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Impact of vermicompost and composted farmyard manure on growth and yield of garlic (*Allium stivum* L.) field crop

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Abstract

The efforts were made to study the impact of vermicomposted and composted farmyard manure (FYM) along with some combination of NPK fertilizers, on field crop of garlic (*Allium stivum* L.). A total of six experimental plots were prepared: T_1 (recommended doze of NPK), T_2 (vermicompost @ 15t/ha), T_3 (20 t/ha vermicompost), T_4 (15t/ha vermicompost + 50 % NPK), T_5 (15t/ha farmyard manure), and T_6 (farmyard manure 15t/ha + 100% recommended NPK) to test the plant production patterns, under field conditions. The maximum range of some plant parameters i.e. root length, shoot length, leaf length, fruit weight, number of cloves in garlic fruit and number of leaves per plant was in the T_4 treatment plot. Also, the average fruit weight was approximately 26.4% greater in T_4 than recommended NPK treatment plot (T_1). The vermicomposted FYM showed a comparatively better result of plant production than composted manure. The plant growth results indicate the presence of some growth-promoting substances in worm-processed material (vermicompost). The vermicomposted FYM also contained a considerable amount of some essential plant micronutrients e.g. Cu (0.973 mg kg^{-1}), Fe (8.68 mg kg^{-1}), Mn (13.64 mg kg^{-1}) and Zn (16.91 g kg^{-1}) that might be responsible for better plant growth and productivity. This study suggests that vermicomposted manures may be a potential source of plant nutrients for sustainable crop production.

Keywords: Vermicompost; Farmyard manure; *Allium stivum*, Plant yield; Plant growth

Introduction

The agriculture development strategy for India in the 21^{st} century must be through increasing productivity of the land under cultivation, with reduced costs of production and higher use efficiency of inputs with no harm to the environmental quality. The prime requisite is the promotion of health of the soil-plant-environment system to be free from economic exploitation under overuse and abuse of the input as if with impunity (Ayala and Prakasa Rao, 2002). No doubt, the use of chemical fertilizers was boon for the past but ban for the present. Now it is time to reanalyze the technological development on the cost of nature destruction. Several mammoth problems related to soil structure and productivity is the results of fossil fuel based energy inputs in intensive cultivations. Changes in the soil pH, soil acidifications and lower humic acid contents are some key problems of overuse of synthetic fertilizers. The poor soil respiration rate and complete vanishing of natural decomposer communities from agroecosystems has questioned the land sustainability and future food security (Suthar, 2008a). Similarly, the escalation in the cost of chemical fertilizers, particularly that of N, coupled with concerns about pollution have focused attention on the use of combined application of nutrients through organic and inorganic source in crop production. Therefore, nutrient supply in crop system should be economically viable, environmental friendly and socially acceptable without affecting the gross plant production. It has been realized that soil fertility can be managed in complete harmony with sustainable agriculture development by careful analysis of current issues of sustainable land productivity (Saleh, 2008; Srinivasarao *et al.*, 2008).

The organic manure is an eco-friendly, economically viable and ecologically sound that also played a significant role in soil biology, chemistry and physics. It is interesting that each year, human, livestock and crops produce approximately 38 billions metric tons of organic waste worldwide, which may be an efficient source of organic matter supply in soils. According to a conservative estimation, around 600 to 700 million tones (mt) of agricultural waste (including 272 million tones of crop residues) are available in India every year, but most of it remains unutilized. This huge quantity of wastes can be converted into nutrient rich bio-fertilizer (vermicompost) for sustainable land restoration practices (Suthar, 2008b). In general, a great proportion of the crop nutrient input during cultivation returned in the form of the plant residues. Estimation showed that 30-35 % of applied N & P and 70-80 % for K remained in the crop residues of food crops. Such nutrient rich crop residues must be 'prepared' before they are used as a fertilizer, and earthworms are suitable candidates for the same (Suthar, 2007). The earthworm-processed organic wastes, often referred to as vermicomposts, are finely divided peat-like materials with high porosity, aeration, drainage, and water holding capacity (Edwards and Burrows, 1988). The vermicomposting is biooxidation and stabilization of organic material involving the joint action of earthworms and microorganisms. Although, microbes are responsible for the biochemical degradation of the organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering biological activity (Aira *et al.*, 2002; Suthar, 2008c). The studies have revealed that vermicompost may be potential sources of nutrients for field crops if applied in suitable ratios with synthetic fertilizers. Also, vermicompost may contain some plant growth-stimulating substances. The plant-hormone-like is extensively reported in worm-processed materials possibly due to higher microbial populations (Krishnamoorthy and Vajranabhaian, 1986; Tomati *et al.*, 1987; Mascolo *et al.*, 1999). Also, Suthar *et al.* (2005) reported a hormone like effect of earthworm body fluid on seedling growth of some legumes. The earlier workers have reported a positive effect of vermicompost application on growth and productivity of cereals and legumes (Benik and Bhebaruah, 2004; Suthar, 2006), ornamental and flowering plants (Kale *et al.*, 1987; Nethra *et al.*, 1999), vegetables (Edwards and Burrows; 1988; Atiyeh *et al.*, 2000) etc. Atiyeh *et al.* (2001) concluded that vermicomposts, whether used as soil additives or as components of greenhouse bedding plant container media, have improved seed germination, enhanced seedling growth and development and increased overall plant productivity.

In most part of the northern India, farmyard manure is widely recommended for sustainable nutrient supply in crop fields. On the other hand, the application of vermicompost for commercial crop production in India is under trail. The main objective of this study was to evaluate the impact of different dozes of vermicomposted and composted farmyard manure (Table 1) on growth and yield of a popular spice crop of tropics i.e. *Allium stivum* Linn under field conditions, for two subsequent cropping years.

Table 1. Treatment design for production of garlic.

Treatments	Composition
T_1	Recommended dose of NPK
T_2	15 t/ha Vermicompost
T_3	20 t/ha Vermicompost
T_4	15 t/ha Vermicompost + 50% NPK
T_5	15 t/ha FYM
T_6	15 t/ha FYM + 100 % NPK

Materials and methods

The experimented was conducted in an agriculture plot situated in Bhakhra canal belt of Tibbi village, Hanumangarh, India. The experiment was conducted for two subsequent cropping years during 2000 – 2002, in the same experimental field. Geographically, the site is located between 28° 44' and 29° 57' N and 73° 47' to 75° 31' E. According to the agro-ecological classification (Faroda, *et al.*, 1999), this region is under the category of northern canal irrigated sub region of Indian Thar desert. The annual rain fall of this area is ranged between 250 – 300 mm. The soils of this region are of Torripsamments (P) subgroups. The climate of this region is semi arid with extreme temperature conditions in summer (up to 45 °C) and winter (up to 1 °C). The site is under the influence of Indian southern-west or summer monsoon (June – September) and during winter (December – February) by Siberian anticyclones. The main rainy season is during July and August when almost 80 % of the annual rainfalls. The annual mean rain fall was recorded as 253.0 mm.

The experiment was conducted in an irrigated plots receiving canal water. The major chemical characters of experimental plot soils were: 7.56 pH, 3.78 g kg^{-1} organic carbon, 1.18 g kg^{-1} nitrogen, 0.69 g kg^{-1} available phosphorous, and 0.87 g kg^{-1} exchangeable potassium. The experimental field were ploughed three times and divided into 7 treatments plots of 10 meter square sized. Each treatment was replicated two times. One feet space was left between the two adjacent treatment plots. Six treatments for growth and yield study, as described in Table 1, were designed. One treatment plot received only recommended NPK (chemical fertilizers) (T_1), which acted as control to compare the growth and yield data of garlic plant. One week old ready vermicompost and composted farmyard manure was used as organic supplement for crop production. The vermicompost was prepared from crop residue (straw of *Triticum aestivum* L.) mixed with fresh cow dung in 1:3 ratios by using earthworm *Eudrilus eugeniae* in indoor beds. Farmyard manure was collected (2 week old) from a local dairy farm, mainly consisted of discarded cattle feed, chopped fodder and animal excreta, dumped in the boundary of it. The farmyard manure was composted by following popular pit method as described by Agriculture Research Station, Govt. of Rajasthan, India. The chemical properties of composted farmyard manure and vermicompost is presented in Table 2.

Table 2. Physiochemical properties of vermicompost and Farmyard manure used for experimentation (mean ± SEm).

Parameters	Vermicompost	Farmyard manure
pH	7.82 ± 0.04	7.81 ± 0.01
$_{org}$C (g kg^{-1})	286.5 ± 1.67	266.3 ± 0.51
$_{tot}$N (g kg^{-1})	23.1 ± 1.0	14.4 ± 0.31
$_{avai}$P (g kg^{-1})	9.85 ± 0.10	6.59 ± 0.03
Organic matter (g kg^{-1})	495.5 ± 2.7	461.2 ± 1.31
C/N ratio	12.3 ± 0.13	18.5 ± 0.13
$_{exch}$K (g kg^{-1})	15.2 ± 0.19	8.87 ± 0.05
$_{exch}$Ca (g kg^{-1})	23.8 ± 2.91	15.7 ± 1.31
$_{exch}$Mg (g kg^{-1})	6.74 ± 0.10	2.59 ± 0.06
$_{exch}$Na (g kg^{-1})	6.03 ± 0.06	5.70 ± 0.01
$_{ext}$Cu (mg kg^{-1})	0.97 ± 0.04	0.77 ± 0.01
$_{ext}$Fe (mg kg^{-1})	8.68 ± 0.14	5.59 ± 0.121
$_{ext}$Mn (mg kg^{-1})	13.6 ± 0.18	7.72 ± 0.12
$_{ext}$Zn (g kg^{-1})	16.9 ± 0.17	8.31 ± 0.10

tot – Total, avai – Available, exch – Exchangeable, ext – Extractable

dva Malec variety of garlic (*Allium sativum*) was used @ 600 Kg/ha for present experiment. The certified ripen fruit, as a seed for new crop of garlic were use. After preparing the experimental plots, cloves of garlic fruit were sown in rows in ready plot following the method as described by Horticulture Department, Jodhpur. The total organic supplement material (vermicompost and composted farmyard manure) to be used in each experimental plot (Table 1) was applied in three dozes, the first 10 days before the plantation or showing of garlic, other two during the vegetative and fruiting stages of garlic plant. The nitrogen fertilizer (NPK) was applied in three splits: half at the time of sowing, one fourth at active growth stage, and one fourth at the fruit ripening stage (when garlic fruit began to take shape). The recommended dozes of phosphorous and potassium fertilizer was applied basal entirely. The care was taken to protect the crop from pests and chemical pesticides were applied timely, if required. The weeds were removed timely from the experimental plots by using mechanical methods. During each year, at the time of harvesting, ten plants were selected randomly from each experimental plot and the plant characteristic namely lengths of plant, number of leaves/plant, length of leaf, length of roots were recorded. After shade drying for 10 days, other characteristics of plants e.g. weight of fruit, weight of stem along with leaves and number of cloves in garlic fruit was also registered. The whole plant was than washed in tap water to remove adhering soils from the plant and subsequently kept in hot air oven at 60 °C until the complete drying of plants. After complete drying, the whole plant was weighted and values of total dry mass production in each treatment plot were recorded. The average of two year's data, for each observed parameter of plant, was calculated.

The experimental field soil, vermicompost and composted farmyard manure were tested in laboratory for their different physico-chemical parameters (Table 2). The pH was measured) in 1/10 (w/v) aqueous solution (deionized water) using digital pH meter (Systronic made. The organic carbon was determined by the partially-oxidation method (Walklay and Black, 1934). Total nitrogen was measure by following micro Kjeldahl method (Jackson, 1975). Available phosphorous was measured using the method described by Anderson and Ingram (Olsen *et* *al*., 1954). Exchangeable K, Ca and Mg were determined after extracting the sample using ammonium acetate (Simard, 1993) and analyzing with a Perkin-Elmer model 3110 double beam atomic absorption spectrophotometer (AAS). Metals were determined by DTPA (diethylenetriaminepentaacetatic acid) extraction method. 10gm of air-dried soil was taken in a 50 ml conical flask and 20 ml of the DTPA extracting solutions was added to it. The solution was extracted on a horizontal shaker for two hours. After exactly two hours of shaking, suspension was filtered by gravity through Whatmann No.42 filter paper. The filtrate was analyzed for Fe, Zn, Cu and subjected for Mn using AAS.

Data were analysis of variance (ANOVA) Duncan's multiple–ranged test was performed to identify the homogeneous type of the data sets among different treatments for different plant parameters in different treatments.

Results

Effect of different doses of compost, vermicompost and NPK on plant growth

As presented in Figure (a, b and c), a significant difference in plant growth parameters: leaf length (ANOVA, F=68.15, P<0.001), shoot length (F=553.51, P<0.001) and root length (F=137.13, P<0.001) was among the treatments. The maximum values of leaf length 31.38 (cm) was in T_4 experimental plot (vermicompost @ 15t/ha+50 % NPK) showing approximately 28.8 %, 46.8 %, 5.9 %, 79.9 % and 0.6 % higher than T_1, T_2, T_3, T_5, and T_6 treatment plots, respectively (Figure 1a). An average leaf length for different plots was in the order: $T_4>_5>T_3>T_1>T_2>T_6$. The value of shoot length (Figure 1b) was also greater 79.39 (cm) in T_4 treatment, while T_6 (56.57 cm) showed the lowest value for the same parameter. The shoot length in T_4 was approximately 2.5 %, 33.2 %, 6.5 %, 40.3 % and 31.4 % higher than T_1, T_2, T_3, T_5, and T_6, respectively. The maximum and minimum average root length (cm) was in T_4 (8.94) and T_5 (4.13), respectively. The root length in garlic plant was in the order: T_4 (8.94) > T_3 (7.26) > T_6 (5.75) > T_1 (5.12) > T_2 (4.53) > T_5 (4.13) (Figure 1c). The data clearly indicates that vegetative growth was higher in plots that received integrated (organic and inorganic) nutrient supply. Moreover, plant growth was better in vermicompost treated plots than composts FYM treated plots. T_4 plot, which received vermicompost @15 t/ha along with 50 % recommended NPK, showed approximately 28.7 % more leaf length, 2.5 % more shoot length as well as 74.6 % more root length than the control treatment (recommended NPK). Dramatically, T_6 treatment plot, which received the same quantity of organic manure and chemical fertilizer (farmyard manure @15 t/ha along with 50 % recommended NPK), did not show the expected results. The observed difference between T_4 and T_6 clearly indicated the importance of vermicompost than farmyard manure.

Effect of different doses of compost, vermicompost and NPK on yield and dry mass of plant

There was statistically significant difference among treatments for plant yield parameters: fruit weight (F = 306.50, P<0.001) and number of cloves per garlic fruit (F =12.30, P< 0.001) (Figure 2 a-c). The maximum fruit weight, number of cloves per fruit and number of leaves per plant were recorded in T_4 (57.62 g), T_6 (40.44) and T_4 (7.31)

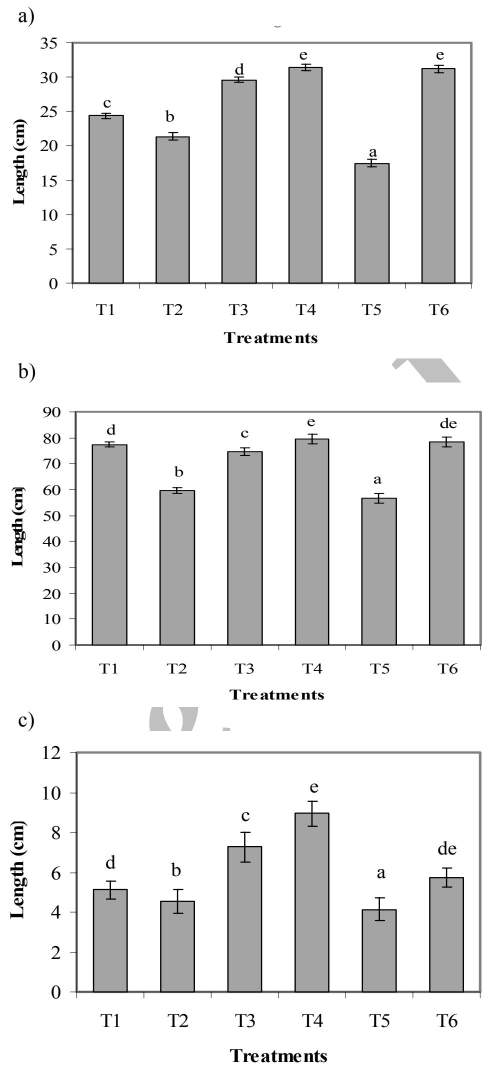

Figure 1. Leaf length (a), shoot length (b) and root length (c) of garlic plant in different treatment Plots. Significant differences ($P<0.05$) are indicated by different letters

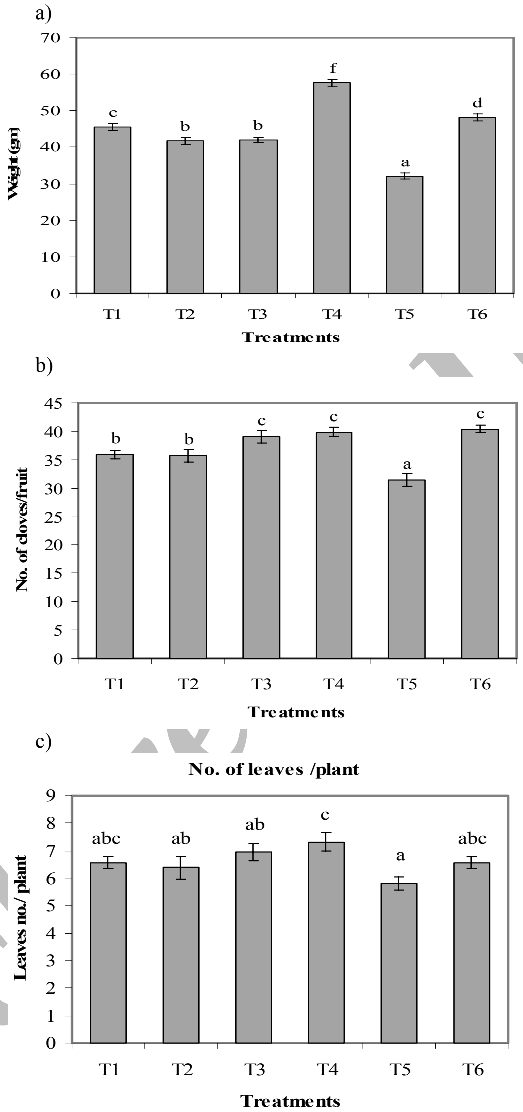

Figure 2. Fruit weight (a), no. of cloves per garlic fruit (b) and number of leaves per plant (c) of garlic plant in different treatment Plots. Significant differences (P<0.05) are indicated by different letters

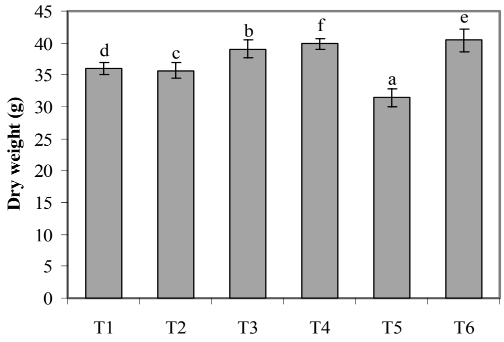

Figure 3. Total dry weight a plant of garlic plant in different treatment Plots. Significant differences (P<0.05) are indicated by different letters

treatment, respectively. However, average fruit weight T_4 was approximately 12.6 %, 13.3 %, 3.5 5, 1.4 %, and 28.3 % more than other experimental plots: T_1, T_2, T_3, T_5, and T_6, respectively (Figure 2 a). The average fruit weight did not show significant difference between T_2 and T_3 treatments (P =0.959). In T_4 plot garlic fruit weight was about 26.4 % more than recommended NPK treatment (T_1). In equal dose (@15 t/h) experiments i.e. T_2 (vermicompost) and T_5 (composted farmyard manure) treatment, the fruit weight was higher (29.8 %) in T_2 than T_5. The minimum values of weight of fruit, number of cloves per garlic fruit and number of leaves per plant were observed in T_2 (41.69 g), T_6 (31.43) and T_5 (5.81) treatment, respectively (Figure 1 b). Total dry mass per plant was statistically significant among treatments studied (F =703.68, P<0.001). The maximum dry mass (g) of a whole plant was in T_4 (58.5) followed by T_6 (52.8), T_1 (48.7), T_2 (45.7), T_3 (44.1) and T_5 (36.8) (Figure 3). The plant obtained from T_4 and T_6 treatment plot showed approximately 20.1 % and 8.33 %, respectively, more total plant biomass than T_1 (recommended NPK) treatment. In equal doze treatment of vermicompost (T_2) and composted farmyard manure (T_5); total dry mass was higher (nearly 24 %) in T_2 than T_6.

Discussions

The vermicompost with a relatively high content of humus-like compounds, active micro organisms and enzymes, greatly contribute to the enhancement of the biochemical fertility of soils degraded by intensive – cultivation, pollution or natural causes (Perucci, 1992). The casts of earthworm is one of the most useful and active agent in introducing suitable chemical, physical and microbiological changes in the soil and, thereby, directly increasing the fertility and crop producing power in the soil (Joshi and Kelkar, 1951). Nijhawan and Kanwar (1952) observed that in earthworm casts application-plots; there was an increase in plant height, number of tillers and of leaves, early ear heading, ear head length and dry matter per plant in*Triticum aestivum* than control. Edward and Burrows (1988) concluded that seedlings emergence of tomato, cabbage, and radish was much better in vermicompost than in thermophilically composted animal waste. In this study the growth and yield data of garlic showed the great variations between T_4 and T_7 treatment plots (receiving equals dozes of organic manure + 50% recommended NPK), which directly indicates the importance of vermicompost than that of composted material. This agrees with the results of Edwards and Borrows (1988). An important feature of vermicompost is that, during the processing of the various organic wastes by earthworms, many of the nutrients that it contents are change to forms that are more readily taken by plants such as nitrate or ammonium nitrate, exchangeable phosphorous and soluble potassium, calcium and magnesium (Suthar and Singh, 2008 a b). Suthar (2006) demonstrated that during the vermicomposting of some crop residues mixed with cattle dung resulted in an increase in total N (91 – 144%), available P (63 – 105%), and exchangeable K (45 – 90 %) content of it. Therefore, ready vermicompost relatively contains more exchangeable plant nutrient than those by other plant growth media. Present results support above hypothesis that worm casts can act as a best plant growth media when conjugated with some amount of NPK fertilizer. The excellent results of both growth and yield parameters in T_4 and T_6 treatment plots (organic manure and fifty per cent recommended doze experiments) supports the hypothesis that integrated nutrient supply, in the form of traditional inorganic NPK and in the form of organic manures, brigs an excellent biochemical changes in soil structure, which ultimately promotes plant growth and production. However, the earthworm casts not only affects soil's physio-chemical structure, it but also promotes biological properties of it. Enzymatically, active humus fractions extracted from vermicompost have been found to be particularly efficient in mitigation soil salinity and in improving its physical structure when added in fertiirrigation solution, both in laboratory and field experiments (Garcia et. al., 1995). The excellent plant growth in vermicompost was possibly due to some plant growth promoters in worm casts. Tomati *et al.* (1987) demonstrated a great quantity of microorganisms, especially bacteria, and a high concentration of plant hormones such as auxins, gibberellins and cytokinins in earthworm-processed sewage sludge. Krishnamoothy and Vajranrabhaian (1986) reported some plant growth promoters such as cytokinins and auxins in worm cast. Similarly, Mascolo *et al.*, (1999) reported auxin-like effects of earthworm worked humic matter on cell growth and nitrogen metabolism in *Daucus carota*. Nielson (1985) stated that the presence of plant-growth-promoting compounds elaborated by earthworm promote a significant increase in plant growth and N uptake. Earthworm casts promotes soil microbial nutrient mineralization and activation. Kale *et al.* (1992) demonstrated the influence of vermicompost on available macronutrient and microbial populations in paddy fields. They noted that application of vermicompost enhances the activity of some microbial populations and there was a high level of total N in experimental plot that received less quantity of fertilizers. This was due to higher N fixer in experimental plot than control. Since earthworm casts alters microbial nutrient spectrum in soils. Atiyeh and his group, while working in Ohio State University, U.S.A., conducted a series of experiments on a variety of plants by using different dozes of vermicompost prepared from different organic wastes (Atiyeh *et al.*, 2000; 2001). They claimed the increased plant growth and production to nutrition factors of vermicompost. Arancon *et al.* (2006) concluded that two of the contributions of vermicompost to the field soils were the increased microbial populations and activities which are key factor in rates of soil nutrient cycling, production of plant-growth-influencing materials, the build-up of plant resistance or tolerance to crop disease and nematode attack. Kale *et al.* (1987) showed that when vermicompost was used as substrate for China aster the stem girth increased and the micorrhizal root colonization enhanced uptake of phosphorous. Above reports clearly demonstrates that vermicompost application in soil enhances the biological potential of soils and consequently affects plant production. Except to NPK worm casts contains excellent concentrations of some essential micronutrient i.e. iron, zinc, copper, and manganese. So, integrated application of NPK fertilizer along with vermicompost in field crops not only influences growth and production of plants but at the same time also reduces the production budget. Nethra *et al.* (1999) observed the increase in stem girth and number of branches in china ester by using vermicompost with recommended NPK in different proportions.

Overall the greater production in conjugation treatment of recommended NPK with vermicompost could be summarized as follow:

1. Vermicompost contains a good range of some very essential micronutrient other than NPK fertilizers, required for healthy plant growth.
2. The prolified growth and production in vermicompost treated plots could be due to the presence of certain phytoharmone, produced by microorganisms in worm worked materials.
3. The higher concentration of soil enzymes, soil organic matter and soil microorganisms in worm casts creates suitable microclimatic conditions in soils for rapid mineralization and transformation of plant nutrients in soil.

Present results extend and confirm the hypothesis that the combination of vermicompost with chemical fertilizer increases the budget of essential soil micronutrients and promotes microbial population, which ultimately promotes the plant growth and production at sustainable basis. The land production could be sustained via successive removal of inorganic fertilizer by organic fertilizers in the duration of 4-5 years without affecting annual crop production. Moreover, organic-input-basis agriculture practices not only restores the soil physio-chemical structure, which has been destroyed during the last fifty years of intensive agriculture practices, but at the same time also enhances the biological nutrient transformation in soils for sustainable land productivity.

Conclusions

The vermicompost and composted farmyard manure along with some combinations of NPK was applied in field crop of *Allium stivum* to test its importance in plant growth and productivity. There was excellent plant growth as well as yield in garlic plants that received vermicompost as nutrient main nutrient supplier in field. The results indicated the advantages of vermicompost in such field crop production, but here such effects could be attributed to the nutritional status of vermicompost and to a variety of other factors (soil microbial structure and activity, mineralization, soil enzymatic factors and presence of some phytoharmones in worm-processed materials). The data clearly indicates that vermicompost may be an efficient plant growth media for sustainable plant production, if applied with some combinations of NPK.

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