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Effects of Intra-Row Spacing of Pearl Millet (*Pennisetum glaucum* (L.) R. Br) and Cropping Systems on the Productivity of Soybean-Pearl Millet Intercropping System in a Southern Guinea Savanna Location, Nigeria

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ABSTRACT

A field experiment was conducted from June to November, during the 2013 and 2014 cropping seasons at the Research Farm, University of Agriculture, Makurdi, Nigeria, to evaluate the effects of intra-row spacing of pearl millet and cropping systems on the productivity of soybean-pearl millet intercrop and to assess the yield advantages of the intercropping system. The experiment was a 3x4 factorial arrangement of treatments, fitted in a randomized complete block design (RCBD), replicated four times. The cropping systems (sole soybean, sole pearl millet and soybean-pearl millet intercrop) constituted the main plots, while the intra-row spacing of pearl millet (15 cm, 20 cm, 25 cm and 30 cm) into soybean were allocated to the subplots. Results of study showed that to maximize intercrop yields of soybean and pearl millet in a soybean-pearl millet intercrop, the optimal intra-row spacing for pearl millet is 30 cm. Intercropping soybean and pearl millet significantly ($P \leq 0.05$) reduced yields of soybean (25.0 % and 22.2 % respectively, in years 2013 and 2014) and that of pearl millet (34.4 % and 33.3 % respectively, in years 2013 and 2014). Though, the highest land equivalent ratio (LER) values, highest land equivalent coefficient (LEC) values and lowest competitive ratio (CR) values were recorded for pearl millet sown into soybean at the intra-row spacing of 15 cm, however, highest aggressivity was obtained sowing pearl millet into soybean at the intra-row spacing of 25 cm, the level at which both crops dominated each other.

Keywords**:** cropping systems; intra-row spacing; soybean; pearl millet; Nigeria

1. INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L). R. Br.) is one of the most important cereals and is a staple grain for over 150 million people in West Africa and India (FAO, 1997). In recent times, pearl millet has drawn a lot of attention as a replacement for maize and sorghum because of its ability to reliably produce grains on a wide range of soils and harsh production environment (Dewey *et al*., 2012). Millet production in Nigeria grew from 2.6 million metric tonnes in 1961 to over 6.6 million metric tonnes in 2004 (BOSADP, 2006). The country has a world share of 4.5 % of the quantity of millet production (FAOSTAT, 2012).

Soybean (*Glycine max* L. Merril) is a leguminous vegetable that grows in tropical, subtropical and temperate climates. It consists of more than 36 % protein, 30 % carbohydrate, vitamins and minerals. It also contains 25 % oil, which makes it the most important crop for producing edible oil (IITA, 2009). More than 2.6 million tonnes of soybeans were produced worldwide in 2007, of which 1.5 million were in Africa. Nigeria is the largest producer of soybean in sub-saharan Africa (IITA, 2009).

In the Southern Guinea savanna zone of Nigeria, information on the effect of intra-row spacing of maize and okra on the yields and yield components of crop mixtures such as maize-egusi melon, okra-maize, maize-soybean and maize-sesame abound in literature (Muoneke *et al*., 2007; Ijoyah *et al*., 2012; Ijoyah *et al*., 2015), but documented scientific information on the influence of intra-row spacing of pearl millet and its intercropping effects on the performance of soybean-pearl millet intercrop is scarce. The study therefore was undertaken to evaluate the effects of intra-row spacing of pearl millet and cropping systems on the productivity of soybean-pearl millet intercropping system, with the objectives of:

1. Identifying the optimal intra-row spacing of pearl millet that will maximize yields of soybean-pearl millet intercrop.
2. Determine the effect of soybean and pearl millet to intercropping.
3. Assess the yield advantages of the intercropping system.

2. MATERIALS AND METHODS

2. 1. Study location and crop varieties

A field experiment was conducted from June to November, during the 2013 and 2014 cropping seasons at the Reseach Farm, University of Agriculture, Makurdi, Nigeria, to evaluate the effects of intra-row spacing of pearl millet and cropping systems on productivity of soybean-pearl millet intercrop. The soybean variety 'TGX 1448-2E' was obtained from the Seed Technology Centre, University of Agriculture, Makurdi, while the pearl millet 'Amine' is a local variety, popularly grown by farmers in the locality. The varieties of both crops show good adaptation to Makurdi environment.

2. 2. Experimental design, experimental area and crop arrangement

The experiment was a 3 x 4 factorial laid out in a randomized complete block design with four replications. The cropping systems, which consisted of sole soybean, sole pearl millet and pearl millet-soybean were assigned to the main plots, while the varied intra-row spacing of pearl millet (15 cm, 20 cm, 25 cm and 30 cm) into soybean were allocated to the subplots. The experimental area was 1150.3 m^2 and consisted of 48 subplots. Each treatment plot had an area of 20.0 m^2.

The experimental field was cleared, ploughed, harrowed and ridged. Each plot consisted of 5 ridges. In sole pearl millet plot, each ridge consisted of 13 pearl millet stands, at the recommended intra-row spacing of 30 cm. A total of 65 pearl millet stands were sown in each plot. In sole soybean plots, 80 soybean stands were planted on each ridge, at an intra-row spacing of 5 cm (Dugje *et al*., 2009), giving a total of 400 soybean stands per plot. In the sole plots, pearl millet and soybean were sown in a single row on top of the ridge, at their recommended intra-row spacing.

In the intercrop plots, soybean was planted on top of ridge, while pearl millet was sown by the side of ridge, but at the varied intra-row spacing. The crops were sown at same time in late June.

2. 3. Cultural practices

Three manual weedings, with the use of the native hoe were done at 3, 6 and 9 weeks after planting (WAP). Hand pulling of weeds was done when necessary. Mixed fertilizer NPK 15:15:15 was applied at the rate of 60 kg N, 30kg P_2O_5 and 30 kg K_2O ha^{-1} at land preparation by broadcasting (Ekpete, 2000). Urea (65 kg) was applied to millet stands by side placement at 6 WAP. Soybean was harvested when the pods have turned brown and seeds are at the hard-dough stage with moisture content between 14 and 16 % (Dugje *et al*., 2009). Pearl millet was harvested when the leaves turned yellowish and fallen off which were signs of senescence and seed maturity.

2. 4. Data collected and statistical analysis

Data collected on pearl millet include days to 50 % flowering (taken by counting the number of days from when crop was sown to when 50 % flowered), days to maturity (number of days from planting to physiological maturity), plant height at maturity (distance from the ground level to the base of the flag leaf), number of tillers per plant, number of nodes per plant (at physiological maturity), internode length (at physiological maturity), panicle length (at harvest), panicle width (at harvest), panicle weight (at harvest) and grain yield (t ha^{-1}).

Data collected on soybean include days to 50 % flowering, days to maturity (when at least 80 % of pods have dried and turned brown), plant height at 8 WAP, number of branches per plant at 8 WAP, number of leaves per plant, number of pods per plant, number of seeds per pod and seed yield (t ha^{-1}).

Analysis of variance (ANOVA) for factorial experiment was carried out on each observation and the Least Significant Difference (LSD) was used for means separation ($P \leq 0.05$) following the procedure of Steel and Torrie (1980). Direct treatment effects and the magnitude of interactions were also determined.

2. 5. Evaluation of yield advantages

The land equivalent ratio (LER) was determined as described by Willey (1985) using the formula:

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

The competitive ratio (CR) as described by Willey and Rao (1980) was determined using the formula:

$$CR = Ls/Lp,$$

where; Ls: Partial LER for soybean; Lp: Partial LER for pearl millet.

The percentage (%) land saved as described by Willey (1985) using the formula:

$$\%\ \text{land saved} = 100 - 1/LER\ X\ 100$$

Aggressivity (A) gives a simple measure of how much the relative yield increase in component 'a' is greater than that for component 'b' as described by McGilchrist (1971) using the formula:

$$A = \frac{Mixture\ yield\ of\ 'a'}{Expected\ yield\ of\ 'a'} - \frac{Mixture\ yield\ of\ 'b'}{Expected\ yield\ of\ 'b'}$$

where:
A = 0: indicates that both crops are equally competitive; A = -: indicates dominated component; A = +: indicates dominant component

The land equivalent coefficient (LEC) as described by Adetiloye *et al*., (1983) was determined using the formula:

$$LEC = La\ x\ Lb;$$

where La: LER of main crop; Lb: LER of intercrop.

These calculations were used to assess the yield advantages of the intercropping system.

3. RESULTS AND DISCUSSION

3. 1. Effects of intra-row spacing of pearl millet and cropping systems on growth and yield of pearl millet in a soybean-pearl millet intercropping system.

The main effects of intra-row spacing of pearl millet and cropping systems on days to attain 50 % flowering for pearl millet, pearl millet height at maturity, days to maturity and number of tillers per plant is given in Table 1.

Early days to 50 % flowering and maturity were recorded in closer intra-row spacings (15 cm and 20 cm), as compared to those recorded for wider intra-row spacing of 25 cm and 30 cm. This could be due to the higher population density and greater competition for nutrients at closer intra-row spacing. The stressed plants in closer intra-row spacing attained 50 % flowering and maturity earlier than those from wider intra-row spacing. Getachar *et al.*, (2012) reported similar findings in *Solanum tuberosum* in Ethiopia and attributed the result to intensified competition in closely spaced plants, resulting in nutrient depletion, subsequently inducing early days to flowering and maturity.

Pearl millet height significantly ($P \leq 0.05$) increased as intra-row spacing of pearl millet increased (Table 1). This could be linked to lesser competition for available nutrients at higher intra-row spacing of pearl millet. The result agreed with Mass *et al*., (2007) who reported that plant height of millet increased with wider row spacing in the south eastern coastal plains of America, but contradict that of Miko and Manga (2008) who reported increase in sorghum height at closer intra-row spacing. The reason for the contradiction in results could be attributed to the genetical potential of the variety of different crops used. The reduction in pearl millet height under intercropping could have been induced by the intense overcrowding effect of the component crops in the intercrop as compared to sole cropping for available nutrients. This view agreed with that of Madu and Nwosu (2001), who reported that yam planted soles, generally have greater efficiency in utilizing the growth environment.

Table 1. Main effects of intra-row spacing of pearl millet and cropping systems on days to attain 50% flowering for pearl millet, pearl millet height, days to maturity, and number of tillers per plant in years 2013 and 2014 at Makurdi, Nigeria.

Intra-row spacing of pearl millet	Days to attain 50% flowering for pearl millet		Pearl millet height (cm)		Days to maturity		Number of tillers per plant	
	2013	**2014**	**2013**	**2014**	**2013**	**2014**	**2013**	**2014**
15 cm	64.0	63.0	148.7	166.5	85.0	84.0	3.7	4.3
20 cm	64.0	63.3	175.6	184.6	85.0	84.3	4.2	4.4
25 cm	66.0	65.0	222.5	244.1	86.3	85.3	4.5	4.9
30 cm	66.0	65.0	240.9	275.5	86.5	85.8	4.8	5.4
LSD ($P \leq 0.05$)	0.4	0.2	9.7	10.4	0.2	0.3	0.2	0.3
Cropping systems								
Sole pearl millet	65.6	65.2	202.7	214.0	85.6	85.1	4.8	5.4
Soybean-Pearl millet	65.3	65.1	176.4	183.7	84.2	84.0	4.3	3.2
LSD ($P \leq 0.05$)	3.2	5.6	12.1	14.0	7.3	10.2	0.3	1.5

Number of tillers per plant increased as intra-row spacing of pearl millet increased up to 30 cm. Intercropping pearl millet and soybean significantly ($P \leq 0.05$) reduced number of tillers per plant (Table 1). This result agreed with Silwana and Lucas (2002) who reported that intercropping reduced vegetative growth of component crops. Increasing intra-row spacing of pearl millet from 15 cm to 30 cm significantly ($P \leq 0.05$) increased number of nodes per plant, internode length, panicle length, panicle width, panicle weight and grain yield (Table 2). The lowest competition for growth resources which might have occurred at the wider intra-row spacing of pearl millet could be attributed to the increase in panicle weight and yield at wider intra-row spacing. Ayoola and Makinde (2008) also reported that yield was higher with decrease in cassava population. The highest grain yield of pearl millet was obtained when sown at the intra-row spacing of 30 cm. In year 2013, sowing pearl millet at the intra-row spacing of 30 cm significantly ($P \leq 0.05$) increased grain yield by 59.5 %, 40.5 % and 14.3 % respectively, compared to sowing pearl millet at the intra-row spacing of 15 cm, 20 cm and 25 cm, while in year 2014, by 53.5 %, 39.5 % and 9.3 % respectively, compared to sowing pearl millet at the intra-row spacing of 15 cm, 20 cm and 25 cm. Intercropping pearl millet and soybean significantly ($P \leq 0.05$) reduced grain yield of pearl millet by 34.4 % and 33.3 % respectively, in years 2013 and 2014, as compared to that obtained from pearl millet sown as a sole crop (Table 2). This result agreed with those of Olufajo (1992) and Muoneke *et al.*, (2007) who reported higher yield in sole cropping over intercropping.

Table 2. Main effects of intra-row spacing of pearl millet and cropping systems on number of nodes per plant, internode length, panicle length, panicle width, panicle weight and grain yield.

Intra-row spacing of pearl millet	Number of nodes per plant		Internode length (cm)		Panicle length (cm)		Panicle width (cm)		Panicle weight (g)		Grain yield (t ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
15 cm	7.1	7.8	8.4	11.6	42.5	53.9	1.3	1.5	45.9	54.0	173.0	200.1
20 cm	8.2	8.8	12.8	15.8	54.8	65.9	1.5	1.8	65.9	70.0	250.0	258.2
25 cm	11.6	13.6	14.7	17.0	63.1	70.3	2.3	4.0	69.7	79.9	362.4	392.6
30 cm	13.0	15.2	15.8	19.7	68.7	78.2	2.6	4.4	80.8	90.3	420.1	425.2
LSD ($P \leq 0.05$) Cropping systems	1.5	0.7	0.8	1.2	3.3	4.2	0.2	0.1	6.2	8.0	10.5	12.6
Sole Pearl millet	12.3	10.2	14.5	16.6	62.7	68.4	2.4	3.8	77.4	79.8	320.4	327.8
Soybean – Pearl millet	9.3	7.1	11.3	12.2	56.4	54.0	1.6	1.8	68.2	66.0	210.2	215.3
LSD ($P \leq 0.05$)	2.4	1.6	2.1	2.7	4.1	6.3	0.5	1.2	5.4	8.2	15.6	18.4

Table 3. Interaction of cropping system x intra-row spacing of pearl millet on days to attain 50% flowering for pearl millet, pearl millet height, days to maturity and number of tillers per plant in years 2013 and 2014 at Makurdi, Nigeria.

Cropping systems	Intra-row spacing of pearl millet	Days to attain 50% flowering for pearl millet		Pearl millet height (cm)		Days to maturity		Number of tillers per plant	
		2013	2014	2013	2014	2013	2014	2013	2014
Sole pearl millet	15 cm	68.0	68.5	94.6	95.8	4.9	5.2	22.7	23.4
	20 cm	67.8	67.2	92.6	92.3	4.6	4.2	20.5	20.2
	25 cm 30 cm	67.3	67.5	85.1	84.6	4.5	4.0	20.3	18.0
Soybean-Pearl millet	15 cm	66.9	67.2	80.7	81.4	5.9	5.7	20.0	22.3
	20 cm	66.0	66.4	77.4	78.2	4.8	4.6	19.1	19.3
	25 cm 30 cm	66.3	66.6	63.2	64.0	4.1	4.2	16.6	17.0
LSD ($P \leq 0.05$)		3.1	4.2	2.0	2.5	0.3	0.2	0.4	0.6

Sowing pearl millet at the intra-row spacing of 30 cm into soybean gave the highest number of tillers per plant (Table 3), highest panicle weight and highest pearl millet yield of 4.7 t ha^{-1} and 4.9 t ha^{-1} respectively, in years 2013 and 2014 (Table 4).

Table 4. Interaction of cropping systems x intra-row spacing of pearl millet on number of nodes per plant, internode length, panicle length, panicle width, panicle weight and grain yield in years 2013 and 2014 at Makurdi, Nigeria.

Cropping systems	Intra-row spacing of pearl millet	Number of nodes per plant		Internode length (cm)		Panicle length (cm)		Panicle width (cm)		Panicle weight (g)		Grain yield (t ha^{-1})	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Sole pearl	15 cm	6.9	6.8	8.5	13.4	44.3	51.3	1.8	1.7	53.4	56.1	3.7	3.6
Millet	20 cm	7.6	9.2	12.2	15.3	53.3	65.1	1.9	1.9	65.0	79.2	4.0	4.2

	25 cm	12.4	12.8	14.2	15.8	70.1	75.4	2.4	2.9	78.4	89.1	4.5	4.6
	30 cm	14.2	14.6	17.8	20.4	78.2	79.5	3.6	4.5	86.0	105.1	5.0	5.2
Soybean-Pearl millet	15 cm	6.4	6.7	7.5	11.3	42.1	49.2	1.3	1.3	42.6	51.3	3.6	3.5
	20 cm	7.4	8.1	10.4	14.1	59.2	61.3	1.5	1.7	62.9	74.9	3.8	3.8
	25 cm	11.2	12.0	12.5	14.2	62.4	70.3	1.8	2.4	75.2	82.2	4.3	4.5
	30 cm	12.0	13.4	15.4	18.8	68.2	76.6	2.4	3.8	78.4	94.3	4.7	4.9
LSD ($P \leq 0.05$)		3.5	2.1	2.5	2.3	5.4	6.1	0.2	0.3	3.0	5.4	0.04	0.06

3. 2. Effects of intra-row spacing of pearl millet and cropping systems on the growth and yield of soybean in a soybean-pearl millet intercropping system.

Though days to attain 50 % flowering and days to maturity for soybean was not significantly ($P \leq 0.05$) affected by the intra-row spacing of pearl millet, however, intercropping soybean and pearl millet significantly ($P \leq 0.05$) reduced days to attain 50 % flowering and days to maturity for soybean (Table 5). The longer days taken to attain 50 % flowering for sole soybean as compared to intercropped soybean contradicted the results of Ijoyah *et al*., (2012), who reported longer days to attain 50 % flowering for intercropped soybean in a soybean-maize intercrop. The difference in results could be due to the growth habit of component crops, and possibly the arrangement of the component crops in the intercrop. Increasing the intra-row spacing of pearl millet up to 30 cm, increased height of soybean plants (Table 5). Sowing pearl millet at the intra-row spacing of 30 cm gave the highest soybean heights of 81.2 cm and 80.4 cm respectively in years 2013 and 2014. Intercropping soybean and pearl millet produced taller soybean plants than that obtained from monocropped soybean (Table 5). The competition for light from the greater population of plants in intercropping might have induced taller soybean plants.

The highest number of branches of soybean was produced with the intra-row spacing of 30 cm for pearl millet (Table 5). This could be attributed to the reduced competition for growth resources at the widest intra-row spacing of 30 cm.

Table 5. Main effects of intra-row spacing of pearl millet and cropping systems on days to attain 50 % flowering for soybean, plant height, days to maturity at 8 WAP, and number of branches of soybean in years 2013 and 2014 at Makurdi, Nigeria.

Intra-row spacing of pearl millet	Days to attain 50% flowering for soybean		Plant height at 8 WAP (cm)		Days to maturity at harvest		Number of branches per plant at 8 WAP	
	2013	2014	2013	2014	2013	2014	2013	2014

15 cm	54.5	55.6	70.5	65.0	94.2	93.1	6.4	6.7
20 cm	56.2	56.0	75.1	73.2	95.0	93.6	7.2	7.4
25 cm	56.1	56.4	79.4	77.8	96.0	95.1	7.6	7.9
30 cm	54.0	56.4	81.2	80.4	96.4	95.0	8.2	8.6
LSD ($P \leq 0.05$) Cropping systems	4.7	8.2	2.7	3.1	10.2	8.1	4.6	7.2
Sole soybean	56.2	56.8	71.1	73.0	94.1	94.6	7.5	7.8
Soybean- Pearl millet	54.4	53.6	80.3	81.4	92.0	92.2	6.3	6.6
LSD ($P \leq 0.O5$)	0.6	0.4	5.0	3.6	0.3	0.6	8.6	5.0

WAP: Weeks after planting

Though number of soybean leaves was not significantly ($P \leq 0.05$) affected varying the intra-row spacing of pearl millet, however number of pods per plant, number of seeds per pod and seed yield of soybean significantly ($P \leq 0.05$) increased as the intra-row spacing of pearl millet increased (Table 6). The highest number of pods per plant, number of seeds per plant and highest seed yield of soybean was obtained at the intra-row spacing of 30 cm for pearl millet (Table 6). The highest number of branches per plant and highest number of leaves per plant produced from soybean at the intra-row spacing of 30 cm for pearl millet could be responsible for the highest number of pods and highest soybean yield obtained. This view supports Ijoyah *et al*., (2010) who reported that number of pods would depend on the intensity of plant growth. Intercropping soybean and pearl millet significantly ($P \leq 0.05$) reduced seed yield of soybean by 25.0 % and 22.2 % respectively in years 2013 and 2014, as compared to that obtained from sole cropping of soybean.

Table 6. Main effects of intra-row spacing of pearl millet and cropping systems on number of leaves per plant, number of pods per plant, number of seeds per pod and seed yield of soybean in years 2013 and 2014, at Makurdi, Nigeria.

Intra-row spacing of pearl millet	Number of leaves per plant		Number of pods per plant		Number of seeds per pod		Yield of soybean ($t\ ha^{-1}$)	
	2013	2014	2013	2014	2013	2014	2013	2014
15 cm	46.4	46.9	51.4	52.0	4.2	4.6	1.4	1.3

20 cm	51.5	53.2	59.0	62.4	5.0	5.2	1.6	1.8
25 cm	57.8	59.3	68.1	70.2	5.8	6.2	1.9	1.8
30 cm	65.3	64.1	82.6	85.1	8.3	8.8	2.3	2.5
LSD (P ≤ 0.05) Cropping systems	15.3	18.2	5.6	6.4	0.5	0.8	0.1	0.4
Sole soybean	64.8	62.7	80.2	85.4	8.4	8.6	1.6	1.8
Soybean-P	44.2	41.9	58.0	56.0	5.3	5.6	1.2	1.4
LSD (P ≤ 0.05)	10.1	13.4	12.0	15.6	1.6	1.9	0.3	0.2

Table 7. Interaction of cropping systems x intra-row spacing of pearl millet on days to attain 50 % flowering for soybean, plant height of soybean at 8WAP, days to maturity and number of branches per plant in years 2012 and 2013, at Makurdi, Nigeria.

Cropping systems	Intra-row spacing of pearl millet	Days to attain 50% flowering for soybean		Plant height of soybean at 8 WAP		Days to maturity		Number of branches per plant	
		2013	2014	2013	2014	2013	2014	2013	2014
Soybean-Pearl millet	15 cm	54.7	54.6	59.4	62.0	94.2	94.4	6.0	6.3
	20 cm	54.9	54.9	65.8	68.4	94.1	94.0	7.2	7.2
	25 cm	55.8	55.6	74.3	76.4	95.4	95.0	7.5	7.5
	30 cm	54.5	55.6	79.5	80.0	95.2	94.8	8.2	8.3
LSD (P ≤ 0.05)		8.2	6.4	4.1	3.0	8.2	10.4	7.3	11.2

WAP: Weeks after planting

Table 8. Interaction of cropping systems x intra-row spacing of pearl millet on number of soybean leaves per plant, number of pods per plant, number of seeds per pod and yield of soybean in years 2013 and 2014, at Makurdi, Nigeria.

Cropping systems	Intra-row	Number of soybean leaves per plant		Number of pods per plant		Number of seeds per pod		Seed yield of soybean ($t\ ha^{-1}$)	
	spacing of pearl millet	2013	2014	2013	2014	2013	2014	2013	2014
Soybean-Pearl millet	15 cm	43.0	43.1	50.4	51.1	4.2	4.4	1.4	1.3
	20 cm	50.1	49.2	56.2	55.0	4.7	4.8	2.0	1.8
	25 cm	54.3	56.1	64.3	65.2	5.6	6.0	2.3	2.2
LSD ($P \leq 0.05$)	15.3	15.3	18.1	2.5	3.2	0.3	0.1	05	0.03

The highest plant height and highest number of branches of soybean, were obtained when pearl millet was sown in the intercrop at the intra-row spacing of 30 cm (Table 7). Sowing pearl millet at the intra-row spacing of 30 cm into soybean produced the highest number of pods per plant and gave the highest seed yield of soybean (2.5 $t\ ha^{-1}$ and 2.8 $t\ ha^{-1}$) respectively, in years 2013 and 2014 (Table 8).

3. 3. Intercropping advantages of soybean and pearl millet as affected by intra-row spacing of pearl millet and cropping systems in years 2013 and 2014, at Makurdi, Nigeria

Irrespective of the main effects of intra-row spacing of pearl millet and cropping systems, total intercrop yields were greater than the intercrop yields of component crops (Table 9). The land equivalent ratio (LER) values for all treatments at the 2-way interaction of cropping systems x intra-row spacing of pearl millet were all above 1.0, indicating yield advantage of the intercropping system (Table 10).

Average of both years showed that the highest land equivalent ratio (LER), highest percentage (%) land saved, highest land equivalent coefficient (LEC) values of 2.12 and 1.75 respectively obtained in years 2013 and 2014 and lowest competitive ratios were recorded when pearl millet was sown into soybean at the intra-row spacing of 15 cm (Table 10). Adetiloye *et al*., (1983) reported that for a two crop mixture, the minimum expected productivity coefficient value is 0.25. The highest aggressivity was obtained sowing pearl millet into soybean at the intra-row spacing of 25 cm, the level at which both crops dominated each other (Table 10).

Table 9. Sole crop yields, intercrop yields and total intercrop yields as affected by the main effects of intra-row spacing of pearl millet and cropping systems in a soybean –pearl millet intercrop, in years 2013 and 2014, at Makurdi, Nigeria.

Intra-row spacing of pearl millet	Sole crop yields (t ha^{-1})				Intercrop yields (t ha^{-1})				Total intercrop yields (t ha^{-1})	
	Soybean		Pearl millet		Soybean		Pearl millet			
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
15 cm	1.4	1.3	1.7	2.0	1.4	1.3	3.6	3.5	5.0	4.8
20 cm	1.6	1.8	2.5	2.6	2.0	1.8	3.8	3.8	5.8	5.6
25 cm	1.9	1.8	3.6	3.7	2.3	2.2	4.3	4.5	6.6	6.7
30 cm Cropping systems	2.3	2.5	4.2	4.3	2.5	2.8	4.7	4.9	7.2	7.7
Soles	1.6	1.8	3.2	3.3	_	-	-	-	-	-
Soybean-Pearl millet	-	-	-	-	1.2	1.4	2.1	2.2	3.3	3.6

Table 10. Evaluation of yield advantages of soybean-pearl millet intercrop as influenced by the interaction of intra-row spacing of pearl millet x cropping systems in years 2013 and 2014, at Makurdi, Nigeria.

Cropping systems	Intra-row spacing of pearl millet	Ls		Lp		LER		CR		% land saved		Aggressivity		LEC	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Soybean-Pearl millet	15 cm	1.00	1.00	2.12	1.75	3.12	2.75	0.47	0.57	67.9	63.6	-1.12	-0.75	2.12	1.75
	20 cm	1.25	1.00	1.52	1.46	2.77	2.46	0.82	0.68	63.9	59.3	-0.27	-0.46	1.90	1.46
	25 cm	1.21	1.22	1.19	1.23	2.40	2.45	1.02	0.99	58.3`	59.2	0.02	-0.01	1.44	1.50
	30 cm	1.09	1.12	1.12	1.14	2.21	2.26	0.97	0.98	54.8	55.8	-0.03	-0.02	1.22	1.28

LER: Land equivalent ratio
Aggressivity (A) where:
A = 0 (component crops are equally competitive)
A = - value (Dominated crop)
A = + value (Dominant crop)
Ls: Partial LER for soybean
Lp: Partial LER for pearl millet
CR: Competitive ratio
LEC: Land equivalent coefficient

4. CONCLUSION

From the results obtained, it can be concluded that sowing pearl millet into soybean at the intra-row spacing of 30 cm produced the highest intercrop yields of soybean and pearl millet. While the highest LER values and highest LEC values were obtained sowing pearl millet into soybean at the intra-row spacing of 15 cm, highest aggressivity was recorded sowing pearl millet into soybean at the intra-row spacing of 25 cm.

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