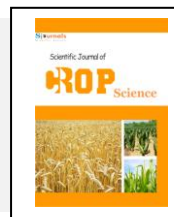


Contents lists available at Sjournals

Scientific Journal of  
**CROP** ScienceJournal homepage: [www.Sjournals.com](http://www.Sjournals.com)**Original article****Plant growth, Leaf Nutrient status, fruit yield and quality of Nagpur mandarin (*Citrus reticulata* Blanco) as influenced by potassium (K) fertigation with four potash fertilizer sources****P.S. Shirgure\*, A.K. Srivastava**

National Research Centre for Citrus (ICAR), Nagpur, Maharashtra-440 010.

\*Corresponding author; National Research Centre for Citrus (ICAR), Nagpur, Maharashtra-440 010.

## ARTICLE INFO

## ABSTRACT

*Article history:*

Received 09 March 2013

Accepted 18 March 2013

Available online 29 March 2013

*Keywords:*

Potassium fertigation

Potash fertilizers

Citrus

Nagpur mandarin

Yield

Fruit

To investigate the effect of different potassium (K) fertilizers applied through fertigation system during three different seasons on yield and quality behaviors of 14-16 years Nagpur mandarin an experiment was conducted at National Research Centre for Citrus, Nagpur during 2009-2012. The Nagpur mandarin plants requires potassium which, when applied in different amounts during the flower bud initiation to before fruit maturity can affect the yield and quality of fruit as well. The treatments in experiment consisted of; T<sub>1</sub> - fertigation with potassium chloride [KCL], T<sub>2</sub>- fertigation with potassium nitrate [KNO<sub>3</sub>], T<sub>3</sub>- fertigation with potassium sulphate [K<sub>2</sub>SO<sub>4</sub>] and T<sub>4</sub>- fertigation with mono potassium phosphate [KH<sub>2</sub>PO<sub>4</sub>] @ 150 g K<sub>2</sub>O/plant. 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 P<sub>2</sub>O<sub>5</sub> acid. Nitrogen element 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 15 days interval and fruit yield and quality were measured at harvest. Results showed the highest response of the fruit yield (31.13 t/ha) with treatment mono potassium phosphate followed by in fertigation with potassium nitrate (29.4 t/ha). The total soluble solids was highest (10.49 °Brix) in K fertigation with mono potassium phosphate followed by fertigation with potassium sulphate (10.48 °Brix). Highest juice content (38.76 %) and low acidity (0.77 %) was found in K fertigation with mono

potassium phosphate. The highest TSS to acidity ratio (sweetness indicator) was observed in Mono potassium Phosphate (13.6) followed by Potassium sulphate (13.1).

© 2013 Sjournals. All rights reserved.

---

## 1. Introduction

Nagpur mandarin (*Citrus reticulata* Blanco) is an important citrus fruit grown in central Indian states like Maharashtra, Madhya Pradesh, Rajasthan and Chattisgarh occupying 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 2013) with fertigation (Shirgure *et al.*, 2003a) 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 reticulata* 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, 2013). 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). 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 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 study the effect of potassium fertigation with various potash (K) fertilizers on plant vegetative growth, leaf nutrients and up-take, yield and fruit quality of Nagpur mandarin (*Citrus reticulata* 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 evaluation of the common four different potassium fertilizers 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 Potassium Chloride (KCl) (150 g K<sub>2</sub>O/plant) at 15 days interval (T1), fertigation with Potassium Nitrate (KNO<sub>3</sub>) (150 g K<sub>2</sub>O/plant) at 15 days interval (T2), fertigation with Sulphate of Potash (K<sub>2</sub>SO<sub>4</sub>) (150 g K<sub>2</sub>O/plant) at 15 days interval (T3) and fertigation with Mono Potassium Phosphate (KH<sub>2</sub>PO<sub>4</sub>) (150 g K<sub>2</sub>O/plant) at 15 days interval (T4) in randomized block design with six replications. The texture of the soil is clay loam and depth of the soil is 45 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 28.14% and 19.1 % respectively. The available water content of the soil is 8.15%. The bulk density of the soil in field was determined

using core sampler having 100 cm<sup>3</sup> volume and oven drying. The bulk density of the field is 1.5 g/cc. The water holding capacity of the soil is 12.23 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 studying suitability of the different potassium fertilizers for the K fertigation in Nagpur mandarin fertilizers Potassium Chloride (KCL) (0:0: 60), Potassium Nitrate (KNO<sub>3</sub>) (13: 0: 46), Potassium Sulphate (K<sub>2</sub>SO<sub>4</sub>) (0: 0: 50) and Mono Potassium Phosphate (KH<sub>2</sub>PO<sub>4</sub>) ( 0: 52:34 ) are used. The recommended fertilizer dose to be given to the Nagpur mandarin through irrigation is 500: 150: 150 (N: P: K). Fertigation is started from month of October at the interval of 15 days. It is given on 2nd and 16th day of the month. Nitrogen is given from October to January and all N, P and K are given from February – June. From October to January months nitrogen (N) was given through urea (46 % N) and 11.60 Kg urea was fertigated in all the treatments uniformly. From February to June different potassium fertilizers fertigation was done. The various fertilizers combination along with the quantity of fertilizers for 48 plants in each fertigation treatment is given below for the total plants in each treatment.

1. For Treatment T1 i.e. KCL: In this treatment Urea Phosphate, Urea and + KCL are used in following quantities.

KCL + Urea Phosphate + Urea (1.20 Kg + 1.632 Kg + 2.256 Kg)

2. For Treatment T2 i.e. KNO<sub>3</sub>: In this treatment Urea Phosphate, Urea and + KNO<sub>3</sub> are used in following quantities.

KNO<sub>3</sub> + Urea Phosphate + Urea (1.6 Kg + 1.637 Kg + 1.806 Kg)

3. For Treatment T3 i.e. K<sub>2</sub>SO<sub>4</sub>: In this treatment Urea Phosphate, Urea and + K<sub>2</sub>SO<sub>4</sub> are used in following quantities.

K<sub>2</sub>SO<sub>4</sub> + UP + Urea (1.44 Kg + 1.632 Kg + 2.256 Kg)

4. For treatment T4 i.e. KH<sub>2</sub>PO<sub>4</sub> : In this treatment Urea + KH<sub>2</sub>PO<sub>4</sub> + P<sub>2</sub>O<sub>5</sub> acid (86 %) are used in following quantities.

KH<sub>2</sub>PO<sub>4</sub> + P<sub>2</sub>O<sub>5</sub> acid (86%) + Urea (1.385 Kg + 0.290 Kg + 2.898 Kg)

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<sub>2</sub>SO<sub>4</sub>: HClO<sub>4</sub> in 2.5:1 ratio. The leaf N was determined using alkaline permanganate 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. Plant growth and canopy volume of Nagpur mandarin with K fertigation**

The effect of different potassium (K) fertigation using four different potash fertilizers 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 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 highest average plant height (5.53 m) and stock girth (77.25 cm) of the Nagpur mandarin plant was recorded in mono-potassium phosphate fertigation. The plant height (5.50 m) and stock girth (77.2 cm) was medium in K fertigation with potassium sulphate, followed by K fertigation with potassium chloride (plant height, 5.50 m; and stock girth 75.26 cm). The lowest plant height (5.42 m) and stock girth (73.63 cm) was observed in K fertigation with potassium nitrate during 2009 to 2012. The significant growth was observed in plant canopy

volume ranging from 65.05 to 71.51 m<sup>3</sup>, 77.51 to 84.88 m<sup>3</sup> and 79.0 to 88.09 m<sup>3</sup> during the year 2009-10, 2010-11 and 2011-12 respectively. The highest average canopy volume of the Nagpur mandarin plant (81.49 m<sup>3</sup>) was recorded with K fertigation using mono-potassium phosphate. The average canopy volume of the mandarin plant was medium (78.87 m<sup>3</sup>) with K fertigation with potassium sulphate, followed by K fertigation with potassium chloride (75.46 m<sup>3</sup>). The lowest plant canopy (73.85 m<sup>3</sup>) was observed in K fertigation with potassium nitrate during 2009 to 2012 (Table 2).

**Table 1**

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

Treatments	Plant height, m				Stock girth, cm				Canopy volume, m <sup>3</sup>			
	2009-2010	2010-2011	2011-2012	Mean	2009-2010	2010-2011	2011-2012	Mean	2009-2010	2010-2011	2011-2012	Mean
T <sub>1</sub>	5.31	5.54	5.65	5.50	74.13	75.75	75.90	75.26	67.31	78.57	80.25	75.46
T <sub>2</sub>	5.19	5.50	5.57	5.42	70.92	74.59	75.38	73.63	65.05	77.51	79.00	73.85
T <sub>3</sub>	5.26	5.53	5.70	5.50	73.32	78.25	80.04	77.20	70.38	81.37	84.86	78.87
T <sub>4</sub>	5.26	5.64	5.68	5.53	75.07	77.83	78.86	77.25	71.51	84.88	88.09	81.49
LSD	NS	NS	NS	-----	NS	NS	NS	-----	NS	0.28	0.67	-----

(P = 0.05)

T<sub>1</sub> -Fertigation with potassium chloride, T<sub>2</sub>- Fertigation with potassium nitrate, T<sub>3</sub>- Fertigation with potassium sulphate and T<sub>4</sub>- Fertigation with mono potassium phosphate.

**Table 2**

The leaf nutrient concentration under different K fertigation treatments

Treatments	Macronutrients (%)			Micronutrients (ppm)			
	N	P	K	Fe	Mn	Cu	Zn
<b>Initial leaf nutrient status (2009-10)</b>							
	Macronutrients (%)			Micronutrients (ppm)			
T <sub>1</sub>	1.97	0.08	0.97	122.0	58.7	8.8	18.2
T <sub>2</sub>	1.86	0.078	0.88	168.5	37.5	10.2	18.4
T <sub>3</sub>	2.08	0.079	1.18	117.4	38.4	19.3	28.2
T <sub>4</sub>	2.08	0.084	1.01	142.5	33.0	9.3	16.6
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS
<b>Final leaf nutrient status (2011-12)</b>							
	N	P	K	Fe	Mn	Cu	Zn
T <sub>1</sub>	1.98	0.09	1.01	112.4	43.6	9.1	19.2
T <sub>2</sub>	2.04	0.087	1.08	114.8	49.8	9.6	23.1
T <sub>3</sub>	2.14	0.092	1.10	120.8	53.1	10.8	24.9
T <sub>4</sub>	2.23	0.095	1.16	127.1	60.1	10.9	26.2
CD(P=0.05)	0.08	NS	0.07	1.04	4.6	NS	1.47

T<sub>1</sub> -Fertigation with potassium chloride, T<sub>2</sub>- Fertigation with potassium nitrate, T<sub>3</sub>- Fertigation with potassium sulphate and T<sub>4</sub>- Fertigation with mono potassium phosphate.

This may be due to the application of the potassium fertilizers during the plant growth stages and frequent 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.

### 3.2. Leaf nutrient status with K fertigation using four potash fertilizers

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 (1.97 to 2.08%), P (0.078 to 0.084%), K (0.97 to 1.18%), Fe (117.4 to 142.5 ppm), Mn (33.0 to 58.7 ppm), Cu (8.8 to 19.3 ppm) and Zn (16.6 to 28.2 ppm) was observed in the K fertigated treatments. In the final leaf nutrient analysis the K fertigation with mono potassium phosphate recorded the highest concentration of macronutrients (N, P and K) and micronutrients (Fe, Mn, Cu, and Zn) compared to rest of the other irrigation scheduling treatments (Table 2). The K fertigation treatment with mono potassium phosphate recorded the highest concentration of macronutrients (2.23 % N, 0.095 % P and 1.16 % K) compared to rest of the other potash fertilizers fertigation treatments. Leaf N (2.14 %), P (0.92 %) and K (1.1 %) contents were observed significantly higher with sulphate of potash fertigation than N (2.04 %), P (0.087 %) and K (1.08 %) content with potassium nitrate K fertigation. The lowest leaf nutrient composition N (1.98 %), P (0.09 %) and K (1.01 %) was observed with potassium chloride K fertigation 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 K fertigation schedules, but the element Copper (Cu) not non-significant. The leaf analysis revealed that the K fertigation treatment with mono potassium phosphate recorded the highest concentration of micronutrients (127.1 ppm Fe, 60.1 ppm Mn, 10.9 ppm Cu and 26.2 ppm Zn) compared to rest of the other potash fertilizers fertigation treatments. Leaf Fe (120.8 ppm), Mn (53.1 ppm), Cu (10.8 ppm) and Zn (24.9 ppm) contents were observed significantly higher with sulphate of potash fertigation than with potassium nitrate K fertigation (Fe, 114.8 ppm), Mn (49.8 ppm), Cu (9.6 ppm) and Zn (23.1 ppm). The lowest leaf micronutrients nutrient composition leaf Fe (112.4 ppm), Mn (43.6 ppm), Cu (9.1 ppm) and Zn (19.2 ppm) content was observed with potassium chloride K fertigation during 2009-2012 (Table 2).

### **3.3. Fruit yield of Nagpur mandarin under K fertigation sources**

The potassium (K) fertigation with four different potash fertilizers had a positive effect on the yield as well as fruit 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. The Nagpur mandarin yield and fruit quality were significantly influenced by the different K fertilizers fertigated in Nagpur mandarin. The number of fruits per plant, fruit yield, average fruit weight, total soluble solids (TSS) juice percentage and acidity was found significant during 2010-11 and 2011-12. Yield and quality were significantly influenced by the different K fertilizer fertigation treatments (Table 3). The average number of fruits per plant was 590 to 697 in all the K fertigation treatments. The highest number of fruits per plants (697 fruits/plant) was in K fertigation with mono-potassium phosphate followed by K fertigation with of potash nitrate (668 fruits/plant) and potassium sulphate (625 fruits/plant). The lowest number of fruits per plant was with K fertigation using potassium chloride (590 fruits/plant) may be due to the single K element and not with nitrogen (N) or phosphorus (P) during the fruit development phases. The various potassium fertigation with potash fertilizers treatments significantly influenced the yield of the Nagpur mandarin. The average Nagpur mandarin fruit yield was 24.32 to 31.13 tonnes/ha in all the K fertigation schedules. The highest fruit yield per hectare was in K fertigation with mono-potassium phosphate fertilizer (31.13 tonnes/ha) followed K fertigation with potassium nitrate (29.40 tonnes/ha) and with potassium sulphate (26.77 tonnes/ha). The lowest fruit yield was with potassium chloride (murate of potash) (24.32 tonnes/ha) may be due to the single K source and not with N and K elements in critical fruit growth development periods during 2009-2012 (Table 3). This is clearly indicated that the potassium (K) fertigation with mono-potassium phosphate (MKP) is essential for production of good quality mandarin fruits. The drip irrigation maintained higher as well as continuous soil moisture along with potassium availability influenced by the water and nutrient uptake resulting into good quality fruits besides enhancing the yield.

### **3.4. Fruit quality of Nagpur mandarin affected due to K fertigation**

The highest average fruit weight (156.24 g), TSS (10.49°Brix), juice percent (38.76 %) and lowest acidity (0.77) is observed in K fertigation with mono-potassium phosphate (MKP) followed by K fertigation with potassium sulphate (SOP). The moderate fruit quality was observed with K fertigation with potassium sulphate (SOP) followed by K fertigation with potassium nitrate. The average fruit weight (155.33 g), TSS (10.48 °Brix), juice percent (37.55 %) and acidity (0.8) is observed in K fertigation with potassium sulphate (SOP) and potassium nitrate (the average

fruit weight, 155.28 g; TSS, 10.44 °Brix; juice percent, 38.05 and acidity as 0.8. The lowest average fruit weight (154.96 g), TSS (10.07 °Brix), juice percent (37.16 %) and highest acidity (0.85) is observed in K fertigation with potassium chloride. 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 (13.6) was found in K fertigation with mono-potassium phosphate (MKP) followed K fertigation with potassium sulphate (SOP) in which the TSS to acidity ratio is 13.1. The TSS to acidity ratio was 12.4 with the K fertigation with potassium nitrate. The lowest TSS to acidity (11.8) was observed the K fertigation with potassium chloride (Table 3). 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).

**Table 3**

The 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, °Brix	Juice, %	Acidity, %	TSS/acid Ratio
T <sub>1</sub>	590	24.32	154.96	10.07	37.16	0.85	11.8
T <sub>2</sub>	668	29.40	155.28	10.44	38.05	0.84	12.4
T <sub>3</sub>	625	26.77	155.33	10.48	37.55	0.80	13.1
T <sub>4</sub>	697	31.13	156.24	10.49	38.76	0.77	13.6
LSD (P = 0.05)	31	1.72	0.03	2.81	0.52	NS	----

T<sub>1</sub>-Fertigation with potassium chloride, T<sub>2</sub>- Fertigation with potassium nitrate, T<sub>3</sub>- Fertigation with potassium sulphate and T<sub>4</sub>- Fertigation with mono potassium phosphate.

#### 4. Conclusion

The quality fruit production of Nagpur mandarin can be increased with K (potassium) fertigation. Potassium fertigation can be done using potassium chloride [KCL], potassium nitrate [KNO<sub>3</sub>], potassium sulphate [K<sub>2</sub>SO<sub>4</sub>] and mono-potassium phosphate [KH<sub>2</sub>PO<sub>4</sub>] potash fertilizers in 14-16 years bearing Nagpur mandarin in central India. The leaf nutrient uptake and status was high in fertigation with Mono Potassium Phosphate (150 g K<sub>2</sub>O/plant) from February to June at 15 days interval. The mandarin yield was highest (31.13 tones/ha) with fertigation with Mono Potassium Phosphate (150 g K<sub>2</sub>O/plant) followed by fertigation with Potassium Nitrate (150 g K<sub>2</sub>O/plant) at 15 days interval (29.4 t/ha). The fruit quality is also affected with different potash fertilizers. Highest fruit TSS (10.48 °Brix) and fruit weight (156.24 g) was observed in K with fertigation with mono-potassium phosphate at 15 days interval. The highest TSS to acidity ratio (a measure of sweetness) was observed in Mono potassium Phosphate (13.6) followed by Potassium sulphate (13.1). Thus the use of different potash (K) fertilizers through micro-irrigation and fertigation technique can be a sustainable solution for increasing the citrus production as well as fruit quality and protecting the Nagpur mandarin from decline.

#### 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., M., Brum, 1984. The effect of fertigation and partial wetting of the rootzone on production of shamouti orange. Proc. Int. Soc. of 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 and Sub-tropical fruit. J., 62, 8-12.
- Gomez, K.A., Gomez, A.A., 1984. Statistical Procedures for Agriculture Research. John Wiley and Sons pp 664-5.
- Koo, R.C.J. 1981. Results of Citrus fertigation studies. Proc. of 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, F., 1990. Nitrogen fertigation of citrus summery of citrus research. Citrus research centre and Agricultural station. University of California 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 Hill 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 Conserv., 27 (1), 45 – 49
- Shirgure, P.S., Srivastava, A.K., Singh, S., 2001a. 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., 2001b. 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., 2001c. Effect of nitrogen fertigation and band placement fertilizer application on soil -leaf nutrient build-up and incremental growth of acid lime. J. Soil and Water Cons., 45 (3&4), 176-181.
- Shirgure, P.S., Srivastava, A.K., Singh, S., 2001d. 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., 2003a. Evaluating micro-irrigation systems in Nagpur mandarin under sub-humid tropical climate. Trop. Agri., 80 (2), 91-96.
- Shirgure, P.S., Srivastava, A.K., Singh, S., 2003b. 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., 2004a. 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., 2004b. Growth, yield and quality of acid lime under pan evaporation based drip irrigation scheduling. Indian J. of Soil Cons., 32 (1), 32-35.
- Shirgure, P.S., Srivastava, A.K., Singh, S., 2004c. Integrated water and nutrient management in acid lime. Indian J. of Soil Cons., 32 (2), 148-151.
- Shirgure, P.S., Srivastava, A.K., 2012. The effect of four under tree micro-jet irrigation (180-300<sup>0</sup>) systems on fruit yield and quality of Nagpur mandarin in Central India. Sci. J. Agri., 1 (7),177-186.
- Shirgure, P. S., 2012a. Effect of pulse irrigation scheduling with hybrid station controller on fruit yield and quality of Nagpur mandarin (*Citrus reticulata* Blanco). Sci. J. Crop Sci., 1 (5), 76-82.
- Shirgure, P.S., 2012b. 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.
- 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.
- Sriastava, A.K., Ram, L., 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. Agr., 80 (2), 97-104.
- Syvetsen, 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.