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Fertigation Effect on Growth, Yield and Physiology in Kinnow Mandarin (*Citrus reticulata* Blanco) under High Density Planting

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The trial was laid out during three consecutive year i.e, 2013-14, 2014-15, 2015-16 to show the effect of fertigation on growth, yield and physiology in Kinnow mandarin under high density planting. Result of three years pooled data on growth parameters showed that increase in current season shoot (8.52 cm), leaf area (27.34 cm^2), leaf area index (7.99), increase in plant height (82.23 cm), trunk girth (6.32 cm), canopy volume (57.97 cm^3) and yield (16.93 Kg/plant) were higher under higher doses of fertigation i.e. 120 % RDF followed by 100 % RDF. Physiological observations like total chlorophyll content (3.60 mg/100g), photosynthetic rate (7.19 µmol CO_2 m^{-2} sec^{-1}), stomatal conductance (0.38 (mmol m^{-2} s^{-1}), total transpiration rate (5.82 µmol H_2O m^{-2} sec^{-1}) and leaf internal CO_2 concentration (332.00 ppm) were also recorded higher under higher doses of fertigation. Yield (22.61 ton hac^{-1}) was also observed under higher dose of fertilizer. However, all essential nutrients (macro & micro) influence low yield which may improve by the application of balanced dose of fertilizer in split through fertigation.

Introduction

In India citrus are mainly cultivated in four zones viz. central India (Gujarat, Madhya Pradesh and Maharashtra), north-eastern India (Assam, Meghalaya and Sikkim), southern India (Karnataka and Andhra Pradesh), and north-western India (Haryana, Punjab, western UP and Rajasthan). Different zones have specific leading cultivar which represents their respective area (Etebu and Nwauzoma, 2014). These crops play an important role in the economy of our country and hold third position in fruit industry of India, NHB database (2016) but their yield levels are very low (Srivastava and Singh, 2009). Citrus is a leading fruit crop in the world and third leading crop in India after

mango and banana. Productivity and quality of fruits directly correlated with application of fertilizer. Yield of these crops depend on several abiotic (soil, nutrition, site, climate and irrigation management) and biotic (cultivar, rootstock, disease and pest management) factors (Davies and Albrigo, l994; Iglesias *et al*., 2007). The annual fertilizer application rate, timing and its placement are the pre-requisite to enhance nutrient uptake efficiency and to reduce nutrient losses (Tucker *et al*., 1995).These crops are available whole the year. It is not only refreshing and delicious in taste but also beneficial for human health because it is a rich source of vitamin C and minerals.

Kinnow (*Citrus reticulata* Blanco.) is an inter-specific hybrid i.e. from King (*Citrus nobilis)* and Willow leaf (*Citrus deliciosa*). It was developed by H.B. Frost at California University in the year 1936 and introduced in India in 1956. Firstly it was introduced in Punjab region and it occupies utmost place in citrus orcharding by replacing traditionally grown species of citrus. It might be due to its attractive colour, refreshing juice, nutritive value and overall productivity. Feasibility of Kinnow cultivation in Bihar was also tested at Sabour on large scale due to its wider adaptability and high economic return. Among mandarin group Kinnow ranked top and occupies about 41 per cent of total mandarin production in India. Since, the productivity of citrus orchards in India is 7-8 tonnes per hectare compared to 20-25 tonnes per hectare in leading citrus producing countries in the world indicating the tremendous scope for flourishing the citrus industry in the country.

It is difficult to increase production by increasing the land area. Therefore, adequate nutrition of the plant for optimum productivity with quality produce is one of the alternate solutions (Srivastava and Singh, 2002). However, the gap in productivity level is a major cause of concern and is often ascribed to poor physical condition of the soil and unbalanced nutrition (Srivastava and Singh, 2002). Though, citrus is a nutrient demanding crop and highly responsive to applied nutrients in the form of fertilizers. Among the essential nutrients nitrogen, phosphorus and potassium plays a vital role in improving vegetative growth, physical and quality parameters in citrus. However, fertigation are able to supply water and nutrient on required time with equal distribution in the plants to fulfill the nutrient demand of the crop (Narda and Chawla, 2002). There are several factors of low productivity of orchard but some of them are poor fertility status of the soil, non availability of recommended dose of fertilizers to the plant, lack of timely irrigation as well as fertigation etc. Fertigation supply all sorts of nutrients to the plants in right proportion in right time. Without nutrients it will not be able to complete its life cycle (Ibrahim *et al*., 2011).

Materials and Methods

The trial was laid out during 2013-14, 2014-15, and 2015-16 at B. A. C., Sabour under Bihar Agricultural University, Sabour, Bhagalpur, Bihar in high density planting of citrus. The climate of Sabour, Bihar is sub-tropical with slightly arid in summer, cold in winter and rainfall status is moderate which is depicted graphically in (Fig. 1). Before beginning of fertigation practice, initial soil data were analyzed and depicted graphically in (Fig. 2). Experimental plot was inter-cultured time-to-time for proper ventilation in soil which ensures good microbial activities in the soil.

The trial was done in three consecutive years on four years of plant which were planted under high density planting with 3.0 m × 2.5

m spacing. The fertigation levels were seven in randomized block design. The initial fertilizer dose of N: P: K was 300:90:90 gram/plant/year and that were given as recommended dose of fertilizer. Seven treatments were made on the basis of that RDF i.e. 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 - 100 % RDF in basal with drip irrigation and T_7 - 100 % RDF in basal without drip irrigation in randomized block design with three replications. The treatments T_1 to T_5 were gave to plants in split doses while; T_6 and T_7 were supplied directly in basin of the plant. Fertigation was started from November and this was done at monthly interval upto August (Table 1). The source of nitrogenous fertilizer was urea whereas phosphorus and potassium were mono potassium phosphate and sulfate of potash respectively.

Vegetative parameters

The vegetative parameters *viz.* growths of current season shoot, canopy volume, plant height and trunk girth of 12 plants were randomly selected from every treatment was measured in November i.e. before fertigation and during August after fertigation with the help of measuring tape. Further the canopy volume was calculated according to formula given by Roose *et al.,* (1986). The leaf area index (LAI) of selected plants was measured using the instrument canopy analyzer (LP-80, PAR/LAI Ceptometer, Decagon Devices, Inc., WA, USA).

Physiological parameters

The physiological parameters in terms of leaf area of five fully expanded leaves from each treatment each replication were 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 analyzer) during August-September.

Yield

Yield in Kg/plant was recorded by weighing fruits with the help of balance.

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

Growth characters

The data pertaining to vegetative parameters were recorded and depicted in Table 2. It was clearly indicated that the effect of different fertilizer doses affect the vegetative growth of plants The significantly highest increase in current season shoot (8.52 cm) was recorded under T_1 followed by T_2 (8.09 cm) whereas lowest (6.28 cm) in T_4 which shows parity with T5. Similarly highest increase in plant height (82.23 cm) was observed inT1 which was at par with T_7 (79.81 cm) whereas lowest (62.35 cm) in T5 which was at par with T_4 (65.11 cm). Increase in trunk girth was also

recorded highest under T_2 (6.32 cm) which shows parity with T_1 and T_5 whereas minimum (4.93 cm) in T_4 which was at par with T_3, T_5, T_6 and T_7. In respect of leaf area maximum (27.34 cm2) was recorded inT_1 which was statistically at par with T_2 (27.06 cm) whereas minimum in T_5 (25.56 cm). LAI was highest under T_2 (7.99) whereas minimum (6.91) under lowest dose of fertilizer. In continuation of vegetative growth canopy volume was also found highest (57.97 cm^3) under T_1which was at par with T_2 and significantly minimum (34.52 cm^3) in T_4.The effect of fertigation on elongation of plant height, trunk girth, canopy volume leaf area, LAI etc. were found highest under higher doses of fertilizer i.e. T_1 which showed parity with T_2 whereas lowest was observed under ring method of irrigation and fertilizer application.

Yield and physiological parameters

The yield and physiological parameters of Kinnow plant were differed significantly with different doses of fertilizer application through fertigation. The data showed (Table 3) that the highest yield (16.93 Kg/plant) was recorded with 120 % RDF which was at par with T_2 and T_3 whereas lowest under T_7 (6.47 Kg/plant). The application of major nutrients viz. NPK through fertigation at right stages in right time in different split doses could favours vegetative, reproductive and ultimately yield of the crop. These nutrients are also called body building nutrients which are responsible for overall development in the plants. Similar results were also observed in sweet orange by Vijay, 2016 and Wei *et al.*, 2002. Total chlorophyll content (3.60 mg/g) was observed in T_1 i.e. higher dose of fertilizer which was at par with T_2 (3.53 mg/g) and T_7 (3.57 mg/g) whereas lowest (2.48 mg/g) in T_5 which was lowest dose of fertilizer. Different fertilizer doses of major nutrients like NPK affect significantly on photosynthesis rate in Kinnow plants. The maximum photosynthesis rate (7.19 µmol $m^{-2}sec^{-1}$) was observed in T_1 which showed parity with T_2 and T_7 whereas minimum (5.26 µmol $m^{-2}sec^{-1}$) in lower dose of fertilizer i.e. in T_5. In respect of stomatal conductance it was found highest (0.38 mmol $m^{-2} s^{-1}$) in T_1 which was followed by T_7, T_6, T_2 and T_3 whereas lowest (0.20 mmol $m^{-2} s^{-1}$) in T_5 which showed at par with T_4. Data pertaining to transpiration rate it was also found similar trend as photosynthesis rate. As higher the photosynthesis rate higher transpiration rate was observed and it was found with higher dose of NPK fertilizer. The highest transpiration rate (5.83 mg H_2O m^{-2} sec^{-1}) was observed in T_1 whereas lowest (3.89 mg H_2O m^{-2} sec^{-1}) in T_4, which were significantly differed from all the treatments. Data pertaining to leaf internal CO_2 concentration, the significantly highest (332.04 ppm) was recorded under higher dose of fertigation which was followed by T_2 (317.91 ppm) whereas lowest (292.76 ppm) in T_5 which showed parity with treatments T_3 and T_4.

The growth parameters were increased with increased dose of fertilizer. It might be due to continuous supply of water in the root zone as well as balanced nutrient availability because fertilizers were applied in split doses. It also might be due to plants were in growing phase so positive response of fertilizer doses were observed. The above findings are in conformity with the result of Shirgure *et al.*, (2001) in mandarin who found higher growth parameters when fertigation dose of NPK was kept 100% RDF in mature plants Bhalerao *et al.*, (2010) in banana and Grace *et al., (*2011) in Kinnow. These findings are supported by the data Ramana *et al.,* (2014) who found highest growth parameters with higher dose of major nutrients i.e. NPK in sweet orange. Above findings are also in accordance with the research conducted by Nirgude *et al.*, (2016) in Mosambi and Kumari *et al.,* (2017)

in Kinnow. The results obtained are in conformity with the findings of Boman, (2001), Patel *et al*., (2009) and Rattanpal *et al*., (2015) in sweat orange. The yield and physiological parameters of Kinnow plant were differed significantly with different doses of fertilizer application through fertigation. Similar results are also reported by (Soni *et al.*, 2018) who reported that, the increase in yield can be because of better root proliferation, increased nutrient elements in the soil, enhanced uptake of nutrients and water and higher photosynthesis leading to an increase in the assimilation rates. Under control condition there are fewer nutrients available to plants because most of the nutrients are either leached or evaporated resulting poor flowering, fruit set, weight and size of fruits (Patel *et al.,* 2012) who observed that the modification of above mentioned parameters could be due to microbial action in the root zone who makes nutrients available to the plants resulting increase in vegetative parameters like increase in the number of leaves and increase in leaf area which increase photosynthetic structure, enhances carbohydrate content in the plant body. Ultimately produces large number of flowers, higher number of fruit set, fruit retention, yield and their attributes and finally increase in marketable yield. These results are supported by earlier findings by Srivastava and Singh (2002) and Shirgure *et al.,* (2016) in Nagpur mandarin. The yield and their attributes are decreased with decreasing nutrient and irrigation level by lowering fruit weight and lesser number of fruits. This might be due to lower photosynthesis rate under soil water deficit condition i.e. in control which causes lower stomatal conductance and photosynthates in the plants.

Nitrogen is a major nutrient which helps to enhance chlorophyll content and is responsible for production of carbohydrates in the plant. Nitrogen plays an important role in production of amino acids, glycine and succinic acid. Pyrole rings around the chlorophyll of leaves are made up of these amino acids. According to Intrigliolo *et al.,* (1992) the continuous fertigation practices significantly improved all the plant physiological status in citrus tree. (Leuning, 1995) found that the rate of photosynthesis mainly depends on amount of CO_2 supply and stomatal conductance of leaves which is directly correlated with intensity of light as well as leaf area.

Table.1 Scheduling of fertigation

Month	Date	N	P	K
February	15	Yes	Yes	No
March	15	Yes	Yes	Yes
April	15	Yes	Yes	Yes
May	15	Yes	No	Yes
June	15	Yes	No	Yes
July	15	No	No	Yes
August	15	No	No	Yes
October	15	No	No	No
November	15	No	Yes	No

Table.2 Effect of fertigation on vegetative parameters in Kinnow

Pooled data of 2013-14, 2014-15 and 2015-16						
Treatments	Current season shoot (cm)	Increase in plant height(cm)	Increase in trunk girth (cm)	Leaf area (cm^2)	LAI	Canopy volume (cm^3)
120 % RDF	8.52	82.23	5.98	27.34	7.53	57.97
100 % RDF	8.09	73.28	6.32	27.06	7.99	52.20
80 % RDF	7.55	68.96	5.26	26.48	7.31	42.91
60 % RDF	6.28	65.11	4.93	26.11	7.46	36.36
40 % RDF	6.29	62.35	5.68	25.56	6.91	34.52
100 % RDF with drip irrigation	7.09	74.79	5.24	26.46	7.57	43.68
100 % RDF without drip irrigation	7.17	79.81	4.94	26.42	7.24	52.17
SEm (±)	0.16	2.17	0.45	0.35	0.29	2.93
CD (P = 0.05)	0.35	4.72	0.90	0.71	0.58	6.39

Table.3 Yield and physiological parameters in Kinnow

Pooled data of 2013-14, 2014-15 and 2015-16						
Treatments / observations	Yield (Kg/plant)	Total chlorophyll content (mg/100g	Photosynthetic rate (µmol CO_2 $m^{-2}sec^{-1}$)	Stomatal conductance (mmol m^{-2} s^{-1})	Transpiration rate (µmol H_2O $m^{-2}sec^{-1}$)	Leaf internal CO_2 conc. (ppm)
120 % RDF	16.93	3.60	7.19	0.38	5.82	332.04
100 % RDF	14.43	3.53	6.97	0.28	5.33	317.91
80 % RDF	11.33	3.40	5.95	0.28	5.02	298.84
60 % RDF	9.87	2.97	5.56	0.21	4.54	293.21
40 % RDF	7.86	2.48	5.26	0.20	3.89	292.76
100 % RDF with drip irrigation	6.89	3.26	5.54	0.29	4.44	304.75
100 % RDF without drip irrigation	6.47	3.57	6.58	0.33	5.37	309.12
SEm (±)	3.79	0.08	0.32	0.02	0.22	3.02
CD (P = 0.05)	8.26	0.15	0.69	0.04	0.48	6.11

Medina *et al*., (1999) reported that application of nutrients through fertigation maintained moisture level as well as nutrient status of soil which helps in better physiological activity in citrus plant, in contrary to this under water scarcity the plant closes their stomata to minimize dehydration which resulted into less photosynthesis and transpiration rate both. The (Don, 2001) was stated that the positive effect of nitrogen to increase in leaf area may be due to many important factors like genetic, metabolic compounds and plant structures

which are correlated with that nutrient. Major nutrients like NPK are important constituents of many organic compounds in the plants such as formation of proteins, nucleic acid, chlorophyll, and enzymes which is essential for plant growth and development (Sah *et al.*, 2014).

On the basis of three years pooled data it has been shown that the application of higher dose (120 % RDF) of fertilizer observed highest current season shoot, increase in plant height, increase in girth, leaf area, LAI, canopy volume, yield, total chlorophyll content, photosynthesis rate, stomatal conductance, transpiration rate and leaf internal CO_2 concentration in Kinnow under high density planting condition which was almost equal with 100 % RDF. On the basis of above findings it may be concluded that plants were in growing stage so; it shows positive response of fertilizers in respect of growth, yield and physiological parameters. Hence, treatment 100 % RDF can be recommended as best under Sabour, Bihar conditions for growing Kinnow crop for higher returns.

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