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Effect of Integrated Nutrient Management on Micronutrient Uptake, Status, Microbial Count and Yield of Ridge Gourd in Lateritic Soil

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A field experiment was conducted during *Kharif* season of 2016 at Central Experiment Station, Wakawali to study the effect of integrated nutrient management on micronutrient uptake, status, microbial count and yield of ridge gourd in lateritic soil of coastal Maharashtra. The results of the experiment showed that application of 50 per cent recommended dose of nitrogen (RDN) + 50 per cent N through poultry manure + P and K+ *Azotobacter* @ 250 g per 10 kg seed significantly improved content and uptake of micronutrients, namely DTPA extractable iron, manganese, copper and zinc. Highest content of bacteria (44.00 x 10^6 cfu g^{-1}), actinomycetes (23.33 x 10^6 cfu g^{-1}) followed by fungi (10.00 x 10^6 cfu g^{-1}) were also observed under the same treatment. This treatment produced significantly highest fruit yield (16.64 t ha^{-1}) as compared to absolute control (9.39 t ha^{-1}) and RDF alone (14.86 t ha^{-1}) treatments. However, it was at par with treatment (16.24 t ha^{-1}) consisting 50 per cent RDN + 50 per cent N through vermicompost + P and K + *Azotobacter* @ 250 g per 10 kg seed. It is therefore recommended to use manures, fertilizers and biofertilizer in an integrated manner to improve micronutrient content, uptake and microbial population and also the yield of ridge gourd in lateritic soil of coastal region of Maharashtra.

(***Key words:*** *Lateritic soil, INM, Micronutrients, Microbial count, Ridge gourd*)

Ridge gourd is an important vegetable crop and is grown throughout the year. It is an excellent blood purifier, possessing laxative properties, cure for jaundice, aids in weight loss, has anti-inflammatory and antibiotic properties, fortifies the immune system, and is good for skin care and stomach. Ridge gourd contains about 300 µg β-carotene and 1000 µg carotenoids per 100 g of fresh fruits (Kandlakunta *et al*., 2008).

Fertilizers and organic manures play an important role in increasing production, improving quality of vegetables and sustaining soil fertility. However, the continuous use of fertilizers may cause imbalance in the microflora in the long-run and thereby directly or indirectly influence the biological properties. Ultimately, it may have deleterious effect on the soil leading to its degradation.

Therefore, the integrated nutrient supply system (INSS) approach which involves the combined use of chemical fertilizers, organic manures and biofertilizers ensures higher crop production, helps to restore and sustain the soil fertility, helps to overcome micronutrients deficiencies and increase the efficiency of applied chemical fertilizers (Kadrekar, 1993). Soil harbours a dynamic population of micro-organisms. The activity of soil microflora in mineralization of nitrogen is a link in making it available to plants (Rangaswamy, 1966). Iron, manganese and sulphur are transformed from unavailable to available forms by microbial oxidation and reduction.

Ridge gourd is a nutrient loving crop and responds well to added nutrients in soil. Fertilizing soils to bring all the deficient elements at high levels as to provide sufficient ionic activity in soil solution for crop uptake is one of the important considerations for maximization of the crop yield (Verma *et al*., 2013). Keeping all these facts in view, the present investigation aimed at understanding the effect of integrated nutrient management on micronutrient status, uptake, microbial count and yield of ridge gourd in lateritic soil of coastal region of Maharashtra.

MATERIALS AND METHODS

The field experiment was conducted at Central Experiment Station, Wakawali which is situated

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between 17°40′ to 17°45′ N latitude and 73°16′ to 73°19′E longitude. The height above mean sea level is 167 m to 234 m and the area has a hot and humid climate with well-expressed three seasons *viz*., summer (March to May), monsoon (June to October) and winter (November to February). The Wakawali centre received a total of 754.09 mm rainfall during crop growth period (24th to 42nd meteorological week). The mean weekly maximum and minimum temperature recorded was 31.8°C and 19.8°C in 24th and 38th meteorological week, respectively. The mean relative humidity of 70 and 89 per cent was observed during the 24th and 38th meteorological week, respectively. The experiment was conducted in randomized block design with eight treatment combinations which were replicated thrice. The soil of the study site is lateritic in nature. During kharif 2016, ridge gourd cv. Konkan Harita was grown.

The treatments comprised of T_1 - Absolute control, T_2 - RDF (recommended dose of fertilizer; 100 kg N, 50 kg P_2O_5 & 50 kg K_2O ha^{-1}), T_3 - 75 per cent RDN (recommended dose of nitrogen) + 25 per cent N through farm yard manure (FYM), T_4 – 75 per cent RDN + 25 per cent N through vermicompost, T_5 - 75 per cent RDN + 25 per cent N through poultry manure, T_6 - 50 per cent RDN + 50 per cent N through FYM, T_7 - 50 per cent RDN + 50 per cent N through vermicompost and T_8 - 50 per cent RDN + 50 per cent N through poultry manure. The amount of organic manures added to supply 25 and 50 % RDN were FYM @ 3.48 and 6.97 kg plot^{-1}: vermicompost @ 1.49 and 2.98 kg plot^{-1} and poultry manure 1.55 and 3.10 kg plot^{-1}, respectively. In treatments T_3 to T_8, recommended doses of P and K were applied and the seed was inoculated with *Azotobacter* @ 250 g per 10 kg seed.

Soil samples were collected at the beginning of the experiment (initial), at 60 and 90 days after sowing (DAS) and after harvest for analysis. The surface soil samples collected from 0-20 cm depth from each treatment were air-dried and processed with the help of wooden pestle and mortar and passed through 2 mm sieve. The processed samples were used for the determination of physico-chemical properties and available macro and micro-nutrient status. Another set of fresh soil sample was used for the determination of microbial population. The physical properties *i.e*., particle density and bulk density of initial soil samples were estimated by pycnometer method and clod coating method, respectively (Black, 1965). The mechanical analysis was carried out by Bouyoucos hydrometer method (Bouyoucos, 1951) and the textural classes were determined by using textural triangle (Chopra and Kanwar, 1978).

The soil pH and electrical conductivity were determined by glass electrode pH meter and EC meter, respectively using 1:2.5 soil: water suspension (Jackson, 1973), organic carbon content by wet digestion using Walkley and Black's rapid titration method (Black, 1965), available N by Subbiah and Asija (1956) and DTPA extractable Fe, Mn, Zn and Cu were extracted from soil by forming the method of Lindsay and Norvell (1978). The extracting solution used for this purpose consisted of 0.005 M DTPA (Diethylene Triamine Penta Acetic acid), 0.01 M $CaCl_2$ and 0.1 M TEA (Tri Ethanol Amine) buffered at pH 7.3 and concentration of these micronutrients were determined with Atomic Absorption Spectrophotometer (Analyst 200). The microbial population of bacteria, fungi and actinomycetes population were measured by serial dilution method (Pramer and Schmidt, 1964). The data were statistically analysed by the method suggested by Panse and Sukhatme (1967).

RESULTS AND DISCUSSIONS

Initial soil characteristics

The soil of the experimental site (Table 1) was lateritic, sandy clay loam in texture and moderately acidic (pH 5.53) in reaction and non-saline (EC 0.257 dS m^{-1}). It had very high organic carbon (13.8 g kg^{-1}) content. The bulk density of the experimental site was 1.54 and particle density was 2.52 Mg m^{-3}. The soil was sandy clay loam in texture having 62.12, 15.19 and 22.69 per cent sand, silt and clay, respectively. The major available nutrients *viz*., nitrogen, phosphorus and potassium contents were medium (316.73 kg N ha^{-1}), very low (9.33 kg P_2O_5 ha^{-1}) and moderately high (228.48 kg K_2O ha^{-1}), respectively.

The DTPA extractable micronutrients *viz*., Fe, Mn, Zn and Cu were well supplied in soil and were 20.14, 35.22, 1.12 and 3.40 mg kg^{-1}, respectively. The microbial population observed in the initial soil sample consisted of bacteria (10.50 x 10^{6} cfu g^{-1}), fungi (6.00 x 10^{6} cfu g^{-1}) and actinomycetes (1.50 x 10^{6} cfu g^{-1}).

Table 1. *Effect of integrated nutrient management on micronutrient uptake by ridge gourd, microbial population in soil and yield of ridge gourd*

Tr. No.	Treatments	Micronutrient uptake by ridge gourd plant (g ha^{-1})				Bacteria	Fungi	Actino mycetes	Yield (t ha^{-1})
		Fe	Mn	Zn	Cu	(x 10^6 cfu g^{-1})			
T_1	Absolute control	379.93	1177.23	475.67	614.16	21.50	11.33	2.33	9.39
T_2	Recommended dose of fertilizer (100:50:50 N:P_2O_5:K_2O kg ha^{-1})	801.05	2384.99	1093.27	1295.14	26.17	13.33	3.00	14.86
T_3	75 % RDN + 25% N through FYM+ P and K + *Azotobacter*	535.36	1643.28	632.46	759.72	27.17	16.83	4.17	11.24
T_4	75 % RDN + 25% N through vermicompost + P and K + *Azotobacter*	650.16	1901.96	770.11	945.10	29.50	14.83	5.67	14.15
T_5	75 % RDN + 25% N through poultrymanure + P and K + *Azotobacter*	882.65	2493.41	1147.02	1515.96	31.67	18.00	6.83	14.48
T_6	50 % RDN + 50 % N through FYM+ P and K + *Azotobacter*	679.54	1993.88	832.43	1042.89	34.83	19.67	8.67	11.74
T_7	50 % RDN + 50 % N through vermicompost+ P and K + *Azotobacter*	972.08	2775.08	1352.65	1697.11	42.50	20.50	7.67	16.24
T_8	50 % RDN + 50 % N through poultrymanure + P and K + *Azotobacter*	1004.19	2916.92	1418.68	1800.04	44.00	23.33	10.00	16.64
	Mean	738.12	2160.84	965.29	1208.76	32.17	17.23	6.04	13.59
	S.E.±	12.256	24.838	13.357	21.335	0.591	0.351	0.427	0.273
	C.D. (P=0.05)	37.174	75.337	40.513	64.775	1.791	1.064	1.296	0.828

Uptake of micronutrients

The uptake of micronutrients (Table 1) was significantly influenced due to various treatments. The Fe content ranged from 379.93 g ha^{-1} to 1004.19 g ha^{-1}. Among the treatments the T_8 treatment consisting of 50 per cent RDN + 50 per cent N through poultry manure + P and K + *Azotobacter* @ 250 g per 10 kg seed showed its superiority over all other treatments in respect of DTPA extractable Mn (2916.92 g ha^{-1}), Zn (1418.68 g ha^{-1}) and Cu (1800.04 g ha^{-1}) contents. However, in respect of Fe content the T_8 treatments was significantly superior over all other treatment except treatment T_7 *i.e.*, 50 per cent RDN + 50 per cent N through vermicompost + P and K + *Azotobacter* @ 250 g per 10 kg seed. An increasing trend of micronutrient uptake was observed in the treated plots as compared to control by Salvi *et al*. (2014) and Dodake *et al*. (2015).

Effect on available micronutrients

The data presented in Table 2 revealed that the DTPA extractable iron, zinc, copper and manganese status was found to be adequate in the soil. Significantly highest DTPA extractable Fe (44.16, 43.19 and 41.77 mg kg^{-1} at 60, 90 and at harvest, respectively) was recorded with the treatment T_8 consisting 50 per cent RDN + 50 per cent N through poultry manure + P and K + *Azotobacter* which was significantly superior over all other treatments. Katyal and Sharma (1991) reported that the high content of available Fe may be due to accumulation of sesquioxides and also higher organic matter content, which keeps iron in complexes and available form. Ghayal (2016) reported highest Fe content (66.4 µg kg^{-1}) due to application of poultry manure @ 4.5 t ha^{-1}. Kapse (2016) also reported highest Fe content in chilli in lateritic soils of Konkan region due to application of 50 per cent N through vermicompost + 50 per cent N through urea. The treatment T_8 recorded significantly highest DTPA extractable manganese content at 60, 90 DAS and at harvest which was 88.23, 86.16 and 83.55 mg kg^{-1}, respectively as compared to all other treatments except treatment T_7. The high concentration of DTPA extractable Mn might be due to decomposition and mineralization of organic matter in warm and humid climate of the region (Mehta and Patel, 1967). The above results in respect of the manganese content are in agreement with those results reported by Mhalshi (2013) who reported the highest Mn content at harvest of cowpea due to application of 25:60:40 $N:P_2O_5:K_2O$ kg ha^{-1} + biofertilizers in lateritic soil of Konkan. Ghayal (2016) also reported highest Mn content at 30, 60 DAS and after harvest of cucumber in lateritic soil of Konkan.

At 60, 90 DAS and at harvest, maximum DTPA extractable zinc (1.95, 1.90 and 1.87 mg kg^{-1}, respectively) in soil was noticed in the treatment T_8 which was significantly superior over all the treatments except treatment T_7 which was found at par at 60 DAS. From the above results it is clear that application of organic manures increase the available Zn content in soil which may be due to its release in the soil on being solubilized and mobilized by organic acids and bases (Tisdale *et al*., 1993). These observations are similar with those reported by Kapse (2016).

The DTPA extractable copper content in soil under different treatments varied significantly from 5.53 to 8.42 mg kg^{-1} at 60 DAS with a mean value of 7.11 mg kg^{-1}; at 90 DAS, it varied from 4.23 mg kg^{-1} to 7.32 mg kg^{-1} with mean value of 5.88 mg kg^{-1} and at harvest it varied from 2.41 to 4.45 mg kg^{-1} with mean value 3.35 mg kg^{-1}. The highest DTPA extractable copper content (8.42, 7.32 and 4.45 mg kg^{-1} at 60, 90 and 120 DAS, (at harvest stage), respectively was recorded with the treatment, T_8 which was found to be statistically significant over all other treatments except treatment T_7. The high concentration of available Cu might be due to decomposition and mineralization of organic matter due to warm and humid climate of the region (Mehta and Patel, 1967). Diwale (2012) also observed increase in available Cu with graded levels of poultry manure on lateritic soils of Konkan. These results corroborate the findings of Mhalshi (2013) and Kapse (2016) who reported an increase in the DTPA extractable Cu content due to application of fertilizers + biofertilizers and fertilizers + manure, respectively. Ghayal (2016) also reported the highest available copper (8.41 mg kg^{-1}) content due to application of poultry manure @4.5 t ha^{-1}.

In general, the higher availability of micronutrients in soil with the application of organic manures might be due to complexing properties of organic manures with the metal ions which prevents precipitation and fixation and also due to production of chelating agents

Table 2. *Effect of integrated nutrient management on available micronutrient status of soil*

Tr. No.	Treatments	Fe (mg kg^{-1})			Mn (mg kg^{-1})			Zn (mg kg^{-1})			Cu (mg kg^{-1})		
		60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest	60 DAS	90 DAS	At harvest
T_1	Absolute control	31.81	29.25	29.29	64.68	64.27	62.55	1.37	1.32	1.28	5.53	4.23	2.41
T_2	Recommended dose of fertilizer (100:50:50 N:P_2O_5:K_2O kg ha^{-1})	40.71	39.51	37.70	82.92	80.73	78.84	1.83	1.79	1.76	7.34	6.15	3.44
T_3	75 % RDN + 25% N through FYM+ P and K + *Azotobacter*	33.46	32.16	31.57	74.28	71.33	70.26	1.51	1.48	1.45	6.50	4.95	2.88
T_4	75 % RDN + 25% N through vermicompost + P and K + *Azotobacter*	34.81	34.29	32.88	75.79	73.35	71.75	1.66	1.62	1.57	6.69	5.65	2.95
T_5	75 % RDN + 25% N through poultrymanure + P and K + *Azotobacter*	36.67	36.55	36.01	79.61	76.14	74.43	1.79	1.77	1.73	6.89	6.11	3.10
T_6	50 % RDN + 50 % N through FYM+ P and K + *Azotobacter*	41.77	37.44	36.42	85.04	82.29	81.09	1.87	1.83	1.81	7.46	6.25	3.72
T_7	50 % RDN + 50 % N through vermicompost+ P and K + *Azotobacter*	42.75	41.34	39.84	86.60	84.38	81.49	1.92	1.85	1.83	8.08	6.39	3.87
T_8	50 % RDN + 50 % N through poultrymanure + P and K + *Azotobacter*	44.16	43.19	41.77	88.23	86.16	83.55	1.95	1.90	1.87	8.42	7.32	4.45
	Mean	38.27	36.72	35.43	79.64	77.33	75.49	1.74	1.70	1.66	7.11	5.88	3.35
	S.E.±	0.500	0.450	0.43	0.9000	0.776	0.707	0.010	0.011	0.008	0.162	0.155	0.052
	C.D. (P=0.05)	1.517	1.364	1.305	2.795	2.355	2.146	0.030	0.033	0.026	0.492	0.471	0.159

during the decay of organic manures which have the ability to transform solid phase of micronutrient cations into the soluble metal complexes (Madhavi *et al*., 1996).

Microbial count

The population of bacteria, fungus and actinomycetes in soil (Table 2) varied significantly amongst the treatments. The bacteria population at harvest varied from 21.50 x 10^6 to 44.00 x 10^6 cfu g^{-1} with mean value of 32.17 x 10^6 cfu g^{-1}, fungal population varied from 11.33 x 10^6 to 23.33 x 10^6 cfu g^{-1} with mean value of 17.23 10^6 cfu g^{-1} and population of actinomycetes varied from 2.33 x 10^6 to 10.00 x 10^6 cfu g^{-1} with mean value of 6.04 x 10^6 cfu g^{-1}. Maximum population of bacteria, fungi and actinomycetes were observed in treatment T_8 *i.e.,* 50 per cent RDN + 50 per cent N through poultry manure + P and K + Azotobacter, which was significantly superior over all other treatments. The minimum microbial population *i.e.,* bacteria (21.50 x 10^6 cfu g^{-1}), fungi (11.33 x 10^6 cfu g^{-1}) and actinomycetes (2.33 x 10^6 cfu g^{-1}) were observed in treatment absolute control, which was statistically inferior over rest of the treatments. Arbad and Syed Ismail (2011), Singh and Dhar (2012) also observed the maximum bacterial, fungal and actinomycetes populations with the combined application of organic and inorganic fertilizers. Increases in the microbial population due to integrated nutrient management was also reported by Salvi *et al*. (2015) who found an increasing trend of microbial population with the application of RDF + zinc sulphate ($ZnSO_4$) + borax + FYM + *Azospirillum* as compared to control treatment.

Fruit yield

It was observed that the fruit yield of ridge gourd was significantly influenced due to effect of integrated use of manures, fertilizers and biofertilizer. The lowest fruit yield (9.39 t ha^{-1}) was observed in absolute control. Among the various treatments, treatment T_8 consisting 50 per cent RDN + 50 per cent N through poultry manure + P and K + *Azotobacter* recorded significantly higher fruit yield (16.64 t ha^{-1}) as compared to all other treatments, except treatment T_7 (16.24 t ha^{-1}) consisting 50 per cent RDN + 50 per cent N through vermicompost + P and K + *Azotobacter* which was at par. This implied that the application of 50 per cent RDN + 50 per cent N through poultry manure + P and K + *Azotobacter* could be substituted by the application of 50 per cent RDN + 50 per cent N through vermicompost + P and K + *Azotobacter*. It was also observed that the treatments T_8 and T_7 produced, 11.98 and 9.29 per cent more yield of ridge gourd and were significantly superior to the treatment (T_2) consisting recommended dose of fertilizer application.

The higher yield of ridge gourd is also related to the influence of combined effect of organic, inorganic and biofertilizers which produced more number of fruits per plant and fruit yield per plant ultimately contributed to more fruit yield per hectare. The increase in the yield may be due to the poultry manure which is the best source of nitrogen. These results corroborate the findings of Arfan-ul-Haq *et al*. (2015) who obtained higher yield of bitter gourd due to application of poultry manure. Anjanappa *et al*. (2012) also reported more fruit yield per hectare resulting from production of a greater number of fruits per plant and fruit yield per plant. The increases in yield also might be due to the fact that the biofertilizers effectively enhanced the nutrient availability. Dodke *et al*. (2015) observed higher fruit yield of bitter gourd due to application of 50 per cent RDF + biofertilizers (PSB + *Azotobacter*) @250g per 10 kg seed. Similar results were also reported by Ghayal (2016) who reported the highest fruit yield due to application of 50 per cent RDF through inorganic + 50 per cent RDF through poultry manure.

Among the different treatments tried in the present investigation, it can be concluded that integrated use of 50 per cent RDN + 50 per cent N through poultry manure + P and K + *Azotobacter* @ 250 g per 10 kg seed is essential for improving the micronutrient uptake and soil micronutrient status, as well as, biological activity in soil (microbial population) thereby improving the yield of ridge gourd in lateritic soil of coastal Maharashtra.

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