EFFECT OF FERTIGATION ON AVAILABLE SOIL MICRO-NUTRIENT UNDER KINNOW MANDARIN

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Abstract

A field experiment was conducted at Division of Fruit and Horticultural Technology, Indian Agricultural Research Institute (IARI), on 5-year-old plants at Todapur Orchard, IARI, New Delhi, during 2010-2011, to study the effect of fertigation on nutrient distribution pattern under Kinnow mandarin. Standard dose of fertilizers were 600g of N, 300g of P, and 400g of K per tree per year, scheduled in three splits during the period of February (300g N, 75g P and 100g K), April (150g N, 112.5g P and 150g K) and August (150g N, 112.5g P and 150g K) respectively. The soil nutrient was measured at the start and end of the experiment in February 2010 and January 2011 at three depths, *viz*. 0-15, 15- 30 and 30- 60 cm corresponding to two radial distances (50 and 100 cm) for different experimental treatments. The highest amount of soil iron at the end of experiment was observed in T_6having 3.98 ppm, followed by 3.78 ppm and 3.72 ppm at three different depths viz: 0-15, 15-30 and 30- 60 cm respectively at 50 cm distance whereas 3.56 ppm followed by 3.49 ppm and 3.32 were found at 100 cm distance away from the tree. T_6recorded the highest amount of available copper in soil having 2.76 ppm followed by 2.73 ppm and 2.67 ppm from 0-15, 15-30 and 30- 60 cm depths respectively at the distance of 50 cm while, 2.68 ppm, 2.65 ppm and 2.61 ppm from 0-15, 15-30 and 30- 60 cm depths respectively at 100 cm away from the tree. T_8 recorded the highest amount of soil zinc at the end of experiment, 2.59 ppm, 2.50 ppm and 2.20 ppm from 0-15, 15-30 and 30- 60 cm depths respectively from the distance of 50 cm and 2.31 ppm, 2.20 ppm and 1.74 ppm from 0-15, 15-30 and 30- 60 cm depths respectively away from the tree. The highest amount of soil manganese was recorded in T_8at the end of experiment. From 0-15, 15-30 and 30- 60 cm depths respectively 28.38 ppm followed by 24.84 ppm and 21.09 ppm at a distance of 50 cm while 29.88 ppm, 22.40 ppm and 17.43 ppm were observed at 0-15, 15-30 and 30- 60 cm depths respectively away from the tree. Fertigation resulted in increase in concentrationsof micro- nutrients near the zone of active roots (0-15 and 15-30 cm depths), exhibiting a radial decrease with increasing horizontal distance from the point of application, i.e. higher at 50 cmand lower at 100 cm distance from the trunk. It was recommended that fertigation with 75 per cent N and 100 per cent P & K (450 g N, 300g P and 400 g K) can be recommended for application in three splits during February (225N:75P:100K), Apri1(112.5N: 112.5P: 150 K) and August (112.5N: 112.5P: 150 K) for young Kinnow orchards.

Key words: Kinnow, fertigation, micronutrient, depth, distance

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Introduction

Fertigation is generally accepted as a technology to improve use efficiency of often limited irrigation water and fertilizers, mainly in horticultural production as it combines the two main factors in plant growth and development, water and nutrient. Fertigation, injecting fertilizer into drip irrigation system, offers the benefits of supplying the correct amounts of nutrients to the crop at the times when they are most needed by it, directly into the root zone (Bar Yosef, 1999). It offers more possibilities to exploit growth, physiological and biochemical parameters, nutrient acquisition, yield and quality in citrus than conventional irrigation and fertilization practices. This technology has become popular due to careful regulation and monitoring of nutrients supply and even distribution of nutrients matched in amount and timing to the plant nutrients requirements (Burt *et al.* 1998). The widespread adoption of fertigation in fruit crops has been facilitated by the expansion of micro-irrigation techniques. Drip irrigation has achieved a preference place as an efficient and economically method due to its highly localised application and flexibility in scheduling water and chemical applications (Mmolawa andOr,2000; Mengel and Kirkby,2001).

Having knowledge on plant nutrient distribution in soil is the foundation to manage fertigation schedules to meet the crop nutrient requirement matching the plant growth stages. Nutrient uptake by roots is dependent on both the ability of the roots to absorb nutrients and the nutrient concentration at the surface of the root. Plant nutrients are divided into two categories, *viz*., those which are taken up by the plant roots easily and those that are excluded by the plant roots. In this way, plant roots have become selective in taking up the nutrients, which in return affect the concentration, movement as well as distribution of nutrients within the effective root zone of the plant. Those taken up by the plant become depleted so fast in the root zone and those excluded remain in the root zone at high concentration, whereas the first may lead to plant nutrient deficiency the last may be detrimental for optimum plant growth.

Combined together the citrus (*Citrus* sp.) family is the world largest group of commercially grown fruit crops.Citrus belongs to the family Rutaceae and most genotypes originated in the areas of temperate in Southeast Asia. Mandarin group including Kinnow have changed dramatically the fresh citrus market worldwide in past 20 years because of the consumer and supermarket preferences. Kinnow is valued due to its high juice content, special flavour and as a rich source of vitamin C (Joshi *et al.,* 1997; Ejraie*et al*, 2009). Kinnow productivity depends on the adequate fertilizer and irrigation application. However, excess or deficient application of fertilizers has resulted in adverse effect on soil physical and chemical properties, affecting the economic production, by decreasing yield and quality of Kinnow. It is therefore important to optimise the usage of fertilizers by supplying the nutrient required by the plant matching to the stages of growth and development. This study thus was aimed to study the nutrient distribution patternunder fertigation.

Materials and Methods

Site description

The field experiment with citrus crop (Kinnow/*JattiKatti* rootstock) was carried out at the Todapur orchard of Division of Fruits and Horticultural Technology, Indian Agricultural Research Institute (IARI), New Delhi. IARI is situated in West Delhi between the latitudes of 28^0 38' 22" N and 38^0 39' 05" N and longitudes of 77^0 9' 45" E and 77^0 10' 24"E at an average elevation of 228.61 m above the mean sea level. Climate of Delhi is categorized as semi-arid, subtropical with hot dry summer and cold winter and it falls in the Agro-eco-region-IV. The mean annual temperature is 25^{0}C. May and June are the hottest months with maximum temperature of 40 to 45^{0}C. December and January are the coldest months with a temperature of 7^{0}C however, the minimum temperature dips to as low as 1^{0}C. The mean annual rainfall is 710 mm of which as much as 75 per cent is received during monsoon season (June to September). Some winter showers are also received during December-March. Frost occurs occasionally during month of December-January. The average relative humidity varied from 34.1 to 97.9 per cent and average wind speed is 0.45 to 3.96 m per sec. Soils of IARI represent a typical alluvium profile of *Yamuna* origin. The entire farm is covered under several soil series. The soil type ranges from sandy loam to clay loam. The texture up to depth of about 150 cm appears almost uniform. As per USDA textural classification, major portion of the area belongs to sandy loam class. Porosity in general is about 40% and soil belongs to good class as far as its permeability is concerned.

Experiment Detail

Experiment was conducted in 2010-11 on 5-years-old Kinnow/*JattiKatti* plants. Plant to plant and row to row spacings were 4.5 m x 5.0 m,respectively. Standard dose of fertilizers was 600 g of N, 300 g of P and 400 g of K per tree per year, scheduled in three splits during February (300 g N, 75 g P and 100 g K), April (150 g N, 112.5 g P and 150 g K) and August, 2010 (150 g N, 112.5 g P and 150 g K), respectively. For basal application to soil urea, single super phosphate and potassium suphate were used. While for fertigation soluble NPK (10:24:24), urea and potassium sulphate were used. The experiment was planned with eight treatments (one tree as unit) having replicated four times following a randomized block design. The treatments considered in the study are given below.

Treatments (8)

T_1: Ring irrigation with standard dose of N, P, K as soil application
T_2: Drip with 100% N, P, K as soil application
T_3: Fertigation with 100% N and P, K as soil application
T_4: Fertigation with 75% N and P, K as soil application
T_5: Fertigation with 50% N and P, K as soil application
T_6: Fertigation with 100% N, P, K
T_7: Fertigation with 75% N and 100% P, K fertigation
T_8: Fertigation with 75% N, P, K

An online drip irrigation system was chosen for Kinnow crop orchard. The control head of the system consisted of sand filter, flow control valve, screen filter, pressure gauges etc. The system was connected to fertigation pump for the application of fertilizers. A PVC sub-mainline (50 mm outer diameter, 4 kg/cm^2 working pressure)already was installed in the experimental field area. Lateral lines of LDPE (16 mm diameter) were connected to the sub main line for the irrigation of Kinnow plant. The lateral lines were placed along the Kinnow row having a ring of six online emitters of four litres per hour (4 l/hr) capacity surrounding the tree with a valve control at individual tree. Each lateral line was provided with flow control valve at the start of the line to achieve specific irrigation and fertigation operation for each treatment. The data on soil micronutrients were collected and analysed at the start and end of experiment during February 2010 and January 2011 respectively.

Statistical Analysis

The data were statistically analysed for analysis of variance (ANOVA) using SAS software. The significance of variance was observed by applying 'F' test and critical difference was calculated at 0.05 level of probability.

Results

Available Iron

The available iron in soil at the end of experiment in all the treatments taken under observation are presented in Table.1. The different treatments did not influence the Fe content significantly, however it varied with depth and radial distance. T_6 indicated the highest amount of available iron in soil having 3.98 ppm, followed by 3.78 ppm and 3.72 ppm at three different depths viz: 0-15, 15-30 and 30- 60 cm respectively at 50 cm distance whereas 3.56 ppm followed by 3.49 ppm and 3.32 were found at 100 cm distance away from the tree. T_1 showed less amount of soil iron 3.62 ppm followed by 3.54 ppm, 3.31 ppm from 0-15, 15-30 and 30-60 cm depths respectively from the distance of 50 cm and 3.37 ppm, 3.20 ppm and 2.85 ppm from 0-15, 15-30 and 30-60 cm depths respectively away from the tree. . T_5 was found next to T_1 in recording less iron at the end of experiment having 3.53 ppm followed by 3.37 ppm and 3.20 ppm at three different depths viz: 0-15, 15-30 and 30- 60 cm respectively at 50 cm distance whereas 3.38 ppm, 3.21 ppm and 2.17 ppm were found at 100 cm distance away from the tree at 0-15, 15-30 and 30- 60 cm respectively. In case of T_3, Iron has found to decrease when depths increased or when radial distance increased away from the tree recording 3.56 ppm, followed by 3.48 ppm and 3.0 ppm at 50 cm while 3.38 ppm, 3.34 ppm and 3.1 ppm were observed at 100 cm distance.

Table 1. Effect of fertigation on soil available iron. content (ppm)

Particulars										Initial
Radial Distance	Depth	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	value*
50 cm	0-15 cm	3.62	3.68	3.56	3.53	3.63	3.98	3.73	3.78	3.45
	15-30 cm	3.54	3.54	3.48	3.37	3.31	3.78	3.59	3.65	3.27
	30-60 cm	3.31	3.30	3.00	3.20	3.01	3.72	3.47	3.43	3.06
100 cm	0-15 cm	3.37	3.43	3.38	3.38	3.48	3.56	3.73	3.58	3.21
	15-30 cm	3.20	3.29	3.34	3.21	3.12	3.49	3.64	3.46	3.10
	30-60 cm	2.85	3.00	3.10	2.17	2.18	3.32	3.29	3.23	2.72

C. D. at 5%: Radial Distance: 5.16; Depth: 6.30; Treatment: 10.30; Radial Distance x Depth: 8.92; Radial Distance x Treatment: 14.56; Depth x Treatment: 17.84; Radial Distance x Depth x Treatment: 25.24

*not included for analysis purpose

Available Copper

Copper movement in soil at the end of experiment is has been given in Table.2. Different treatments did not influence the Copper content significantly. The highest amount of soil copper at the end of experiment was observed in T_6 having 2.76 ppm followed by 2.73 ppm and 2.67 ppm from 0-15, 15-30 and 30- 60 cm depths respectively at the distance of 50 cm while, 2.68 ppm, 2.65 ppm and 2.61 ppm from 0-15, 15-30 and 30- 60 cm depths respectively at 100 cm away from the tree. T_8 recorded the highest amount of soil copper at the end of experiment following T6. From 0-15, 15-30 and 30- 60 cm depths respectively 2.73 ppm followed by 2.70 ppm and 2.65 ppm were recorded at a distance of 50 cm while 2.69 ppm, 2.63 ppm and 2.56 ppm were observed at 0-15, 15-30 and 30-60 cm depths respectively at 100 cm away from the tree. The least amount of soil copper at the end of experiment was observed in T_5 where 2.30 ppm, followed by 2.26 ppm and 2.22 ppm at three different depths viz: 0-15, 15-30 and 30-60 cm respectively at 50 cm distance whereas 2.27 ppm followed by 2.23 ppm and 2.20 were found at 100 cm distance away from the tree at 0-15, 15-30 and 30- 60 cm respectively.

Table.2. Effect of fertigation on soil available copper content (ppm)

Particulars										Initial
Radial Distance	Depth	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	value*
50 cm	0-15 cm	2.34	2.43	2.54	2.38	2.30	2.76	2.57	2.73	2.46
	15-30 m	2.30	2.28	2.51	2.34	2.26	2.73	2.53	2.70	2.28
	30-60 m	2.09	2.16	2.46	2.28	2.22	2.67	2.48	2.65	2.94
100 cm	0-15 cm	2.02	2.40	2.47	2.32	2.27	2.68	2.54	2.69	2.32
	15-30 cm	1.96	2.37	2.39	2.29	2.23	2.65	2.48	2.63	2.23
	30-60 cm	1.91	2.20	2.25	2.24	2.20	2.61	2.41	2.56	2.72

C. D. at 5%: Radial Distance: 0.29; Depth: 0.35; Treatment: N.S; Radial Distance x Depth: 0.50; Radial Distance x Treatment: NS; Depth x Treatment: N.S; Radial Distance x Depth x Treatment: N. S

*not included for analysis purpose

Available Zinc

The zinc movement and distribution in soil at the end of experiment in all the treatments taken under observation are presented in Table.3. T_8 recorded the highest amount of soil zinc at the end of experiment, 2.59 ppm, 2.50 ppm and 2.20 ppm from 0-15, 15-30 and 30- 60 cm depths respectively from the distance of 50 cm and 2.31 ppm, 2.20 ppm and 1.74 ppm from 0-15, 15-30 and 30- 60 cm depths respectively away from the tree. The lowest amount of copper was recorded in T_1 having 2ppm, 1.77ppm, 1.34ppm, from 0-15, 15-30 and 30- 60 cm depths respectively from the distance of 50 cm and 1.82ppm,1.34ppm,1.14ppm from 0-15, 15-30 and 30- 60 cm depths respectively at 100 cm radial distance. The treatment T_2 indicated higher amount of available zinc in soil next to T_1 having 2.09 ppm, followed by 2.06 ppm and 1.07 ppm at three different depths viz: 0-15, 15-30 and 30- 60 cm respectively at 50 cm distance whereas 2.16 ppm followed by 1.63 ppm and 1.29 were found at 100 cm distance away from the tree. When compared between the two radial distances the available zinc content in soil decreased as the distance from the tree increased.

Table.3. Effect of fertigation on soilavailable zinc content (ppm)

Particulars										Initial
Radial Distance	Depth	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	value*
50 cm	0-15 cm	2.00	2.09	2.29	2.30	2.12	2.56	2.33	2.59	3.23
	15-30 cm	1.77	2.06	2.24	2.20	2.11	2.41	2.31	2.50	3.15
	30-60 cm	1.34	1.07	2.15	2.14	2.08	2.21	2.23	2.20	2.96
100 cm	0-15 cm	1.82	2.16	2.26	2.23	2.19	2.44	2.23	2.31	3.08
	15-30 cm	1.34	1.63	2.08	2.06	2.00	2.28	2.15	2.20	2.95
	30-60 cm	1.14	1.29	1.61	1.63	1.58	1.70	1.70	1.74	2.55

C. D. at 5%: Radial Distance: 0.26; Depth: 0.32; Treatment :0.52; Radial Distance x Depth: 0.45; Radial Distance x Treatment: 0.73; Depth x Treatment: 0.90; Radial Distance x Depth x Treatment: 1.27

*not included for analysis purpose

Available Manganese

Manganese movement in soil at the end of experiment is shown in Table.4. The highest amount of soil manganese was recorded in T_8at the end of experiment. From 0-15, 15-30 and 30- 60 cm depths respectively 28.38 ppm followed by 24.84 ppm and 21.09 ppm at a distance of 50 cm while 29.88 ppm, 22.40 ppm and 17.43 ppm were observed at 0-15, 15-30 and 30- 60 cm depths respectively away from the tree. T_6recorded the highest amount of copper next to T_8 from 0-15, 15-30 and 30- 60 cm depths respectively 28.38 ppm followed by 24.84 ppm and 21.09 ppm at a distance of 50 cm while 29.88 ppm, 22.40 ppm and 17.43 ppm were observed at 0-15, 15-30 and 30- 60 cm depths respectively away from the tree.The least amount of soil manganese at the end of experiment was observed in T_5 where 24.12 ppm, followed by 21.11 ppm and 17.92 ppm were recorded at three different depths, *viz*., 0-15, 15-30 and 30- 60 cm respectively at 50 cm distance whereas 25.40 ppm followed by 19.04 ppm and 14.82 were found at 100 cm distance away from the tree at 0-15, 15-30 and 30- 60 cm respectively. In general highest levels of Mn were seen in the upper 0-15 cm of soil at a distance of 100 cm from the tree.

Table.4. Effect of fertigation on soil available manganese content (ppm)

Particulars										
Radial Distance	Depth	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	Initial value*
50 cm	0-15 cm	24.83	25.18	26.84	26.60	24.12	28.02	27.67	28.38	35.38
	15-30 cm	21.74	22.05	23.49	23.29	21.11	24.52	24.22	24.84	30.97
	30-60 cm	18.45	18.72	19.95	19.77	17.92	20.82	20.56	21.09	26.29
100 cm	0-15 cm	26.15	26.52	28.26	28.01	25.40	29.50	29.13	29.88	37.26
	15-30 cm	19.60	19.88	21.19	21.00	19.04	22.11	21.84	22.40	27.93
	30-60 cm	15.25	15.47	16.49	16.34	14.82	17.21	17.00	17.43	21.74

C. D. at 5%: Radial Distance: 2.86; Depth: 3.50; Treatment: NS; Radial Distance x Depth: NS; Radial Distance x Treatment: N.S; Depth x Treatment: N.S; Radial Distance x Depth x Treatment: N. S

*not included for analysis purpose

Discussion

The depletion of nutrients from the wetting zone of drip irrigated crops necessitates the continuous replenishment of nutrient reserves. The mobility of the nutrients ions in soil is particularly important in relation to nutrient distribution. A general trend of decrease in levels of iron, zinc and copper with increase in depth and radial distance has been recorded. The highest levels were found in the upper 0-15 cm layer of soil and there was a marked decrease in the levels in the lower layers as well as with increasing horizontal distance from the tree. In the case of manganese highest levels were found at 100 cm radial distance from the tree as compared to the other micro-nutrients. A significant decrease in manganese levels were seen with increase in depth. Fan *et al.* (2011) found total recoverable Cu decreased more rapidly with depth in relatively high-pH soils than low-pH soils. Copper concentration up to 441 mg kg^{-1} was measured in the top 5 cm, but the downward movement of Cu along soil profile was minimal and Cu concentration decreased markedly with soil depth. Fertigation made Iron available for plant absorption while Meng et al., (2010) found that most Fe in soils is unavailable for plant absorption. The balance between the uptake of cations and of anions by the plants affects the pH in the rhizosphere (Marschner, 1995). Nitrate and ammonium are the main forms of nitrogen available for plant uptake. When plant takes up more nutrient cations than anions, as occurs when NH_4^+ is the main N source, protons are exuded by the roots and acidify the rhizosphere. If the anion uptake is predominant, as when NO^{-3} is the main source of N, the roots exude OH^-, which results in a pH rise in the rhizosphere. The rhizosphere pH varies with the form and concentration of the N fertilizer, but the extent of the pH change in the zone around the root depends on the buffer capacity of the soil. Zinc availability is inversely related to soil pH and its deficiency in variety of plant species is frequently noted on calcareous soils with pH>8.0 (Srinivasara*et al.*, 2008; Rajaie*et al.*, 2009). The availability of Zn and Mn, is also low in alkaline conditions due mainly to adsorption and precipitation processes (Parker and Walker, 1986; Srivastava and Sethi, 1981).

Conclusion

Fertigation resulted in increase in concentrationsof micro-nutrients near the zone of active roots (0-15 and 15-30 cm depths), exhibiting a radial decrease with increasing horizontal distance from the point of application, i.e. higher at 50 cmand lower at 100 cm distance from the trunk. The higher amount of fertilisers retained in the soil at the harvest were found in the treatment with ring irrigation with soil application compared to fertigation treatments. Fertigation with 100 per cent N, P and K in three splits had shown improved utilisation of applied nutrients and their distribution in upper two soil layers (0-15 and 15-30 cm) compared to ring method of irrigation and drip irrigation along with soil application of fertilisers. Hence, fertigation with 75 per cent N and 100 per cent P & K (450 g N, 300g P and 400 g K) can be recommended for application in three splits during February (225N:75P:100K), Apri1(112.5N: 112.5P: 150 K) and August (112.5N: 112.5P: 150 K) for young Kinnow orchards.

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