Sjournals
Scientific Journals
Agricultural Advances (2013) 2(8) 242-249
ISSN 2251-7820
doi: 10.14196/aa.v2i8.897

Contents lists available at Sjournals
Agricultural Advances
Journal homepage: www.Sjournals.com

Original article

Optimizing the potassium (K) dose of fertigation for the Nagpur mandarin (Citrus reticulate Blanco)

P.S. Shirgure*, A.K. Srivastava
National Research Centre for Citrus, Nagpur (M. S.), India.

*Corresponding author; National Research Centre for Citrus, Nagpur (M. S.), India.

ARTICLE INFO

Article history:
Received 02 August 2013
Accepted 19 August 2013
Available online 26 August 2013

Keywords:
Citrus
Drip irrigation
Micro-irrigation
Nagpur mandarin
Potassium fertigation
Sulphate of potash
Yield and quality

ABSTRACT

To standardize the potassium sulphate fertilizer dose through fertigation system during three Ambia flowering (October flush) on yield and quality of 14-16 years Nagpur mandarin a field experiment was conducted at National Research Centre for Citrus, Nagpur during 2009-2012. The Nagpur mandarin plants requires potassium besides N and P which, when applied in during the flower bud initiation to before fruit maturity can affect the yield and fruit quality. The treatments in experiment consisted of; F1- Fertigation with 20 g K_2O/plant/month, F2- Fertigation with 30 g K_2O/plant/month, F3- Fertigation with 40 g K2O/plant/month and F4- Fertigation with 50 g K2O/plant/month. The recommended fertigation dose was 500:150:150 (N:P:K) and given through these treatments along with various fertilizers combination of urea of phosphate, urea and potassium sulphate. Nitrogen and phosphorus was given from October to January month and N, P and K all were given from February to June month. Each fertigation treatment was given at 30 days interval and fruit yield and quality were measured at harvest. Results showed the highest response of the fruit yield (26.67 tonnes/ha) with 50 g K_2O/plant potassium sulphate followed by in K-fertigation with 40 g K_2O/plant dose (25.52 tonnes/ha). The total soluble solids was highest (9.74 0Brix) in K fertigation with 50 g K_2O/plant dose followed by fertigation with potassium sulphate 40 g K_2O/plant dose (9.61 0Brix). Highest juice content (39.72 %) and low acidity (0.86 %) was found in K fertigation with potassium sulphate 50

g K_2O/plant dose. The highest TSS to acidity ratio (sweetness indicator) was observed in 50 g K_2O/plant dose (11.32) followed by 40 g K_2O/plant dose Potassium sulphate (10).

1. Introduction

Nagpur mandarins (Citrus reticulate Blanco) are an important citrus fruit grown in central Indian states and occupy 0.0286 Mha. area. The efficient use of water and fertilizer to increase the crop yield and fruit quality is important concern in today's citricultural system (Shirgure, 2012b). For maximizing the water use and minimizing the input cost of irrigation and fertilizers, the adoption of modern micro-irrigation systems (Shirgure et al., 2001d), irrigation scheduling based on pan evaporation (Shirgure et al., 2001a; 2003b; 2004a; Shirgure 2013a) with fertigation (Shirgure et al., 2003a; 2013b) is essential which will maximize the yield, fruit quality and nutrient uptake while using optimum amounts of water and fertilizer. Among the various factors responsible for higher yields and quality fruits of Nagpur mandarin (Citrus reticulate Blanco) is use of proper quantity of potassium fertilizers along with other N and P fertilizers at appropriate time of the fruit growth stages. Amount of NPK fertilizer either in the form of organic or inorganic and its application method plays a vital role in enhancing the growth and productivity (Beridze, 1990). At present the fertilizer dose is split into three doses and given in June, October and February. As these fertilizers are applied in bulk, lot of fertilizer go waste due to the leaching, evaporation and fixation in the soil. Moreover these applied fertilizers get transmitted to areas beyond the active root zone and are no longer useful to plants. Drip irrigation and fertigation are the most efficient methods of modern irrigation systems which has a potential advantage of water and fertilizer saving (Koo, 1981; Haynes, 1985; Shirgure, 2013b). Fertigation which combines irrigation with fertilizers is well recognized as the most effective, economical and convenient means of maintaining optimum fertility level and water supply according to the specific requirement of each crop and resulting in higher yields and better quality fruits (Smith, 1979; Syvertsen, 1996; Shirgure, 2013a). Fertigation offers the best and some times the only way of ensuring that nutrients enter the rootzone in areas with inadequate rainfall. The fertigation and Nitrogen fertigation was studied on Shamouti sweet orange (Bielori, 1984), Valencia orange (Koo, 1984) Naval orange (Fouche and Bester, 1987; Louse, 1990), Sunburst mandarin (Ferguson, 1990), Nagpur mandarin (Shirgure et al., 2001b; Shirgure and Srivastava, 2012; Shirgure, 2012a) and acid lime (Shirgure et al., 1999; 2001c). The concept of potassium (K) fertigation during flower initiation to fruit growth and development is latest technology (Shirgure and Srivastava, 2013) and no literature as well as work is available on Nagpur mandarin under central Indian agro-climatic conditions. The main objective of this investigation was to standardize the dose of potassium fertigation with sulphate of potash (SOP) fertilizer on plant vegetative growth, leaf nutrients and up-take, yield and fruit quality of Nagpur mandarin (Citrus reticulate Blanco).

2. Materials and methods

The field experiment was conducted in the block of 0.25 ha with 6 x 6 m plant spacing at experimental farm of National Research Centre for Citrus, Nagpur for the standardization of the K fertigation dose with potassium sulphate fertilizer on nutrient up-take due to K fertigation and the effect on growth and productivity of 12-14 years old bearing Nagpur mandarin during 2009 to 2012. The treatments consisted of Fertigation with 20 g K2O/plant/month (F1), Fertigation with 30 g K_2O/plant/month, (F2), Fertigation with 40 g K_2O/plant/month, (F3) and Fertigation with 50 g K_2O/plant/month at 30 days interval (F4) in randomized block design with six replications. The texture of the soil is clay loam and depth of the soil is 47 cm. The composite soil samples were collected for determination of field capacity and permanent wilting point. Volumetric soil moisture content at field capacity (FC) and the permanent wilting point (PWP) soil moisture content was determined using pressure plate method. The FC and PWP of the field under study is 30.62 % and 22.2 % respectively. The available water content of the soil is 8.42%. The bulk density of the soil in field was determined using core sampler having 100 cm3 volume and oven drying. The bulk density of the field is 1.3 g/cc. The water holding capacity of the soil is 10.95 cm/m depth of soil. The drip irrigation system consisting of 4 lph drippers 4 per plant 4 point on the lateral arrangement

were installed in the field along with the liquid dispenser (DOSTRAN, France) for fertigation. For evaluation of the monthly dose of K fertigation in Nagpur mandarin potassium sulphate (K_2SO_4) (0: 0: 50) is used. For standardizing the potassium dose for the K fertigation in Nagpur mandarin following fertilizers are used as Potassium Sulphate (SOP)(0: 0: 50) for K, Urea phosphate (UP)(18: 44: 0) for N and P and Urea (U)(46: 0: 0) for N. The recommended fertilizer dose to be given to the bearing Nagpur mandarin through fertigation is 500: 150: 150 (N:P:K). K-fertigation is started from February month at the interval of 30 days. It is given on 2nd day of the month. Nitrogen and phosphorous is given from October to January and all N, P and K as per the treatments defined are given from February and will continue till June. The detailed fertigation scheduling is given in Table 1.

Table 1
The fertigation scheduling of N, P and K fertilizers (g/plant).

Month	Date	N g/plant	P g/plant	Potassium (K) g/plant			
				F1	F2	F3	F4
October	(2)	55.55	16.67	-	-	-	-
November	(2)	55.55	16.67	-	-	-	-
December	(2)	55.55	16.67	-	-	-	-
January	(2)	55.55	16.67	-	-	-	-
February	(2)	55.55	16.67	20	30	40	50
March	(2)	55.55	16.67	20	30	40	50
April	(2)	55.55	16.67	20	30	40	50
May	(2)	55.55	16.67	20	30	40	50
June	(2)	55.55	16.67	20	30	40	50
Total		500	150	100	150	200	250

Since only N and P is being given from October to January. All the plants are uniformly provided with Urea and Urea phosphate fertilizers. The quantity of the fertilizers combination is (UP 5.455 Kg + Urea 15.250 Kg). From February onwards the K1 to K4 treatments having different dose of K fertigation along with N and P dose were given as per the following schedule. The potassium is given using Sulphate of potash fertilizer. The biometric growth parameters of Nagpur mandarin plants (plant height and tree spread) were recorded in October, 2009, 2010 and 2011. The plant stock girth was taken 15 cm above the soil surface. The canopy volume of the mandarin tree was calculated according to formula suggested by Castle (1983). Nagpur mandarin fruit yield and quality analysis was also carried out as per procedures described by Ranganna (1986). The initial soil and leaf samples were collected from the different treatments as per the technical programme during November, 2009. The standard leaf and soil sampling method was adopted while collecting the samples. The standard leaf sampling method was adopted while collecting the samples. Leaf samples were collected as per procedures suggested by Srivastava et al., (1994) and finally prepared samples were digested in diacid mixture of H_2SO_4 : $HClO_4$ in 2.5:1 ratio. The leaf N was determined using alkaline permangate steam distillation method, P by vanadomolybdophosphoric acid method and K flame photo metrically. The data on fruit yield and quality attributing to the different K fertigation for 3 years were analysed by Analysis of variance method (Gomez and Gomez, 1984).

3. Results and discussion

3.1. Effect of K fertigation dose on growth and canopy volume of Nagpur mandarin

The effect of different doses of potassium (K) fertigation using sulphate of potash fertilizer has influenced on the biometric growth of 14-16 years Nagpur mandarin during 2009-2012. The data on biometric growth parameters of Nagpur mandarin revealed that out of various growth parameters, only canopy volume produced a significant effect in relation to K doses fertigation treatments. The growth of mandarin plant (plant height, stock girth, and canopy volume) recorded during October month of the year 2009-10, 2010-11 and 2011-12. The data of plant height and plant spread have been used in estimating the canopy volume of the tree with Castel (1983) formula. The plant height and stock girth is not significant. But the canopy volume is significant during the three

years of the study (Table 1). The average plant height (4.49 m) and stock girth (53.13 cm) of the Nagpur mandarin plant was recorded in potassium fertigation @ 50 g/plant. The plant height (4.4 m) and stock girth (52.64 cm) was medium in K fertigation @ 40 g/plant, followed by K fertigation @ 20 g/plant (plant height, 4.42 m; and stock girth 51.69 cm). The lowest plant height (4.33 m) and stock girth (51.05 cm) was observed in K fertigation @ 30 g/plant during 2009 to 2012. The significant growth was observed in plant canopy volume ranging from 24.60 to 28.43 m3, 30.61 to 33.06 m3 and 32.67 to 35.03 m3 during the year 2009-10, 2010-11 and 2011-12 respectively. The highest average canopy volume of the Nagpur mandarin plant (32.17 m3) was recorded with K fertigation potassium sulphate @ 50 g/plant. The average canopy volume of the mandarin plant was medium (31.08 m3) with K fertigation @ 40 g/plant followed by K fertigation with potassium sulphate @30 g/plant (29.44 m3). The lowest plant canopy (29.59 m3) was observed in K fertigation with potassium sulphate @ 20 g/plant during 2009 to 2012 (Table 1). This may be due to the correct amount of potassium dose during the plant growth stages and frequent drip irrigation and fertigation scheduled favoring fruit growth development. The similar type of observations were also recorded in the earlier studies on fertigation scheduling in Nagpur mandarin (Shirgure et al., 2001b) and in acid lime (Shirgure et al., 2004c) under the central Indian conditions.

Table 1
The plant growth and canopy volume of Nagpur mandarin during 2009-2012.

Treatments	Plant height, m				Stock girth, cm				Canopy volume, m3			
	2009-2010	2010-2011	2011-2012	Mean	2009-2010	2010-2011	2011-2012	Mean	2009-2010	2010-2011	2011-2012	Mean
F1	4.13	4.53	4.60	4.42	46.58	53.83	54.67	51.69	25.50	30.61	32.67	29.59
F2	4.04	4.46	4.49	4.33	46.71	52.25	54.15	51.05	24.60	30.62	33.10	29.44
F3	4.09	4.62	4.75	4.40	49.08	53.83	55.00	52.64	26.24	32.43	34.57	31.08
F4	4.28	4.76	4.67	4.49	47.96	55.08	56.35	53.13	28.43	33.06	35.03	32.17
SD (P = 0.05)	NS	NS	NS	----	NS	NS	NS	------	NS	NS	1.15	-----

F1 - Fertigation with 20 g K2O/plant/month, F2- Fertigation with 30 g K2O/plant/month.
F3- Fertigation with 40 g K2O/plant/month and F4- Fertigation with 50 g K2O/plant/month.

3.2. Effect of different K fertigation doses on leaf nutrient status and up-take

The effect of differential K fertigation with different four different potassium fertilizers treatments on leaf status and nutrient up-take was monitored with periodical analysis of leaf. The initial and final leaf samples were collected from different irrigation treatments were analysed for N, P and K contents as well as Fe, Mn, Zn and Cu elements in 2009-2012. Before the imposition of the fertigation treatments the leaf nutrient status viz., N (1.98 to 2.15 %), P (0.079 to 0.085 %), K (0.87 to 1.10 %), Fe (121.2 to 70.6 ppm), Mn (47.1 to 57.4 ppm), Cu (4.0 to 7.3 ppm) and Zn (15.9 to 31.4 ppm) was observed in different potassium fertilizer dose treatments. In the final leaf nutrient analysis the K fertigation @ 50 g/plant recorded the highest concentration of macronutrients (N, P and K) and micronutrients (Fe, Mn, Cu, and Zn) compared to rest of the other K fertigation dose treatments (Table 2). The potassium dose fertigation treatment with @ 50 g/plant recorded the highest concentration of macronutrients (2.19 % N, 0.08 % P and 1.28 % K) compared to rest of the other potash dose fertigation treatments. Leaf N (2.12 %), P (0.07 %) and K (1.0 %) contents were observed significantly higher with sulphate of potash fertigation @ 40 g/plant than N (2.10 %), P (0.09 %) and K (0.99 %) content with potassium sulphate @ 30 g/plant K fertigation. The lowest leaf nutrient composition N (1.94 %), P (0.09 %) and K (1.10 %) was observed with potassium sulphate K fertigation dose of 20 g/plant during 2009-2012. Similarly the final elemental leaf analysis of micro-nutrients (Fe,

Mn, Cu and Zn) is done during March 2012. The Fe, Mn and Zn elements were significant due to the different K fertigation doses, but the element Copper (Cu) not non-significant. The leaf analysis revealed that the K fertigation doses with potassium sulphate @ 50 g/plant recorded the highest concentration of micronutrients (112.0 ppm Fe, 53.0 ppm Mn, 7.3 ppm Cu and 25.1 ppm Zn) compared to rest of the other potash fertilizers dose fertigation treatments. Leaf Fe (110.4 ppm), Mn (56.4 ppm), Cu (6.9 ppm) and Zn (19.0 ppm) contents were observed significantly higher with sulphate of potash fertigation @ 40 g/plant than with 30 g/plant K fertigation (Fe, 96.5 ppm), Mn (60.3 ppm), Cu (7.0 ppm) and Zn (17.6 ppm). The lowest leaf micronutrients nutrient composition leaf Fe (108.6 ppm), Mn (53.5 ppm), Cu (7.9 ppm) and Zn (15.5 ppm) content was observed with potassium sulphate K fertigation @ 20 g/plant dose during 2009-2012 (Table 2).

3.3. Effect of various K fertigation doses on fruit yield of Nagpur mandarin

The potassium (K) fertigation with sulphate of potash fertilizer @ 20 to 50 g K2O/plant had a positive effect on the fruit yield as well as quality of the Nagpur mandarin during 2009-2012. The Nagpur mandarin fruits were harvested during first fortnight of November month in the year 2009, 2010 and 2011. The average number of fruits per plant, yield, TSS, Juice content, and acidity was analysed for the study period and pooled data and mean values were presented (Table 3). The Nagpur mandarin yield and fruit quality were significantly influenced by the different K fertilizer doses fertigated to Nagpur mandarin. The number of fruits per plant, fruit yield, average fruit weight, total soluble solids (TSS) and juice percentage was found significant and acidity was non-significant during 2010-11 and 2011-12. Yield and quality were significantly influenced by the different K fertigation doses treatments (Table 3). The average number of fruits per plant was 489 to 580 in all the K fertigation doses treatment. The highest number of fruits per plants (580 fruits/plant) was in K fertigation with potassium sulphate @ 50 g K2O/plant followed by K fertigation @ 40 g K2O/plant with of sulphate of potash (567 fruits/plant) and potassium sulphate @ 30 g K2O/plant (519 fruits/plant).

Table 2
The leaf nutrient concentration under different K fertigation treatments.

Treatments	**Macronutrients (%)**			**Micronutrients (ppm)**			
	N	**P**	**K**	**Fe**	**Mn**	**Cu**	**Zn**
Initial leaf nutrient status (2009-10)							
	Macronutrients (%)			**Micronutrients (ppm)**			
F1	2.09	0.080	0.97	137.2	55.2	6.7	15.9
F2	2.14	0.085	0.87	164.2	57.4	7.3	23.2
F3	1.98	0.085	0.94	170.6	47.1	4.0	16.7
F4	2.15	0.079	1.10	121.2	52.0	5.0	31.4
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS
Final leaf nutrient status (2011-12)							
	N	P	K	Fe	Mn	Cu	Zn
F1	1.94	0.09	1.10	108.6	53.5	7.9	15.5
F2	2.10	0.09	0.99	96.5	60.3	7.0	17.6
F3	2.12	0.07	1.00	110.4	56.4	6.9	19.0
F4	2.19	0.08	1.28	112.0	53.0	7.3	25.1
CD(P=0.05)	0.14	NS	0.16	0.03	0.71	NS	1.22

F1 - Fertigation with 20 g K2O/plant/month, F2- Fertigation with 30 g K2O/plant/month.
F3- Fertigation with 40 g K2O/plant/month and F4- Fertigation with 50 g K2O/plant/month.

The lowest number of fruits per plant was with K fertigation dose 20 g K2O/plant using potassium sulphate (489 fruits/plant) may be due to the low monthly K dose during the fruit development phases. The various potassium (K) fertigation doses with potassium sulphate fertilizer treatments significantly influenced the yield of the Nagpur mandarin. The average Nagpur mandarin fruit yield was 21.39 to 26.67 tonnes/ha in all the K fertigation doses schdules. The highest fruit yield per hectare was in K fertigation with @ 50 g K2O/plant (26.67 tonnes/ha) followed K fertigation @ 40 g K2O/plant (25.32 tonnes/ha) and with @ 30 g K2O/plant (23.33 tonnes/ha). The lowest fruit yield was with @ 20 g K2O/plant (21.39 tonnes/ha) may be due to the lower K dose in

critical fruit growth development periods during 2009-2012 (Table 3). This is clearly indicated that the potassium (K) fertigation doses with 20-50 g K2O/plant with potassium sulphate is essential for production of good quality mandarin fruits. The drip irrigation maintained higher as well as continuous soil moisture along with potassium (K) availability influenced by the water and nutrient uptake resulting into good quality fruits besides enhancing the yield.

Table 3
Average yield and fruit quality parameters of the Nagpur mandarin during 2009-2012.

Treatments	No. of fruits	Yield, t/ha	Average wt. of fruit, g	TSS, 0Brix	Juice, %	Acidity, %	TSS/acid Ratio
F1	489	21.39	155.85	9.60	37.88	1.13	9.5
F2	519	23.33	159.53	9.63	38.74	1.12	8.6
F3	567	25.52	163.30	9.61	37.15	0.96	10.0
F4	580	26.67	164.37	9.74	39.72	0.86	11.32
LSD (P = 0.05)	28	1.83	1.94	0.04	0.32	NS	----

F1 - Fertigation with 20 g K2O/plant/month, F2- Fertigation with 30 g K2O/plant/month.
F3- Fertigation with 40 g K2O/plant/month and F4- Fertigation with 50 g K2O/plant/month.

3.4. Fruit quality of Nagpur mandarin with different K fertigation doses

The highest average fruit weight (164.37 g), TSS (9.74 oBrix), juice percent (39.72 %) and lowest acidity (0.86) is observed in K fertigation dose with potassium sulphate @ 50 g K2O/plant followed by K fertigation dose @ 40 g K2O/plant. The moderate fruit quality was observed with K fertigation with potassium sulphate @ 40 g K2O/plant followed by K fertigation @ 30 g K2O/plant. The average fruit weight (163.30 g), TSS (9.61 oBrix), juice percent (37.15 %) and acidity (0.96) is observed in K fertigation with @ 40 g K2O/plant and @ 30 g K2O/plant (the average fruit weight, 159.53 g; TSS, 9.63 oBrix; juice percent, 38.74 and acidity as 1.12). The lowest average fruit weight (155.85 g), TSS (9.60 oBrix), juice percent (37.88 %) and highest acidity (1.13) is observed in K fertigation with @ 20 g K2O/plant dose. The higher TSS to acidity ratio is the indicator of sweetness of the fruit of Ambia (flush during October-November month) flowering. If the TSS to acidity ratio is high means that the fruits have more TSS (total soluble solids) and less acidity. This ratio was analysed and the highest TSS to acidity ratio (11.32) was found in K fertigation with @ 50 g K2O/plant followed by 40 g K2O/plant K fertigation with potassium sulphate (SOP) in which the TSS to acidity ratio is 10. The TSS to acidity ratio was 9.5 with the K fertigation dose @ 20 g K2O/plant with potassium sulphate. The lowest TSS to acidity (8.6) was observed the K fertigation dose @ 30 g K2O/plant potassium fertigation (Table 3). The diameters of the growing Nagpur mandarin fruits were measured by vernier calliper during March to November months. The changes in fruit size in all the four treatments were relatively constant during the season during 2010-2011. Fruit size for all years showed fruit diameter ranging from 0.82 to 7.36 cm. The fruit growth of the K-1 (40 K20 g/plant fertigation at monthly interval from fruit set) was higher over the rest of the K doses treatments. The similar fruit growth trend was also seen in 2011-2012. The similar fruit yield and quality experimental results are observed in Nagpur mandarin (Shirgure et al., 2001a; Srivastava et al., 2003) and acid lime (Shirgure et al., 2001c).

4. Conclusion

The Nagpur mandarin yield can be increased with K-fertigation using sulphate of potash fertilizer. Potassium fertigation doses can be given sulphate of potash fertilizer. The leaf nutrient status was high in fertigation with sulphate of potash (50 g K2O/plant) at 30 days interval from February to June. The mandarin yield was highest (26.67 t/ha) with sulphate of potash fertigation @ 50 K2O/plant followed by K-fertigation @ 40 K2O/plant at 30 days interval (25. 32t/ha). The fruit quality is also affected with different potash fertilizers doses. Highest fruit TSS

(9.74 0Brix) and fruit weight (164.37 g) was observed with K fertigation 50 g K2O/plant at 30 days interval. The highest TSS/acidity ratio was observed with K fertigation with 50 g K2O/plant at 30 days interval (11.32). Sulphate of potash fertilizer fertigation with 50 g K2O/plant at 30 days interval through micro-irrigation can be a sustainable solution for increasing the fruit production and quality of Nagpur mandarin.

References

Beridze, T.R., 1990. The effect of organic fertilizers on lemon tree productivity. Sub tropicheskie Kul'tury. No., 3, 83-86.

Bielorai, H., Deshberg, E., Brum, M., 1984. The effect of fertigation and partial wetting of the rootzone on production of shamouti orange. Proc. Int. Soc. Citriculture., 1, 118-120.

Castle W., 1983. Growth, yield and cold hardiness of seven year old "Bearss" lemon on twenty seven rootstocks. Proc. Florida State. Hort. Soc., 96 23–25

Ferguson, J.J., Davies, F.S., Bulger, J.M., 1990. Fertigation and growth of young `Sunburst' tangerine trees. Proc. of Flor. Stat. Hort. Sci., 103, 8-9.

Fouche, P.S., Bester, D.H., 1987. The influence of water soluble fertilizer on nutrition and productivity of Navel orange trees under microjet irrigation. Citrus. Sub-tropical. fruit. J., 62, 8-12.

Gomez, K.A., Gomez, A.A., 1984. Statistical Procedures fior Agriculture Research. John Wiley and Sons pp 664-5.

Koo, R.C.J. 1981. Results of Citrus fertigation studies. Proc. Florida. State. Horti. Sci., 93, 33-36.

Koo, R.C.J., Smjstrala, A.G., 1984. Effect of trickle irrigation and fertigation on fruit production and fruit quality of Valencia orange. Proc. florida state Hort. Sci., 97, 8-10.

Louse Ferguson., 1990. Nitrogen fertigation of citrus summery of citrus research. Citrus research centre and Agricultural station. Univ. Calif. Riverside., p, 20-22.

Haynes, R.J., 1985. Principles of fertilizer use for trickle irrigated crops. Fert. Res., 6, 235-255.

Ranganna, S., 1986. Handbook of analysis and quality control for fruit and vegetable products. Tata Mc. Grow Hil Pub. Comp. Ltd., New Delhi., pp 881-2.

Shirgure, P.S., Lallan Ram, R.A., Marathe Yadav, R.P., 1999. Effect of Nitrogen fertigation on vegetative growth and leaf nitrogen content of acid lime. Indian J.Soil. Conservat., 27 (1), 45 – 49.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2001. Effect of pan evaporation based irrigation scheduling on yield and quality of drip irrigated Nagpur mandarin. Indian J. Agri. Sci., 71 (4),264-6, April, 2001.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2001. Growth, yield and quality of Nagpur mandarin (Citrus reticulata Blanco) in relation to irrigation and fertigation. Indian J. Agri. Sci., 71(8), 547-50, August, 2001.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2001. Effect of nitrogen fertigation and band placement fertilizer application on soil -leaf nutrient build-up and incremental growth of acid lime. J. Soil Water Cons., 45 (3&4) , 176-181.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2001. Effect of drip, microjets and basin irrigation method on growth, soil and leaf nutrient change in acid lime. Indian J. Soil Cons., 29 (3) , 229-234.

Shirgure, P. S., Srivastava, A.K., Singh, S., 2003. Evaluating micro-irrigation systems in Nagpur mandarin under sub-humid tropical climate. Tropical. Agriculture., 80 (2), 91-96.

Shirgure, P. S., Srivastava, A.K., Singh, S., 2003. Irrigation scheduling and fertigation in acid lime (Citrus aurantifolia Swingle). Indian J. of Agric. Sci., 73(7), 363-7.

Shirgure, P. S., Srivastava, A.K., Singh, S., Pimpale, A.R., 2004. Drip irrigation scheduling growth, yield and quality of acid lime (Citrus aurantifolia Swingle). Indian J. of Agric. Sci., 74 (2), 92 – 4.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2004. Growth, yield and quality of acid lime under pan evaporation based drip irrigation scheduling. Indian J. Soil Cons., 32 (1) , 32-35.

Shirgure, P.S., Srivastava, A.K., Singh, S., 2004. Integrated water and nutrient management in acid lime. Indian J. Soil Cons., 32 (2), 148-151.

Shirgure, P. S., Srivastava, A.K., 2012. The effect of four under tree micro-jet irrigation (180-3000) systems on fruit yield and quality of Nagpur mandarin in Central India. Sci. J. Agricultural., 1 (7), 177-186.

Shirgure P. S., Srivastava A. K., Singh S., 2012. Potassium (K) fertigation using Sulphate of Potash (SOP) in Nagpur mandarin. Abstract National Dialogue on Citrus, Improvement, Production and Utilization conducted by National Research Centre for Citrus, Nagpur in the silver jubilee celebration during 27-29th February, 2012 p-162.

Shirgure, P. S., 2012. Effect of pulse irrigation scheduling with hybrid station controller on fruit yield and quality of Nagpur mandarin (Citrus reticulate Blanco). Sci. J. Crop Sci., 1 (5),76-82.

Shirgure, P. S., 2012. Micro-irrigation systems, automation and fertigation in Citrus. Sci. J. Rev., 1 (5), 156-169.

Shirgure, P. S., 2013. Yield and fruit quality of Nagpur mandarin (Citrus reticulata Blanco) as influenced by evaporation based drip irrigation schedules. Sci. J. Crop Sci., 2 (2), 28-35.

Shirgure, P. S,. Srivastava, A.K., 2013. Plant growth, leaf nutrient status, fruit yield and quality of Nagpur mandarin (Citrus reticulate Blanco) as influenced by potassium (K) fertigation with four potash fertilizer sources. Sci. J. Crop Sci., 2 (3), 36-42.

Shirgure, P. S., 2013. Citrus fertigation – a technology of water and fertilizers saving. Sci. J. Crop Sci., 2(5) 56-66.

Smith, M.W., Kenworthy, A.L., Bedford, C.L., 1979. The response of fruit trees to injections of Nitrogen through a trickle irrigation system. J. Amer. Soc. Hort. Sci., 104, 311-313.

Srviastava, A.K., Ram Lallan, Huchche, A.D., Kohli, R.R. Dass, H.C., 1994. Standardisation of leaf sampling technique in Nagpur mandarin under sub-humid tropical climate. Indian J. Hort. Sci., 51(1), 32-6.

Srivastava, A.K., Shirgure, P.S., Singh, S., 2003. Differential fertigation response of Nagpur mandarin (Citrus reticulata Balanco) on an alkaline Inceptisol under sub-humid tropical climate. Trop. Agriculture., 80 (2), 97-104.

Syvertsen, J.P., Smith, M.L., 1996. Nitrogen uptake efficiency and Leaching losses from Lysimeter grown citrus trees fertilized at three nitrogen rates. J. Amer. Soc. Hort. Sci., 121 (1), 57-62.