RESEARCH ARTICLE

Establishing integrated nutrient management techniques for kinnow mandarin fruit crop of hyper arid region of western Rajasthan

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In the Central Institute of Arid Horticulture, Bikaner, Rajasthan, a study on "Establishing integrated nutrient management techniques for horticulture Kinnow crop in arid zone" was conducted in 2018-2019. The study employed a combination of inorganic fertilizers treated with varying combinations, as well as organic manures and biofertilizers. The use of organic manures and biofertilizers with inorganic fertilizers had a substantial impact on the plant's vegetative development, reproductive, and cost-benefit metrics.T11-RDF of NPK+FYM+PSB+AZB+AMF, (1000:500:750 g+50 kg+250 g+250 g+500 g), reveals the maximum plant height (5.50 m), tree spread (N-S) direction (3.55 m) and in (E-W) direction (3.10), stem diameter (95 cm), yield, and fruit quality parameters like the maximum fruit weight (225 g), fruit yield (22.80 t/ha), T.S.S (13.50 Brix), acidity percentage (0.65%), juice percentage (52.00%), and more. For a 17-year-old Kinnow fruit crop, the benefit-cost ratio of several INM treatments was assessed. Results under the same Treatment (T11) showed a value of 3.96. Lack of nutrient delivery may be the reason for the lowest value for vegetative growth, reproductive, and cost-benefit characteristics under management.

Key Words: *Azotobactor; PSB; AMF; Integrated nutrient management; Kinnow; Quality; Yield*

INTRODUCTION

Studies have reported a multitude of nutrient deficiencies and lack of nutrient management in citrus orchards leading to low productivity [1]. Researchers have reported a decline in productivity of citrus orchards in India (north-west, north-east, south and central region) due to single or multiple nutrient deficiencies [2-4]. A lot of efforts have been put in to growing citrus organically in the aftermath of depleting soil fertility owing to over use of chemical fertilizers. Since nitrogen is the main nutrient required for plant growth, the use of organic N source is being encouraged for N management as nitrogen is released slowly rather than instantly as seen in water-soluble, inorganic fertilizer [5]. Organic fertilizers are effective source of macro and micro nutrients and have the required potential to improve yield to save costly chemical fertilizers. So, in order to sustain high crop yields, the soil nutrients should be managed as such that there is an integration of nutrients from various. Integrated Nutrient Management (INM) is a concept that emphasizes nutrient management in an orchard from all sources (organic, inorganic and biofertilizers). It can not only sustain high yields for multiple years but also help in improving the physical, chemical and microbiological health of the soil [6]. Therefore, the goal of the current study was to assess how integrated nutrient management practices in the arid horticultural Kinnow crop of Rajasthan's Bikaner region affect the growth, yield, and quality attributes of the crop when using both inorganic and organic sources of nutrients in addition to biofertilizers.

MATERIALS AND METHODS

In 2018 and 2019, the experiment was conducted in the Central Institute for Arid Horticulture's fruit farm in Bikaner, Rajasthan. In addition to inorganic fertilizers applied in various treatment combinations, the treatment included biofertilizers and organic manures. Eleven treatments were Randomized Block Design (RBD) replicated three times (Table 1). The use of organic manures and inorganic fertilizers with biofertilizers had a substantial impact on the plant's vegetative development, reproductive, and cost-benefit metrics. The following fruit quality data were noted: T.S.S (Brix), fruit weight (g), fruit yield (kg), stem diameter (cm), plant height (m), tree spread (North-South) and in (East-West) directions, acidity percentage (%), and juice percentage (%). The benefit-to-cost ratio of several INM treatments was assessed for fruit crops that were 17 years old, Kinnow. The statistical approach of Panse et al., [7] was used to examine the data produced by this research.

TABLE 1

Details of treatment combination in brief

Treatment details	Amount/plant/year (Kinnow)
T1:Control	0
T2:RDF of NPK	1000:500:750 g
T3:RDF of NPK+FYM (5 kg/year)	1000:500:750 g+50 kg
T4:RDF of NPK+Azotobactor	1000:500:750 g+250 g
T5:RDF of NPK+PSB	1000:500:750 g+250 g
T6:RDF of NPK+AMF	1000:500:750 g+500 g
T7:RDF of NPK+FYM+AZB	1000:500:750 g+50 kg+250 g
T8:RDF of NPK+FYM+PSB	1000:500:750 g+50 kg+250 g
T9:RDF of NPK+FYM+AMF	1000:500:750 g+50 kg+500 g+250 g
T10:RDF of NPK+FYM+PSB+AZB	1000:500:750 g+50 kg+500 g+250 g
T11:RDF of NPK+FYM+PSB+AZB+AMF	1000:500:750 g+50 kg+250 g+250 g+500 g

RESULTS AND DISCUSSION

The application of biofertilizers with inorganic fertilizers and organic manures had a substantial impact on the reproductive characteristics of plants.

Different INM treatments' effects on the microbial population

The information in Table 2 showed that three different forms of biofertilizers-PSB, AMF and *Azotobactor* are intended to be used in the various treatments in the current study. The microbial load of the materials used to make standard doses of biofertilizers was examined. When the bacterial population of the *Azotobactor* biofertilizer was checked, 6.5×10^6 cfu were recorded. Other quality criteria, such as color, moisture, and granulation, were also recorded and the same were found to be in order. *Pseudomonas* population testing using the PSB biofertilizer revealed 11.3×10^9 bacterium population, along with other physiochemical parameters identified in order. Similar to this, when VAM was assessed for *Glomus* species fungal colonies, a significant amount of hyphae was seen, and they were also proliferating in the live host material (Table 2).

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TABLE 2

Impact of several INM treatments on the population of microbes in a 17-year-old Kinnow orchard

Treatments	0-15 cm depth				15-30 cm depth			
	Bacteria (Cfug^{-1} × 10^5)	Fungal (Cfug^{-1} × 10^5)	*Actinomycetes* (Cfug^{-1} × 10^5)	Total	Bacterial (Cfug^{-1} × 10^5)	Fungal (Cfug^{-1} × 10^5)	*Actinomycetes* (Cfug^{-1} × 10^5)	Total (Cfug^{-1} × 10^5)
Control	6	2	12	20	5	1	12	18
RDF	14	1.4	16	31.4	12	1.3	14	27.3
RDF+FYM	28	2	22	52	24	2	21	47
RDF+Azotobactor	30	1.4	12	43.4	27	1.5	14	42.5
RDF+PSB	31	1.5	15	47.5	24	1.8	15	40.8
RDF+VAM	10	2.5	13	25.5	11	2.6	10	23.6
RDF+FYM+AZB	32	2	20	54	28	1.5	18	47.5
RDF+FYM+PSB	31	1.5	16	48.5	27	1.5	14	42.5
RDF+FYM+VAM	32	3	22	57	30	2.5	18	47.5
RDF+FYM+PSB+AZB	32	2	23	57	30	2	20	52
RDF+FYM+PSB+AZB+VAM	32	3	25	60	30	2.5	22	54.5
SE ±	3.2	0.11	3.25	-	2.63	0.13	3.1	-
CD 5%	8.65	0.33	9.25	-	7.32	0.31	8.9	-

The kinnow field experiment of integrated nutrient management in 2018-19 monitored the microbial community at two depths (0.00-0.15 and 0.15-0.30 m) (Table 1). In several INM treatments in Kinnow orchard, the bacterial population ranged from 7.5 to 36 × 10^5 cfu g^1 soils, the fungal population from 2.2 to 4.2 × 10^5 cfu g^1 soil, and the *Actinomycetes* population from 18-20 × 10^5 cfu g^1 soils. The total microbial population was lowest in the absolute control and considerably higher in the treatment where the consortium of biofertilizers and FYM were linked to the recommended doses of N, P, and K at both depths. With the participation of FYM and the consortium of biofertilizers, both the overall population and the population of individual microorganisms rose. This is due to the fact that the majority of soil microorganisms are chemo heterotrophs, meaning they need an organic carbon source for sustenance and oxidize organic material to produce energy. Under various INM treatments, the total and individual population of various microorganisms was higher in the areas where nutrients were supplied by combinations of RDF of NPK+FYM+PSB+Azotobactor+VAM, RDF of NPK+FYM+Azotobactor treatment, and the lowest number of microorganisms was seen in the control treatment. The large C:N ratio in the FYM treated plants indicated more carbon content and a slower rate of mineralization, which may have led to an increase in both the overall and individual microbial populations. The surface soil had greater microbial populations overall and among particular microorganisms than the deep soil. Ping et al., [8] and Shankar et al., [9] have similarly shown similar results in guava.

Impact of various INM treatments on Kinnow morphological parameters

Table 3 findings showed that the RDF of NPK+FYM+PSB+Azotobactor+VAM treatment had a considerably higher maximum plant height (5.50 m) than the control (2.95 m). The pattern of plant height showed that the addition of RDF, FYM, and a group of biofertilizers has the greatest growth-increasing effects on plants. In the same INM treatment, there was also more plant spread in both directions. The largest stem diameter was seen in the RDF+FYM+PSB+AZB+VAM and RDF+FYM+PSB+AZB treatments. The data on stem diameter varied widely throughout INM treatments as well. According to Ping et al., [8] and Shankar et al., [9] the optimal dosage of nutrient combinations (NPK) speeds up the plant's metabolic processes by raising meristematic activities. This increases vegetative growth and, in turn, increases flowering, maximum fruit setting percent, and maximum fruit retention percent in guava plants (Table 3).

Growth is aided by the application of nitrogen and the balanced nutrition that FYM provides since the two together promote leaf expansion and dark green color, which is favorable to photosynthesis and respiration. In addition to adding organic matter and macro- and micronutrients, it also enhances the physico-chemical characteristics of the soil, resulting in better growing and development conditions for plants. These results are consistent with those found in Kinnow [10].

Impact of INM treatments on Kinnow fruit quality and yield parameters

The RDF of N, P, K+FYM+PSB+Azotobactor+VAM had the highest fruit weight (225 g), which was considerably comparable to the RDF of NPK+FYM+Azotobactor treatment. According to the data in Table 4 from the current study, different INM treatments for fruit weight, fruit yield, TSS, acidity, and juice recovery were all measured. The minimal fruit weight of 10^5 g for the control treatment was observed. The fruit yield was assessed, with the maximum production (22.80 t/ha) recorded in the RDF of NPK+FYM+PSB+Azotobactor+VAM treatment and the lowest yield (7.75 t/ha) estimated in the control treatment. (Table 4). The TSS of mature fruits from all treatments was measured, and the findings indicated that the TSS level was increased by the addition of FYM and inorganic fertilizers. The measurement range for Brix was 12.50 to 13.50°C. Although FYM reduced the juice's acidity, the control and inorganically fertilized groups had the greatest acidity concentrations. The treatments with FYM as a component showed the highest juice (52%) according to reports. There was a range of 45 to 52 percent juice recovery. Ping et al., [8] and Shankar et al., [9] have also reported comparable outcomes in guava.

Benefit-cost ratio analysis of several INM treatments for the Kinnow fruit crop

A 17-year-old kinnow fruit crop's benefit-cost ratio was examined for a number of INM treatments. All activities, excluding the prescribed therapy, were finished at the predetermined expense. Concurrent calculations were made for each therapy's cost, and the fixed and treatment costs for all treatments were then added together. Additionally, a yield estimate was made, hectare by hectare. The gross income for each treatment was computed using a cost of output of Rs. 10,000 per tonne. After that, net income was computed by deducting the total cost from the gross income of each treatment. Finally, the benefit-to-cost ratio was computed for each treatment. Treatment T11 had the highest benefit cost ratio (3.96) and treatment T1 had the lowest (2.10), according to Table 5. The findings demonstrated that, although the addition of AMF did not improve the benefit in income, the addition of FYM in conjunction with the proper dosage of NPK did raise the benefit cost ratio. Ping et al., [8] and Shankar et al., [9] have also reported comparable outcomes in guava (Table 5).

TABLE 3

Impact of several INM treatments on Kinnow orchard morphological parameters (plant average age: 17 years)

Treatment	Tree height (m)	Tree spread		Stem diameter (cm)
		N-S (m)	E-W (m)	
Control	2.95	2.75	2.6	85
RDF	3.2	2.7	2.7	85
RDF+FYM	3.95	3.15	3	85
RDF+Azotobactor	3.9	2.85	2.95	85
RDF+PSB	3.6	3	2.95	85
RDF+VAM	3.6	2.9	2.9	85
RDF+FYM+AZB	4.9	3.15	2.9	80
RDF+FYM+ PSB	4.95	3.1	3	80
RDF + FYM+VAM	4.85	3.1	3	90
RDF+FYM+PSB+AZB	5.5	3.3	3.05	92
RDF+FYM+PSB+AZB+VAM	5.5	3.55	3.1	95
SE ±	0.28	0. 21	0.19	6.8
CD 5%	0.62	0.51	0.41	20.07

TABLE 4

Impact of several INM treatments on fruit quality and yield characteristics in a Kinnow orchard (plant average age: 17 years)

Treatment	Fruit weight (g)	Fruit yield (t/ha)	TSS (° Brix)	Acidity (%)	Juice (%)
Control	105	7.75	12.5	0.85	45
RDF	160	12.5	12	0.7	50
RDF+FYM	225	15	12.5	0.6	51
RDF+Azotobactor	185	12.5	12.5	0.6	50
RDF+PSB	165	13.5	12.5	0.7	51
RDF+VAM	170	13.5	12.5	0.7	50
RDF+FYM+AZB	195	20	13	0.7	52
RDF+FYM+PSB	200	20	13	0.7	52
RDF+FYM+VAM	205	19.5	13.5	0.7	52
RDF+FYM+PSB+AZB	225	21.5	13.5	0.65	52
RDF+FYM+PSB+AZB+VAM	225	22.8	13.5	0.65	52
SE ±	13.17	2.08	0.6	0.25	1.23
CD 5%	40.39	5.62	1.75	NS	3.62

TABLE 5

Benefit-cost ratio analysis of several INM treatments applied to the 17-year-old Kinnow fruit crop

Treatments	Fixed cost (‘000)	Treat cost (‘000)	Total cost (‘000)	Yield (t/ha)	Gross income (‘000)	Net income (‘000)	B:C ratio
Control	25	-	25	7.75	77.5	52.5	2.1
RDF of N, P and K	25	10	35	12.5	125	90	2.57
RDF+FYM	25	15	40	15	150	90	2.25
RDF+AZB	25	12	37	12.5	125	88	2.38
RDF+PSB	25	12	37	13.5	135	98	2.65
RDF+AMF	25	12	37	13.5	135	98	2.65
RDF+FYM+AZB	25	17	42	20	200	158	3.76
RDF+FYM+PSB	25	17	42	20	200	158	3.76
RDF+FYM+AMF	25	17	42	19.5	195	153	3.65
RDF+FYM+PSB+AZB	25	19	44	21.5	215	171	3.89
RDF+FYM+PSB+AZB+AMF	25	21	46	22.8	228	182	3.96

As demonstrated by the data in Table 6, which also illustrates how these parameters varied over the year, the physico-chemical properties of the soil under various INM treatments were regularly examined in the current investigation. The findings demonstrated that the pH of the soil did not change considerably when chemical fertilizers were the only ones applied; however, the pH of the soil did fall when FYM was added. There was no discernible change in the pH of the soil following the application of biofertilizers. The application of FYM increased the amount of Organic Carbon (OC) in the soil, but inorganic and biofertilizer fertilizers had no effect on the OC status of the soil, according to data on the OC state of the soil. The maximum status of accessible P and K_2O in the soil was improved by the use of inorganic fertilizers in conjunction with FYM. The amount of P and K_2O that was available was impacted by the administration of INM treatments. The recommended amounts of N, P, and K also made more P and K_2O available in the soil. In a similar vein, using FYM has increased the soil's iron and zinc concentration and availability. The long-term integrated nutrient management approaches did not appreciably change the soil's BD or porosity. By influencing the accumulation of biomass from living plants, the production of litter, and the exudates from the roots, changes in land use can modify net primary production. The long-term INM operations significantly reduced the pH of the surface soil. The contents of available N, P and K in INM treatments increased significantly in comparison to inter row space. INM often alters the chemical properties of orchard soils, such as pH and available nutrient fractions, by removing bases and adding organic sources of nutrients that create acids. Furthermore, INM dramatically changed the soil's biological and biochemical properties [5,10] (Table 6).

The findings of a monitoring program for the soil moisture condition of the soil under various INM treatments showed that the application of FYM alone or in combination with inorganic and biofertilizers increased the soil moisture status at both strata. Based on soil status monitoring at two depths, the more moisture that has accumulated at lower levels (Table 7). Applying biofertilizers alone did not result in an improvement in the moisture content of the soil.

Soil available nutrient and fruit yield

The range and mean values of soil accessible nutrients and fruit yield in treated and control treatments are taken into consideration, according to data in Table 8 of the current study. Samples of fruit and plant petioles were collected in order to estimate the levels of N, P, and K and determine the crop's uptake of them. According to the methodology outlined by Ramamoorthy et al., [11], treatment-wise soil test data, nutrient doses, yield, and uptake were used to determine NR (nutrient required to produce one tonne of kinnow fruits), %CS (percent contribution of nutrients from treatment), and %C-OM (percent contribution of nutrients from organic matter). Equations for fertilizer recommendations based on soil tests were created using these characteristics in order to meet the targeted production targets for kinnow under NPK and NPK plus FYM. Table 8 presents the basic statistics, which includes the percentage contribution of nutrients from soil, fertilizer, and FYM, as well as the NR for producing one tonne of Kinnow fruits (Table 8).

The impact of integrated nitrogen sources on Kinnow revealed notable variations across all macronutrients, as shown in Table 9. T11 (RDF of N, P, K+FYM+PSB+AZB+AMF) had the highest content (2.65%), phosphorus content (0.40), and potassium content (1.65), followed by T7 and T10. The control treatment yielded the lowest levels of potassium, phosphorus, and nitrogen. Treatment T11 had the highest calcium (2.70%) and zinc (19.00%) levels in the foliage of the micronutrient. The highest iron level (160%), maximum copper content (2.70%), and Mn amounts (40%) were noted in T7. Under control, the minimum levels of macro and micronutrients for leaves were noted. This could be because nitrogen fixers produced enzyme complexes that solubilized and made available the form of nutrients that were previously unavailable. Sharma et al., [12] have also reported that urea application increases the nitrogen content of the leaves. It's possible that the improved phosphorus availability and translocation brought about by *Azotobacter* treatment caused the rise in phosphorus intake. Yadav et al., [13] observed that the addition of vermicompost increased the leaf nitrogen, phosphorus, and potassium content of Kinnow mandarin, likely as a result of the organic manure in the guava. The current study's increase in the foliar potassium concentration is consistent with Singh et al., [14] findings regarding sweet orange cv. Mosambi (Table 9).

TABLE 6

Impact of various INM treatments on the soil's physicochemical characteristics

Treatment	pH	Organic carbon (%)	Available P (kg/ha)	Available K_2O(kg/ha)	Available Zn (ppm)	Available Iron (ppm)
Control	8.1	0.13	8	170	0.5	3.4
RDF	8.2	0.15	15.5	205	0.45	3.45
RDF+FYM	7.5	0.3	15.5	220	0.62	4.35
RDF+Azotobactor	8	0.15	15	220	0.58	3.75
RDF+PSB	8	0.15	16	220	0.58	3.78
RDF+VAM	8	0.15	16.5	220	0.58	3.8
RDF+FYM+AZB	7.6	0.32	16.5	220	0.67	4.85
RDF+FYM+PSB	7.5	0.32	18.5	220	0.67	4.85
RDF+FYM+VAM	7.5	0.32	19.5	225	0.67	4.85
RDF+FYM+PSB+AZB	7.5	0.32	19.5	225	0.67	5.1
RDF+FYM+PSB+AZB+VAM	7.5	0.32	19.5	230	0.67	5.1
Initial level	8.2	0.08	8	185.5	0.5	3.5

TABLE 7

Impact of various INM treatments on the soil's physicochemical characteristics

Treatment	Soil moisture (%) after 24 hrs of irrigation	
	0-0.30 m	0.30-0.60 m
Control	2.8	3.5
RDF	3.5	3.5
RDF+FYM	5.5	6

RDF+Azotobactor	3.4	3.5
RDF+PSB	3.5	3.5
RDF+VAM	3.8	4.5
RDF+FYM+AZB	5.5	6.5
RDF+FYM+PSB	5	6
RDF+FYM+VAM	6	6
RDF+FYM+PSB+AZB	6.5	6.5
RDF+FYM+PSB+AZB+VAM	6	6

TABLE 8

Estimation of fertilizer prescription based on soil test for 22 t ha^{-1} Kinnow fruit yield in aridisols

Soil test value			Fertilizer dose (kg ha^{-1}) under NPK alone			Fertilizer doses (kg ha^{-1}) under NPK+FYM @40 t ha^{-1})		
SN	SP_2O_5	SK_2O	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
120	10	140	128	45	98	106	40	92
145	12.5	160	120	42	86	100	37	78
185	14.5	180	112	39	78	92	32	62
205	16.5	200	104	36	62	74	29	54

TABLE 9

Impact of INM treatments on Kinnow foliage's macro and micronutrient status

Treatments	Macronutrients (%)				Micronutrients (ppm)			
	N	P	K	Ca	Zn	Mn	Fe	Cu
Control	2.3	0.22	1.35	2.4	15.5	35	130	2.2
RDF of N, P and K	2.52	0.28	1.55	2.45	16	38	135	2.3
RDF of N, P, K+FYM	2.55	0.3	1.55	2.5	17	38	140	2.45
RDF of N, P, K+Azotobactor	2.55	0.3	1.55	2.5	16.5	39	140	2.5
RDF of N, P, K+PSB	2.55	0.35	1.5	2.5	17	38	145	2.5
RDF of N, P, K+AMF	2.5	0.35	1.55	2.45	17.5	40	150	2.5
RDF of N, P, K+FYM+AZB	2.6	0.35	1.6	2.55	18	40	150	2.6
RDF of N, P, K+FYM+PSB	2.55	0.35	1.55	2.55	18	38	155	2.6
RDF of N, P, K+FYM+AMF	2.55	0.35	1.55	2.5	18	39	160	2.65
RDF of N, P, K+FYM+PSB+AZB	2.6	0.4	1.6	2.7	18.5	39	155	2.65
RDF of N, P, K+FYM+PSB+AZB+AMF	2.65	0.4	1.65	2.7	19	38	160	2.7

CONCLUSION

The combined application of recorded under T11-RDF of N, P, K+FYM+PSB+AZB+AMF, (1000:500:750 g+50 kg+250 g+250 g+500 g) in an integrated manner was beneficial for improving soil chemical properties, improving growth, yield quality, and benefit-cost ratio of Kinnow mandarin in the Bikaner region of Rajasthan, it can be concluded in light of the results obtained from this investigation.

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