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Improvement of Yield of Bean Grown on Inceptisol Jatinangor Applied with Granular Organic Fertilizer and Harvest Interval

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ABSTRACT

Low bean production in Indonesia is caused by several factors such as poor soil condition and low quality of the pods. The use of granular organic fertilizer can optimize soil as a growing medium of beans. In addition, the application of harvest interval setting in combination with the use of granular organic fertilizer probably can improve production and quality bean pods. The research aimed to find out granular organic fertilizer doses and harvest interval setting that resulted in good effects on the growth, yield, and quality of beans grown on Inceptisol from Jatinangor, West Java. A field experiment was carried out at Ciparanje field, Jatinangor, West Java from February to April 2016. The experiment was arranged in a Randomized Block Design (RBD) with 12 treatments and 3 replications. The results showed that the dose of 150 kg ha^{-1} granular organic fertilizer and harvest interval of every two days resulted in shoot:root ratio of 12.8, increased percentage of productive branches up to 57.48%, increased percentage of grade B pods (60.17%) and lowered the percentage of grade C pods (29.21%).

Keywords: Bean, granular organic fertilizer, harvest interval, Inceptisol, pod quality

ABSTRAK

Rendahnya produksi buncis di Indonesia diakibatkan karena beberapa faktor diantaranya adalah kondisi media tanam yang kurang optimal serta kualitas polong yang kurang baik. Penggunaan pupuk organik granul dapat mengoptimalkan tanah untuk media tanam buncis. Dipadukan dengan pengaturan interval panen, produksi dan kualitas polong buncis dapat ditingkatkan. Penelitian ini bertujuan untuk menentukan dosis pupuk organik granul (POG) dan interval panen yang memberikan pengaruh terbaik terhadap pertumbuhan, hasil dan, kualitas hasil buncis tegak yang ditanam pada tanah Inceptisol, Jatinangor. Percobaan ini dilaksanakan di kebun Ciparanje, Jatinangor, Kabupaten Sumedang dari bulan Februari sampai April 2016. Rancangan percobaan yang digunakan adalah Rancangan Acak Kelompok (RAK) dengan 12 perlakuan yang diulang sebanyak 3 kali. Hasil penelitian menunjukkan bahwa perlakuan yang diaplikasikan memberikan pengaruh terhadap Nisbah Pupus Akar (NPA), persentase jumlah cabang produktif, serta persentase polong berdasarkan kualitas grade B dan C. Dosis pupuk organik granul 150 kg ha^{-1} dan interval panen 2 hari sekali memberikan hasil terbaik dengan NPA sebesar 12,8, persentase jumlah cabang produktif sebesar 57,48 % serta persentase polong grade B tertinggi 60,17% dan grade C terendah 29,21%.

INTRODUCTION

Bean consumption in Indonesia increased in 2012-2015 consecutively but the supply decreased in 2010-2014 (Pusat Data dan Sistem Informasi Pertanian 2015). The supply of bean in Indonesia can be fulfilled by production and import. Considering the data, bean production in Indonesia is still low. Nutrient availability is an important requirement for growing media because it can support and supply nutrients for growth and development of plants. Feleafel and Zohair (2014) suggest that poor nutrient content of soil as a growing medium can stunt bean growth.

Soil characteristics in Indonesia are very diverse which can affect bean production. One of

the locations that can be used for bean production is Jatinangor. The obstacles of bean production in Jatinangor is the characteristics of the soil. Inceptisol is the soil type that spreads over Jatinangor which is unfertile because has low soil nutrient content, therefore, nutrient addition through fertilization is necessary. The key success of proper fertilization is balance in the use of organic and inorganic fertilizers (Triwulaningrum 2009). Organic fertilizers provide not only nutrients but also can improve the physical, chemical, and biological soil characteristics (Lengkong and Kawulusan 2008). Types of organic fertilizers used in bean production vary, one of them is granular organic fertilizer.

Granular organic fertilizer (GOF) is one type of organic fertilizers which made from livestock manure, leaf litter, and garbage that have been fermented and shaped in the form of small granules, making it easier to be used. The advantages of GOF is the shape that resembles synthetic fertilizer, so it is easy to be applied, needed in relatively small quantity compared to other organic fertilizers (manure of cattle or sheep, compost), easily obtained, cheap, odorless, and free of debris (Adamy *et al.* 2012).

Several studies have used granular organic fertilizer in their experiments. Granular organic fertilizer showed an effect on the height of rubber seedlings (Tabita *et al.* 20017); addition of granular organic fertilizer made from biogas waste showed a significant effect on the growth of tomato plants (Chalimah and Sulaiman 2015); red onion applied with granular organic fertilizer significantly produced higher yield than those applied with inorganic fertilizer (Brotodjojo and Arbiwati 2017). In addition, organic fertilizers also affect the physical properties of soil (Habi 2015).

Another factor that also influences bean production is quality of pods. The quality of bean pods is largely determined by genetic and environment (Salisbury and Ross 1995). One way to improve the quality of bean pods is by setting the harvest interval. Beans are commonly harvested when the seeds have not formed yet. Longer harvest interval may cause problems. When the harvest is late, the yield will increase because of the weight of pods increases, but it does not meet the market quality standard (Kusumiyati 2017). The pods are not marketable because the seeds protruding to pod surface, resulting in bumpy pod surface (Djuariah 2008). Early harvest can result in a better quality of beans because the seeds have not been formed. For farmers, the harvest interval seems not profitable due to lower weight pods.

The availability of nutrients in soil will support faster plant growth and affect the speed of pod formation. Granular organic fertilizer releases nutrients gradually so that the fertilizer will meet every phase of pod formation. Applying granular organic fertilizer in higher doses will enrich the nutrients in the soil so that the pod formation occurs more rapidly. The pods that are formed more rapidly would speed up the harvest time and shorten the harvest interval. Therefore, the objectives of study were to understand the effects of granular organic fertilizer doses and harvest interval on the growth, yield, and quality of beans, and to know which treatment(s) result in good effects on the growth, yield, and quality of beans.

MATERIALS AND METHODS

Experimental Setup and Design

A field experiment was carried out at Ciparanje Experimental Farm, Faculty of Agriculture, University of Padjadjaran, Jatinangor, West Java in February to April, 2016. The materials and tools used in the experiment include bean cultivar Balitsa 1, granular organic fertilizer (50% doses = 0.5 Mg ha^{-1}, 100% doses = 1 Mg h^{-1}, 150% doses = 1.5 Mg ha^{-1}), anorganic fertilizers consisting of urea 100 kg ha^{-1}, SP-36 250 kg ha^{-1}, and KCl 250 kg ha^{-1}, Furadan pesticide (Carbofuran) (given on 1 and 3 weeks after planting), Decis insecticide (Deltamethrin), hoes, watering tools, height measuring tools, vernier caliper, digital scale, scissors, rope, oven and laboratory equipments.

The experiment was arranged in a randomized block design (RBD) with 12 treatments and 3 replications, so there were 36 experimental units. The size of each plot was 2 m × 2 m. The treatment consisted of four doses of granular organic fertilizer as much as 0 kg ha^{-1} (p0), 500 kg ha^{-1} (p1), 1000 kg ha^{-1} (p2), and 1500 kg ha^{-1} (p3). The beans in each treatment were harvested with interval of every 1 day (i1), 2 days (i2), and 3 days (i3).

Measurements

Micro climate (air humidity, temperature and rainfall) which affected the growth, yield, and quality of beans was measured every day during the experiment. The soil samples and granule organic fertilizer were taken and analyzed in the begining of the experiment. Growth components (leaf area, shoot:root ratio), yield (weight of pods per plant), and grading quality were also measured.

Leaf Area

The leaf area was measured during the final vegetative phase at 4 weeks after planting (WAP). Bean plants were sampled destructively, then the whole leaves were weighted. Ten holed leaves from each plant sample were taken using a hole maker with the diameter (r) of 0.8 cm, then the leaves were weighted. All the leaves were dried in the oven for 3 × 24 hours at temperature of 80°C until constant weight was obtained (Nugroho and Yuliasmara 2012). The leaf area are calculated using the following formula:

$$\text{Leaf Area}\,(cm^2) = \frac{\text{Dry weight of whole leaf sample}\,(g)}{\text{Average dry weight of leaf pieces}\,(g)} \times 3.14r^2$$

Shoot:Root Ratio

The shoots as the upper part of the plant consist of pods, flowers (if any), leaves, and stems. The shoots and roots were separated and then dried in the oven for 3 × 24 hours at temperature of 80°C to obtain a constant weight. The shoot:root ratio was calculated using the following formula:

$$\text{Shoot : Root Ratio} = \frac{\text{Dry weight of shoots}\,(g)}{\text{Dry weight of roots}\,(g)}$$

Weight of Pods per Plant

Pods were harvested in several times. One day harvest interval means the pods were harvested every day, 2 days harvest interval means the pods were harvested every two days, and 3 days harvest interval means the pods were harvested every three days. The weight of pods per plant was determined by weighing the total yield of pods of each plant sample from the first harvest till the last harvest.

Quality of Beans

Harvested beans were sorted by dividing beans into marketable and non-marketable pods. Marketable pods can be seen from various criteria such as shape and pod damage (Table 4). After sorting, the marketable pods were categorized into three grades, namely grade A, B, and C. Grading was based on shape, weight, length, diameter, color, and pod damage. Some criteria of grading such as pod length and pod diameter were measured. The length of the pod (cm) was measured using a tape measure. The pod diameter (cm) was measured using a vernier caliper from the front side to the back side of the bean pod. Pod weight, length, and diameter were collected from the data of each harvest interval.

Data Analysis

Measurements were conducted on leaf area, shoot:root ratio, the percentage of productive branches, weight of pods per plant, the percentage of marketable and non-marketable pods, the length and diameter of pod, and the percentage of pods based on grade A, B, and C (Table 4). The effects of treatments were evaluated using F test at 5% significance level and continued with Duncan's Multiple Range Test at 5% significance level to examine the differences of the average values among the treatments.

RESULTS AND DISCUSSION

Growth Components

The characteristics of Incepticol used in the current study are low in organic C (1.98%), total N (0.16%), K_2O (13.28 mg 100 g^{-1}), K-dd (0.14 cmol(+) kg^{-1}), Na-dd (0.10 cmol(+) kg^{-1}), and the soil texture contains of 6% sand, 14% silt, and 80% clay. The use of inceptisol as a growing plant medium without adding fertilizer can cause less optimal growth and low production of bean plants. Eventhough the leaf area of the bean plants in this study did not show any differences among the treatments, however, the shoot:root ratios were different among the treatments.

The absence of the effects on the leaf area can be due to the nutrients contained in granular organic fertilizer were released slowly. Liu et al (2017) indicated that slow-release fertilizer contains nutrients in the form that make them unavailable. It takes time for plants to take up the nutrients after the fertilizer has been applied. In addition, the leaf area is influenced by plant genetics so the ability of the plants to increase the leaf area is not visible because the leaf's optimal ability is limited. The leaf area measured during the experiment are presented in Table 1.

Another bean growth component such as shoot:root ratio shows a different trend from leaf area (Table 1). The application of granular organic fertilizer during the experiment showed a significant effect on the shoot:root ratio. The soil applied with 50 kg ha^{-1} granular organic fertilizer resulted in the highest shoot:root ratio compared to other doses. The highest shoot:root ratio obtained in this study was 22.40.

Table 1. The effect of granular organic fertilizer doses and harvest intervals on bean growth components.

Treatments	Leaf Area (cm^2)	Shoot:Root Ratio
0 kg ha^{-1}, 1 day	230.26	10.46abc
0 kg ha^{-1}, 2 days	229.93	9.19ab
0 kg ha^{-1}, 3 days	316.28	9.41ab
50 kg ha^{-1}, 1 day	250.87	18.92cd
50 kg ha^{-1}, 2 days	216.85	22.40d
50 kg ha^{-1}, 3 days	287.83	18.86bcd
100 kg ha^{-1}, 1 day	259.70	8.59a
100 kg ha^{-1}, 2 days	222.74	9.69abc
100 kg ha^{-1}, 3 days	234.84	7.49a
150 kg ha^{-1}, 1 day	254.79	13.72 abcd
150 kg ha^{-1}, 2 days	318.57	12.83 abcd
150 kg ha^{-1}, 3 days	244.33	13.55 abcd

Note: The numbers followed by the same letters in the same column show no significant differences, while the numbers followed by different letters show significant differences according to Duncan's Multiple Range Test at 5% significance level.

The treatments applied with more doses of granular organic fertilizer allow the competition among plants and granular organic fertilizer granules in absorbing water. One of the characteristics of granular organic fertilizer is granule material ability to absorb and bind water from soil. The more doses of granular organic fertilizer applied, the amount and distribution of granular organic fertilizer granule in the soil will increase so that the water hold by the granular organic fertilizer will also increase. This will cause the water potential of the soil will be low and will affect water absorption by the roots. The roots will grow more rapidly in the soil to search for water until the shoots become smaller due to the photosynthate produced by the plant will be transported more to the roots.

The shoot:root ratio indicates the direction of transport and allocation of photoassimilates produced by plants. According to Fageria and Moreira (2011), lack of water and nutrients leads to photosynthates directed toward the roots so the roots can grow more widely to find water and nutrients. Therefore, the decrease of doses of granular organic fertilizer applied to the soil resulted the decrease of the shoot:root ratio.

Yield Components

Bean plant is a determinate plant that will not experience the second vegetative phase after the generative phase. Bean flowers emerge at the end of the plant branches. Later the flowers will turn into bean pods. Not all branches produce flowers and not all flowers form pods. The results of analysis of variance showed that the treatments significantly affect percentage of productive branches (Table 2). The results of this study are in accordance with the study of Olfati *et al.* (2012) which states that the level of organic fertilizer applied can increase the number of branches per bean plant.

Each treatment of addition of granular organic fertilizer results in higher percentage of productive branches than that without addition of granular organic fertilizer. Addition of granular organic fertilizer enhances nutrients in the soil to support plant growth in the beginning of the generative phase. Granular organic fertilizer used in this study has a quite high organic-C content, *i.e.* about 17% with P-total and K-total of 2% each (Table 3). High organic carbon content is a source of food for microbes in the soil. The high amount of organic fertilizer added to the soil allows the population of symbiotic microbes increase.

The increase of the number of productive branches does not necessarily increase the weight of harvested pods per plant. The results of analysis of variance indicate that granular organic fertilizer doses and harvest intervals show no significant effect on the weight of pods per plant (Table 2). An important nutrient that plays a role in the formation and filling of pods is phosphorus (Soepardi 1983). Upon entering the generative phase during the experiment, the rainfall increased. Based on the data obtained, rainfall from February to April 2016 was 163 mm, 396.5 mm, and 174.5 mm, repectively, or 245 mm per month on average, meanwhile the amount of rainfall needed by bean plants is about 100-200 mm per month (Lakitan 1997). High rainfall can lead to phosphorus leaching (Xue *et al*. 2013).

Table 2. The effect of granular organic fertilizer doses and harvest intervals on bean yield components.

Treatments	Productive Branches (%)	Weight of pod per plant (g)
0 kg ha^{-1}, 1 day	39.72 ab	62.51
0 kg ha^{-1}, 2 days	35.66 a	69.83
0 kg ha^{-1}, 3 days	31.99 a	53.99
50 kg ha^{-1}, 1 day	53.73 bc	70.34
50 kg ha^{-1}, 2 days	53.37 bc	58.77
50 kg ha^{-1}, 3 days	54.40 bc	52.36
100 kg ha^{-1}, 1 day	56.74 cd	53.48
100 kg ha^{-1}, 2 days	57.12 cd	35.10
100 kg ha^{-1}, 3 days	65.60 cd	38.23
150 kg ha^{-1}, 1 day	70.49 d	48.14
150 kg ha^{-1}, 2 days	57.48 cd	53.66
150 kg ha^{-1}, 3 days	56.58 cd	58.99

Note: The numbers followed by the same letters in the same column show no significant differences, while the numbers followed by different letters show significant differences according to Duncan's Multiple Range Test at 5% significance level.

Table 3. Characteristics of granular organic fertilizer.

Parameter	Value
pH	5.71
Water content	13.69%
C-Organic	14.25%
N-Total	2%
P-Total	2%
K-Total	2%
Fe	7900 ppm
Co	19 ppm
Zn	4500 ppm
Mn	4500 ppm
Cu	2000 ppm
B	1000 ppm
Mo	10 ppm

Note: Data obtained from Super TS-412 product packaging PT Agro Tani Marisi (2016).

Quality Components

Harvested beans from each treatment went through the sorting and grading stage. Sorting was done by dividing beans into marketable and non-marketable pods. After sorting, marketable pods were then categorized into three grades, namely grade A, B, and C. Grading was based on shape, weight, length, diameter, color, and pod damage (Table 4).

The results show that there is no significant effect of treatments on the percentage of marketable and non-marketable pods (Table 5). The absence of the effect of granular organic fertilizer and harvest interval can be due to unsuitable environmental conditions. During the experiment, the average air humidity was 90.42%. It can hamper the growth and pod formation so the quality of pods declines. Elisa (2010) indicated that high humidity will hamper roots to absorb nutrients. The air temperature during the expeiment was 23.06^{o}C to 23.39^{o}C which is suitable enough for bean plants (Sumpena and Yusdar 2004).

In addition, the treatments applied did not significantly affect the length and diameter of bean pods. The data presented in Table 6 show that in all treatments the pod lengths and diameters are smaller

Table 4. Quality criteria of marketable (Grade A, B, C) and unmarketable beans*.

Criteria	Grade A	Grade B	Grade C	Unmarketable
Shape	Straight	Straight	Straight or less than 5% bend	No symmetric, No straight (bend)
Color	Green pale	Green pale	Green pale	Not selective in Grade A, B, C
Damage	No physical, mechanical, and biological damage	No physical, mechanical, and biological damage	No biological damage Physical & mechanical damage less than 5%	Not selective in Grade A, B, C
Seed	Not formed yet	Not formed yet	Small seed formed	seed formed
Pod Lenght	15-16cm	12-13 cm	10-12 cm or 16-19 cm	Not selective in Grade A, B, C
Pod diameter	0.7-0.8 cm	0.5-0.6 cm	0.4-0.5 cm or 0.8-0.9 cm	Not selective in Grade A, B, C
Pod weight	5-6 g	3-4 g	2-3 g or 6-7g	Not selective in Grade A, B, C

*Personal communication to Bimandiri Agro Sedaya (2015).

than the the pod length and diameter of bean variety of Balitsa 1 (length 15-16 cm, diameter 0.7-0.8 cm). During the experiment, the formation of pods was inhibited because of the high humidity and heavy rainfall that lead to nutrient leaching. Besides, the presence of pest might cause the supply of nutrients absorbed by plants in each treatment was inhibited. Seed fly attacked bean stems and further caused the supply of nutrients from the roots to the pods was inhibited.

The second factor affecting the length and diameter of pods is the genetic of plants itself. According to study of Rachmadhani *et al.* (2014), pod length and diameter of beans applied with organic fertilizer did not show significant results because the influence of plant genetic is more dominant. The same result was also demonstrated in the study of Bashir *et al.* (2011), which showed that the length and diameter of bean pods were not affected by nutrient addition, but significant effects of nutrient addition were observed for different cultivars of bean plants, indicating that the length and diameter of pods will vary depending on the types of beans.

The results of analysis of variance show that granular organic fertilizer doses and harvest intervals

Table 5. The effect of granular organic fertilizer doses and harvest intervals on bean quality components.

Treatments	Pod Percentage (%)				
	Marketable	Non-marketable	Grade A	Grade B	Grade C
0 kg ha^{-1}, 1 day	45.01	54.98	6.19	35.10 abc	61.48 bc
0 kg ha^{-1}, 2 days	59.66	40.34	7.26	41.17 bc	51.55 abc
0 kg ha^{-1}, 3 days	43.32	56.67	7.20	40.80 abc	52.00 abc
50 kg ha^{-1}, 1 day	46.18	53.81	6.04	34.25 abc	63.86 bc
50 kg ha^{-1}, 2 days	40.02	59.97	6.36	15.94 a	73.33 bc
50 kg ha^{-1}, 3 days	41.51	58.49	5.00	28.33 ab	66.66 bc
100 kg ha^{-1}, 1 day	45.94	53.31	7.06	40.04 abc	56.59 abc
100 kg ha^{-1}, 2 days	56.55	43.44	3.00	17.00 ab	80.00 c
100 kg ha^{-1}, 3 days	35.86	64.14	2.75	15.58 a	73.33 bc
150 kg ha^{-1}, 1 day	38.58	58.47	3.85	21.85 ab	64.76 bc
150 kg ha^{-1}, 2 days	44.71	55.28	10.62	60.17 c	29.21 a
150 kg ha^{-1}, 3 days	43.79	56.20	5.85	33.19 ab	46.30 ab

Description: The numbers followed by the same letters in the same column show no significant differences, while the numbers followed by different letters show significant differences according to Duncan's Multiple Range Test at 5% significance level.

Table 6. The effect of granular organic fertilizer doses and harvest intervals to the length and diameter of bean pods.

Treatments	Pod Diameter (cm)	Pod Lenght (cm)
0 kg ha^{-1}, 1 day	0.72	11.93
0 kg ha^{-1}, 2 days	0.66	11.65
0 kg ha^{-1}, 3 days	0.66	11.93
50 kg ha^{-1}, 1 day	0.67	11.27
50 kg ha^{-1}, 2 days	0.64	11.75
50 kg ha^{-1}, 3 days	0.66	11.69
100 kg ha^{-1}, 1 day	0.63	11.15
100 kg ha^{-1}, 2 days	0.67	11.27
100 kg ha^{-1}, 3 days	0.67	11.68
150 kg ha^{-1}, 1 day	0.64	12.24
150 kg ha^{-1}, 2 days	0.63	12.19
150 kg ha^{-1}, 3 days	0.68	12.07

Note: The data in the same column show no significant difference based on the F-test at 5% significance level.

did not show any significant effects on the quality of Grade A, whereas in Grade B and C each treatment significantly affects. Table 5 shows that the treatment of 150 kg ha^{-1} granular organic fertilizer and the harvest interval of 2 days result in the highest percentage of grade B pods and the lowest percentage of grade C pods compared to other treatments. This result shows that the higher dose of granular organic fertilizer applied, the better pod quality will be produced. The harvest interval of 2 days causes the harvested pods have accumulated the optimal amounts of photosynthates. The use of 150 kg ha^{-1} granular organic fertilizer supplies relatively higher amounts of nutrients (Table 3), optimizing the energy formation in plants and distributing photosynthates into the pods.

Slow release characteristic of granular organic fertilizer distributes nutrients into the plant slowly, so the period of pod formation and development is relatively longer. Harvest interval of 2 days is the most optimal treatment of the addition of granular organic fertilizer because at interval of 1 day photosynthate accumulation on pods is not optimal so the pods are smaller, while at interval of 3 days the seeds in the pods are already formed and grown (as seen from the diameter and length of pods).

CONCLUSIONS

The doses of organic fertilizer granules and harvest intervals affected the growth component (*i.e.* shoot:root ratio), yield component (percentage of productive branches) and quality component (percentage of grade B and C) of beans grown on Inceptisol from Jatinangor, West Java.

The application of 150 kg ha^{-1} granular organic fertilizer and harvest interval of 2 days resulted in shoot:root ratio of 12.83, percentage of productive branches of 57.48%, the high percentage of grade B pods, *i.e.* 60.17% and the low percentage of grade C pods, *i.e.* 29.21% .

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