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THE EFFECT OF CULTIVATION TECHNIQUES ON SOIL CHARACTERISTICS AND BAMBARA GROUNDNUT PRODUCTION

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Abstract

The potential of bambara groundnut (Vigna subterranea (L.) Verdcourt) as a source of protein is relatively high, but the production is relatively low. Efforts that can be made to increase production include modifying cultivation techniques. The aim of this research is to determine the effect of cultivation techniques on soil characteristics and bambara groundnut production, as well as to determine the correlation between production variables and soil characteristics. This research was conducted in Dukuh Tanjung, Umbulmartani Village, Sleman district. The design used was a Randomized Complete Block Design with one factor and three replications/blocks. The factors applied are 2 cultivation techniques: using beds and without using beds. The variables observed in this research include pod yield variables and soil character analysis. The bambara groundnut cultivation technique with beds produces a lighter density per mass than the cultivation technique without beds. The element P (phosphorus) content in the soil is an element that has a real positive correlation with all yield variables. The dust fraction is the soil fraction that is most significantly negatively correlated: negatively correlated with the number of pods per plant, dry pod weight per plot, N content and K content in the soil.

Keyword*: bambara groundnut, beds, dust fraction, number of pods, phosphorus.*

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdcourt) are originating from North Africa, then spread by native people to South Africa (Fatimah and Kuswanto, 2023). Currently, bambara groundnut have spread to Madagascar, India, Ceylon, Indonesia, Malaysia, the Philippines, Iowa, New Caledonia, Australia, tropical Central America and Brazil (Fatimah and Kuswanto, 2023). This plant was introduced to Indonesia at the beginning of the 20th century as a new source of protein but is less popular due to its low production and until now was considered a side food (Alhamdi et al., 2020).

Hidayah (2005) recommended bambara groundnut as a healthy food because their fat content consists mostly of unsaturated fatty acids (palmitic, oleic, linoleic and caprylic) which are very important for body health. Bambara groundnut are also a plant that has potential as an alternative food source for producing protein and carbohydrates. Suwanprasert et al. (2006) stated that the dry seeds of this plant have a fairly high protein content, i.e. 16 – 21%, carbohydrates 50 – 60% and low fat 4.5 – 6.5%, and contain calcium, phosphorus, iron and vitamin B1 (Suwanprasert et al. al., 2006). The protein content of bambara groundnut is known to reach 33% (Hindun et al., 2013). Bambara groundnut as an alternative food ingredient can be processed into other products such as milk and yogurt (Pahane et al., 2017), soft cheese (Gozali, 2017), rolls, cookies, cakes, muffins, donuts, pastry pies, bread and other traditional practices (Yasufu and Ejeh, 2018).

The productivity of bambara groundnut in Indonesia is still relatively low. According to Redjeki (2003), bambara groundnut production in Indonesia for population with mixed testa colors (black, red and cream) produces 2 tons of dry seeds ha^{-1}, the black testa population produces 0.9 tons ha^{-1}, while the red and cream populations produce 1 ton ha^{-1}. According to Al Hamdi (2020) the highest productivity was shown in the Sukabumi landrace, which is 2 tons ha^{-1}. Meanwhile in the Africa, Kouassi and Zoro (2010) reported that the production of dry bambara groundnut seeds at high density in Ivory Coast could produce 3.9 tons ha^{-1}.

Soil character is one of the most influential factors in bambara groundnut cultivation. The South African Department of Agriculture and Fisheries (2016) stated that the ideal soil texture for bambara groundnut is sand to sandy loam. According to Linneman and Azam-Ali (1993), bambara groundnut are also tolerant of high rainfall and limited nutrients. Therefore, research is needed on soil characteristics, field capacity and nutrient content in the soil to analyze the effects of stress.

One effort to increase bambara groundnut production is modifying cultivation techniques. Modification treatments in cultivation techniques will have an influence on land conditions and plant conditions. Thus, this research aimed to determine the effect of cultivation techniques on soil characteristics and bambara groundnut production, as well as determine the correlation between production variables and soil characteristics.

METHOD

This research was conducted on 18 m x 11 m land in Dukuh Tanjung, Umbulmartani Village, Ngemplak Sub district, District of Sleman (7°41'56.8"S 110°26'22.7"E). The design used was a Complete Randomized Block Design with one factor and three replications/blocks. The factors applied were cultivation techniques which consisted of 2 techniques: the first was cultivating bambara groundnut using beds 20 cm high, 1 m wide and 5 m long, while the second was cultivating bambara goundnut without using beds. Each treatment used 5 m x 6 m land. In the bed treatment, the planting distance used was 25x50 cm, in each bed there were 2 rows of plants. In the treatment without beds, the planting distance used was 25x65 cm. Each treatment consisted of 216 plant populations. The seeds used were local accession seeds from various regions in Java Island.

Figure 1 Cultivation techniques with beds and without beds

The research began with land processing using a tractor. After the soil was loose, beds were made in the cultivation technique treatment with beds, beds are not made in the treatment without beds. Then the land was spreaded with goat manure at the same dose, which was 2 ton.ha^{-1} two weeks before planting. The manure sown in the bed treatment was spread evenly only on the bed, while in the treatment without beds it was spread evenly over the entire surface of the soil. Planting began on June 24 2023 and harvest in early October 2023. Planting was carried out in the dry season without any rain throughout planting. Irrigation is carried out only three times, i.e. 1 day before planting, 2 weeks after planting (WAP) and 5 WAP. NPK fertilization was carried out at 5 WAP and 8 WAP with a dose of 2 grams per planting hole. Earthing up was done when flowers start to appear, namely 60 days after planting (DAP) and 76 DAP.

Production variables observed included wet pod weight per plant, number of pods per plant, dry pod weight per plant and dry pod weight per treatment plot. Apart from that, there was also soil testing carried out at the UPN Veteran Yogyakarta Soil Science Laboratory. Soil samples were taken at 2 WAP at all treatment points. Soil characteristics tested include N tsd (ppm), P tsd (ppm), K Tsd (me%), dust fraction content, sand clay (%),soil bulk density per-volume, soil bulk density per-mass, porosity and field capacity.

Data were analyzed by analysis of variance (ANOVA) using the STAR (Statistical Tool for Agricultural Research) 2.0.1 application. If there was a significant difference, the data was tested further with the Least Significant Difference Test (LSD). Apart from the analysis of variance, the Pearson correlation test was also carried out on all observed variables using the same application.

RESULTS

The results of ANOVA showed that there were no significant differences in production variables regarding differences in cultivation techniques (Table 1). In the soil character variable, there was a significant difference in soil bulk density per-mass depending on the cultivation technique and the sand fraction was significantly different in different blocks.

Table 1. Recapitulation of results of analysis of variance (ANOVA) on all variables

Research variable	Cultivation technique	Block
Wet pod weight/plant (WP)	ns	ns
Number of pods/plant (NP)	ns	ns
Dry pod weight /plant (DP)	ns	ns
Dry pod weight/plot (DPP)	ns	ns
N tsd (ppm)	ns	ns
P tsd (ppm)	ns	ns
K tsd (me %)	ns	ns
Soil bulk density per-volume (SBV) (g cm^{-3})	ns	ns
Soil bulk density per-mass (SBM) (g cm^{-3})	*	ns
Porosity	ns	ns
Dust fraction (%)	ns	ns
Clay fraction (%)	ns	ns
Sand fraction (%)	ns	*
Field Capacity (%)	ns	ns

Note: ns= not significant
* = significant

Cultivation techniques influenced soil density per mass (Table 2). The treatment without beds was significantly higher than the cultivation technique with beds. This difference is thought to be caused by the application of goat manure 2 weeks before planting. The difference between the 2 cultivation techniques is that the cultivation technique with raised beds only involves spreading manure on the beds so that the maximum amount of organic material given can be absorbed into the raised beds. Meanwhile, in the bedless technique, the manure is spread evenly over the entire plot of land so that the organic material is distributed evenly over the entire surface of the soil. Saputra et al. (2018) stated that adding organic material to the soil can increase the amount of soil pore space and form a crumbly soil structure, thereby reducing the bulk density of the soil. The difference in sand fraction on the land showed that block II has a significantly higher sand fraction compared to blocks I and III. This may be caused by environmental differences.

Table 2. The effect of cultivation techniques and block differences on soil characteristics

Cultivation technique	soil bulk density per-mass	
With beds	2.3	b
Without beds	2.48	a
Block	**Sand fraction**	
I	81.02	b
II	84.94	a
III	81.97	b

Note: Numbers followed by the same letter are not significantly different at the 5% level of the Least Significant Difference (LSD)

Table 3 showed that there are significant differences in several observation variables. The variables WP, NP, DP and DPP showed a significant correlation with each other. This is natural because the object of observation for the four variables is the same so they are interconnected. Likewise with the levels of N, P, and K, all three of which are correlated with each other. Regarding soil characteristics, the variables soil bulk density per-mass, soil bulk density per-volume and soil porosity do not show a significant correlation with all other variables. This showed that soil bulk density and porosity do not affect bambara groundnut production or NPK soil content in bambara groundnut cultivation.

The N content in the soil was significantly positively correlated with the number of pods per plant and the dry weight of the pods per plot. The research results of Puspasari et al. (2018) on soybean plants stated that the provision of N elements must be optimal, there must be no excess or deficiency, if it is not optimal there will be a decrease in the number of pods. In this study, N fertilizer was given equally, namely NPK at 2 and 5 WAP. This correlation shows that if the N content decreases, the number of pods and dry weight of pods per plant will decrease, and vice versa.

The P content had a significant positive correlation with all bambara grondnut production variables. This showed that the greater the P content in the soil, the greater the wet and dry pod weight and the number of bambara groundnut pods. Mahmudul et al. (2018) stated that P application greatly influences various aspects of bambara groundnut plant physiology such as photosynthesis, flower formation, pod formation and seed maturity which has an impact on better productivity.

Table 3 showed that the dust fraction in the soil is significantly negatively correlated with the number of pods per plant and dry pod weight per plant. Dust is a soil fraction that has the smallest granular size which may prevent bambara groundnut from forming pods in the soil. Sari et al. (2022) stated that clay or soil that contains a lot of dust can damage seeds, this is because clay will become harder, especially when conditions are dry. Hard soil can damage seeds during harvest, as well as hinder gynophores from forming pods in the soil. A gynophore is a specific flower stalk that supports the gynoecium (the part of the flower that produces egg cells), raising it above the branching point of the rest of the flower.

The gynophores in bambara groundnut are located at the base of the stem and produce pods and seeds (Figure 2). This showed that the more dust content will reduce the number of pods per plant and the dry weight of pods per plot.

Figure 2 Bambara groundnut pod and gynophore as a connection to the leaf stalk

A significant negative correlation also exists between the dust fraction and the N and K content (Table 3). This showed that if the dust content in the soil is high, the N and K elements will decrease. According to Soniari (2016), the dust fraction in the soil influences the cation exchange capacity so that the N and K levels in this study are more easily absorbed from the soil. Dust fraction levels can affect the binding of N and K to the soil so that available N and K levels decrease.

Table 4 is one of the results of soil analysis using raised bed cultivation techniques that contain the highest NPK nutrients. Field capacity in areas using bed cultivation techniques is higher than in areas using bedless cultivation techniques. In general, field capacity water content is defined as the soil water content in the field when drainage water has stopped or almost stopped flowing due to gravity after the soil has previously experienced complete saturation (Haridjaja et al. 2013). The field capacity on land with raised beds is greater with higher levels of clay fraction than the clay content on land without beds. Soil with a higher clay content has the potential to have a high water holding capacity due to a more stable soil (aggregate) structure (Arsyad, 2012).

Table 3. Pearson correlation table between observed variables

	WP	NP	DP	DPP	N	P	K	SBV	SBM	Porosity	Dust	Clay
WP	1											
NP	0.951**	1										
DP	0.945**	0.958**	1									
DPP	0.968**	0.976**	0.972**	1								
N	0.768tn	0.909*	0.788tn	0.838*	1							
P	0.897*	0.944**	0.833*	0.876*	0.927**	1						
K	0.749tn	0.854*	0.686tn	0.811tn	0.914*	0.876*	1					
SBV	-0.547tn	-0.372tn	-0.503tn	-0.555tn	-0.169tn	-0.218tn	-0.204tn	1				
SBM	-0.656tn	-0.658tn	-0.618tn	-0.618tn	-0.741tn	-0.698tn	-0.605tn	0.584tn	1			
Porosity	0.337tn	0.312tn	0.522tn	0.462tn	0.087tn	-0.001tn	0.046tn	-0.666tn	-0.144tn	1		
Dust	-0.788tn	-0.868*	-0.793tn	-0.895*	-0.875*	-0.078tn	-0.917*	0.505tn	0.718tn	-0.4tn	1	
Clay	0.765tn	0.588tn	0.572tn	0.686tn	0.437tn	0.604tn	0.538tn	-0.796tn	-0.709tn	0.188tn	-0.616tn	1
Sand	0.306tn	0.565tn	0.485tn	0.511tn	0.711tn	0.446tn	0.672tn	0.078tn	-0.269tn	0.336tn	-0.707tn	-0.121tn

Note: WP= Wet pod weight/plant, NP= Number of pods/plant, DP= Dry pod weight/plant, DPP= Dry pod weight per plot, N= Nitrogen element in soil, P= Phosphorus element in soil, K= Potassium element in soil, SBV= Soil bulk density per-volume, SBM= soil bulk density per-mass.
* = indicates a correlation at 5% significance or 0.05.
**= indicate correlation at 1% significance or 0.01.

Table 4. Table of soil characteristics in one of the cultivation technique treatments with beds and without beds

Sample			With bed	Without bed
Field capacity(%)			2.56	1.42
pH			6.63	6.42
N tsd (ppm)			218.24	75.72
P tsd (ppm)			12.99	6.19
K Tsd (me%)			2.7	0.8
Fraction (%)	▪	Dust	11.76	18.66
	▪	Clay	5.19	0.54
	▪	Sand	83.04	80.79
SGV (g cm^{-3})			1.17	1.21
SGM (g cm^{-3})			2.26	2.48
Porosity			47.98	51.13

CONCLUSION

The bambara groundnut cultivation technique with beds produces a lighter density per mass than the cultivation technique without beds. The element P (phosphorus) content in the soil is an element that has a significant positive correlation with all yield variables. The dust fraction is the soil fraction that is most significantly negatively correlated, i.e. negatively correlated with the number of pods per plant, dry pod weight per plot, N content and K content in the soil.

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