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NUTRIENT COMPOSITIONS OF LIQUID AND SOLID FRACTIONS OF ORGANIC WASTE FERMENTATION AND THE INFLUENCE ON GROWTH AND YIELD OF OKRA

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ABSTRACT

The study was carried out in a screen-house in the Department of Crop Science, Faculty of Agriculture, University of Nigeria, Nsukka to investigate the nutrient compositions of liquid and solid fractions (biol and biosol) of organic waste fermentation, and the influence on growth and yield of okra (*Abelmoschus esculentus* (L) Moench). The organic waste materials used were rice husk, moringa pod husk and dry grass (*Panicum maximum*). The morphological characteristics considered were plant height (cm), stem girth (cm) and number of leaves. The yield characteristics were number of fruits/plant, number of seeds/fruit, 100 seed weight (g), fresh fruit weight (g/plant), fruit length (cm) and fruit circumference (cm). Laboratory chemical analysis was carried out to determine the percentage nitrogen (N), phosphorus (P), potassium (K) and carbon (C) contents of the organic waste materials. Proximate analysis of the waste materials was also carried out to determine the percentage crude protein, ash, fat and moisture contents. The result of the chemical analysis of the waste plant materials after fermentation showed high concentrations of N, P, K and percentage carbon (%C) in the solid than liquid fraction. Percentage crude protein, ash and fat contents of the waste materials were more in the solid than the liquid fraction in all the plant materials. The moisture contents of the plant materials increased after fermentation. Rice husk significantly ($p < 0.05$) increased the morphological characteristics. At six weeks after planting, the liquid fraction (biol) gave the highest plant height, stem girth and leaf number compared with the solid fraction (biosol) and combination of the liquid and solid fractions. The particle size difference had no significant ($t > 0.05$) effect on the morphological and yield parameters. Boil gave the highest values of most of the yield characteristics followed by combination of boil and biosol in the two months of fermentation.

INTRODUCTION

"Biol" and "Biosol" are liquid and solid fractions of fermentation or digestion of organic materials in a fermentation unit or digester. "Biol" and "Biosol" have been found to be excellent fertilizers for a variety of crops including okra (*Abelmoschus esculentus* (L) Moench). The quality of the "biol" and "biosol" in a given fermentation process, in terms of nutrient composition and physical properties, depends on the organic material(s) used during fermentation. Most of the plant materials used as organic fertilizers are rich in cellulose. Cellulose is a polymer of D-glucose units bound together with β-(1-4) links. Cassava slurry, germinating barley and maize had been found to contain β-amylase which hydrolyses malt sugar (Alais and Linden, 1999). The fungus, *Aspergillus niger,* which had been isolated from rotten groundnuts contains cellulase enzymes which hydrolyse cellulose and other cellulosic compounds to ethanol and carbondioxide. Most yeasts which have cell-bound β-glucosidase activity, such as *Candida* and *Brettanomyces*, can hydrolyse cellobiose but have little activities on cellotriose and cellodextrins (cellulosic compounds). *Torulopsis wickerhamii* produces extracellular exogluconase which is capable of hydrolyzing the β-(1-4) linked glucose in cellulose to ethanol and cabondioxide (Rohrbach, *et al*., 1985, Wayman and Parekh, 1990) Conversion of organic waste materials into liquid or solid bio-fertilizer is immensely important to reduce soil, water and air pollution, boost crop growth, maximize yield and reduce soil damage resulting from use of inorganic fertilizers (Moyin-Jesu and Atoyosoye, 2002, Mbah and Mbagwu, 2003 and

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Adeoye *et al*., 2008). Use of organic waste materials as sources of bio-fertilizers will also reduce emission of green-house gases such as methane and carbondioxide thereby mitigating global warming (Adeniyi, 2010). Okra is an important fruit vegetable crop widely cultivated in different parts of West and Central Africa and eaten in many parts of the world (FAOSTAT, 2008). In Nigeria, fresh okra fruits are used in vegetable soups with fluted pumpkin (*Telfairia occidentalis*) leaves. The fresh fruits are very rich in potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), iron (Fe), zinc (Zn), manganese (Mn) and nickel (Ni). It also contains reasonable levels of phenolic compounds, carbohydrates, proteins and cholesterol lowering compounds. The seed oil is rich in oligomeric catechins (2.5mg/g of seeds), flavournoid derivatives (3.4mg/g of seeds) and zinc (80mg/g of seeds). The mesocarp of the fruit consists of fibre, hydroxycinnamic and quercetin derivatives (0.2 and 0.3mg/g fruit mesocarp). The dried fruits contain beta-carotene (Vitamin A retinol) for the eye (Arapitsas, 2008; Avallone *et al*., 2008). Okra plant is tolerant to a wide range of soils. It grows well both in the rainy season (rainy season varieties) and dry season (dry season varieties) but some cultivars are sensitive to excessive soil moisture. Okra responds very well to organic manure application. Moyin – Jesu (2007) demonstrated an excellent use of plant residues to improve soil fertility, fruit nutrient composition, root growth and fruit weight of okra plant. The present study was designed to investigate the nutrient compositions of organic waste fermentation and influence on growth and yield of okra.

MATERIALS AND METHODS

Preliminary analysis of the organic materials

The organic materials used for fermentation i.e. rice husks, moringa pod husks and dry grass (*Panicum maximum*) were analyzed in the laboratory for chemical and proximate qualities. The percentages of some chemical elements such as nitrogen, phosphorus, potassium and carbon were determined using the methods stipulated by the Association of Analytical Chemists (AOAC, 2005). The proximate properties such as total ash, crude protein, crude fat, crude fibre and moisture contents were also determined using the recommended methods of AOAC (2005).

Fermentation of organic materials

The fermentation units consisted of eighty litre (80L)-capacity black plastic buckets with lids each containing sixty-five litres (65L) of water. The organic waste materials i.e. rice husks, moringa pod husks and dry grass were ground and sieved into two mesh sizes (0.63m and 1mm) to increase the surface area for fermentation and ensure uniform sizes of the fermentation materials. Five kilograms (5kg) of a particle size of each waste material was added to a fermentation unit. Twenty grams (20g) of rotten groundnut paste containing *Aspergillus spp* (fungus) was added to each fermentation unit for supply of cellulase enzymes which would hydrolyze the cellulosic compounds in the waste materials (Lastick, *et al*., 1983). There were no acid and alkaline treatments of the waste materials before fermentation. Fermentation of the waste materials was done periodically for one month and two months respectively. Thus, twelve fermentation units were set up for the experiment in a completely randomized design (CRD) with the units properly tagged. At the end of each fermentation period, the liquid fraction (biol) was separated from the solid component (biosol) by filtration. The boil was stored in a refrigerator, at low temperature, to stop further fermentation process (for split-dose application). Fermentation was done under anaerobic conditions.

Planting of okra with Biol and Biosol

One thousand, two hundred and eighty black polythene bags each containing three kilograms (3 kg) of topsoil and fermented fractions (boil, biosol or biol + biosol) of the two particle sizes (0.63mm or 1mm) of an organic waste material, were used in planting the okra seeds in the screen-house after one and two months of fermentation. Forty-five day-Clemson spineless okra variety was used for the experiment. Untreated topsoil medium was used as the control. In each growth period, six hundred and forty polythene bags were laid out in split – split manner in completely randomized design (CRD) with four replications. Each replicate consisted of one hundred and sixty polythene bags, treated with a mixture of topsoil and the fermentation fraction (biol, biosol or biol+biosol) of a particular size of the waste material. The biosol (solid fraction) was mixed with the topsoil at the rate of 50 g dry weight/bag before planting the okra seeds, while the biol (liquid fraction) was applied in split doses of 300mls/bag before planting and at one month after seedling emergence. The okra seeds were planted three per bag and thinned down to one after seedling emergence.

Sampling, data collection and analysis

Sampling was done weekly to collect the morphological data of plant height (cm), stem girth (cm) and number of leaves. The yield data included number of fruits/plant, number of seeds/fruit, 100seed weight (g), fresh fruit weight (g/plant), fruit length (cm) and fruit circumference (cm). Data collected were analyzed statistically using analysis of variance (ANOVA) and T-test. The significant means were separated using fisher's least significant difference according to Obi (2002).

RESULTS

Chemical and proximate properties of the waste materials

The result of the chemical analysis of the organic waste materials showed high concentration of N, P, K and percentage carbon (%C) in the solid than liquid fraction (Table 1). Percentage crude protein, ash and fat contents of the waste materials were more in the solid than the liquid fraction in all the plant materials. The moisture contents of the waste materials increased after fermentation (Table 2).

Morphological growth characteristics

Rice husk significantly ($p<0.05$) increased plant height and gave the highest plant height values, six weeks after planting, in the two months of fermentation compared with moringa pod husk and dry grass. Dry grass gave the least values, six weeks after planting, in the two months of fermentation. The liquid fraction (biol) gave the highest plant heights, six weeks after

Table 1. Chemical analysis of the plant waste materials one and two months after fermentation

	Un-fermented	1 month biosol	2 months biosol	1 month biol	2 months biol
		RICE HUSK			
Nitrogen(ppm)	0.67	0.52	0.59	0.45	0.49
Phosphorus(ppm)	9.43	10.07	11.27	8.88	9.24
Potassium(ppm)	0.43	0.30	0.30	0.22	0.26
Carbon(ppm)	0.41	0.31	0.25	0.23	0.21
		GRASS			
Nitrogen(ppm)	1.13	0.31	0.79	0.41	0.43
Phosphorus(ppm)	11.87	9.88	11.36	8.54	9.04
Potassium(ppm)	0.52	0.49	0.41	0.24	0.26
Carbon(ppm)	0.41	0.37	0.21	0.25	0.24
		MORINGA POD HUSK			
Nitrogen(ppm)	1.30	0.28	0.45	0.35	0.36
Phosphorus(ppm)	16.38	8.63	10.14	7.25	8.36
Potassium(ppm)	0.54	0.39	0.37	0.24	0.25
Carbon(ppm)	0.37	0.33	0.26	0.25	0.26

Table 2. Proximate qualities of the plant waste materials one and two months after fermentation

	Un-fermented	1month biosol	2months biosol	1 month biol	2 months biol
			RICE HUSK		
% Moisture	6.85	51.22	56.35	88.62	87.40
% Ash	4.86	2.80	2.70	0.82	0.84
% Protein	4.20	3.87	3.68	2.86	3.07
% Fats	2.04	2.22	1.81	1.83	1.74
			GRASS RESIDUE		
% Moisture	7.00	60.76	66.20	88.78	85.00
% Ash	4.37	4.09	4.00	0.91	0.94
% Protein	7.09	4.51	4.99	2.45	2.71
% Fats	2.04	1.73	1.43	1.73	1.65
			MORINGA POD HUSK		
% Moisture	6.40	52.60	56.20	85.33	83.28
% Ash	4.29	3.98	3.95	0.87	0.87
% Protein	8.14	2.95	2.80	2.05	2.28
% Fats	2.65	2.05	1.87	1.97	1.85

Table 3. Effects of particle sizes of plant wastes fermented for one month on morphological characteristics of okra plant at 2, 4 and 6 weeks after planting

Plant waste materials	Particle sizes and morphological characteristics								
	Plant height (cm)			Stem girth (cm)			Number of leaves		
	0.63mm	1mm	t>0.05	0.63mm	1mm	t>0.05	0.63mm	1mm	t>0.05
		2 weeks after planting							
Moringa pod husks	10.64	12.63	ns	2.58	2.52	ns	3.0	3.0	ns
Grass	12.16	10.62	ns	2.58	2.86	ns	3.0	3.0	ns
Rice husks	12.16	15.38	ns	3.37	3.27	ns	3.0	3.0	ns
Mean	11.65	12.88		2.84	2.88		3.0	3.0	
$LSD_{0.05}$	ns	1.05		ns	ns		ns	Ns	
		4 weeks after planting							
Moringa pod husks	14.94	17.25	ns	2.81	2.50	ns	4.42	3.92	ns
Grass	15.39	14.50	ns	2.67	2.94	ns	3.67	4.00	ns
Rice husks	20.33	22.33	ns	3.77	3.63	ns	6.08	5.42	ns
Mean	16.89	18.03		3.08	3.02		4.72	4.44	
$LSD_{0.05}$	1.84	2.01		ns	ns		ns	Ns	
		6 weeks after planting							
Moringa pod husks	17.89	19.68	ns	4.07	3.83	ns	4.50	2.92	ns
Grass	17.39	16.82	ns	3.89	3.98	ns	3.25	3.38	ns
Rice husks	24.89	24.72	ns	5.46	4.63	ns	.25	4.58	ns
Mean	20.06	20.41		4.47	4.15		4.67	3.67	
$LSD_{0.05}$	1.74	2.03		ns	ns		ns	Ns	

ns means not significant

planting, in the two months of fermentation, compared with the solid fraction (biosol) and combination of the liquid and solid fractions (Figures 1 and 2). The particle size difference had no significant ($t > 0.05$) effect on plant heights at both periods of fermentation (Tables 3 and 4). The rice husk gave significantly ($p<0.05$) the highest values of stem girth, six weeks after planting, in the first month of fermentation. Grass gave the least values of stem girth six weeks after planting in the first month of fermentation while moringa pod husk gave the least values in the second month but there were no significant differences ($p>0.05$) among the treatment means (Tables 3 and 4). The liquid fraction (biol) consistently and significantly ($p<0.05$) gave the highest values of both stem girth and number of leaves, six weeks after planting, in the two

Table 4. Effects of particle sizes of plant wastes fermented for two months on morphological characteristics of okra plant at 2, 4 and 6 weeks after planting

Plant waste materials	Particle sizes and morphological characteristics								
	Plant height (cm)			Stem girth (cm)			Number of leaves		
	0.63mm	1mm	t>0.05	0.63mm	1mm	t>0.05	0.63mm	1mm	t>0.05
	2 weeks after planting								
Moringa pod husks	10.03	10.10	ns	3.05	3.10	ns	2.67	3.0	ns
Grass	9.92	9.36	ns	3.46	3.33	ns	2.58	2.50	ns
Rice husks	8.86	10.56	ns	3.18	3.11	ns	3.0	2.83	ns
Mean	9.60	10.01		3.23	3.18		2.75	2.78	
$LSD_{0.05}$	ns	ns		ns	ns		ns	Ns	
	4 weeks after planting								
Moringa pod husks	12.64	13.04	ns	3.15	3.21	ns	4.00	3.75	ns
Grass	12.17	11.67	ns	3.92	3.93	ns	3.67	4.00	ns
Rice husks	13.72	16.11	0.88	3.38	3.54	ns	4.33	4.67	ns
Mean	12.84	13.61		3.49	3.49		4.00	4.14	
$LSD_{0.05}$	ns	0.92		ns	ns		ns	Ns	
	6 weeks after planting								
Moringa pod husks	15.42	15.88	ns	3.49	3.28	ns	4.58	4.00	ns
Grass	14.25	13.27	ns	5.21	4.02	ns	3.92	3.67	ns
Rice husks	19.83	20.25	ns	3.68	3.87	ns	7.33	4.83	0.92
Mean	16.50	16.47		4.13	3.72		5.28	4.17	
$LSD_{0.05}$	1.22	2.34		ns	ns		1.04	Ns	

ns means not significant

Table 5. Effects of three forms of plant waste materials fermented for one and two months on okra yield

Plant waste material	Form of manure	Yield/Month of fermentation											
		100 seed weight (g)		Number of seeds/fruit		Average seed weight/plant (g)		Fruit length (cm)		Fruit circumference (cm)		Fresh Fruit weight /plant (g)	
		1 month	2 months	1 month	2 months	1 month	2 months	1 month	2 months	1 month	2 months	1 month	2 months
Moringa pod husks	Biol	3.93	3.34	10.50	19.12	0.43	0.64	5.75	6.63	4.50	4.98	0.78	1.01
	Biosol	2.00	0.01	3.25	0.01	0.07	0.01	3.75	0.01	2.13	0.01	0.20	0.01
	Biol + biosol	2.13	1.00	2.00	1.00	0.04	0.02	2.00	1.50	1.00	0.88	0.10	0.05
	Mean	2.69	1.45	5.25	6.71	0.18	0.22	3.83	2.71	2.54	1.96	0.36	0.36
	$LSD_{0.05}$	ns	0.85	2.25	2.89	0.04	0.047	ns	1.27	1.02	0.88	ns	ns
Grass	Biol	3.43	1.85	11.25	5.63	0.43	0.10	5.40	5.13	4.39	3.25	0.73	0.29
	Biosol	2.79	0.01	3.75	0.01	0.11	0.01	2.75	0.01	2.25	0.01	0.23	0.01
	Biol + biosol	3.09	1.00	4.00	1.00	0.14	0.02	3.41	1.50	2.75	0.50	0.25	0.05
	Mean	3.10	0.95	6.33	2.21	0.23	0.04	3.86	2.21	3.13	1.26	0.40	0.12
	$LSD_{0.05}$	ns	ns	2.87	1.47	ns	ns	ns	1.07	ns	0.66	ns	ns
Rice husks	Biol	4.32	2.65	9.25	0.64	0.46	0.35	5.44	5.85	4.68	4.09	0.83	0.59
	Biosol	2.98	0.67	9.50	0.01	0.19	0.08	3.88	3.34	4.40	2.50	0.65	0.20
	Biol + biosol	3.31	1.50	14.63	0.02	0.29	0.12	3.75	4.00	4.96	2.25	1.04	0.20
	Mean	3.54	1.61	11.16	0.26	0.31	0.18	4.96	4.40	4.34	2.94	0.84	0.33
	$LSD_{0.05}$	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

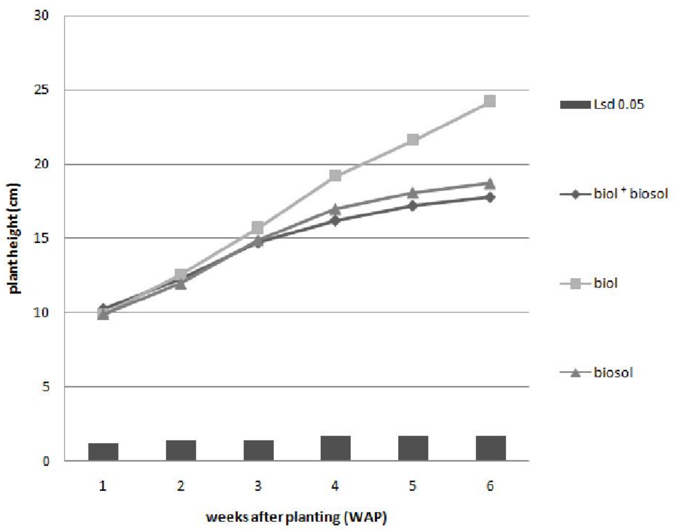

Fig. 1. Effect of form of manure fermented for one month on plant height (cm)

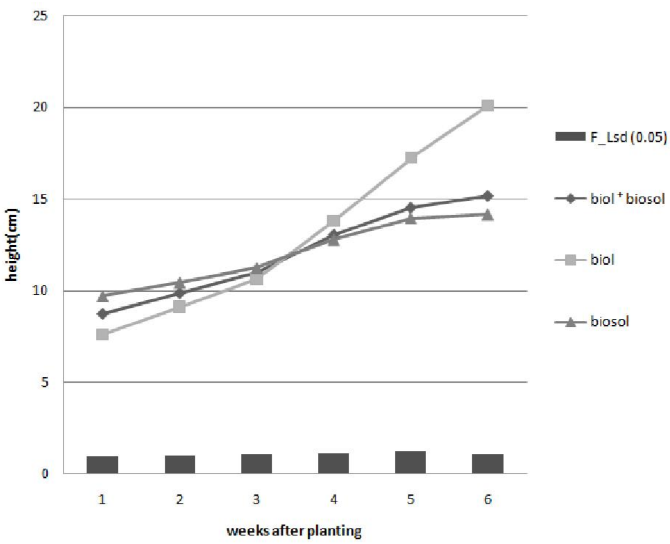

Fig. 2. Effect of form of manure fermented for two months on plant height

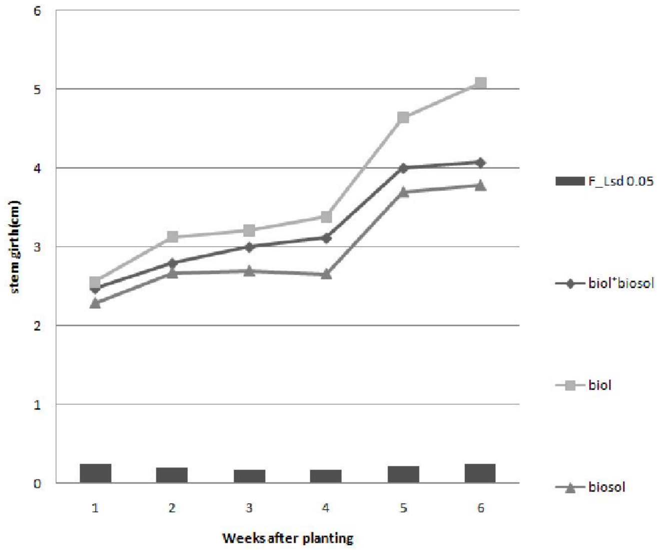

Fig. 3. Effect of form of manure fermented for one month on plant stem girth

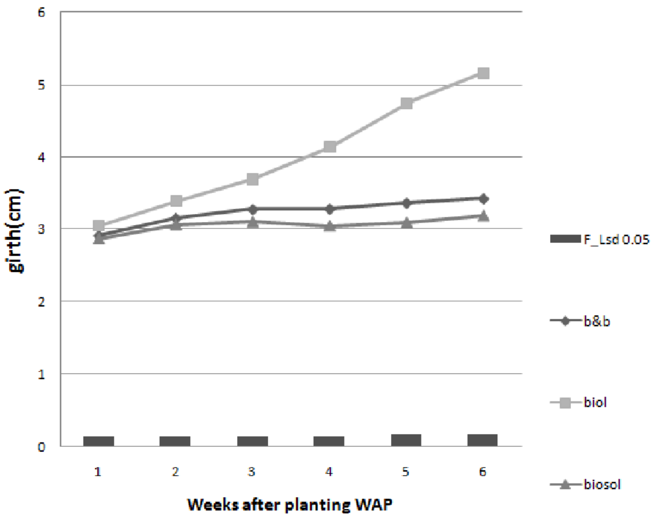

Fig. 4. Effect of form of manure of wastes fermented for two months on plant stem girth

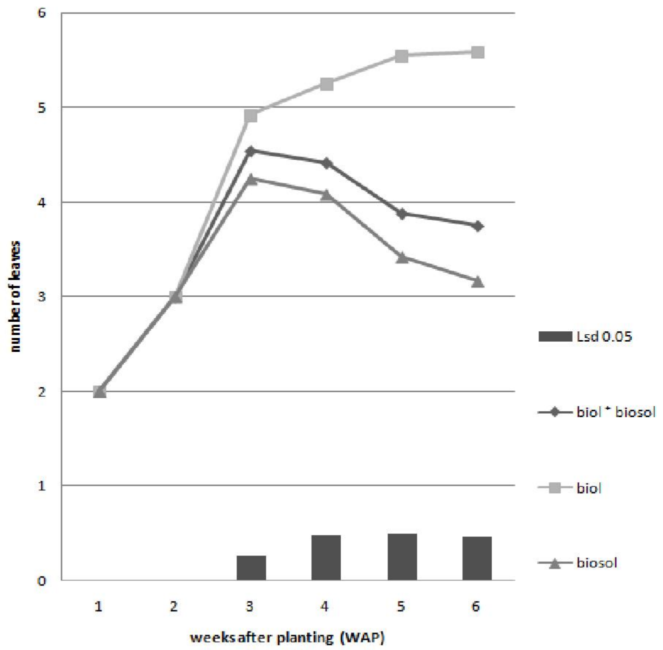

Fig. 5. Effect of form of manure on the number of leaves for wastes fermented for one month

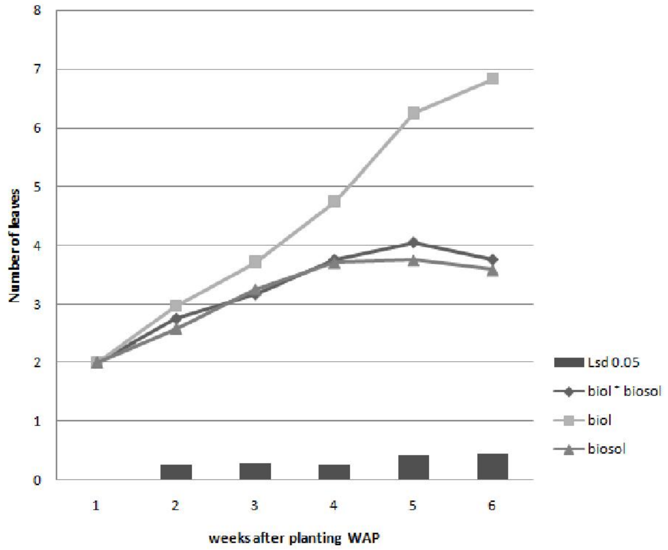

Fig. 6. Effect of form of manure fermented for two months on the number of leaves

months of fermentation while the solid fraction (biosol) consistently gave the least values (Figures 3, 4, 5 and 6). Particle size differences had no significant (t>0.05) effects on the stem girth and number of leaves at both periods of fermentation.

Yield characteristics

Boil gave the highest values of most of the yield characteristics followed by combination of boil and biosol in the two months of fermentation (Table 5). The particle size difference did not have significant (t>0.05) effects on the yield characteristics.

DISCUSSION

Rice husk gave the highest values of all the morphological growth characteristics. Rice bran contains a lot of protein. During rice grain processing, a lot of the protein is removed with the husk. This can be one of the reasons for high level of protein in the rice husk. Nitrogen and phosphorus were also found to be highest in the rice husk compared to moringa pod husk and dry grass. Most organic materials have been found to be rich in nitrogen and protein after decomposition and, thus, increase crop yield (Mbah and Mbagwu, 2003 and 2006, Moyin-Jesu, 2007). The liquid fraction (biol) gave the highest values of the morphological growth characteristics. This can be attributed to easy nutrient availability in the biol for plant growth. According to Ojeniyi *et al*. (2012), application of liquid agro-industrial by-products increased soil-plant nutrient supply by releasing structurally bound elements, such as N, P and Ca, in the soil solution during decomposition thereby increasing crop growth and yield. High protein, nitrogen and phosphorus levels were also obtained in the liquid fraction (biol) in the results of the chemical and proximate analyses of the plant materials. Organic manures are slow-release fertilizers. Thus, nutrient element complexes in the solid fraction (biosol) of the manure may not be readily available for plant use and this can account for the poorest performance of the plants treated with biosol alone. Okra plants performed better in terms of plant height, number of leaves (especially in the first four weeks of planting), and all the yield characteristics, in one month of fermentation compared to the two months. Fermentation of organic substrates is done by living micro-organisms which have short life spans. Rate of fermentation depends on the concentration of enzyme and substrate temperature among other conditions (Noggle and Fritz, 1979). Enzymes are proteinous in nature and prolonged fermentation can denature them especially with the build-up of heat in the fermentation medium. It was likely that most of the enzymes became virtually inactive at two months of fermentation.

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