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Influence of integrated supply of vermicompost, biofertilizer and inorganic fertilizer on productivity and quality of rose scented geranium (*Pelargonium* species)

Sukhmal Chand*, Ankit Pandey, Mohammed Anwar and Dharni Dhar Patra
Central Institute of Medicinal and Aromatic Plants, P.O. CIMAP, Lucknow-226 015, Uttar Pradesh, India

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Application of organic source of nutrient with no or very less quantity of fossil fuel based inorganic fertilizers is becoming a popular practice for sustaining crop productivity and soil fertility. However, there is a need to elucidate the optimum combination of inorganic fertilizers, organic manure and biofertilizers for specific crop and soil condition for the most economic output. In this context, pot experiments were conducted with nine different treatment combinations of organic manure (vermicompost), biofertilizer (CIM grow^{R}, a plant growth promoting rhizobacteria (PGPR) and inorganic fertilizers (NPK) to elucidate their influence on herb, oil yield, nutrient uptake and quality of oil in rose scented geranium (*Pelargonium graveolens* L'Herit.). Results revealed that combined application of vermicompost, CIM Grow® and inorganic fertilizer produced higher herbage and oil yield of geranium as compared to control and sole application of either organic or inorganic fertilizer. Similarly, some of the principal constituents like linalool, isomenthone, citronellol, geraniol and citronellyl formate were also found maximum with conjugated supply of organic (vermicompost), biofertilizers and inorganic fertilizer. Maximum nitrogen and phosphorus uptake were recorded under combined application of 50% NPK + vermicompost @ 5 t/ha. Whereas, highest potassium uptake was recorded with sole application of 100% NPK (T_2). The extent of increase in available N, P and K were about 4.0, 4.4 and 3.9-folds in post harvest soil under integrated supply of nutrient, over their respective control. Availability of copper, zinc and manganese were also enhanced by integrated supply of organic, inorganic and biofertilizer. Iron content, however, was either at par or reduced with combined application of vermicompost and inorganic fertilizer as compared to sole application of CIM grow or vermicompost.

Keywords: Geranium, *Pelargonium graveolens,* Biofertilizer, Essential oil, Vermicompost.

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Introduction

In the present agricultural scenario, where cultivable land area is shrinking, the requirement of food and other agricultural commodities is increasing due to increase in human and domestic animal population. There is virtually no scope for horizontal expansion of area under cultivation and it necessitates adopting strategies to enhance agricultural productivity per unit area per unit time[14]. Use of fertilizers is one of the major inputs in augmenting agricultural productivity. The major concerns of this ongoing practice are the development of multi nutrient deficiency and fertilizer related environmental pollution, leading to, loss of soil health and unsustainable crop yield. In response to this concern, there is a need of concerted effort to use green manuring, legumes and organic manure to produce the same amount of food, fiber, fuel and other crops with less fossil fuel based inorganic fertilizers. Similarly, increased prices and limited availability of fertilizer entail search of organic source and biofertilizers as an alternative to supplement the nutrient requirement of different crops. Fertilizer with available quantity of manure is now commonly used to maintain optimum soil fertility and maintain desired level of yield[1,2]. The genus *Pelargonium* belonging to Geraniaceae family is an essential oil bearing plant and is rich in rose alcohol and 1-citronellol. The quantity of essential oil depends on the relative composition of the oil constituents, which is influenced by agro-climatic condition and nutrient management to the crop (s)[3]. No research has been reported on the influence of organic manure and combined application of manure and inorganic fertilizer vis-à-vis biofertilizer on yield and quality of

*Correspondent author, E-mail: sukhmal2002@yahoo.co.in
Phone: +91 522 2716008; Fax: +91 522 2342666

geranium oil. Keeping this in view, an investigation was carried out to study the effect of integrated supply of nutrients through organic manure, biofertilizer CIM grow^R and inorganic sources of macronutrients on growth, herb and quality of essential oil of geranium *vis-à-vis* the soil health following the crop harvest.

Materials and Methods

A pot experiment was conducted during 2006-2007 and 2007-2008 at the Central Institute of Medicinal and Aromatic Plants (CIMAP) research farm Lucknow, India. Eight kg of air dried and sieved (<2 mm) soil was filled in 20 cm diam. earthen pot of nine liter capacity. Physico-chemical characteristics of the soil, taken up to a depth of 15 cm in the research farm of the Institute and used in this experiment, are presented in Table 1. Nine combinations consisting of vermicompost, nitrogen, phosphorus, potassium and CIM-grow® (a patented biofertilizer developed from the selective strain of *Bacillus subtilis*), viz. control (T_0), 50% NPK (75:30:30 kg/ha) of recommended dose (T_1), 100% NPK @ 150:60:60 kg/ha as recommended dose (T_2), vermicompost @ 2.5 g/kg soil (T_3), vermicompost @ 5 g/kg soil (T_4), 0.g kg/ha CIM grow + 24.5 g/kg vermicompost (T_5), 1.0 g/kg CIM grow + 49.0 g/kg vermicompost (T_6), 25% NPK (37.5:15:15 kg/ha) of recommended dose + vermicompost @ 5 g/kg soil (T_7) and 50% NPK of recommended dose + vermicompost @ 5 g/kg soil (T_8) were laid out in a completely randomized design (CRD) with three replications. Chemical composition of the vermicompost used in this study is given in Table 2. Fifty day old uniform rooted cuttings of rose scented geranium (*Pelargonium graveolens* cv. 'Bourbon') raised in poly bags were transplanted (one plant in each pot) during the last week of January 2006 and irrigated immediately after planting. Nitrogen, phosphorus and potassium as per the treatment combination were applied in the form of urea, single superphosphate and muriate of potash, respectively. Fifty percent of nitrogen, full dose of phosphorus and potassium were applied as basal dose and remaining quantity of nitrogen applied after 45 days of planting. Crop was harvested in last week of April and biomass and oil yield were recorded. A composite fresh biomass sample (200 g) each from three replications was used to estimate the essential oil concentration employing Clevenger[4] apparatus.

The chemical composition of essential oil for quality evaluation was performed on Perkin Elmer GC model Auto XL with FID and capillary column PE (50 m×0.32×0.25 m) using a temperature program from 100°C to 280°C @ 3% and H_2 carrierat 10 psi inlet pressure. The injector and detector temperatures of 220°C and 290°C, respectively were applied in the analyses. Turbochrom software was used for peak percentage calculation. Identification of components was based on GC-MS analysis on Perkin Elmer Turbo Mass system using identical column and condition with He as a carrier gas at 10 psi and comparison of mass spectra with NIST and Wiley libraries.

Soil samples were collected from each pot and shade dried and sieved (<2 mm). Samples were analysed for pH, EC, organic carbon, mineralizable N, available P and K by standard procedures as described by Page *et al*[5]. For mineral element analysis, the plant samples were washed with distilled water, oven dried (65°C), ground and digested in H_2SO_4 and H_2O_2. Nitrogen, phosphorus and potassium were determined by standard procedures as per Jackson[6]. Iron, manganese and zinc were estimated by Atomic Absorption Spectrometer (UNICAM 969) following Lindsay and Norvell[7] method. The soil samples from each pot were harvested after harvest of geranium. The soils were shade dried and analysed for different parameters following standard procedures of Jackson[6]. Micronutrients were analysed by Atomic

Table 1—Chemical characteristics of the soil prior to experimentation

Property	Value
pH	8.12
EC (dSm^{-1})	0.11
OC (%)	0.28
N (ppm)	38.0
P (ppm)	22.0
K (ppm)	126.0
Fe (ppm)	3.70
Mn (ppm)	1.95
Zn (ppm)	1.28
Cu (ppm)	0.65

Table 2—Chemical composition of vermicompost used for the experiment

Property	Value
N (%)	1.58
P (%)	0.50
K (%)	1.18
Fe (ppm)	4821
Mn (ppm)	179
Zn (ppm)	65
Cu (ppm)	82

Absorption Spectrometer (UNICAM 969) after extraction with DTPA[7]. Data on the observations were subjected to analysis of variance (ANOVA) and least significant differences (LSD) were calculated using F methods[8]. As the trends of the results during 2006-2007 and 2007-2008 were similar, the data for two years were pooled for statistical calculation.

Results and Discussion

Herb and oil yield

There was a significant difference of treatments on herb and oil yield of geranium (*Pelargonium graveolens*). Maximum herb and oil yield were recorded in T_8 (50% NPK + vermicompost 2.5 g/kg soil) followed by T_2, T_7, T_1 and T_6 (Table 3). Herb yield increased by 232, 222, 151 and 127% with T_8, T_2, T_7 and T_1, respectively, over control. Oil yield also followed the same pattern. Application of 100% NPK (T_2) increased the herb yield by 28.2% over its (NPK) 50% dose. Similarly, higher dose of sole application of vermicompost (5 g/kg soil) increased the herb yield by 23.5% as compared to that with 2.5 g/kg level. Change in the magnitude of herb yield was more with sole application of inorganic fertilizer than organic manure. However, under combined application of organic and inorganic fertilizer, herb yield increased by 158 and 232% with T_7 and T_8, respectively, over controls. Similarly, application of CIM-grow^R at 1% and 2% level with carrier vermicompost increased the herb yield by 99 and 144%, respectively over the control (no manure or fertilizer). Improvement in herb yield was attributed to sustained availability of macro and micronutrients for longer period of crop growth. Similar observations were made by Chand *et al*[9] and Anil Kumar *et al*[10] in mint (*Mentha arvensis* Linn.) and *Piper longum* Linn., respectively. Further, it was observed that combination of 50% NPK + vermicompost 2.5 g/kg (T_8) was superior to 25% NPK + vermicompost 5 g/kg (T_7) with respect to herb yield of geranium crop.

Like herb yield, oil yield was also recorded to be highest in T_8 (50% NPK + vermicompost 2.5 g/ kg soil) followed by T_2, T_7 and T_1. Oil yield recorded in T_1 and T_7 were at par. Under integrated supply of nutrient, oil yield increased by about 122, 155 and 233% times with T_6, T_7 and T_8, respectively, over control. Sole application of vermicompost @ 5 g/kg soil, increased the oil yield by 28.5% over its application at 2.5 g/kg. Similarly, full dose of NPK increased the oil yield by about 26% as compared its 50% application. Biofertilizer CIM-grow® was found very effective with respect to fresh herb and dry matter yield as well as oil yield of geranium, when applied with vermicompost as the carrier at both the levels.

Table 3—Effect of integrated nutrient management on geranium herb, oil and dry matter production

Treatments	Fresh herb yield (g/pot)	Oil yield (ml/pot)	Dry matter (g/pot)
T_0	59.77	0.09	23.40
T_1	150.30	0.23	42.81
T_2	192.76	0.29	55.70
T_3	95.60	0.14	43.57
T_4	118.11	0.18	49.28
T_5	115.20	0.18	51.20
T_6	146.03	0.22	53.16
T_7	154.27	0.23	47.56
T_8	198.53	0.30	59.36
CD at 5%	38.18	0.05	15.16

T_0- control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ha as recommended dose; T_3- Vermicompost @ 2.5 g/kg soil; T_4- Vermicompost @ 5 g/kg soil; T_5- 0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/kg soil; T_8- 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil.

Dry matter production

All the treatments significantly influenced the dry matter production of geranium over control (Table 3). Maximum dry yield was recorded in T8 (50% NPK + vermicompost 2.5 g/kg) and it was about 2.5 times higher than in control. Dry matter yield further increased under combined application of nutrients and biofertilizer, as compared to control and other treatments. The extent of increase were 119, 127, 103 and 154% with T_5, T_6, T_7 and T_8, respectively, over control. Dry matter yield increased by 30% with the application of the recommended (full dose) doses of NPK as compared to that with 50% of the recommended NPK. Similarly, sole application of vermicompost @ 5 g/kg soil enhanced the dry matter production by about 13% over its 50% dose (2.5 g/kg soil). Dry matter yield with combined application of organic manure and inorganic fertilizer was observed to be less than that with full dose of NPK by more than 50% of NPK application.

Oil quality

Quality of essential oil depends on the relative composition of different ingredients. Data presented in Table 4 indicates that the content of principal ingredients was significantly influenced by

Table 4—Effect of integrated nutrient management on linalool, isomenthone, citronellol, geraniol and citronellyl formate content in geranium oil

Treatments	Constituents (%)				
	Linalool	Isomenthone	Citronellol	Geraniol	Citronellyl formate
T_0	0.30	5.29	15.94	1.45	3.81
T_1	0.60	5.97	28.39	1.83	5.62
T_2	0.50	6.72	31.68	3.32	7.84
T_3	0.48	6.48	31.55	2.33	6.40
T_4	0.33	4.60	33.51	2.43	5.27
T_5	0.36	3.60	29.36	1.90	5.35
T_6	0.45	4.05	37.47	2.39	5.82
T_7	0.65	8.57	24.77	3.22	5.43
T_8	0.75	5.80	33.58	4.03	8.94
CD at 5%	0.32	0.77	0.76	0.30	0.10

T_0- control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ ha as recommended dose; T_3- Vermicompost @ 2.5 g/kg soil; T_4- Vermicompost @ 5 g/kg soil; T_5- 0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/ kg soil; T_8- 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil.

the different treatment combinations. However, no significant trend was observed with respect to their content. Linalool content decreased with increase in the inorganic and organic source of nutrient from their lower to higher level of their application. However, combined application of these two sources (T_7, T_8) resulted in the increase in linalool content by 220 and 250% over the control (no manure or fertilizer). Isomenthone also followed the same trend. Concentration of isomenthone ranged from 3.6 to 8.6% under different treatments. Citronellol increased by 55 and 110% with T_7 and T_8 (integrated supply of organic and inorganic nutrients), respectively over control. Increase in NPK level (from 50 to 100%) did not have any significant influence on citronellol content in the oil. However, reverse trend was observed with vermicompost application. Unlike isomenthone and citronellol, geraniol content increased as organic (T_4) and inorganic (T_2) sources of nutrient increased from 50 to 100% level. Geraniol content in the oil varied ranges from 122 to 403% under different treatments. There was a significant increase in geraniol content with combined application of nutrients through organic and inorganic sources; the extent of increase was 2.2 and 3.3 times, respectively over the control. However, it marginally reduced with full supply of vermicompost over its 50% dose. Citronellyl-formate content also followed the same pattern.

Nutrient concentration in plant

Nitrogen, phosphorus potassium

Results (Table 5) indicated that nitrogen, phosphorus and potassium content were significantly affected by the treatment combinations. Maximum N, P and K were registered in T_8, T_8 and T_2, respectively. Nitrogen content increased by 450% in T_8 over control. While with sole application of full dose (100%) of NPK (T_2), N content increased by 120% over its 50% dose (T_1). Similarly, application of vermicompost 5 g/kg (T_4) increased the nitrogen content by about 40% as compared to that with 2.5 g/kg application (T_3). Comparing with full dose of inorganic fertilizer (T_2), N content increased by 18, 27, 45, and 63% with T_5, T_6, T_7 and T_8, respectively, under integrated supply of nutrients. Phosphorus and potassium content varied within the range of 0.12-0.38 and 0.89-2.28%, respectively. Phosphorus and potassium increased by 316 and 256% with T_8 and T_2, respectively as compared to the respective

Table 5—Effect of integrated nutrient management on major nutrient concentration (N, P and K) in geranium

Treatments	Nutrient concentration (%)		
	Nitrogen	Phosphorus	Potassium
T_0	0.66	0.12	0.89
T_1	0.83	0.21	1.90
T_2	1.83	0.29	2.28
T_3	1.66	0.16	1.20
T_4	2.33	0.20	1.78
T_5	2.16	0.16	1.35
T_6	2.33	0.25	2.05
T_7	2.66	0.24	1.59
T_8	2.99	0.38	1.92
CD at 5%	0.32	0.10	0.35

T_0; control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ha as recommended dose; T_3- Vermicompost @ 2.5 g/kg soil; T_4-Vermicompost @ 5 g/kg soil; T_5- 0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/kg soil; T_8- 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil.

control. Application of full dose of inorganic fertilizer (T_2) and organic manure (T_4) increased the P and K content by about 38, 25 and 20, 48%, respectively over their 50% dose. Similar results were observed by Jayasari *et al*[11] and Patel *et al*[12]. Phosphorus content of the plant in T_3, T_5 and T_6, T_7 were at par. Combined application of organic and inorganic fertilizer (T_7, T_8) increased the phosphorus and potassium content by about 200, 316 and 178, 216% over their respective control. Similar trends in major nutrient content under integrated nutrient management were reported by Patra *et al* [1] and Anwar *et al*[13] in mint and French basil, respectively.

Micronutrient iron, copper, manganese and zinc concentration

Micronutrients, viz. manganese, copper, zinc content was significantly affected by all the treatments (Table 6). Manganese, copper and zinc content in the plant varied from 68-114, 27.2- 42 and 12-29.4 mg/kg, respectively. Maximum Mn, Cu and Zn were recorded in T_2, T_6 and T_4 and the extent of increase were 67, 96 and 145%, respectively over control. Manganese content observed in T_3, T_7 and T_5, T_8 were at par. It increased by 24% with application of full dose of NPK (100%) over its 50% application. The corresponding increase in Mn was about 18% with application of higher rate of vermicompost over its lower level. Under combined supply of organic and inorganic nutrients (T_7, T_8), Mn content increased by 6.0 and 25%, respectively over control. Copper and zinc content increased by 20 and 30% with full application of vermicompost at 5 g/kg soil. Likewise, Cu and Zn content in crop increased by 27 and 29% with application of vermicompost at 5 g/kg soil and its 50% application, respectively. Under combined application of nutrients (T_5, T_6, T_7 and T_8) maximum Cu was observed in T_6 followed by T_8, T_7 and T_5. Like Cu, the content of Zn was in the order $T_6<T_8<T_5<T_7$. Comparing to control, copper increased by 32, 96, 27 and 64% under T_5, T_6, T_7 and T_8, respectively.

Nutrient uptake

Nitrogen, phosphorus and potassium

Data revealed that nitrogen, phosphorus and potassium uptake was significantly affected by different treatments (Table 7). Maximum nitrogen and phosphorus uptake was registered under integrated supply of nutrients (T_8). Whereas highest potassium uptake was recorded with sole application of 100% NPK (T_2). It has been observed that magnitude of nitrogen and potassium uptake was higher as compared to phosphorus. Nitrogen, phosphorus and potassium uptake varied within 0.29-1.45, 0.06 and 0.39-1.18 g/pot, respectively. Nitrogen uptake in plant under (vermicompost 5 g/kg soil) and T2 (100% NPK) were 19.5 and 159% over its 50% application, respectively. The magnitude of increase in N uptake was more with sole application of inorganic fertilizer as compared to application of organic sources. Similar results were made by Chand *et al*[14,15] in mint, an essential oil bearing plant. Nitrogen uptake observed in T_3 and T_5

Table 6—Effect of integrated nutrient management on concentration of Fe, Mn, Cu and Zn in geranium

Treatments	Nutrient concentration (ppm)			
	Iron	Manganese	Copper	Zinc
T_0	840	68.0	21.4	12.0
T_1	1008	92.0	34.0	16.0
T_2	1081	114.0	40.9	20.8
T_3	1001	72.0	29.0	23.0
T_4	1204	85.0	37.0	29.4
T_5	932	81.0	28.4	20.0
T_6	1183	90.0	42.0	27.5
T_7	910	71.9	27.4	19.2
T_8	1337	85.4	35.2	26.4
CD at 5%	-	24.16	6.02	9.27

T_0- control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ha as recommended dose; T_3- Vermicompost @ 2.5 g/kg soil; T_4- Vermicompost @ 5 g/kg soil; T_5- 0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/kg soil; T_8- 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil.

Table 7—Effect of integrated nutrient management on nitrogen, phosphorus potassium uptake in geranium

Treatments	Uptake (g pot^{-1})		
	Nitrogen	Phosphorus	Potassium
T_0	0.29	0.06	0.39
T_1	0.39	0.12	0.83
T_2	1.01	0.17	1.18
T_3	0.82	0.08	0.56
T_4	0.98	0.09	0.69
T_5	1.16	0.08	1.12
T_6	1.49	0.10	1.39
T_7	1.27	0.12	0.76
T_8	1.45	0.20	0.91
CD at 5%	0.20	0.08	0.33

T_0- control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ha as recommended dose; T_3 - Vermicompost @ 2.5 g/kg soil; T_4 - Vermicompost @ 5 g/kg soil; T_5-0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/kg soil; T_8 - 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil.

were at par. Comparing with full dose of inorganic fertilizer (100% NPK), nitrogen uptake under T_6, T_7 and T_8 increased by 37.6, 25.0 and 44%, respectively. Phosphorus uptake also followed the same trend. Potassium uptake was found to be highest with full application of organic NPK. Vermicompot applied @ 5 g kg^{-1} increased the potassium uptake 42% over its 50% application. Similar pattern of potassium uptake were observed with application of inorganic fertilizer. Both N and K uptake were marginally higher in CIM-grow^R treated plant as compared to control and other treatments with single application of organic and inorganic nutrients. (at their 50% dose).

Manganese, copper and zinc

Data (Table 8) indicated that highest uptake of copper, manganese and zinc were recorded in T_4, T_6 and T_8, respectively and the extent of increase was about 105, 84 and 163% with T_4, T_6 and T_8, respectively, over control. Whereas iron uptake was not significantly affected by treatment combinations. In general Cu, Mn and Zn uptake were observed higher under integrated supply of nutrients over their respective control. It may be attributed to sustained availability of these nutrients under integrated supply of the nutrients. It corroborates the findings of Chand[16] in mint (*Mentha arvensis* Linn.) and Puttanna *et al*[17] in *Pogostemon cablin* Benth. Copper, manganese and zinc uptake varied from 1.20-3.02, 2.91-4.96 and 0.72-1.90 mg/kg, respectively. Copper uptake under full dose of NPK (100%), increased by 78% as compared to its 50% application. The corresponding increase in zinc was about 50 per cent. With application of vermicompost @ 5 g/kg, Cu, Mn and Zn uptake increased by about 123, 32 and 22% over their application at 2.5 g/kg soil, respectively.

Nutrient status in postharvest soil

Soil samples were analyzed after the harvest of crop to visualize the amount of major and micro nutrients remaining in the soil. Results (Table 9) indicated that macro and micro nutrients (N, P, K Fe, Cu, Mn and Zn) were significantly affected by treatments. Major nutrients, viz. nitrogen, phosphorus and potassium were observed to be maximum under combined application of organic and inorganic nutrients (T_8). The extent of increase in N, P and K were about 4.0, 4.37 and 3.9-folds, respectively, over the control. There was a significant increase in available N, P, K, under full application of NPK 100% (T_2) and full vermicompost (T_4) over their 50% application. Higher availability under combined application of nutrients may be due to improved

Table 8—Effect of integrated nutrient management on concentration of Fe, Mn, Cu and Zn in geranium

Treatments	Uptake (ppm)			
	Iron	Copper	Manganese	Zinc
T_0	26.78	1.20	2.91	0.72
T_1	50.44	1.50	3.90	0.98
T_2	60.98	2.67	4.12	1.47
T_3	40.11	1.35	3.45	1.05
T_4	59.35	3.02	4.56	1.28
T_5	45.02	1.67	3.06	0.83
T_6	54.96	3.01	5.37	1.63
T_7	43.11	1.47	3.42	0.94
T_8	67.22	2.95	4.96	1.90
CD at 5%	-	0.64	1.97	0.50

T_0- control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ha as recommended dose; T_3- Vermicompost @ 2.5 g/kg soil; T_4- Vermicompost @ 5 g/kg soil; T_5- 0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/kg soil; T_8- 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil

Table 9—Effect of integrated nutrient management on macro nutrient in post harvest soil of geranium

Treatments	Nutrient content (ppm)						
	Nitrogen	Phosphorus	Potassium	Iron	Copper	Manganese	Zinc
T_0	16.60	10.80	24.5	1.18	0.90	0.72	0.25
T_1	24.50	13.50	32.6	4.90	1.20	0.94	0.52
T_2	34.80	25.60	53.4	7.20	1.58	2.03	0.69
T_3	26.5	27.0	58.0	3.70	1.90	1.09	0.70
T_4	32.65	38.0	71.0	8.60	2.50	1.87	0.92
T_5	26.50	32.0	66.0	9.20	1.80	1.67	0.81
T_6	42.80	33.5	79.0	12.56	2.75	2.80	0.94
T_7	58.0	36.50	83.0	6.70	1.79	1.86	0.74
T_8	67.0	47.30	97.0	9.50	2.25	2.90	1.01
CD at 5%	4.3	0.32	1.05	0.25	0.39	0.44	0.04

T_0- control; T_1- 50% NPK of recommended dose; T_2- 100% NPK @ 150: 60:60 kg/ha as recommended dose; T_3- Vermicompost @ 2.5 g/kg soil; T_4- Vermicompost @ 5 g/kg soil; T_5- 0.5 g CIM grow + 24.5g vermicompost; T_6- CIM grow + 49.0g vermicompost; T_7- 25% NPK of recommended dose + vermicompost @ 5 g/kg soil; T_8- 50% NPK of recommended dose + vermicompost @ 2.5 g/kg soil.

physical, chemical and biological properties on account of organic matter addition, as observed by Patra *et al*[1], Anwar *et al*[13] and Shivanna *et al*[18]. Nitrogen, phosphorus and potassium content varied within large range of 16.6-67.0, 10.8-47.30 and 24.5-97.0 ppm, respectively. Comparing to 100% NPK application, nitrogen content increased by 23, 66 and 92% with T_6, T_7 and T_8, respectively. Similar trend was observed with respect to available potassium in soil.

Like NPK, availability of iron, copper, manganese and zinc were also significantly affected by treatments in post harvest soil. Under integrated supply of nutrients (T_7 and T_8) iron content reduced and phosphorus availability increased. It may be attributed to antagonistic effect of iron and phosphorus. Maximum iron content was recorded in T_6 followed by T_8, T_5 and T_4. Full dose of inorganic (T_2) fertilizer and organic manure (T_4) increased the iron availability by about 1.47 and 2.32-fold as compared to its 50% application. Iron content recorded in T_5 and T_8 were at par. Copper content increased by 14, 74, 13 and 42% with T_5, T_6 T_7 and T_8, respectively, over full dose of inorganic (T_2) fertilizer. Maximum manganese content was recorded under combined application of nutrients (T_8) and it increased by about 4-folds over control. Manganese content observed with T_4 and T_7 was at par manganese availability with full doses of inorganic fertilizers was about 2-fold higher than its 50% application. The corresponding increase of Mn was 72% with application of vermicompost with its full dose. Zinc content was also observed to be maximum in T_8 and it was more than four times higher over that in control.

Conclusion

Application of vermicompost with inorganic fertilizer significantly increased herb and oil yield of geranium as compared to their sole application biofertilizer (CIM-grow®) further, augmented the beneficial effect of combined application of manure and fertilizer. Chemical constituents of geranium oil like linalool, isomenthone, citronellol, geraniol and citronellyl formate were also recorded maximum under integrated supply of nutrients. Similarly, nutrient (macro and micro) status of post harvest soil significantly improved as a result of combined application of organic and inorganic fertilizer. Looking in to the problem of overmining of the soil due to intensive copping of high yielding varieties, the most appropriate proposition will be adopting integrated nutrient management comprising inorganic fertilizer and manure vis-à-vis biofertilizer, with application of fossil fuel based inorganic fertilizer as minimum as possible to reduce the cost of cultivation, maintain soil health and alleviate the inorganic fertilizer mediated environmental problem. Novelty of the work is that it authenticates the fact that creating moderate stress with respect to nutrient management status of soil and sustained availability of the nutrients through integrated nutrient management enhanced the essential oil content and quality of the oil. Very little work has been done on this subject. Detailed field studies are needed to elucidate the positive effect of integrated nutrient management on geranium, a very high value essential oil bearing crop.

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