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EFFECTIVENESS OF VERMICOMPOST IN SUBSTITUTING UREA FOR PROMOTING GROWTH AND YIELDS OF MUNG BEAN (*Vigna radiata* L.) IN ULTISOLS

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ABSTRACT

Vermicompost is one of increasingly applied organic fertilizer to many vegetable crops in order to reduce the dependency on synthetic fertilizer, including the use of urea as nitrogen source. This experiment aimed to determine the best dosage combination of vermicompost and synthetic urea on growth and yields of mung bean grown in Ultisols. This experiment was arranged in a randomized complete block design with three replicates. Treatments consisted of (1) control, no urea and no vermicompost, (2) 50 kg/ha urea + no vermicompost, (3) 40 kg/ha urea + 3 Mg/ha vermicompost, (4) 30 kg/ha urea + 6 Mg/ha vermicompost, (5) 20 kg/ha urea + 9 Mg/ha vermicompost, (6) 10 kg/ha urea + 12 Mg/ha vermicompost, and (7) 0 kg/ha urea + 15 Mg/ha vermicompost. Results indicated that the combination of urea and vermicompost increased plant height, leaf number, branch number, number of nodules/ plant, shoot to root ratio, number of pods/plant, number of pods/plot, grain dry weight/plant, grain dry weight/plot, and total yield /ha, but not days to flowering and weight of 100 grains. The best combination to increased growth and yields of mung bean was 12 Mg/ha of vermicompost in combination with 10 kg/ha of urea. This combination produced the highest grain yields/ha (2.1 Mg/ha).

Keyword: *Mung bean, synthetic nitrogen, Ultisols, vermicompost*

ABSTRAK

[KEEFEKTIFAN VERMIKOMPOS DALAM MENGGANTIKAN UREA UNTUK MENINGKATKAN PERTUMBUHAN DAN HASIL KACANG HIJAU (*Vigna radiata* L.) DI ULTISOLS]. Vermikompos merupakan salah satu pupuk organic yang semakin banyak diterapkan pada produksi tanaman sayuran untuk mengurangi ketergantungan pada pupuk sintetis, termasuk penggunaan urea sebagai sumber nitrogen. Penelitian ini bertujuan untuk mengetahui kombinasi dosis terbaik vermikompos dan urea sintetik terhadap pertumbuhan dan hasil kacang hijau yang ditanam di Ultisols. Percobaan disusun dalam rancangan acak kelompok lengkap dengan tiga kali ulangan. Perlakuan terdiri dari (1) kontrol, tanpa urea dan tanpa vermikompos, (2) 50 kg/ha urea + tanpa vermikompos, (3) 40 kg/ha urea + 3 Mg/ha vermikompos, (4) 30 kg/ha urea + 6 Mg/ha vermikompos, (5) 20 kg/ha urea + 9 Mg/ha vermikompos, (6) 10 kg/ha urea + 12 Mg/ha vermikompos, dan (7) 0 kg/ha urea + 15 Mg/ha vermikompos. Hasil penelitian menunjukkan bahwa kombinasi pupuk urea dan vermikompos meningkatkan tinggi tanaman, jumlah daun, jumlah cabang, jumlah bintil/tanaman, nisbah pucuk akar, jumlah polong/tanaman, jumlah polong/petak, bobot kering gabah/tanaman, gabah kering bobot/petak, dan hasil total/ha, tetapi tidak mempercepat pembungaan dan bobot 100 butir. Kombinasi terbaik untuk meningkatkan pertumbuhan dan hasil kacang hijau adalah vermikompos 12 Mg/ha yang dikombinasikan dengan pupuk urea 10 kg/ha. Kombinasi ini menghasilkan hasil gabah/ha tertinggi (2,1 Mg/ha).

Kata kunci: *kacang hijau, nitrogen sintetik, Ultisols, vermikompos*

INTRODUCTION

Mung bean (*Vigna radiata* L.) is the third most important legume crops after soybeans and peanuts in Indonesian cuisines since this bean has very high nutritional contents. This bean contains 22.85% protein, 62.90% carbohydrates and 1.20% fat (Rahman & Triyono, 2011). In addition, in each 100 g, it has 125 mg calcium, 320 mg phosphorus, 6 mg vitamin C, and several other minerals which are very beneficial for the human health. Consumer demands to this legume will be inevitable as it is line with the increase awareness of consumers to the significant of healthy food. However, the national production of mung bean in Indonesia has steadily decreased since 2016 (88.3 thousand Mg), declining to 81.8 thousand Mg in 2017, 71.02 thousand Mg in 2018, 65.25 thousand Mg in 2019 and 68.51 thousand Mg in 2020 (BPS, 2020). Efforts to increase mung bean production are challenged with declining arable lands for crop production due to the conversion of agricultural lands into non-agricultural activities. Such phenomenon induces the use of less optimal land for mung bean production to maintain supply for consumer demands.

Ultisols is considered as less optimal agricultural land and, yet, its availability is sufficient to compensate the declining arable land for vegetable productions (Subowo, 2012). In Indonesia, Ultisols are accounted almost 25 % of agricultural lands which is estimated covering almost 48.000.000 ha (Subagyo *et al*., 2004). According to Andalusia *et al*. (2016), Ultisols are characterized with red-yellowish in color, unstable aggregate, low soil porosity and water holding capacity. Its chemical properties are low nutrient elements, low pH, and high soil acidity, low nutrient contents, poor macro- and microorganisms in the soil. Kadir *et al*. (2001) also distinguish that this soil is characterized by high soil acidity, high Al+ and low nutrient availability. Increasing the productivity of Ultisols for crop production could be achieved by applying soil ameliorant, fertilizers, and organic matter (Prasetyo & Suriadikarta, 2006). Clearly, the use of Ultisols for crop production, including mung bean, requires proper fertilizing management in order to provide better growing environment.

Mung bean requires sufficient nutrient supply in order to ensure to have successful growth and development that eventually benefits farmers. Although mung bean is classified as legume crops that has an ability fixate atmospheric nitrogen (N_2) into ammonium (NH_4^+) or into organic nitrogen for plant metabolisms (Foyer *et al.*, 2016), N application is of great interest in nutrient management in sustainable mung bean production. Since N makes up 1-5% of the total plant dry matter and is essential for the production of proteins, nucleic acids, chlorophyll, co-enzymes, phytohormones, and secondary metabolites, plants need a sufficient amount of N (Marschner, 2012). According to Herdiani (2019) recommended dosage for synthetic fertilizer for mung bean is 50 kg/ha of urea, 100 kg/ha of SP36 and 50 kg/ha of KCl. Poor nutrient balance in Ultisols, especially N, can be improved by proper N application that can lead to better mung bean growth and yields. Overuse of N or a one-time application to the soil can result in significant nutrient loss through leaching and/or volatilization, which can ultimately result in financial loss for the producers and harm to the water and land resources. Clearly, the incorporation of organic fertilizer into Ultisols likely enhances the soil's chemical, physical, and biological qualities, all of which will eventually boost soil fertility and enhance crop development and yields in a sustainable manner. Vermicompost is one of increasingly applied to many vegetable crops in order to reduce the dependency on synthetic fertilizer.

Vermicompost is one of the solid organic fertilizers created by composting organic resources (such animal manures) utilizing different kinds of earthworms (Ramnarain *et al*., 2019). Research conducted by Raphael & Velmourougane (2011) concluded that vermicompost produced by exotic earthworm *Eudrilus eugeniae*, fed with coffee dregs, contained organic-C content of around 14.67%, N 1.66%, P 0.41%, K 0.70%, Ca 0.52%, Mg 0.31, and pH of 7.21. While Muktamar *et al*. (2017) reported that nutrient content of vermicompost produced from solid cattle manure contained N, P, K, and organic C as much as 2.15%, 0.24%, 0.55%, and 25.6%, respectively. Indeed, vermicomposting has been shown to enhance crop growth, yield, and nutritional value in addition to soil quality (Piya *et al.,* 2018). Research conducted by Handayani et al. (2018) concluded that the fertilizing mung bean with 15 Mg/ha vermicompost produced the highest plant height, number of productive branches, matured pods and weight of 100 grains, compared to those fertilized with 5 and 10 Mg/ha vermicompost.

Nevertheless, there have been limited information on how vermicompost application the production of mung bean in Ultisols, as well as the possibility of vermicompost to substitute the use of synthetic nitrogen for mung bean production. This research aimed to determine the best dosage combination of vermicompost and synthetic urea on growth and yields of mung bean grown in Ultisols.

MATERIALS AND METHODS

A field experiment was conducted from October to December 2022 on Ultisols in Kota Bengkulu (elevation of 10 m above sea level, 3°, 45’, 26.40” South Latitude and 102°, 15’, 41.78” East Longitude). This experiment was arranged in a randomized complete block design with three replicates. Treatments consisted of (1) control, no urea and no vermicompost, (2) 50 kg/ha urea+no vermicompost, (3) 40 kg/ha urea+3 Mg/ha vermicompost, (4) 30 kg/ha urea+6 Mg/ha vermicompost, (5) 20 kg/ha urea+9 Mg/ha vermicompost, (6) 10 kg/ha urea+12 Mg/ha vermicompost, and (7) 0 kg/ha urea+15 Mg/ha vermicompost. Both 50 kg/ha urea and 15 Mg/ha vermicompost are considered as 100% of recommended dosages.

Prior to planting, soil samples were taken at 20 cm in depth for analysis of N, P, K, organic C and pH. Nutrient contents of vermicompost were also determined in terms of N, P, K, organic C, pH and its water content. Both soil and vermicompost were analyzed in Soil Laboratory of Faculty of Agriculture, University of Bengkulu. The soil samples were air-dried for 2 days, grounded, and sieved with 0.5 mm screen and analyzed for its chemical properties. Soil N was determined using Kjeldahl Method, P using Bray I Method, K using Flame-photometer after soil extraction with 1N NH4Acetate, organic C using Walky and Black Method and soil pH with pH meter at 1:1 ratio of soil and distilled water (BPT, 2009). Soil analysis of the experimental site before planting indicated that the contents of N, P, K, organic C and pH was 0.36%, 5.19 ppm, 0.27 me/100 g, 2.09% and 4.94, respectively.

Experimental site was ploughed and harrowed, and then uniformly limed with 2.12 Mg ha^{-1} dolomite which was conducted at two weeks before planting. The size of each experimental unit was 1m x 4 m, separated by 0,75 m within the block and each block was separated by 1 m away. At one week before planting, each experimental plot was fertilized with vermicompost according to respective treatments. The application of urea was applied 50% at planting day, and the rest at two weeks after planting. At planting, all soil beds were uniformly fertilized with half recommended dosage of TSP (50 kg/ha) and KCl (50 kg/ha).

Mung bean seeds (Vima-3 variety) were selected by soaking it into water and the floating seeds were removed and the drowning seeds were then treated with rhizobium (5 g/kg seeds). Two seeds were sown in each planting hole (about 2.5 cm in depth), arranged in 20 cm away within the row and 40 cm between the rows. Each planting hole was applied with three granules of Furadan 3G. Plants were watered every day in the morning and afternoon if there were no precipitation occurred. At one week after planting, one of the worse plants in each planting hole was removed. Weed removals were manually conducted at 14, 28, and 32 days after planting. During weeding, the soil around the stem were carefully up-hilled to ensure plant establishment in the soil. Pest controls were conducted at 21 and 35 days after planting, by uniformly spraying Profenofos 500 g/L.

Mung bean responses to treatments were measured by plant height at 6 weeks after planting (WAP), leaf number at 6 WAP, branch number, days to flowering, shoot to root ratio, number of pods/plant, number of pods/plot, number of nodules/ plant, grain weight/plant, grain weight/plot, weight of 100 grains, and yield/ha. All data were subjected to homogenous test before analysis of variance at $P \leq 0.05$. Means of treatment effects were compared using Least Significantly Different test at $P \leq 0.05$. Data on monthly average of air temperatures, relative humidity and rain fall during the experiment were collected from Meteorology, Climatology, and Geophysical Agency Bengkulu (ID WMO: 96255).

RESULTS AND DISCUSSION

Environmental condition

Average of monthly precipitations from October to December 2022 were 106 mm, 110 mm, and 73.5 mm. The daily averages of air relative humidity were 79 %, 79 %, dan 76 %, while daily averages temperature was 22.2 ^{o}C, 22.1 ^{o}C, and 22.8 ^{o}C. These climatic conditions, except the daily air temperatures, were sufficient to support mung bean growth. According to Wahyudi (2010), the optimal growth of mung bean takes places with the average rainfalls, air temperatures and daily air relative humidity of 100 mm/month, 25-27 ^{o}C, and 50-89%, respectively.

Soil analysis of the experimental site before planting indicated that the contents of N, P, K, organic C and pH was 0.36%, 5.19 ppm, 0.27 me/100 g, 2.09% and 4.94, respectively. A week before harvesting, soil pH, as measured in each treatment, was 4.71, 4.21, 4.63, 4.36, 4.90, and 5.00 for treatment 1, 2, 3, 4, 5, 6, and 7, respectively. Laboratory analysis also revealed that vermicompost used in this experiment contained organic C of 17.97 %, N of 1.43 %, P of 0.73%, K of 1.87 %, pH of 8.76 and water content of 68.55 %.

Effects on growth of mung bean

Results indicated that treatments significantly affected plant height, leaf number, branch number, number of nodules/plant and shoot to root ratio. However, it did not affect days to flowering. Mung bean fertilized with combination of 10 kg/ha urea and 12 Mg/ha vermicompost (treatment 6) produced the highest plant height (Fig. 1A), number of leaves (Fig. 1B), number of productive branches (Fig. 1C) and shoot to root ratio (Fig. 1F) among the all the treatments. In addition, mung bean fertilized with 15 Mg/ha vermicompost and no urea had the second-best growth performances, except for number of root nodules (Fig. 1E). It also appeared that plant height, leaf number, branch number, number of nodules/plant and shoot to root ratio of mung bean increased with the increasing dosages of vermicompost (Fig. 1F). Furthermore, the highest plant height was 53.81cm, number of leaves was 17.42, number of productive branches was 6.50, number of root nodules 28.22, and shoot to root ratio 13.22. The lowest values of those variables were found at mung bean received no urea and no vermicompost. There was no treatment effect on day of flowering of mung bean and all plants started to flower at 42 or 43 days after planting (Fig. 1D).

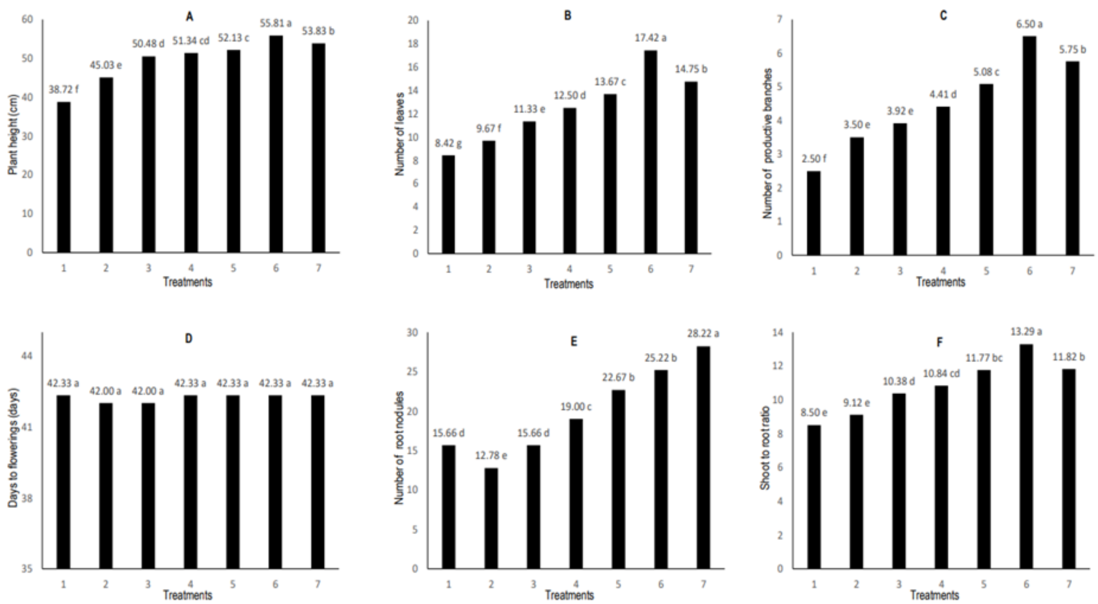

Figure 1. Treatment effects on (A) plant height, (B) number of leaves, (C) number of productive branches, (D) days to flowering, (E) number of root nodules, and (F) shoot to root ratio of mung beans. [Means of treatments in each variable followed by the same letter are not significantly different according Least Significant Difference 5%. Treatment (1) control, no urea and no vermicompost, (2) 50 kg/ha urea+no vermicompost, (3) 40 kg/ha urea+3 Mg/ha vermicompost, (4) 30 kg/ha urea+6 Mg// ha vermicompost, (5) 20 kg/ha urea+9 Mg/ha vermicompost, (6) 10 kg/ha urea+12 Mg/ha vermicompost, and (7) 0 kg/ha urea+15 Mg/ha vermicompost].

The application of 20% urea in combination with 12 Mg/ha vermicompost was likely the best combination to promote growth of mung beans. During the early growth of crop development, plant responses was related to the land friability which might be attributed to the application of sufficient vermicompost (12 Mg/ha). The advantage of organic fertilizer is that it increases soil fertility by increasing the total soil organic carbon, microbial organic carbon, electrical conductivity, total soil nitrogen, accessible P, exchangeable K, and soil pH after the application of organic fertilizer, and decreasing exchangeable Al and bulk density (Butler *et al*., 2009; Mankolo *et al*., 2012; Jouquet *et al*., 2011; Arthur *et al*., 2012; Muktamar *et al*., 2016). According to Roidah (2013), the addition of organic matter to the soil increases the water holding capacity, area and cation exchange capacity of the soil, prevents nutrient leaching by percolation. These positive effects eventually improve nutrient availability in the rhizosphere. The improvement of the soil chemical properties leads to the enhancement of mung bean growth (Anggita *et al*., 2018).

The significance of vermicompost in increasing nutrient availability is reflected by the effects of treatment 2 (50 kg/ha urea+no vermicompost) in which the application of synthetic urea had lower effects in affecting mung bean growth than higher dosages of vermicomposting. According to Handayanto *et al*. (2017), nitrogen leaching might have happened through soil profiles and percolations as synthetic urea has been previously decomposed into NO_{2-} and NO_{3-}

For a plant to have a high net photosynthesis rate and maintain its growth and development, there must be enough nitrogen in the soil, especially during the vegetative growth. In addition to encouraging vegetative growth (leaves, stems, branches, and stems), speeding up the recovery process after mowing, producing chlorophyll, and having other regulatory effects on the synthesis and function of enzymes and proteins, nitrogen is crucial for plant growth and development. The application of 10 kg/ha urea+12 Mg/ha vermicompost (treatment 6) added 177.6 kg N generated from vermicompost into the soil environment (since laboratory analysis reveal that vermicompost contain 14.3 % of N). The abundant

N in the soil due to vermicomposting might have responsible to promoting mung bean growth. According to Delogua *et al*. (1998), since N is involved in all of the metabolic processes of the plant, supply and demand have a significant impact on the rate of N uptake and partition during the stages of plant growth and development. The ability of vermicompost to hold 40-60% soil water (Kusumawati, 2011) might have benefitted mung bean vegetative growth. In addition, vermicompost contains not only macro nutrients, but also growth regulator of auxin, gibberellin and cytokinin (Nurmawati & Suhardianti, 2000). According to Theunissen *et al*. (2010), these growth regulators are responsible in promoting new branches in many plants which eventually increases the number of productive branches of mung beans. Those positive roles of vermicompost might have responsible to the increased plant height, leaf number, branch number, number of nodules/plant and shoot to root ratio of mung beans.

Interestingly, the highest of root nodules of mung bean was recorded at plant fertilized with 0 kg/ha urea and 15 Mg/ha vermicompost (Fig. 1E). Fertilizing with 15 Mg/ha of vermicompost is literally supplying 215 kg N, 110 kg P, and 280 kg K as well as 2.7 Mg organic C into the soil. These high supplies, especially P, is very important for mung bean during the nodulation, since it stimulates the formation of root nodules and activity symbiotic bacteria of *Rhizobium* sp. (Hidayat, 2008). In addition, high N content of applied vermin-compost at planting time also stimulates *Rhizobium* sp. to make early infection on roots, which eventually produces more root nodules (Mayani *et al*., 2021). The use of vermicompost has been recorded to increase plant height, leaf number, branch number of mung bean (Biswash *et al*., 2014). Recently, Senatama *et al*. (2019) concluded that the presence of nitrogen in the soil increased the number of effective nodules of mung bean. Insignificant effects of treatment on day of flowering of mung bean might have due to genetic characters of the plant. Similar result has been reported by Handayani *et al*. (2018) in which the flowering days of mung beans were similar after fertilized with 5 to 15 Mg/ha of vermicompost and 100 to 300 kg/ha of NPK.

Effects on yields of mung bean

Results indicated that treatments significantly affected number of pods/plant, number of pods/plot, grain dry weight/plant, grain dry weight/plot, and total yield/ha, but not on weight of 100 grains. The effects of urea in combination with vermicompost on yield components have similar patterns to those of vegetative growth. All mung beans fertilized with combination of 10 kg/ha urea and 12 Mg/ha vermicompost (treatment 6) produced the highest number of pods/plant (Fig. 2A), number of pods/plot (Fig. 2B), grain dry weight/plant (Fig. 2C), grain dry weight/plot (Fig. 2D), and total yield/ha (Fig. 2F). The highest pods/plant was 22.92, number of pods/plot was 500, grain dry weight/plant was 425,07 g, grain dry weigh/plot was 19.12 g, and total yield/ha was 2.10 Mg (Fig. 2F). The lowest values of those variables were found at mung bean received no urea and no vermicompost. Surprisingly, there was no treatment effect on mung bean's weight of 100 grains with the average weight of 5.86 g (Fig. 2E).

Linear trends of vermicompost effects on the number of pods/plant, number of pods/plot, grain dry weight/plant, grain dry weight/plot, and total grain yield/ha of mung beans (Fig. 2A, 2B, 2C, 2D and 2F) indicated that vermicompost could substitute the use of urea in production of mung beans. It appeared that the use of 10 kg/ha of urea and 12 Mg/ha of vermicompost resulted the best yield performances of mung bean. This additional 172 kg/ha N, 88 kg/ha P, and 224 kg/ha K into the soil from 12 Mg/ha of vermicompost is likely increase nutrient uptakes and photosynthesis by mung beans. Muktamar *et al*. (2017) concluded that the use of vermicompost increased N, P, K uptakes of organic sweet corn production. According to Ningsih *et al*. (2020), the availability of nitrogen for mung bean determines the numbers of pods/plant through stimulating the synthesis of protein and chlorophyll which later responsible in the pod formation. Increased number of pods/plant is followed by the increased number of pods/plot (Fig. 2A, 2B). Similar effects of vermicompost were also noticed in weight/plant, grain weight/plot and total grain yield of mung beans (Fig. 2C, 2D and 2F).

Increased grain dry weight/plant, grain dry weight/plot, and total grain yield/ha might have due to increased nutrient availability for mung bean in the rhizosphere. According to Santana *et al*. (2017), the availability of N at planting and during the grain filling determine the increased of soybean yields. Biswash *et al*. (2014), concluded that the use of vermicompost increased number of pods/plant and seed yield of mung bean. Although there was no treatment effect on weight of 100 grains, the increases in pod numbers, weight of pods/plant, weight of pods/plot will finally increase total grain yields/ha. According to Handayani *et al*. (2018), the application of a combination of vermicompost fertilizer 15 Mg/ha and NPK fertilizer 200 kg/ha resulted in the highest yields compared to other treatments. Their research also concluded that the application of vermicompost did not significantly increased weight of 100 grains.

Agronomical consequences of this experiment may include the possibility to reduce the use of synthetic nitrogen (urea) by using vermicompost. The use of synthetic input in vegetable production must be reduced in a sustainable manner, minimizing the ecological degradation of agricultural land and water resources, without sacrificing the economic benefits to the farmers.

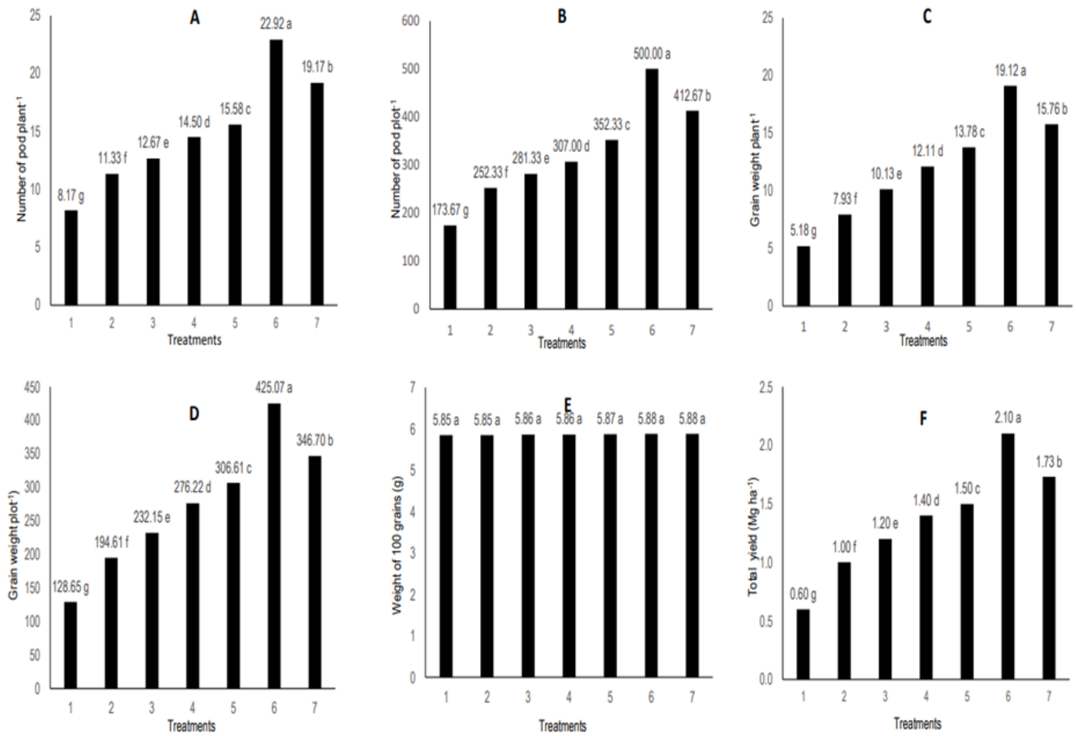

Figure 2. Treatment effects on (A) number of pods, (B) number of pods/plot, (C) grain weight/plant, (D) grain weight/plot,(E.) weight of 100 grains, and (F) total grain yield/ha) of mung beans. [Means of treatments in each variable followed by the same letter are not significantly different according Least Significant Difference 5%. Treatment (1) control, no urea and no vermicompost, (2) 50 kg/ha urea+no vermicompost, (3) 40 kg/ha urea+3 Mg/ha vermicompost, (4) 30 kg/ha urea+6 Mg/ha vermicompost, (5) 20 kg/ha urea+9 Mg/ha vermicompost, (6) 10 kg/ha urea+12 Mg/ha vermicompost, and (7) 0 kg/ha urea+15 Mg/ha vermicompost].

CONCLUSION

Combination use of urea and vermicompost increased plant height, leaf number, branch number, number of nodules/plant, shoot to root ratio, number of pods/plant, number of pods/plot, grain dry weight/plant, grain dry weight/plot, and total yield/ha. The use of 12 Mg/ha of vermicompost in combination with 10 kg/ha of urea produced the highest grain yields/ha, *i.e.*, 2.1 Mg/ha, which was higher than the average yield of this variety (1.8 Mg/ha). The use of 100% recommended dosage of urea (50 kg/ha) produced lower growth and yields of mung bean compared to those of combined with the use of vermicompost. Further research could be focused of the effects of vermicompost and urea combination nitrogen uptakes of mung bean.

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