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INTEGRATED USE OF ORGANIC AND INORGANIC FERTILIZERS ON YIELD, QUALITY AND NUTRIENT CONTENT OF KHASI MANDARIN (*Citrus reticulata*) IN ASSAM

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ABSTRACT

The experiment was carried out during 2013 to 2016 to find out the effect of integrated use of organic and inorganic fertilizer on yield, quality and nutrient content of Khasi mandarin in Tinsukia district of Assam, India. The experiment was laid out with 5 m 5 m spacing along with 5 treatments, 4 replications and designed with RBD. Existing technology for application of nutrients in Khasi mandarin is split application of the recommended doses of N, P_2O_5 and K_20 *i.e.*, 600:300:600 g N, P_2O_5 and K_2O $pl^{-1}yr^{-1}$ along with 7.5 kg mustard oil cake $pl^{-1}yr^{-1}$ in two splits. The results revealed that application of 75% RDF + VAM (500 g pl^{-1}) + PSB (100 g pl^{-1}) + *Azospirillum,* (100 g pl^{-1}) + *T. harzianum* (100 g pl^{-1}) were found effective in improving the yield, soil nutrient status and quality of Khasi mandarin with B: C ratio of 4.50. The fruit obtained under this treatment was found significantly superior in quality as evident from highest juice content i.e. 48.95%, TSS i.e. 13.77%, Ascorbic acid i.e. 48.93%, total sugar i.e. 7.47% and lowest acidity i.e. 0.37%. The time taken for maturity was the lowest (244 days), while shelf life was the highest (18 days) though not significant. Significantly higher soil fertility status (N, P_2O_5 and K_2O) and superior N, P, K content of leaf were observed under this treatment.

(Key words: Biofertilizer, Khasi mandarin, recommended doses of fertilizer)

INTRODUCTION

Citrus is one of the largest fruit industries in the world having nutracutical properties. In India, citrus holds a prominent place among the major commercial fruits covering an area of about 1003 thousand ha with an annual production of 12546 thousand metric tons and productivity of 12.5 t ha^{-1}(Anonymous,2018).

Among the Citrus fruits, Khasi mandarin covering an area of 14.95 thousand ha, and production of 203.72 thousand metric tons in Assam (Anonymous, 2018),whereas it occupies 1.47 thousand ha area, 24.37 thousand metric tons production in Tinsukia with highest productivity of 15.8 t ha^{-1}(Anonymous, 2018).

'Among the citrus cultivars, Khasi Mandarin is the most important citrus fruit cultivated in N.E. India. The Khasi mandarin (*Citrus reticulata*), commonly known as Orange, produced in this region is famous in India for its superior quality in respect of its flavour, Juice content, soluble sugar and acidity ratio. The soil climatic conditions of this region are most suitable for its production and it has the potentiality to generate livelihood in the rural areas substantially.

Harmful effect of chemical fertilizer has shifted the interest of researcher to work on organic fertilizer which can increase the production of crops. Crop productivity is often limited may be due to low availability of essential nutrients, using chemical fertilizers alone that led to imbalance nutrition. The long-standing use of inorganic fertilizer without addition of organic fertilizers damaged the physical, chemical and biological properties of soil and causes pollution of soil and reduction of productivity (Moghadam *et al*., 2014, and Asefa and Alemayehu, 2021). Therefore, in order to make the soil well supplied with all the plant nutrients, in the readily available form and to maintain good soil health, it is necessary to use the organic fertilizer in conjunction with inorganic fertilizer to obtain optimum yield (Singh *et al*., 2021). To maintain or adjust the soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of the benefits from all possible sources of plant nutrients should be used in an integrated (Organic and Inorganic) manner. The nutritional requirement of Khasi mandarin varied widely owing to its perennial in nature. Mandarins, being a commercially important fruit crop, proper and correct dose of organic, inclusive of bio-fertilizers in an integrated way with inorganic fertilizers need to be evaluated to ensure high economic productivity and sustaining the nutrition of the plant at a desirable level. Moreover, the quantification of most of the bio-fertilizers to substitute a unit quantity of chemical fertilizer are yet to be established in most of the fruit crops. Keeping all these aspects in view, the present study was undertaken to find an economically viable INM practice in Khasi mandarin based on nutrient content of plant as well as in the soil and also find out the effect of bio-fertilizers on yield, quality and nutrient content of citrus.

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MATERIALS AND METHODS

The present investigation was carried out on twelve years old Mandarin orange (*Citrus reticulata* Blanco.) of uniform growth and vigour in Makumkilla areas of Tinsukia district of Assam in India during 2013 to 2016 with five different treatments *viz*., T1 : Recommended dose of NPK-RDF (Control), T2 = RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum* (50 g plant^{-1}), T3 = 100% RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}), T4 = 75% RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}) and T5 = 50% RDF + VAM (500 g plant^{-1}) + PSB - (100 g plant^{-1}) + *Azospirillum* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}).

The treatments were applied in randomized block design with four replications having four plants each. The sources of N, P_2O_5 and K_2O were urea, rock phosphate and muriate of potash, respectively. All the inorganic components with rock phosphate and mustard oil cake (MOC) except bio-fertilizers were applied in two equal split doses during March and September. Biofertilizers were applied as single dose with required quantities of mustard oil cake (MOC) during the month of March. Soil samples were collected during the month of September. Organic carbon content was determined by Wet Oxidation method (Walkley and Black ,1934), available nitrogen content was analyzed by Kjeldhal method (Jackson,1973), available P content was estimated by Brays method (Jacson,1973) and available K content in soil was measured by ammonium acetate extraction method using Flame photometer (Jackson, 1973). Number of fruits and otherq uality p arameters (juice %, TSS, Ascorbic acid, Shelf life, yield) were estimated by adopting the standard techniques. Leaf samples were collected during the month of March (after flowering) and December (after harvesting). Leaf N content was estimated by Kjeldhal method (Jackson, 1973), P content was estimated by vanadomolybdo phosphoric acid yellow colour method as described by Jackson (1973) and K contents was estimated by ammonium acetate extraction method using Flame photometer (Jackson, 1973). Benefit: Cost ratio was determined after pooling the data over the years of experiment. The data generated in three consecutive years viz., 2013 to 2016 were pooled and used to prepare analysis of variance table and accordingly. SE(m) and C.D. 0.5% were computed as described by Panse and Sukhtame (1954).

RESULTS AND DISCUSSION

Soil characteristics

Initial soil characteristics (Table 1) showed that soils were acidic in nature (pH 4.7) and high organic carbon contents. Initial available N, P_2O_5 and K_2O content in soils were found to below.

After application of treatments higher organic carbon contents and maximum available N, P_2O_5 and K_2O content in soils were observed in T_4 treatment involving application of 75% RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum,* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}) followed by T_3 treatment with having100% RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}). Statistical analysis revealed that significant differences were found in soil parameters i.e organic carbon content, available N, P_2O_5 and K_2O content in soil with having critical difference CD at 5% *i.e.* 0.12; 18.9;5.4; 7.8 respectively.

Leaf nutrient content

After application of treatments leaf nutrient content were observed after flowering (F) and harvesting (H) of Khasi mandarin. Leaf nutrient content of N, P and K were found maximum in T_4 treatment both flowering (F) and harvesting (H) of Khasi mandarin. Significant differences were observed in leaf N, P and K content.

Growth

Maximum plant height (6.46 m) and canopy volume (45.62 m^3) was observed under the treatment (T4) involving with 75% recommended dose of NPK (450 g N, 225 g P_2O_5, 450 g K_2O and 5.625 kg Neem Oil Cake) + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum,*(100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}) (Table 3). This could be explained by the activities of the biofertilizers *viz*., nitrogen fixation, release and solubilize the Pi from insoluble phosphate, mobilize the phosphate, production of phytohormones etc. with simultaneous uptake of nutrients. Increase cell elongation and cell multiplication due to enhanced nutrient uptake following application of *Azospirillum* and PSB might have increased plant height. Beside this application of 75% recommended dose of NPK along with *Azospirillum* might have increased the nitrogen content. Nitrogen is a constituent of protein which helps in division and enlargement of cell, thereby, enhancing plant growth.

Yield

The higher yield (39.60 tha^{-1}) was found in T_4 treatment involving application of 75% RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum,* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}) followed by T3 treatment having100% RDF + VAM (500 g plant^{-1})+ PSB (100 g plant^{-1}) + *Azospirillum* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}). Statistical analysis revealed that significant differences were observed in yield of Khasi mandarin**.** Improved yield might be due to combine application of organic and inorganic fertilizer as a result of availability of major and minornutrients at all the essential stages of growth and development and improvement of physiochemical properties of soil; increase in enzymatic activity, microbial population and also increase in plant growth hormones and application of biofertilizers helps to increase the biological nitrogen fixation, and availability of phosphorus which is required for strong vegetative growth and upon decomposition-release nitrogen and phosphorus contents and allele-chemicals leading to disease suppression. Maskar *et al*.(2018)reported that application of chemical fertilizer combined with *Azospirillum*

and PSB performed well in respect of growth and yield of Sapota.

Quality attributes of mandarin

The fruit obtained under the treatment T_4, having 75% recommended dose of NPK (of 450 g N, 225 g P_2O_5, 450 g K_2O and 5.625 kg Neem Oil Cake) + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum,* (100 g plant^{-1}) + *T. harzianum* (100 g plant^{-1}) was also found significantly superior in quality as evident from highest juice content, 48.95%, TSS, 13.77%,ascorbic acid, 48.93%, total sugar, 7.47% and lowest acidity, 0.37%. The time taken for maturity was the lowest (244 days), while shelf life was the highest (18 days) though not significant. Such an increase in total sugars, TSS and juice per-centage might be due to the beneficial effect of combine application of organic and inorganic fertilizers by enhancing enzyme activities and supplying multiple nutrients.Maximum B: C ratio (4.5) was also observed under this treatment (T_4). Cost of cultivation was marginally increased when nutrients were applied through combine use of organic and inorganic fertilizer but due to higher fruit yield and higher net return, B:C ratio was found higher. Meshram *et al*. (2018) reported that cost of cultivation was marginally increased when nutrients were applied through combine source of organic and inorganic fertilizer but due to higher straw and grain yield and higher net return in rice, B:C ratio was higher under integrated use of organic and inorganic fertilizer.

From the results it is concluded that application of 75% RDF + VAM (500 g plant^{-1}) + PSB (100 g plant^{-1}) + *Azospirillum, (*100 g plant^{-1}*)* + *T. harzianum* (100 g plant^{-1}) was found to be effective in improving the yield and quality of mandarin compared to the rest of the treatments including application of recommended doses of fertilizer control.The maximum B: C ratio of 4.50 was found under this treatment.

Table 1. Effect of bio-fertilizers on soil fertility status

Treatments	Soil Properties				
	pH	O C %	Av. N	Av. P_2O_5	Av.K_2O
			(kg ha^{-1})		
T_1	4.7	1.09	298	26.9	132.5
T_2	4.9	1.13	318	28.6	158.4
T_3	5.1	1.28	327	32.8	155.1
T_4	5.4	1.41	360	33.9	175.3
T_5	5.0	1.28	302	24.3	134.2
Initial	**4.7**	**0.95**	**234**	**19.05**	**131.9**
SE (m) ±	-	0.04	6.3	1.8	2.6
CD at 5%	-	0.12	18.9	5.4	7.8

Table 2. Effect of bio-fertilizers on leaf N, P and K at flowering (F) and harvest (H) of mandarin (Pooled data)

Treatments	Leaf nutrient concentration (%)					
	N		P		K	
	F	H	F	H	F	H
T_1	2.48	2.24	0.19	0.16	1.21	1.17
T_2	2.40	2.26	0.29	0.22	1.26	1.20
T_3	2.67	2.51	0.28	0.27	1.38	1.32
T_4	2.94	2.64	0.31	0.30	1.56	1.49
T_5	2.50	1.99	0.23	0.17	1.12	1.07
SE (m) ±	0.10	0.08	0.03	0.06	0.37	0.38
CD at 5%	0.30	0.24	0.09	0.18	1.11	1.14

F-After Flowering during the month of March, H- After Harvesting during the month of December

Table 3. Effect of bio-fertilizers on growth and quality attributes and B:C ratio of mandarin (Pooled data)

Treatments	Plant height (m)	Canopy volume (m^3)	Fruit (t ha^{-1})	Juiice (%)	Acidity (%)	TSS (^{0}Brix)	Ascorbic acid (mg 100 ml)	TSS/ Acid ratio	Shelf life days	B:C ratio
T_1	6.27	38.02	32.34	43.02	0.46	10.60	43.43	23.04	14	3.08
T_2	6.28	38.27	29.58	43.33	0.45	11.43	45.83	25.4	15	3.24
T_3	6.31	44.78	32.63	46.58	0.42	11.60	46.23	27.61	17	4.05
T_4	6.46	45.62	39.60	48.95	0.37	13.77	48.93	37.21	18	4.50
T_5	6.11	40.15	30.55	41.01	0.45	10.25	45.88	22.77	16	3.08
SE (m) $\pm$	0.07	1.94	0.93	2.10	-	0.66	0.96	3.02	-	-
CD at 5%	0.21	5.82	2.79	6.30	-	1.98	2.88	9.06	-	-

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