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Effect of nutrient levels and split application through fertigation on yield and quality of Nagpur mandarin

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Abstract
The present investigation was carried out in Narayangaon Rithi village on farmer's field, Tehsil Narkhed, District Nagpur on 8 years old Nagpur mandarin during 2023-24 on ambia bahar. The experiment was laid in split plot design in selected orchard having drip irrigation system and treatments were imposed. It was observed that, number of fruits per tree (642), weight of fruit (162.3 g) and fruit yield (41.11 t ha^{-1}) were significantly highest under (NL 5) 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1}. Significantly highest weight of fruit (140.7 g) and yield (34.72 t ha^{-1}) was recorded under application of 24 splits at 10 days interval. The treatment combination of 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) and 18 splits (S2) at 15 days interval recorded significantly highest fruit yield (44.02 t ha^{-1}). Further, the result also indicated that, superior fruit quality parameters such as juice percent (50.98%), TSS (11.03 ^{0}Brix), Brix: acid ratio (13.08) and ascorbic acid (35.82 mg 100 ml^{-1}) found in treatment 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} and highest juice percentage (49.92%), TSS (10.51 ^{0}Brix), Brix: acid ratio (12.05) and ascorbic acid (35.55 mg 100 ml^{-1}) with 24 splits at 10 days interval.

Keywords: Fertigation, Nagpur mandarin, balanced nutrient, fruit yield and fruit quality

Introduction
India's diverse agro-climatic conditions, which favour the production of agricultural and horticultural produce like citrus in bulk, and availability of production and process technologies with promising infrastructure are the primary factors that aided the Indian citrus production to attain significant position in the world. India is the third highest citrus producer in the world after China and Brazil. In India, citrus has attained a prominent place among cultivated fruits and is being extensively grown under tropical and subtropical conditions. Within the commercially cultivated citrus species, mandarin (*Citrus reticulata*), sweet orange (*Citrus sinensis*) and acid lime (*Citrus aurantifolia*) are the common citrus fruits having 50, 21 and 15 percent of the total area, respectively. In India, citrus is grown on an area of 1.064 million hectares and production of 14 million tonnes. Among citrus, mandarin has an area of 4.81 lakh hectare and a production of 63.99 lakh metric tonnes and with productivity 11.9 t ha^{-1} (Second Advance Estimates of Area and production of Horticultural crops, 2021-22). Maharashtra is the main mandarin producing state in the country, having an area of 1.07 lakh hectares and production of 7.97 lakh metric tonnes with productivity of 7.4 t ha^{-1} in 2019-20 (NHB, 2020). Mandarin cultivation in India benefits from a steady domestic demand and its adaptability to various agro-climatic conditions, making it a popular choice among growers. Among the varieties of mandarins, the 'Nagpuri' or 'Nagpur' mandarin is particularly esteemed for its distinctive sweet and sour flavour, which is both refreshing and sought after. In Maharashtra, the Amravati and Nagpur districts collectively account for 80% of the total area under mandarin orchards, with Amravati contributing 48 percent and Nagpur 31 percent (Wankhede *et al.*, 2017) [11].

In Maharashtra, orange is mainly grown in Vidarbha and known as Nagpur Mandarin having productivity very low to low. Improper water and fertilizer management is one of the reason of low productivity and decline of citrus orchards. Imbalance use of nutrients to fruit crops or under nutrition as per the requirement lead to deficiency of particular nutrients, ultimately the plant become susceptible to insect pests and diseases. Therefore, it is of utmost importance to supply all the required nutrients in balanced quantity and as per the need by plant throughout the growing period i.e. from flowering to harvesting to obtain higher yield and good quality production. Hence, the present study was undertaken.

Materials and Methods

The field experiment was conducted at the farmer's field of Narayangaon Rithi village, Narkhed Tehsil, Nagpur district, on eight year old Nagpur mandarin orchard in the year 2023-2024. The experiment was laid in split plot design in selected orchard and treatments were imposed. Three plants were selected for imposing each treatment. In main plot treatment five nutrient levels were given as NL 1 (175 N + 87 P_2O_5 + 175 K_2O + 10 S + 4 Mg + 1 Zn + 2.5 Fe + 0.5 B kg ha^{-1}), NL 2 (210 N + 100 P_2O_5 + 210 K_2O + 15 S + 9 Mg + 3 Zn + 5 Fe + 0.75 B kg ha^{-1}), NL 3 (250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1}), NL 4 (290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1}) and NL 5 (325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1}) with 15 and 30 percent less and higher than NL 3. In sub plot treatment, the nutrient levels were split as S1 (12 splits at 20 days interval), S2 (18 splits at 15 days interval) and S3 (24 splits at 10 days interval). The observations recorded during the investigation were tabulated and subjected to statistical analysis. The weight of fruit was recorded by using digital weighing balance. The fruit juice was expressed as weight of juice out of the total fruit weight in percent (Garwell *et al.*, 2000) [3]. The titratable acidity was estimated by titrating with 0.1 N NaOH using phenolphthalein indicator by using the method as suggested by Ranganna (2001) [8]. Ascorbic acid was determined by using the method described by Ranganna (2001) [8]. Total soluble solids (TSS) of fruit was determined by using digital hand refractometer (Lacey, 2009) [6]. The results were interpreted in accordance with the statistical method outlined by Gomez and Gomez (1983) [4].

Results and Discussion

Effect of nutrient levels on fruit yield of Nagpur mandarin

The data pertaining to number of fruit per tree, weight of fruit and fruit yield of Nagpur mandarin (Table 1) revealed that nutrient levels significantly influenced yield contributing characters and fruit yield of Nagpur mandarin. The number of fruits and weight of fruit varied from 524 to 642 per tree and 113 to 162 g respectively. The application of nutrients through drip @ 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) recorded significantly highest number of fruits per tree (642) and weight of fruit (162.3 g). It could be noticed that the treatment NL 4 (290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1}) and NL 5 recorded 11.77 percent and 18.22 percent higher fruit weight as compared to 250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1} (NL 3). Treatment NL 3 recorded 15.76% higher fruit weight than NL 2 treatment. This indicated that magnitude of increase in fruit weight increased with balanced and higher level of nutrients through drip. The increased efficiency of metabolic processes in plants due to nutrients encourages plant growth, leading to larger fruit size and weight. Fruit yield ranged from 59.61 to 105.09 kg $tree^{-1}$ and 23.26 to 41.11 t ha^{-1} respectively. Significantly highest fruit yield (105.09 kg $tree^{-1}$) was recorded in treatment 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5). Significantly highest fruit yield (41.11 t ha^{-1}) was registered with application of 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) followed by application of 290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1} (NL 4). Moreover, the treatment of NL 4 recorded significantly higher fruit yield (36.86 t ha^{-1}) as compared to NL 3 (31.81 t ha^{-1}). This might be attributed application of balanced nutrition to mandarin trees as per the requirement. These results are in conformity with the findings of Dalal *et al.* (2019) [1] who recorded significantly highest fruit yield with the treatment I_3 (irrigation at 90% ER) and F_3 (fertigation with 80% RDF). It was observed that, though the moisture content was adequate but due to lower nutrient, lowest fruit yield (23.26 t ha^{-1}) was recorded by the treatment of 175 N + 87 P_2O_5 + 175 K_2O + 10 S + 4 Mg + 1 Zn + 2.5 Fe + 0.5 B kg ha^{-1} (NL 1). The treatments NL 4 and NL 5 recorded 16.77 percent and 30.24 percent higher fruit yield per ha as compared to application @ 250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1} (NL 3). In nutshell, it could be noticed that, the nutrient application to Nagpur mandarin in balanced quantity helped to enhance the fruit yield. This can be ascribed that, Nagpur mandarin plants required nutrients in optimum quantity to fulfil the need of the plant for balanced growth and development of plants as well as fruits to obtain higher fruit yield with good quality fruits.

Effect of nutrient levels on fruit quality

The data pertaining to fruit quality parameters of Nagpur mandarin indicated that, increasing nutrient levels had significant influence on fruit quality parameters of Nagpur mandarin (Table 2). The highest fruit juice percentage (50.98%) was observed with nutrient application @ 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} through drip (NL 5) which was found significantly superior over all the treatments and followed by nutrient application @ 290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1} (50.41%) (NL 4) and 250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1} NL 3 (49.74%). Optimal soil moisture content and a better synchronization of the nutrient demand and supply relationship under fertigation might have resulted in higher juice content. The increase in fruit juice percentage might also be attributed to potassium's potential regulation of plant water relations, alongside its role in facilitating the development of larger fruits with enlarged juice vesicles. Desai *et al.* (1986) [2] observed an increase in juice percentage with higher levels of NPK in sweet orange, while Shirgure *et al.* (1999) [9] reported similar findings in acid lime. Sudharshan *et al.* (2017) [10] obtained nearly identical results in Nagpur mandarin.

Table 1: Fruit yield parameters of Nagpur mandarin as influenced by nutrient levels and split application through drip

Treatments		No. of Fruit per tree	Weight of fruit (g)	Fruit yield (kg $tree^{-1}$)	Fruit yield (t ha^{-1})
A. Main plot: Nutrient levels					
NL1:	175 N + 87 P_2O_5 + 175 K_2O + 10 S + 4 Mg + 1 Zn + 2.5 Fe + 0.5 B kg ha^{-1}	524	113.3	59.61	23.26
NL2:	210 N + 100 P_2O_5 + 210 K_2O + 15 S + 9 Mg + 3 Zn + 5 Fe + 0.75 B kg ha^{-1}	563	121.8	68.74	26.81
NL3:	250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1}	594	137.3	81.54	31.81
NL4:	290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1}	627	150.4	95.33	36.86
NL5:	325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1}	642	162.3	105.09	41.11
SE (m) ±		11.79	3.49	1.87	0.67
CD at 5%		32.73	9.67	5.12	1.85
B. Sub plot: No. of Splits					
S1:	Total 12 split (20 days interval)	549	132.1	73.75	28.53
S2:	Total 18 split (15 days interval)	592	138.4	83.52	32.66
S3:	Total 24 split (10 days interval)	628	140.7	88.92	34.72
SE (m) ±		5.49	1.42	0.98	0.43
CD at 5%		23.64	6.09	4.25	1.84
C. Interaction (NLxS)					
SE (m) ±		12.29	3.12	2.20	0.95
CD at 5%		-	7.30	5.08	2.19

Significantly highest TSS was recorded with the balanced application of nutrients @ 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) (11.03 ^{0}Brix), lowest value of acidity (0.85%) and maximum Brix: acid ratio (13.08) through drip indicating that, best quality parameters followed by nutrient application @ 290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1} (NL 4) (10.59 ^{0}Brix, 0.93 and 10.75 respectively). The higher production of photosynthates, resulting from hydrolysis of starch, may lead to increased levels of Total Soluble Solids (TSS). The higher fruit quality index (Brix: acid ratio) in fertigated trees attributed to the increased TSS and decreased acid concentration in the fruit juice. A higher Brix: acid ratio and lower acidity serve as indicators of enhanced sweetness in fruits, as sugar content tends to increase with a higher Brix: acid ratio. The ascorbic acid is significantly influenced by the different nutrient levels and optimum use of nutrients and water. The highest ascorbic acid (35.82 mg 100 ml^{-1}) was recorded with nutrient application @ 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} through drip (NL 5) which was found significantly superior over all the treatments and followed by nutrient application @ 290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1} (35.44 mg 100 ml^{-1}) (NL 4) and 250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1} NL 3 (35.42 mg 100 ml^{-1}). The increased availability of soil water and nutrients could be a contributing factor to the higher ascorbic acid content observed in Nagpur mandarin fruits. Hendre *et al.* (2020) [5], reported higher quality parameters in sweet oranges were observed at higher fertigation levels.

Table 2: Fruit quality of Nagpur mandarin as influenced by nutrient levels and split application through drip

Treatments		Juice (%)	TSS (°Brix)	Acidity (%)	Brix: Acid ratio	Ascorbic acid (mg 100 ml^{-1})
A. Main plot: Nutrient levels						
NL1:	175 N + 87 P_2O_5 + 175 K_2O + 10 S + 4 Mg + 1 Zn + 2.5 Fe + 0.5 B kg ha^{-1}	48.65	10.01	0.93	10.75	35.36
NL2:	210 N + 100 P_2O_5 + 210 K_2O + 15 S + 9 Mg + 3 Zn + 5 Fe + 0.75 B kg ha^{-1}	49.32	10.14	0.90	11.23	35.40
NL3:	250 N + 125 P_2O_5 + 250 K_2O + 20 S + 14 Mg + 5 Zn + 7.5 Fe + 1 B kg ha^{-1}	49.74	10.28	0.88	11.51	35.42
NL4:	290 N + 145 P_2O_5 + 290 K_2O + 25 S + 19 Mg + 7 Zn + 10 Fe + 1.25 B kg ha^{-1}	50.41	10.59	0.85	12.59	35.44
NL5:	325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1}	50.98	11.03	0.85	13.08	35.82
SE (m) ±		0.04	0.07	0.004	0.11	0.06
CD at 5%		0.11	0.20	0.011	0.32	0.17
B. Sub plot: No. of Splits						
S1:	Total 12 split (20 days interval)	49.68	10.30	0.89	11.61	35.39
S2:	Total 18 split (15 days interval)	49.86	10.42	0.88	11.84	35.53
S3:	Total 24 split (10 days interval)	49.92	10.51	0.87	12.05	35.55
SE (m) ±		0.05	0.05	0.002	0.07	0.06
CD at 5%		0.22	0.20	0.010	0.28	-
C. Interaction (NLxS)						
SE (m) ±		0.11	0.10	0.007	0.15	0.13
CD at 5%		-	0.24	-	-	0.29

Effect of split application of nutrients on fruit yield and quality of Nagpur mandarin

The significantly highest number of fruits (628 fruits per tree) and weight of fruit (140 g) were noticed in treatment of 24 splits at 10 days interval which was at par with 18 splits at 15 days interval (138.4 g) for weight of fruit. It could be noticed from the results that application of balanced nutrients through drip in higher number of splits could provide sufficient nutrients for enhancing metabolic processes and higher photosynthetic activity to increase weight of fruits. Significantly highest fruit yield was recorded in treatment with 24 splits at 10 days interval (88.92 kg $tree^{-1}$). Significantly highest fruit yield (34.72 t ha^{-1}) was noticed with 24 splits application of nutrients at 10 days interval and followed by 18 splits at 15 days interval (32.66 t ha^{-1}) and significantly higher than 12 splits at 20 days interval (28.53 t ha^{-1}). This indicated that, Nagpur mandarin plants require nutrients in balanced and optimum quantity for proper growth and development of trees as well as proper development of fruits. It is also noticed that, as number of splits of nutrients increased the fruit yield also increased.

The data revealed that, highest juice percentage (49.92%) was noticed in treatment of 24 splits at 10 days interval which was statistically at par with 18 splits at 15 days interval (49.86%).

Significantly highest TSS (10.51 ^{0}Brix), lowest acidity (0.87%) and highest Brix: acid ratio (12.05) was noticed in treatment of 24 splits at 10 days interval followed by 18 splits at 15 days interval (10.42 ^{0}Brix), acidity (0.88%) and Brix: acid ratio (11.84) respectively. The split application of nutrients had no significant effect on ascorbic acid. It could be revealed from the data that highest ascorbic acid (35.55 mg 100 ml^{-1}) was noticed in treatment of 24 splits at 10 days interval while 12 splits at 20 days interval recorded lowest ascorbic acid (35.39 mg 100 ml^{-1}).

Effect of interaction on fruit yield and quality

Interaction effect of nutrient levels and number of splits were found to be significant in respect of yield contributing characters *viz.*, weight of fruit (g) fruit yield (t ha^{-1}). The treatment combination of 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) and 18 splits (S2) at 15 days interval recorded significantly highest fruit yield (44.02 t ha^{-1}) and NL5 along with S3 on par (Table 3). Increasing the split applications of nutrient from 12 splits to 18 splits improves the fruit yield by 19 percent. This indicates that in black soil area for ambia bahar of Nagpur mandarin 18 splits observed optimum to maintain the availability of nutrients. Concisely, it could be inferred that, to obtain optimum plant growth development, higher number of fruits, comparatively higher fruit weight and ultimately higher fruit yield and excellent fruit quality, balanced and optimum quantity of nutrients (N, P, K, S, Mg, Fe, Mn, Zn, Cu and B) are very essential to be applied through drip in higher number of splits to cater the need of nutrients by mandarin from flowering to development of fruits for harvest.

Table 3: Interaction effect of nutrient levels and split application on fruit yield (t ha^{-1}) of Nagpur mandarin

Treatments	NL 1	NL 2	NL 3	NL 4	NL 5
S1	20.34	24.68	28.11	32.41	37.10
S2	22.86	25.72	33.34	40.79	44.02
S3	26.57	30.03	33.97	37.37	42.22
SE (m) ±	0.95				
CD at 5%	2.19				

Nutrient levels in combination with increasing split have positive effect on total soluble solids content in fruits. Nutrient level (NL5) recorded higher TSS with Split level S3 and S2 than other combination (Table 4). The fruit yield and quality parameters, including juice percentage, Brix: acid ratio, and ascorbic acid concentration, were also found superior in fertigated trees with the treatment combination of 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) and 18 splits (S2) at 15 days interval recorded significantly highest fruit yield (44.02 t ha^{-1}). Hence, it could be inferred that, balanced nutrient application with optimum number of splits through fertigation significantly influenced both yield and quality parameters of Nagpur mandarin.

Table 4: Interaction effect of nutrient levels and split application on TSS (^{0}Brix) of Nagpur mandarin

Treatments	NL 1	NL 2	NL 3	NL 4	NL 5
S1	10.0	10.2	10.3	10.4	10.6
S2	10.0	10.1	10.1	10.7	11.2
S3	10.0	10.1	10.4	10.7	11.3
SE (m) ±	0.10				
CD at 5%	0.24				

Conclusion

From the present investigation it can be concluded that treatment combination of nutrient level of 325 N + 160 P_2O_5 + 325 K_2O + 30 S + 24 Mg + 9 Zn + 12.5 Fe + 1.5 B kg ha^{-1} (NL 5) with 18 splits at 15 days interval (S2) recorded highest fruit yield (t ha^{-1}) and improved fruit quality (Juice percent, TSS and acidity) of Nagpur mandarin.

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