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Response of NPK fertigation on pheno-physiological status of *Citrus sinensis* Osbeck cv. Mosambi under high density planting

Vishal Nirgude[1*], K. Karuna[1], Abhay Mankar[1], Vikash Kumar[1], Maggidi Spandana[2]

[1]Department of Horticulture (Fruit & Fruit Technology), Bihar Agricultural University, Sabour- 813210 (Bihar), INDIA

[2]Department of Horticulture (Fruit & Fruit Technology) ASPEE College of Horticulture & Forestry, Navsari Agricultural University, Navsari -396450 (Gujrat), INDIA

*Corresponding author. E-mail: nirgude.v7hort@gmail.com

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Abstract: The field experiment was conducted during 2013-14 to study the effects of fertigation on the phenology and physiological status of *Citrus sinensis* cv. Mosambi. The experiment was laid out in randomized block design with seven fertigation level, *viz*. T_1- 120% of RDF; T_2- 100% of RDF; T_3- 80% of RDF; T_4- 60% of RDF; T_5- 40% of RDF; T_6- Full dose in basal with drip irrigation and T_7- Full dose in basal without drip irrigation and each treatment were replicated three times. Results obtained showed that increase in plant height (36.75 cm), trunk girth (4.67 cm), canopy volume (1.83 m^3), leaf area index (5.51) and growth of current season shoot (9.42 cm^2) of the plant were more responsive to higher dose of fertigation *i.e.* T_1 followed by T_2. The treatment effect was not marked on reproductive growth as expressed in terms of bud emergence, full bloom, fruit set and duration of bud emergence to maturity. The tree physiological parameters *viz*. total chlorophyll (2.65 mg/g), net photosynthesis rate (6.83 µmol CO_2 / m^2/sec), stomatal conductance (0.18 mol/m^2/sec) and leaf area (31.9 cm^2) were also higher under treatment receiving higher dose of fertigation *i.e*. T_1. Therefore, on the basis of results obtained, treatment 120% RDF found superior in maintaining pheno-physiological status of mosambi plant under high density planting.

Keywords: Citrus, Fertigation, Phenology, Physiology.

INTRODUCTION

Citrus is one of the most popular fruit of tropical and sub-tropical region of the world and number one group of fruits grown in more than 140 countries in the world (Shirgure, 2012). It has appreciated not only for its beautiful appearance and pleasing flavour but also for its excellent food, juice, nutritional and medicinal properties. The geographical situation of India by possessing different types of climate permits to grow all types of horticultural crops. Increase in fruit production and productivity in India is major task at present in order to fulfil the minimum requirements first and thereafter lessen the pressure on cereals which helps in solving the food problems.

Nutritional requirement are essential for high density orchard of citrus crops. Fertigation is one of the most advance and efficient practice for enhancing fertilizer management, which includes application of water soluble fertilizers through drip irrigation system directly to the plant roots. Apart from this, it includes application of fertilizers in small and frequent doses that fit within scheduled irrigation intervals matching the plant water use to avoid leaching. It has also potential in enhancing use efficiency of water and fertilizer, control of nutrient concentration in soil solution and saving in application cost (Solaimalai *et al.*, 2005 and Singh *et al.*, 2010). There is limited scope for bringing new area under cultivation and hence more emphasis will be given on increasing the yield per unit area. Hence in Indian condition, where population pressure is more and land is inadequate, another strategy such as high density orchard system should be recommended as compared to scatter kind of planting system to achieve maximum yield from same piece of land (Choudhary, 1984).

Out of essential elements, nitrogen, phosphorus and potassium are called critical elements in any manurial programme. These elements are required in relatively large amount due to their major role in fundamental structure and various metabolic functions of plant. Nitrogen is mainly responsible for the growth attributes and occurs as nucleoprotein, amino acid, amines, amino sugars, polypeptide and helps in many other metabolic functions of a plant. Phosphorus is comparatively prominent as a plant nutrient than many other elements with their both organic and inorganic form available in the soil. It is a constituent for many compounds of the plants such as nucleic acid, phytins, and phospholipids and the co-enzymes, nicotinamide adenine dinucleotide (NAD), nicotinamide adenine dinucleotide phosphate (NADP) and adenosine tri phosphate (ATP). Potassium acts as a co-factor for many

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enzymes and plays a vital role in plant metabolism such as regulation of transpiration and water condition in the plant cells. It is also essential in certain enzymatically catalyzed and in the coupling of certain amino acids to form peptides (Sah *et al.,* 2014).

Citrus plants are more sensitive to the deficiency of certain elements than many other cultivated crops. Adequate information on fertilizer requirement of different citrus species is lacking in India. Drip irrigation and fertigation are the most efficient methods of modern irrigation systems which have a potential advantage of water and fertilizer saving. (Koo, 1981; Haynes, 1985 and Shirgure, 2013). The efficient use of water and fertilizer to increase the crop yield is important concern in today's citricultural system (Shirgure, 2012). Furthermore, *Citrus sinensis* osbeck cv. Mosambi have shown good performance in scattered planting under Bihar conditions, the crop has shown promise in bearing at Sabour condition but there is lack of knowledge about its proper fertigation scheduling at different stages of growth and age of plant for better growth and yield. In view of the above, the present investigation was carried out to study the response of NPK fertigation on pheno-physiological status of *C. sinensis* osbeck cv mosambi under high density planting to work out proper fertigation practices under high density orchard system.

MATERIALS AND METHODS

Field location: The field experiment was carried out at high density orchard of the permanent experimental area of Bihar agricultural university (87°2'42" E, 25° 15'40" N) at Sabour, Bihar, at an altitude of 46 m above mean sea level in the heart of vast Indo-Gangatic plains of North India, during 2013-14. The climate of this place is sub-tropical of slightly semi-arid nature. It is characterized by dry summer, moderate rainfall and cold winter (Table 4). The soil of the experimental plot had well drained sandy loam texture with good fertility and levelled surface.

Treatment details: The experiment was laid out in randomized block design with seven fertigation level based on recommended dose of fertilizer (RDF) *i.e.* 300:90:90 gram/ plant/ year, the treatments were T_1- 120% of RDF (360:108:108g); T_2- 100% of RDF (300:90:90g); T_3- 80% of RDF (240:72:72g); T_4- 60% of RDF (180:54:54g); T_5- 40% of RDF (120:36:36g); T_6- Full dose (300:90:90g) in basal with drip irrigation and T_7- Full dose (300:90:90g) in basal without drip irrigation and each treatment were replicated three times with four plant in each replication. The treatment T_1, T_2, T_3, T_4 T_5 were applied in split doses whereas, treatment T_6 and T_7 supplied directly in plant basin. Fertigation scheduling was administrated at monthly interval starting from November (Table 5). The fertilizer source used for fertigation were urea for nitrogen and mono potassium phosphate and sulfate of potash for phosphorus and potassium. The four year old mosambi plants were planted under high density planting (HDP), at a spacing of 3.0 × 2.5 m apart.

Procedure: The phenological parameters *viz.* plant height, trunk girth, canopy volume, growth of current season shoot of 12 randomly selected plants from each treatment was measured with the help of measuring tape before and after fertigation during August. Further the canopy volume was calculated according formula given by Roose *et al.* (1986). The leaf area index (LAI) of selected plants was measured using the instrument canopy analyser (LP-80, PAR/LAI Ceptometer, Decagon Devices, Inc., WA, USA). The reproductive or fruiting parameters were recorded by visiting the experimental orchard frequently after bud emergence to fruit maturity. The physiological parameters in terms of leaf area of fifty fully expanded leaves from each treatment was recorded using leaf area meter (CI-203 CA, CID Bio-sciences, Camas, USA). The total chlorophyll content of the leaves was analysed following the method of Barnes *et al.* (1992). In which the fully mature (August-September) open leaf was taken as the experimental sample for chlorophyll estimation. The rate of photosynthesis, stomatal conductance, transpiration rate and internal CO_2 concentration of mature leaves of 12 randomly selected plants was measured by portable photosynthesis system (LICOR - 6400 XT, Lincoln, NE, USA) by using IRGA (Infra-red gas analyser) during August-September. The leaf relative water content (RWC %) in the recently mature leaves (August-September) was determined using the method suggested by Weatherley (1950).

Statistical analysis: The experimental data were subjected to statistical analysis in order to find out which of the treatments showed significant variation in different parameters studied under investigation. The technique of analysis of variance (ANOVA) for randomized block design (RBD) was adopted as suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Phenology parameters

Growth parameter: Data indicates that vegetative parameters were significantly influenced by different fertigation treatments (Table 1). The treatment T_1 showed the maximum plant height (36.75 cm) which has shown superior to rest of the treatments followed by 29.33 cm under T_2. However, the lowest plant height (18.50 cm) was observed in T_5 followed by (24.62 cm) in T_6. Canopy volume was reported highest (1.83 m^3) under treatment T_1 followed by 1.72 m^3 in T_2 and found statistically at par to each other. The highest Leaf area index (5.51) was recorded in treatment T_1 followed T_2, T_3 and these treatments were found statistically at par. The maximum trunk girth (4.67 cm) was reported in T_2 followed by 4.58, 4.42, 4.33 cm. in T_1, T_3, T_4 respectively and these values were found at par

Table 1. Effect of fertigation on phenological (growth) parameters of *C. sinensis* cv. Mosambi.

Treatments	Plant height (cm)	Trunk girth (cm)	Canopy volume (m^3)	Leaf Area Index	Growth of current season shoot (cm^2)
120 % RDF	36.75	4.58	1.83	5.51	9.11
100 % RDF	29.33	4.67	1.72	5.13	9.42
80 % RDF	24.92	4.42	1.28	5.05	7.33
60 % RDF	25.67	4.33	1.45	4.84	7.00
40 % RDF	18.50	4.00	1.35	4.02	8.34
100 % RDF with drip irrigation	24.62	4.20	1.71	4.35	8.65
100 % RDF without drip irrigation	26.22	4.00	1.63	4.35	6.83
C.D. at 5%	2.99	0.38	0.19	0.51	0.94
C.V. (%)	6.26	5.33	6.88	5.98	6.50
SEm(±)	1.37	0.17	0.08	0.23	0.43

whereas the minimum trunk girth (4.00 cm) was reported under T_5 and T_7. The maximum growth of current season shoot (9.42 cm^2) was recorded in T_2 followed by T_1 and T_6 and these treatments had non-significant difference due to different treatments, while the treatment T_7 had the minimum growth of shoot (6.83 cm) followed by T_3 and T_4 and these values were found statistically at par. The increased growth parameters recorded under T_1 and T_2 fertigation treatments due to increased nutrient requirement under high density planting of citrus crop, in addition to this, present investigation revealed that nutritional requirement at Sabour, Bihar condition was found still high and it is due to the fact that the before experiment NPK status of the soil was found low and it might have results in uptake of more nutrient from same piece of land (Table 6). Furthermore, there was a continuous supply of nutrients in fertigation as the fertilizers were applied in 15 split doses during the entire growth period of the plants, which might have helped in meeting the requirements of nutrients during the critical period of growth. These above findings are in accordance with Ramana *et al.* (2014) who obtained highest plant growth parameters *i.e.* plant height (3.09 m), stem girth and canopy volume (20.9 m^3) when higher dose of NPK were applied in sweet orange. Kachwaya and Chandel (2015) reported that higher doses of NPK (150, 100, 120 kg/ha.) through fertigation increased growth parameters like maximum fruit length (42.49 mm), fruit breadth (31.74 mm) and fruit weight (19.87 g) in strawberry cv. Chandler. Ahmad *et al.* (2010) also observed that vegetative growth was positively related to the amount of nitrogen applied through drip fertigation in sweet cherry. The findings in relation to canopy volume was found agreement with results of Menino *et al.* (2003), who found that application of nitrogen at higher rate *i.e.* 720g N leads to the greatest tree canopy volume in Valencia trees. The highest value of LAI with the T_1 may be due to the effect of nitrogen, the findings in relation to LAI by nitrogen application were supported by Chatterjee (2013) in Tomato.

Reproductive parameter: The finding in relation to influence of different fertigation treatments on the reproductive phase of mosambi plant was carefully observed and presented in Table 2. The information of time and length of flowering is pre-requisite for taking up a crop improvement programme through hybridization. Although the variation was not very significant due to different treatment, still a trend was there under such observation. In general with increase in level of nitrogen, bud emergence showed a tendency to get delayed because it make plant to survive under vegetative condition for longer period and ultimately delayed flowering occurred whereas, phosphate stimulate flowering and adds in fruit setting and hence, a balanced combination of NPK was found necessary to induced early flowering and fruiting of citrus plant. Wassel *et al.* (2007) observed that initial and final fruit setting were increased by raising the amount of nitrogen fertilization. Whereas, a balance dose of phosphate and potash may enhance the anthesis period for better fruit setting, hence a combination of NPK fertilization results in early fruit setting. The similar findings in relation to early flowering and fruiting due to combined NPK fertilization was reported by Sah *et al.* (2014) in pear. Maturity of fruit was also influenced more or less on a similar pattern. The fruit maturity was observed to be delayed with increase in level of nitrogen, this may be due to the fact that excess nitrogen may produce large fruits with thick skin (Jacob and Uexkull, 1958) and consequently delayed the maturity. The effect of phosphorus in respect of decreasing the period of maturity was more pronounced (Lekvinadze (1972) and Ghosh *et al.* (1981). Phosphate and potash also play an important role in balancing the effect of nitrogen and therefore, combination of NPK have tendency to balance maturity of fruits at all levels of nitrogen, the results is in agreement with findings of Choudhary (1984) in mosambi.

Physiological parameters: The physiological characters of mosambi plant were significantly influenced by

Table 2. Effect of fertigation on phenological (reproductive) parameters of *C. sinensis* cv. Mosambi.

Treatments	Bud emergence		Full bloom		Number of days from full bloom since bud emergence	Fruit set		Number of days for first fruit set since bud emergence	Date of maturity	Number of days from bud emergence to maturity
	Date	Days	Date	Days		Date	Days			
120 % RDF	12-2-2014 to 22-2-2014	10	07-3-2014 to 14-3-2014	07	20-24	11-3-2014 to 17-3-2014	06	23-27	21-10-2014	241-251
100 % RDF	14-2-2014 to 23-2-2014	09	03-3-2014 to 15-3-2014	12	18-21	09-2014 to 16-3-2014	07	22-24	21-10-2014	241-249
80 % RDF	13-2-2014 to 21-2-2014	08	29-2-2014 to 13-3-2014	13	16-20	05-3-2014 to 14-3-2014	09	19-21	21-10-2014	242-250
60 % RDF	11-2-2014 to 21-2-2014	10	01-3-2014 to 15-3-2014	14	19-22	06-3-2014 to 16-3-2014	11	23-24	30-10-2014	251-261
40 % RDF	15-2-2014 to 21-2-2014	06	29-2-2014 to 13-3-2014	13	14-20	05-3-2014 to 12-3-2014	07	19-24	28-10-2014	249-255
100 % RDF with drip irrigation	13-2-2014 to 23-2-2014	10	29-2-2014 to 11-3-2014	11	16-17	03-3-2014 to 14-3-2014	11	19-19	31-10-2014	250-260
100 % RDF without drip irrigation	15-2-2014 to 23-2-2014	08	06-3-2014 to 15-3-2014	09	20-20	08-3-2014 to 17-3-2014	09	22-22	02-11-2014	252-260

Table 3. Effect of fertigation on physiological parameters of *C. sinensis* cv. Mosambi.

Treatments	Total chlorophyll content (mg/g)	Photosynthetic rate (µmol CO_2 /m^2/sec)	Stomatal conductance (mol/m^2/sec)	Transpiration rate (µmol H_2O/ m^2 /sec)	Leaf internal CO_2 conc. (ppm)	Leaf area (cm^2)	Leaf RWC %
120 % RDF	2.65	6.83	0.18	1.96	311.48	31.95	85.91
100 % RDF	2.39	5.24	0.16	2.00	301.58	30.15	91.44
80 % RDF	2.23	4.41	0.14	2.09	292.90	26.15	87.65
60 % RDF	2.16	3.35	0.11	3.89	288.35	28.74	84.06
40 % RDF	2.15	3.30	0.11	2.97	283.24	28.69	87.67
100 % RDF with drip irrigation	2.28	3.93	0.12	2.69	287.94	27.91	91.73
100 % RDF without drip irrigation	2.31	4.17	0.15	2.04	291.62	29.13	93.67
C.D. at 5%	0.23	0.53	0.016	0.32	N. S.	3.37	N. S.
C.V. (%)	5.59	6.21	6.82	7.18	6.13	6.53	6.55
SEm(±)	0.105	0.24	0.0077	0.14	14.72	1.54	4.75

Table 4. Meteorological data of the year 2013-14.

Months	Temperature (°C)		Relative Humidity (%)		Rainfall	Wind Velocity
	Max.	Min.	7.00 AM	2.00 PM	(cm)	(Km/hr.)
Nov, 13	26.9	15.3	89.0	59.0	1.42	1.0
Dec, 13	23.4	10.1	98.0	62.0	0.0	1.2
Jan, 14	20.2	10.4	95.0	69.0	0.1	3.5
Feb, 14	22.7	10.9	91.6	59.7	1.2	3.6
Mar, 14	30.0	15.3	77.2	41.0	0.1	3.7
April, 14	37.0	20.0	62.2	29.9	0.0	5.4
May, 14	37.8	24.3	65.1	41.2	6.0	8.2
June, 14	34.2	24.5	83.6	61.4	4.1	5.5
July, 14	32.3	25.3	88.8	77.2	16.5	7.1
Aug, 14	32.4	24.9	89.3	78.0	7.5	5.6
Sept, 14	32.2	23.0	88.0	77.1	4.5	4.0
Oct, 14	32.3	20.5	87.2	67.8	0.1	2.1

Source: Agro-meteorology department, Bihar Agricultural University, Sabour

Table 5. Time line chart for fertigation scheduling of N, P and K fertilizers in *C. sinensis* cv. Mosambi.

Month	Date	N	P	K
January	15	-	-	-
February	15	✓		-
March	15	✓	✓	✓
April	15	✓	✓	✓
May	15	✓	-	✓
June	15	✓	-	✓
July	15	-	-	✓
August	15	-	-	✓
September	15	-	-	-
October	15	-	-	-
November	15	-		-
December	15	-	-	-

Table 6. Soil status of experimental land before treatment with different dose of fertilizers.

Soil Depth (cm)	0-15	15-30
pH (1:2.5)	7.37	7.24
EC (ds/m)	0.42	0.40
Organic C (%)	0.53	0.46
N (Kg/ ha.)	213.50	194.45
P_2O_5 (Kg/ ha.)	29.75	27.50
K_2O (Kg/ ha.)	165.25	134.77

different fertigation treatments. The results (Table 3) showed that there was significant variation in total chlorophyll content among different treatments. The maximum total chlorophyll content (2.65 mg/g) was recorded in treatment T_1 which has shown superior to rest of the treatments followed by 2.39 mg/g under T_2, whereas, the minimum chlorophyll content (2.15 mg/g) was recorded in T_5 and found at par with T_3, T_4, T_6 and T_7. The highest photosynthesis rate (6.83 µmol/m^2/ sec.) was recorded under T_1 followed by 5.24 and 4.41 µmol/m^2/sec. under treatment T_2 and T_3 respectively. However, minimum photosynthesis rate (3.30 µmol/ m^2/sec.) was recorded in T_5 which was statistically found at par with T_4. The stomatal conductance was found maximum (0.18 µmol/m^2/sec.) in T_1 followed by 0.16 µmol/m^2/sec. under T_2, whereas, minimum stomatal conductance (0.11 µmol/m^2/sec.) was noticed in leaves of treatment T_4 and T_5 and found at par with T_6. The maximum transpiration rate (3.89 µmol/m^2/ sec.) was recorded in T_4. Whereas, minimum transpiration rate (1.96 µmol/m^2/sec.) was recorded in T_1, which were found statistically at par with T_2, T_3 and T_7. The treatment T_1 showed highest (31.95 cm^2) leaf area and it was found statistically at par with T_2, T_4, T_5 and T_6. Whereas, minimum leaf area was recorded under T_3. The data in relation to internal CO_2 concentration and relative water content of leaves were found statistically non-significant by different level of fertilizer treatments. Nitrogen is an integral part of many compounds, including chlorophyll, nucleic acid, proteins and enzymes and found essential for plant growth and development (Sah *et al.*, 2014). The pyrole rings of chlorophyll arise after prior combination of amino acids, glycine and succinic acid. Nitrogen application increases chlorophyll content, which results in production of photosynthates. Intrigliolo *et al.* (1992) found that continuous fertigation significantly improved physiological plant status like photosynthesis rate, transpiration rate and stomatal conductance in citrus tree. (Leuning, 1995) found that the rate of photosynthesis, required supply of CO_2 and stomatal conductance of leaves are highly correlated to intensity of light, which subsequently increase with higher leaf area. The increase in leaf area may be due to the positive effect of nitrogen on many important plant structures, genetic and metabolic compounds in plant cells (Don, 2001). In present investigation, nutrient application through fertigation resulted in maintaining optimum moisture and nutrient content of soil and hence, responsible for better physiological activity of citrus plant whereas, under water deficit condition plant close their stomata to prevent dehydration which affects both transpiration and photosynthesis in citrus (Medina *et al*., 1999). The leaf relative water content was found non-significant among different treatments which might be due to light, temperature and stress conditions during the period of investigation.

Conclusion

The study has revealed that the application of fertigation with NPK at the dose of 120% RDF

(360:108:108g/plant/year) gave the highest plant height, canopy volume, LAI, total chlorophyll content, photosynthesis, stomatal conductance and leaf area in *Citrus sinensis* Osbeck cv. mosambi under high density planting condition. Hence, treatment 120% RDF can be recommended under sabour, Bihar, India agro-climatic conditions for growing sweet orange crop to fetch higher returns.

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