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The efficacy of jatropha (*Jatropha curcas* L.*)* seed cake as an organic fertilizer

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Studies to evaluate the efficacy of *Jatropha curcas* L. (Jatropha) seed cake as an organic fertilizer were carried out at Bunda College of Agriculture during the 2010/2011 growing season using an on-station experiment. The major objective was to evaluate the efficacy of Jatropha seed cake as an organic fertiliser. The field experiment was laid in a 3 × 3 design with 3 levels of Jatropha (0, 92 and 184 kg N/ha corresponding to 0, 2875 and 5750 kg DM of Jatropha seed cake, respectively) and 3 levels of inorganic fertilizer (0, 23 and 46 kg N/ha). Field results showed that maize yields responded to the amount of Jatropha seed cake while inorganic fertilizer rate and the combination of Jatropha seed cake and inorganic fertilizer (at the same level of Jatropha seed cake) did not affect the grain yield of maize. The best performer in terms of grain yield was a treatment combination of 5750 kg/ha of Jatropha seed cake and 23 kg N/ha of inorganic fertilizer which produced a grain yield of 2483 kg/ha. However, this was comparable to 2331 kg/ha produced by the combination of 2785 kg/ha of Jatropha seed cake and 46 kg N/ha of inorganic fertilizer. The grain yield of sole Jatropha 5750 kg/ha was 2126 kg/ha. The grain yield of full rate of inorganic fertilizer (23:21:0+4S + urea) application was 2853 kg/ha. It can be concluded from this study that sole application of Jatropha seed cake has a potential of producing grain yield comparable to full rate inorganic fertlizer application.

Key words: Jatropha seed cake, organic fertiliser, inorganic fertiliser.

INTRODUCTION

The term soil fertility is generally defined as the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil, are favorable (NAL, 2015). The inherent soil fertility decreases with an increase in soil cropping; especially when the essential nutrients taken up by crops are not replenished (Ilex EnvironSciences, 2018). Zingore et al (2015) reported that land degradation associated with poor soil fertility leading to decreasing agricultural productivity is a problem in sub-Saharan Africa (SSA) whereas Mungai

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et al. (2016) indicated that low soil fertility was among the factors that limits sustainable agricultural production in Central Malawi.

A decline in soil fertility leads to a number of consequences. These include a marked decline in crop productivity and food insecurity as the main consequence. The other consequences include less fodder for cattle, less fuel wood for cooking, and less crop residues and cattle manure to recycle nutrients. These effects often increase runoff and erosion losses because there is less plant cover to protect the soil (liu et al., 2018). Soil fertility depletion also decreases above and below ground biodiversity and increases the encroachment of forests and woodlands in response to the need for additional agricultural land (Gomiero, 2016). In sustainable agricultural and horticultural enterprises, efforts must always be made to maintain not only inherent soil fertility but also soil productivity. Soil fertility is the status of a soil with respect to its ability to supply the nutrients essential to plant growth while soil productivity is the capacity of a soil, in its normal environment, for producing a plant or crop sequence under a specified system of management (Singh, 2017). The maintenance of inherent soil fertility without maintaining soil productivity does not assure sustainable agricultural production. For soil productivity to be maintained, the soil must, *inter alia*: (a) be in a position to furnish plant nutrients, air and water in suitable proportions; (b) have a suitable reaction in the chemical sense; (c) contain no substances that are phytotoxic; (d) be physically permeable to cultivation and resistant to soil erosion; and (e) serve as a suitable culture medium for the micro–flora and micro-fauna to be of character able to ameliorate the general chemical and physical properties of the soil and soil-plant relationship. Any substance which, when added to the soil, brings about an improvement in any of these directions can legitimately be considered as fertilizer or manure using the terms in their widest sense (Maida, 2015).

Traditional methods of soil-fertility management range from recurring fertilizer applications to low external input agriculture based on organic sources of nutrients. In Malawi the external input agriculture based on organic inputs include the use of organic fertilizers, crop rotations, intercropping, biological nitrogen fixations, agroforestry techniques and fallowing (Nalivata et al., 2017).

Concurrent with the efforts of using inorganic fertilisers to address the problem of low and declining soil fertility are those initiatives aimed at the use of organic fertilisers in the form of compost manure, surface mulch, crop residues farmyard manure and green manure (Nalivata et al., 2017). When incorporated into the soil, organic fertilisers improve both chemical and physical properties of the soil (Hossain et al, 2017). The complementary use of organic and inorganic fertilisers is, therefore, of paramount importance in any agricultural production programme designed to maintain soil productivity. Among the soil fertility management technologies outlined above, the use of organic fertilisers ranks highly. In their study on farmer perceptions, choice and adoption of soil management technologies in maize-based farming systems in Malawi, Kabuli and Phiri, (2004) concluded that the use of organic matter technologies offer practical solutions to sustainable soil fertility management in Malawi so long as crop residues and green manures are returned to the soil. This therefore calls for increased research in other forms of organic fertilisers in addition to the already existing alternatives so that the smallholder farmers may have a wider range of choice. An alternative seems to have risen in the name of a crop called *Jatropha curcas* L. (Jatropha). There is a growing interest in Jatropha as an oil “miracle tree” to help alleviate the energy crisis and generate income in rural areas of developing countries. Jatropha is becoming a foster child among some proponents of renewable energy and appropriate technology, especially as an oil-bearing, drought resistant tree for marginal lands for small farmers. If this technology is fully adopted in Malawi there is likelihood that there is going to be a problem of managing the residues that will be left after the extraction of oil from the Jatropha. However, according to Massoud et al. (2017). *J. curcas* seed cake (J.S.C.) is a useful organic byproduct containing considerable amounts of nitrogen, phosphorus, potassium and micronutrients. It can be considered as a green economy soil amendment.

MATERIALS AND METHODS

Study site description and Jatropha seed cake analysis

The on - station, and researcher designed experiment was conducted at Bunda College, Department of Crop and Soil Sciences Research Farm in the 2010/2011 growing season. The farm is situated at latitude 14°11'S and longitude 33°46'E and it is at 1184 m above sea level. The total amount of rainfall in the 2010/2011 growing season was 932 mm. The mean rainfall for the recent five-year period (2010/2011 inclusive) is 892 mm. Thus the 2010/2011 season had better rainfall. Soils at Bunda have been classified as Chromic Luvisols in the World Reference Base System (Typic Hapludalfs in the USDA Soil Taxonomy) (Mutegi et al., 2015). The area is dominated by acidic to strongly acid sandy clay and sandy clay loam soils. Mean total N % was 0.472 and 0.495 in the depth ranges of 0-20 and 20- 40 cm respectively. Soil organic matter values were 1.5 and 1.1% in the depth ranges of 0- 20 and 20- 40 cm.

Treatments, experimental plot size and layout

The field experiment included exclusive application of Jatropha seed cake and a combination of Jatropha seed cake and inorganic sources of N in the soil. The experiment was set out in a 3 × 3 complete factorial arrangement in a completely randomised block design replicated three times. The Jatropha seed cake (JSC) was applied in the soil as follows:

JSC_0 = 0 kg seed cake/ha (supplying equivalent of 0 kg N/ha)
JSC_1= 2875 kg seed cake/ ha (supplying equivalent of 92 kg N/ha)

Table 1. Schematic lay out of the treatment plots.

Plot number	Rep 1	Rep 2	Rep 3
1	JSC_2IF_2	JSC_2IF_1	JSC_1IF_0
2	JSC_1IF_0	JSC_0IF_1	JSC_1IF_2
3	JSC_0IF_1	JSC_2IF_2	JSC_2IF_0
4	JSC_0IF_0	JSC_0IF_0	JSC_0IF_2
5	JSC_0IF_2	JSC_2IF_0	JSC_0IF_0
6	JSC_1IF_2	JSC_1IF_0	JSC_2IF_1
7	JSC_1IF_1	JSC_1IF_1	JSC_1IF_1
8	JSC_2IF_1	JSC_0IF_2	JSC_0IF_1
9	JSC_2IF_0	JSC_1IF_2	JSC_2IF_2

JSC_2= 5750 kg seed cake/ha (supplying equivalent of 184 kg N/ha)
Three levels of inorganic N fertilizer (IF), urea (46% N), were applied as follows:

IF_0 = 0 kg N/ha
IF_1 = 23 kg N/ha
IF_2 = 46 kg N/ha

There was also an external plot for full rate of inorganic N fertiliser (92 kg N/ha). This was added to be used as a basis for comparison with the treatments under study. The schematic presentation of the treatment plots is shown in Table 1. The gross plot size was 4 ridges each measuring 5 m long spaced at 0.75 m. The net plot was the central 2 ridges measuring 4 m long, thus leaving at both ends 0.5 m. The maize was planted on the ridge at 0.25 m apart and 1 plant per planting station.

Research processes and procedures

The test crop was maize (*Zea mays*) variety SC403 which matures within 100 to 125 days and its potential yield is 5000 kg/ha. Before planting, the Jatropha seed cake was applied at a depth of 20 cm on the ridge to all the plots that required Jatropha seed cake as part of the treatment combinations. Germination took seven to eight days after planting and thinning was done on 28th February 2011. The same day 23:21:0 + 4S fertiliser as a basal dressing fertiliser was applied in the plots with full rate of inorganic fertiliser. Top dressing with urea (46% nitrogen) fertiliser was applied on 16th March 2011 in all the plots according to the treatment combinations. All the other agronomic practices like weeding, banking and pest control were done according to Guide to Agricultural Production (MoAI, 2014). During the maize growing season, we experienced a midseason dry spell. The plants were irrigated according to water requirements to avoid water stress. Harvesting of all the plots was done on 25th June 2011. Only the net plot was harvested to avoid border effects.

Growth, yield and yield components data

The growth data collected in this research were plant height and chlorophyll levels. Grain yield, stover yield (fresh and dry weight), 100-seed weight, and total biomass comprised the yield and yield components data that were collected. Maize plant heights were collected starting 27 days after planting and this was done every 2 weeks until time of harvesting. Ten plants were selected randomly from the net plot. The mean height was calculated accordingly. The height was measured using a meter rule from the top of the ridge up to the highest leaf. The crop growth rate was then calculated accordingly.

Chlorophyll levels were collected after 41, 55 and 69 days after planting. Ten plants were selected randomly from the net plot. From the ten plants, the mean chlorophyll level was calculated. The chlorophyll levels were measured using a chlorophyll meter (Minolta SPAD-502). Care was taken to make sure that the same leaf position was taken on each of the plants sampled for consistency sake. The mean chlorophyll level was calculated accordingly. The stover yield was determined by weighing all the stover in the net plot after removing the cobs without the husks. A sample of the stover was collected and oven dried at 80°C for 24-48 h for moisture determination. From the moisture determination the total dry stover yield for each plot was calculated. This was letter converted to stover yield in kilograms per hectare.

The 100 seed fresh weight was determined by randomly sampling 100 seeds from each net plot and weighing them while fresh. This was oven dried at 80°C for 24-48 h for moisture content determination. The seeds were reweighed after drying. The weight was recorded representing the dry weight of 100 seeds. The grain yield was determined by weighing the entire grain yield from each net plot while fresh. Then from the moisture content determined from the 100 seed weight, the dry weight of the grain yield for each net plot was calculated and this was later converted to yield in kilograms per hectare. The total biomass was determined by the addition of the dry weights of total stover, total grain, and total cores for each net plot. This was again converted to total biomass yield in kilograms per hectare.

Data analysis

The data from the two experiments was analysed using Genstat, 12th edition, computer package for analysis of variance (ANOVA). Means which were significantly different were separated by Fisher's protected least significance differences (LSD) at P = 0.05 level.

RESULTS AND DISCUSSION

Evaluating the effect of Jatropha seed cake and inorganic fertilizer on maize growth and yield

Chlorophyll in maize plant leaves

The results on the effect of Jatropha seed cake on

Table 2. Mean chlorophyll levels in maize leaves with time for the field experiment involving the use of jatropha seed cake and inorganic fertiliser at bunda college research farm during the 2010/2011 growing season.

Jatropha seed cake (kg/ha)	Inorganic fertilizer (kg N/ha)	Sampling time (days after planting)			
		41	55	69	Mean
0	0	30.44	35.70	35.77	33.97[d]
	23	33.01	38.35	45.12	38.83[c]
	46	31.14	42.90	45.23	39.76[c]
	Mean	31.53[c]	38.98[c]	42.04[c]	
2875	0	45.03	37.85	39.04	40.64[c]
	23	48.16	48.90	48.76	48.61[b]
	46	51.96	51.75	50.91	51.54[ab]
	Mean	48.38[b]	46.17[b]	46.24[b]	
5750	0	50.02	53.60	50.84	51.49[ab]
	23	54.32	54.65	52.37	53.78[a]
	46	50.36	54.85	51.82	52.34[ab]
	Mean	51.57[a]	54.37[a]	51.68[a]	
	Grand mean	43.83[b]	46.51[a]	46.65[a]	
Inorganic fertilizer (23:21:0+4S + urea)		46.01	54.00	53.68	
				$LSD_{0.05}$	**F prob**
Jatropha seed cake				2.459	<0.001
Inorganic fertilizer				2.459	<0.001
Sampling time				2.459	0.044
Jatropha seed cake × inorganic fertilizer				4.258	0.038
% CV		7.9			

* Means with different superscripts in the same column and row are significantly different (P<0.05).

chlorophyll in maize plant leaves are given in Table 2. The results indicate that there were significant differences (P<0.001) in chlorophyll index among the Jatropha seed cake rates. The levels of chlorophyll increased with increase in Jatropha seed cake rates. The rates of inorganic fertilizer also significantly affected (P<0.001) the index of chlorophyll. This increased with increase in inorganic fertilizer level. A closer scrutiny of Table 3 indicates that the inorganic fertilizer influenced more chlorophyll development than the *Jatropha* seed cake. The stage of crop growth also significantly affected the index of chlorophyll (P = 0.044). The index of chlorophyll increased as the crop was developing. However, there were no significant differences in chlorophyll index between 55 and 69 days after planting. The index of chlorophyll in the maize leaves were also significantly (P = 0.038) affected by the combination of Jatropha seed cake and inorganic fertilizer. At all levels of Jatropha seed cake rates, the chlorophyll index were increasing with increase in inorganic fertilizer rates. However, at all these levels of Jatropha seed cake, the difference between adding 23 or 46 kg N/ha of inorganic fertilizer did not bring significant differences. The highest synergy was recorded in the treatment combination of 5750 kg /ha of Jatropha seed cake and 23 kg N/ha of inorganic fertilizer (53.78) but this was comparable to 51.54 recorded in the treatment combination of 2875 kg/ha of Jatropha seed cake and 46 kg N/ha of inorganic fertilizer.

The increase in chlorophyll index with increase in Jatropha seed cake could be attributed to more nitrogen available where there was more Jatropha seed cake applied. The same could apply to increase in chlorophyll index with increase in amount of inorganic fertilizer. Schlichting et al. (2015), reported that chlorophyll content is usually strongly related to N concentration. Similar results were reported by Akhter et al. (2016). Nitrogen is part of the enzymes associated with chlorophyll synthesis (Chapman and Barreto, 1995) and the chlorophyll concentration reflects relative crop N status and yield level (Blackmer and Schepers, 1995). The observed change in chlorophyll content with the stage of crop growth coincided with Argenta et al. (2004) findings, who reported that the chlorophyll reading, mainly in initial stages, varied more compared to the later stages. Sunderman et al. (1997) also found greater increases in reading values in early vegetative stages (six to seven and 10 to 11 expanded leaves) than during reproductive stages (R1 and R6).

Table 3. Mean maize crop growth rate (cm/day) with time for the field experiment involving the use of jatropha seed cake and inorganic fertiliser at bunda college research farm during the 2010/2011 growing season.

Jatropha seed cake (kg/ha)	Inorganic fertilizer (kg N/ha)	Sampling time (days after planting)					
		27 – 41	41- 55	55 – 69	69 - 83	Mean	
0	0	0.630	0.608	1.448	2.177	1.215^{d}	
	23	1.051	1.428	2.458	1.995	1.733^{c}	
	46	0.981	1.117	2.491	2.877	1.867^{bc}	
	Mean	0.887^{b}	1.051^{b}	2.132^{b}	2.350^{a}		
2875	0	2.657	1.568	3.170	2.139	2.383^{a}	
	23	2.325	2.115	2.575	1.669	2.171^{abc}	
	46	2.583	2.147	3.121	1.357	2.302^{ab}	
	Mean	2.522^{a}	1.943^{a}	2.955^{a}	1.722^{b}		
5750	0	2.080	2.035	2.670	2.084	2.217^{ab}	
	23	3.012	2.546	2.916	1.512	2.497^{a}	
	46	2.594	1.832	3.201	0.712	2.087^{ab}	
	Mean	2.562^{a}	2.138^{a}	2.929^{a}	1.436^{c}		
	Grand mean	1.990^{b}	1.710^{b}	2.672^{a}	1.837^{b}		
Inorganic fertilizer (23:21:0+4S + urea)		2.044	2.076	3.161	1.440	2.180	
						$LSD_{0.05}$	**F prob**
Jatropha seed cake						0.256	<0.001
Inorganic fertilizer						0.256	0.287
Sampling time						0.296	<0.001
Jatropha seed cake × inorganic fertilizer						0.443	0.032
% CV						21.3	

*Means with different superscripts in the same column and row are significantly different (P<0.001).

Effect of Jatropha seed cake and inorganic fertilizer on maize crop growth rate

The results on the effect of Jatropha seed cake and inorganic fertilizer on maize crop growth rate are shown in Table 3. The results indicate that crop growth rate was significantly (P<0.001) affected by the amount of Jatropha seed cake applied. For sole Jatropha seed cake, the highest mean growth rate (2.383 cm/day) was observed where 2875 kg/ha of Jatropha seed cake was applied and this was significantly different from that of 5750 kg/ha of Jatropha seed cake (2.217 cm/day). The lowest (1.215 cm/day) crop growth rate was where no Jatropha seed cake was applied. The mean of crop growth rate for full rate inorganic fertilizer was 2.180 cm/day. The crop growth was however not significantly affected by the amount of inorganic fertilizer applied. The combination of Jatropha seed cake and inorganic fertilizer had also a significant (P = 0.032) effect on the crop growth rate. The mean crop growth rate was highest (2.497 cm/day) in the combination of 5750 kg/ha of Jatropha seed cake and 23 kg N/ha of inorganic fertilizer. This value was however not significantly different from 2.302 cm/day observed in the combination of 2875 kg/ha of Jatropha seed cake and 46 kg N/ha of inorganic fertilizer. These two values were comparable to 2.218 cm/day observed in full rate inorganic fertilizer. The time of sampling also significantly (P<0.001) affected the crop growth rate. The crop growth rate was high in the early stages of growth and dropped between 41 and 55 days after planting. The highest crop growth rate was experienced between 55 and 69 days and then dropped again towards harvest time.

The plant height which is used in determining the growth rate is among the most important biomass yield components of maize crop. Besides being a genetic trait, it is also a reflection of nutrient availability, management and favorable prevailing weather. The fact that a combination of 5750 kg/ha of Jatropha seed cake and 46 kg N/ha of inorganic fertilizer gave the highest growth rate which also means that it gave the tallest plants is an indication that abundant nutrient supply is directly correlated to growth. This might be due to the availability of N required for plant growth and development. Similar results were reported by Imran et al. (2015) who stated that application of high N rates had significant effect on plant height of maize and therefore on growth rate. The observed trend in the growth rate with time could be explained by the availability of water which is one the most essential requirements for plant growth. The high growth rate during the early stages could be due to availability of moisture with respect to the time the maize was planted. This growth rate was observed around the months of February and March when the area received a

Table 4. Mean maize 100-seed weight (g) for the field experiment involving the use of Jatropha seed cake and inorganic fertiliser at Bunda College research farm during the 2010/2011 growing season.

Jatropha seed cake (kg /ha)	Inorganic fertilizer (kg N/ha)			
	0	**23**	**46**	**Mean**
0	16.46	19.84	19.24	18.52[b]
2875	18.24	24.18	22.90	21.77[a]
5750	24.22	22.42	23.59	23.41[a]
Mean	19.64	22.15	21.91	
100-seed weight of inorganic fertilizer (23:21:0+4S + urea)				25.60
			$\mathbf{LSD_{0.05}}$	**F prob**
Jatropha seed cake			2.854	0.011
Inorganic fertilizer			2.854	0.145
Jatropha seed cake × inorganic fertilizer			4.942	0.234
% CV			10.3	

* Means with different superscripts in the same column are significantly different (P<0.05).

lot of rainfall. The other reason could be the fact that the plants were still young and growth was fast. Another contributing factor would be the plant nutrients released with the fast decomposition of Jatropha in the first 14/28 days. The drop in growth rate between 41 and 55 days after planting could be attributed to low rainfall which fell in the month of April. A sudden increase in the growth rate thereafter could be attributed to more moisture content availability since the plants were irrigated after the rains stopped. The drop in growth at the end could be attributed to the fact the plants were approaching maturity and therefore growth was slow.

Effect of Jatropha seed cake and inorganic fertilizer on maize 100-seed weight

The results on the effect of Jatropha seed cake and inorganic fertilizer are given in Table 4. The results indicate that maize 100 seed weight was significantly (P = 0.011) affected by the amount of Jatropha seed cake applied. There was an increase in 100 seed weight with increase in Jatropha seed cake. Inorganic fertilizer and the combination of Jatropha seed cake and inorganic fertilizer did not significantly affect maize 100 seed weight. It is clear from Table 4 that the seed weights were higher between Jatropha seed cake rates than between inorganic fertilizer. For sole Jatropha the highest weight (24.22 g) was produced where 5750 kg of Jatropha seed cake was applied and this was comparable to 25.60 g produced where full rate of inorganic fertilizer was applied. In the combinations between Jatropha seed cake and inorganic fertilizer, the highest weight (24.18 g) was produced where 2850 kg of Jatropha seed cake was combined with 23 kg N/ha of inorganic fertilizer and this was once again comparable again to the seed weight for full rate of inorganic fertilizer.

The increase in seed weights with Jatropha seed cake and not with increase in inorganic fertilizer could be attributed to the availability of macro nutrients throughout the plant life especially at the time of flowering and seed setting. The three macro elements, N, P, and K were available in the Jatropha seed cake and only N was available in the inorganic fertilizer used. One of the macro nutrients worth mentioning is K which is one of 12 nutrient elements required for normal corn growth and development. Basically, K is associated with movement of water, nutrients, and carbohydrates within the plant. These functions will stimulate early growth, increase protein production, and improve the efficiency of water use and resistance to diseases and insects. As reported by Anarson (2015) the maize grain is composed mainly of starch (80%), and protein (10-15%). The other components are oil (5-6%), fiber (9-15%), sugar (1-3%), and ash (1.7%).

Effect of Jatropha seed cake and inorganic fertilizer on maize plant biomass

The results on maize plant biomass are given in Table 5. The results show that maize plant biomass was significantly affected (P = 0.004) by the amount of Jatropha seed cake. The biomass increased with increase in Jatropha seed cake. The maize plant biomass was also significantly affected (P = 0.011) by the amount of inorganic fertilizer. Here also the maize plant biomass increased with increase in inorganic fertilizer. However, the combination of Jatropha seed cake and inorganic fertilizer did not significantly affect the maize plant biomass. It is shown that the maize plant biomass was highest between the Jatropha seed cake as compared to values between the inorganic fertilizer. The highest value (5206 kg/ha) for sole Jatropha was where 5750 kg /ha of Jatropha seed cake was applied and this was comparable to 5959 kg/ha for full rate of inorganic

Table 5. Mean maize plant biomass (kg/ha) for the field experiment involving the use of Jatropha seed cake and inorganic fertiliser at Bunda College research farm during the 2010/2011 growing season.

Jatropha seed cake (kg /ha)	**Inorganic fertilizer (kg N/ha)**			
	0	**23**	**46**	**Mean**
0	763	2211	2959	1978[c]
2875	4399	4589	5615	4868[b]
5750	5206	5647	6297	5717[a]
Mean	3456	4149	4957	
Maize biomass weight of inorganic fertilizer (23:21:0+4S + urea)				5959
		$LSD_{0.05}$		**F prob**
Jatropha seed cake		1769.2		0.002
Inorganic fertilizer		1769.2		0.213
Jatropha seed cake × inorganic fertilizer		3064.3		0.956
% CV		32.4		

*Means with different superscripts in the same column are significantly different (P<0.05).

fertilizer. For the combinations of Jatropha seed cake the best performer was 5750 kg/ha of Jatropha seed with 46 kg N/ha which produced 6297 kg/ha. However, the one produced by a combination of 5750 kg/ha of Jatropha seed cake with 23 kg N/ha of inorganic fertilizer (5647 kg/ha) was comparable to the one produced where there was a full rate of inorganic fertilizer applied.

The observed significant performance in plant biomass with the application of Jatropha seed cake could be attributed to the essential nutrient elements contained in the Jatropha seed cake that are associated with increased photo-synthetic efficiency. This finding corroborates the report of Kareem et al. (2017) who observed significant increases in dry matter accumulation in maize with successive increases in organic manure rates. This could be due to the ability of the organic manure to supply the nutrient elements necessary to promote more vigorous growth, improve meristematic and physiological activities in the plants, as well as improve the soil properties; thereby resulting in the synthesis of increased photo-assimilates that enhanced maize yielding ability. The better biomass produced by a combination of Jatropha seed cake and inorganic fertilizer is consistent with other researchers' findings. Combination of organic and mineral fertilizer sources have been shown to result in synergistic effects and improved synchronization of nutrient release and uptake by crop, leading to higher yields. The use of organic fertilizer combined with NPK fertilizer can be applied to increase the biomass production, and maize grain yield in sustainable ways (Maswar and Soelaeman, 2015).

Effect of Jatropha seed cake and inorganic fertilizer on maize stover and grain yields

The results of the effect of Jatropha seed cake and inorganic fertilizer on maize stover and grain yield are given in Tables 6 and 7, respectively. The results indicate that both the grain and stover yield were significantly affected (P = 0.007 and P = 0.018 for grain) by the amount of Jatropha seed cake applied. There was an increase in stover and grain yield with increase in Jatropha seed cake. Both the stover and grain yield were not significantly affected by the inorganic fertilizer rates and neither were these two significantly affected by the combination of Jatropha seed cake and inorganic fertilizer. Once again here the Jatropha seed cake is showing to have more effect on the stover and grain yield as compared to the inorganic fertilizer. With respect to sole Jatropha seed cake, the highest stover yield (2774 kg/ha) was produced where 5750 kg/ha of Jatropha seed cake was applied. However, even the stover yield for 2875 kg/ha of Jatropha seed cake (2508 kg /ha) was comparable to the one produced by full rate of inorganic fertilizer which was 2572 kg/ha. For the combinations, the highest stover yield was produced in the treatment combination of 5750 kg/ha of Jatropha seed cake and 46 kg N/ha of inorganic fertilizer. However, it can also be noted from Table 6 that the treatment combination of 5750 kg/ha of Jatropha seed cake performed well. This produced 2807 kg/ha compared to 2572 kg/ha for the full rate inorganic fertilizer.

In terms of grain yield, the highest yield for sole Jatropha was realized from 5750 kg/ha of Jatropha seed cake while that for full rate inorganic fertilizer was 2853 kg/ha. As for the combinations, the highest grain yield (2418 kg/ha) was realized from the treatment combination of 5750 kg/ha Jatropha seed cake and 23 kg N/ha of inorganic fertilizer. Once again the observed significant performance in stover and grain yield with the application of Jatropha seed cake could be attributed to the essential nutrient elements contained in the Jatropha seed cake that are associated with increased photo-synthetic efficiency. This finding corroborates the report of Kareem et al. (2017) as already alluded to in this

Table 6. Mean maize stover yield (kg/ha) for the field experiment involving the use of Jatropha seed cake and inorganic fertiliser at Bunda College research farm during the 2010/2011 growing season.

Jatropha seed cake (kg /ha)	Inorganic fertilizer (kg N/ha)			
	0	**23**	**46**	**Mean**
0	404	1332	1255	997[b]
2875	2508	2484	2807	2598[a]
5750	2774	2757	3924	3152[a]
Mean	1894	2191	2662	
Stover yield of inorganic fertilizer (23:21:0+4S + urea)				2572
			$LSD_{0.05}$	**F prob**
Jatropha seed cake			1192.7	0.007
Inorganic fertilizer			1192.7	0.380
Jatropha seed cake × inorganic fertilizer			2065.8	0.835
% CV			40.6	

*Means with different superscripts in the same column are significantly different (P<0.05).

Table 7. Mean maize grain yield (kg/ha) for the field experiment involving the use of Jatropha seed cake and inorganic fertiliser at Bunda College research farm during the 2010/2011 growing season.

Jatropha seed cake (kg /ha)	Inorganic fertiliser (kg N/ha)			
	0	**23**	**46**	**Mean**
0	281	677	1375	778[c]
2875	1530	1729	2331	1863[b]
5750	1993	2418	1966	2126[a]
Mean	1268	1608	1891	
Maize grain yield of inorganic fertilizer (23:21:0+4S + urea)				2853
			$LSD_{0.05}$	**F prob**
Jatropha seed cake			896.6	0.018
Inorganic fertilizer			896.6	0.335
Jatropha seed cake × inorganic fertilizer			1552.9	0.712
% CV			43.2	

*Means with different superscripts in the same column are significantly different (P<0.05).

study. The better stover and grain yield produced by a combination of Jatropha seed cake and inorganic fertilizer is consistent with what other researchers found ((Maswar and Soelaeman, 2015), as already pointed out in this study. The observed significant effect on grain yield with increases in Jatropha seed cake application could also be attributed to biomass and 100-seed weight which were also significantly increased with application of Jatropha seed cake which resulted in an overall increase in grain yield per hectare. Ogbonna and Obi (2005) reported similar results where increases in organic manure application resulted in high dry matter partitioning towards increased grain yield and higher harvest index. The other contributing factor to the observed yield differences could be the plant height. It was observed from the study that the plant height increased with increased levels of Jatropha seed cake. The height of plant is an important growth character directly linked with the productive potential of plants in terms of grains. An optimum plant height is claimed to be positively correlated with productivity of plant (Saeed et al., 2001).

The observed trend in maize grain yield also corresponded with the increase in chlorophyll content in maize leaves which increased with increase in Jatropha seed cake rates. The results showed that there is direct relationship between the leaf chlorophyll and maize yield corroborating (Mehasen and Al-Fageh Mehasen, 2004). The lack of interaction between the Jatropha seed cake and the inorganic fertlizer is indicative of the fact that organic fertilizer alone was capable of providing enough of the nutrient elements. This may be due to the fact that the soil of the experimental site was found to be rich in total N and organic carbon content.

Conclusions

Base on the study findings and the objectives that were investigated using the field experiment, the following conclusions are made. Sole Jatropha of about 6 tonnes per hectare has a potential of producing yields comparable to full rate of inorganic fertiliser. For smallholder farmers, Jatropha seed cake will be a favourable source of nutrients as it is cost effective, locally available and also effective in increasing the availability of essential plant nutrients. The use of Jatropha seed cake as an organic fertiliser could offer smallholder farmers a better source of organic fertiliser with manageable rates of residues as compared to other sources of organic fertiliser. For instance, the rates used in this research were between 3 and 6 tons/ha as compared to about 15 tons/ha for farmyard manure.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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