DOI : 10.5958/0974-0112.2018.00016.6

Indian J. Hort. 75(1), March 2018: 92-98

Effect of integrated nutrient management on growth, yield and quality of turmeric under Nagaland conditions

S.P. Kanaujia*, Alongba Tzudir, C.S. Maiti and Sentimenla
Department of Horticulture, SASRD, Nagaland University, Medziphema 797106

ABSTRACT

A field experiment was conducted in two consecutive years during 2013 and 2014 to evaluate the effect of integrated nutrient management on growth, yield and quality of turmeric under Nagaland conditions. Eighteen treatments which include, inorganic fertilizers, organic manures and biofertilizers alone or in combination were included in the experiment. Results revealed that application of different levels of fertilizers, organic manures and *Azospirillum* either alone or in combination significantly increased growth, yield and quality of turmeric as compared to control. The maximum plant height (83.22 cm), number of leaves plant^{-1}(10.45), leaf area (905.73 cm^2), number of tillers clump^{-1} (3.22), chlorophyll content (0.97 mg g^{-1} fresh weight), number of primary fingers clump^{-1}(8.50), number of secondary fingers clump^{-1}(19.50), fresh rhizome yield (48.06 t ha^{-1}), cured rhizome yield (8.22 t ha^{-1}) and curcumin content (6.68%) were recorded in the integrated application of 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}). Maximum uptake of nitrogen (182.25 kg ha^{-1}), phosphorus (50.80 kg ha^{-1}) and potassium (283.98 kg ha^{-1}) were also observed in the same treatment combination. Thus, integrated application of 50% NPK + 50% poultry manure + *Azospirillum* was found to be the best treatment combination for obtaining higher yield with quality turmeric.

Key words: *Curcuma longa*, biofertilizers, nutrient uptake.

INTRODUCTION

Turmeric (*Curcuma longa* L.) belongs to family Zingiberaceace. It is one of the most important and ancient spice crop of India. The processed and dried underground portion called 'rhizome' forms the basis of commerce which is use in culinary, medicinal, cosmetics and textile industries. India produces turmeric about 1.19 million tonnes from an area of 0.233 million hectares with an average productivity of 5.10 tonnes ha^{-1} (Anonymous, 2). The climatic condition of the North Eastern region is quite conducive to commercial cultivation of turmeric. But inspite of the favourable agro-climatic conditions, production level is low due to lack of proper package of practices. Among various factors responsible for low production of turmeric, nutrition is of prime importance. Turmeric being a heavy feeder and exhaustive crop responds very well to nutrients application. Therefore, to reduce dependency on chemical fertilizers and conserving the natural resources in align with sustainable crop production are vital issues in present time which is only possible through integrated plant nutrient supply system. Besides fertilizers, there are several sources of plant nutrients *viz.* organic manures, biofertilizers etc. to improve soil and crop productivity. Use of organic manures in INM help in mitigating multiple nutrient deficiency. Application of organic manures to acidic soil reduces the soluble and exchangeable Al temporarily by forming complex and provides better environment for growth and development in addition to improvement in physical, chemical and biological properties of soil (Tekaasangla *et al.*, 14). Biofertilizers have also emerged promising components of nutrient supply system. Application of biofertilizers, which is environment friendly and low cost input with organic and inorganic fertilizers as part of an integrated nutrient management strategy and play significant role in plant nutrition. The role of biofertilizers is perceived as growth regulators besides biological nitrogen fixation (Yeptho *et al.*, 16). The diverse agro-climatic conditions, varied soil types and abundant rainfall under foothills condition of Nagaland enable the favourable cultivation of turmeric. Meagre no information is available on the nutrient management of turmeric in North Eastern region including Nagaland in particular, hence the present study was undertaken.

MATERIALS AND METHODS

An experiment was carried out during 2013 and 2014 at Experimental Farm, Department of Horticulture, School of Agricultural Sciences and Rural Development, Medziphema Campus, Nagaland University, Nagaland, The field lies at the altitude of 304.8 m above mean sea level with geographical location at 20º 45' 43'' N latitude and 93º 53' 04''

*Corresponding author's E-mail: sp.kanaujia@yahoo.co.in

E longitude. The pH, organic carbon, available N, P and K contents of experimental plot were 4.5, 1.5%, 240.86 kg ha^{-1}, 9.68 kg ha^{-1} and 219.43 kg ha^{-1}, respectively. The experiments were laid out in Randomized Block Design with 18 treatments consisted of T_1= Control (without application of manures/ fertilizers/ biofertilizers), T_2 = 100% RDF (80:60:60 kg NPK ha^{-1} Bendangsenla, 2), T_3 = FYM (40 t ha^{-1}), T_4 = Pig manure (30 t ha^{-1}), T_5 = Poultry manure (25 t ha^{-1}), T_6 = Vermicompost (10 t ha^{-1}), T_7 = FYM + *Azospirillum*, T_8 = Pig manure + *Azospirillum*, T_9 = Poultry manure + *Azospirillum*, T_{10} = Vermicompost + *Azospirillum*, T_{11}- 50% NPK + 50% FYM, T_{12} = 50% NPK + 50% Pig manure, T_{13} = 50% NPK+ 50% Poultry manure, T_{14} = 50% NPK + 50% vermicompost, T_{15} = 50% NPK + 50% FYM + *Azospirillum*, T_{16} = 50% NPK + 50% pig manure + *Azospirillum*, T_{17} = 50 % NPK + 50% Poultry manure + *Azospirillum*, T_{18} = 50% NPK + 50% vermicompost + *Azospirillum*) with three replications. The rhizomes were planted at 30 cm × 30 cm spacing and 2.4 m × 2.4 m plot size (64 plants) was maintained. N, P and K were given through urea, SSP and MOP, respectively. Full dose of P and K and half dose of N were applied at the time of planting and remaining half dose of N was given in two equal split doses, *i.e.* 45 and 90 days after planting. Manures *viz.,* FYM, pig manure, poultry manure and vermicompost were incorporated as per treatment in respective plot 20 days prior to planting. *Azospirillum brasilense* (biofertilizer) was inoculated to seed rhizome prior to planting @ 5 kg ha^{-1}. The doses of organic manures were applied equivalent basis. Observations on growth and yield characters were recorded at harvest (180 days after planting). Total chlorophyll content in leaf was estimated spectrophotometrically as described by Ranganna (11) and expressed in mg g^{-1} of fresh weight. Freshly harvested rhizomes were washed to make them free from inert materials and cured to obtain cured yield. The dried powder of rhizomes was used for estimation of curcumin content in turmeric (Sadasivam and Manikam, 12). The dried powder of rhizomes and leaves were used for estimation of macro and micro nutrients content in rhizomes and NPK contents in leaves. Nitrogen was estimated through micro Kjeldahl steam distillation method, phosphorus was estimated through vanadomolybdo phosphoric method, potassium was estimated through flame photometry method and Ca, Mg, S, Fe, Cu, Zn and Mn using atomic absorption spectrophotometer. The nutrient uptake by the plant was worked out by multiplying dry matter yield (kg ha^{-1}) with percent nutrient content in plant. The result thus obtained was expressed in term of kg ha^{-1}. The composite soil samples were collected before and after the experiment from the experimental plots. Soil samples were analysed for pH, organic carbon, available nitrogen, phosphorus and potassium using standard procedure (Jackson, 6). The pooled date of two consecutive years was analysed statistically following the method of Panse and Sukhatme (9).

RESULTS AND DISCUSSION

Integrated application of inorganic fertilizers, organic manures and biofertilizer alone or in combination had significant effect on growth parameters of turmeric (Table 1). Growth behaviour of all the 18 treatments varied considerably. Treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) exhibited the maximum plant height (83.22 cm), which was found significantly superior over other treatments except T_{18} (50% NPK + 50% vermicompost + *Azospirillum*). Minimum plant height (66.25 cm) was recorded in T_1 (control). The additional supply of poultry manure in INM improved physical properties of soil, availability of NPK in soil and well developed root system resulting in better absorption of nutrients and water, due to which plant height might be increased. *Azospirillum* used in INM might have helped in production of growth promoting substances leading to increased plant height. Number of leaves $plant^{-1}$ due to different treatments was found to have significant difference among different treatments. The maximum number of leaves $plant^{-1}$ (10.45) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) whereas the minimum number of leaves $plant^{-1}$ (8.50) was recorded in T_1 (control). Leaves are the main site of photosynthesis as such its effective number per plant is considered an important factor in determining the growth and productivity of crop. The increase in the number of leaves might be due to effective function of biofertilizer which provided bioactive substances having similar effects as that of growth regulators which enhance the number of leaves when applied in combination with poultry manure and inorganic fertilizers. All the treatments showed significant increase in leaf area as compared to control. Like the other growth parameters, treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded significantly higher leaf area (905.73 cm^2) as compared to other treatments. While the lowest leaf area (670.25 cm^2) was recorded in T_1 (control). The added poultry manure and *Azospirillum* in integrated nutrient management might have improved the physical, chemical and biological properties of soil, which helps in better nutrient absorption and utilization by plant and more translocated to the aerial parts for protoplasmic protein and synthesis of other compound resulting better plant growth and thereby

Table 1. Effect of INM on growth, yield and quality of turmeric (pooled data of two years).

Treatment	Plant height (cm)	No. of leaves plant^{-1}	Leaf area (cm^2)	No. of tillers plant^{-1}	Chlorophyll content (mg g^{-1})				No. of primary fingers plant^{-1}	No. of secondary fingers plant^{-1}	Fresh rhizome yield (t ha^{-1})	Cured rhizome yield (t ha^{-1})	Curcumin content (%)
					90 DAP	120 DAP	150 DAP	180 DAP					
T_1	66.25	8.50	670.25	1.61	0.85	1.02	0.70	0.46	4.50	9.83	23.14	4.24	5.70
T_2	71.60	9.78	757.70	2.56	1.11	1.32	1.01	0.73	6.67	16.33	33.85	5.90	6.28
T_3	66.63	9.17	704.40	1.89	0.91	1.14	0.77	0.57	4.67	11.17	29.35	4.94	5.78
T_4	67.53	9.28	713.36	2.11	0.94	1.14	0.82	0.58	5.67	12.17	29.94	5.22	5.82
T_5	68.20	9.39	729.47	2.28	1.01	1.21	0.92	0.59	6.00	14.17	30.60	5.44	6.23
T_6	67.36	9.33	721.47	2.11	0.96	1.17	0.88	0.62	5.83	12.67	30.29	5.24	6.14
T_7	69.26	9.56	737.12	2.33	1.05	1.25	0.96	0.63	6.33	14.17	30.65	5.51	6.19
T_8	71.31	9.56	748.97	2.33	1.07	1.26	0.99	0.65	6.33	14.83	31.05	5.56	6.20
T_9	71.60	9.72	757.22	2.50	1.09	1.29	1.00	0.67	6.33	15.33	32.24	5.81	6.22
T_{10}	71.20	9.67	749.70	2.45	1.08	1.26	0.97	0.67	6.50	15.17	31.61	5.75	6.24
T_{11}	72.08	9.83	760.12	2.61	1.21	1.43	1.10	0.75	6.83	16.50	35.05	6.12	6.34
T_{12}	72.08	9.83	772.50	2.61	1.24	1.46	1.14	0.77	7.17	16.67	37.51	6.21	6.37
T_{13}	73.64	10.06	802.93	2.72	1.29	1.52	1.19	0.87	7.50	17.17	39.39	6.81	6.45
T_{14}	72.14	9.89	777.22	2.67	1.27	1.49	1.17	0.85	7.33	17.17	38.44	6.74	6.41
T_{15}	74.78	10.11	828.01	2.78	1.30	1.52	1.20	0.90	7.83	17.50	40.27	6.89	6.46
T_{16}	78.05	10.22	848.35	2.78	1.33	1.53	1.23	0.91	8.00	18.33	40.32	7.19	6.51
T_{17}	83.22	10.45	905.73	3.22	1.45	1.62	1.34	0.97	8.50	19.50	48.06	8.22	6.68
T_{18}	81.00	10.28	861.42	2.95	1.35	1.55	1.26	0.94	8.17	18.83	44.05	7.35	6.53
$CD_{(0.05)}$	2.30	0.57	5.08	0.45	0.05	0.06	0.05	0.03	0.69	2.07	7.70	1.23	0.21

DAP = Days after planting

increase in leaf area. Number of tillers plant^{-1} was found to have significant difference among different treatments. Maximum number of tillers plant^{-1} (3.22) was obtained under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*), whereas the minimum number of plant^{-1} (1.61) was recorded in T_1 (control). This might be attributed to the release of nitrogen from poultry manure which is readily made available to the plant. Poultry manure also contains uric acid having 60% nitrogen which changes rapidly to ammoniacal form (NH_4^+) and hence efficiently utilized by plants. The possible reason might be because of certain growth promoting substances secreted by the microbial inoculants, which in turn, might have lead to better root development, better transportation of water, uptake and deposition of nutrients leading to more number of tillers. Significant difference on chlorophyll content due to various treatments was observed at all stages of plant growth. There was an appreciable increase in the chlorophyll content up to 120 days after planting, there after declined at later stages. As apparent from the table 1, that treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded the highest chlorophyll content with the value of 1.45, 1.62, 1.34 and 0.97 mg g^{-1} at 90, 120, 150 and 180 days after planting, respectively. This was followed by T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) and T_{16} (50% NPK + 50% pig manure + *Azospirillum*). The minimum chlorophyll content was recorded in T_1 (control). This might be due to the fact that nitrogen is a component of chlorophyll, which cause increase in chlorophyll content. Moreover, higher number of leaves and maximum size of leaves under this treatment may have also attributed to higher chlorophyll content. These results are in accordance with the findings of Padmapriya *et al.* (8) who reported maximum plant height, number of leaves plant^{-1} and leaf area index in turmeric was recorded with treatment combination of 50% NPK + 50% FYM + coir compost + biofertilizer. Earlier, Nanda *et al*. (7) and Yanthan *et al.* (15) reported positive effect of IPM on ginger.

It is revealed from the Table 1 that integrated application of 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}) recorded the significant variation in yield and yield attributing characters. Numbers of

primary and secondary fingers plant^{-1} were found to be significantly different among all the treatments. Maximum number of primary and secondary fingers plant^{-1} (8.50 and 19.50) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) followed by treatment (T_{18}) 50% NPK + 50% vermicompost + *Azospirillum* (8.17 and 18.83) and (T_{16}) 50% NPK + 50% pig manure + *Azospirillum*, *i.e.* 8.00 and 18.33, respectively, which were at par with each other. However, the minimum number of primary and secondary fingers plant^{-1} (4.50 and 9.83) was recorded in T_1 (control). Higher vegetative growth under integrated application of nutrients might have helped in synthesis of greater amount of food material which was later translocated into developing rhizomes resulting in increased healthy primary and secondary fingers. There was a significant difference in fresh rhizome yield among the treatments. The treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded the maximum fresh rhizome yield (48.06 t ha^{-1}) closely followed by yielded 44.05 t ha^{-1} with the treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*). The minimum yield (23.14 t ha^{-1}) was found in T_1 (control). The treatment difference between treatment 50% NPK + poultry manure + *Azospirillum* (T_{17}) and 50% NPK + 50% vermicompost + *Azospirillum* (T_{18}) was found statistically at par. The treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) recorded 41.97% higher fresh rhizome yield over T_2 (80:60:60 kg NPK ha^{-1}). This result indicates positive effects of integrating NPK with organic manures as well as biofertilizer on yield of turmeric. This might be due to favourable effect of integrated application of organic manure, biofertilizer and inorganic fertilizer in supplying all essential nutrients in balanced ratio and improved the fertility status of soil. Biofertilizer inoculant also might have played a vital role in increasing the rhizome yield. This finding has close conformity with Nanda *et al.* (7) who reported the maximum number of primary and secondary fingers, maximum fresh yield and dry yield of turmeric with integrated nutrient management of 75% NPK + 10 t FYM + micronutrients + biofertilizers. Similar results were also reported by Yeptho *et al*. (16) where they revealed that integrated application of 50% NPK + 50% poultry manure + biofertilizers recorded significantly higher yield in tomato under Nagaland condition. As was apparent from the data, the cured yield was found to be significantly different among the treatments. Maximum cured yield (8.22 t ha^{-1}) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) followed by treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with the value of 7.35 t ha^{-1}. However, the minimum cured yield (4.24 t ha^{-1}) was recorded in T_1 (control). This finding has close conformity with Senapati *et al*. (13) on turmeric.

The quality of turmeric is often determined on the basis of curcumin content in cured rhizomes. Though this character is generally considered as varietal and has high genotype × environmental influence (Anandaraj *et al.*, 1) it has also been observed that it is influenced by the nutrient management. The data pertaining to the curcumin content of rhizome has been represented in table 1. The curcumin content in rhizomes were found to be significantly different among the treatments. Maximum curcumin content (6.68%) was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) followed by treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with 6.53%, which was at par with each other. However, the minimum curcumin content (5.70%) was recorded in T_1 (control). These results are in accordance with the findings of Nanda *et al.* (7) who reported maximum content of curcumin in turmeric (5.90 %) with the integrated application of 75 % NPK + 10 t ha^{-1} FYM + micronutrient + biofertilizers. Hu *et al.* (5) reported that 1/3rd poultry manure + 2/3rd chemical fertilizer recorded the maximum curcumin content in turmeric.

It is evident from the Table 2 that various treatments showed appreciable impact on enhancing the nutrients concentration in rhizome and leaves over control. The application of 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}) recorded the maximum accumulation of N (1.54%), P (0.44%), K (2.92%), Ca (0.37%), Mg (0.15), Mn (55.17 ppm), Zn (31.83 ppm), Cu (2.75 ppm) and S (0.45 ppm) while the maximum accumulation of Fe (98.17ppm) in turmeric rhizome was recorded the maximum in T_{18} (50 % NPK + 50 % vermicompost + *Azospirillum*). The lowest accumulation of nutrients in turmeric rhizome was observed in T_1 (control). The concentration of NPK in leaves had shown significant difference among the various treatments. The highest concentration of N (1.90%), P (0.53%) and K (2.94%) in leaves was observed under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) which was followed by treatment T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with N (1.84%), P (0.52%) and K (2.84%) The lowest concentration of NPK in leaves was recorded in T_1 (control). The reason for higher content of NPK and micronutrients in rhizome might be due to better vegetative growth under this treatment, which might have attributed increased microbial activities in the root zone which decomposes organic manures and also fixed unavailable form of mineral nutrients into available form in soil which helped in better accumulation of the nutrient in the plant and the rhizome. It might also

Table 2. Effect of INM on nutrients content in rhizome and leaves (pooled data of two years).

Treatment	Nutrient content in rhizome										Nutrients content in leaves		
	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	S (ppm)	N (%)	P (%)	K (%)
T_1	1.37	0.31	2.26	0.25	0.09	68.17	32.67	22.83	1.90	0.17	1.14	0.24	2.13
T_2	1.43	0.38	2.51	0.29	0.12	84.17	37.17	25.83	2.39	0.35	1.60	0.42	2.53
T_3	1.38	0.35	2.28	0.26	0.10	81.00	33.00	23.50	2.08	0.19	1.25	0.29	2.16
T_4	1.40	0.33	2.29	0.26	0.11	74.17	33.17	23.83	2.12	0.23	1.30	0.29	2.19
T_5	1.42	0.35	2.32	0.27	0.11	76.67	34.67	24.00	2.13	0.27	1.40	0.32	2.29
T_6	1.41	0.33	2.29	0.27	0.11	79.00	33.83	23.17	2.08	0.26	1.35	0.29	2.21
T_7	1.42	0.36	2.33	0.28	0.11	81.50	35.00	24.50	2.15	0.27	1.44	0.34	2.31
T_8	1.42	0.37	2.42	0.28	0.11	82.83	36.50	24.50	2.18	0.29	1.50	0.35	2.33
T_9	1.43	0.38	2.48	0.28	0.12	83.33	37.00	25.00	2.20	0.35	1.58	0.38	2.47
T_{10}	1.43	0.38	2.46	0.28	0.12	84.00	36.83	24.67	2.18	0.32	1.55	0.36	2.43
T_{11}	1.45	0.38	2.53	0.30	0.12	84.33	37.67	26.50	2.32	0.35	1.65	0.45	2.55
T_{12}	1.46	0.38	2.58	0.30	0.13	84.83	38.00	27.17	2.40	0.36	1.65	0.46	2.58
T_{13}	1.48	0.39	2.71	0.31	0.13	85.50	39.50	28.83	2.48	0.37	1.73	0.47	2.67
T_{14}	1.48	0.39	2.64	0.30	0.13	91.17	38.50	27.50	2.43	0.37	1.73	0.48	2.66
T_{15}	1.49	0.40	2.70	0.31	0.13	93.33	40.00	29.50	2.50	0.39	1.78	0.50	2.72
T_{16}	1.50	0.41	2.75	0.32	0.14	94.00	42.17	31.00	2.63	0.39	1.80	0.51	2.73
T_{17}	1.54	0.44	2.92	0.37	0.15	97.33	55.17	31.83	2.75	0.45	1.90	0.53	2.94
T_{18}	1.51	0.41	2.89	0.33	0.14	98.17	49.50	31.50	2.75	0.41	1.84	0.52	2.84
$CD_{(0.05)}$	0.09	0.10	0.21	0.14	0.13	8.76	3.42	1.76	0.68	0.11	0.05	0.10	0.04

be due to combined application of organic manures, inorganic fertilizers and biofertilizer, which allowed normal carbohydrate utilization to take place, thus ultimately enhanced efficiency of leaves and as a result more photosynthates were translocated to fleshy or storage organ, which caused more yield and more accumulation of nutrients in turmeric rhizomes. Bendangsenla (3) reported increase in nitrogen and potassium concentration in leaf and rhizome significantly in turmeric at 80 kg N ha^{-1} under terrace condition of Nagaland. She also reported that biofertilizer also showed a positive impact in enhancing the concentration of N, P and K in leaf as well as in rhizome.

It is evident from the table 3 that integrated application of inorganic fertilizers, organic manures and biofertilizer alone or in combination significantly influenced the nutrient uptake by plants. Maximum uptake of N (182.25 kg ha^{-1}), P (50.80 kg ha^{-1}) and K (283.98 kg ha^{-1}) was recorded from treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*). This might be due to the supplementation of nutrient into the soil after mineralization that contributes to the availability of the plant nutrients resulting in better uptake by the plant. This finding are in corroboration with the findings of Rajnarayan *et al.* (10). The data in Table 3 showed there was significant increase in available N, P_2O_5 and K_2O due to various treatments over control. Among the treatment, the highest available nitrogen (297.40 ha^{-1}) was recorded in T_2 (80:60:60 kg NPK ha^{-1}), which was followed by treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*) and T_{18} (50% NPK + 50% vermicompost + *Azospirillum*) with the value of 293.77 and 287.48 kg ha^{-1}, respectively. The lowest available nitrogen (177.22 kg ha^{-1}) was found in T_1 (control). The probable cause of high available nitrogen after harvest in 100% NPK might be due to poor soil physical structure, lack of organic manures and microbial activities, thus resulting in poor utilization of N to plants at its growth stages. As such the applied N could bring about higher residual nitrogen. The highest available P_2O_5 (13.43 kg ha^{-1}) and K_2O (197.25 kg ha^{-1}) in the soil after harvest was recorded under treatment T_{17} (50% NPK + 50% poultry manure + *Azospirillum*). The lowest available P_2O_5 and K_2O were found in T_1 (control). The comparative higher level of P_2O_5 and K_2O in soil after harvest under treatment 50% NPK + 50% poultry manure + *Azospirillum* (T_{17}) might be attributed to increased microbial activities in

Table 3. Effect of INM on nutrient uptake by plant and nutrient status of soil after harvest (pooled data of two years).

Treatment	Nutrient uptake by plant			Nutrient status of soil after harvest				
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Organic carbon (%)	pH
T_1	23.51	4.76	44.29	177.22	7.32	149.08	1.41	4.47
T_2	79.33	20.64	126.14	297.40	12.22	188.90	1.93	4.65
T_3	43.19	9.88	74.67	252.88	10.04	167.99	2.28	4.55
T_4	47.01	10.50	79.46	250.78	9.74	163.78	2.17	4.55
T_5	54.55	12.59	89.53	251.15	9.81	174.00	2.27	4.55
T_6	47.46	10.28	78.06	257.27	9.81	165.80	2.21	4.55
T_7	54.94	12.97	88.69	268.49	10.90	178.85	2.40	4.58
T_8	65.31	15.36	102.22	265.61	10.52	173.76	2.33	4.57
T_9	73.97	17.65	116.40	270.70	10.72	179.89	2.34	4.62
T_{10}	67.15	15.61	105.87	268.74	10.60	176.39	2.34	4.58
T_{11}	87.87	23.85	136.19	273.87	11.39	185.49	2.55	4.63
T_{12}	97.11	26.73	152.29	272.06	10.87	182.73	2.45	4.62
T_{13}	110.02	30.12	171.50	276.86	11.28	187.99	2.53	4.63
T_{14}	105.58	29.17	163.50	275.19	11.23	184.55	2.47	4.63
T_{15}	120.18	33.76	185.23	285.03	12.43	192.95	2.66	4.67
T_{16}	132.49	37.48	202.47	283.25	12.21	186.82	2.56	4.63
T_{17}	182.25	50.80	283.98	293.77	13.83	197.25	2.60	4.71
T_{18}	152.92	43.09	237.95	287.48	12.31	190.01	2.58	4.66
$CD_{(0.05)}$	19.01	5.32	29.83	3.34	1.07	2.69	0.06	NS

NS = non-significant

the root zone, which decomposes organic manures and also fixed unavailable form of mineral nutrients into available form in soil thereby, substantiates crop requirements and also further enhances residual P_2O_5 and K_2O. The affects of integrated nutrient management on the general nutrient availability in the soil after harvest is better than those treatments without integration with the exception to application of 100% NPK, which gave the highest available N after harvest. The highest organic carbon content (2.66%) was recorded in treatment T_{15} (50% NPK + 50% FYM + *Azospirillum*). However, there was no significant difference by the various treatments on the pH after harvest. These findings are in corroboration with the findings of Choudhury *et al.* (4) on tomato.

Based on the present findings, it may be concluded that integrated application of 50% NPK + 50% poultry manure + *Azospirillum* is considered the best treatment for getting higher yield and curcumin content in turmeric under Nagaland conditions. By adopting this treatment, 50% chemical fertilizers can be reduced without any adverse effect on yield, quality and fertility of soil.

REFERENCES

1. Anandaraj, M., Prasath, D., Kandiannan, K., Zachariah, T. John, Srinivasan, V., Jha, A.K., Singh, B.K., Singh, A.K., Pandey, V.P., Singh, S.P., Shoba, N., Jana, J.C., Kumar, K. Ravindra and Maheshwari, K. Uma 2014. Genotype by environmental interaction effects on yield and cucurmin in turmeric (*Curcuma longa* L.). *Indust. Crops Prod.* **53**: 358-64.

2. Anonymous, 2014. *Indian Horticulture Database*. National Horticulture Board, Gurgaon, Haryana.

3. Bendangsenla, 2002. Effect of nitrogen and biofertilizers on growth, yield and quality of turmeric (*Curcuma longa* L.) cv. PCT-13. M.Sc. thesis, SASRD, Nagaland University, Medziphema.

4. Choudhury, M.R., Talukdar, N.C. and Saikia, A. 2005. Changes in organic carbon, available N, P_2O_5 and K_2O under integrated use of organic manure, biofertilizer and inorganic fertilizer on sustaining productivity of tomato and fertility of soil. *Res. Crops* **6**: 547-50.

5. Hu, Min Fu, Tsai ,Shwu Jene, Chang, Ia Fa and Liu, Sin Yie. 2003. Effects of combined chicken compost and chemical fertilizer application on the yield and quality of turmeric (*Curcuma longa* L.). *J. Agric. Res. China.* **52**: 334-40.

6. Jackson, M.L. 1980. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

7. Nanda, S.S., Mohapatra, S. and Mukhi, S.K. 2012. Integrated effect of organic and inorganic sources of nutrients on turmeric (*Curcuma longa* L.). *Indian J. Agron.* **57**: 191-94.

8. Padmapriya, S., Chezhiyan, N. and Sathiyamurthy, V.A. 2009. Influence of partial shade and integrated nutrient management on morphological parameters and yield of turmeric (*Curcuma longa* L.). *Asian J. Hort.* **4**: 275-80.

9. Panse, V.G. and Sukhatme, P.V. 1989. *Statistical Methods for Agricultural Workers*, ICAR Pub., New Delhi.

10. Rajnarayan, Magray, G.M., Ahmed, N. and Samanta, A. 2004. Effect of organic manures on nutrient uptake and quality of capsicum (*Capsicum annum* var. g*rossum* L.). *Hort. J.* **17**: 141-44.

11. Ranganna, S. 2000. *Manual of Analysis of Fruit and Vegetable Products.* Tata McGraw-Hill Pub. Co. Ltd., New Delhi.

12. Sadasivam, S. and Manikam, A. 1992. *Biochemical Methods for Agriculture Science*, Wiley Eastern Ltd. New Delhi.

13. Senapati, H.K., Pal, A.K. and Samant, P.K. 2005. Effect of chemical fertilizer, organic manure, lime and biofertilizer on yield of turmeric (*Curcuma longa*). *J. Agric. Sci.* **75**: 593-95.

14. Tekaasangla, Kanaujia, S.P. and Singh, P.K. 2015. Integrated nutrient management for quality production of cauliflower in acid Alfisol of Nagaland. *Karnataka J. Agric. Sci.* **258**: 244-47.

15. Yanthan, L., Singh, A.K. and Singh, V.B. 2010. Effect of INM on yield, quality and uptake of N, P and K by ginger. *Agropedol.* **20**: 74-79.

16. Yeptho, A.V., Singh, A.K., Kanaujia. S.P. and Singh, V.B. 2012. Quality production of kharif onion (*Allium cepa*) in response to biofertilizers inoculated organic manures. *Indian J. Agric. Sci.* **82**: 236-40.

Received : August, 2016; Revised : December, 2017;
Accepted : February, 2018