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# Influence of vermicompost and split applied nitrogen on growth, yield, nutrient uptake and soil fertility in pole type french bean (*Phaseolus vulgaris* L.) in an Acid Alfisol

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## ABSTRACT
A field experiment was conducted for two years at Himachal Pradesh Agricultural University, Palampur on the influence of vermicompost and split applied nitrogen in pole French bean. Twelve treatment combinations comprising of organic manures, nitrogen fertilization and methods of application were evaluated. The performance of yield and yield related traits increased significantly with application of vermicompost, 125% of recommended nitrogen through split application. Use of vermicompost + 125% nitrogen resulted in highest seed yield (10.43 q/ha) and NPK uptake. Seed yield and NPK uptake with application of vermicompost + 75% N was at par with that of recommended application of N indicating thereby saving of 25% of nitrogen fertilizers. Split applied nitrogen at 125% of recommended dose resulted in 50% increase in seed yield over basal application. Hence, application of vermicompost and split applied nitrogen is a better option to harness high seed productivity and to maintain soil fertility.

**Key words:** Interactions, Nitrogen levels, Nutrient uptake, *Phaseolus vulgaris* L., Seed yield, Split application, Vermicompost.

## INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the popular and nutritious crops among leguminous vegetables across the world. It is consumed as green pods and shell beans and is quite rich source of protein, vitamins, calcium and iron (Sharma *et al.*, 2016). Beans have traditionally been grown in the humid sub temperate regions of the north western Himalayas comprising Himachal Pradesh, Uttarakhand and Jammu & Kashmir and have great potential for its commercial cultivation. It is grouped into bush and pole type on the basis of growth habit. The bush type cannot be cultivated effectively during rainy season as rotting of pods occurs while coming in contact with soil. Hence, pole type finds favour as off-season crop in mid hills of Himachal Pradesh having high rainfall. The pods are available in the rainy season and find ready market in the plains bringing lucrative returns to the growers.

Presently, the hill farmers are indiscriminately using chemical fertilizers due to lack of knowledge. The use of chemical fertilizers to enhance soil fertility and crop productivity has often negatively affected the complex system of biogeochemical cycles (Sharma *et al.*, 2014 a). The leaching and run-off losses of nutrients applied through fertilizers lead to environmental degradation like toxicity, deterioration of physical properties of soil, poor aeration resulting in decreased productivity. Therefore, there must be a balance between optimal nutrient use efficiency and optimal crop productivity (Roberts, 2008). It is pertinent to mention that the addition of chemical fertilizers in French bean is recommended as basal application. However, in areas with heavy monsoon rainfall, there is a risk in pre-monsoon nitrogen fertilization as most of the nitrates would leach and won't be available in the later growing period. Denitrification, leaching and volatilization may result in loss of productivity and negative environmental impact. Split nitrogen application is one way to tackle these challenges. Splitting the application of nitrogenous fertilizers can improve nitrogen use efficiency and result in better quality and quantityof the harvest.

In the present scenario, interest has been generated in environmentally sustainable agricultural practices to decrease negative impacts resulting from inefficient use of chemical fertilizers by following integrated use of organic manures and mineral fertilizers. Addition of organic manure is the prime necessity for maintaining soil fertility and sustained productivity. This will in turn help to meet the nutrient requirement of the crops as well as maintaining sustainability in terms of productivity and soil health. Further, no systematic research has been done particularly in pole type french bean to study the influence of integrated nutrient management and split applied nitrogen on seed yield and its related traits under wet temperate conditions of north western

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Himalayan region. Hence, the present study was undertaken to evaluate the effect of vermicompost, and different levels of nitrogen along with its method of application on the performance of pole type French bean.

## MATERIALS AND METHODS

The experiment was conducted during summer seasons of 2008 and 2009 at the Vegetable Research Farm of CSK Himachal Pradesh Agricultural University, Palampur. The site is situated at $32^0$ 62 N longitude and $76^0$ 32 E latitude having an altitude of 1291 m above mean sea level in the north-western Himalayan region and is characterized by humid sub-temperate climate with high rainfall (2500 mm). The soil is clay loam with pH 5.6 and is taxonomically classified as Typic Hapludalf. The organic carbon content was 0.92 per cent and available N, P and K contents were 227, 21 and 176 kg/ha, respectively. The experiment consisted of 12 treatment combinations comprising two levels of organic manures *viz.*, farmyard manure @ 20 t/ha ($M_1$) and vermicompost @ 10 t/ha ($M_2$), three levels of nitrogen fertilization *i.e.* 75% ($N_1$), 100% ($N_2$) and 125% ($N_3$) of the recommended dose and two levels of method of application *i.e.* full N as basal dose ($A_1$) and split application of N in two equal halves ($A_2$) {half as basal dose and remaining half one month after sowing}. The experiment was conducted in factorial randomized block design with three replications. The variety 'Luxmi' was sown in 4.0 m × 2.7 m plots at spacing of 100 cm between rows and 15 cm between plants on June 14 and June 16 in the first and second year, respectively. The crop was grown over trellises to provide support to the plants. Organic manures (farmyard manure and vermicompost) were incorporated manually into the soil one week prior to sowing in the respective plots as per treatments. The vermicompost was prepared using cow dung, *Lantana camara* and different crop biomass with the use of *Eudrilus euginie* species of earthworms and it contained 1.9% N, 0.92% P and 0.62% K. The farmyard manure contained 0.55% N, 0.3% P and 0.5% K. The recommended rate (100%) of N, $P_2O_5$ and $K_2O$ is 50, 100 and 50 kg/ha, respectively in French bean in Himachal Pradesh (Thakur *et al.*, 2009). Full dose of P and K were given at the time of sowing while N was applied as per treatments. N, P and K were applied through calcium ammonium nitrate, single super phosphate and muriate of potash, respectively. Irrigation was provided prior to sowing and later at 10 days interval during initial growth stages until monsoon rains arrived. Pendimethalin @ 1.5 kg ai/ha was applied immediately after sowing to manage the weeds followed by two hand weedings at 40 and 65 days of sowing.

Five plants were randomly tagged in each treatment for recording data on different growth and yield related attributes namely, branches/plant, pod length (cm), seeds/pod, plant height (m) and pods/plant. Seed and straw yields (kg) were recorded on plot basis and converted to tonnes/ha. The crop was harvested manually and took around 110 days for seed maturity from sowing date. The nutrient uptake by seed and straw was calculated separately and was summed up to calculate the total nutrient uptake and was calculated as:

Nutrient uptake (kg $ha^{-1}$) = Concentration (%) of nutrient × yield on dry weight basis (kg $ha^{-1}$)

Soil samples were collected at completion of the experiment and analyzed for change in available N, P and K status using standard methods (Jackson, 1973). Mean values of all observations of each year were statistically analyzed using the F-test (Gomez and Gomez, 1984). The data of the two years on each character under study were pooled using standard statistical procedures.

## RESULTS AND DISCUSSION

The application of vermicompost resulted in significantly better performance of seed yield attributing traits namely, branches/plant, pod length, seeds/pod, plant height and pods/plant over farmyard manure during both the years and pooled over years (Table 1). This superior performance of yield attributing traits through vermicompost application resulted in significant higher seed yield to the tune of 22 per cent over farmyard manure application in pooled years along with higher straw yield and biological yield (Table 2). The superiority of vermicompost over farmyard manure might be due to its nutritional richness, quick mineralization and more availability of nitrogen and other plant nutrients (Mujahid and Gupta, 2010). The organic manures have the ability to improve soil microbial activity which in turn plays a significant role in nitrogen fixation and phosphate mobilization. Thus, the increased nutrient availability and uptake might have helped in better growth and yield (Korwar *et al.,* 2006) through application of vermicompost. The poor response of farmyard manure might be attributed to its poor quality especially high carbon to nitrogen ratio. In general, it contains less than one per cent of total N (Jonah *et al.,* 2012).

The performance of seed yield and related traits increased significantly with increased levels of nitrogen in both the years and pooled over years (Table1 and 2). Application of 125 per cent nitrogen over recommended dose (100% N) resulted in maximum seed yield. The per cent increase being 7% over the recommended nitrogen application in pooled years (Table 2). However, nitrogen application above a threshold amount may cause decrease in these parameters (Tan and Serin, 1995) but crop in this experiment reacted positively to higher levels of nitrogen because the soil of the experimental region is medium in nitrogen and organic matter. Increase in seed yield was not due to increase in any single factor but it was due to improvement in different growth and yield parameters of this crop which resulted in increased photosynthetic active area and its efficiency to utilize solar radiation. Better performance of different parameters by the application of higher dose of nitrogen may be due to the fact that plant

**Table 1:** Effect of organic manures, different doses of nitrogen and their method of application on different growth parameters of pole French bean.

| Treatment | Branches/plant | | | Pod length (cm) | | | Seeds/pod | | | Plant height (m) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool |
| Organic manure | | | | | | | | | | | | |
| Farmyard manure | 2.31 | 2.07 | 2.19 | 10.85 | 9.48 | 10.17 | 5.95 | 6.04 | 6.0 | 2.39 | 2.10 | 2.25 |
| Vermicompost | 2.56 | 2.27 | 2.41 | 12.21 | 10.94 | 11.57 | 6.87 | 6.83 | 6.85 | 2.73 | 2.23 | 2.48 |
| CD (P≤0.05) | 0.17 | 0.11 | 0.10 | 0.33 | 0.28 | 0.21 | 0.23 | 0.24 | 0.18 | 0.03 | 0.03 | 0.02 |
| N application (per cent of recommended dose) | | | | | | | | | | | | |
| 75 | 2.39 | 2.15 | 2.27 | 11.42 | 10.38 | 10.90 | 6.31 | 6.39 | 6.35 | 2.63 | 2.18 | 2.40 |
| 100 | 2.48 | 2.19 | 2.33 | 11.62 | 10.50 | 11.06 | 6.63 | 6.54 | 6.58 | 2.56 | 2.16 | 2.36 |
| 125 | 2.44 | 2.16 | 2.30 | 11.54 | 9.75 | 10.65 | 6.30 | 6.38 | 6.34 | 2.49 | 2.14 | 2.32 |
| CD (P≤0.05) | NS | NS | NS | NS | 0.34 | 0.26 | 0.29 | NS | NS | 0.03 | 0.03 | 0.02 |
| Method of N application | | | | | | | | | | | | |
| Basal (BD) | 2.41 | 2.16 | 2.28 | 11.50 | 10.04 | 10.77 | 6.29 | 6.37 | 6.33 | 2.50 | 2.15 | 2.33 |
| Split | 2.46 | 2.18 | 2.32 | 11.56 | 10.38 | 10.97 | 6.53 | 6.50 | 6.52 | 2.62 | 2.17 | 2.40 |
| CD (P≤0.05) | NS | NS | NS | NS | 0.28 | NS | 0.23 | NS | 0.18 | 0.03 | NS | 0.02 |

**Table 2:** Effect of organic manures, different doses of nitrogen and their method of application on different yield parameters of pole French bean

| Treatment | Pods/plant | | | Straw yield (t/ha) | | | Seed yield (t/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool |
| Organic manures | | | | | | | | | |
| Farmyard manure | 31.74 | 21.54 | 26.64 | 1.46 | 1.12 | 1.29 | 0.88 | 0.65 | 0.76 |
| Vermicompost | 40.96 | 29.64 | 35.30 | 1.80 | 1.29 | 15.48 | 1.12 | 0.75 | 0.93 |
| CD (P≤0.05) | 1.27 | 1.14 | 0.92 | 0.08 | 0.04 | 0.50 | 0.03 | 0.03 | 0.02 |
| N application (per cent of recommended dose) | | | | | | | | | |
| 75 | 36.35 | 28.40 | 32.38 | 1.71 | 1.40 | 1.56 | 1.03 | 0.81 | 0.92 |
| 100 | 36.23 | 26.07 | 31.15 | 1.70 | 1.23 | 1.46 | 1.02 | 0.71 | 0.87 |
| 125 | 36.48 | 22.29 | 29.38 | 1.48 | 0.99 | 1.23 | 0.95 | 0.57 | 0.76 |
| CD (P≤0.05) | NS | 1.39 | 1.13 | 0.10 | 0.05 | 0.06 | 0.03 | 0.03 | 0.02 |
| Method of N application | | | | | | | | | |
| Basal(BD) | 34.82 | 24.01 | 29.42 | 1.60 | 1.15 | 1.38 | 0.96 | 0.66 | 0.81 |
| Split | 37.89 | 27.16 | 32.52 | 1.66 | 1.26 | 1.46 | 1.04 | 0.73 | 0.89 |
| CD (P≤0.05) | 1.27 | 1.14 | 0.92 | NS | 0.04 | 0.05 | 0.03 | 0.03 | 0.02 |

growth is stimulated by nitrogen supply since the crop has poor nodulation (Lad *et al.*, 2014).

Regarding method of application, it was observed that split application of nitrogen resulted in significant better performance of seed yield and other related traits over basal nitrogen application alone during both the years (Table 1 and 2).The increase in seed yield was to the extent of 37 % over basal application which might be ascribed to the fact that nitrogen is required throughout the growth period particularly of beans with indeterminate growth habit and hence adequate and regular nitrogen supply is essential for better growth. It is likely that a significant portion of the basal applied N might have lost through leaching and denitrification due to monsoon rains and during this high rainfall period. Therefore, split nitrogen application during pre-monsoon and monsoon period might have resulted in better growth and ultimately leading to higher seed and straw yield. By applying a portion of the N at later stage might have resulted in better utilization of nutrients thereby, leading to get more output from fertilizer investment and simultaneously lessening the fertilizer losses that can contribute to environmental pollution (Ahmad *et al.,* 1999).

Interaction effect of organic manure and nitrogen application revealed that at each level of N, seed yield was significantly increased with the conjoint application of vermicompost and N application over the combined application of farm yard manure and nitrogen application in pooled years (Table 5). The combined use of vermicompost and 125 per cent nitrogen resulted in highest seed yield that was 7% higher over farmyard manure + 125 per cent N application and 50% higher over recommended dose of farmyard manure + N (100%). The seed yield with the application of vermicompost + 75 per cent N was at par with that of recommended application (farmyard manure + 100% N) resulting net saving of 25 per cent synthetic nitrogen fertilizers with the use of vermicompost. Similar trend was also observed for straw yield and biological yield. Thus, increased rate of photosynthetic and symbiotic activity following balanced application of nitrogen and vermicompost, stimulated better vegetative and reproductive growth of the crop resulting in higher yields (Kumawat *et al.,* 2013). Better performance of vermicompost might be attributed to readily available plant nutrient, growth enhancing substances and number of beneficial organisms like $N_2$ fixing and P solubilising and cellulose decomposing organisms (Bark and Gulati, 2009).This enhanced performance through addition of organic manures and inorganic fertilizers might be due to the increased availability of nutrients to plants, improvement in soil physical conditions and maintaining the soil microbial populations while the inorganic fertilizers alone might have adverse effects on microbial strains and ultimately on the nutrient availability (Vashist and Sharma, 2003). Besides, manures increase water retention capacity of soil for longer time (Jaga and Upadhyay, 2013). The higher yields in treatments supplemented with vermicompost could be the result of regulated release and balanced supply of nutrients, tilting microbial dynamics in favour of growth and creation of salutary soil environmental conditions for crop growth (Sharma *et al.,* 2014 a). In addition, besides its better nutrient contents, it could have increased the efficiency of added chemical fertilizer by its temporary immobilization which might have reduced leaching loss of plant nutrients (Das *et al.,* 2006).

Interaction effect of rate and time of N application was found significant (Table 6). The highest seed yield was noticed through split application of 125 per cent nitrogen, 8% higher over 100 per cent N as split application while there was 50% increase over recommended N application (100%) as basal dose only. Similarly, increase in straw yield and biological yield were observed through split application of N as compared to the whole application of N as basal dose. This indicates that split application improves nitrogen use efficiency along with reduction in leaching losses and hence, the crop received balanced nitrogen supply during its growth and development. The application of N in split doses would also optimize the overall plant growth because of the availability of more photo-assimilates. Similarly, split application of nitrogen with increasing levels significantly resulted in higher nutrient uptake over nitrogen applied as basal dose (BD) alone (Table 6). The highest N, P and K uptake was observed through split application of 125 per cent nitrogen.

Total uptake of N, P and K nutrients by plants increased significantly with the application of vermicompost as compared to farmyard manure and also through split application of nitrogen over basal application only (Table 3). The buildup of soil fertility in terms of available N, P and K was significantly higher through vermicompost application in comparison to farmyard manure but there was no effect at different levels of nitrogen application and method of N application (Table 4). Application of manures improve the soil structure, aeration, buffering capacity, water holding capacity, influences solubility of the mineral and provide energy for growth and development of microorganisms (Sharma *et al.* 2014 b). All these may lead to increase in nutrients (N, P and K) availability of soil in the plot receiving vermicompost application.

As regards interaction effect, uptake of N, P and K by the crop increased significantly through the combined application of vermicompost and N over the use of farmyard manure and nitrogen application. The integrated application of vermicompost and 125 per cent nitrogen increased uptake of N, P and K by 35%, 49% and 45% over recommended dose of farmyard manure + N (100%), respectively (Table 5). The N, P and K uptake through application of vermicompost + 75 per cent N was at par with that of recommended application (farmyard manure + 100% N) revealing 25% saving of synthetic nitrogen fertilizers through vermicompost application. This might be due to higher content of nutrients

**Table 3:** Effect of organic manures, different doses of nitrogen and their method of application on plant nutrient uptake in pole French bean

| Treatment | N uptake (kg/ha) | | | P uptake (kg/ha) | | | K uptake (kg/ha) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool | 1st year | 2nd year | Pool |
| Organic manure | | | | | | | | | |
| Farmyard manure | 65.83 | 49.84 | 57.83 | 31.69 | 21.89 | 26.79 | 33.84 | 25.73 | 29.79 |
| Vermicompost | 83.46 | 57.76 | 70.61 | 41.79 | 25.96 | 33.87 | 44.69 | 30.28 | 37.49 |
| CD (P≤0.05) | 2.87 | 1.93 | 1.87 | 2.54 | 1.69 | 1.63 | 2.32 | 1.11 | 1.11 |
| N application (per cent of recommended dose) | | | | | | | | | |
| 75 | 77.25 | 62.26 | 69.76 | 37.26 | 26.19 | 31.72 | 39.25 | 32.16 | 35.71 |
| 100 | 76.81 | 55.30 | 66.06 | 38.20 | 25.16 | 31.68 | 41.05 | 28.79 | 34.92 |
| 125 | 69.87 | 43.84 | 56.85 | 34.75 | 20.42 | 27.59 | 37.49 | 23.06 | 30.28 |
| CD (P≤0.05) | 3.52 | 2.36 | 2.29 | NS | 2.07 | 2.0 | NS | 1.36 | 1.36 |
| Method of N application | | | | | | | | | |
| Basal (BD) | 72.17 | 51.02 | 61.59 | 35.16 | 22.62 | 28.89 | 37.61 | 26.45 | 32.03 |
| Split | 77.12 | 56.59 | 66.85 | 38.32 | 25.22 | 31.77 | 40.92 | 29.56 | 35.24 |
| CD (P≤0.05) | 2.87 | 1.93 | 1.87 | 2.54 | 1.69 | 1.63 | 2.32 | 1.11 | 1.11 |

**Table 4:** Effect of organic manures, different doses of nitrogen and their method of application on available nutrient status of soil

| Treatment | Organic carbon(%) | Available N ( kg ha$^{-1}$) | Available P ( kg ha$^{-1}$) | Available K ( kg ha$^{-1}$) |
|---|---|---|---|---|
| Organic manure | | | | |
| Farmyard manure | 1.01 | 212.92 | 23.20 | 273.55 |
| Vermicompost | 1.02 | 239.02 | 26.94 | 287.37 |
| CD (P≤0.05) | NS | 10.93 | 0.90 | 6.12 |
| N application (per cent of recommended dose) | | | | |
| 75 | 1.01 | 224.79 | 24.93 | 278.73 |
| 100 | 1.02 | 225.84 | 25.02 | 281.15 |
| 125 | 1.02 | 227.27 | 25.27 | 281.51 |
| CD (P≤0.05) | NS | NS | NS | NS |
| Method of N application | | | | |
| Basal (BD) | 1.00 | 224.55 | 23.13 | 275.56 |
| Split | 1.03 | 227.05 | 25.01 | 282.57 |
| CD (P≤0.05) | NS | NS | NS | NS |

**Table 5:** Interaction effect of organic manures and nitrogen application on yield parameters and nutrient uptake of pole French bean in pooled over years

| Treatments | Seed yield (t/ha) Nitrogen levels | | | Straw yield (t/ha) Nitrogen levels | | | Biological yield (t/ha) Nitrogen levels | | |
|---|---|---|---|---|---|---|---|---|---|
| Organic manures | 75 | 100 | 125 | 75 | 100 | 125 | 75 | 100 | 125 |
| Farmyard manure | 0.66 | 0.79 | 0.84 | 1.11 | 1.36 | 1.40 | 1.77 | 2.15 | 2.24 |
| Vermicompost | 0.78 | 0.98 | 1.04 | 1.33 | 1.56 | 1.75 | 2.12 | 2.54 | 2.79 |
| CD (P≤0.05) | - | - | 0.03 | - | - | 0.09 | - | - | 0.11 |
| **Treatments** | **N uptake (kg/ha)** Nitrogen levels | | | **P uptake (kg/ha)** Nitrogen levels | | | **K uptake (kg/ha)** Nitrogen levels | | |
| Organic manures | 75 | 100 | 125 | 75 | 100 | 125 | 75 | 100 | 125 |
| Farmyard manure | 48.73 | 60.29 | 64.49 | 20.73 | 27.93 | 31.70 | 23.57 | 31.39 | 34.20 |
| Vermicompost | 58.04 | 72.65 | 81.14 | 25.0 | 34.97 | 41.66 | 28.72 | 37.99 | 45.75 |
| CD (P≤0.05) | - | - | 3.24 | - | - | 2.83 | - | - | 2.71 |

**Table 6:** Interaction effect of different nitrogen levels and method of N application on yield parameters and nutrient uptake of pole French bean in pooled over years

| Treatments | Seed yield (t/ha) Nitrogen levels | | | Straw yield (t/ha) Nitrogen levels | | | Biological yield (t/ha) Nitrogen levels | | |
|---|---|---|---|---|---|---|---|---|---|
| Application method | 75 | 100 | 125 | 75 | 100 | 125 | 75 | 100 | 125 |
| Basal (BD) | 0.63 | 0.74 | 0.78 | 1.08 | 1.17 | 1.30 | 1.70 | 1.91 | 2.08 |
| Split | 0.82 | 1.02 | 1.10 | 1.36 | 1.75 | 1.84 | 2.18 | 2.78 | 2.95 |
| CD (P≤0.05) | - | - | 0.03 | - | - | 0.09 | - | - | 0.11 |
| **Treatments** | **N uptake (kg/ha)** Nitrogen levels | | | **P uptake (kg/ha)** Nitrogen levels | | | **K uptake (kg/ha)** Nitrogen levels | | |
| Application method | 75 | 100 | 125 | 75 | 100 | 125 | 75 | 100 | 125 |
| Basal (BD) | 46.18 | 54.02 | 59.69 | 19.65 | 25.53 | 29.66 | 22.29 | 28.17 | 32.39 |
| Split | 60.60 | 78.92 | 85.94 | 26.08 | 37.37 | 43.70 | 30.0 | 41.42 | 47.56 |
| | - | - | 3.24 | - | - | 2.83 | - | - | 1.91 |

at this level, which is the result of root proliferation by stimulating the cellular activities and translocation of certain growth stimulating compounds to roots (Sharma and Sharma, 2016). Thus, the extensive root system development with the balanced fertilization along with organic manures in adequate amount might have assisted the efficient absorption of water and utilization of other nutrients owing to the improvement in the soil physical conditions and biological environment with the addition of organic material (Sutaria *et al.,* 2010; Sharma *et al.,* 2014 a; Sharma *et al.,* 2016). Application of organic manures helps in solublization of nutrients due to chelating effect of complex intermediate organic molecules as produced during decomposition (Laxminarayan and Patiram, 2005). Application of organic amendments may increase supply of macro- and micro-nutrients to plants and could mobilize unavailable nutrients to available forms, and as a cumulative effect, nutrient uptake is higher than synthetic fertilizers (Sharma *et al.,* 2008).

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