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The performance of Soybean using *Moringa* as alley to improve soil productivity in North-Central Nigeria

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This study assesses the performance of intercropping *Glycine max* (Soybean) and *Moringa oleifera* under alley cropping in Abuja, Nigeria during the 2014 and 2015 cropping season. The field experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The replicates contained five plots each, separated between blocks by 1 m pathway and 0.5 m within the blocks. The plot measured 5.0 m × 4.0 m each. Thus, a total of 15 (treatments) plots were used. Results showed that total nitrogen, like all other elements observed, significantly reduced during first cropping season (0.03%) but improved significantly at P<0.05 (0.07%) after the second trial except Sodium. Sodium concentration reduced to 0.38 Cmol^{-1} in Glycine max/Moringa inter crop plots of 50,000 stands of Soybean and 10,000 stands of *M. oleifera* in 2015. Highest Soybean seed yield (0.68 tha^{-1}) in 2015 cropping season and Maximum Land Equivalent Ratio (23 and 68% more yield in 2014 and 2015 respectively) were obtained from 50,000 Soybean stands + 10,000 stands of *M. oleifera*. The intercropping showed positive relationship between the two plants in terms of yield and the improvement of Nigeria Guinea Savannah soil fertility through organic biomass.

Key words: Alley cropping, fertility, Moringa, soybean, yield.

INTRODUCTION

Alley cropping, an agroforestry approach where annual (agricultural) or perennial (horticultural) crops are cultivated between widely spaced rows of economic woody species (Kang, 1997). Alley cropping, over the years, is a system that increased agricultural productivity, improved livelihoods through income diversification, enhanced conservation strategies, promoted organic waste recycling and induce landscape aesthetics value among others over the continuous mono cropping (de la Fuente et al., 2014; Stoltz and Nadeau, 2014; Kang, 1997). The system had the challenge to increasing the sustainability of agricultural yield with limited inputs to meet the growing human needs, while maintaining the natural resource base and reducing environmental degradation through recycling of organic matter (Cardinael et al., 2015, Ramsdale et al., 2006).

The continuous monocropping without adequate fertilization has led to soil fertility depletion and

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subsequent low crop yields in the savannahs of Nigeria (Esu, 2010). However, in recent times, the awareness of farmers in Nigeria to adopt alley cropping over monocropping due to its importance, increased in rate by 55% in the zone (Alene et al., 2015; Ajeigbe et al., 2010; Inaizumi et al., 1999). The adoption is as a result of efforts by agricultural extension services agents and short-term trainings occasionally organized by Nigeria's Ministry of Agriculture and International Institute of Tropical Agriculture (IITA) (IITA, 2008). This becomes necessary due to geometric increase in human population and urbanisation coupled with other climate change drivers such as deforestation thereby reducing arable land size and its fertility over time (Magigi and Drescher, 2010; Peter and Runge-Metzger, 1994). Hence, alley cropping as an alternative to maximize land use output, improve agro-ecosystem resilience and enhance sustainable livelihoods (Glover et al., 2012).

Soybean (*Glycine max*) is one of the commonly grown legumes under sole cropping system in Nigeria, the largest producer of the crop in Sub-Saharan Africa (ACET, 2014; Kamara, 2009). The tremendous potential to improve incentive of resource-poor farmers, particularly in a developing country like Nigeria can be achieved through adoption of innovative agricultural land use approach (ACET, 2014; Alene et al., 2015; Danshiell, 1994). Land-use conflict has been recognized as one of the challenges leading to unproductive yield in the savannah zones; others are soil fertility decline, poor seeds and low input (Cardinael et al., 2015; Peter and Runge-Metzger, 1994). Soil fertility have increased overtime on fields that soybean are grown through nitrogen fixing.

Meanwhile, in the Guinea Savannah region of Nigeria, farmers (including women) are growing *Moringa oleifera* as the woody perennial crop on their farmlands is increasing (Abdullahi et al., 2014; Torimiro et al., 2009). The tree plant, though not a nitrogen-fixing plant, is among the known promising exotic multipurpose tree species recommended for fuel wood, fodder, food, medicinal value, and soil fertility improvement (Edward et al., 2011; Goss, 2012). The tree also provides semi-shade, thus useful in alleys where intensity of direct sunlight exposure could damage crops (Nouman et al., 2013). However, there is the need to experiment the integration of *Moringa* with soybean as an alley crop in the Guinea savannah farmlands of Nigeria to examine the high leguminous crop productivity in terms of yield and its effects on soil properties. Hence, the study aims at evaluating the effect of *Moringa* intercropping on the yield components and growth performance of Soybean, and to determine the mixture productivity of intercropping soybean and *M. oleifera* on same field plots.

MATERIALS AND METHODS

The Federal Capital Territory (FCT), Abuja, lies in the transect between Southern Guinea and Derived Savannah agro-ecological zones of Nigeria, majority of the farmers in the zone grow similar arable crops under monocropping system (Figure 1). Field trails were conducted in two cropping (rainy) seasons (2014 and 2015) at the Teaching and Research Farm of Faculty of Agriculture, University of Abuja, Nigeria, located on latitude 8°98' East and longitude 7°19' North. Average annual temperature in the area is 33°C with 14% humidity during planting season and an annual rainfall of 1,200 to 1,600 mm.

A Randomized Complete Block Design (RCBD) with three replicates was used in the two trials. Each replicate (block) contained five plots and separated from the other block by one meter pathway. The plot measured 5.0 m × 4.0 m each and 0.5 m alley was used to divide the plots within the block. Thus, a total of 15 plots were used in the trials. The treatments of which effects were assessed include 40,000 stand/ha Soybean only, 62,500 stand/ha Soybean and *Moringa* stand, 50,000 stand/ha Soybean and *Moringa* stand, 40,000 stands/ha Soybean and *Moringa* stand and Sole *Moringa* stand. All *Moringa* stand were at 10,000 stand/ha each.

Seedlings raised from *Moringa* seeds (Bauchi Local) under a nursery were transplanted after 3 weeks to the field. Planting of Soybean (TGX 1440 – 7t) seeds and *Moringa* seedlings were done simultaneously at the first week of August. *M. oleifera* seedlings were planted at spacing of 1 m × 1 m giving a population of 10000 stands ha^{-1}. Plant population of soybean were varied; 50 cm × 50 cm (40,000 stands ha^{-1}), 40 cm × 40 cm (62,500 stands ha^{-1}), and 50 cm × 40 cm (50,000 stands ha^{-1}) respectively. Beating up and supply was done on *Moringa* seedlings and soybean seeds respectively after 7 days from the initial establishment on the field. The plots were manually weeded at 21 and 47 days after planting.

Data collected on Soybean include, number of leaves/plant, plant height (measured at a distance between the soil surface to the tip of the apical bud), number of pods/plant (determined by counting the number of pods-containing at least two seeds from 10 plants selected at random and dividing the total number of pods by 10), number of seeds per pod (obtained by counting the number of seeds from 10 pods selected at random and dividing the total by 10. Others are the biomass yield of *M. oleifera* and Soybean, Land Equivalent Ratio (LER) and Land Equivalent Coefficient (LEC). The following formula were used to determine LER and LEC as described by Willey (1985):

$$LER = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of A}} + \frac{\text{Inter crop yield of crop B}}{\text{Sole crop yield of crop B}}$$

$$LEC = \frac{\text{Intercrop yield of crop A}}{\text{Sole crop yield of A}} \times \frac{\text{Inter crop yield of crop B}}{\text{Sole crop yield of crop B.}}$$

Data on all the parameters were subjected to Analysis of Variance (ANOVA) using Randomized Complete Block Design (RCBD), $X_{ij} = \mu + T_i + \beta_j + \sum_{ij}$; where Xij = Trial SS, μ = Population mean = 0, Tij = Experimental Treatment effects, βij = Block effect and ∑ij = Error terms. Treatment means were separated with Least Significant Difference (LSD) (Gomez and Gomez, 1984).

Using the methods described by Reeuwijk (1992), the Bouyoucus hydrometer method was used in determining soil textural analysis. The soil pH soil was measured using a glass-calomel electrode (MP 220 AFAB Lab, LLC) (IITA, 2008). Soil organic matter and carbon as well as Total Nitrogen were all determined using titration and kjedahl digestion (1992). The soil available phosphorous content was also analysed by 0.5 M sodium bicarbonate extraction solution at pH 8.5 using the methods in Reeuwijk (1992). Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined by using atomic absorption spectrometry (AAS) and the soil sample

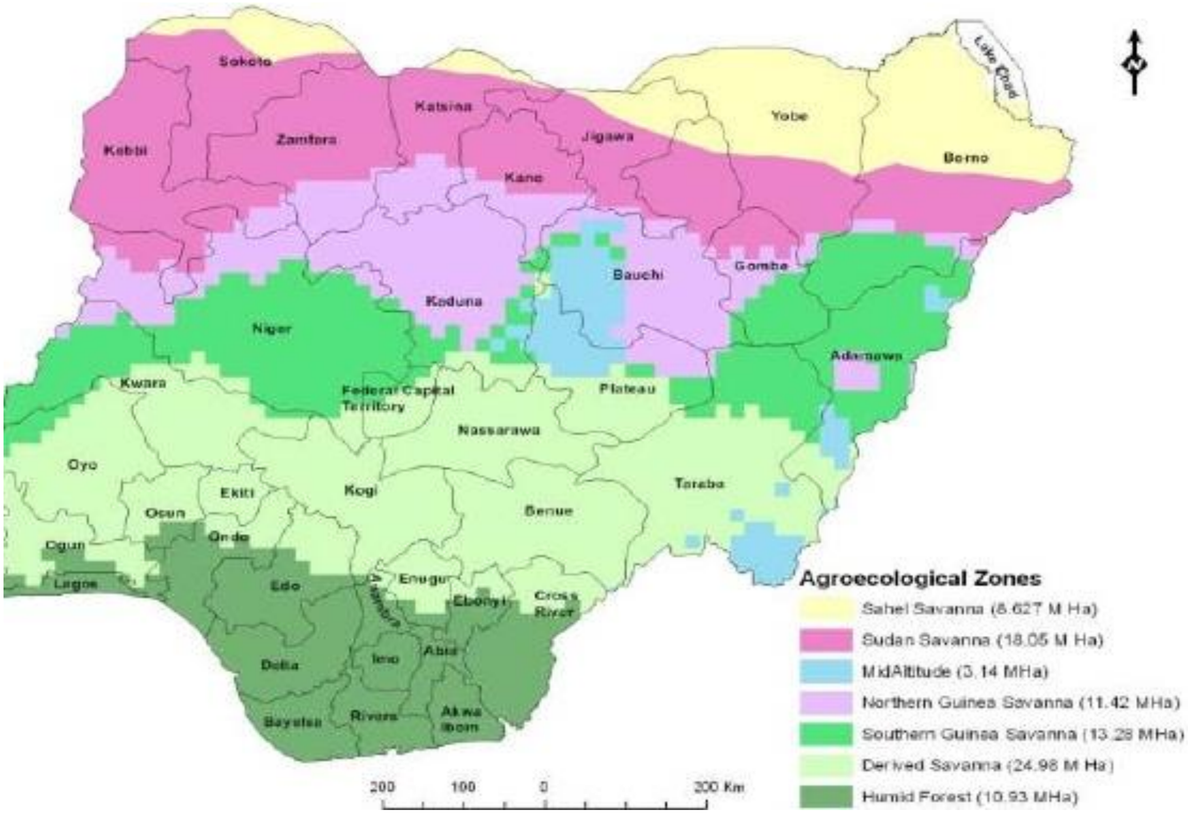

Figure 1. Map of Nigeria showing the agroecological zones, in Federal Capital Territory lies the transect between two savannah agroecological zones (Source: www.iita.org).

saturated with 1N NH4OAc solution at pH 7 (Chapman, 1965).

RESULTS AND DISCUSSION

Tables 1 and 2 showed the soil physicochemical properties of the field before and after planting in each cropping season respectively. The Guinea savannah soil classified as Alfisols and mostly well drained (Salako, 2003; Nwaka, 2012; Esu, 2010) is strongly acidic with pH values of 5.20 prior to planting in 2014 but became moderately acidic after the second trial in 2015 with pH ranges from 5.8 in sole crop plot of *Glycine max* to 6.8 in soybean/*Moringa* inter crop plots. This is an indication that the Moringa alley cropping reduces soil acidity as reported in Undie et al. (2013).

There was a significant reduction (0.03%) in total nitrogen after the first cropping season in 2014, but the trend reversed with a significant improvement (0.07%) after the second cropping season trial in 2015 (Table 2). The trend was similar for all the basic cations being assessed except the elemental sodium value that drastically reduced from 0.90 to 0.38 $Cmol^{-1}$ in *G. max/Moringa* inter crop plots of 50,000 stands of *Glycine* and 10,000 stands of *M. oleifera* in 2015. The result indicated that nutrient loss in the first year of planting, thus the plants did not make significant impact on improving soil fertility. The M. oleifera stands at early stage requires soil nutrients for absorption and adsorption to aid rapid growth, contributing significantly to the soil fertility loss (Undie et al., 2013, Emmanuel et al., 2011).

Table 1. Pre-planting physicochemical properties of the soil in the experimental site.

Elements	Values
Clay	40%
Silt	17%
Sand	43%
Textural class	Clay loam
pH (ratio 1:2:5)	5.80
Organic carbon	2.4%
Total nitrogen	0.05%
Available phosphorus	19.3 ppm
Exchangeable cations	**$cmolkg^{-1}$**
Ca	2.60
Mg	2.22
K	0.63
Na	0.90

Table 2. Physicochemical properties of the soil as influenced by Soybean/*Moringa* intercrop after harvest in 2014.

Year	Treatment		Elements					Exchangeable cations					
	Soybean (Pltsha^{-1})	Moringa (Pltsha^{-1})	Clay	Silt	Sand	pH	Organic	Mg	K	Na	N	P	Ca
2014	40,000	0	40	17	43	5.6	2.5	0.04	15	2.0	2.05	0.62	0.74
	62,500	10,000	40	17	43	5.6	2.4	0.03	18	2.5	2.12	0.62	0.70
	50,000	10,000	40	16	43	5.8	2.5	0.04	15	2.5	2.50	0.65	0.78
	40,000	10,000	39	17	43	5.7	2.5	0.05	15	2.0	2.50	0.65	0.70
	0	10,000		17	43	5.8	2.6	0.05	15	2.0	2.00	0.62	0.79
2015	40,000	0	40	17	43	5.8	2.5	0.05	15	4.0	3.05	0.62	0.54
	62,500	10,000	40	17	43	5.6	2.4	0.03	18	2.5	2.12	0.62	0.70
	50,000	10,000	40	16	43	6.8	2.8	0.07	09	3.5	4.50	0.65	0.38
	40,000	10,000	39	17	43	6.7	2.7	0.06	11	4.0	3.50	0.65	0.40
	0	10,000		15	43	6.6	2.7	0.05	18	4.0	4.00	0.62	0.59

Pltsha^{-1}, Plants/ha.

Although Abdullahi et al. (2014) and Nouman et al. (2013) reports contradicts M. oleifera inhibiting soil fertility improvement and maintenance in alley cropping at first growing season. The contribution within the short period from the Soybean component did not replenish the soil at the first cropping season as reported in Table 2. Alene et al. (2013), Ajeigbe et al. (2010) and Ouédraogo et al. (1999) had reported that Soybean cultivation gradually expands as a result of its nutritive and economic importance and soil fertility enhancement through nitrogen fixation over time. The clay, sand and silt composition of the soil did not change even after the trials, indicating negligible effect on the physical component of the soil by the practice. Thus, the intercropping is not only environmentally friendly but also sustainably maintains the soil fertility and acidity of the experimental area. Matusso et al. (2012) and Okoruwa (2001) reported that inter cropping involving legumes reduces soil temperature and moisture loss, which favours multiplication and growth of some soil microorganisms that will enhance foliage multiplication

In 2014 cropping season, the seed yield of soybean was not significantly (P>0.05) influenced by *Moringa* intercropping (Table 4) except in the intercrop plot of 62,500 stands of soybean/10,000 stands of *Moringa*. The seed yield of soybean was fairly the same in both sole crop plots and inters crop plots in 2014. This non-significant difference in seed yield of soybean in both cropping systems in 2014 confirmed the fact that *Moringa* component in the first few months of its establishment was unable to contribute to the soil fertility or its neighbourhood effect on the component crop. However, in 2015 cropping season, the seed yield of *G. max* in the intercrop plots was 30% greater than that obtained from the sole crop plot.

While the highest (P>0.05) seed yield of *G. max* was obtained from inter crop plot of 50,000 Soybean stands and 10,000 stands of *M. oleifera*, the lowest seed yield was recorded in sole crop plots of soybean in 2015. In both years of cropping, the seed yield of soybean in the intercrop plot of 62,500 of soybean and 10,000 stands of *Moringa* was relatively low, being reduced by 12% in 2015 (Table 3). Also, the leafiness and height of the alley species planted within rows of soybean of 2015 season was slightly higher than the previous season as stated in Table 3. This reduction showed that crop competition in the affected plots was very aggressive indicating that a plant population of 72,500 ha^{-1} will encourage serious crop competition for Soybean and *Moringa* inter cropping venture. Hussain et al. (2013) and Nabavi and Mazaheri (1998) reported decrease in the formation of nitrogen at the nodules on soybean roots was attributed to competition and shading effects under inter cropping situation and the phenomenon consequently reduced the seed yield of soybean. The trend in the seed yield of soybean as influenced by *Moringa* inter cropping was the same as those of its growth characters and yield components.

In the 2015 cropping season, seed yield of soybean, irrespective of treatments was 20% greater than the previous cropping season. During the second year of cropping, the *Moringa* component was well established and the non-harvestable portion were pruned and spread as green manure. The exercise thus may have improved the fertility status of the soil to the benefit of the companion crop as discussed in Larwanou et al. (2014) and Hussain et al. (2013) that *Moringa* leaves extract improves growth and productivity.

Meanwhile the biomass yield of *M. oleifera* in both cropping systems were fairly the same in both 2014 and 2015 respectively (Tables 5 and 6). The result on biomass weight was the same as those of the dry matter and crude oil content of *Moringa* plants. The above results on *Moringa* showed that intercropping with Soybean has no negative effect on its growth and development rather it improved as shown in the inter-crop

Table 3. Growth performance and yield of Soybean intercropped with *M. oleifera.*

Season	Moringa (Popn/ha)	Soybean (Popn/ha)	No. of leaves/plant	Height (cm)/plant	No. of pods/plant	Seed yield (t/ha)
	40,000	-----	25.33	44.51	23	0.32
	62,500	10,000	23.21	38.23	18	0.26
2014 season	50,000	10,000	25.23	45.60	24	0.38
	40,000	10,000	25.45	45.34	24	0.36
	-------	10,000	------	-----	----	------
Mean			**24.81**	**43.42**	**23.25**	**0.33**
LSD P >0.05			**1.09**	**2.43**	**1.87**	**0.021**
	40000	-----	28.45	45.21	18	0.20
	62500	10000	24.81	34.87	25	0.42
2015 season	50,000	10000	27.33	48.45	35	0.68
	40,000	10000	27.67	46.34	35	0.64
	-------	10000	------	-----	----	------
Mean			**27.07**	**43.72**	**28.25**	**0.49**
LSD P>0.05			**1.55**	**1.22**	**4.37**	**0.04**

Popn/ha, Population/ha.

Table 4. Biomass yield (t ha^{-1}/harvest) of *Moringa* intercropped with Soybean, 2014.

Harvest period	Soybean (Popn/ha)	Moringa (Popn/ha)	Fresh biomass	Dry biomass	Crude protein
	40,000	-----	---	-----	
	62,500	10000	5.4	1.54	0.33
70 days	50,000	10000	7.7	2.03	0.38
	40,000	10000	6.7	1.88	0.46
	-------	10000	6.7	1.97	0.43
Mean			**6.63**	**1.86**	**0.40**
	40,000	-----	----	-----	
	62,500	10000	6.0	1.63	0.28
115 days	50,000	10000	4.6	1.32	0.30
	40,000	10000	7.8	2.27	0.26
	-------	10000	7.6	2.19	0.25
Mean			**6.50**	**1.60**	**0.27**
160 days	40,000	-------	---		
	62,500	10000	4.8	1.22	0.13

Table 4. Contd.

	50,000	10000	5.8	1.53	0.12
	40,000	10000	6.4	2.12	0.10
	--------	10000	5.5	2.01	0.13
Mean			**5.63**	**1.72**	**0.12**

Popn/ha, Population/ha.

Table 5. Biomass yield (t ha^{-1}/harvest) of *Moringa* intercropped with Soybean, 2015.

Harvest period	Soybean (Popn/ha)	Moringa (Popn/ha)	Fresh biomass	Dry biomass	Crude protein
	40,000	---	---	----	
	62,500	10000	5.4	1.54	0.33
70 days	50,000	10000	7.7	2.03	0.38
	40,000	10000	6.7	1.88	0.46
	-------	10000	6.7	1.97	0.43
Mean			**6.63**	**1.86**	**0.40**
	40,000	-----	----	-----	
	62,500	10000	6.0	1.63	0.28
115 days	50,000	10000	4.6	1.32	0.30
	40,000	10000	7.8	2.27	0.26
	-------	10000	7.6	2.19	0.25
Mean			**6.50**	**1.60**	**0.27**
	40,000	-------	---		
	62,500	10000	4.8	1.22	0.13
160 days	50,000	10000	5.8	1.53	0.12
	40,000	10000	6.4	2.12	0.10
	--------	10000	5.5	2.01	0.13
Mean			**5.63**	**1.72**	**0.12**

Popn/ha, Population/ha.

plots of 50,000 stands of soybean crops and 1000 stands of *Moringa* plants per hectare. There are several reports on *Moringa* biomass productivity increase during intercropping with other crops, producing mutual relationship that enhances yield and repairs degraded soil through nutrient fixing (Abdullahi et al., 2014; Larwanou et al., 2014; Nouman et al., 2012; Goss, 2012).

The mixture productivity of soybean and *M. oleifera* in the trial is shown in Table 6. The Land Equivalent Ratio (LER) values for intercropping systems (except in 62,500 stands of soybean/ 10000 stands of *M. oleifera* in 2014), were greater than unity in all seasons. Anyaegbu (2014) reported that intercropping *Solanum tubersum*

Table 6. Mixture productivity of Soybean and *M. oleifera* Intercrop in 2014 and 2015.

Soybean population (ha^{-1})	Moringa population (ha^{-1})	2014		2015	
		LER	LEC	LER	LEC
40,000	---	1	---	1	---
62500	10000	0.87	0.23	1.12	0.26
50000	10000	1.23	0.45	1.68	0.78
40000	10000	1.25	0.44	1.57	0.65
---	10000	1	---	1	---

LER, Land equivalent ratio; LEC, land equivalent coefficient.

and *Abelmoschus esulentus* is more advantageous in terms of land economy and productivity when induced with organic manure of *Moringa* leaf extract. Averagely, over the two seasons, the LER was maximum in the intercropping system of 50,000 stands of soybean and 10000 stands of *Moringa* plants. Thus, in this cropping system, inter cropping produced 23 and 68% more yield in 2014 and 2015 than the sole crop yields of both crops. This implied that efficient use of the land using mixture population increased yield and sustain organic fertilization than other treatments. The poor results obtained under 62,500 stands of Soybean and 10000 stands of *Moringa* mixture showed that competitive pressures among the component crops were high. The evidence of the good performance of the crops under the cropping system (50,000 stands of soybean and 10,000 stands of *Moringa*), was shown by their individual Land Equivalent Coefficient, (LEC). A LEC of 78% as recorded in 50,000 soybean/10000 stands of Moringa ha^{-1} in 2015 showed that the neighbourhood effects between and among the crops were significantly beneficial and involved full complementary. Optimization of land resources as evaluated in LEC is developed to assess the interaction and productivity potential of crop mixtures and formulating proportions consists of economic and ecological optimization (Keesman et al., 2007; Yanfang et al., 2002). Amanullah et al. (2016), Yilmaz et al. (2008), and Odhiambo and Ariga (2001) also reported greater LER as greater than 1.0 in maize-common beans intercropping, another leguminous cash crop with high protein value. Intercropping has also been proven to result in efficient use of natural resources (Li et al., 2006). As farmers in semi-arid regions of Kenya have embraced the system over monocropping due to its profitability (over 40% net profit) (Rao and Mathuva, 2000). Hussain (2013) in his paper discussed the advantages of intercropping not only in terms land equivalent ratio but also in weed suppression and sustainable land fertility.

Conclusion

The result of the experiment showed that the total nitrogen and all other basic cations assessed reduced after the first cropping season but improved significantly at the end of the second trial in 2015. The effect of *Moringa* intercropping did not influence seed yield of soybean at the first cropping season until the second cropping season in 2015, the seed yield of all the inter-crop plots was 30% higher than that obtained from the sole crop plot. Highest seed yield (0.68 tha^{-1}) of Soybean and maximum Land Equivalent Ratio (LER) with 23 and 68% more yield in 2014 and 2015 than the sole crop yields of both crops were obtained from treatment plot of 50,000 Soybean stand + 10,000 stand of *M. oleifera*. The relationship between the two plants as assessed by LEC was cordial and complementary. There is the need to investigate the socio-economic analysis of intercropping the two species, especially at this period of price fluctuations and hyperinflation in Nigeria. Thus, an intercropping system involving 50,000 stands of *G. max* and 10,000 stands ha^{-1} of *M. oleifera* is recommended for good seed yield of *G. max* and biomass productivity of *M. oleifera* in the Guinea savannah zone of Nigeria.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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