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Coix lacryma-jobi L. photo by flowers.la.coocan.jp

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Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

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Short Communication: Volcanic ash utilization as planting medium of curly lettuce with charcoal husk and urban waste compost as soil amendment

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Abstract. *Mulyono, Maas A, Purwanto BH, Sudira P. 2018. Short Communication: Volcanic ash utilization as planting medium of curly lettuce with charcoal husk and urban waste compost as soil amendment. Asian J Agric 2: 39-43.* During a volcanic eruption, volcanic ash spreads over an extensive area and can cause environmental disturbances. Because of this, volcanic ash should be disposed of far from settlements. On the other hand, volcanic ash is useful in urban areas where pot-planting is often lacking in soil medium. However, the utilization of volcanic ash as a direct planting medium has many obstacles due to its characteristics such as the acidic, nitrogen nutrients rareness, compressed and dull to water. Hence, to be ready to use, it should be improved by using soil amendment. This study used charcoal husk combined with compost as the soil amendment. The purpose of this study was to use the volcanic ash as the planting medium, by obtaining a proper dose of volcanic ash and the soil amendments for the growth and yield of curly lettuce. The experimental design applied in this study was the completely randomized design (CRD) with three replications. The first factor was the 5 levels of charcoal husk (on volcanic ash) doses, namely 0.30; 0.40; 0.50; 0.60; and 0.70. The second was the ratio between the media and the 3 levels of urban waste compost doses, namely: 3:1; 2:1 and 1:1, resulting in 5 x 3 total combinations with three replications. The plant growth and yield data results were analyzed by using the variance analysis and continued with Duncan Multiple tests (Duncan Multiple Range Test). The results showed that when used as the sole planting medium, the volcanic ash could not support the growth of lettuce plants. The evidence was shown from the same size and weight of the curly lettuce after the age of 35 days (5 g/plant). The utilization of husk and urban waste compost treatment showed significant growth rise. The combination of volcanic ash and soil amendments showed that the best effect on the growth and yield of curly lettuce was from M3K3 treatment at the dose of 25% volcanic ash, 25% charcoal husk and 50% urban waste compost (60 g/plant).

Keywords: Charcoal husk, curly lettuce, municipal waste compost, volcanic ash

INTRODUCTION

Indonesia is susceptible to volcanic eruptions. However, one of the useful eruption products is volcanic material as it contains valuable soil nutrients. The volcanic ash layers on soil surface make the soil to experience rejuvenation and weathering process where new soil layer establishes with the help of water and organic acids. It increases the cation concentration (Ca, Mg, K and Na) in the soil, up to 50% than the original condition. Also, it functions as ameliorant that will hold nutrient supply degradation, because it contains more complete compositions, as well as neutralization power to 40% acidity which equals $CaCO_3$ (Subiksa et al. 1997; Fiantis 2006).

The use of volcanic ash as the planting medium has several constraints, which are its rapid sedimentation and hardening when exposed to water. Such conditions cause difficulty for root development, resulting in withering and death. One of the efforts to improve the physical condition of volcanic ash is by utilizing biochar, a substance with high carbon concentration. Adding biochar to the soil can increase the C concentration and water retention and improve nutrients in the soil (Lehman and Joseps 2009; Gani 2009).

Besides being used as the soil amendment material, rice husk is potentially useful in composting process and nutrition, as well as sustaining N within the composting process when added with rice husk (Theba et al. 2012). Husk characteristics include lightweight (0.20 g/cm^2), coarse (consequently, with high air circulation), high water resistance and can reduce disease influence, especially bacteria. According to Djatmiko (Purnamasari 2008) charcoal husk that is added to a planting media, will decrease the weight/volume of the planting media, rapidly increase the drainage pore space, and slowly decrease the drainage pore. Carter et al. (2013) obtained a result where the use of charcoal husk would increase the plant and root biomass, the plant weight, and the number of leaves within all plant cultivation in comparison to without charcoal husk treatment because its addition increased the soil pH and CEC (Cation Exchange Capacity).

Besides biochar, volcanic ash requires additional nutrient intake from both inorganic and organic fertilizer. This study emphasized more on the use of organic fertilizer from urban waste compost, which comes from a large number of organic wastes produced by households.

Usually, the biodegradable can be decomposed into simpler compounds due to the microbial activity (Sulistyawati and Ridwan 2012). In general, compacted waste coming from urban and rural area contains more than 75% of decomposable material, such as plant remains. The amount of decomposable waste is a quite potential source of humus, macro and micronutrient and soil conditioner (Setiyo 2007).

This study used lettuce plant (*Lactuca sativa* L.), a common consumable vegetable that is favored for salad, raw snacks, and garnish. It comes in a bright color, fine texture, and aroma that refreshes the looks of food and increases appetite. It is high source of mineral, pro-vitamin A, vitamin C and fiber (Rubatzky and Yamaguchi 1998).

MATERIALS AND METHODS

This study was carried out in the glasshouse of General Soil Laboratory, Soil Chemistry and Fertility Laboratory of the Soil Science Department, in Kuningan and Bulaksumur, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Materials

The planting media used was volcanic ash and charcoal husk. Volcanic ash was taken from an eruption result of Mt Kelud that fell in Yogyakarta area on 13 February 2014. Fertilizer used was organic fertilizer (urban waste compost fertilizer). As an indicator plant, lettuce was used (*Lactuca sativa* L.).

Instruments

This study used the soil chemical and plant tissue analysis as instruments, as well as the experiment instruments. The main instrument was the pot with 2 kg media by weight.

Research design

The experiment design (Table 1) applied was the *Complete Randomized Design* (CRD) with 5 x 3 and three replications. The first treatment factor was the media factor with various planting media levels (M) that included M1 (70% Volcanic ash (AV) and 30% Charcoal husk (AS)), M2 (60:40), M3 (50:50), M4 (40:60) and M5 (30:70). The second factor was the urban waste compost fertilizer dose (K) based on the comparison between media and fertilizer of K1 (3:1), K2 (2:1) and K3 (1:1), which was 15 units of total treatment. The controls applied in this study were: M01 (AV 100: AS 0%), M02 (AV 50: AS 50%), and M03 (AV 50: K 50%).

The mixing of media material and compost was carried out by using the composite method. The materials were overlaid onto plastic sheet by holding up the sheet tips and then pulling them to the center to make it homogeny and then putting the materials into the pots for planting the curly lettuce. The plant was given daily maintenance to reach 35 days of age and ready to be harvested. Watering was carried out through sprinkling system to reach field capacity.

Table 1 Experiment design

Media treatment (AV: AS)	**Media: compost (3:1)**	**Media: Compost (2:1)**	**Media: Compost (1:1)**
M1 (70: 30)	M1*K1	M1*K2	M1*K3
M2 (60: 40)	M2*K1	M2*K2	M2*K3
M3 (50: 50)	M3*K1	M3*K2	M3*K3
M4 (40: 60)	M4*K1	M4*K2	M4*K3
M5 (30: 70)	M5*K1	M5*K2	M5*K3

Observation variable

The variables observed in this study were classified into two groups: (i) planting media and amendment analysis variable, and (ii) plant variable. The first group included: pH, EC (Electrical Conductivity), C organic, CEC, Ca, N, P, and K total. The second included the plant height, numbers of leaf, the root weight, the fresh consumption, and the total weight.

RESULTS AND DISCUSSION

This study observed the volcanic ash feasibility to be used as vegetable planting media, especially for curly lettuce, based on the improvement of physical and chemical volcanic ash characteristics with charcoal husk amendment and urban waste compost fertilizer.

The physical and chemical analysis of the media and amendment

The Mt. Kelud volcanic ash used as the planting media in this study consisted of wrinkled silt texture dominated by silt fraction (52.24%), sand (43.81%) and a small amount of clay fraction (3.95%). The volcanic ash acidity was slightly acid and acid with undetected N content, a little amount of medium degree P, and low degree K. Also, with very low degree EC (Electrical Conductivity) and CEC volcanic ash (Table 2).

The planting media from volcanic ash was given with amendment to improve the physical and chemical characteristics. The amendment used was charcoal husk and urban waste compost fertilizer. Referring to Table 2, charcoal husk contained very low N, P, and K with neutral pH and very low EC with 5.24 cmol/kg CEC. On the other hand, the urban waste compost pH was slightly alkali, with significantly low EC, and nutrient content of 0,75% N, 0,25% P2O5, and 0,83% K. Due to the compost medium C/N ratio level, the renovation process was faster because it experienced decomposition. The compost CEC was classified as high level while the content of total N, P, and K was classified as very low level.

The plant growth and yield analysis

Based on the variance analysis and variation coefficient (Table 3), no interaction was identified between the combination of media and compost. The influence of media and amendment mixture was significantly different at all observed parameters that included the number of leaves, the plant height, the fresh consumption weight, the fresh root weight, and the total weight. In addition, Table 4 showed the variance analysis result of each treatment of media (5 treatments) or compost (3 treatments). It was indicated that the influence of mix between media and compost was significantly different for all parameters of the plant result. In general, the best planting result was obtained from treatment M3, except for the number of leaves which was obtained from treatment M5.

Table 3. Anova Tabulation and variance coefficient between treatments

Parameters	Media	Compost	M x K	Var. Coef.
Number of leaves	NS	*	NS	11.6
Fresh consumption weight	**	**	NS	15.0
Fresh root weight	**	**	*	18.5
Total Weight	**	**	NS	14.2

Note: ** significantly different; * Significantly Different; NS insignificantly different

Table 5. The influence of treatment combination on the growth parameters (per plant)

Treatment combination	Number of leaves	Consumption weight (gram)	Root weight (gram)	Total weight (gram)
M01	5.33 (c)	3.13 (e)	1.93 (f)	5.03 (e)
M02	6.33 (c)	4.92 (e)	3.56 (ef)	8.49 (e)
M03	8.66 (b)	19.75 (d)	3.77 (efd)	23.63 (d)
M1K1	10.00 (ab)	31.49 (bc)	4.86 (cde)	36.35 (c)
M1K2	8.66 (b)	30.84 (bc)	6.46 (bc)	37.31 (c)
M1K3	10.33 (ab)	35.15 (bc)	6.10 (bc)	41.26 (c)
M2K1	9.33 (ab)	34,10 (bc)	5.04 (bcde)	39.14 (c)
M2K2	9.00 (b)	37.42 (bc)	3.77 (def)	41.20 (c)
M2K3	9.00 (b)	36.64 (bc)	7.28 (b)	43.92 (c)
M3K1	9.33 (ab)	32.42 (bc)	6.21 (bc)	38.63 (c)
M3K2	10.00 (ab)	49.49 (a)	6.19 (bc)	55.68 (ab)
M3K3	10.66 (ab)	50.38 (a)	9.44 (a)	59.82 (a)
M4K1	9.66 (ab)	33.84 (bc)	6.20 (bc)	40.04 (c)
M4K2	9.33 (ab)	38.92 (bc)	5.67 (bcde)	44.59 (c)
M4K3	10.33 (ab)	40.63 (b)	5.70 (bcde)	46.34(bc)
M5K1	10.66 (ab)	30.31 (c)	6.07 (bc)	36.39 (c)
M5K2	9.66 (ab)	34.74 (bc)	5.94 (bcd)	40.68 (c)
M5K3	11.33 (a)	39.85 (bc)	7.25 (b)	47.10 (bc)

Table 2. The physical and chemical analysis of volcanic ash, charcoal husk, and compost

Parameter (unit)		The physical/chemical characteristic value (degree)					
		Volcanic ash		Charcoal husk		Compost	
Clay	(%)	3.95	Wrinkled texture	-		-	
Silt	(%)	52.24	Silt	-		-	
Sand	(%)	43.81		-		-	
pH H2O		6.31	Slightly acid	7.07	Neutral	8.19	Slightly alkali
pH KCl		5.38	Slightly acid				
EC	(mS/cm)	0.15	Very Low	0.50	Low	0.30	Very Low
CEC	(cmol/kg)	2,74	Very Low	5.24		22.51	Low
N Total	(%)	-		0.52		0.79	
P Available	(ppm)	9.88	Medium	0.33	Total*)	0.25	Very Low
K Available	($cmol^{+}kg^{-1}$)	0.12	Low	0.96	Total*)	0.83	Very Low
C Organic	(%)			5.71		9.60	Low
Organic matter	(%)			11.42		53.90	High
C/N	-			10.98		12.15	Medium

Table 4. Variance analysis of the influence of media and compost to the plant parameter (per plant)

Parameter	M1	M2	M3	M4	M5	K1	K2	K3
Numbers of Leaf	9.66 (ab)	9.11 (b)	9.77 (ab)	10.00 (ab)	10.55 (a)	9.80 (ab)	9.33 (b)	10.33 (a)
Fresh consumption weight	32.49 (b)	36.09 (b)	44.09 (a)	37.81 (b)	34.97 (b)	32.43 (b)	38.28 (a)	40.53 (a)
Fresh root weight	5.81 (b)	5.36 (b)	7.28 (a)	5.86 (b)	6.42 (b)	5.67 (b)	5.60 (b)	7.15 (a)
Total Weight	38.30 (b)	41.42 (b)	51.38 (a)	43.66 (b)	41.39 (b)	38.11 (b)	43.89 (a)	47.69 (a)

Note: The numbers followed with the same letter in the row were insignificantly different in the DMRT 5% experiment

When observed based on the variance of single factor with combined media and compost treatment (Table 5), the control treatment of sole volcanic ash (M01) as the planting media of curly lettuce produced minimum yield amongst all treatments for all growth parameters. This was because the planting media only consisted of the volcanic ash that was solid, water dull, and with no N content that would disturb the growth and development of the plant. The addition of amendment to the volcanic ash in the form of charcoal husk with equal composition (M02) would increase the yield, although insignificantly. The addition of charcoal husk to the volcanic ash could improve the soil physical characteristics by adding porosity. However, it could not improve the macronutrient required by the plant.

The third control treatment, M03, with 1:1 composition of volcanic ash and compost, could increase the yield especially for consumption weight parameter in comparison to the other two previous treatments. This indicated that although it was not maximum, soil chemical improvement provided better results than physical improvement.

The most optimum result of curly lettuce was obtained from M3K3 combination (volcanic ash 25%, charcoal husk 25%, and compost 50%) especially for the consumption weight (50.38 gram), root weight (9.44 gram), and total weight (59.82 gram) parameters. The optimum result for the number of leaf parameters (11.33) was obtained from treatment M5K3 (volcanic ash 15%, charcoal husk 35%, and compost 50%). These results showed a relation between the composition of volcanic ash and amendment as well as its influence on the increase of planting in un-linear pattern (Figure 1). This indicated that the reduction/increase of amendment did not necessarily increase the yield.

The parameter of planting result being further analyzed was the consumption weight of the curly lettuce. Figure 1 showed the relation of media and compost to the consumption weight of the curly lettuce based on various analysis perspectives: (i) the influence of media and compost combination based on the compost treatment, (ii) the charcoal husk treatment, (iii) treatment combination, and (iv) single factor treatment. Figure 1.A. shows that the increase of compost dose generally increased the consumption weight except for treatment media M2, and the highest result was on treatment media M3. Figure 1.B showed that the increase of charcoal husk dose resulted in maximum consumption weight, especially for the compost treatment K2 and K3. The combination of treatment media and compost to the consumption weight can be fully seen in Figure 1.C. Based on the graphics, it can be wholly seen that the best consumption weight result was obtained from treatment M3K3. Moreover, such un-linearity of the influence of the amendment composition to the consumption weight is presented in Figure 1.D with equation of polynomial order-6 where the maximum result of the consumption weight was obtained from treatment M3K3.

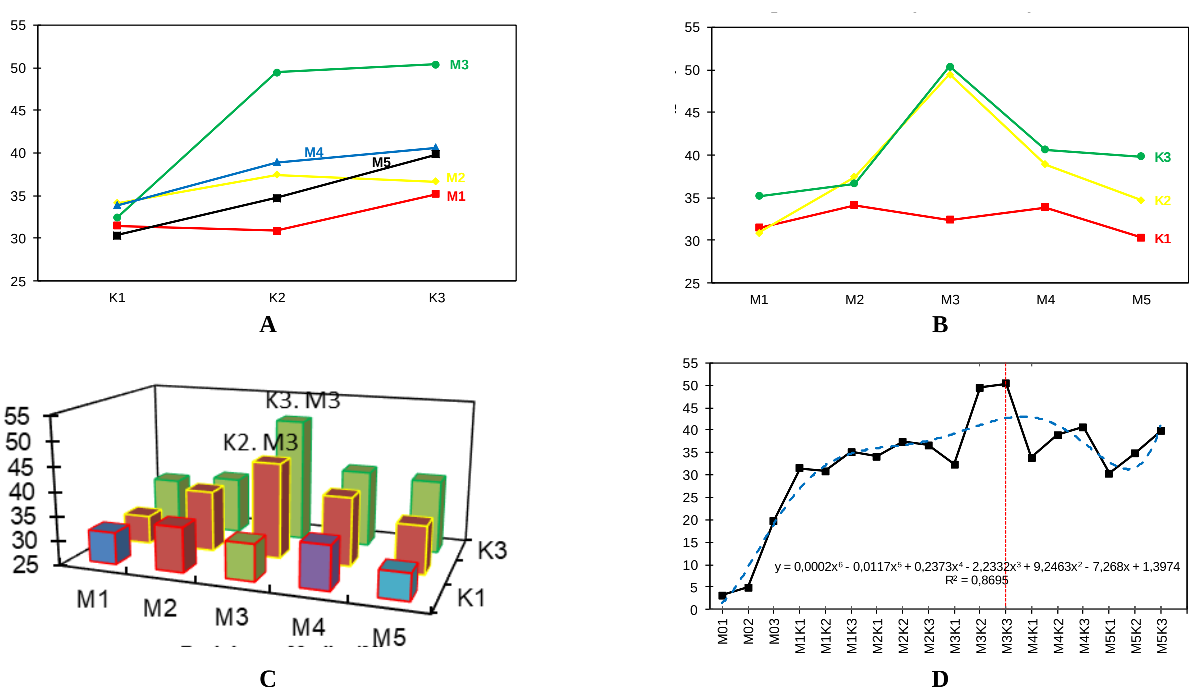

Figure 1. The analysis of the relation of the media and amendment to the planting result: A. The increase of compost dose in response to dry consumption weight (g/kg), B. The increase of charcoal husk dose in response to dry consumption weight (g/kg), C. The combination of media and compost in response to dry consumption weight (g/kg), D. The relation pattern and non-linear result of treatment in response to dry consumption weight.

In compost treatment K3, the increase of charcoal husk dose in treatment M4 and M5 decreased consumption weight relatively to treatment M3 (treatment with optimum result). This was likely because the addition of charcoal husk would increase the media porosity that the infiltration rate would also increase and give impact on the decrease of media availability to store the moisture which was essential for the plant. Such decrease of available moisture would give direct impact on the growth and development of the plant and un-optimum plating results.

In conclusion, volcanic ash with the addition of husk and compost can be used as planting media as amendment materials. Such addition could improve the soil physical and chemical characteristics. The best compost treatment obtained was K3 with M3 as the largest dose and the best treatment of charcoal husk. The relation correlation of the addition of amendment (charcoal husk and compost) to the planting result was un-linear where the best treatment was M3K3 (volcanic ash 25%, charcoal husk 25%, and compost 50%). The exceeded addition of charcoal husk in the M3K3 dose treatment decreased the planting result. This was due to the increase of charcoal husk dose that could raise the infiltration rate, consequently decreasing the media ability to store moisture and improving the growth and development of the plant. Recommendations for further study include several points: (i) with low level of N caused nonoptimum lettuce, a fertilizer with higher N is required, (ii) volcanic ash as the media should be given with larger portion than the addition of amendment (iii) the numbers of combination of media treatment is limited to M3, because the media M4 and M5 showed decreasing planting result, and (iv) it is required to measure the available moisture capacity to provide evidence on the correlation of charcoal husk dose to the infiltration rate.

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The identification of soil fungi isolated from rhizosphere in different varieties of jali (*Coix lacryma-jobi*) in Loa Kulu, Kutai Kartanegara, Indonesia

SOPIALENA[1,♥], N. AKHSAN[1], A. SURYADI[1], JULI NURDIANA[2,♥♥]
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Manuscript received: 19 September 2018. Revision accepted: 22 November 2018.

Abstract. *Sopialena, Akhsan N, Suryadi A, Nurdiana J. 2018. The identification of soil fungi isolated from Rhizosphere in different varieties of jali plants (*Coix lacryma-jobi*) in Loa Kulu, Kutai Kartanegara, Indonesia. Asian J Agric 2: 44-47.* Rhizosphere effects can indicate the development of an active microbial population around the roots, driving from a loss of organic materials. This research was intended to identify rhizosphere microbes by identifying the potential microbes of four different varieties of jali (*Coix lacryma-jobi* L.) in Loh Sumber, Loa Kulu, Kutai Kartanegara, Indonesia, i.e., *jelai beras, jelai ketan, ketan lekat,* and *jelai kaltara*. The soil samples were collected and isolated in a jali plantation in Loa Kulu, Kutai Kartanegara at 45 days after planting. As many as 16 isolated samples were used, collected from four different varieties of jali and replicated 4 times. The results showed that a variety of microbes at Rhizosphere could be classified as *Trichoderma* sp., *Aspergillus* sp., *Pythium* sp., *Fusarium* sp., *Cunninghamelal* sp., and *Penicillium* sp.

Keywords: Rhizosphere, jali, *Coix lacryma-jobi*, fungus, Indonesia

INTRODUCTION

In Indonesia, the commodity of jali (*Coix lacryma-jobi* L.) can be found in Sumatra, Java and Kalimantan. However, to date, it has not been widely developed in East Kalimantan (Juliardi et al. 2014). Based on the information collected, there are more than one varieties of jali cultivated in East Kalimantan, namely (i) *jelai beras (padi jelai sumber rejeki I)*, (ii) *jelai ketan (padi jelai sumber rejeki II),* (iii) *ketan lekat (padi jelai sumber rejeki III),* and the variety of *jelai kaltara* (Suyadi 2011). Rhizosphere is the part of the soil surrounding the roots and serves as a first layer defense for pathogens (Nurbailis et al. 2014). Some rhizosphere microorganisms, have proven to play an important role in nutrient cycling, soil formation, plant growth, microorganism activities and acting as a biological control against the pathogens surrounding the plant roots. The benefits of a microbial population around the rhizosphere include maintaining the nutrient intake for the plant (Budiarti et al. 2014).

In general, there are two types of microorganisms living in the rhizosphere; microbial antagonists and pathogenic microbes (Beneduzi et al. 2012; Trabelsi and Mhamdi 2013; Barea 2015). Antagonists microorganisms commonly found in the root zone, include *Trichoderma, Aspergillus*, and *Penicillium*. While pathogenic microorganisms are mostly found as *Phytophthora*, *Pythium, and Fusarium* which can reduce plant production, thus ultimately impact on the loss of productivity. Therefore, this study aimed to identify the rhizosphere microorganism in jali's at the village of Loh Sumber, Loa Kulu District of Kutai Kartanegara. The function of this research is to know the types of rhizosphere fungi living in the four types of jali. Though jali is commonly known as fodder, it often is used by malt producer, and serves as kind of health food. Nowadays, there is an attempt to utilize and cultivate jali is some part of Indonesia, included in the village Loh Sumber, Loa Kulu (Badan Ketahanan Pangan dan Penyuluhan 2016).

Microorganisms living in the rhizosphere have a vital role in maintaining soil fertility because of their ability as decomposers. Some microorganisms that live at the roots of healthy plants are known to be protective against pathogens. Naturally, they can hamper the development of pathogens in the soil. In addition, the ability of the organism to adapt to various environmental conditions has great potential for them, allowing them to serve as a biological control agent. Rizospheric fungi are among the groups of microorganisms that have been reported to induce plant resistance to various diseases, including ground-borne diseases. They also support the growth of the plant through various mechanisms such as increasing nutrient uptake, biological control of pathogens, and producing the hormone for the plants (Pereg and McMillan 2015; Jacoby et al. 2017).

The concept of rhizospheres, was first proposed by Hiltner in 1904 (Larry et al. 2016). The population of microorganisms in the rhizosphere is usually more numerous and varied than in the non-rhizosphere zones. Rhizosphere soil affected the roots and substances released from the roots into the soil solution, to create favorable conditions for fungi. The presence of antagonistic microorganisms in the rhizosphere can inhibit the spread and root infection by pathogens, a condition referred to as a natural microbial barrier (Rodrigo et al. 2013; de Boer et al. 2015). The main biological facts of rhizosphere, or root-affected areas, are the high number and high activity of soil microorganisms in this area compared to rootless soils (Fety et al. 2015; Suyadi et al. 2017). As biological control agents, the antagonist microorganisms will detain the spreading of the pathogens. This situation is natural and a microbial barrier, this microbial antagonist is potentially developed as a biological control agent (Gusnawaty et al. 2014). In the rhizosphere, it is suggested that there are harmful organisms around the roots of unhealthy plants. While on the other hand, it is found that beneficial organisms live at the roots of healthy plants. It is reported that the fungi of the genus Trichoderma and Gliocladium, are antagonistic fungi that often can be found in the area of the rhizosphere (Nurbailis et al. 2014). The results of research showed 8 fungal isolates from the potato plant rhizosphere, consisting of two isolates of *Trichoderma* genus, one *Penicillium* isolate, two *Phytophthora* isolates, one *Mucor* isolates and two isolates unknown to its genus (Budiarti and Nurhayati 2014). The rhizosphere effect indicated the development of active microbial population around the roots driving from the loss of organic materials. Considering the rhizosphere effects, this research aimed to identify the available potential microbes at different four varieties of jali (*Coix lacryma-jobi* L.) in Loa Kulu, Kutai Kartanegara, Indonesia. Even though there are many discussions around microbes and the rhizosphere, this study can bring scientific value in terms of the identification of microbes for jali in Loa Kulu which has not been previously explored.

MATERIALS AND METHODS

This research was conducted between May to August 2017 in jali cultivation areas; Loh Sumber village, Loa Kulu, Kutai Kartanegara. The soil sampling was collected 45 days after planting by drilling, to reach a depth of 30 cm with 10 cm distance from the planting hole. There were 5 sample points taken by zigzag pattern, which then were composited into 1 kg mixture, and then composited for a second time into 100 g (1 ounces). The total samples used were 16 pieces, consisting of 4 samples of each variety and 4 replications.

To identify the isolated fungi, the soil sample of four different varieties of jali was firstly weighed at 1 g, and then inserted into a test tube containing 10 ml of sterile distilled water and then shaken. From the solution, 1 ml was taken and put into a test tube containing 9 ml of sterile aquadest. This process kept recurring until it reached a 10-3 dilution level of cpu (cell per unit). From the dilution, 1 ml was taken and then injected into the petri dish which had been filled with Potato Dextrose Agar (PDA) and isolated for 3-7 days at a room temperature of 27-28ºC. Later, a direct observation using the microscope was performed to identify the fungal colonies taken by an ose of the needle and adding it with a methylene blue liquid. The purification process was carried out to fungal colonies. For each different fungi, it was taken and re-grown on a petri dish containing solid PDA. The fungi identification was then referred to Alexopoulus and Mims (1979) and Samson and van Reenen-Hoekstra (1988) using an Optilab camera.

RESULTS AND DISCUSSION

Rhizosphere is part of the soil that has the highest metabolic activity defined as a small portion of the soil volume, which is directly affected by the growth and metabolism of plant roots. Plants and microbes interact and stimulate each other, this is caused by root exudates (Hunter et al. 2014). Where root exudates affect the growth and activity of microorganisms in the Rhizosphere, Rhizoplan, and its surroundings. Various types of microorganisms inhabit the rhizosphere such as fungi, bacteria, actinomycetes, algae, and nematodes. The activity of microorganisms in the rhizosphere and rhizoplane is different from the surrounding soil, depending on the root exudate released. In this regard, this study identified the fungal activity in the rhizosphere to characterize the type of fungal microbes for specific plants and certain geographic areas.

Based on the field information collected, this research classified the different varieties of isolated fungi rhizosphere based on jali's varieties and the replication from *Jelai Beras, Jelai Ketan, Ketan Lekat* and *Jelai Kaltara*. The results were presented in Table 1,.

The findings in Table 1 clearly show that in the 1st, 2nd and 4th replication, the rhizosphere fungi of four different varieties of jali can be grouped as *Trichoderma* sp., *Aspergillus* sp. and *Pythium* sp. Only in the 3rd replication, was a more varied fungus shown, i.e., *Trichoderma* sp. (Figure 1.A-B), *Aspergillus* sp. (Figure 2.A-B), *Pythium* sp. (Figure 3.A-B), *Fusarium* sp. (Figure 4.A-B), *Cuninghamella* sp. (Figure 5.A-B), and *Penicillium* sp. (Figure 6.A-B). This finding suggests that more fungi can live in jali's rhizosphere. Meanwhile, Anggraeni and Usman (2015) identified that *Trichoderma sp.* and *Aspergillus sp.* were also mostly found in Banana's rhizosphere. It is suggested that the different variety and characteristics of the fungus depend on many factors including substrate and environmental conditions (Sutton-Grier et al. 2011; Haleem Khan and Karuppayil 2012; Basu et al. 2015).

Table 1. Name of fungi isolated from rhizosphere in different varieties of jali.

Name of jali's varieties	Number of replication			
	1st	2nd	3rd	4th
Jelai beras	1, 2	1, 2	2, 3	1, 2
Jelai ketan	1, 3	1, 3	1, 2, 5	1, 2
Ketan lekat	1, 2	1, 2, 3	1, 2, 4	1, 2, 3
Jelai Kaltara	1, 3	1, 2	1, 2, 6	1, 2, 3

Note: 1. *Trichoderma* sp., 2. Aspergillus sp., 3. *Pythium* sp., 4. *Fusarium* sp., 5. *Cunninghamella* sp., 6. *Penicillium* sp.

Substrate is the main source of nutrients for fungi. New nutrients can be utilized after the fungus excretes extracellular enzymes that can break down the complex compounds from the substrate into more simple compounds. Fungi that cannot produce enzymes, according to substrate composition by themselves cannot utilize the nutrients in the substrate (Fety et al. 2015). While the environmental conditions that affect the presence of fungi, include moisture and temperature (Suyadi 2011; Suyadi et al. 2017). In addition, humidity is also very important for fungi growth. In general, fungi such as *Aspergillus*, *Penicillium*, *Fusarium*, and many other *Hyphomycetes* can live in lower relative humidity. A good temperature for fungus growth is very influential. Most fungi, including mushrooms, have a mesophilic temperature which allows them to grow at the optimum temperature between 25-35ºC (Kapoor and Sharm 2014). Even so, it is also noted that there are thermophilic fungi that are able to grow at high temperatures (Saroj et al. 2017). Identifying the temperature range of the fungus growth is very important, in order to have a supportive environment for the fungus (Singh and Chauchan 2013; Lene 2014).

The results of this study supported the research conducted by Sopialena et al. (2017) which identified that besides Rhizoctonia, *Phytium* sp., *Penicillium* sp., *Aspergillus* sp., have become the four main types of fugal which are often found in East Kalimantan, particularly in post-coal-mining areas. Also, two other types of fungal were located; *Cuninghamella* sp. and *Trichoderma* sp. *Aspergillus* sp. and *Fusarium* sp. seems to be dominated in East Kalimantan, in particular for Kutai Kartanegara (Sopialena et al, 2018). Further, Rosfiansyah, et al. (2017) also noticed that likewise *Massarina* sp. and *Rhizoctonia* sp., *Phytium* sp., and *Penicillium* sp. retain potential value as biofertilizer for land reclamation in post-coal mining areas in Samarinda. Therefore, this study deepens the knowledge of fungal inventory observed in East Kalimantan land that only a limited number of fungal found on the soil, mainly due to the climatic conditions i.e., rainfall and temperature, and the type of soil which is dominated by red yellow podzolic.

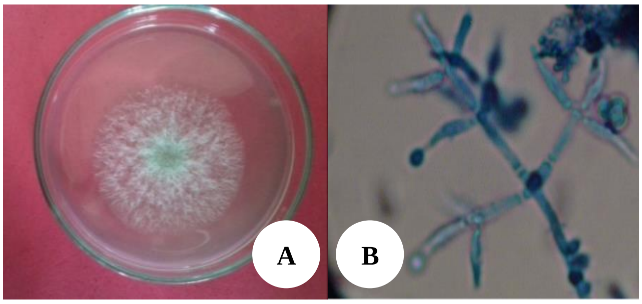

Figure 1. *Trichoderma* sp.

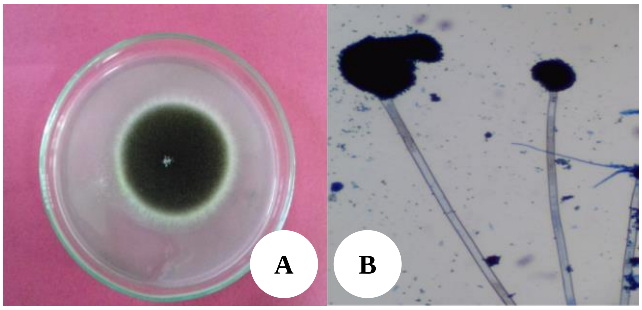

Figure 2. *Aspergillus* sp.

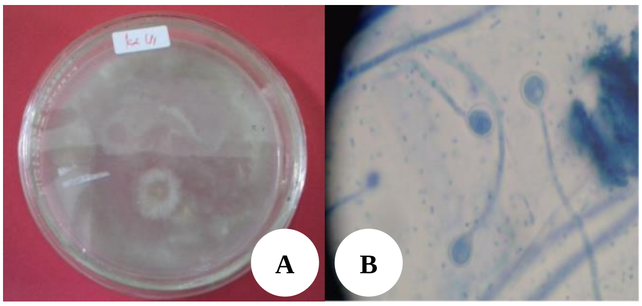

Figure 3. *Pythium* sp.

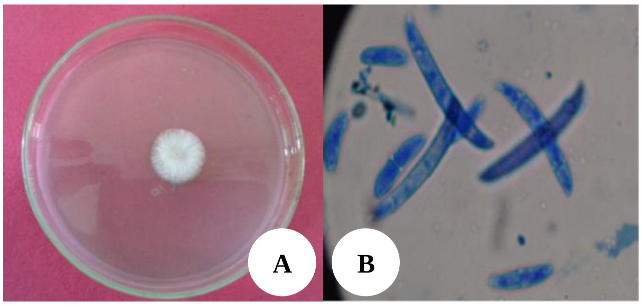

Figure 4. *Fusarium* sp.

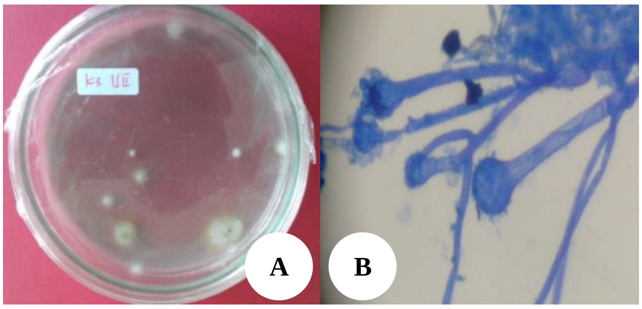

Figure 5. *Cuninghamella* sp.

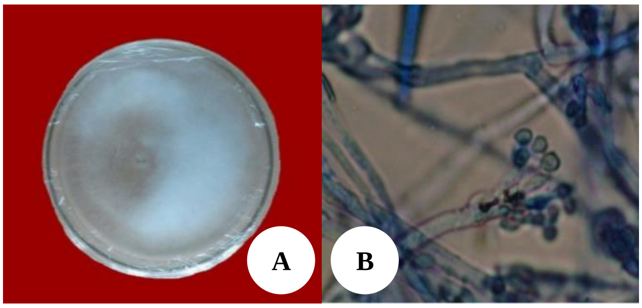

Figure 6. *Penicillium* sp.

In regard to the climate condition of Kutai Kartanegara area, the average monthly rainfall is recorded at 259.8 mm/month, which suggests becoming the main reason for the wet/ humid condition of the subsurface soil. This condition is advised to have significant effect on soil microorganism activities, the speed of chemical synthesis, and the soil nutrients due to percolation and lessivation of water (Sopialena and Pratiwi 2017). Heavy rainfall has a significant impact on kinetic energy, which may cause changes in the composition and size of soil particles. Further, the run-off water on the soil surface may generate erosion and material translocation, in particular for areas where the level of cover is ruined. High rainfall causes inundation or flooding in some flat areas. In addition, the slight difference in range temperature from day to night, may also affect the organism decomposition process, which is shown from the low rate of soil macro contents such as N, P and K.

In conclusion, this study brought a new finding of rhizosphere microbes of jali (*Coix lacryma-jobi* L.) in Loa Kulu, Kutai Kartanegara. It has expanded the knowledge on the identification of microbes in three different varieties of jali in East Kalimantan. The results indicate that there are six main fungi found at the rhizosphere, namely *Trichoderm*a sp. *Aspergillus* sp., *Pythium* sp., *Fusarium* sp., *Cunninghamella* sp., and *Penicillium* sp.

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Functional properties of *Saccharomyces kluyveri* Y97-fermented solo black garlic

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Abstract. *Setiyoningrum F, Pribadi G, Afiati F, Herlina N, Solikhin A, Lisani N. 2018. Functional properties of* Saccharomyces kluyveri *Y97-fermented solo black garlic. Asian J Agric 2: 48-51. Saccharomyces kluyveri* Y97-fermented solo black garlic was made by fermentation of fresh solo garlic in medium containing *S. kluyveri* aging in 70°C and relative humidity close to 60%. The fermentation period of fresh solo garlic in the medium was 0, 2, 4 and 6 days. The black aging period was 0 (fresh garlic), 7, 14 and 21 days. Antioxidant capacity, flavonoid content, and total polyphenol were observed. *S. kluyveri* Y97-fermented solo black garlic had higher antioxidant capacity, flavonoid content and total polyphenol compared to solo black garlic without fermentation. Fermentation of fresh solo garlic by *S. kluyveri* Y97 before the aging process could increase solo black garlic's functional properties.

Keywords: solo black garlic, *S. kluyveri* Y97, antioxidant, flavonoid, polyphenol

INTRODUCTION

Black garlic is a product of garlic breeding development, especially for medicinal purposes. It has many bioactivities including inhibition of colon and gastric cancer cell growth, antioxidant, alteration of lipid profile in diabetes, anti-obesity, anti-inflammatory, and antiallergic activities (Seo et al. 2009; Ha et al. 2015; Kimura et al. 2017). Processing method and garlic cultivars affect the quality and bioactive value of black garlic (Kimura et al. 2017; Chen et al. 2013; Bae et al. 2014). Solo or single garlic has a higher benefit than normal garlic (Naji et al. 2017). Controlled heating at high temperature and humidity was widely used for black garlic processing (Ngan et al. 2017; Kang et al. 2008; Bae et al. 2014; Choi et al. 2014; Kimura et al. 2017). In addition, the use of enzyme treatment and curing can be applied to make black garlic (Wang and Su 2017). Those treatments are applied to eliminate unpleasant odor and increase its palatability (Pure et al. 2017; Bae et al. 2014; Lu et al. 2017; Zhang et al. 2015).

Phenol oxidation is the key to the success of black garlic production. Increasing antioxidant, phenol and flavonoid are due to phenol oxidation process. Such process is in line with the increasing antitumor effect (Wang et al. 2012) and immunostimulatory activity (Purev et al. 2012). S-allyl-cysteine is a special product from phenol oxidation and plays an essential role in black garlic's pharmacological effects (Ngan et al. 2017). Its amount is five to six times higher than fresh garlic (Bae et al. 2012; Wang et al. 2012). Brown color and sweeter taste on black garlic caused by non-enzymatic browning like Maillard reaction and caramelization (Bae et al. 2012; Zhang et al. 2016). Some antioxidant compounds are made using such process (Osada and Shibamoto 2006; Yilmaz and Toledo 2005).

Some experiments added the immersion/soaking process on microorganism medium before or after aging of black garlic i.e., kombucha and vinegar (Pure et al. 2017) *Lactobacillus plantarum* (*L. plantarum*) PN05 (*Ngan* et al. 2017) and *S. cerevisiae* KCTC 7910, *M. pilosus* KCTC 26768, and *Lactobacillus plantarum* KCTC 3104 (Kim et al. 2016), *Streptococcus thermophiles*, *Bifidobacterium*, *Candida utilis*, and *Saccharomyces cerevisiae* (CN104336550A). Although the purpose of the process was important to increase the value of black garlic benefit, the data about the physiochemical properties including functional properties such as antioxidant value, total flavonoid content and total polyphenol is still limited. The aim of this study was to examine the functional (bioactive) properties of solo black garlic fermented by *S. kluyveri* Y97 before aging process.

MATERIALS AND METHODS

Materials

Fresh solo garlic was obtained from local market in Bogor. The reagent used in this research were DPPH (α,α-diphenyl-β-picrylhydrazyl), garlic acid, quercetin (Sigma Aldrich), Follin Ciocalteu, sodium carbonate, ethanol, methanol aluminum chloride, potassium acetate (Merck). Isolate of *S. kluyveri* Y97 was obtained from Indonesian Culture Collection (InaCC).

DPPH (α,α-diphenyl-β-picrylhydrazyl) radical scavenging ability

Here, method from Muanda et al (2011) was used to determine DPPH radical scavenging ability. Garlic extract 0.2 mL were added to 0.8 mL DPPH methanol solution (0.2 mM). The mixture was shaken and left to stand for 30 minutes in dark conditions. After that, the absorbance was measured at 517 nm using a spectrophotometer. The inhibition percentage of DPPH radical scavenging ability was calculated by the following equation:

$$\textbf{\% inhibition} = (A_0 - A_1) * 100 / A_0$$

Where:

A_0= absorbance of the mixture of DPPH and methanol solution,

A_1= absorbance of the mixture of DPPH and garlic extract.

S. kluyveri Y97-fermented solo black garlic processing

Fresh solo garlic was fermented in medium containing *S. kluyveri* Y976 of 10 x10º7 cfu/ml for 0, 2, 4, 6 days. Solo garlic was cultivated and aged at the temperature of 70ºC with air moisture of about 60% for 0, 7, 14 and 21 days. Solo black garlic was stored in the freezer-20ºC until It was analyzed.

Determination of total polyphenol content

The polyphenol content was reported as garlic acid equivalents using following linear equation based on calibration curve: y=0.0015x+0.0007, R^2 = 0,9939, where y is the absorbance at 750 nm and x is the concentration of garlic acid equivalents (ppm). A garlic extract (50 µL) was diluted in 800 µL distilled water. Diluted garlic extract was mixed with 50 µL Follin-Ceucalteu (10 %) and 100 µL sodium carbonate (7%). After incubation for 30 minutes at room temperature, the absorbance was measured at 750 nm. The incubation process was done in dark conditions (Chang et al. 2002).

Determination of total flavonoid content

Total flavonoid content was determined according to Chang et al. (2002) with quercetin as standard. Quercetin equivalent was standardized using following linear equation based on calibration curve: y=0.0041x-0.0063, R^2=0.9968, where y is the absorbance at 415 nm and x is the concentration of quercetin (ppm). 50 µL garlic extract was mixed with ethanol absolute (30uL), 10% aluminum chloride (50µL), and 1M potassium acetate (50µL). The mixture was diluted in 600 µL distilled water and incubated at room temperature for 30 minutes. The absorbance was recorded at 415 nm.

Data analysis

All experiments were carried out in duplo. The data were expressed as mean values and analyzed using SPSS 16.0 software.

RESULTS AND DISCUSSION

Results

Fresh solo garlic had 3.76% of antioxidant capacity. Fermentation of fresh solo garlic in medium containing *S. kluyveri* Y97 10^7 cfu/ml for 2, 4 dan 6 days increased the antioxidant capacity about 9.24, 10.14 and 18.94% respectively (Figure 1). The 21 days-aging process increased the antioxidant capacity 9.08, 8.33, and 4.51 times of solo garlic fermented by *S. kluyveri* Y97 for 2, 4 and 6 days respectively, compared to *S. kluyveri* Y97 fermented solo garlic without aging. The antioxidant capacity of 21-days aging of solo black garlic for all fermentation treatments was around 83.90-85.6%. The highest antioxidant capacity was observed at solo black garlic fermented by *S. kluyveri* Y97 for 6 days. At 21 days aging time, the fermentation by *S. kluyveri* Y97 increased antioxidant capacity reaching 2 times compared to without *S. kluyveri* Y97 fermentation.

Fermentation by *S. kluyveri* Y97 for 2, 4 and 6 days increased the total flavonoid content of solo garlic 17.6, 22.2, and 25.2-fold respectively, compared to the fresh solo garlic. Fresh solo garlic had 0.53 mg QE/g wet basis of flavonoid content. In line with antioxidant capacity results, the highest total flavonoid content was obtained by 21-aged solo garlic with fermentation. Compared to 21 days aged solo black garlic without fermentation, the total flavonoid content of 21 days aged solo garlic increased 2.6, 2.9, and 2.9-fold for 2, 4 dan 6 days fermentation respectively. The highest was obtained by solo black garlic which was fermented for 6 days and continued by aging process for 21 days and the 85.58 mg QE/g wet basis. The total flavonoid of solo black garlic without fermentation and aged 21 days was 29.64 mg QE/g wet basis.

The highest of total flavonoid was obtained by 6 days fermented of *S. kluyveri*-21-days aged solo black garlic, 116.72 mg GAE/g wet basis. Its total polyphenol content increased 1.26-fold compared to 21-days aged solo black garlic without fermentation. In solo black garlic without fermentation, 21-days aging process induced the increase of total polyphenol content reached 3.6-fold. Fresh solo garlic had 26.13 mg GAE/g wet basis of total polyphenol content. Compared to 21 days aged solo black garlic, *S. kluyveri* Y97 fermented on 21-days aging process induced the increase of total polyphenol content 1.18; 1.26; 1.23-fold for 2, 4, 6 days of fermentation respectively.

Discussion

Fermentation of *S. kluyveri* Y97 before aging process on solo black garlic increased the antioxidant capacity. The analysis of variance showed that there was an interaction between fermentation time and aging time. Fermentation for 4 and 6 days gave the same results (not significant) on the quality of solo black garlic. An optimal antioxidant capacity was shown by solo black garlic solo fermented for 4 days and continuing aged for 21 days. There is no literature that reveals a clear mechanism for increasing bioactive properties due to fermentation yet.

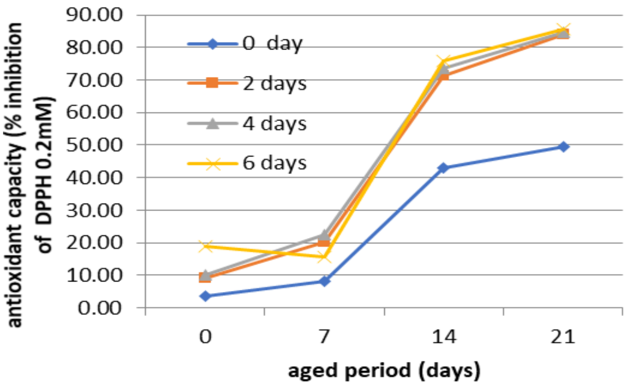

Figure 1. Antioxidant capacity of *S. kluyveri* Y97 fermented on solo black garlic

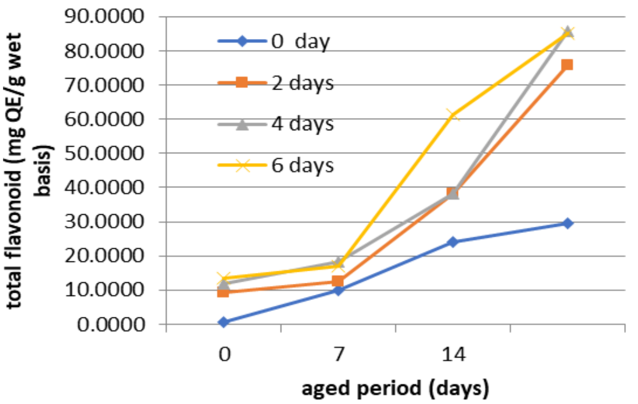

Figure 2. Total flavonoid content of *S. kluyveri* Y97 fermented on solo black garlic

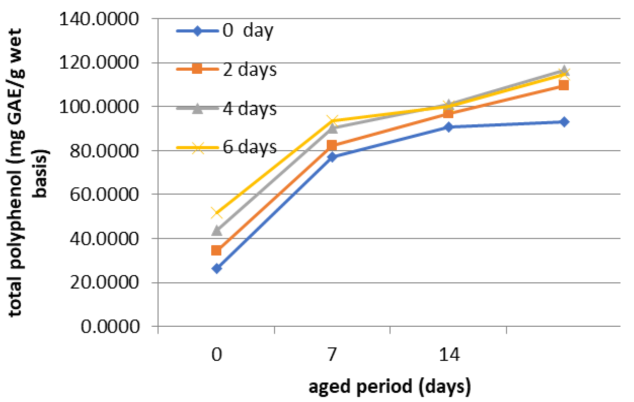

Figure 3. Total polyphenol content of *S. kluyveri* Y97 fermented on solo black garlic

Research by Jung et al. (2011) revealed that black garlic fermented by *S. cerevisiae* increased antioxidant activity in vitro by EDA (electron-donating activity) antioxidant activity, which the EDA of fermented black garlic was 13.65% and meanwhile the unfermented black garlic was 10.32%. Antioxidant capacity enhancement was alleged to those microbes convert several components in food or substrate and changes sugar to alcohol and lactic acid which can increase bioactivity of the components (Bae et al. 2004; Trint et al. 2007). Jung et al. (2017) mentioned the antioxidant capacity of red ginseng extract by the probiotic *Lactobacillus plantarum* KCCM 11613P. That phenomenon was like this research. In recent years, Hien-Trung et al. (2007) discovered that the bioactivity of ginseng could be enhanced by yeast fermentation. Therefore, they hypothesized that the bioactivity of black garlic may also be enhanced by yeast fermentation (Kimura et al. 2017). The presence of flavonoid and polyphenol compounds could increase the antioxidant capacity.

Some flavonoid compounds in black garlic are catechin, epicatechin, epigallocatechin gallate, quercetin, apigenin, myricetin, resveratrol, morin, quercitin, kaempferol and narigenin (Kim et al. 2013). Abundant concentration of myricetin, quercetin and apigenin was found in black garlic (Miean and Mohamed 2001). Heat thermal during the aging process induced the increase of flavonoid content in black garlic (Kim et al. 2013). The result of this research noted that there was interaction between fermentation and aging time ($p<0.05$). In this research, total flavonoid content increased about 1.23-fold on solo black garlic fermented by *S. kluyveri* Y97 for 6 days and aged for 21 days. The optimum process to produce an optimal quality of solo black garlic was 4 days fermented by *S. kluyveri* Y97 then continuing aged for 21 days.

Consistent with antioxidant results, total polyphenol content of *S. kluyveri* Y97-fermented on solo black garlic was increased along with fermentation and aging period. The increase of total polyphenols could be caused by an increase in the level of complex polyphenols from the final phase of browning reactions as revealed by Robards et al (1999). Moreover, Guihua et al (2007) found that the heating process increased the phenolic content due to cleavage of the bound form (esterification and glycosylation), which results in an increase in free form. In addition, another possible reason for the increase of phenolic content in heated samples was the reduction/ inhibition of enzymatic oxidation involving antioxidant compounds in raw plant material (Dewanto et al. 2002; Nicoli et al.1999). Kim et al. (2013) revealed that high concentration of hydroxycinnamic acid derivates was found in aged black garlic, such as chlorogenic acid, caffeic acid, p-coumaric acid, ferulic acid, m-coumaric acid, o-coumaric acid.

The analysis of variance showed that there was no interaction between fermentation and aging time ($p>0.05$), but the fermentation and aging time affected the result significantly ($p<0.05$).

The optimum process to produce an optimal quality of solo black garlic based on total polyphenol content, was 4 days fermented by *S. kluyveri* Y97 then continuing to age for 21 days, producing about 116.72 mg GAE/g wet basis. At the time of writing, there was no literature that explained a clear mechanism of relation between TPC and fermentation by yeast. Other literature mentioned that fermentation is conducted to improve the storage period, nutrition, and sensory characteristics related to foods (Nout and Motarjemi 1997). Research in other raw plant materials showed that the total phenolic content in black ginseng fermented by *S. cerevisiae* was higher than that of raw ginseng and black ginseng (Jung et al. 2017). Jhan et al. (2015) reported that the total phenolic content increased after fermentation, when red beans were fermented by *B. subtilis* and *L. delbrueckii* sub sp. *bulgaricus.* Based on Jung et al. (2011), *S.cerevisiae*-fermented on black garlic exhibited much better bioactivity against syndromes such as hyperlipidemia, obesity, nephropathy, and hepatopathy than ordinary (aged) black garlic. Furthermore, fermented BG 400 mg/kg and 200 mg/kg revealed significantly higher effects than aged black garlic 400 mg/kg. In other words, fermented black garlic has more effective bioactivity against high feed diet-induced obesity, hyperlipidemia, nephropathy, and hepatopathy than ABG. Therefore, the bioactivity of BG could be enhanced by yeast fermentation, and fermented BG may be more qualified to improve diabetes and its related complications (Jung et al. 2011; Kimura et al. 2017). In addition, the functional properties, and the bioactivity of some natural products in increased by fermentation.

In conclusion, fermentation by *S. kluyveri* on solo black garlic processing could increase its functional properties due to enhanced bioactivity such as antioxidant capacity, total flavonoid content, and total polyphenol contents. The optimum quality of solo black garlic in this research was produced by 4 days of fermentation on *S. kluyveri* Y97 medium then continuing aged for 21 days.

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Quality assessment of the physicochemical properties of vermiwash produced from different sources during successive storage periods

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Abstract. *Jaikishun S, Adonis S, Ansari AA. 2018. Quality assessment of the physicochemical properties of vermiwash produced from different sources during successive storage periods. Asian J Agric 2: 52-57.* Organic farming is crucial for not only maintaining our health, but with improving quality and quantity of crop production in environmentally friendly farming practices. Vermiwash is poised to be one of the key components in organic farming and reducing the enormous amounts of pollutants from the environment. This study aimed to determine the physicochemical characteristics related to vermiwash from different sources (Jamun, Neem and Grass with combination and mixed with cattle dung) during a three-month storage period with monthly assessments and compared to a fresh sample. While an increase in Electrical Conductivity (EC) was seen in the first month, successive decreases were noted thereafter with a significant difference (p=0.05) being observed among the treatments (p=0.05) after three months. Total dissolved salts decreased over the storage period with significant difference being observed among the treatments and storage period revealed that at p=0.05, F (7, 21) = 3.9>2.49 Fcrit. and F (3, 21) = 3.8>2.49 respectively. Phosphorous decreased, while potassium increased with T7 having the highest. Calcium showed a significant difference (p=0.05) among the treatments, while magnesium fluctuated during the period but deceased at the end of the storage period. Analysis of ferrous content revealed a significant difference (p=0.05, F (7, 21) = 3.8>2.48 Fcrit.) with the time being significantly different (p=0.05, F (3, 21) = 6.8>3.0) with an increase at the end of the storage period. Fresh form of vermiwash is best to use to obtain maximum nutrients as the general nutrient composition deteriorates over time.

Keywords: Cattle dung, vermicompost, micronutrients, organic materials, soil, vermiwash

INTRODUCTION

There is an ever-growing global manifestation of the detrimental impacts of waste disposal. Many kinds of waste are produced daily. Some are useful and can be recycled in different fields, such as agriculture and other productive industries. One such is organic waste used to produce bio-fertilizers. Organic waste disposal from different sources like domestic, agriculture, and industrial has been a cause of concern for us since they create unaesthetic and unhealthy environment for the inhabitants. This results in environmental and economic problems for both urban and rural populations. Recycling of organic waste can be necessitated in the production of useful organic manure for agricultural applications (Aira et al. 2007; Ansari 2012).

Composting is becoming a very common technique in recycling organic waste, thereby increasing in productivity of food in an environmentally friendly way (Ansari and Jaikishun 2010; Ansari 2012). Various composting techniques offer solutions to the organic waste produced daily. One such technique is vermicomposting that not only reduces the organic waste but also promotes agricultural development in a more efficient, economical, and environmentally friendly manner (Ismail 2005; Ansari 2012; Manyuchi et al. 2012). Vermicomposting is a method of making compost by using earthworms which generally live in the soil, eat biomass, and excrete earthworm cast. The earthworms fragment the organic substrates, stimulate microbial activity significantly and increase rates of mineralization. Vermicompost is a finely divided peat-like material with excellent structure, porosity, aeration, drainage, and moisture holding capacity (Domínguez 2004; Ismail 2005; Ansari 2012; Manyuchi et al. 2012). Vermiwash is a liquid fertilizer collected after the passage of water through a column of worm action and may be used as a foliar spray (Ismail 2005; Ansari 2011).

Jamun {*Syzygium cumini* (L.) Skeels} is a very common tree found in Guyana. It belongs to the family Myrtaceae. The leaves of this tree range from being entire to lanceolate. The leaves are comprised of 9.1% crude protein, 4.3% fat, 17% crude fiber, 1.3% calcium and 0.29% phosphorous. The leaves are believed to have medicinal properties (Datta 1969). Neem (*Azadirachta indica* A. Juss) is another good source of food for earthworms. It belongs to the family Meliaceae. Neem is beneficial to earthworms. Neem leaves and seed kernels increased the number of earthworms in the potting soil in greenhouses. Neem is rich in nutrients, which also aid the fatter growth of earthworms. Another study conducted showed that vermicomposting of neem is accomplished at a high rate since the earthworm densities are quite high as compared to vermicomposting using mango leaves (Datta 1969). Earthworms contribution to the soil is in the form of organic carbon, nitrogen, inorganic phosphorus, potassium, magnesium among others in the excreta or worm casts

(Hendrix and Bohlen 2002; Ansari 2011; Picón and Teisaire 2012).

Vermiwash is a liquid that is collected after the passage of water through a column of worm-worked soil and is very useful as a foliar spray. It is a collection of excretory and secretory products of earthworms, along with micronutrients of the soil and soil organic molecules that are useful for plants. Vermiwash also acts as a mild biocide (Ansari 2012). Magnesium, chloride, calcium, organic carbon, nitrate, nitrogen, phosphorous and carbon are the major nutrients found in vermiwash. Carbohydrates, proteins, lipids, and amino acids are other nutrients that are found in vermiwash (Ansari and Jaikishun 2010; Sundaravadivelan et al. 2011; Ansari 2012).

MATERIALS AND METHODS

Materials

Vermiwash units were set up at the University of Guyana, at the Faculty of Natural Sciences, Biology laboratory. The mature leaves (Grass clippings, Neem and Jamun leaves) were collected from the university campus and air dried completely before adding to the vermiwash unit. Cattle dung was obtained from NARIE (National Agricultural Research and Extension Institute, Guyana) Chemical analyses of vermiwash were done at the Guyana Sugar Corporation Central Laboratory. Conversion of vermiwash into powdered form and storage was executed at the University of Guyana's biology laboratory.

Procedures

The vermiwash unit was set up using nine buckets. The buckets were fixed with taps about an inch from the bottom and placed on a stand to facilitate collection. A 25 cm of broken pebbles were placed at the bottom of each bucket, which was followed by a 25 cm layer of coarse sand. Water was then allowed to flow through these layers to enable the settling of the basic filter bed. A 20-30 cm layer of loamy soil was placed on top of the filter bed. Earthworms (25) were introduced into the soil, for the eight buckets. Cattle dung (150g) and selected organic (75g-total) materials in specified quantities were placed on top of the soil in the buckets with the earthworms (Control – Cattle dung, T1-Grass clippings, T2-Neem leaves, T3-Jamun leaves, T4-Grass clippings + Neem leaves, T5-Neem + Jamun leaves, T6-Grass clippings + Jamun leaves, T7-Grass clippings+ Neem + Jamun leaves). The units were irrigated and drained every two days to maintain moisture for the earthworms. Units were monitored and specified quantities of organic material were added every month (Ansari and Jaikishun 2010; Ansari 2012).

Collection and storage of vermiwash

After four months of setting up and maintaining units, 300 ml of vermiwash was collected. The collected vermiwash was placed into bottles, of the same size, for storage in a cool, dry, and dark place. Storage took place over a 3-month period to determine its effectiveness. Vermiwash from different organic materials was collected and stored every month. Vermiwash collected was tested monthly for the following physicochemical properties: pH, electrical conductivity, total dissolved salts, turbidity, nitrogen, available phosphate, potassium, exchangeable calcium, exchangeable magnesium, iron, and manganese (Homer 2003; AOAC 2012).

RESULTS AND DISCUSSION

A decrease in electrical conductivity (EC) was noted after three months of storage. It was seen that T1 showed a decrease but had a minimal increase for the 3rd month of storage. T2 had a significant increase in the first month, but then decreased after the 2nd and 3rd months, similar trend in noticed in T5. T4 showed an increase in the 2nd and 3rd months but decreased in the final month. However, treatments 3 and 7 had an increase in electrical conductivity in which T7 had a significant increase. An increase in T7 was because of the combination of organic material used, which caused an increase in the number of ions present in the sample (Figure 1). Anova Two-Factor without replication analyses for EC among the treatments and time indicated significant difference with p=0.05, F (7, 21) = 3.7>2.49 Fcrit. and F (3, 21) = 3.5>3.1 Fcrit respectively. According to Najar and Khan (2010), the increase in EC might have been due to the loss of weight of organic matter and release of different mineral salts in available forms such as: phosphate, ammonia, and potassium. Further, the increase of ions means an increase in electrical conductivity of a solution. The more dissolved solids that are present, the higher the conductance of the solution. This is because the solids dissolve into positively and negatively charged ions that can conduct an electrical current proportional to their concentration. Electrical conductivity is the basis of determining the presence of solids in a solution such as potassium, magnesium, calcium, etc. The decreased EC may mean that the amount of available soluble solids such as salts (ions) may be low in the vermiwash samples. A decrease in EC may be due to the increased rate of loss of organic matter and consequently release of different minerals salts (Chauhan and Singh 2012).

There is an increase in the pH after three months (Figure 2). It is seen that for the control there was an increase for the 1st month then a gradual decrease after the 2nd month. T1, T2, T4, T5, T6, and T7 showed a gradual increase in pH throughout the 3-month period, however, for T3 there was an increase for the 1st month then a decrease after the 1st and 2nd months. Earthworms contribute several nutrients in the form of nitrogenous wastes. Anova Two-Factor without replication analyses for sample pH among the treatments and time showed a significant difference with p=0.05, F (7, 21) = 4.6>2.48 Fcrit. and F (3, 21) = 4.9>3.1 Fcrit. respectively. According to Najar and Khan (2010), the increase in pH with time interval, is due to the decomposition of ammonia, which forms a large proportion of nitrogenous matter excreted by earthworms. The pH regulates the rate of dissolution of substances, and thus absorption. Soil pH is one of the most important soil properties that affect the availability of nutrients. Macronutrients tend to be less available in soils with low pH, and micronutrients tend to be less available in soils with high pH. Thus, it is necessary for vermiwash to have pH when added to the soils to promote absorption of nutrients (Domínguez 2004; Ansari and Rajpersaud 2012; Degefe et al. 2012).

An overall decrease in total dissolved salts in vermiwash was observed after storage for 3 months. T1 and the control showed an overall decrease, however, there was an increase after the 1st month for the rest of the samples, and a subsequent decrease at the 2nd month. However, T4 showed a major increase in the 2nd month and a subsequent decrease in the 3rd month. T7 had a major increase in the 3rd month. There were fluctuating changes in total dissolved salts content; nevertheless, there was an overall decrease in total dissolved salts (Figure 3). Since total dissolved salts are related to electrical conductivity, then a decrease in TDS may be due to increased rate of loss of organic matter. And consequently, a release of different minerals salts. Anova Two-Factor without replication analyses for TDS among the treatments and time revealed that at p=0.05, F (7, 21) = 3.9>2.49 Fcrit. and F (3, 21) = 3.8>2.49 respectively with significant difference. TDS are the inorganic dissolved solids in a liquid and therefore incorporate dissolved ionic minerals. Both anions (such as phosphates, fluorine, and chlorine) and cations (such as magnesium, calcium, iron, nitrogen, and potassium) are important constituents. An increase in total dissolved salts may contribute to a decrease in photosynthesis in plants (Datta 1969; Jensen 1999; Domínguez 2004; Degefe et al. 2012).

There was a general increase in turbidity of vermiwash after three months. However, a decrease in turbidity was noted in the 1st month and subsequently increased in the 2nd and 3rd months a common trend. There was fluctuation for the samples amidst the overall increase in turbidity (Figure 4). Anova Two-Factor without replication analyses for turbidity among the treatments and time revealed that at p=0.05, F (7, 21) = 2.6>2.5 Fcrit. and F (3, 21) = 4.1>2.2 respectively with significant difference, an indication that with time and the different treatments more insoluble substances are released. Suspended materials in a liquid may reduce water and cause turbidity (Tiwari 2015).

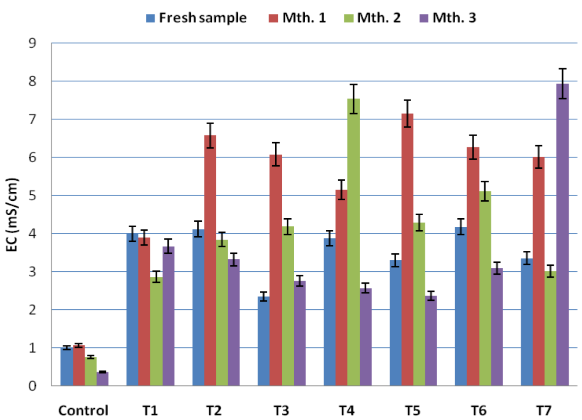

Figure 1. Effect of storage period on the Electrical conductivity

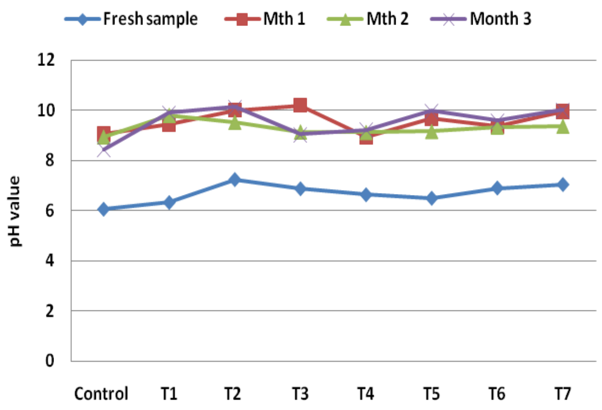

Figure 2. Effect of storage period on the pH of vermiwash

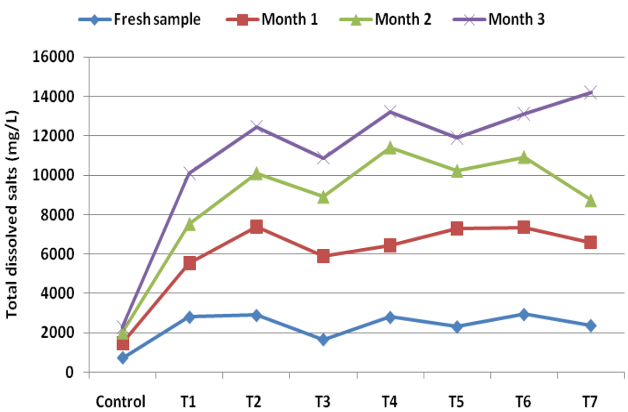

Figure 3. Effect of storage period on the Total Dissolved Salts (TDS)

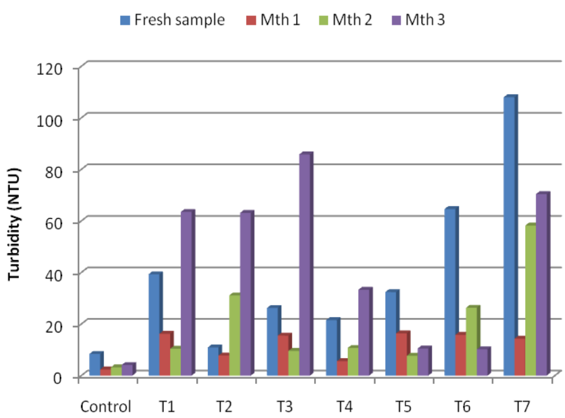

Figure 4. Effect of storage period on the turbidity of vermiwash mixture

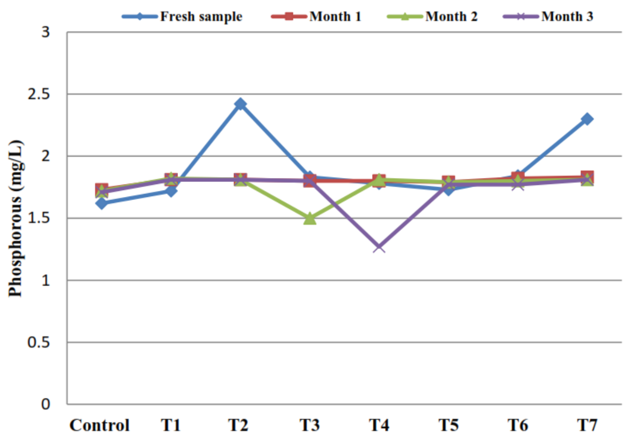

Figure 5. Phosphorous content of vermiwash during the storage period

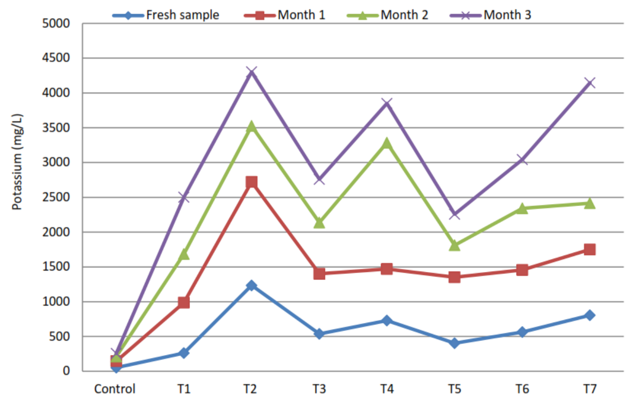

Figure 6. Potassium content during the storage period

There was an overall decrease in phosphorous content over the three-month period for majority of the treatments. For the control, there was a gradual increase then a small decrease in phosphorous after the 3rd month. Even though there was a fluctuating pattern in the amount of potassium found in T2, T3, T4, and T6 it was subsequently seen that there was a decrease after the three months of storage of vermiwash. T1 and T5, however, showed an increase after the 3rd month but this increase was quite small (Figure 5) Anova Two-Factor without replication analyses for P among the treatments and the three-month period indicated no significant difference with p=0.05, F (7, 21) = 1.5<2.48 Fcrit and F (3, 21) = 1.8<3.1 respectively. Similarly, Khwairakpam and Bhargava (2007) observed a decrease in P and attributed it to the mineralization of organic phosphorus and consumption by microbes. The passage of organic matter through the gut of a worm, results in phosphorus being converted to more bio-available forms. This is done by both worm's gut enzyme 'phosphatases' and by the phosphate solubilizing microorganisms in the worm cast (Nath et al. 2009; Degefe et al. 2012).

There was an increase in potassium content for T1, T3, T5, T6, and T7. However, T2 and T4 showed a major decrease after the 3rd month. There was a fluctuation in the amount of K observed in the units T1, T3, T5, T6, and T7 but at the end of the three-month period, a general increase was observed. T1 and T5 showed a major increase, whilst T3 and T6 had a slight increase of K content. T7 had a dramatic increase due to the combination of all organic materials used while the control showed a decrease in potassium content. However, there was an overall increase in K (Figure 6). Anova Two-Factor without replication analyses for K among the treatments indicated a significant difference (p=0.05, F (7, 21) = 4.0>2.48 Fcrit.) while with time, there was an insignificant difference (p=0.05, F (3, 21) = 0.9<3.12 Fcrit.) observed. According to Nath et al., (2009) earthworm processed waste material contains high concentration of exchangeable potassium, due to enhanced microbial activity during the vermicomposting process, which consequently enhanced the rate of mineralization. The increased potassium content is due to large number of symbiotic microflorae present in the gut and the cast of earthworms in collaboration with secreted mucus and water. This might increase the degradation of ingested organic matter and the release of assailable metabolites. These metabolites enhanced the enrichment of the vermiwash with exchangeable potassium. The decrease in potassium in T2 and T4 may be because of leaching of this soluble element, after water was applied for collection (Ansari and Rajpersaud 2012; Chauhan and Singh 2012; Degefe et al. 2012).

For the control, there was a general decrease in calcium content. There was an overall increase in calcium content for samples T1, T2, T4, T5 and T6. T1 and T2 showed a gradual decrease while T4 and T5 showed a great increase for both months 1 and 2, then decreased greatly for the 3rd month. T6 showed fluctuation in value, however, decreased after the final month. T3 and T7 also had a fluctuating change in value however there was an increase in calcium content for the 3rd month. Anova Two-Factor without replication analyses for Ca among the treatments revealed a significant difference (p=0.05, F (7, 21) = 3.3>2.48 Fcrit.) while with time had no significant difference (p=0.05, F (3, 21) = 2.8>3.0 Fcrit.). It is suggested that this increase is due to gut processes, associated with calcium metabolism, which is primarily responsible for enhanced content of inorganic Ca content in worm cast (Najar and Khan 2010). A percentage decrease in calcium could be because of leaching of this soluble element by the excess water that is drained through for collection {Table 1} (Domínguez 2004; Najar and Khan 2010; Degefe et al. 2012).

Table 1. Percentage change in Ca, Mg and Fe during the storage period

Treatment	Content change (%)		
	Ca	**Mg**	**Fe**
Ck	67.25	-4.20	-99.18
T1	56.56	101.25	1190.59
T2	42.01	60.39	364.84
T3	-8.95	198.12	544.59
T4	47.77	52.04	45.96
T5	57.11	24.12	-17.78
T6	7.066	203.35	1231.72
T7	-18.38	201.59	480.48

There was an overall percentage increase for magnesium for all the samples. For the control, there were fluctuating changes, however, a final decrease in Mg content was observed. All the samples, excluding T1, showed a major increase for the 1st month. However, there was a decrease in the 2nd month then increased during the 3rd month. T3, T4, and T5, however, showed a decrease instead of an increase in Mg content after the 3rd month (Table 1). Anova Two-Factor without replication analyses for Mg among the treatments revealed a significant difference (p=0.05, F (7, 21) = 5.7>2.48 Fcrit.) with the time being significantly different (p=0.05, F (3, 21) = 8.12>3.0 Fcrit.) as well. The increase of Mg may be due to the conversion of this nutrient to plant available form during passage through the earthworm gut (Najar and Khan 2010; Ansari 2011; Degefe et al. 2012).

There was a general increase in iron for all the treatments however for T5 there was a decrease after the third month when compared to the fresh sample. There was a fluctuating change for all the treatments but an eventual increase in Fe content. Anova Two-Factor without replication analyses for Fe among the treatments revealed a significant difference (p=0.05, F (7, 21) = 3.8>2.48 Fcrit.) with the time being significantly different (p=0.05, F (3, 21) = 6.8>3.0). Iron (Fe) is one of the main nutrients needed for the biosynthesis of chlorophyll (Quaik et al. 2012).

Vermiwash obtained from the different organic sources (Jamun, Neem leaves, Grass clippings, and Cattle dung) was found to be highly efficient with the necessary macro and micronutrients. Physicochemical analysis of the different treatments showed excellent content of the nutrients required for successful plant growth and development. The macro and micronutrients present in vermiwash are essential and easily available to plants. This has been proven by previous research. The physicochemical, nutritional, and biochemical parameters of vermiwash were produced from different leaf litters by using two earthworm species. Vermiwash is highly efficient in not only essential nutrients for plants but also carbohydrate, protein, lipid, and amino acid which are also important factors for plant growth (Ansari 2008; Ansari and Sukhraj 2010; Sundaravadivelan et al. 2011; Manyuchi et al. 2012).

Thus, the quality of vermiwash produced improved with duration of vermicomposting but varied with the leaf litter. Earthworms assimilate nutrients like energy, from a wide range of ingested materials with variable efficiency depending on the species and the nature of the ingested materials. The quality of vermiwash may also be a result of the use of organic material of plant and animal origin, which may be very efficient in nutrient quality. The organic degradable refuse of plant and animal origin have been shown to provide a good source of nutrients to improve crop productivity (Domínguez 2004; Ansari 2011; Sundaravadivelan et al. 2011; Degefe et al. 2012).

In conclusion, it is also seen that vermiwash is best in the first month, but the quality reduces with time. The physicochemical properties of vermiwash have excellent mineral content, with essential nutrients in desired quantities that may be readily available for plant growth. The quality of vermiwash produced with the use of leaf litter from three different plants namely Neem, Jamun, and Grass, clearly shows that the food quality largely influences the vermiwash potential. The quality of vermiwash produced may be due to the quality and type of organic material used. The organic degradable refuse of plant and animal origin, has shown to provide a good source of nutrients to improve productivity. Hence, making vermiwash can be very efficient in organic farming because of adequacy of nutrient composition for plant growth and simultaneously promoting positive attributes in the environment.

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Determinants of technical efficiency in cotton production in the southern cotton growing zone of Nigeria: A stochastic production frontier approach

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Abstract. *Olatidoye MS, Alimi T, Akinola AA. 2018. Quality assessment of the physicochemical properties of vermiwash produced from different sources during successive storage periods. Asian J Agric 2: 58-63.* This study investigated socio-economic factors and estimated the technical efficiency indices and factors influencing technical efficiency of sampled cotton farmers in the southern cotton growing zone of Nigeria. A multistage sampling technique was employed to select a total sample of 300 cotton farmers. The study made use of only primary data which was collected through the aid of a well-structured questionnaire. The data were analyzed using descriptive statistics and stochastic frontier production parametric model. The results of the descriptive statistics showed that majority (83%) of the cotton farmers in the study area were males, while the mean age of the respondents was 49 years. The average household size was 8 persons per household, and majority (69%) of the respondents had formal education. Majority of the respondents (59%) had no access to credit facilities, while the majority (80.4%) of the cotton farmers had reasonable years of experience ranging between 11 and above in cotton production. Furthermore, the study found that the technical efficiency of the farmers ranges from 0.35 and 0.99 with a mean of 0.79. This indicates ample opportunity for farmers to increase their productivity through improvement in their technical efficiency. Seed, fertilizer, pesticides, and farm size were found to be statistically significant and positively related to farmers' output while education, credit, extension contact, and farming experience of the respondents negatively influenced farmers' technical inefficiency. The farmers, therefore, need to increase their output through more intensive use of seed, land, pesticides, and fertilizers.

Keywords: Cotton, southern cotton growing zone, technical efficiency

INTRODUCTION

Many developing countries rely on agriculture to support their teeming populations. Hence, the development of policies that target increasing agricultural productivity is the governments' typical domestic reaction to the challenge of reducing poverty and increasing food security in rural areas (Moradeyo and Arene 2010). While the adoption of and dissemination of innovative farming practices eventually contributes to improvements in productivity and income (Awotide et al. 2013; Olatidoye et al. 2017), effective resource use and well-organized farm management are expected to boost their sustainability (Karimov 2013). Production efficiency means the attainment of production goals without waste. Efficiency is often used synonymously with that of productivity which relates output to input (Ajao et al. 2012). In Agriculture, the analysis of efficiency is generally associated with the possibility of farm production to attain optimal level of output from a given bundle of input at least cost. Thus, the crucial role of efficiency in increasing agricultural output has been widely recognized by policymakers and researchers alike. It is not surprising that considerable effort has been devoted to the analysis of farm-level efficiency in developing countries including Nigeria. An underlining premise behind much of this work is that farmers are not making efficient use of existing technology, then efforts designed to improve efficiency would be more cost-effective than introducing new technologies as a means of increasing agricultural output (Coelli et al. 1998; Ajao et al. 2012).

Cotton (*Gossypium* spp) remains by far the most important natural fiber. It ranks first followed by jute, kenaf and sisal in the world production of fibers. It represents (38.5%) of the fiber market and it is considered a strategic commodity because of its standing as a source of rural employment and foreign exchange (Adeniji 2011). In Nigeria, prior to the oil boom, cotton was one of the main sources of foreign exchange and second largest employer of labor after the public sector (Gbadegesin and Uyovnisere 1994; Alam et al. 2013). Alam et al. (2013) submitted that in 1993, cotton output was roughly equivalent to the requirement of the textile industry. However, as of 2015, cotton production in Nigeria can only account for (29%) of the requirement of the textile industry while the remaining 71% was imported. This was further corroborated by Olatidoye et al. (2017) that cotton production in the country has taken a downward trend as the gap between demand and supply is becoming wider and wider every year because the supply does not equate to demand.

Batterham (2000) asserted that supply is yet to satisfy the level of demand for cotton, and this has caused great concern in the textile cotton fiber supply situation in the local market and export profile in the country. Thereby having a declining effect in its contribution to the gross domestic product (GDP) of the country. Hence, achieving higher yields is a major concern for those involved in the entire cotton value chain. However, the price of cotton in the country is relatively fixed (there is small price change depending on the quality), thus a farmer can achieve higher margins only by increasing yields and efficiently using input resources. Unfortunately, yield numbers at the country level illustrate that cotton production has decreased since independence (USAID 2015). This decline is believed, in part, due to the inefficient use of resources. Moreover, the official statistics do not include resource data, thus making it difficult to acquire accurate information about the intensity of resource utilization in cotton production.

This study enlightens this issue in the context of frontier efficiency analysis by looking at some of the factors that are assumed to influence cotton production and empirically examining their significance.

MATERIALS AND METHODS

The study area

The study was conducted in the southern cotton-growing zone of Nigeria (Figure 1). This zone covers a land area of about 170,593 square kilometers representing (19.6%) of the country's landmass and comprises the savannah/derived savannah vegetative zone of these seven states: Osun, Oyo, Ogun, Ondo, Edo, Kogi and Kwara (Institute of Agricultural Research (IAR), 2010). The livelihood activities of the households in the savannah and derived savannah area of this zone are predominantly farming, trading and artisans. The study area spread between latitude 6^o and 9^{o}N and longitude 2^o 30′ and 6^{o}30′E constituting 36 Local Government Areas (LGAs) with a combined human population of about 32,243,222 (NPC 2006). The area is characterized by sandy-loam soil type and tropical climate, with average annual rainfall ranging between 1250mm and 1850mm, almost evenly distributed throughout the wet season while temperature varies between 21^{o}C and 29^{o}C. The study area experiences rainfall for approximately eight months (March-October) and usually four months (November-February) of dry season each year (FAO 2013). Agriculture provides income for about (75%) of the populace with notable food crop production including yam, maize, cassava, and rice while the notable non-food crop in the area is cotton (Adeniji 2011). The existence of good soil factors and favorable climatic conditions ensure continuous and sustainable cultivation of these crops coupled with their proven high return on investment (Olatidoye et al. 2017). Figure 1 is the map of Nigeria showing the cotton growing states and their respective zonal classifications.

Sampling procedure, data collection and sample size

A multistage sampling technique was employed using a well-structured questionnaire in selecting the respondents. The first stage was the purposive selection of two states (Oyo and Ogun States) out of the seven, constituting the southern cotton growing zone based on the predominance and almost near equal proportions of registered cotton farmers, 315 and 335 respectively, in these two states. The second stage also involved the purposive selection of three Local Government Areas (LGAs) from each of the two States also based on the predominance/scale of production of the cotton farmers in these areas. The third stage was the random selection of five villages in each of the LGAs, while the fourth stage was the selection of ten cotton farmers from each of the villages using simple random sampling technique to give a total of 300 sampled respondents. Primary data was only used for this study.

Analytical technique

The study made use of descriptive statistics and stochastic production frontier (SPF) approach to analyze the socio-economic characteristics and estimate the efficiency indexes, respectively, of cotton farmers in the study area. The SPF, a parametric model, was used in estimating technical efficiency scores of cotton production as well as the factors influencing efficiency levels since it gives better results, allows for the measurement of random errors such as inefficiencies of production, statistical noise measurement and the confidence of the results is much higher than from non-parametric models (Ajao et al. 2012). The frontier production function was specified by the Cobb-Douglas Stochastic Production Function including all the explanatory variables. Following Battese and Coelli (1995), a one stage procedure was employed given away the biases of the two steps potential estimation procedure. The model’s basic structure is as specified below:

$$Y_i = f(X_i, \beta)\, e^{v-u}$$

Where:
Y_i = Output of the ith farm
X_i = Quantity of input used.
β = Scalar parameter (vector) to be estimated,
e_i = error term = V_i-U_i = composite error term

Hence, the technical efficiency model may be explicitly expressed as:

$$LnY_i = \beta_0 + \beta_1 LnX_1 + \beta_2 LnX_2 + \beta_3 LnX_3 + \beta_4 LnX_4 + \beta_5 LnX_5 + V_i - U_i$$

Where:
Ln = natural logarithm
Y_i = output of cotton from the ith farmer (kg)
X_1 = quantity of seed (kg)
X_2 = quantity of fertilizer used (kg)
X_3 = quantity of pesticides used (litre)
X_4 = total labour used (man day)
X_5 = farm size (Hectares)
β_1-β_5= regression coefficients ;
V_i = A random variable in production that accounts for the random variation is output by factors beyond the control of farmers.

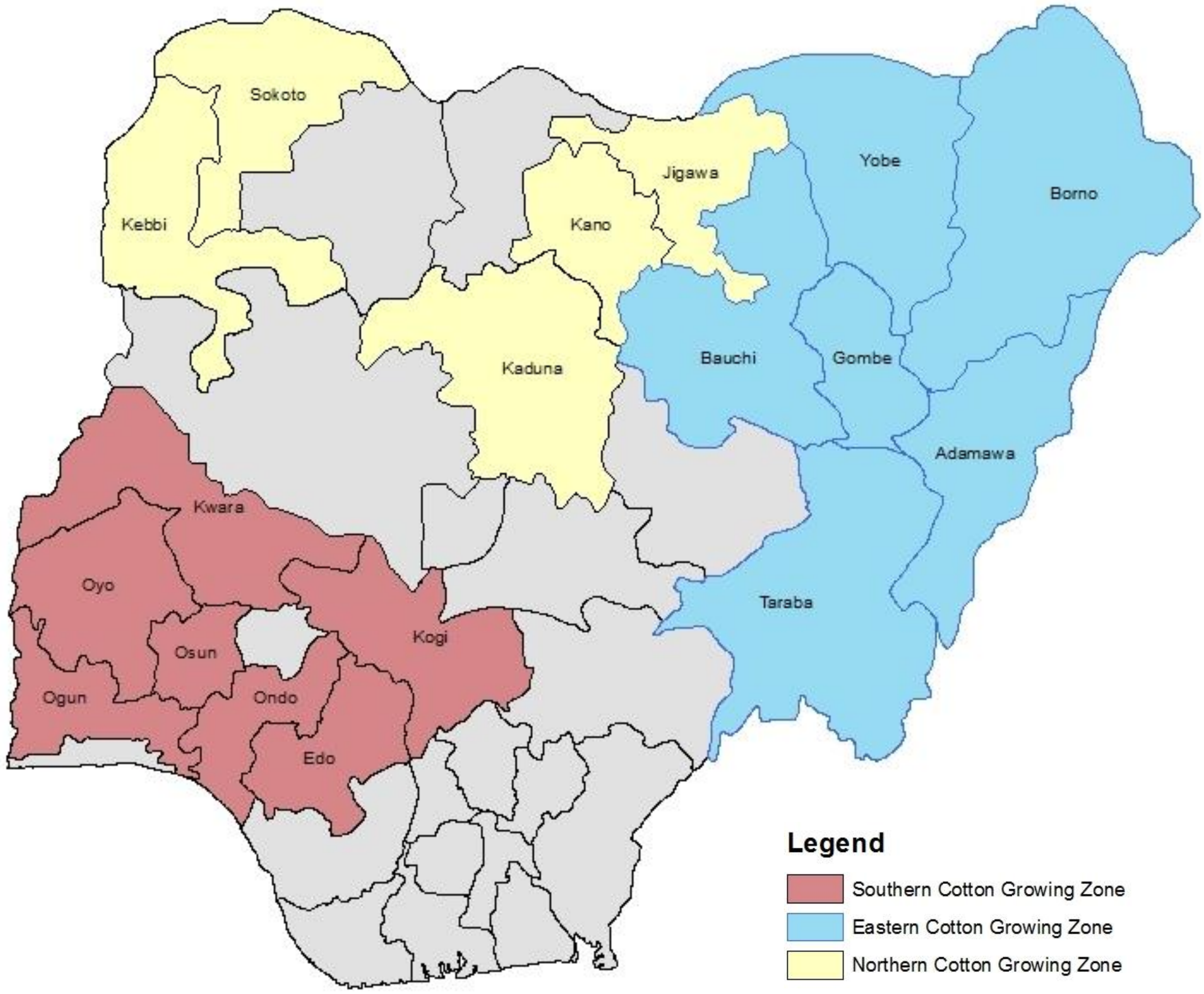

Figure 1. Map of Nigeria showing the cotton growing zones.

U_i = Technical inefficiency effects independent of V_i, and half normal distribution with zero mean and constant variance ($\sigma^2 u_i$).

β_0 = intercept

The technical inefficiency effects, U_i is defined by:

$$U_i = \delta_o + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + \delta_5 Z_{5i} + \delta_6 Z_{6i} + \delta_7 Z_{7i}$$

Where:
Z_1 = Age of farmer (years)
Z_2 = level of education of farmer (years)
Z_3 = access to credit
Z_4 = Household size
Z_5 = Membership of cooperative
Z_6 = Extension contact
Z_7 = Farming experience (years)

Cotton output is expected to be influenced positively by seed, fertilizer. pesticides, labor and farm size; while all the efficiency factors are expected to be negatively signed.

RESULTS AND DISCUSSION

The socio-economic/demographic characteristics investigated included: age, gender, household size, education, membership of association, experience in cotton production, access to credit, and extension contact. The results are presented in Table 1. The results showed that the mean age of the cotton farmers in the study area was 49 years, implying that cotton farming in the study area is embraced predominantly by young and middle-aged men which are strong, agile, and active and can participate adequately in farming activities. The distribution of the respondents by gender, showed that majority (83%) were males. This shows the dominance of male farmers in cotton farming in the study area. The household size distribution of the respondents showed that the mean household size was 8 persons per household, thus implying that there is appreciable number of family labor supply to accomplish various farm operations. The mean years of education were 11 years, suggesting that many cotton farmers in the study area had secondary education. The implication of this is that the costs of obtaining new technical and related information by the farmers will be reduced substantially when they can read and understand published materials and simplified farm journals which are increasingly becoming the modern vehicle of disseminating information. The distribution of members of association shows that majority (60.4%) of the respondents belonged to Cotton Farmers' Association (CFA). Table 1 further revealed that majority of the cotton farmers (52.3%) have been in cotton production between 11-15 years, with the mean years of experience being 13 years. About (60%) of the respondents had no access to credit facilities with extension service access being available to (44%) of the sampled farmers while about (56%) had no extension contacts.

Estimate of stochastic frontier production parameters

The maximum likelihood estimate of the Stochastic Production function for cotton farmers is presented in Table 2. There was presence of technical inefficiency effects in cotton production, as confirmed by a high significant gamma (γ = 0.72) for the cotton farmers. This implies that about (72%) variations in the maximum output among farmers in the study area were due to inefficiencies on the part of the farmers rather than random variability. Also, the significance of sigma-squared (σ^2 = 1.25) at 1 percent for the cotton farmers shows that the Cobb Douglas Stochastic Production Function which is estimated with inefficiency effects fits the data better than the conventional production model.

The results in Table 2 further revealed that the estimated coefficients of all parameters of production function were positive in compliance with *apriori* expectations. Seed, fertilizer, pesticides, and farm size were positively significant at (5%) level of probability. Hence, these variables were important determinants of yield/output in cotton production in the study area. The average technical efficiency for the farmers was 0.789, implying that on average the respondents can obtain (79%) of potential output from a given mixture of production inputs. Thus, in the short run, there is minimal scope (21%) of increasing the efficiency of the cotton farmers.

The estimated coefficient for seed was 0.195, which is positive and statistically significant at (5%) level. The estimated 0.195 elasticity of seed implies that increasing seed by (100%) will increase cotton output by 19.5. The significance of seed quantity is, however, since seed determines to a large extent the output obtained. If correct seed rates and quality seed are not used, output will be low even if other inputs are in abundance. This agrees with the findings of Neba et al. (2010) and Alam et al. (2013). The production elasticity of output with respect to quantity of fertilizer was 0.4 which is positive and statistically significant at (5%) level. This implies that a (1%) increase in fertilizer will increase cotton output by (0.35%). The coefficient of fertilizer also has the highest value. This indicated that fertilizer devoted to cotton production was the most important input to which output was responsive because it has the highest elasticity. Hence, intensifying the usage of fertilizers and at the recommended dosage will increase the yield/output of cotton. This also agrees with the finding of Adeniji (2011). The coefficient of farm size was also positively significant at (5%) level**.** This implies that a (1%) increase in the hectarage of cotton cultivated will increase output by 0.125. It also implies that as the farm size increases, technical efficiency of the cotton farmers also increases. This corroborated the findings of Ajagbe (2012) and Alam et al. (2013), who submitted that small farm holders are technically inefficient, and that efficiency increases as the farm size increases. The same thing goes for other factors. Hence, an increase in the quantity/quality of these factors in cotton production would result in increase in output.

Table 1. Socio-economic characteristics of cotton farmers in the southern cotton growing zone of Nigeria.

Parameters	Freq.	Percent. (%)	Mean	SD
Age range (years)				
31-40	13	4.3		
41-50	109	36.3		
51-60	146	48.7	49	±2.30
61-70	31	10.3		
70 and above	01	0.3		
Gender				
Male	249	83		
Female	51	17		
Household size				
Less than 6	158	52.7		
6-10	90	30.0	8	±3.12
11-15	40	13.3		
16-20	12	4.0		
Level of education				
No formal education	93	31.0		
Primary education	87	29.0	11	±2.13
Secondary education	118	39.3		
Tertiary education	2	0.7		
Membership of association				
Cooperative society	70	23.3		
Cotton farmers' Association	181	60.4		
Community-based organization	18	6.0		
Religious based organization	22	7.3		
None	9	3.0		
Years of experience in cotton farming				
1-5	37	12.3		
6-10	22	7.3		
11-15	71	23.7	13.2	±5.11
16-20	157	52.3		
Above 20	13	4.4		
Access to credit				
Yes	121	40.3		
No	179	59.7		
Extension contact				
Yes	131	43.7		
No	169	56.3		

Note: SD: Standard Deviation

The determinants of technical efficiency in cotton production as presented in Table 2 shows that the coefficient of household size was negative but insignificant at (5%) probability level. Education showed a negative relationship with technical inefficiency and is significant at (5%) level. The negative coefficient of education reveals that the level of education results in reduction in technical inefficiency of cotton farmers. This is because education sharpens managerial input and leads to a better assessment of the importance and complexities of good decisions in farming. This is in accordance with *a priori* expectation and agrees with the findings of Adzwala et al. (2013).

The coefficient for extension contact was negative and significant at (5%) level. Access to extension services increases the level of cotton farmers' availability to information about technical aspects of crop technologies that play an important role in increasing farm-level efficiency. Furthermore, farmers who are members of extension-related organizations exhibit higher levels of efficiency. This agrees with Kehinde and Awotide 2012. The coefficient of cooperative membership was positive and significant at (1%) level. This was contrary to *a priori* expectation as reported by several authors including Alam et al. (2013) and Odedokun (2014). The reasons might be that although farmers belong to a cooperative association, they do not derive much benefit from their membership, but rather tie down their resources and end up being used in unprofitable ventures. The coefficient for farming experience was negative and significant at (5%). This shows that it increases technical efficiency and decreases technical inefficiency. This was perhaps due to their ability to draw on experience to suit their farming condition. This finding agrees with Neba et al. (2010) and Adzwala et al. (2013). The coefficient of access to credit was negative and significant at 1% level. This is in accordance with *a priori* expectation because credit is believed to increase crop area, more input application, and more yields (Adeyemo et al. 2010). The coefficient of household size was negative, although not significant. This shows that increase in household size decreases technical inefficiency. The more the household size, the more availability of family laborers to carry out various farm operations. This agrees with the findings of Kehinde and Awotide (2012).

The returns to scale were 0.81 (Table 3) which was less than one, thus indicating that the cotton farmers were producing in the region of positive decreasing return to scale (stage II) of production process where every farmer strives to maximize output and minimize cost of production. The results also show that if all the inputs included in the production function model are increased by (1%), cotton output will increase by (0.81%).

Frequency distribution of technical efficiency estimates of cotton farmers

Technical efficiency score shows the ability of a firm to obtain maximum output from the given inputs and technology. The estimates of technical efficiency of the cotton farmers were as presented in Table 4.

Table 2. Estimated determinants of technical efficiency of cotton farmers

Variables	Parameter	Coefficient	Standard error	T-ratio
Constant	β_0	8.7456	0.7889	11.0858
Seed	β_1	0.1953* *	0.0551	3.5445
Fertilizer	β_2	0.3469**	0.1042	3.3292
Pesticides	β_3	0.1257*	0.0553	2.2731
Labor	β_4	0.0215	0.0304	0.7072
Farm size	β_5	0.1247**	0.0316	3.9462
Constant	δ_0	0.8193	0.1980	4.1378
Age	δ_1	0.0255	0.0237	1.0782
Education	δ_2	-0.0878*	0.0407	-2.1573
Access to credit	δ_3	-0.1672**	0.0510	-3.2784
Household size	δ_4	-0.0017	0.0016	-1.0625
Cooperative membership	δ_5	0.0875**	0.0119	7.3529
Extension contact	δ_6	-0.0137*	0.0050	-2.7400
Farming experience	δ_7	-0.0331*	0.0159	-2.0817
Diagnostic statistic				
Sigma-squared		1.2498	0.0917	13.6293
Gamma		0.717	0.0577	12.4263
Log-likelihood function		-535.57		
Total number of observations		300		
Mean efficiency		0.79		

Note: *5% level of significance, **1% level of significance.

Table 3: Elasticity of production and return to scale in cotton production.

Variables	Parameter	Coefficient
Seed	β_1	0.1953
Fertilizer	β_2	0.3469
Pesticides	β_3	0.1257
Labor	β_4	0.0215
Farm size	β_5	0.1247
Return to scale (RTS)		0.81

Table 4. Frequency distribution of Technical efficiency estimates

Technical efficiency	Frequency	Percentage (%)
0.31-0.40	7	2.3
0.41-0.50	12	4.0
0.51-0.60	19	6.3
0.61-0.70	73	24.3
0.71-0.80	122	40.7
0.81-0.90	45	15
0.91-100	22	7.4
Total	300	100
Average	79	
Std. Deviation	10.2	
Maximum	99	
Minimum	35	

The results showed that the mean technical efficiency is (79%). This suggests that there is about (21%) chance of increasing output without additional inputs in cotton production. This also indicates that for the average cotton farmer to achieve the technical efficiency level of the most technically efficient farmer, he/she would realize about (20.2%) (i.e., 1-79/99) cost-saving. On the other hand, the least technically efficient farmer will have about (64.7%) (i.e., 1-35/99) cost saving on inputs using the same technology. These results indicate a high technical inefficiency exists among the cotton farmers in the study area. Hence, there is great potential to enhance cotton productivity by improving technical efficiency of the cotton farmers, resulting in improved income, with a resultant impact on poverty reduction and wealth creation in the study area.

Conclusion and recommendations

The study has shown the distribution of technical efficiency of cotton farmers in the southern cotton growing zone of Nigeria. Farmers' specific factors like education, access to credit, frequency of extension contacts and farming experience contributed positively to technical efficiency level of the cotton farmers in the study area. Also, production inputs like seeds, fertilizer, pesticides, and farm size positively influenced cotton output. Furthermore, 72% of the variations in input use among the farmers were due to inefficiency on the part of the farmers rather than random variability. Hence, on average, technical efficiency of the cotton farmers could be increased by 21%, using the current production technology.

Based on the findings of this study, it is recommended that: (i) Policies that would guarantee adequate access to credit facilities by the cotton farmers are strongly advocated. This will ensure that the farmers have enough resources for expansion. (ii) An effective extension service should be established to bridge the gap between cotton farmers and research institutions, and to create awareness about improved technologies in cotton production. (iii) Government should assist by improving the educational status of the farmers through adult education and farmers should be educated and taught effective management of the available resources through workshops, training, and seminars.

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