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Effect of integrated nutrient management on growth, yield and fertility status of soil after harvest of Nagpur mandarin

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Abstract
This research was conducted to investigate the "Effect of integrated nutrient management on growth, yield and fertility status of soil after harvest of Nagpur mandarin (*Citrus reticulata* Blanco)"during 2019-2020 at the research farm of Central Citrus Research Institute (CCRI), Nagpur. This is the twelve year of experimentation to establish, how much inorganic chemical fertilizers in form of RDF can be saved through application of microbial consortium different modules of INM. was conducted with a total of five treatments *viz*., T_1 - 100% RDF (600 g N - 200 g P - 300 g K - 200 g $ZnSO_4$ - 200 g $FeSO_4$ - 200 g $MnSO_4$ tree^{-1} year^{-1}), T_2 - 45% RDF + 45% vermicompost + microbial consortium, T_3- 40% RDF + 40% vermicompost + microbial consortium, T_4- 35% RDF + 35% vermicompost + microbial consortium, and T_5- 30% RDF + 30% vermicompost + microbial consortium replicated four times on a soil taxonomically classified as Vertic Ustochrept under randomised block design. The microbial consortium carried as many five microbes such as: *Bacillus pseudomycoides* (MF113272), *Acinetobacter radioresistens* (MF1132273), *Micrococcus yunnanensis* (MF113274), *Aspergillus flavus* (MF113270) and *Paenibacillus alvei* (MF113275). The observations on growth parameters including plant height, tree spread canopy volume (Table 1), fruit yield (Table 2) and soil fertility status (Table 3), of the trees under the experiment have been organized with a view to study the quantity of chemical fertilizers we can reduce via introduction of microbial consortium loaded vermicompost.

Keywords: Nagpur mandarin, Integrated Nutrient Management, Microbial consortium, Plant growth, fruit yield, soil reaction, soil fertility status

Introduction
Citrus is the third important fruit crop in India after banana and mango. Important citrus species in India are Mandarin, Acid Lime and Sweet orange. Nagpur mandarin (*Citrus reticulate* Blanco.) is a well known commercial fruit crop. The acreage under the crop is increasing exponentially each year due to its high production economics, as well as the cultivar suitability in this region. In India it is cultivated on 329900 ha i.e. 3.9% of the total area under fruit crops with annual production of 3431400 MT. In India the average productivity of Mandarin is 10.4 t ha^{-1}(National Horticulture Database 2015). In India, it is majorly grown in Maharashtra which grows well in temperature between 40 ^{0}F as to 108 ^{0}F. Citrus trees are sensitive to high concentration of salt and cannot stand in waterlogged conditions for longer time, pH range from 5-8 is more ideal. Citrus has also some medicinal value. The production of fruits can be increased by proper supply of nutrients in the form of fertilizer. Fertilizer is one of the major inputs accounting for nearly one third of the cost of cultivation and its production consumes a lot of energy used in production. The conventional farming system involves enormous use of chemical in production of citrus. Continuous use of chemical fertilizers has degraded the soil health in terms of fertility and has also caused soil pollution. Organic manures have been used for their eco-friendly and beneficial effect on environment and citrus crops. The era of development in the field of integrated nutrient management will ensure fairly high level of fruit production with sufficiently reduced dose of fertilizers and nutrients. Therefore, increasing need is being felt to integrate nutrient supply with organic sources to restore the health of soil.

Hence the concept of integrated nutrient management (INM) came in which lays emphasis on continuous improvement in soil fertility on long term basis through appropriate use of fertilizer, bio-fertilizer and vermicompost and their scientific management for optimum growth, yield and quality of crop in specific agro-ecological situation. Integrated use of nutrient supplements *viz*., organic, inorganic and microbial consortium in combination holds a good potential to overcome some of soil chemical constraints.

The integrated nutrient management (INM) is considered to be the best module with regard to efficient use of manure and fertilizers. Bio-fertilizers are microbial preparations containing living cells of different microorganisms, which have the ability to mobilize plant nutrients of soil from unusable to usable form through biological process. They are environmental friendly and play significant role in crop production. It is mainly used for field crops but now-a-days it is also used for fruit crops. Bio-fertilizers are used in live formulation of beneficial microorganism which on application to seed, root or soil, mobilize the availability of nutrients particularly by their biological activity and help to build up the lost micro flora and in turn improve the soil health in genera. Vermicompost increase soil organic matter and nutrient content, improves the soil structure and increase cation exchange capacity. By considering these facts, the present study was conducted to study the effect of integrated nutrient management on growth, yield and fertility status of soil after harvesting of Nagpur mandarin.

Material and Methods

The studies were carried out at Research farm of Central citrus research institutes, Nagpur during 2019-20. Twelve years old orchard of Nagpur mandarin trees having uniform size and vigour were selected. The experiment was laid out in Randomized Complete Block Design with five treatments and four replications *viz*., T_1 - 100% RDF (600 g N - 200 g P - 300 g K - 200 g $ZnSO_4$ - 200 g $FeSO_4$ - 200 g $MnSO_4$ $tree^{-1}$ $year^{-1}$), T_2 - 45% RDF + 45% vermicompost + microbial consortium, T_3- 40% RDF + 40% vermicompost + microbial consortium, T_4- 35% RDF + 35% vermicompost + microbial consortium, and T_5- 30% RDF + 30% vermicompost + microbial consortium. Nagpur is the geographical center of India with total geographical area of about 9, 86,000 ha and located between 21°45' north to 20°30' North latitude and 78°15' East to 79°45' East of longitude at altitude 310 m above mean sea level (MSL). Nagpur is characterized by hot and dry summer and fairly cold winter. This area shows wide diurnal fluctuation in temperature. The average maximum temperature is 33.09 ºC in kharif (June-September), 30.66 ºC in rabi (Oct.-Jan.) and 37.2 ºC in summer (Feb.-May). Humidity ranged from 11 to 94 per cent. The meteorological data in respect of rainfall, humidity, maximum and minimum temperatures during course of study for the period from, January 2019 to March, 2020 are furnished in Appendix 1.

Appendix 1: Mean weekly weather parameters during the experiment period (2019-20)

Date		Met Week	Temp ^{0}c		R.H. %		Total Rainfall (mm)	No. of Rainy days	BSH	Wind Speed Km/hr	Evaporation (mm)
			Max	Min	Morn	Eve					
02 - 08	Jul19	27	29.4	24.1	87	72	64.0	2	0.0	7.4	4.4
09 - 15		28	33.7	25.5	76	52	8.2	1	3.9	7.2	4.2
16 - 22		29	35.4	25.5	73	46	55.8	1	6.7	5.4	4.7
23 - 29		30	31.8	24.3	86	76	167.0	4	3.4	5.2	3.2
30 - 05		31	26.6	22.8	93	85	102.4	5	0.0	6.1	1.2
06 - 12	Aug19	32	29.1	23.6	90	71	92.2	3	1.3	5.5	2.2
13 - 19		33	31.1	24.1	80	57	15.4	2	4.6	5.3	3.2
20 - 26		34	31.5	23.9	81	58	11.0	2	3.5	7.0	4.1
27 - 02		35	29.4	23.1	90	72	53.0	3	1.2	4.0	3.9
03 - 09	Sep19	36	28.8	23.8	91	84	187.0	6	0.0	2.9	1.6
10 - 16		37	30.3	24.1	86	62	40.0	2	0.6	4.4	2.8
17 - 23		38	29.3	24.3	90	75	106.8	3	1.8	2.5	2.8
24 - 30		39	29.7	23.8	94	80	68.0	6	2.1	2.9	2.1
01 - 07	Oct 19	40	31.1	23.2	81	58	9.0	1	5.3	2.1	3.6
08 - 14		41	31.9	22.9	71	52	0.0	0	6.1	2.1	4.4
15 - 21		42	30.8	21.1	81	58	53.0	1	4.1	2.3	3.7
22 - 28		43	27.8	20.3	88	77	48.0	2	1.3	3.5	3.5
29 - 04		44	31.5	21.8	76	52	0.0	0	4.6	2.1	4.4
05 - 11	Nov19	45	31.3	20.9	78	50	0.0	0	7.0	1.7	3.1
12 - 18		46	30.6	17.6	74	47	0.0	0	6.7	1.9	3.2
19 - 25		47	29.5	16.1	81	51	0.0	0	7.2	1.6	2.9
26 - 02		48	29.7	15.9	79	54	0.0	0	7.1	1.6	2.6
03-09	Dec19	49	27.8	13.5	80	49	0.0	0	7.5	2.2	2.4
10-16		50	27.5	14.5	84	63	4.6	1	5.7	2.2	2.5
17-23		51	27.1	14.4	82	66	0.0	0	4.3	2.4	2.3
24-31		52	25.7	11.6	87	62	8.0	1	2.8	3.0	2.0
01 - 07	Jan 20	1	23.9	11.9	88	73	86.0	3	2.4	3.2	1.8
08 - 14		2	25.3	12.3	80	67	8.2	1	5.5	2.8	2.5
15 - 21		3	27.4	14.1	80	66	0.0	0	4.6	2.4	3.0
22 - 28		4	29.0	13.7	76	49	0.2	0	5.3	2.1	3.0
29 - 04		5	26.7	14.3	78	57	0.3	0	5.4	3.3	3.6
05 - 11	Feb 20	6	25.7	13.0	89	60	7.8	1	2.4	4.3	2.5
12 - 18		7	31.0	14.7	75	34	0.0	0	7.3	2.2	4.4
19 - 25		8	32.1	16.2	67	34	0.0	0	8.0	2.7	5.2
26 - 04		9	32.0	16.7	68	37	0.0	0	9.0	2.7	5.8
05 - 11	Mar 20	10	32.3	18.2	69	31	0.0	0	7.9	2.5	6.3
12 - 18		11	33.3	20.9	62	30	9.0	1	8.8	2.5	6.5
19 - 25		12	34.2	18.9	58	24	0.0	0	8.7	2.7	6.6
26 - 01		13	35.8	19.8	42	23	0.0	0	8.9	3.0	6.8

The growth parameters of Nagpur mandarin plant height and stem girth were recorded during Initial 2019 i.e twelve cycle of experiment and after harvesting of crop. The plant height and stem girth (at 15 cm above the soil surface) were taken. he East-West canopy spread (m) and North - South canopy spread (m) were measured by metric scale at the start of experiment and after months of first dose of fertilizers application. The representative soil samples from the zone of maximum feeder root concentration at a depth of 0 - 20 cm and at a distance of 110 to 125 cm from the trunk were collected by using soil auger during (April, 2019) and soil samples were collected after harvesting of the crop. The details of the above treatments applied in the present investigation are as under. Inorganic fertilizers, Vermicompost, microbial consortium were applied in three circular strips around the trees as per the schedule. Application of N in three splits (April, August, November) where as P_2O_5, K_2O and micronutrient applied during August and November in two split.

Results and Discussion

The experimental findings obtained from the present study have been discussed here in following heads.

Growth parameters

The result of the present investigation (Table 1) revealed that effect of organic and inorganic fertilizers with biofertilizer on various growth character, and different INM-based treatments produced a significant response on plant height and tree spread(E-W x N-S), translating into the canopy volume m with treatment T_5 (30% RDF + 30% vermicompost + microbial consortium), displaying the superiority of treatment T_5 (30% RDF + 30% vermicompost + microbial consortium) over rest of the other treatments *viz*., T_1(100% RDF (600 g N - 200 g P - 300 g K - 200 g $ZnSO_4$ - 200 g $FeSO_4$ - 200 g $MnSO_4$ $tree^{-1}$ $year^{-1}$)), T_2 (45% RDF + 45% vermicompost + microbial consortium), T_3 (40% RDF + 40% vermicompost + microbial consortium) or even T_4(35% RDF + 35% vermicompost + microbial consortium), saving as much as 40% of chemical fertilizers.

Likewise, the response of different treatments on tree spread, both the directions (E-W or N-S) was statistically significant. The tree spread through E-W and N-S observed maximum as 2.49 m and 2.96 m respectively, with treatment T_4 (35% RDF +35% vermicompost + microbial consortium), with maximum canopy volume of 15.04 m^3. While minimum canopy volume of 11.11 m^3 was observed with treatment T_1 (100% RDF (600 g N - 200 g P - 300 g K - 200 g $ZnSO_4$ - 200 g $FeSO_4$ - 200 g $MnSO_4$ $tree^{-1}$ $year^{-1}$)). While evaluating the response of different treatments of the increase in canopy volume over 2019-20, maximum increase was observed with treatment T_3 (40% RDF + 40% vermicompost + microbial consortium) followed by T_4 (35% RDF + 35% vermicompost + microbial consortium) and T_5 (30% RDF + 30% vermicompost + microbial consortium).

Table 1: Response of different INM- based treatments on vegetative growth parameters over

Treatments	Plant height (m)	Branching height (m)	Tree spread(m)		Canopy volume (m^3)	Increase over 2019-20 (m^3)
			E-W	N-S		
T_1	3.83 (3.72)	0.54	2.50 (2.40)	2.58 (2.50)	11.11 (10.31)	0.81
T_2	3.90 (3.80)	0.46	2.61 (2.52)	2.57 (2.46)	12.08 (11.15)	0.92
T_3	3.74 (3.65)	0.48	2.52 (2.45)	2.73 (2.65)	11.77 (10.71)	1.06
T_4	3.98 (3.92)	0.68	2.94 (2.88)	2.96 (2.90)	15.04 (14.06)	0.97
T_5	4.07 (3.93)	0.60	2.60 (2.54)	2.71 (2.62)	12.81 (11.83)	0.99
SEM	0.03 (0.05)	0.04	0.02 (0.09)	0.02 (0.08)	0.31 (0.38)	-
CD (*P=0.05*)	0.11 (-)	-	0.08 (-)	0.07 (-)	1.10 (-)	-

Yield parameters

Data presented in [Table-2] showed significant differences among treatment on yield and all the three fruit yield attributing features *viz*., average fruit weight, number of fruits / tree and fruit yield (expressed in kg/tree and tons / ha) have displayed varying response of different INM-based treatments (Table 2). The average fruit weight Varied from 138.4g with treatment T_2 (45% RDF + 45% vermicompost + microbial consortium) to as much as 142.3g T_1 (100% RDF (600 g N - 200 g P - 300 g K - 200 g $ZnSO_4$ - 200 g $FeSO_4$ - 200 g $MnSO_4$ $tree^{-1}$ $year^{-1}$))with treatment T_1. However, number of fruits /tree showed a different pattern of response. The maximum fruits/tree was observed as 582 fruits/tree with T_4 (35% RDF + 35% vermicompost + microbial consortium) and 578 fruits/ tree with treatment T_5 (30% RDF + 30% vermicompost + microbial consortium) Fruit yield, either expressed in terms of kg/tree or tons/ha was significantly affected different treatments. The most effective treatment was though, observed as T_5 (30% RDF + 30% vermicompost + microbial consortium) recording 48.6 kg/tree or 13.8 tons/ha, but was statistically on par with rest of all the other treatments. These observations lend strong support that as much as 40% chemical fertilizers saving could be achieved by incorporating microbial consortium into INM treatment.

Table 2: Response of different INM - based treatments on fruit yield related parameters

Treatments	Fruit weight (gm)	No. of fruits/tree	Fruit yield		*Fruit size distribution (%) (200 fruits basis)		
			(kg/tree)	(tons/ha)	A-Grade (>6cm)	B-Grade (5-6cm)	C-Grade (<5cm)
T_1	142.3	510	48.4	13.4	22.5	42.1	35.4
T_2	138.4	496	49.6	13.7	20.1	40.5	39.4
T_3	141.4	510	44.2	12.3	21.1	38.8	40.1
T_4	140.2	582	48.0	13.3	20.2	41.1	38.4
T_5	139.8	578	48.6	13.8	18.4	45.4	36.2
SEM	0.38	11.1	1.02	0.02	-	-	-
CD(P=0.05)	NS	NS	NS	NS	-	-	-

Response on Soil Fertility Changes

The result of the present investigation [Table-3] revealed that effect of organic and inorganic fertilizers with biofertilizer (INM) on soil fertility characters and Changes in soil fertility (Soil pH, EC, organic carbon, $KMnO_4$ -N, Olsen-P, NH_4OAc-K, DTPA-Fe, DTPA-Mn, DTPA-Cu and DTPA-Zn) were evaluated in response to different INM-based treatments (Table 3). Soil chemical properties such as $p^{H,}$ and organic carbon (OC) varied marginally from 7.5 to 7.6, 0.20 to 0.31 ds/m and from 0.61 to .68%, regardless of different INM-based treatments. Amongst different plant available macronutrients, only Olsen-P displayed a significant response of different treatments while $KMnO_4$ -N and NH_4OAc-K, showed no significant difference amongst response of different treatments. The response on different plant available micronutrients, only DTPA-Mn showed a significant variation, while other three micronutrients *Viz*., DTPA-Fe, DTPA-Cu and DTPA-Zn showed no significant variation amongst different treatments. DTPA-Mn showed a variation of 12.2 mg/kg with treatment T_1 to as high as 10.5 mg/kg with treatment T_4 These responses clearly indicate that treatment T_1 and T_5 produced statically similar magnitude of response.

Table 3: Response of different INM - based treatments on plant assimilable macro-and micronutrients in soil

Treatments	pH	EC (dS m^{-1})	OC (%)	Available nutrients (mg kg^{-1})						
				Macronutrients			Micronutrients			
				$KMnO_4$ -N	Olsen-P	NH_4OAc-K	DTPA-Fe	DTPA-Mn	DTPA-Cu	DTPA-Zn
T_1	7.5	0.24	0.68	138.2	12.1	172.9	12.2	10.1	1.18	0.81
T_2	7.6	0.20	0.61	142.1	13.1	181.4	14.1	9.2	1.10	0.84
T_3	7.5	0.28	0.64	142.4	14.2	184.0	12.1	10.1	1.14	0.88
T_4	7.6	0.31	0.68	139.2	13.4	179.2	13.2	10.8	1.20	0.80
T_5	7.6	0.28	0.64	140.1	11.4	182.1	12.8	9.4	1.24	0.80
SEM	0.01	0.02	0.01	0.86	0.46	1.65	0.4	0.27	0.02	0.01
CD(*P=0.05*)	NS	NS	NS	NS	1.10	NS	NS	0.84	NS	NS

Conclusion

In the light of the results obtained from this investigation, from it can thus be concluded that the combined application of 40% RDF + 40% vermicompost + microbial consortium at par 35% RDF + 35% vermicompost + microbial consortium In an integrated manner was beneficial for improving soil chemical properties, improving growth, yield of Nagpur mandarin.

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