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Effect of Manure Dosage on the Growth and Yield of Bambara Beans through a Multilocation Test

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ABSTRACT

The purpose of this study is to determine the suitability and productivity level of Bambara beans in the Special Region of Yogyakarta, especially to determine and examine the effect of the use of organic fertilizer from livestock manure on the growth and yield of Bambara beans. The implementation of the study involved a multi-location test of Bambara bean cultivation in three subdistricts, namely Tempel, Sedayu, and Cangkringan. In these three areas, manure was applied with 3 dose variations, namely 10 tons/Ha, 20 tons/ha and 30 tons/ha. The study was arranged in a Completely Randomized Design (CRD) where each treatment was carried out with 3 replication plots. The test results showed that the dose of manure was not significantly different from the production of Bambara beans. Therefore, a dose of manure of 10 tons/ha can be recommended to achieve higher economic benefits in Bambara bean cultivation. In addition, based on the evaluation of the growth phase and plant yield, the location of Bambara bean planting in Tempel gave higher yields compared to Sedayu and Cangkringan. Bambara bean cultivation in Tempel can produce 686.45 g/plot.

1. INTRODUCTION

Yogyakarta is one of the centers of food production with fertile natural resources and a community (farmers, livestock breeders, and food processing UMKM) that supports the development of the agricultural sector from upstream to downstream. However, the agricultural sector in Yogyakarta still has problems where the diversity of plant commodities is dominated by rice plants so that the rotation of less varied cropping patterns causes the condition of the soil to decline in quality. Another problem encountered is the dependence of farmers on the use of chemical fertilizers in plant cultivation.

In order to respond to these challenges, the Department of Agrotechnology and the Department of Animal Husbandry and Agricultural Product Technology (both at the Faculty of Agroindustry, Mercu Buana University Yogyakarta), collaborates to carry the concept of integrated agriculture in an effort to increase community income. The development of integrated agriculture, especially the cultivation of Bogor beans or Bambara beans (*Vigna subterranean* (L.) Verdcourt), is expected to give positive impact on the community. Bambara beans are tolerant to water shortages and low-nutrient soil conditions. Bambara beans are also plants that are easily adaptable to high temperature changes but are also resistant to high rainfall (Kurniawan *et al*., 2021). Seeing this adaptability, Bambara beans have the potential to be developed in the Special Region of Yogyakarta. Bambara beans can then be used as raw materials for Bambara bean processing to support the development of MSMEs.

Bambara beans have high nutritional content. Every 100 grams, bambara beans have a protein content of 20.6%, a fat content of 6.6%, a fiber content of 6.3%, an ash content of 3.25%, and a carbohydrate content of 56.61% (Aminah

et al., 2019). Bambara beans have a fat content that mostly consists of unsaturated fatty acids (palmitic, oleic, linoleic and caprylic) which are important contents for body health (Agustina & Haryani, 2021). Bambara beans have a balance between essential amino acids with relatively high levels of lysine and methionine (Eltayeb *et al*., 2011). According to Plahar & Yawson (2004), Bambara beans have a higher protein content when compared to soybeans and cowpeas. Bambara beans contain 32.72% of the total essential amino acids and 66.10% of the total non-essential amino acids (Fitriyani *et al*., 2020).

According to the Department of Agriculture, Forestry and Fishery of the Republic of South Africa (DOAFF, 2016), Bogor beans or Bambara beans originate from the African continent which has been cultivated by humans for several centuries. The cultivation of Bambara beans has expanded its territory until it was brought by the Arabs to the Madagascar region. Until the 17th century, these beans had been cultivated in Brazil and Suriname and spread to Southeast Asia, especially in Indonesia. Bambara beans have been successfully cultivated in the Bogor area and the eastern part of West Java. Distribution in other areas, namely Central Java (Kudus and Pati), East Java in the Gresik area, and in various areas outside Java, namely in the NTT, Lampung and NTB areas (Alfiyah & Yulianah, 2017). The use of Bambara beans is often found as simple processed foods by boiling or frying. The development of processed Bambara bean products still has opportunities such as processed yogurt and milk (Pahane *et al*., 2017), processed vegetable cheese (Gozali, 2017), processed cakes, bread and other traditional dishes (Nti, 2004). One alternative processed product is instant Bambara peanut milk which can be a solution to reduce dependence on soybeans.

In general, agricultural land shows a decline in fertility and damage and has shown symptoms of reduced land productivity levels, especially in intensified rice fields. Various factors that cause this condition are: a) imbalance in soil nutrient levels; b) lack of nutrients in the soil; c) decreased soil organic matter levels; d) shallowing of the tillage layer; e) pollution by chemicals in the agricultural sector or waste; f) decreased microbial activity and population; and g) soil alkalinization and salinity. Inappropriate management of nutrient content in agricultural areas causes agricultural land to show low organic matter levels (Hunila *et al*., 2023). In addition to this, another crucial problem is that agricultural efforts are considered not to have a positive impact on improving community welfare.

One way to improve the quality of soil fertility is by providing organic fertilizer from livestock waste. In this case, Yogyakarta has quite large ruminant livestock resources, namely dairy cattle, beef cattle, beef goats, and dairy goats. Waste from these livestock can be used to increase the fertility of agricultural land and improve soil structure. This current study is purposed to determine the suitability and productivity levels of Bambara beans in the Special Region of Yogyakarta through multi-location cultivation test in three different areas. The multi-location test is carried out especially to assess and evaluate the effect of the use of organic fertilizer from livestock manure on the growth and yield of Bambara beans in different areas of Yogyakarta. The results of this research are expected to provide an overview of the suitability of Bambara bean cultivation and improve agricultural efficiency and productivity with the use of appropriate doses of manure fertilizer in an effort to substitute the use of chemical fertilizers. The research is also expected to encourage the development of processed Bambara beans to improving the welfare of farmers.

2. METHOD

Field experiments were conducted by cultivating Bambara beans at three locations, namely Subdistricts of Tempel (7°41'08.4"S; 110°17'20.2"E), Sedayu (7°48'31.2"S; 110°16'09.6"E), and Cangkringan (7°37'16.3"S; 110°26'19.8"E). The three sites were selected taking into account slight different climatic characteristics and soil conditions, as detailed in Table 1. The three locations were presented in in the map of the Special Region of Yogyakarta in Figure 1.

2.1. Design of Experiment

In this research, Bambara beans of Gresik accession (Figure 2) was cultivated with planting space of 25 cm × 40 cm. Goat manure was applied by spreading on the soil surface just after land preparation finish. Field experimental plots of 2 m by 2 m size were depicted in Figure 3. In the three locations, different treatments of manure dosages were performed with 3 replications. The manure dose treatments consisted of P1 (manure 10 ton/ha or 4 kg/plot), P2 (manure 20 ton/ha or 8 kg/plot), and P3 (manure 30 ton/ha or 12 kg/plot). The experiment plots was arranged according to a complete randomized design.

Table 1. Climate and soil conditions of the planting sites

Treatment	Sedayu	Tempel	Cangkringan
Humidity (%)	40.0	46.6	51.0
Light intensity (lux)	352.2	425.8	334.9
Wind speed (m/s)	1.40	2.70	2.90
Temperature (°C)	32.0	33.4	31.3
Soil type	Vertisol	Cambisol	Regosol
Soil pH	7.0	7.0	6.8

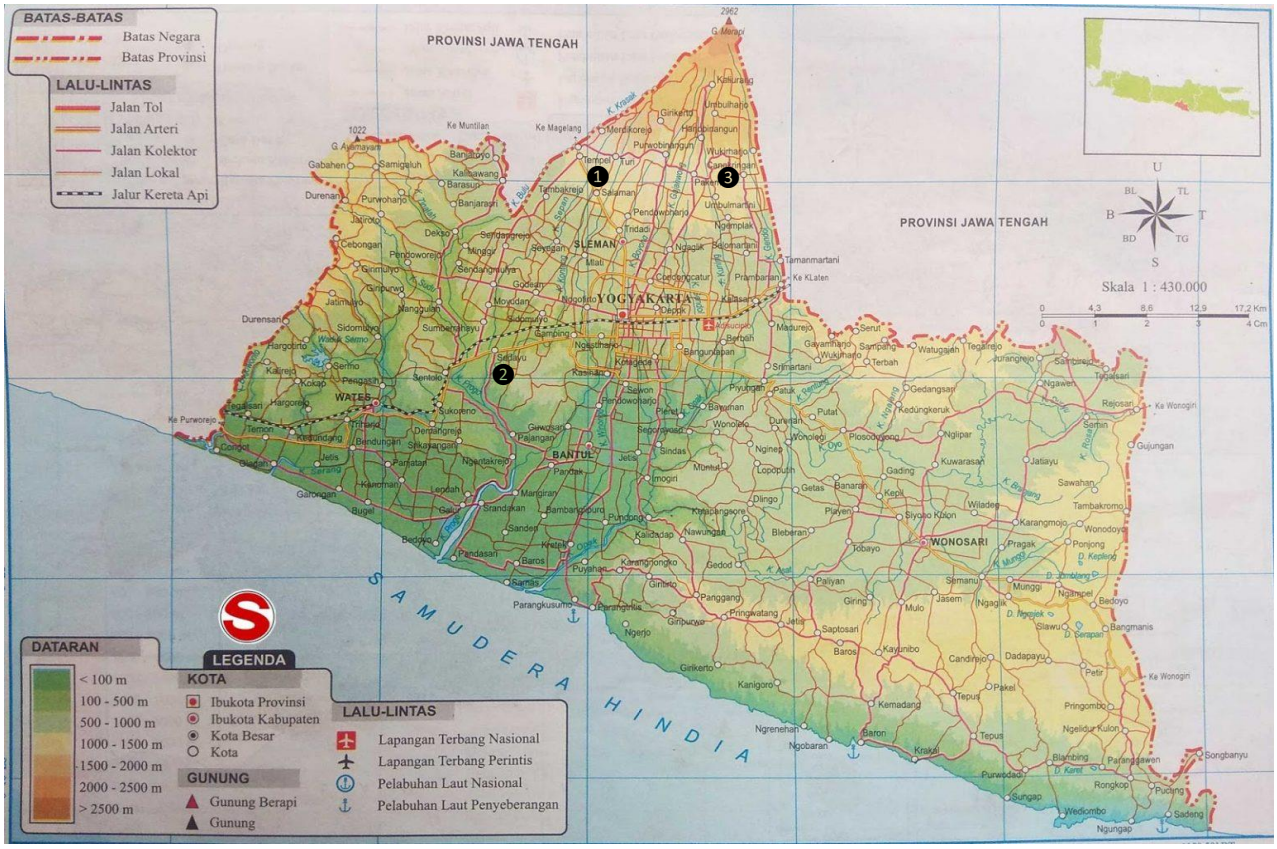

Figure 1. Experiment location within Yogyakarta map (❶Tempel; ❷Sedayu; ❸Cangkringan)

Figure 2. Bambara beans of Gresik accession used in the experiment

Figure 3. Field experimental plots. From left to right: Tempel, Sedayu, Cangkringan

2.2. Growth Variables

- *Plant height*. Plant height was measured from the base of the stem to the growing point using a bar. Plant height measurement was carried out at intervals of 2 weeks, started when the plant was 2 weeks after sowing (WAS) till the initial of generative phase which is characterized by the appearance of flowers.
- *Number of leaves*. Observation was done biweekly by counting all number of leaves, started when the plant was one WAS until harvest time.
- *Stem diameter*. Measurement of the diameter of the stem of the plant was done biweekly using a caliper on the stem that has been given a sign, started when the plant was 2 WAS until the initial of generative phase.
- *Fresh weight*. Fresh weight measurement was done at the harvest time. Measurements were carried out throughout the Bambara bean plant using an analytical balance.
- *Dry weight*. Plant samples with known fresh weight were oven-dried at 80 °C for 24 hours, then weighed for dry weight.

2.3. Yield Variables

- *Number of pods per plant*. Measurement of the number of pods per plant was carried out by counting the number of pods on the harvested Bambara bean plant sample.
- *Pod weight*. Observations were carried out by weighing only the pods using an analytical balance.
- *Number of full pods*. Observations were made by counting full pods of the harvested Bambara bean plant sample.
- *Weight of full pods*. Observations were made by weighing the full pods on the sample using an analytical balance.
- *Weight of 100 seeds*. Measurements were made by weighing 100 seeds of Bambara bean using analytical balance.

2.4. Data Analysis

All measured data were analyzed using ANOVA to evaluate the effect of treatment, and if the treatment of planting location and manure dose resulted a significant effect, then it is continued with Duncan Multiple Range Test (DMRT).

2. RESULTS AND DISCUSSION

Based on research in the field related to planting Bambara beans on the location and use of different doses of manure, it is obtained various results through observation of growth variables in the vegetative phase and variable results in the generative phase of plants.

3.1. Growth Variables

Plant growth was observed with a variety of observation variables, namely plant height, number of leaves, stem diameter, wet or fresh weight, and dry weight of plant biomass. Plant height variable is one of the parameters used to see easily the effect of treatment or environment on the plant growth (Wahyu *et al*., 2022). The following results of the analysis of the effect of planting sites and manure fertilizer doses on the plant height of Bambara bean at week 1 to week 4 are shown in Table 2.

Table 2. Effect of location and manure dose on the plant height (cm) of Bambara bean

Treatment	Observation time			
	Week 1	Week 2	Week 3	Week 4
Research Locations				
Cangkringan	7.68 ab	14.35 a	16.08 b	15.78 b
Tempel	8.27 a	15.07 a	20.60 a	25.19 a
Sedayu	7.24 b	9.43 b	12.17 c	15.96 b
Manure Dosage				
Fertilizer dosage 4kg	8.14 a	13.55 a	16.53 a	18.70 a
Fertilizer dosage 8kg	7.60 a	12.32 a	15.77 a	19.09 a
Fertilizer dosage 12kg	7.45 a	12.99 a	16.56 a	19.15 a

Note: same lowercases after mean values in the same column and same factor indicate not significantly different at 5% DMRT

Table 2 shows the results of observations of plant height at 3 different research sites and the use of 3 different doses of manure fertilizer. Based on Table 2, it can be seen that the planting location shows a significant difference in plant height as indicated by data from week 1 to week 4. In this case, planting in the Tempel area shows the best plant height compared to the other 2 areas (Sedayu and Cangkringan). Based on the results of the analysis, there was no interaction between the research location and the dose of manure, which means that there is no real relationship between planting Bambara beans in several locations and different doses of manure.

The next observed growth variable is the number of leaves. Leaves are parts of plants that have a function as the location of the photosynthesis process that produces photosynthesis. In the presence of sunlight elements, carbon dioxide and water are processed by chlorophyll turns into carbohydrates, organic compounds and oxygen (Ahmad *et al*., 2021). Nutrients produced in the process of photosynthesis are used for the needs of plants and for food reserves (Irianti *et al*., 2022). The results of the analysis of the effect of planting sites and kinds of doses of manure on the number of Bambara bean leaves are shown in Table 3. It shows the results that the planting sites significantly affect the growth of Bambara beans, especially in the variable of the number of leaves. The largest number of leaves is shown differently at the planting site in Tempel. In the 4 WAS Bambara beans planted in the Tempel areas produce the highest number of leaves more than those planted in Sedayu and Cangkringan. The number of leaves will affect plant growth (Arifin *et al*., 2023). The greater number of leaves in plants produces higher photosynthesis results, it affects plant growth (Nugroho & Setiawan, 2022).

Table 3. Effect of location and manure dose on the number of leaves of Bambara bean

Treatment	Observation Time			
	Week 1	Week 2	Week 3	Week 4
Research Locations				
Cangkringan	3.36 b	6.91 c	12.69 b	20.58 c
Tempel	4.11 a	11.16 a	30.60 a	57.31 a
Sedayu	3.76 ab	9.33 b	15.60 b	32.16 b
Fertilizer Dosage				
Fertilizer dosage 4kg	3.87 a	9.49 a	20.56 a	37.80 a
Fertilizer dosage 8kg	3.76 a	8.71 a	18.16 a	34.89 a
Fertilizer dosage 12kg	3.60 a	9.20 a	20.18 a	37.36 a

Note: same lowercases after mean values in the same column and same factor indicate not significantly different at 5% DMRT

Another growth variable observed was the stem diameter of Bambara beans. Stem diameter was observed for 4 weeks. Observation on week 1, 3, and 4 showed no interaction between the research site and manure fertilizer doses on the number of leaves of Bambara beans. The planting locations are significant on the stem diameter, but doses of manure fertilizer are not significant. In week 1 to week 4 planting sites in the Subdistrict of Tempel showed the highest results for the stem diameter, greater than the other 2 locations. The interaction between planting sites and manure doses are, however, significant at the second week of planting (Table 5). In this case, the use of manure of 8 kg/plot showed the best results in term of stem diameter at the 3 sites.

Table 4. Effect of location and manure dose on the stem diameter (cm) of Bambara bean

Treatment	Observation Time		
	Week 1	Week 3	Week 4
Research Locations			
Cangkringan	0.21 b	0.344 b	0.368 b
Tempel	0.31 a	0.48 a	0.61 a
Sedayu	0.18 b	0.33 b	0.36 b
Fertilizer Dosage			
Fertilizer dosage 4kg	3.87 a	20.56 a	37.80 a
Fertilizer dosage 8kg	3.76 a	18.16 a	34.89 a
Fertilizer dosage 12kg	3.60 a	20.18 a	37.36 a

Note: same lowercases after mean values in the same column and same factor indicate not significantly different at 5% DMRT

Table 5. Interaction effect of location and manure dose on the stem diameter (cm) of Bambara bean at week 2

Research Locations	Fertilizer dosage 4kg	Fertilizer dosage 8kg	Fertilizer dosage 12kg
Cangkringan	0.24 b	0.39 a	0.30 b
Tempel	0.24 b	0.38 a	0.26 b
Sedayu	0.25 b	0.41 a	0.28 b
Average	0.24	0.39	0.28

Note: same lowercases after mean values in the same column indicate not significantly different at 5% DMRT

Table 6. Effect of treatment on fresh weight (g) of shoots

Treatment	Fresh weight
Locations	
Cangkringan	28.14 b
Tempel	57.73 a
Sedayu	53.72 a
Fertilizer Dosage	
Fertilizer dosage 4kg	42.15 a
Fertilizer dosage 8kg	49.97 a
Fertilizer dosage 12kg	47.47 a
Average	46.53

Note: same lowercases after mean values in the same column and same factor indicate not significantly different at 5% DMRT

Table 7. Effect of treatment on dry weight (g) of shoots

Treatment	Dry weight
Locations	
Cangkringan	5.82 c
Tempel	12.21 b
Sedayu	21.04 a
Fertilizer Dosage	
Fertilizer dosage 4kg	12.26 a
Fertilizer dosage 8kg	13.40 a
Fertilizer dosage 12kg	13.41 a
Average	13.02

Note: same lowercases after mean values in the same column and same factor indicate not significantly different at 5% DMRT

Furthermore, the growth variable observed when the plant is in the vegetative phase is the weight of wet and dry shoots to see the nutrient uptake that can be used for plant development. Wet weight of plants is the weight of the plant after harvesting which is directly measured before the plant withers due to water evaporation. The weight of the shoot is the total weight of the plant without roots which shows the results of metabolic activity of the plant (Susilo, 2019). The results of the analysis of observations of wet shoots can be seen in Table 6. It shows that there is a significant difference between the locations of Bambara beans planting on the weight of fresh shoots. Higher scores were shown at the planting sites of Tempel and Sedayu, while the use of different doses of manure fertilizer did not show significantly different results. Wet weight of shoots shows the amount of nutrients and water that can be absorbed by plants (Albadri *et al*., 2022). The weight of the crop is a representation of the results of photosynthesis during the plant growth process, the nutrients absorbed by the plant well will be seen from the growth of leaves in larger plants so that the photosynthesis process goes better (Pangaribuan *et al*., 2020). The number of leaves more leaves will make a greater yield of photosynthesis, photosynthesis is used for plant growth (Sari *et al*., 2019).

As for the dry weight after drying until a constant weight is achieved, it can be seen in Table 7. It shows the significant influence of the planting sites on the weight of dry shoot. In this case, the planting site with the highest

score is shown by Sedayu area and then the Tempel area. Dry weigh can describe the pattern of a plant accumulating the products of the photosynthesis process (Zulkifli *et al*., 2022). The dry weight of a plant indicates the end result of photosynthesis. The higher the dry weight of the plant, the better the growth (Kartika, 2018). Various observation variables in the growth phase are important to see how plant growth in different planting climates and the influence of various doses of manure on the growth of Bambara beans. The soil type and climate condition of the 3 planting sites has been previously summarized in Table 1. Different soil types exist, namely cambisol in Tempel Subdistrict with soil pH around 7.0, vertisol soil on Sedayu Subdistrict with soil pH around 7.0, and regosol soil type in Cangkringan Subdistrict with soil pH around 6.8.

2. Yield Variables

The generative phase of the plant was observed with a variety of variables such as the total number of pods, total pod weight, number of full pods, weight of full pods, harvest weight per plot, and weight of 100 seeds. The results of observations of the total number of pods on the treatment site and the dose of compost fertilizer are shown in Table 8. It shows that there is no real interaction between the treatment of planting sites and the use of fertilizer dose variation on the total number of pods. Based on the results of the analysis showed that the total number of pods best shown at the planting site in Tempel, while the next best planting location shown at Sedayu and Cangkringan. As for the treatment of fertilizer doses, it does not have a significant effect on the total number of pods.

Variable number of total pods correlates to the total pod weight. As shown Table 9, the best total pod weight is shown by planting location in Tempel. Table 9 shows that there is no real interaction between the treatment of planting sites and the use of fertilizer dose variation on total pod weight. Other generative variables is the number of full pods that describe the results of the treatment of research sites and fertilizer doses. The number of full pods is lead by planting site in Tempel, while for the treatment of manure doses did not show a difference between the 3 dosages. The As shown in Table 10, there is no significant interaction between the planting sites and the dose of manure fertilizer on the number of full pods. The number of filled pods and the weight of the full pods describe the yield of Bambara beans that can be utilized and have economic value. As can be observed in Table 11, the best weight of full pods is shown in planting sites in Tempel. While the treatment dose of fertilizer showed no difference between treatments. Table 11 also shows that there is no significant interaction between the treatment of planting sites and the use of fertilizer dose variation on the weight of the pods.

Table 8. Interaction effect of location and manure dose on the total number of pods per plant of Bambara bean

Location	Fertilizer 4kg	Fertilizer 8kg	Fertilizer 12kg	Average	
Cangkringan	5.33	5.27	6.07	5.56	c
Tempel	28.20	26.40	28.33	27.64	a
Sedayu	7.73	12.73	11.80	10.75	b
Average	13.75 a	14.80 a	15.40 a		

Table 9. Interaction effect of location and manure dose on the total pod weight (g/plant) of Bambara bean

Location	Fertilizer 4kg	Fertilizer 8kg	Fertilizer 12kg	Average	
Cangkringan	11.65	11.32	12.96	11.98	b
Tempel	45.71	36.35	50.77	44.28	a
Sedayu	8.73	19.09	16.96	14.92	b
Average	22.03 a	22.25 a	26.89 a		

Table 10. Interaction effect of location and manure dose on the total number of full pods per plant of Bambara bean

Location	Fertilizer 4kg	Fertilizer 8kg	Fertilizer 12kg	Average	
Cangkringan	4.53	4.47	5.20	4.73	b
Tempel	28.13	26.27	27.60	27.33	a
Sedayu	5.73	10.60	8.07	8.13	b
Average	12.80 a	13.78 a	13.62 a		

Table 11. Interaction effect of location and manure dose on the total weight (g/plant) of full pods of Bambara bean

Location	Fertilizer 4kg	Fertilizer 8kg	Fertilizer 12kg	Average	
Cangkringan	10.21	10.07	11.72	10.67	b
Tempel	45.72	36.29	50.08	44.03	a
Sedayu	3.23	5.63	3.53	4.13	c
Average	19.72 a	17.33 a	21.78 a		

Table 12. Interaction effect of location and manure dose on the yield of harvesting plot (g/m^2)

Location	Fertilizer 4kg	Fertilizer 8kg	Fertilizer 12kg	Average	
Cangkringan	169.76	162.60	201.44	177.93	b
Tempel	721.60	514.80	822.94	686.45	a
Sedayu	103.32	115.74	95.32	104.79	b
Average	331.56 a	264.38 a	373.23 a		

Table 13. Interaction effect of location and manure dose on the weight of 100 grains (g)

Location	Fertilizer 4kg	Fertilizer 8kg	Fertilizer 12kg	Average	
Cangkringan	51.76	53.82	57.30	54.29	b
Tempel	74.54	73.98	73.93	74.15	a
Sedayu	44.21	57.46	50.50	50.72	b
Average	56.84 a	61.75 a	60.58 a		

In addition to the various variables observed results, in this study also examined the picture of the results of each treatment. The harvest plot in an experimental study describes the production of the planting area on the scale of the study. In this study, the best harvest plots were shown in the treatment of research sites in Tempel, while the treatment of fertilizer doses did not show significant differences between treatments. The data can be seen in Table 12.

Based on the results of the analysis conducted, table 13 shows that there is no real interaction between the treatment of planting sites and the use of fertilizer dose variation on the weight of the harvest plot. The weight of 100 seeds shows the results of photosynthetic plants that are focused in the generative phase to form Bambara bean seeds. This study shows that the weight of the 100 best seeds shown in the treatment of planting sites in Tempel Sleman, while the treatment dose of fertilization does not show a real difference. The results of the analysis also showed that there was no real interaction between the treatment of planting sites and the use of fertilizer dose variation on the weight of 100 seeds. Based on the various variables observed in the generative phase of the plant, overall Bambara bean planting sites in Tempel has the best results. The dose of fertilizer does not give different results between treatments.

4. CONCLUSION

The following conclusions can be drawn based on research that has been carried out, namely related to the trial planting of Bambara beans at 3 different locations and the use of 3 different doses of manure. Based on the results of data analysis on the growth phase and crop yield, it can be suggested that the location of planting and development of Bambara beans can be done in Tempel or surrounding areas that still have similar climatic and soil characteristics. The use of fertilizer doses of 10 tons/ha, 20 tons/ha and 30 tons/ha in Bambara bean cultivation does not show any significant difference so that it can use fertilizer recommendations of 10 tons/ha in order to achieve efficient use of manure and achieve higher economic value.

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