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Microbial dynamics and physico-chemical properties of soil in the rhizosphere of chrysanthemum (*Dendranthema grandiflora*) as influenced by integrated nutrient management

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ABSTRACT

Soil physico-chemical properties and microbial population were assessed to get the knowledge of the effect of integrated nutrient management in chrysanthemum (*Dendranthema grandiflora* Tzvelev) flower production system in the mid-hill conditions of Himachal Pradesh. Plants of chrysanthemum cultivars Purnima and Ajay were grown in open field condition with 17 different nutritional regimes during 2009 and 2010. The experiment was laid out in factorial randomized block design, replicated thrice. Findings revealed highest amount of available soil N (373.04 kg/ha), K (283.18 kg/ha) and organic carbon content (1.260 %) in the plots receiving 30 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers. Maximum available soil P (39.86 kg/ha) was recorded with the application of 22.5 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers. No significant change was observed in soil pH and electrical conductivity due to different treatments. *Azotobacter* population (10.50 × 10^6 cfu/g of soil) and phosphorus solubilizing bacterial count (12.83 × 10^6 cfu/g of soil) were maximum with the application of 15 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers. However, maximum arbuscular mycorrhizal fungi spore count (196.58 per 20 g of soil) was observed with the application of vermicompost (1 kg/m^2) + biofertilizers. The overall multifaceted effects of different integrated nutrient management treatments that facilitated beneficial soil conditions in the present study also reflected the significant increase in the flower yields of both Purnima and Ajay even over the ad-hoc recommended treatment (30 g/m^2 each of NPK).

Key words: *Azotobacter*, Chrysanthemum, *Dendranthema grandiflora,* NPK, Phosphorous solubilizing bacteria, Vermicompost

Chrysanthemum (*Dendranthema grandiflora* Tzvelev) is an important ornamental plant in the global floriculture industry both as cut flower and as pot plant. Increased flower production, quality of flowers and perfection in plant forms are the important objectives to be reckoned in commercial flower production. Though the quality of cut flowers is primarily a varietal trait, it is greatly influenced by climatic, geographical and nutritional factors among which nutrition plays a major role. Boodley (1975) considered quality to be a function of nutrient level. Toxic level of nutrients adversely affects the quality of ornamental plants.

Soil is a precious natural resource which is being degraded due to the adverse effects of indiscriminate use of chemical fertilizers. In the present scenario of eco-conciousness, it is therefore imperative to make the harmonious use of these resources on sustainable basis which can be accomplished by the conjoint use of organic and inorganic fertilizers in a balanced proportion.

Microbial inoculants or bio-fertilizers are important components of organic farming. Although, biofertilizers are not a substitute for chemical fertilizers but they may be useful in increasing the yield when supplemented with organic manure and inorganic fertilizers in balanced proportion (Chaudhary *et al*. 2004). They help to nourish the crops by making all the nutrients in available form and in adequate proportions as required by the plants. They help to fix atmospheric nitrogen, solubilize and mobilize phosphorus, translocate minor elements like; Zn, Cu, Fe etc. to the plants, produce plant growth promoting hormones, vitamins,

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aminoacids as well as control soil borne fungal diseases (Wani 1990). These activities improve the soil health and increase crop production.

Along with the mineral nutrition, an appropriate proportion of organic manure is required to maintain the ideal C: N ratio, water holding capacity and microbial population of the soil profile. Vermicompost is found superior over farmyard manure in respect of available plant nutrients (Suhane 2007). Commercial availability of vermicompost and biofertilizer inoculants paved the way for their use in commercial flower production. Standardization for the replacement of inorganic fertilizers through various organic sources, without affecting the yield and quality of chrysanthemum is the thrust need. Therefore, the present studies were planned to ascertain the effect of conjoint use of chemical fertilizers, vermicompost and biofertilizers on soil health and flower production of chrysanthemum.

MATERIALS AND METHODS

The experiment was carried out at the experimental farm of the Department of Floriculture and Landscaping, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the year 2009 and 2010. The experimental site is located at an elevation of 1276 m above mean sea level lying between 32^o 51'0" North latitude and 77^{o}11'30" East longitude. The climate is sub-temperate with annual rainfall ranges between 800-1300 mm.

The studies were conducted on two commercial cultivars of chrysanthemum namely; Purnima and Ajay. Planting of rooted cuttings of both the cultivars, was done on 30th June in both the years. The rooted cuttings were planted in lines at a spacing of 30 cm × 30 cm. One week before planting, well rotten farmyard manure (FYM) (5 kg/m^2) was applied uniformly. Along with this, vermicompost (1 kg/m^2), full doses of phosphorous and potassium and half dose of nitrogen were incorporated into the beds according to the treatment requirements. The remaining half dose of nitrogen was applied after 30 days of planting. Nitrogen, phosphorous and potassium were applied through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Vermicompost used in the experiment contained 2.12% N, 0.93% P_2O_5 and 1.11% K_2O.

Biofertilizers, viz. *Azotobacter chroococcum*, phosphorous solubilizing micro-organisms (*Bacillus polymyxa* + *Pseudomonas striata*) and vesicular arbuscular mycorrhiza (*Glomus mosseae* + *G. fasiculatum*) were procured from the Division of Microbiology, Indian Agricultural Research Institute, New Delhi. *Azotobacter* and phosphorous solubilizing micro-organism were applied by dipping the roots of the cuttings into a slurry of 200 g of the inocula dissolved in one litre of 10 % sugar solution at the time of planting, whereas VAM (2 g/plant) was incorporated in the planting pit.

A randomized block design in factorial concept was used for this experiment. Two cultivars Purnima and Ajay were combined with 17 nutritional treatments using three replicates. Twelve plants were planted per replication per treatment (102 plots). The nutritional treatments comprised of control (no fertilizer application) (T_1), 30 g/m^2 each of NPK (Ad-hoc recommendation) (T_2), 45 g/m^2 each of NPK (T_3), 22.5 g/m^2 each of NPK (T_4), 15 g/m^2 each of NPK (T_5), 30 g/m^2 each of NPK + vermicompost (T_6), 30 g/m^2 each of NPK + biofertilizers (T_7), 30 g/m^2 each of NPK + vermicompost + biofertilizers (T_8), 22.5 g/m^2 each of NPK + vermicompost (T_9), 22.5 g/m^2 each of NPK + biofertilizers (T_{10}), 22.5 g/m^2 each of NPK + vermicompost + biofertilizers (T_{11}), 15 g/m^2 each of NPK + vermicompost (T_{12}), 15 g/m^2 each of NPK + biofertilizers (T_{13}), 15 g/m^2 each of NPK + vermicompost + biofertilizers (T_{14}), vermicompost (T_{15}), biofertilizers (T_{16}), vermicompost + biofertilizers (T_{17}). A basic study of the soil of the experimental field was conducted before starting the experiment. The pH of the experimental site was 6.89 with 0.35 dS/m electrical conductivity and 1.28% organic carbon and available N, P and K were 324.80, 31.60, 230.70 kg/ha respectively. The experimental soil also contained an initial viable microbial population of *Azotobacter* spp (2 × 10^6 cfu/g of soil), phosphorous solubilizing bacteria (3 × 10^6 cfu/g of soil), 32 spores of arbuscular mycorrhizal fungi per 20 gram of soil.

The composite samples of the growing medium were collected following the standard procedure. The samples were collected before treatment application and after the termination of the experiment in both the years. These samples were air-dried in shade, ground with pestle and mortar, passed through 2 mm sieve and analyzed for important physico-chemical and biological properties using standard methods.

Soil pH and electrical conductivity (EC) were analyzed in soil, water ratio of 1:2 as described by Jackson (1973). Organic carbon content of the soil sample was determined by chromic acid titration method of Walkley and Black (1934), available nitrogen by alkaline potassium permanganate method (Subbiah and Asija 1956), available phosphorous by development of color chlorostanous reduced molybdophos-phoric acid method (Olsen *et al*. 1954), and available potassium was extracted in 1N neutral normal ammonium acetate (Merwin and Peech 1951) and determined by using a flame photometer.

The AM fungal spores present in the rhizosphere soil was determined by spore isolation through 'Wet Seiving and Decanting' method (Gardemann and Nicholson 1963) and spore counted via most probable number method (Porter 1979).

Isolation of viable *Azotobacter* and phosphorous solubilizing bacterial count in pure culture was done by serial dilution method on Jenson's and Pikovskaya's (PVK) media; respectively. 1 g of sieved soil from each sample was drawn and serially diluted aseptically to 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} and 1 ml of the serially diluted suspension of soil was spread on pre-poured, cooled and solidified medium. After incubation of 24 to 48 hours at 28°C, the isolated colonies developed on enriched medium. Populations were expressed as colony forming units (CFU) per gram of dried soil.

The experimental data of two years relating to each parameter were pooled and statistically analyzed by applying the technique of analysis of variance using factorial randomized block design (Gomez and Gomez 1985). The level of significance for t-test was kept at 5% (P=0.05). Data were analyzed within the ANOVA of the SPSS software program, version 6.0.

RESULTS AND DISCUSSION

Physico-chemical properties of soil

A pH range of 5.2 to 6.5 is rated by most nutritionalists as ideal for the optimum growth of most of plants because all essential elements are soluble and available within this range. Maintaining the recommended pH range is important in order to provide ideal range of nutrient solubility and optimal plant production (Brady 1974).

Addition of nutrients through different sources significantly influenced the physico-chemical properties of the soil on all parameters except soil pH and EC in the present studies. The static results may be due to the short duration of the experimentation. Initial pH value of the soil, 6.89 was slightly increased. However, it remained in neutral range. The electrical conductivity (EC) of soil was lowered from the initial value of 0.35 dS/m by the application of all the integrated nutrient management treatments during the investigation (Table 1).

In general, organic sources have the tendency to keep the soil pH in neutral range. However, slight increase in soil pH could be ascribed to added organic matter to soil and proton release resulting in accumulation of organic anions such as malate, citrate and oxalate in plants (Gaur 2006).

The organic carbon content of the soil was increased statistically over control (0.924 %) under treatment 30 g/m^2 each of NPK + vermicompost + biofertilizers (1.260 %). These findings are in conformity to that of Kanwar *et al.* (2002) and Sen (2003) who reported increase in soil organic carbon content with the treatments having organic manures in comparison to inorganic treatments. The soil in which cultivar Purnima (1.162 %) was grown contained more organic carbon than those of Ajay (1.144 %).

Macronutrients like; N, P and K were also quantified to assess the nutritional build up in soil profile. In general, all the treatments recorded higher available NPK content over control (Table 2). However, the highest N (373.04 kg/ha) and K (283.18 kg/ha) build up was observed in treatments recieving 30 g/m^2 each of NPK + vermicompost + biofertilizers and maximum P (39.86 kg/ha) build up in the soil was recorded with the application of 22.5 g/m^{2}each of NPK + vermicompost + biofertilizers. These findings are in line to that of Jambhekar (1992) who found increased N, P_2O_5 and K_2O content in vermicompost inoculated soil. The improvement in the availability of macronutrients might be due to the reduction in N losses through leaching, enhancement of cation exchange capacity (CEC) of the soil, increased biological nitrogen fixation and residual effect of applied nutrients and greater mineralization of vermicompost.

Phosphorus availability too improved with addition of nutrients through inorganic or organic sources. Treatments having vermicompost with biofertilizer inoculation had higher availability of phosphorus due to continuous mineralization and conversion of insoluble inorganic phosphate to organic phosphates. Kohler *et al.* (2007) reported that secretion of phosphatase enzyme by PSB and AM fungi is a mode of facilitating the conversion of insoluble form of P to plant available forms and thus enhance plant P uptake.

Sen (2003) also observed that combination of organic manures and inorganic fertilizers increased available N, P, K contents in the soil thereby improving the soil health and justified the need of balanced fertilization in vertisol. The roots of mycorrhizae inoculated plants can absorb several times more phosphate ions than non-infected roots from soils (Gianinazzi-Pearson *et al.* 1981). This might be due to increased root colonization which increased the surface area for nutrient absorption. Increase in soil available K due to the application of vermicompost may be ascribed to the direct addition of K to the available K pool of the soil and also due to the reduction of K fixation.

The soil in which cultivar Purnima was grown contain more available NPK in comparison to the soil in which cultivar Ajay was grown. This might be due to the difference in nutrient uptake capacity of the two cultivars which in turn affect the residual NPK content of the soil.

Microbial status of soil

Micro-organisms are the important component of soil environment. Their presence in large number is indicative of better soil health and improved nutrient availability to the plants. Soil microbial population plays very important role in organic matter decomposition and nutrient mobilization. Various sources of nutrients exert influence on their population through different mechanisms. *Azotobacter chroococcum,* an important free-living N-fixing bacterium rarely exceeded 10^4 to 10^5 per gram of soil under Indian conditions due to lack of soil organic matter (Subba Rao 1993). The amount of organic carbon in soils of India is relatively low, ranging from 0.1 to 1% and typically less than 0.5 % (Swarup *et al.* 2000).

Under the present investigations biofertilizer inoculation along with vermicompost significantly increased the microbial populations in the soil profile (Table 3). However, a gradual decrease in biological properties of soil was noticed with the increase in inorganic fertilizer doses. Inorganic fertilizers supplied must have acted as food for the local population of

Table 1 Effect of integrated nutrient management on available macro-nutrient contents of the soil of chrysanthemum field (Data are the pooled means of two years)

Treatment	Available nitrogen content of soil (kg/ha)			Available phosphorous content of soil (kg/ha)			Available potassium content of soil (kg/ha)		
	Purnima	Ajay	Mean	Purnima	Ajay	Mean	Purnima	Ajay	Mean
T_1 Control	323.82	318.47	321.14	31.88	31.50	31.69	246.17	241.43	243.80
T_2 30 g/m^2 each of NPK (Ad-hoc recommendation)	347.50	343.87	345.68	36.88	35.37	36.13	277.62	270.88	274.25
T_3 45 g/m^2 each of NPK	351.02	348.17	349.59	37.57	36.57	37.07	277.92	272.90	275.41
T_4 22.5 g/m^2 each of NPK	342.38	339.02	340.70	36.42	35.80	36.11	276.17	270.03	273.10
T_5 15 g/m^2 each of NPK	334.33	332.57	333.45	35.17	34.38	34.78	270.68	268.62	269.65
T_6 30 g/m^2 each of NPK + vermicompost (1 kg/m^2)	353.38	349.23	351.31	37.68	36.55	37.12	280.25	277.12	278.68
T_7 30 g/m^2 each of NPK + biofertilizers*	360.88	357.45	359.17	38.45	37.33	37.89	282.47	279.92	281.19
T_8 30 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	373.73	372.35	373.04	39.18	38.52	38.85	284.73	281.63	283.18
T_9 22.5 g/m^2 each of NPK + vermicompost (1 kg/m^2)	352.57	349.50	351.03	37.18	36.37	36.78	279.52	275.05	277.28
T_{10} 22.5 g/m^2 each of NPK + biofertilizers*	369.68	360.20	364.94	38.00	37.55	37.78	281.77	278.85	280.31
T_{11} 22.5 g/m^{2}each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	357.55	375.75	366.65	40.30	39.42	39.86	284.10	281.00	282.55
T_{12} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2)	340.82	335.60	338.21	34.77	33.85	34.31	271.63	268.38	270.01
T_{13} 15 g/m^2 each of NPK + biofertilizers*	345.73	341.75	343.74	35.23	34.58	34.91	273.22	269.05	271.13
T_{14} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	337.45	344.85	341.15	36.02	35.30	35.66	263.07	259.95	261.51
T_{15} vermicompost (1 kg/m^2)	326.72	326.27	326.49	33.83	33.80	33.82	249.78	246.78	248.28
T_{16} biofertilizers*	330.18	329.15	329.67	34.22	34.20	34.21	252.53	247.32	249.93
T_{17} vermicompost (1 kg/m^2) + biofertilizers*	332.82	331.22	332.02	34.68	34.38	34.53	254.55	248.02	251.28
Mean	345.92	344.44		36.32	35.62		270.95	266.88	
	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments (T)	1.09			0.43			0.62		
Cultivars (C)	0.38			0.15			0.20		
T × C	1.54			NS			0.20		

**Azotobacter chroococcum* and phosphorous solubilizing bacteria were applied as root dip treatment of the cuttings into slurry of 200 g of the inocula dissolved in one litre of 10% sugar solution at the time of planting, whereas VAM (2g/plant) was incorporated into the planting pit

microbes but when it was supplied in heavy doses these must have caused toxicity to the local population of microbes due to feed back inhibition hence less microbial count was noticed with increased fertilizer doses. Maximum AM fungal spore (196.58 per 20 g of soil) was recorded with the application of a combination of vermicompost and biofertilizers (T_{17}) while the minimum fungal spore (19.83 per 20 g of soil) was recorded with the application of 45 g/m^{2}each of NPK. The reduction in mycorrhizal spore count might also be due to the presence of sterile or ineffective spore population due to higher doses of inorganic fertilizers. The higher nitrogen content increased the incidence and population of AM fungi as these fungi have special requirement for nitrogen (Mosse 1973).

No significant difference in AM fungal spore count was observed due to the interaction between the two cultivars and

Table 2 Effect of integrated nutrient management on soil pH, EC and OC of chrysanthemum field (Data are the pooled means of two years)

Treatment	Soil pH			Soil electrical conductivity (dS/m)			Soil organic carbon content (%)		
	Purnima	Ajay	Mean	Purnima	Ajay	Mean	Purnima	Ajay	Mean
T_1 Control	6.93	6.90	6.91	0.22	0.23	0.22	0.973	0.875	0.924
T_2 30 g/m^2 each of NPK (Ad-hoc recommendation)	6.91	6.96	6.93	0.22	0.21	0.21	1.212	1.192	1.202
T_3 45 g/m^2 each of NPK	6.87	7.05	6.96	0.24	0.25	0.24	1.258	1.242	1.250
T_4 22.5 g/m^2 each of NPK	6.91	6.94	6.93	0.22	0.21	0.21	1.195	1.182	1.188
T_5 15 g/m^2 each of NPK	6.96	6.98	6.97	0.26	0.27	0.26	1.148	1.133	1.141
T_6 30 g/m^2 each of NPK + vermicompost (1 kg/m^2)	6.93	6.90	6.92	0.25	0.24	0.25	1.253	1.245	1.249
T_7 30 g/m^2 each of NPK + biofertilizers*	6.96	6.93	6.94	0.22	0.22	0.22	1.178	1.165	1.172
T_8 30 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	6.90	6.91	6.91	0.24	0.24	0.24	1.270	1.250	1.260
T_9 22.5 g/m^2 each of NPK + vermicompost (1 kg/m^2)	6.90	6.91	6.90	0.22	0.24	0.23	1.253	1.240	1.247
T_{10} 22.5 g/m^2 each of NPK + biofertilizers*	6.93	6.89	6.91	0.23	0.23	0.23	1.148	1.142	1.145
T_{11} 22.5 g/m^{2}each of NPK+ vermicompost (1 kg/m^2) + biofertilizers*	6.91	6.87	6.89	0.25	0.25	0.25	1.200	1.183	1.192
T_{12} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2)	6.92	7.01	6.96	0.24	0.25	0.24	1.178	1.163	1.171
T_{13} 15 g/m^2 each of NPK + biofertilizers*	6.95	6.98	6.96	0.22	0.22	0.22	1.100	1.085	1.093
T_{14} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	6.97	6.91	6.94	0.23	0.22	0.23	1.107	1.097	1.102
T_{15} vermicompost (1 kg/m^2)	6.96	6.89	6.93	0.20	0.20	0.20	1.152	1.145	1.148
T_{16} biofertilizers*	6.95	6.90	6.92	0.24	0.23	0.24	1.060	1.048	1.054
T_{17} Vermicompost (1 kg/m^2) + biofertilizers*	7.00	6.95	6.97	0.23	0.22	0.23	1.067	1.065	1.066
Mean	6.93	6.93		0.23	0.23		1.162	1.144	
	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments (T)	NS			NS			0.011		
Cultivars (C)	NS			NS			0.003		
T × C	0.08			NS			0.017		

*_Azotobacter chroococcum_ and phosphorous solubilizing bacteria were applied as root dip treatment of the cuttings into slurry of 200 g of the inocula dissolved in one litre of 10% sugar solution at the time of planting, whereas VAM (2g/plant) was incorporated into the planting pit

different treatments. This finding was contradictory to the findings of Ganadevi and Haripriya (1999) who suggested the differential behaviour of VAM fungi due to the variation in colonization of roots and symbiotic response of host preference of the fungi. It was also found that the AM fungal spore population was lower at higher concentration of phosphorus. A colonization developing under conditions of high P availability may function parasitically, without making any benefit contribution to plant nutrient supply (Stribley *et al.* 1980). As available P increased, increasing mycorrhizal association might depress plant growth, since there was a carbon cost association between the host and the fungi (Mosse 1973).

Results of the present study also reveals that maximum *Azotobacter* colonies (10.50 × 10^6 cfu/g of soil) and phosphorous solubilizing bacterial population (12.83 × 10^6 cfu/g of soil) was recorded with the application of 15 g/m^{2}each of NPK + vermicompost + biofertilizers. Inoculation

Table 3 Effect of integrated nutrient management on microbial population in the rhizosphere of chrysanthemum (Data are the pooled means of two years)

Treatment	*Azotobacter* population ($\times 10^6$ cfu/g of soil)			Phosphorous solubilizing bacterial count ($\times 10^6$ cfu/g of soil)			Arbuscular mycorrhizal fungi spore count per 20 gram of soil		
	Purnima	Ajay	Mean	Purnima	Ajay	Mean	Purnima	Ajay	Mean
T_1 Control	2.83	3.00	2.92	3.50	3.17	3.33	31.00	39.50	35.25
T_2 30 g/m^2 each of NPK (Ad-hoc recommendation)	3.00	2.83	2.92	3.50	3.17	3.33	22.67	31.50	27.08
T_3 45 g/m^2 each of NPK	2.50	2.50	2.50	3.33	3.17	3.25	15.17	24.50	19.83
T_4 22.5 g/m^2 each of NPK	2.83	3.00	2.92	3.83	3.50	3.67	22.17	32.83	27.50
T_5 15 g/m^2 each of NPK	3.17	3.00	3.08	3.33	3.17	3.25	27.33	37.33	32.33
T_6 30 g/m^2 each of NPK + vermicompost (1 kg/m^2)	3.00	2.50	2.75	3.50	3.33	3.42	30.83	40.50	35.67
T_7 30 g/m^2 each of NPK + biofertilizers*	8.33	8.33	8.33	8.33	7.83	8.08	126.83	135.83	131.33
T_8 30 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	9.67	9.33	9.50	8.83	8.33	8.58	137.33	147.17	142.25
T_9 22.5 g/m^2 each of NPK + vermicompost (1 kg/m^2)	3.67	3.00	3.33	3.67	3.67	3.67	55.00	64.17	59.58
T_{10} 22.5 g/m^2 each of NPK + biofertilizers*	8.83	8.83	8.83	10.83	11.17	11.00	142.67	149.17	145.92
T_{11} 22.5 g/m^{2}each of NPK+ vermicompost (1 kg/m^2) + biofertilizers*	10.67	10.17	10.42	11.67	12.00	11.83	157.67	164.50	161.08
T_{12} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2)	3.83	3.33	3.58	4.00	3.83	3.92	39.50	46.17	42.83
T_{13} 15 g/m^2 each of NPK + biofertilizers*	10.00	9.67	9.83	12.33	12.33	12.33	162.83	170.33	166.58
T_{14} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	10.83	10.17	10.50	13.00	12.67	12.83	178.67	186.50	182.58
T_{15} vermicompost (1 kg/m^2)	3.67	3.33	3.50	4.00	3.50	3.75	34.83	43.17	39.00
T_{16} biofertilizers*	8.17	8.50	8.33	11.67	11.67	11.67	185.00	192.50	188.75
T_{17} Vermicompost (1 kg/m^2) + biofertilizers*	8.83	9.00	8.92	12.33	12.33	12.33	191.67	201.50	196.58
Mean	6.11	5.91		7.16	6.99		91.83	100.42	
	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments (T)	0.41			0.48			2.80		
Cultivars (C)	0.14			0.17			0.96		
T × C	NS			NS			NS		

**Azotobacter chroococcum* and phosphorous solubilizing bacteria were applied as root dip treatment of the cuttings into slurry of 200 g of the inocula dissolved in one litre of 10% sugar solution at the time of planting, whereas VAM (2g/plant) was incorporated into the planting pit

of soil with biofertilizer increased microflora population, whereas addition of vermicompost have synergistic effect on microbial population in soil profile. The increase in microbial population may be due to the fact that organic manures provided food and micro-environment for their multiplication and growth.

Similar reports have also been given by Prabhat Kumar *et al.* (2003) in China aster and Shashidhara and Gopinath (2002) in calendula. Further, Debnath and Wange (2003) reported the occurrence of *Azotobacter* in the rhizosphere of almost all flower crops. Its presence in sufficient number was found in soil having a pH of 7.6. This suggested that they prefer slightly alkaline soil reaction for their multiplication. This fact is supported by the earlier findings of Rangaswamy and Sadasivum (1984), who reported occurrence of *Azotobacter chroococcum* in neutral to alkaline soils of Chennai (Tamil Nadu). Fierer and Jackson (2006) also considered pH as the best predictor of soil bacterial diversity and richness, with the lower levels of bacterial diversity observed in acid soils.

Mycorrhizal formation has also been reported to be affected by soil pH (Johnson *et al.* 1984). Its formation was reported to decrease with high levels of NH_4^+ions, but greatest VAM growth benefits occurred with NH_4^+ions in solution at pH 7. The favourable pH values (near neutral) of the growing medium in present studies might have favoured the growth of both *Azotobacter* and VAM.

Flower yield and quality

In the present studies, treatment 22.5 g/m^2 each of NPK + vermicompost + biofertilizers proved to be the best in respect of length of cut flower stems (53.51 cm) and cut flower weight (88.18g) of cultivar Purnima as compared to other treatments (Table 4). This treatment also produced more number of cut flower stems/plant (4.50), longest cut stems (67.60 cm) and maximum cut flower weight (392.86

Table 4 Effect of integrated nutrient management on flower quality of chrysanthemum (Data are the pooled means of two years)

Treatment	Number of cut stems/plant			Cut flower stem length (cm)			Weight of cut flower stem (g)		
	Purnima	Ajay	Mean	Purnima	Ajay	Mean	Purnima	Ajay	Mean
T_1 Control	2.97	2.90	2.93	38.73	54.29	46.51	68.97	299.36	184.16
T_2 30 g/m^2 each of NPK (Ad-hoc recommendation)	3.83	3.70	3.77	48.56	59.15	53.85	86.09	335.61	210.85
T_3 45 g/m^2 each of NPK	4.43	3.70	4.07	49.36	62.64	56.00	84.97	320.15	202.56
T_4 22.5 g/m^2 each of NPK	3.83	3.37	3.60	43.70	62.44	53.07	79.24	297.57	188.40
T_5 15 g/m^2 each of NPK	3.33	3.87	3.60	43.22	62.30	52.76	80.47	311.22	195.84
T_6 30 g/m^2 each of NPK + vermicompost (1 kg/m^2)	4.07	3.53	3.80	44.59	63.01	53.80	82.44	329.63	206.03
T_7 30 g/m^2 each of NPK + biofertilizers*	3.63	4.00	3.82	47.24	61.39	54.32	82.81	330.86	206.84
T_8 30 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	3.90	3.87	3.88	46.47	67.25	56.86	81.84	344.50	213.17
T_9 22.5 g/m^2 each of NPK + vermicompost (1 kg/m^2)	3.67	3.93	3.80	45.38	63.94	54.66	83.37	335.54	209.45
T_{10} 22.5 g/m^2 each of NPK + biofertilizers*	3.43	4.07	3.75	51.83	62.25	57.04	85.18	363.74	224.46
T_{11} 22.5 g/m^{2}each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	3.95	4.50	4.22	53.51	67.60	60.56	88.18	392.86	240.52
T_{12} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2)	3.43	3.67	3.55	39.81	57.80	48.81	81.94	338.86	210.40
T_{13} 15 g/m^2 each of NPK + biofertilizers*	3.50	3.77	3.63	40.74	60.06	50.40	82.04	349.43	215.74
T_{14} 15 g/m^2 each of NPK + vermicompost (1 kg/m^2) + biofertilizers*	4.03	3.57	3.80	48.50	58.02	53.26	86.89	362.72	224.81
T_{15} Vermicompost (1 kg/m^2)	3.10	3.33	3.22	38.74	57.66	48.20	78.88	322.98	200.93
T_{16} Biofertilizers*	2.97	3.53	3.25	43.25	53.84	48.55	75.47	301.65	188.56
T_{17} Vermicompost (1 kg/m^2) + biofertilizers*	3.33	3.33	3.33	42.40	58.65	50.52	80.03	308.51	194.27
Mean	3.61	3.68		45.06	60.72		81.69	332.07	
	$CD_{0.05}$			$CD_{0.05}$			$CD_{0.05}$		
Treatments (T)	0.21			0.34			1.60		
Cultivars (C)	NS			0.11			0.55		
T × C	0.30			0.48			2.26		

**Azotobacter chroococcum* and phosphorous solubilizing bacteria were applied as root dip treatment of the cuttings into slurry of 200 g of the inocula dissolved in one litre of 10% sugar solution at the time of planting, whereas VAM (2g/plant) was incorporated into the planting pit

g) in cultivar Ajay.

The improved flowering parameters with integrated nutrient management treatments may be assigned to easy and better translocation of nutrients to the flowers brought about by inoculation with beneficial microbial inoculants like *Azotobacter*, PSB and VAM. The positive effect of vermicompost on flower diameter has also been reported in marigold (Mashaldi 2000) and increasing stalk length has been reported in golden rod (Kusuma 2001) and gladiolus (Gangadharan and Gopinath 2000). Similar effect of *Azospirillum* and PSB on tuberose spike length was reported by Swaminathan *et al.* (1999) and Wange *et al.* (1995). More photosynthesis enhanced food accumulation which might have resulted in better plant growth and subsequently higher number of flowers/plant and hence more flower yield. Besides this, increase in flower yield may also be attributed to the increased availability of phosphorous and its greater uptake (Kundu and Gaur 1980). Similarly, Narashima Raju and Haripriya (2001) reported higher flower yield in crossandra with the combination of *Azospirillum* and PSB with 100 % NPK. Chandrikapure *et al.* (1999) also reported similar results in marigold.

The higher flower yield due to application of vermicompost has also been reported in China aster (Nethra *et al.* 1999, Srinivas and Narayana Gowda 1999), marigold (Mashaldi 2000) and golden rod (Kusuma 2001). Mathew and Singh (2003) also reported increased number of flowers per plant and flower yield of marigold with the use of PSB + *Azospirillum* + *Azotobacter.* Patil *et al.* (2004) confirmed that using organic, inorganic and *in situ* vermiculture in *Jasminum sambac* increased the number of flowers/plant by increasing the leaf area and chlorophyll content.

It may be concluded that use of organic input coupled with reduced chemical fertilizer can improve the physico-chemical and biological properties of soil in the rhizosphere of chrysanthemum cultivars Purnima and Ajay as well as it resulted in the improvement of flower quality.

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