B and Chakraborty K. 2011. Application of micronutrients on growth, yield and quality of banana. *Journal of Crop and Weed* **7**(1): 52-54.

Radha T and Mathew L. 2007. *Fruit Crops*. New India Publisging Agency, New Delhi, pp. 33.

Suresh S and Savithri P. 2001. Yield and quality of wetland banana as influenced by liming and nutrients application in an acid soil. *Haryana J. Hort. Sci.* **30**(1-2): 12 - 13.

Yadav M K, Patel N L, Patel S R and Kirtibarhan. 2009. Response of banana to micronutrients. *Annals of Plant Physiology* **23**(1): 71-73.

Current Horticulture **5**(1): 53–57, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Effect of planting time on Gerbera *(Gerbera jamesonii)* in open field conditions

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Received: September 2016; **Revised:** March 2017

ABSTRACT

An experiment was conducted to enhance flower yield by manipulating planting time of Gerbera (*Gerbera Jamesonic* Bolus ex Hook.) during 2006-09 at Medziphema, Nagaland, under humid tropical conditions of Nagaland, following eight different dates of planting (15 March- 15 October) on Alfisol in a randomised complete block design in open field conditions. The difference in planting time brought a statistically significant difference in performance of cut flowers, primarily due to difference in soil moisture content (153.2 g/kg during May date of planting to 301.6g/kg during August date of planting, coinciding linearly with amount of rainfall received). However, the treatment with June date of planting gave best response in terms of number of leaves at flowering (15.96), leaf area (138.78 cm^2) and plant height at flowering (27.09 cm). The June date of planting further gave best response on flowering characteristics, *viz.*, flower size (9.12 cm) and stalk length (35.77 cm). These parameters collectively imparted higher number of flowers (220.1 $/m^2$) and flower yield (2.95 kg/m^2) with June date of planting compared to number of flowers (179.7-197.4 $/m^2$) and flower yield (1.45-2.25 kg/m^2) with rest of the other dates of planting. Therefore, an effective benchmark of optimum soil moisture content (201.0 g/kg, *i.e.* 82.8% of 33 KPa soil moisture) is necessary to harness upon the benefit of suitable planting time in order to raise the performance of Gerbera under rainfed open field conditions.

Key Words: Soil moisture, Planting time, Vegetative growth, Flower yield, Alfisol

Gerbera (*Gerbera jamesonii* Bolus ex Hook.) is the latest sensation to Indian Floriculture, commercially grown throughout the world in a wide range of climatic conditions. According to the global trends in floriculture, Gerbera occupies fourth place among cut flowers (Sujatha *et al.*, 2002). Variation in soil moisture in relation to planting time poses most profound effect on both vegetative as well as reproductive features. In a 3-year- trial on Gerbera conducted by Parthasarathy and Nagaraju (2003), it was observed and opined that flower bud initiation, growth, development and flowering were faster during warmer period (April - May and June - July). While the longevity of flowers was more during October - November. Similarly, studies conducted at Dharwad to evaluate the best planting time for Gerbera cv. Sath Bata showed a profound effect of staggered planting on vegetative as well as reproductive attributes, with July planting resulting in maximum flower size (Singh, 2001). Since north-eastern region has been identified as the potential belt for the development of floriculture, an experiment was conducted on planting time to extruct number of harvestings in Gerbera.

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MATERIALS AND METHODS

A field experiment under humid tropical climate (33.9-22.5°C as maximum temperature and 10.9-27.4°C as minimum temperature, 1100 mm rainfall and 80.6 - 91.7% relative humidity) was conducted during 2006-2009 at Government Nursery (25°45'43"N latitude; 93053'44"E longitude at an elevation of 210 m in above mean sea-level) at Dimpur, Nagaland. The experimental soil belonged to Alfisol (sand 594.0 g/kg, silt 241.5 g/kg, clay 164.5 g/kg, 33 KPa 242.6 g/kg, 1500 KPa 104.3 g/kg, soil pH 5.2, $KMnO_4$-N 148.6 mg/kg, Bray's-P 4.2 mg/kg and neutral NH_4OAc-K 98.9 mg/kg. The plot was ploughed deeply and thoroughly harrowed to a fine tilt. Individual beds of 1.2 m × 1.2 m size, raised to a height of 15 cm were prepared. At the time of planting, 7 tonnes FYM / ha along with recommended dose of fertilizer consisting of 60 kg N (urea), 40 kg P_2O_5 (single superphosphate) and 60 kg K_2O / ha were applied uniformly. Healthy suckers of Gerbera cv. Red Gem were collected from experimental farm of Assam Agricultural University, Jorhat, Assam, which was used as the planting material. The individual healthy suckers were separated from the clump, the leaves and roots were trimmed off. Thereafter, suckers were planted with utmost care not to cover the crown with soil.

The suckers were planted at a spacing of 30 cm × 30 cm, accommodating around 16 plants in each plot. Planting was done in evening hours, immediately followed by applying irrigation water. The plots were kept free from weeds throughout the growing period by manual weeding. For proper growth and development of plants, various intercultural operations such as irrigation, earthing-up, removal of dried leaves and flowers were done at regular intervals.

Eight treatments consisting of M_1(15 March date of planting), M_2(15 April date of planting), M_3(15 May date of planting), M_4(15 June date of planting), M_5(15 July date of planting), M_6(15 August date of planting), M_7(15 September date of planting) and M_8(15 October date of planting) replicated three times were tested in a randomized complete block design.

The number of leaves / plant was recorded from each sample plant and the average was taken. The observations were taken at the time of first flowering. Five number of leaves of various sizes were collected from each sample plant and were measured with the help of leaf area meter and the average was recorded in cm^2. The plant height was measured with the help of linear scale and expressed in centimeter. The observations were taken at the time of first flowering from the base of the plant to the tip of the longest leaf.

Days taken from planting to visibility of flower bud (pea-sized) at the ground level, days taken from planting to date when bud first begins to open, number of days taken from bud emergence to bud burst stage, days taken from date of planting to full opening of disc floret, diameter of flower (measured with the help of linear scale at full bloom stage and expressed in centimetre), length of flower stalk (measured in centimeter with the help of linear scale from the base of stalk to point where head is joined to tip of stalk), girth of flower stalk (measured at the mid portion of stalk with the help of Vernier caliper and expressed in centimetre). The flowers were harvested when outer rows of the disc floret were perpendicular to the stalk. Harvesting was done in morning hours by giving a sideward pull at the base of flower stalk. Immediately after harvesting, the stem end was immersed into a container half filled with clean water.

Soil samples (0-15 cm depth) collected at flowering stage were subjected to thermo-gravimetric analysis (Chopra and Kanwar,1986).

Critical Difference (CD) was calculated using as per the standard procedure. Linear coefficient of correlation ($r = \sigma xy / \sigma x \cdot \sigma y$, where σx and σy are standard deviations of x and y, respectively, and σxy the covariance) and regression analyses ($y = a + bx$, where y, a, b and x stand for dependent variable, intercept, regression coefficient and independent variable) were used to screen the soil properties significantly affecting fruit yield and quality (Rangaswamy, 1995).

RESULTS AND DISCUSSION

Different dates of planting from March (M_1) to October (M_8) displayed a significant variation in soil moisture from 153.2 g / kg during May date of planting (M_3) to 301.6 g / kg during August date of planting (M_6). Considering the field capacity (33 KPa) soil moisture, August (M_6) and September(M_7) dates of planting maintained a significantly higher soil moisture, while March (M_1), April (M_2) and May(M_3) registered soil moisture level with nearer to 1500 KPa. Correlation matrix developed for soil moisture variation versus all vegetative growth and yield parameters suggested strong effect of soil moisture on performance of Gerbera.

Correlation matrix developed for soil moisture variation versus all the vegetative growth and flower yield parameters suggested strong effect of soil oisture on the performance of Gerbera as evident from statistically significant correlations of soil moisture with number of leaves ($r = 0.512$, $p = 0.01$), leaf area ($r = 0.632$, $p = 0.01$), plant height ($r = 0.714$, $p = 0.01$), flower size ($r = 0.489$, $p = 0.01$), stalk length ($r = 0.382$, $p = 0.05$), number of flowers ($r = 0.716$, $p = 0.01$) and flower yield ($r = 0.743$, $p = 0.01$). Correlation studies carried out by Kannan and Ramdas (1990) showed that flower yield / plant had significant and positive correlation with a period of flower retention on plant, whereas number of leaves had significantly positive correlation with number of suckers / plant and flower stalk girth.

The time of planting inflicted a significant response on number of leaves / plant (Table 1). The maximum number of leaves / plant (15.96) was recorded when planting was undertaken in June (M_4), followed by July (M_5) month of planting (11.76 leaves / plant). It was statistically on a par with April - May (M_2-M_3) months of planting (10.99-10.78 leaves / plant). While least number of leaves (9.17 leaves / plant) was observed in March planting (M_1) which was statistically on a par with rest of the other months of planting, ranging from August (M_6) to October (M_8) recording 10.08-9.94 leaves / plant. Hence, most effective and least effective treatments were observed as M_4 (15.96 leaves / plant) and M_1 (9.17 leaves / plant), respectively.

The leaf area was observed as 138.78 cm^2 with treatment M_4 when planting was done in June. While on the other hand, minimum leaf area of 74.97 cm^2 was observed with treatment M_8 when planting was done in October. The other dates of planting such as March (M_1), August (M_6) and September (M_7) were not so effective in developing leaf area. While rest of the other treatments having planting dates of July (M_5) and April (M_2) were although responsive on a par to each other, but proved effective treatments as second order treatments to June date of planting (M_4) or July date of planting (M_5) as first order effective treatments.

The pooled data on plant height for both the seasons were analyzed and results obtained were almost of the same magnitude compared to data when analyzed season wise. The treatment M_4 (27.09 cm with June date of planting) continued its supremacy over rest of the other treatments. While M_7 and M_8 were observed as least effective treatment. From the pooled data analysis, June-July date of planting produced best response on plant height, followed by April - May and September - October date of planting.

The treatment M_4 (June date of planting) and M_2 (April date of planting) took 101.82 and 113.45 a days respectively, for bud emergence from planting time. Incidentally, these treatments suggested the most effective and least effective treatment, respectively. The same treatment M_4 (June date of planting) and M_2 (April date of planting) demonstrating as most effective and least effective treatment, respectively (Table 2) on bud burst stage from planting time. However, other treatments showed some variation in response when compared in one season versus next season.

Time taken from bud emergence to bud burst holds a strong promise in the context of readiness to full bloom. Number of days taken from bud emergence to bud burst significantly ($p \leq 0.05$) influenced by different dates of planting (Table 2). The treatment M_4 (June date of planting) took minimum days of 7.49 days when planted in June, closely on a par with other treatments such as M_5 (with July date of planting). However, M_8 was significantly superior to other treatments including M_6 (August date of planting), M_7 (September date of planting), M_8 (October date of planting), M_1 (March date of planting), M_2 (April date of planting) and M_3 (May date of planting).

This is most important criterion deciding the time of harvesting which triggers a profound effect on vase-life of cut flowers. The effect of change in planting time significantly affected the time taken (number of days) in attaining full bloom from planting time. The time taken for attaining full bloom from planting time varied from minimum of 116.56 days (with June date of planting) to maximum of 133.56 days (with October date of planting), coinciding with most effective and least effective treatment, respectively. Hence, by changing of date of planting, flowers can be cut earlier by 17.02 days, keeping all other cultural practices of cultivation the same, simply by virtue of variation in soil moisture variation.

The time of planting showed a significant response on size of flowers, which varied from minimum (7.82 cm), with treatment M_8 (October date of planting). While, maximum flower size was obtained as 9.12 cm with treatment M_4 (June date of planting). These two treatments, M_4 and M_8, were observed as least and most effective treatments, respectively, on the basis of responses obtained during both the season. Pooled data analysis demonstrated the similar pattern of response, where M_8 (7.82 cm) and M_4 (9.12 cm) establishing themselves as least and most responsive treatments respectively. The treatment M_4 displayed its clearcut superiority over rest of the treatments. However, treatments like M_7 versus M_1, M_2 versus M_3 or M_3

Table 1. Effect of planting time on vegetative growth of Gerbera cv. Red Gem

Treatment	Soil moisture (g / kg)	Number of leaves / plant	Leaf area (cm2)	Plant height (cm)
M_1 (March)	182.3	9.17	89.31	19.88
M_2 (April)	164.6	10.99	111.97	23.10
M_3 (May)	153.2	10.78	103.87	25.09
M_4 (June)	201.0	15.96	138.78	27.09
M_5 (July)	284.3	11.76	120.61	24.08
M_6 (August)	301.6	10.08	66.59	20.86
M_7 (Sept.)	284.3	9.80	87.71	19.56
M_8 (Oct.)	204.1	9.94	74.97	19.71
CD (p=0.05)	9.3	3.36	11.54	1.67

Pooled data of 2006-09

Table 2. Days taken to flowering in response to different planting time and flowering characteristics in Gerbera

Treatment	Soil moisture (g/kg)	Days to bud emergence	Bud burst stage from planting time	Bud emergence to bud burst	Full bloom from planting time	Flower size (cm)	Stalk length (cm)
M_1 (March)	182.3	108.96	118.32	9.36	128.20	8.25	26.46
M_2 (April)	164.6	113.45	122.56	9.11	130.44	8.09	26.35
M_3 (May)	153.2	58.92	112.56	9.05	121.63	9.05	31.99
M_4 (June)	201.0	101.82	109.31	7.49	116.56	9.12	35.77
M_5 (July)	284.3	102.21	110.57	8.36	120.10	8.75	36.17
M_6 (August)	301.6	109.70	119.07	9.37	129.96	8.61	29.89
M_7 (Sept.)	284.3	110.60	119.98	9.38	130.53	8.15	27.72
M_8 (Oct.)	204.1	112.53	122.03	9.5	133.56	7.82	27.65
CD (p=0.05)	9.3	1.93	1.93	0.69	2.20	0.30	2.42

Pooled data of 2006-09

versus M_4 showed non-significant difference (Table 2).

In cut flowers, higher length of flowers is a desirable feature. The stalk length was significantly ($p \leq 0.05$) affected by various planting time, irrespective of whether or not comparisons were made season wise or pooled data analysis. During both the seasons, treatments such as M_7, M_8, M_1 and M_2 showed non-significant response amongst themselves. Pooled data analysis responded almost through the same magnitude and pattern of response on stalk length in relation to differential date of planting. The maximum (36.17 cm) and minimum (26.16 cm) stalk length was recorded with treatment M_5 and M_2, respectively. However, M_5 was on a par with M_4, suggesting, thereby, the suitability of June-July as most suitable time of planting (Table 2).

Changing the time of planting has brought significant changes in both number of flowers and flower yield. The highest number of flowers (220.1/m^2) and flower yield (2.95 kg/m^2) were observed with treatment M_4 with June date of planting (Fig. 1). Incidently, this date of planting proved to be highly superior to rest of the other dates of planting. The difference of 50.4 flowers/m^2 was observed between least effective treatment M_7 (179.7 flowers/m^2 with September date of planting) and most effective treatment M_4 (220.1 flowers/m^2 with June date of planting). Likewise, with regard to responses of planting time on flower yield, more distinctive responses were observed . The variation in flower yield between most effective treatment M_4 (2.95 kg/m^2) and least effective treatment M_7 (1.45 kg/m^2) was highly significant (Fig. 2). The pooled data analysis followed the similar pattern of response. The treatment M_4 with June date of planting improved flower yield by 1.50 kg/m^2 compared with M_7 with September date of planting. Rogers (1973) earlier reported that turgidity in plants

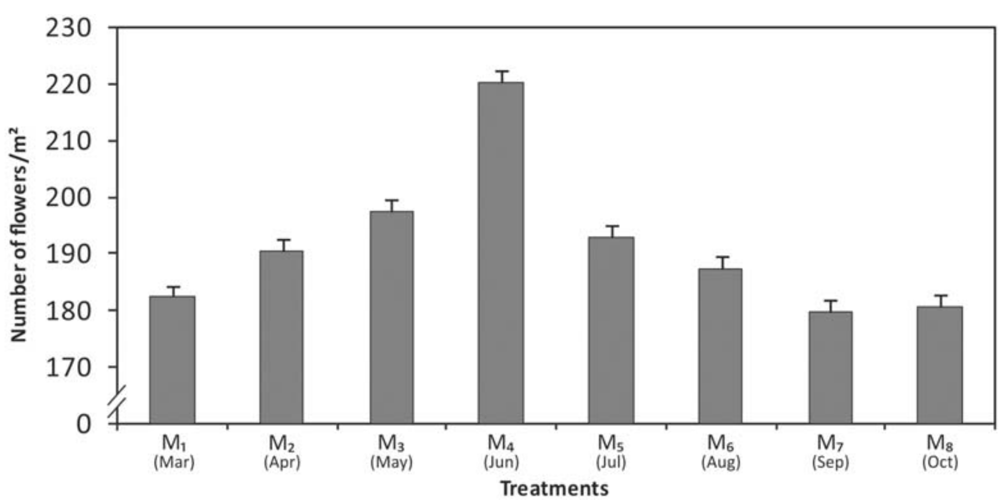

Fig. 1. Effect of different planting time on number of flowers in Gerbera (pooled data of 2006-09)

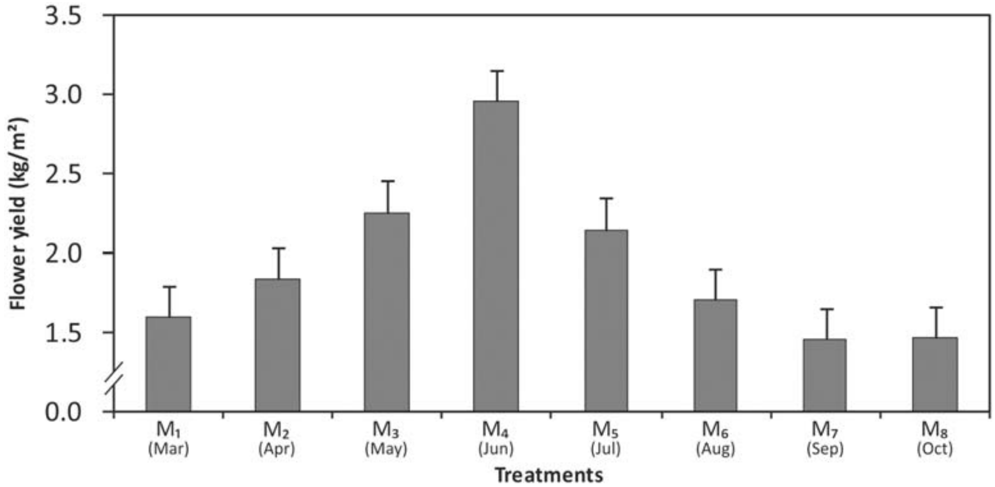

Fig. 2. Effect of different planting time on flower yield of Gerbera (pooled data of 2006-09)

induced by variation in soil moisture and number of florets depended on balance between rate of water loss, by plant and water supply within the rhizosphre.

Thus, the results strongly warranted that, simply changing the time of planting, in a way, using available soil moisture supply, keeping all other cultural practices uniform, could bring so much of improvement in crop response in terms of both number of flowers as well as flower yield in addition to other necessary features of flowers.

REFERENCES

Chopra S L and Kanwar J S. 1986. Soil analysis. In: *Analytical Agricultural Chemistry,* pp. 162-90. Kalyani Publishers, Ludhiana, Punjab.

Kannan M and Ramdas S. 1990, Variability and heritability studies in gerbera *(Gerbera jamesonii)*. *Progressive Horticulture* **22**(1-4): 72-76.

Parthasarathy V A and Nagaraju V. 2003. Evaluation of gerbera under mid-hills of Meghalaya. *Journal of Ornamental Horticulture* **6**(4): 376-80.

Rangaswamy R. 1995. *A Text Book of Agricultural Statistics*. Wiley Eastern Limited, New Delhi, pp. 142-201.

Rogers M N. 1973, A historical and critical review of post harvest physiology research on cut flowers. *Horticultural Science* **8**: 189-194.

Singh K P. 2001. Agro-techiques for gerbera cultivation in India. *Floriculture Today* **5**: 9-13

Sujatha K, Gowda J V N and Khan M M. 2002. Effects of different fertigation levels on gerbera under low cost greenhouse. *Journal of Ornamental Horticulture* **5**(1): 54-59.

Current Horticulture **5**(1): 58–60, January–June 2017 ISSN: 2347-7377; RNI No.: UPENG03865/24/1/2013-TC

Effect of soil fertility and nutrient availability in rhizosphere on Citrus *(Citrus reticulata)* yield

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Received: September 2016; **Revised:** May 2017

ABSTRACT

An experiment was conducted to find out the availability of nutrients in rhizosphere of Nagpur mandarin (*Citrus reticulata* Blanco) orchards, experiencing different levels of productivity during 2012-2013. Soil samples were collected and analysed for various soil fertility related parameters. The soil pH was slightly alkaline due to moderately calcareous soil, pH, and electrical conductivity being within a safe limit. The pH, EC, organic carbon and calcium carbonate varied from 7.12 to 7.74, 0.280 to 0.531 dS m^{-1} at 25° C, 0.70 to 0.89 per cent and 2.47 to 3.60 per cent, respectively in rhizosphere soil. Available nitrogen and phosphorus were low. It varied from 128.57 to 178.75 and 8.28 to 13.9 kg/ha, available potassium and available sulphur ranged from 313.6 to 571.2 kg/ha and 5.824 to 8.064 kg/ha, respectively. In micronutrient, DTPA-Fe, DTPA-Mn, DTPA-Cu and DTPA-Zn, ranged from 11.3 to 16.7, 5.71 to 9.34, 3.28 to 5.30 and 0.38 to 0.62 mg/kg. These limits showed large-scale zinc deficiency, whereas other micronutrients like Fe, Mn and Cu were in optimum limit.

Key Words: Soil fertility, Rhizosphere, Nagpur mandarin, Central India

Citrus (*Citrus reticulata* Blanco) is one of the world's major fruit crops with global availability and popularity, contributing to human diets. The portion of soil inhabited by roots, both horizontally and vertically, known as rhizosphere, influence the soil health, fruit yield and quality of citrus fruits (Srivastava and Singh, 2001b; 2008; Ngullie *et al.*, 2015). In order to sustain rhizosphere properties, microbes play a significant role in biofertilization of crops (Srivastava *et al.* 2014 and 2015). However, in perennial fruits crop like citrus, soil fertility and leaf analysis both complement each other (Srivastava and Singh, 2001a; 2005; 2009b). Earlier studies have shown wide variation in soil properties supporting high-yielding citrus orchards (Jagdish Prasad *et al.;* 2001; Srivsatva and Singh 2003a; 2003b), but such efforts are both soil type and cultivar-specific (Nijjar and Singh 1971; Srivasatva and Singh, 2002). The work on these lines are limiting, especially on Nagpur mandarin, so extensively grown in central India. Therefore, an experiment was conducted to delineated different soil fertility-related parameters vis-à-vis different fruit yield levels in citrus.

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MATERIALS AND METHODS

Four Nagpur mandarin (*Citrus reticulata* Blanco) orchards were selected at Hingna tahsil of Nagpur District. In all, 30 trees were selected from each orchard on the basis of yield, *i.e.* ten trees from low-yielding trees (< 500 fruits/trees), optimum-yielding (500-800 fruits/tree) and high-yielding (> 800 fruits/tree). Rhizosphere soil samples were collected during 2012-2013, from each tree perimeter of selected trees. Following the sampling procedure as outlined by Srivatava *et al.* (1999). The soil samples were brought to laboratory. They were ground and passed through a 100-mesh sieve (2 mm) for the analyses. The soil samples were processed and analysed for pH and EC, following standards procedures of Jackson (1967), electrical conductivity by Richards, (1954), organic carbon by Walkley and Black, (1934) and calcium carbonate by Piper (1966). Available nitrogen was determined by alkaline potassium permanganate method as described by (Subbiah and Asija, 1956), available phosphorus by using Olsen's method (Jackson, 1967), available potassium by extracting the soil with 1N neutral ammonium acetate solution using flame photometer

(Jackson, 1967) and available sulphur by Morgan's extract with turbidity method using colorimeter (Chesnin and Yien, 1950). The micronutrients such as Zn, Fe, Mn and Cu were determined using the procedure of Lindsay and Norvell (1978) using atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The results indicate that all samples were slightly alkaline in reaction. The rhizosphere soil pH varied from 7.12 to 7.50 in low-yielding citrus rhizosphere soils observed in sample low yielding-10 and lowest value (7.12) in sample low-yielding (Table 1). The average soil pH value of low yielding citrus rhizosphere soils was 7.34, while optimum and high-yielding trees were 7.49 and 7.50, respectively, showing that these clay soils have potential to perform well even at soil pH 7.50. The alkaline reaction of soil is probably due to presence of sufficient free lime content in these soils (Jibhkate *et al.* 2009). The electrical conductivity values ranged from 0.341 to 0.531 dS / m) in low-yielding trees (0.406 dS / m, 0.280 to 0.513 dS / m) in optimum-yielding trees. Average (0.382 dS / m) and 0.293 to 0.370 dS / m in high-yielding trees. (average 0.336 dS / m).

The overall electrical conductivity values ranged from 0.280 to 0.531 dS / m at 25°C, which is well within the acceptable limit of EC ranged designated for normal soils (Richards, 1954), indicating that these soils are non-saline. The average value of EC in citrus rhizosphere soils was 0.371 dS / m which is the safe range for growing citrus crop. The most important property controlling physical and chemical properties of soil is organic carbon content in soil (Srivastava *et al.*, 2015; Ngullie *et al.* 2015).

Table 1. Fertility status of citrus rhizosphere soil.

Rhizosphere soil properties	Orchards yield		
	Low (<30kg / kg)	Optimum (30-60kg / kg)	High (>60kg / ha)
Soil pH (1:2)	7.34	7.49	7.50
EC (1:2)	0.406	0.38	0.33
Organic carbon (%)	0.78	0.80	0.79
$CaCO_3$ (%)	3.17	3.13	3.00
$KMnO_4$-N	146.2	147.7	154.1
Olsen-P	11.0	27.6	11.0
NH_4OAc-K	423.7	453.5	427.4
$CaCl_2$-S	6.44	6.91	7.50
DTPA-Fe	13.5	14.3	15.4
DTPA-Mn	7.31	8.26	8.29
DTPA-Cu	6.29	4.48	4.46
DTPA-Zn	0.43	0.51	0.55

The organic carbon content varied from 0.71 to 0.85 per cent, in low-yielding citrus trees (average 0.78 per cent), 0.70 to 0.89 per cent, in optimum-yielding citrus trees, (average 0.80 per cent) and 0.72 to 0.85 per cent, in high-yielding citrus trees (average 0.96 per cent).The average value of organic carbon content in citrus rhizosphere soils was 0.79 per cent. It means majority of orchards belonged to the category of high to very high for content of organic carbon. (Srivastava and Singh, 2002; 2005). The data on calcium carbonate was presented in Table 1. Bacteria are capable of performing metabolic activities which thereby promote precipitation of calcium carbonate in the form of calcite. Siddik *et al.* (2013) showed microbial mineral precipitation. The calcium carbonate content ranged from 2.80 to 3.55 per cent in low-yielding citrus trees, with an average of 3.17 per cent, 2.55 to 3.60 per cent in optimum-yielding citrus trees with an average of 3.13 per cent and from 2.47 to 3.55 per cent in high-yielding citrus trees, with an average value of 3.0 per cent.

The range of available nitrogen varied from 131.7 to 166.2 kg ha (average 146.3 kg / ha) 128.6 to 169.3 kg / ha (average 147.8 kg / ha) and 134.8 to 178.8 kg / ha (average 154.17 kg / ha in low-yielding, optimum-yielding and high-yielding trees, respectively. The rhizosphere soils of citrus orchards were low in available nitrogen due to application of sub-optimum dose of nitrogen. The available phosphorus ranged from 8.5 to 13 kg / ha in low-yielding citrus trees, 8.3 to 13.9 kg / ha in optimum-yielding citrus trees and 8.7 to 13 kg / ha in high-yielding citrus trees, While available potassium ranged from 313.6 to 504 kg / ha in low-yielding citrus trees 313.6 to 537.6 kg / ha in optimum-yielding citrus trees and 313.6 to 571.2 kg / ha in high-yielding citrus trees.

Overall available potassium ranged from 313.6 to 571.2 kg / ha in citrus rhizosphere soils. Similar observations were also reported by Nijjar and Singh (1971), Kalbande *et al.* (1983), Ingole *et al.* (1993). Our study showed citrus rhizophere soils have optimum to high K-supply level. The available sulphur ranged from 5.82 to 7.05 kg / ha in low-yielding citrus rhizosphere soils. The maximum value of available sulphur (7.05) was observed in sample low yielding^{-7} and minimum value of available sulphur (5.82) was observed in sample low-yielding. The average value of available sulphur 6.44 kg / ha was in low-yielding citrus rhizosphere soils. The available sulphur ranged from trees 5.82 to 7.73 kg / ha in optimum-yielding citrus trees and 6.94 to 8.06 kg / ha in high-yielding citrus trees with an available sulphur of 7.50 kg / ha, especially in high-yielding citrus trees.

The dynamics of iron in rhizosphere soil is very similar to that of manganese. The DTPA-iron ranged from 11.3 to 15.2 mg/kg in low-yielding citrus trees, 11.7 to 16.4 mg/kg in optimum-yielding citrus trees and 13.8 to 16.7 mg/kg in high-yielding citrus trees. Likewise, DTPA-Mn ranged from 5.71 to 8.64 mg/kg in low-yielding trees, 7.28 to 9.32 mg/kg in optimum-yielding citrus trees and 6.98 to 9.34 mg/kg in high-yielding citrus trees. The DTPA-Cu ranged from 3.28 to 5.24 mg/kg, 3.48 to 5.30 mg/kg and 3.68 to 5.18 mg/kg in low-yielding optimum and high-yielding trees, respectively with corresponding average value of 4.15 mg/kg, 4.48 mg/kg and 4.46 mg/kg. While, DTPA-Zn ranged from 0.38 to 0.48 mg/kg in low-yielding citrus trees, 0.39 to 0.59 mg/kg in optimum-yielding citrus trees and 0.47 to 0.62 mg/kg in high-yielding citrus trees. A variety number of factors including soil texture, pH, soil water content, organic matter and calcareousness of the soil are known to influence bioavailability of Zn in soil (Alloway, 2008; Srivastava and Singh, 2009b).

REFERENCES

Alloway B J. 2008. Zinc in soils and crop nutrition. International zinc Association and International Fertilizer Industry Association. Brussels, Belgium and Paris, France, pp. 130.

Chesnin L and Yien C H. 1951. Turbidimetric determination of available sulphates. *Soil Science Society America Proceedings* **15**: 149-51.

Ingole B M, Lonare D K and Kadwe R J. 1993. Soils of citrus orchards in Kalamba Taluka of Yavatmal district of Maharashtra state. *Journal of Soils and Crops* **3**(1): 45-48.

Jackson M L. 1967. *Soil Chemical Analysis.* Prentice Hall of India Private Limited, New Delhi.

Jagdish Prasad M S S., Nagaraju, Srivastava S K Rajeev and Chandran P. 2001. Characteristics and classification of some orange growing soils in Nagpur district of Maharashtra. *Journal of Indian Society of Soil Science* **49**(4): 735-739.

Jibhakate S B, Bhede S N, Kharche V K and Selvalakshmi V. 2009. Physio-chemical status of soils of Katol Tahasil in Nagpur District, *Journal of Soils and Crops.* **19**(1): 122-128.

Kalbande A R, Landey R J and Bhattachargee J C. 1983. Characterization of soils under orange cultivation in Nagpur district of Maharashtra. *Indian Agricultural Science* **53**(1): 57-61.

Lindsay W L and Norvell W A. 1978. Development of DTPA soil test for Zinc, Iron, Manganese and Copper. *Soil Science Society of America* **42**: 421-428.

Malewar G U, Varade S B and Jadhav N S. 1978. Distribution of manganese and copper in soils of some citrus growing tract of Marathwada. *Indian Journal of Agricultural Research* **12**(4): 227-230.

Nijjar G S and Singh R. 1971. A survey of mineral nutrition status of sweet orange orchards in Amritsar district. *The Punjab Horticulture Journal* **11**(1-2): 32-39.

Ngullie Ethel Singh A K Sema Akali and Srivastava A K. 2015. Citrus growth and rhizosphere properties. *Communications in Soil Science & Plant Analysis.* **45**: 1540-550.

Piper C S. 1966. *Soil and Plant Analysis*. Hans Publishers, Bombay, pp. 368.

Richards L A. 1954. Diagnosis and Improvement of Saline and Alkali Soils. Agriculture Handbook No. 60. United States Department of Agriculture, USA.

Siddik W C Henifi and brahim K I. 2013. Effect of bacterial calcium carbonate precipitation on the geotechnical properties of soils. 2nd International Balkans Conference on Challenges of Civil Engineering, BCCCE, 23-25 Epoka University, Tirana, Albania.

Subbiah B V and Asija G L. 1954. A rapid procedure for the estimation available nitrogen in soil. *Current Sciences* **25**: 257-260.

Srivastava A K, Kohli R R, Dass H C, Huchche A D and Lallan Ram. 1999. Evaluation of the nutritional status of Nagpur mandarin (*Citrus reticulata* Blanco) by foliar sampling. *Tropical Agriculture* **72**(6): 93-98.

Srivastava A K and Shyam Singh. 2001a. Soil properties influencing yield and quality of Nagpur mandarin (*Citrus reticulata* Blanco). *Indian Society of Soil Science* **49**(1): 226-29.

Srivastava A K and Shyam Singh. 2001b. Soil fertility limit in relation to optimum yield of Nagpur mandarin (*Citrus reticulata* Blanco). *Indian Society of Soil Science* **49**(4):758-62.

Srivastava A K and Shyam Singh. 2002. Soil analysis based diagnostic norms for Indian citrus cultivar. *Communications in Soil Science and Plant Analysis* **33**(11): 1689-706

Srivastava A K and Shyam Singh. 2003a. Soil-plant nutrient limits in relation to optimum fruit yield of sweet orange (*Citrus sinensis* Osbeck) cultivar Mosambi. *Indian Journal of Agricultural Sciences* **73**(4): 209-11.

Srivastava A K and Shyam Singh. 2003b. Plant and soil diagnostic norms for optimum productivity of Nagpur mandarin (*Citrus reticulata* Blanco). *Fertilizer news* **48**(2): 47-63.

Srivastava A K and Shyam Singh. 2005. Diagnosis of nutrient constraints in citrus orchards of humid tropical India *Journal of Plant Nutrition* **29**(6): 1061-076.

Srivastava A K and Shyam Singh. 2008. Citrus nutrition research in India: Problems and prospects *Indian Journal of Agricultural Science* **78**: 3-16.

Srivastava A K and Shyam Singh. 2009. Zinc nutrition in Nagpur mandarin on haplustert. *Journal of Plant Nutrition.* **32**(7): 1065-081.

Srivastava A K and Shyam Singh. 2009b. Citrus decline: Soil fertility and plant nutrition. *Journal of Plant Nutrition* **32**(2): 197-45.

Srivastava A K. 2014. Global Citrus nutrition research : an incisive analysis. *Current Horticulture* **2**(1): 3-4.

Srivastava A K Shyam Singh and Huchche A D. 2015. Evaluation of INM in citrus on Vertic Ustochrept: Biometric response and soil health. *Journal of Plant Nutrition* **38**(5): 1-15.

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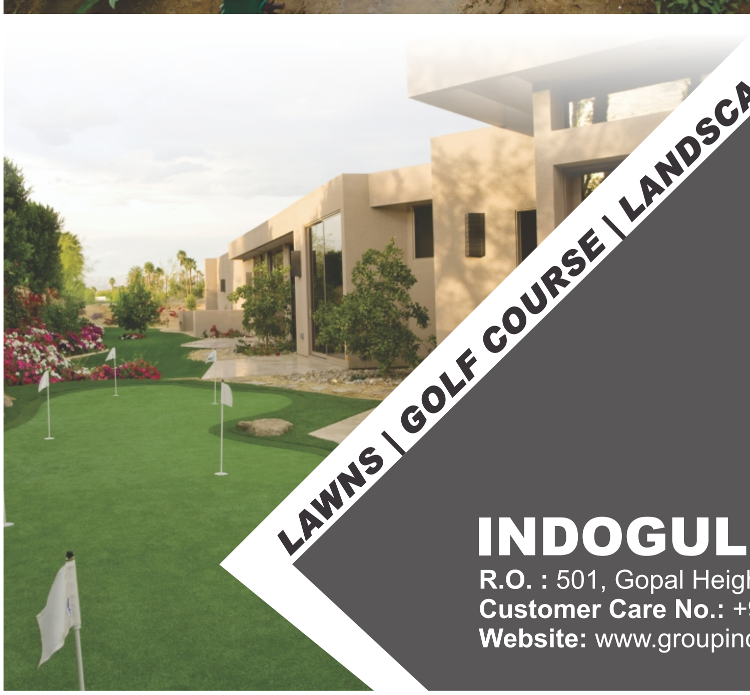

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Published by the Society for Horticultural Research and Development, Modinagar, Ghaziabad, and printed at Alpha Printers, WZ-35/C, Naraina Ring Road, New Delhi 110028, Ph.: 9810804196, E-mail: alphaprinters35@gmail.com

Editor: Dr Amar Singh Kashyap