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# EFFECTS OF VERMICOMPOST, FERTILIZER AND MULCH ON PLANT GROWTH, NODULATION AND POD YIELD OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.)

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Summary

Integration of vermicompost and organic mulch as elements of vegetable production system sustain soil fertility and crop productivity. A field experiment was conducted with the objective to investigate the effects of vermicompost, NPK fertilizer and organic mulch on crop growth, nodulation and pod yield of French bean (*Phaseolus vulgaris* L.) with an ultimate aim of optimizing water and nutrient requirement in mild-tropical climate during dry season. The shoot growth traits, namely shoot length, number of primary branches, shoot fresh weight and shoot dry weight were increased by 28-63% through application of N $P_2O_5$ $K_2O$ 8:13:10 kg·ha$^{-1}$ + vermicompost 3.75 t·ha$^{-1}$ and by 5-50% in organic mulching treatments. Application of vermicompost reduced nodule fresh weight and nodule dry weight by 44.9 and 44.5%, respectively. Likewise, corresponding nodule number, nodule fresh weight and nodule dry weight were reduced by 8.6, 11.1 and 14.1% with organic mulching. Poor nodulations might be due to reduced oxygenation of the soils under vermicompost and organic mulch which is ultimately impeding the nitrogenase activity and biological nitrogen fixation. Mulching of French bean with dried grasses and crop residues are also led to higher single pod weight, pod length, pod weight/plant and pod yield by 10.9, 12.8, 20.1 and 20.2%, respectively. Present study shows that application of N $P_2O_5$ $K_2O$ fertilizer 8-15:13-25:10-20 kg·ha$^{-1}$, vermicompost 2.50-3.75 t·ha$^{-1}$, 4 cm thick mulch of dried crop residues and 50% irrigation is the most suitable and sustainable strategy to improve plant growth, pod formation and pod yield of French bean, and soil health of mild-tropical climate during dry season.

key words: French bean (*Phaseolus vulgaris*), mulching, vermicompost, nodulation, pod yield, split plot design (SPD)

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## INTRODUCTION

French bean (*Phaseolus vulgaris* L.) is one of the most widely cultivated vegetable crops for their tender pods and fresh seeds in Mizoram as well as North East states of India. It is grown during the winter, spring and rainy seasons. The pod yield during winter period is limited by acute soil moisture stress caused by high rate of evapo-transpiration, almost no rain from November-March and low water holding capacity of the sloppy land; despite optimum temperature and appropriate length of day for crop growth, flowering and pod formation. Higher frequency of irrigation could be used to alleviate soil moisture stress. However, the acute shortage of irrigation water in this region necessitates its economy. One way of achieving this is by mulching with crop-forest residues. Integration of vermicompost along with NPK fertilizers is another way to sustain the productivity by using the local organic crop-plant-forest wastes. Humans, livestock and crops-plants-forest produce approximately 600 to 700 million metric tons of agricultural wastes (including 272 million metric tons of crop-plants-forest residues) in India every year, but most remains unutilized (Suthar 2009). In most parts of Mizoram and the North East Hill Regions of India, forest and crop-plant residues are available in abundant. These organic residues could be converted into nutrient rich vermicompost and used as mulch to sustain the vegetable productivity.

Mulch improves the soil environment; stimulates microbial activity; enhances oxygen availability to roots; moderates soil temperature; increases soil porosity and water infiltration; increases nutrient availability; reduces evaporation, fertilizer leaching and soil compaction; controls weeds, runoff and soil erosion; and increases plant growth, yield and quality (Bhatt & Khera 2006, Anikwe *et al*. 2007, Sarkar & Singh 2007, Sarkar *et al*. 2007, Glab & Kulig 2008, Liasu *et al*. 2008, Ekinci & Dursun 2009, Rashidi *et al*. 2009, Arora *et al*. 2011, Vanlalhluana & Sahoo 2011). Vermicompost is an eco-friendly, cost effective and ecologically sound bio-fertilizer. Use of vermicompost is effective for improving soil aggregation, structure, aeration and fertility; contains most of the nutrients in plant-available form such as nitrates, phosphates, exchangeable calcium and soluble potassium; increases beneficial microbial population diversity and activity; improves soil moisture-holding capacity; contains vitamins, enzymes and hormones; and accelerates the population and activity of earthworms (Aggelides & Londra 1999, Mascolo *et al*. 1999, Albiach *et al*. 2000, Marinari *et al*. 2000, Sailajakumari & Ushakumari 2002, Arancon *et al*. 2006, Prabha *et al*. 2007, Azarmi *et al*. 2008). Vermicompost has a significant positive influence on seed germination and seedling vigor, plant growth, flowering, fruiting, tuberization, root development, colour, shelf-life and quality of vegetables (Atiyeh *et al*. 2001, Suthar *et al*. 2005, Arguello *et al*. 2006, Alam *et al*. 2007, Ansari 2008, Gupta *et al*. 2008, Peyvast *et al*. 2008, Premsekhar & Rajashree 2009, Suthar 2009, Chanda *et al.* 2011).

Poor soil respiration and complete destruction of natural decomposer communities from agro-ecosystems threatens sustainability as well as food security. Similarly, escalation in cost of chemical fertilizers (particularly N, P and K) and irrigation water, reduced water table, higher cost of fertilizer transportation in hilly regions of North East India, and ecological concerns toward natural resources management and human health have increased interest of use of integrated approaches for sustainable production. Keeping these in view, the study was undertaken to ascertain effects of vermicompost, fertilizer and mulching on crop growth, nodulation and green pod yield of French bean during dry conditions.

## MATERIALS AND METHODS

The experiment was carried out at the Research Farm, ICAR Research complex for NEH Region, Mizoram Centre, Kolasib, Mizoram (24º12' N, 92º40' E and 650 m above sea level) during 2009-2010. The soil type is an Alfisol and acidic in soil reaction (pH 5.8). The terraced field was tilled and divided into plots (4 × 2.5 m). A 60 cm wide space was left between plots. The experiment was laid-out in split plot design (SPD) with three replications. The treatments comprised five nutrition regimes (N1: N $P_2O_5$ $K_2O$ 30:50:40 kg·ha$^{-1}$, N2: N $P_2O_5$ $K_2O$ 22.5:37.5:30 kg·ha$^{-1}$ + vermicompost 1.25 t·ha$^{-1}$, N3: N $P_2O_5$ $K_2O$ 15:25:20 kg·ha$^{-1}$ + vermicompost 2.5 t·ha$^{-1}$, N4: N $P_2O_5$ $K_2O$ 7.5:12.5:10 kg·ha$^{-1}$ + vermicompost 3.75 t·ha$^{-1}$ and N5: vermicompost 5 t·ha$^{-1}$) in the main-plots, and two mulching treatments such as without-mulch and organic mulch in the sub-plots. The N1 treatment contains N $P_2O_5$ $K_2O$ 30:50:40 kg·ha$^{-1}$, i.e. rate of nutrients. Vermicompost was prepared from crop residues and 15 day-old cow-dung in 1:4 ratios using red crawler earthworm (*Eisenia foetida*) under shed-net. The uniform dose of FYM 3.0 t·ha$^{-1}$ and lime 2 t·ha$^{-1}$ was applied to the each plots at last tilling. The fertilizers (N, P and K) were supplied by urea, single superphosphate (SSP) and muriate of potash (MOP), respectively and mixed thoroughly during plot preparation. Locally available dried grasses and crop residues were used as mulch (4 cm thick) and mulching was done at 15 days after sowing. The seeds of French bean cv. Arka Komal were sown in lines spaced at 40 cm during second week of November 2009. Plants were thinned, to maintain the plant to plant spacing of 10 cm, at 20 days after sowing. All the treatments received only 50% irrigation. During the crop period (November-25$^{th}$ March), a total rainfall of 2 mm was received.

All observations were recorded on 15 randomly chosen plants, other than root related parameters, in each treatment and replication. Data on days to 50% flowering were, however, taken on the whole plot basis. Shoot length, primary branches, trifoliate number and related growth parameters were measured at full-bloom stage. To estimate the leaf area, leaf weight and specific leaf weight, the leaves of 3$^{rd}$, 4$^{th}$ and 5$^{th}$ trifoliate from plants were sampled at full-bloom stage in each replication. Root weight, root length, nodule number and nodule weight were recorded by uprooting 10 plants form each replication at full-bloom stage. The pods were picked in the green maturity stage, counted, measured and weighed to determine total yield. Plot means were computed, and were subjected to analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) using IRRISTAT software (Version 3/93, Biometrics Unit, International Rice Research Institute, Manila, Philippines) to identify homogeneity of data between treatment combinations.

## RESULTS AND DISCUSSION

The partitioning of estimates of analysis of variation (ANOVA) into main-plot (nutrition), sub-plot (mulching), and interaction between main-plot and sub-plot revealed that mean squares due to nutrition were significant for all the traits, apart from days to 50% flowering, root length, root dry weight and nodule number, which are indicating that various levels of N $P_2O_5$ $K_2O$ fertilizers and vermicompost affecting the plant growth and productivity (Table 1). All the traits, other than number of trifoliate and leaf, and pod number per plant, were significantly affected by organic mulch showing the importance of mulching in growth and yield of bean.

### Effect of vermicompost, fertilizer and mulching on plant growth and nodulation of French bean

The various combinations of nutrition significantly affect the shoot length, number of primary branches, shoot fresh weight, shoot dry weight, root fresh weight, nodule fresh weight and nodule dry weight; nevertheless days to 50% flowering, root length, root dry weight and number of nodule per plant were not affected by nutrition (Table 2). Moreover all the parameters of growth and nodulation were significantly affected by mulching with dried grasses and crop residues.

Days to 50% flowering was extended by three days by application of mulch. This is only due to higher vegetative growth delayed the reproductive phase. The traits related to aboveground plant growth, namely shoot length, number of primary branches, shoot fresh weight and shoot dry weight were measured maximum, i.e. increased by 28-63% in N4 treatment (25% rate of nutrients + vermicompost 3.75 $t \cdot ha^{-1}$) and 5-50% higher in mulching plots. The proper balance of organic and inorganic nutrients and uniform moisture and temperature regimes by organic mulching provided a better conducive rhizospheric condition and in turn helped the plants to boost their growth remarkably. These results show that increase in plant growth could probably be due to improvement in the physio-chemical properties of soil, increase in enzymatic activity, increase in microbial population and activity and easy availability of macro- and micronutrients by application of vermicompost and organic mulching (Mascolo *et al*. 1999, Albiach *et al*. 2000, Arancon *et al*. 2006, Prabha *et al*. 2007, Azarmi *et al*. 2008, Ekinci & Dursun 2009).

Root length, root fresh weight and root dry weight were measured significantly higher (32.1, 29.0 and 17.5%, respectively) in mulching treatment. The root growth intensity was comparatively lower for dry weight than root length and root fresh weight. It is interesting to note that nodulation parameters, namely nodule number, nodule fresh weight and nodule dry weight were reduced drastically by application of vermicompost and organic mulching, apart from nodule number by vermicompost. Vermicompost reduced nodule fresh weight and nodule dry weight by 44.9 and 44.5%, respectively. Similarly, corresponding nodule number, nodule fresh weight and nodule dry weight were reduced by 8.6, 11.1 and 14.1% with organic mulching. Decrease in nodulation upon application of vermicompost could have been caused by overtaking of the rhizosphere by fungi over bacteria which might now have to compete for the carbon source with the fungi for multiply to achieve a population count that is optimal for host infection. We believe that in our case the fungi might be aiding the growth more than the rhizobacteria that is nutritional advantage of fungi overtakes nitrogen fixation advantage of bacteria. As for negative effect of mulching on nodulation, might be due to reduced oxygenation of the soils that are already acidic and not very congenial for bacterial reproduction and survival.

**Effect of vermicompost, fertilizer and mulching on leaf growth of French bean**

The parameters related to leaf growth were significantly influenced by nutrition dosages and mulching, except number of trifoliate and leaves by organic mulching (Table 3). The N4 treatment (25% rate of nutrients + vermicompost 3.75 $t \cdot ha^{-1}$) was observed maximum trifoliate, leaves, leaf area and leaf weight, in general, which was at par with N3 treatment (50% rate of nutrients + vermicompost 2.50 $t \cdot ha^{-1}$). This might be due to beneficial effects of vermicompost. Leaf area and leaf weight was increased by 11-26% by organic mulching. Hence, the results emphasize the integration of organic sources of nutrition and mulching will provide maximum area for $CO_2$ fixation and in turn helped the plants to boost their growth. Singh *et al.* (2010) and Adetunji (1990) have reported similar findings in tomato and lettuce, correspondingly. Specific leaf weight showed decreasing pattern by increasing the amounts of vermicompost and application of organic mulch. The finding clearly shows that vermicompost and organic mulching play an important role towards partitioning of photo-assimilates from vegetative source to reproductive sink (leaf to green pod) which will ultimately lead to development of yield attributes. The finding is close conformity with those of Singh *et al*. (2010) in tomato.
more with N3 followed by N2 and N4. The increased yield potential of vegetables through application of vermicompost and mulching has also confirmed by Singh *et al*. (2010), Suthar (2009) and Liasu *et al*. (2008).

Table 1. Analysis of variance (ANOVA) for plant growth, nodulation, pod formation and pod yield of French bean

| Source of variation | d. f. | Days to 50% flowering | Shoot length (cm) | No. of primary branches | Shoot FW ($g \cdot plant^{-1}$) | Shoot DW ($g \cdot plant^{-1}$) | Root length (cm) | Root FW ($g \cdot plant^{-1}$) | Root DW ($g \cdot plant^{-1}$) | No. of nodule/ plant | Nodule FW ($g \cdot plant^{-1}$) | Nodule DW ($mg \cdot plant^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 1.60 | 1.68 | 0.13 | 0.24 | 0.0032 | 0.60 | 0.0001 | 0.0001 | 0.93 | 4.23 | 0.92 |
| Main-plot (N) | 4 | 9.37 | 115.51** | 0.24** | 108.00** | 2.2917** | 5.12 | 0.0089** | 0.0011 | 6.25 | 3030.08** | 1434.35** |
| Error N | 8 | 3.52 | 0.12 | 0.01 | 0.83 | 0.0335 | 3.16 | 0.0008 | 0.0006 | 2.84 | 28.26 | 10.97 |
| Sub-plot (M) | 1 | 80.03** | 322.75** | 1.63** | 648.31** | 6.9437** | 210.67** | 0.1191** | 0.0099** | 42.96** | 875.88** | 669.30** |
| N × M | 4 | 0.37 | 25.45** | 0.08* | 21.60** | 0.4940** | 13.02** | 0.0120** | 0.0016** | 1.02 | 80.52** | 47.86* |
| Error M | 10 | 1.00 | 1.89 | 0.02 | 2.61 | 0.0739 | 0.43 | 0.0003 | 0.0002 | 3.64 | 11.01 | 8.85 |

| Source of variation | d. f. | No. of trifoliate | No. of leaf/plant | Leaf area ($cm^2 \cdot plant^{-1}$) | Leaf weight ($g \cdot plant^{-1}$) | Single leaf area ($cm^2$) | Single leaf weight (g) | Specific leaf weight ($mg \cdot cm^{-2}$) | No. of pods/plant | Single pod weight (g) | Pod length (cm) | Pod weight ($g \cdot plant^{-1}$) | Pod yield ($t \cdot ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replication | 2 | 0.04 | 0.33 | 134 | 0.04 | 1.14 | 0.0003 | 1.0 | 0.04 | 0.96 | 0.31 | 135 | 157 |
| Main-plot (N) | 4 | 1.53** | 13.69** | 77734** | 29.31** | 191.21** | 0.0553** | 128.6** | 13.34** | 3.72** | 15.09** | 2284** | 2620** |
| Error N | 8 | 0.08 | 0.69 | 175 | 1.69 | 3.61 | 0.0066 | 4.4 | 0.28 | 0.14 | 0.12 | 48 | 53 |
| Sub-plot (M) | 1 | 0.03 | 0.30 | 87999** | 19.52** | 342.73** | 0.0480* | 69.6** | 4.03 | 3.40** | 17.03** | 2087** | 2430** |
| N × M | 4 | 0.26 | 2.26 | 5745** | 0.57 | 24.83* | 0.0047 | 19.8** | 1.80 | 0.22 | 2.08** | 93 | 103 |
| Error M | 10 | 0.21 | 1.86 | 239 | 0.23 | 6.72 | 0.0053 | 1.2 | 0.95 | 0.18 | 0.32 | 141 | 164 |

N: nutrition level, M: mulching treatment

Table 2. Effect of nutrition and mulching on plant growth and nodulation of French bean

| Nutrition dosage | Days to 50% flowering | Shoot length (cm) | No. of primary branches | Shoot FW ($g \cdot plant^{-1}$) | Shoot DW ($g \cdot plant^{-1}$) | Root length (cm) | Root FW ($g \cdot plant^{-1}$) | Root DW ($g \cdot plant^{-1}$) | No. of nodule/ plant | Nodule FW ($g \cdot plant^{-1}$) | Nodule DW ($mg \cdot plant^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N1: 100 % rate of nutrients | 68.7 | 39.8 | 1.88 | 18.458 | 3.231 | 20.4 | 0.488 | 0.221 | 26.8 | 119.1 | 81.7 |
| N2: 75 % rate of nutrients + VC 1.25 $t \cdot ha^{-1}$ | 68.6 | 42.8 | 2.13 | 21.389 | 3.683 | 19.6 | 0.514 | 0.252 | 27.1 | 108.9 | 74.0 |
| N3: 50 % rate of nutrients + VC 2.50 $t \cdot ha^{-1}$ | 70.5 | 45.0 | 2.22 | 23.804 | 4.151 | 19.0 | 0.435 | 0.233 | 27.3 | 89.6 | 61.5 |
| N4: 25 % rate of nutrients + VC 3.75 $t \cdot ha^{-1}$ | 69.7 | 51.0 | 2.40 | 29.980 | 4.887 | 18.5 | 0.536 | 0.229 | 27.4 | 74.7 | 51.1 |
| N5: VC 5.00 $t \cdot ha^{-1}$ | 71.3 | 48.1 | 2.33 | 23.698 | 3.805 | 18.1 | 0.511 | 0.218 | 25.3 | 65.6 | 44.5 |
| SEm± | 0.9 | 0.1 | 0.04 | 0.372 | 0.075 | 0.7 | 0.012 | 0.011 | 0.7 | 2.2 | 1.4 |
| LSD at $P < 0.05$ | NS | 0.4 | 0.13 | 1.174 | 0.236 | NS | 0.037 | NS | NS | 6.8 | 4.3 |
| Non-mulching | 68.1 | 42.1 | 1.96 | 18.817 | 3.470 | 16.5 | 0.434 | 0.212 | 27.9 | 97.0 | 67.3 |
| Mulching | 71.3 | 48.6 | 2.43 | 28.114 | 4.432 | 21.8 | 0.560 | 0.249 | 25.5 | 86.2 | 57.8 |
| SEm± | 0.3 | 0.4 | 0.03 | 0.417 | 0.070 | 0.2 | 0.004 | 0.004 | 0.5 | 0.9 | 0.8 |
| LSD at $P < 0.05$ | 0.8 | 1.2 | 0.11 | 1.362 | 0.229 | 0.6 | 0.014 | 0.012 | 1.6 | 2.8 | 2.5 |

100 % rate of nutrients, i.e. N $P_2O_5$ $K_2O$ 30:50:40 $t \cdot ha^{-1}$, VC: vermicompost, FW: fresh weight, DW: dry weight

Table 3. Effect of nutrition and mulching on leaf growth of French bean

| Nutrition dosage | No. of trifoliate | No. of leaf/ plant | Leaf area ($cm^2 \cdot plant^{-1}$) | Leaf weight ($g \cdot plant^{-1}$) | Single leaf area ($cm^2$) | Single leaf weight (g) | Specific leaf weight ($mg \cdot cm^{-2}$) |
|---|---|---|---|---|---|---|---|
| N1: 100 % rate of nutrients | 4.68 | 14.0 | 307.8 | 8.4 | 21.9 | 0.601 | 27.3 |
| N2: 75 % rate of nutrients + VC 1.25 $t \cdot ha^{-1}$ | 4.92 | 14.8 | 448.1 | 12.4 | 30.3 | 0.854 | 27.7 |
| N3: 50 % rate of nutrients + VC 2.50 $t \cdot ha^{-1}$ | 5.77 | 17.3 | 472.0 | 12.4 | 27.3 | 0.717 | 26.3 |
| N4: 25 % rate of nutrients + VC 3.75 $t \cdot ha^{-1}$ | 5.78 | 17.3 | 624.4 | 14.4 | 36.5 | 0.862 | 23.1 |
| N5: VC 5.00 $t \cdot ha^{-1}$ | 5.05 | 15.2 | 504.9 | 11.0 | 33.5 | 0.710 | 21.8 |
| SEm± | 0.11 | 0.3 | 5.4 | 0.5 | 0.8 | 0.033 | 0.9 |
| LSD at $P < 0.05$ | 0.36 | 1.1 | 17.0 | 1.7 | 2.4 | 0.104 | 2.7 |
| Non-mulching | 5.21 | 15.6 | 417.3 | 10.9 | 26.5 | 0.710 | 26.1 |
| Mulching | 5.27 | 15.8 | 525.6 | 12.5 | 33.3 | 0.787 | 23.8 |
| SEm± | 0.12 | 0.4 | 4.0 | 0.1 | 0.7 | 0.019 | 0.3 |
| LSD at $P < 0.05$ | NS | NS | 13.0 | 0.4 | 2.2 | 0.062 | 0.9 |

100 % rate of nutrients, i.e. N $P_2O_5$ $K_2O$ 30:50:40 $t \cdot ha^{-1}$, VC: vermicompost

Table 4. Effect of nutrition and mulching on pod formation and pod yield of French bean

| Nutrition dosage | No. of pods/ plant | | | Single pod weight (g) | | | Pod length (cm) | | | Pod weight (g·plant$^{-1}$) | | | Pod yield (t/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Non-mulching | Mulching | Mean | Non-mulching | Mulching | Mean | Non-mulching | Mulching | Mean | Non-mulching | Mulching | Mean | Non-mulching | Mulching | Mean |
| N1 | 12.23cd | 13.23b | 12.73c | 5.67b | 5.90c | 5.78c | 10.50b | 11.60d | 11.05 | 69.17bc | 78.30b | 73.73c | 7.40bc | 8.40b | 7.90c |
| N2 | 14.23b | 15.30a | 14.77b | 6.10b | 6.90b | 6.50b | 12.43a | 14.83b | 13.63 | 87.27b | 111.17a | 99.22b | 9.37b | 11.93a | 10.65b |
| N3 | 16.33a | 15.20a | 15.77a | 7.13a | 8.23a | 7.68a | 13.10a | 16.17a | 14.63 | 109.73a | 125.20a | 117.47a | 11.73a | 13.43a | 12.58a |
| N4 | 13.37bc | 15.13a | 14.25b | 6.27b | 7.20b | 6.73b | 12.27a | 12.90c | 12.58 | 83.50bc | 109.20a | 96.35b | 8.93bc | 11.67a | 10.30b |
| N5 | 11.63d | 12.60b | 12.12c | 5.63b | 5.93c | 5.78c | 10.87b | 11.20d | 11.03 | 65.70c | 74.90b | 70.30c | 7.03c | 8.03b | 7.53c |
| Mean | 13.56 | 14.29 | - | 6.16 | 6.83 | - | 11.83 | 13.34 | - | 83.07 | 99.75 | - | 8.89 | 10.69 | - |
| Estimate | | SEm± | LSD at $P < 0.05$ | | SEm± | LSD at $P < 0.05$ | | SEm± | LSD at $P < 0.05$ | | SEm± | LSD at $P < 0.05$ | | SEm± | LSD at $P < 0.05$ |
| A | | 0.21 | 0.68 | | 0.15 | 0.48 | | 0.14 | 0.44 | | 2.82 | 8.89 | | 0.30 | 0.93 |
| B | | 0.45 | 1.48 | | 0.23 | 0.75 | | 0.27 | 0.88 | | 5.61 | 18.31 | | 0.60 | 1.96 |
| C | | 0.25 | NS | | 0.11 | 0.36 | | 0.15 | 0.48 | | 3.06 | 10.01 | | 0.33 | 1.08 |
| D | | 0.56 | 1.78 | | 0.24 | 0.77 | | 0.33 | 1.03 | | 6.85 | 21.61 | | 0.74 | 2.33 |

N1: 100 % rate of nutrients, N2: 75 % rate of nutrients + VC 1.25 t·ha$^{-1}$, N3: 50 % rate of nutrients + VC 2.50 t·ha$^{-1}$, N4: 25 % rate of nutrients + VC 3.75 t·ha$^{-1}$, N5: VC 5.00 t·ha$^{-1}$

100% rate of nutrients, i.e. N $P_2O_5$ $K_2O$ 30:50:40 kg·ha$^{-1}$, VC: vermicompost

A: estimate between two main-plots (Nutrition) treatment means

B: estimate between two main-plots (Nutrition) treatment means at the at the same or different levels of sub-plot treatment (Mulching)

C: estimate between two sub-plots (Mulching) treatment means

D: estimate between two sub-plots (Mulching) treatment means at the same level of main-plot treatment (Nutrition)

**Effect of vermicompost, fertilizer and mulching on pod formation and pod yield of French bean**

The pod related parameters such as pod number, single pod weight, pod length, pod weight/plant and pod yield life articulated significant differences by various sources of nutrients and mulch, apart from number of pods by mulch (Table 4). Maximum pod number, pod length, pod weight/plant and pod yield were observed with N3 treatment followed by N2, N4, N1 and N5 treatment. However, single pod weight was highest for N3 treatment followed by N4 and N2 and lowest for N1 and N5 treatment. Mulching of French bean with dried grasses and crop residues led to higher single pod weight, pod length, pod weight/plant and pod yield by 10.9, 12.8, 20.1 and 20.2%, respectively. The interactive effects of nutrients and mulch on green pod length were significantly

## CONCLUSION

The increased amount of humus in soil through application of vermincompost and decomposition of organic mulches by earthworms would certainly help favourable change in physical, chemical and biological properties of soil, and in enhancing the water-holding capacity. In conclusion, the present study shows that application of N $P_2O_5$ $K_2O$ fertilizer 8-15:13-25:10-20 $kg \cdot ha^{-1}$, vermicompost 2.50-3.75 $t \cdot ha^{-1}$, 4 cm thick mulch of dried crop residues and 50% irrigation is the most suitable and sustainable strategy to improve plant growth, pod formation and pod yield of French bean, and soil health of mild-tropical climate during dry season.

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## WPŁYW WERMIKOMPOSTU, NAWOŻENIA MINERALNEGO I ŚCIÓŁKOWANIA NA WZROST ROŚLIN, TWORZENIE BRODAWEK KORZENIOWCH I PLON STRĄKÓW FASOLI ZWYCZAJNEJ (*PHASEOLUS VULGARIS* L.)

### Streszczenie

Integracja wermikompostu i ściółek organicznych jako elementów systemu produkcji warzyw przyczynia się do utrzymania żyzności gleby i wydajności upraw. Przeprowadzono doświadczenie polowe, którego celem było zbadanie wpływu wermikompostu, nawozu NPK oraz ściółki organicznej na wzrost roślin, tworzenie brodawek korzeniowych i plon strąków fasoli zwyczajnej (*Phaseolus vulgaris* L.), a w końcowym rezultacie zoptymalizowanie zapotrzebowania na wodę i składniki mineralne w łagodnym klimacie tropikalnym w okresie pory suchej. Cechy wzrostu pędów, a mianowicie, długość pędu, liczba rozgałęzień głównych, świeża i sucha masa pędów, wzrosły o 28-63% dzięki zastosowaniu N $P_2O_5$ $K_2O$ 8:13:10 kg·ha$^{-1}$ + wermikompost 3,75 t·ha$^{-1}$ i o 5-50% po zastosowaniu ściółki organicznej. Zastosowanie wermikompostu zmniejszyło świeżą i suchą masę brodawek korzeniowych odpowiednio o 44,9 i 44,5%. Podobnie w przypadku ściółkowania organicznego, liczba brodawek korzeniowych, oraz świeża i sucha masa brodawek zostały zmniejszone o 8,6; 11,1 i 14,1%. Słabe tworzenie się brodawek korzeniowych może być spowodowane zmniejszonym natlenieniem gleby pod wermikompostem i ściółką organiczną, które ostatecznie utrudniają aktywność nitrogenazy i biologiczne wiązanie azotu. Ściółkowanie roślin fasoli zwyczajnej suszonymi trawami i resztkami pożniwnymi przyczyniło się również do większej masy pojedynczego strąka, długości strąka, masy strąka na roślinę oraz plonu strąków odpowiednio o 10,9; 12,8; 20,1 i 20,2%. Niniejsze badania pokazują, że zastosowanie nawozu N $P_2O_5$ $K_2O$ w dawce 8-15:13-25:10-20 kg·ha$^{-1}$, wermikompostu w dawce 2,50-3,75 t·ha$^{-1}$, i ściółki z suchych resztek pożniwnych o grubości 4 cm, oraz 50% nawadniania jest najbardziej odpowiednią i zrównoważoną strategią w celu poprawy wzrostu roślin, wytwarzania strąków i plonu strąków fasoli zwyczajnej, oraz zdrowotności gleby w łagodnym klimacie tropikalnym w okresie pory suchej.