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Yield response and economic implications of soybean (*Glycine max* (L.). Merrill) – lowland-upland rice sequential cropping in the rainforest/savanna transitory ecosystem

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ABSTRACT

A sequential cropping system of soybean-lowland (NERICA L-42)-upland (NERICA 2) rice was established at Abeokuta and Ibadan (Nigeria) to evaluate the performance of the cropping system. Field trials were in split-split plot arrangement fitted into randomised complete block design and replicated three times. The first sequence had in the main plot tillage [minimum (MT) and conventional (CT)]. Soybean varieties TGx 1448-2E (V1) and TGx 1740-2F (V2) in sub-plot and spacing in sub-sub plot were 60 cm × 5 cm (R1), 60 cm × 10 (R2) and 60 cm × 15 cm (R3). Individual rice plots were established by dry dibble (DD) seeding and transplanting and sub-sub plot spacing were 15 cm × 15 cm (S1), 20 cm × 20 and 25 cm (S2) × 25 cm (S3). The sequence soybean (V1 CT R3); lowland and upland rice (S3 CT DD) was the most economically efficient (N 1,754 ha^{-1} day^{-1}) in Abeokuta, while soybean (V1 MT R1) and lowland and upland rice (S1 DD MT) was the most economically efficient (N 1,858 ha^{-1} day^{-1}) in Ibadan.

Key words: conventional tillage; dry dibble; economic efficiency; minimum tillage; NERICA rice; soybean varieties; spacing, transplanting

IZVLEČEK

ODZIV PRIDELKA IN EKONOMIČNOST PRIDELAVE SOJE (*Glycine max* (L.). Merrill) V KOLOBARJU Z RIŽEM, PRILAGOJENEM GOJENJU V VODI IN RIŽEM, PRILAGOJENEM GOJENJU V SUHIH RAZMERAH V PREHODNIH EKOSISTEMIH, NASTALIH IZ DEŽEVNEGA PRAGOZDA IN SAVANE

Z namenom ovrednotenja več pridelovalnih sistemov je bil v Abeokuti in Ibadanu (Nigeria) vzpostavljen kolobar soje z rižem, prilagojenem gojenju v vodi ('NERICA L-42') in rižem, prilagojenem gojenju v suhih razmerah ('NERICA 2'). Poskus je temeljil na popolnem naključnem bloku s tremi ponovitvami. Prvi kolobar je na glavnih površinah obsegal dva načina obdelave tal: minimalno (MT) in konvencionalno obdelavo (CT). Sorti soje TGx 1448-2E (V1) in TGx 1740-2F (V2) sta bili na podpovršinah posejani v gostotah 60 × 5 cm (R1), 60 × 10 cm (R2) in 60 × 15 cm (R3). Posamezne površine z rižem so bile osnovane z neposredno setvijo v 'jamice' (DD) in s presajanjem sadik, gostote sklopa pa so bile 15 × 15 cm (S1), 20 × 20 cm in 25 (S2) × 25 cm (S3). Kolobar s sojo (V1 CT R3) ter rižem, prilagojenem gojenju v vodi in rižem, prilagojenim gojenju v suhih razmerah (S3 CT DD) je bil ekonomsko najbolj učinkovit (N 1,754 ha^{-1} day^{-1}) v Abeokuti, medtem, ko je bil kolobar s sojo (V1 MT R1) ter rižem, prilagojenem gojenju v vodi in rižem, prilagojenem gojenju v suhih razmerah (S1 DD MT) ekonomsko najbolj učinkovit (N 1,858 ha^{-1} day^{-1}) v Ibadanu.

Ključne besede: konvencilnalna obdelava tal; neposredna setev v jamice; ekonomska učinkovitost; minimalna obdelava tal; 'NERICA' sorte riža; sorte soje; gostota sklopa; presajanje riža

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1 INTRODUCTION

Meeting the food and nutritional needs of the majority of the populace remains a major challenge to most government in sub-Sahara Africa (SSA). Rice is rapidly becoming a staple food item because of its ease of preparation for consumption. However, in Nigeria the annual consumption of 5.0 M t is far above the 3.0 M t production level (Daramola, 2005). The shortfall is met through massive importation despite dwindling foreign exchange. The situation calls for increased production. Increased production can be achieved through extensive or intensive cultivation. Competing needs for land due to increasing population (Chidumayo, 1987) and requirements for development purposes make extensive cultivation unattractive. Thus, intensive cultivation could provide solution to the challenge. Intensification of farming system has its own challenges. Increased use of agricultural input is beyond the reach of resource challenged farmers. One promising ameliorative measure is sequential cropping system that could ensure double or triple cropping of staple crops like rice in SSA.

Sequential cropping system involving rice must be conducted with the right mix of component crops and management practice to ensure sustainable production. Soybean is an important oilseed crop (Harold et al., 1990) and a potential component of cropping system to increase soil fertility through its capability of biologically fixing atmospheric nitrogen (Harold et al., 1990). Other management practices to ensure sustainable production of rice could be the tillage practice, seeding method and crop spacing. Conventional production of lowland rice involves puddling of the field (Farooq et al., 2011). This technique has its drawbacks such as modification of physico-chemical properties of submerged soil that could negatively affect plant growth and yield (Pande et al., 1985; Wade et al., 1998). Transplanting had been the major seeding method especially for lowland rice, but the cost of its establishment (Chan and Nor, 1993) and the problem of water use efficiency and conservation (Gill et al., 2006) remain its major drawbacks. Rice that is directly seeded had been proposed in the past to address this problem (Ampong-Nyarko, 1996; Fischer and Antigua, 1996; Rao et al., 2007). However, the prevalence of weed (Morris, 1990; Rao et al., 2007), panicle sterility (Farooq et al., 2009) and nutrient availability (Farooq et al., 2011) had reduced its adoption by most farmers. Increasing plant density to the optimum could ensure maximum utilization of growth resources. This would provide the major crop a more competitive edge against the incidence of weeds that was observed in directly seeded rice. This observation was made on maize by Mashingaidze, (2004) and Zimdahl, (2013).

There is very little information in the literature on the agronomic performance of soybean introduced into the cropping sequence in a lowland ecosystem. Hence there is need to know the appropriateness of soybean in soybean-lowland rice-upland rice sequential cropping and its economic implication in rainforest Savanna agroecology. The objectives of the trials were to evaluate grain yield response of soybean and NERICA rice cultivars to tillage and spacing; determine responses of NERICA rice cultivars to seeding methods in the inland valley in soybean-lowland-upland rice cropping system. The trials also aimed to determine productivity of rice-based sequential cropping and its economic consequences in the rainforest/savanna transitory ecology.

2 MATERIALS AND METHODS

2.1 Description of the Study Site

Field trials were established at rainfed inland valley of FUNAAB (latitude 7^{o}15’N and longitude 3^{0}25’E; and altitude 76 m above sea level), and at paddy F14 at the Research Farm of Africa Rice Centre, Ibadan station (latitude 7^{0}30’N and longitude 3^{0}54’E), International Institute of Tropical Agriculture (IITA) premises, Oyo State, Nigeria. At Abeokuta, the total monthly rainfall was between 288.1mm (October, 2011) to absence of precipitation (November, December, 2011 and January, 2012). Mean monthly temperature was in the range 29.2 ^{0}C (April, 2011) to 24.5 ^{0}C (July, 2011) (Table 1).

Table 1: Rainfall and temperature patterns, Abeokuta

Parameters	Units	Jan. '11	Feb. '11	Mar. '11	Apr. '11	May '11	June '11	July '11	Aug. '11	Sept. '11	Oct. '11	Nov. '11	Dec. '11	Jan. '12
Total Rainfall	mm	0.00	139.8	23.9	74.5	73.7	84.5	349.5	88.7	204.1	288.1	3.6	0.00	0.00
Mean Temp.	ºC	27.2	28.9	29.2	29.2	28.0	26.9	24.5	25.3	26.6	26.9	27.9	27.0	27.0

Table 2: Rainfall and temperature pattern, Ibadan

Parameters	Units	Jan. '11	Feb. '11	Mar. '11	Apr. '11	May '11	June '11	July '11	Aug. '11	Sept. '11	Oct. '11	Nov. '11	Dec. '11	Jan. '12
Total Rainfall	mm	0.00	130.6	72.3	103	143.1	224.4	156.4	314.9	280.9	262.4	8	0.00	0.00
Mean Temp.	ºC	26.2	28.3	28.8	28.0	27.6	26.5	25.0	24.5	25.9	25.9	27.7	26.6	26.7

Total monthly rainfall pattern at Ibadan ranges was between 314.9 mm (August, 2011) to absence of precipitation (January and December, 2011 and January, 2012). Mean temperature was between 28.8 ^{0}C (March, 2011) to 24.5 ^{0}C (August, 2011) (Table 2).

2.2 Treatments and experimental design

Sequential cropping system was conducted concurrently at two locations, which commenced from January 2011. The first crop in the sequence was soybean (*Glycine max* (L.). Merrill) varieties TGx 1448-2E (late maturing) and TGx 1740-2F (early maturing), and *Telfairia occidentalis* Hook. F (fluted pumpkin) in the control plot. Lowland rice 'NERICA® L-42' was established in the second sequence in June 2011. This variety is early maturing with maturity range of between 90 to 100 days. 'NERICA® 2' an upland rice variety with maturity range of between 90 to 100 days was established as the third crop in the sequence between September and October 2011 in Abeokuta and Ibadan respectively. The experiments were established in a split-split plot arrangement fitted to randomised complete block design with three replicates in 2011/ 2012 cropping season. All experiments had tillage (conventional and minimum) in the main plot. For the soybean trial the main plot size was 33.5 m × 26.5 m. The sub-plot size was 13.5 m × 13 m, which consisted soybean variety (TGx 1448-2E and TGx 1740-2F) and sub-sub plot size measured 5 m × 4 m, consisted of plant spacing (60 cm × 5 cm, 60 cm × 10 cm and 60 cm × 15 cm). Net plot size was 9.6 m^2. For the rice trials, the sub-plot measured 13.5 m × 13 m. Individual rice plots were established by dry direct seeding and transplanting. The sub-sub plot was 5 m × 4 m had spacing (15 cm × 15 cm, 20 cm × 20 cm and 25 cm × 25 cm). The control plot in the sequences was *Telfairia*-lowland-upland rice. *Telfairia occidentalis* was transplanted and land prepared for conventional tillage on mounds at 1 m × 1 m (20 plants plot^{-1} and 10,000 plants ha^{-1}), with the application of N P K 20:10:10 at the rate of 300 kg N ha^{-1}(60 g 20 m^{-2} plot) (Akanbi et al., 2007). For the rice trials (both lowland and upland crops) plots were prepared conventionally and transplanted with 200 kg ha^{-1}(40 g 20m^{-2} plot) of NPK 15:15:15 as basal application at transplanting and 65.2 kg ha^{-1} (13.0 g 20 m^{-2} plot) of urea as topdressing in two equal splits of 32.6 kg ha^{-1} (6.52 g 20 m^{-2} plot) at mid-tillering (4 WAT/7 WAP) and panicle initiation (6 WAT/9 WAS). Soybean stover ranged between 2.96 to 6.70 kg plot^{-1} and lowland rice straws of between 5.41 and 6.96 t ha^{-1}of 10 cm in lengths were incorporated into the soil and left for two weeks before planting succeeding crop to allow for decomposition and mineralisation. Dried poultry dropping was incorporated into to all the soybean plots two weeks before sowing at the rate of 16.6 kg plot^{-1}and 2.1 kg plot^{-1} (8.3 and 1.03 t ha^{-1}) for Abeokuta and Ibadan respectively as suggested by Azeez & Van Averbeke, (2010). This translated to 40 g N plot^{-1} (20 kg N ha^{-1}). The poultry droppings were sourced from layers pen under battery cage system.

2.3 Land preparation

Plots were laid out with an alley of 0.5m between plots and 1 m between replicates. For soybean establishment minimum and conventional tillage methods were achieved manually (hand hoe), however, the intensity of soil disturbance was increased in conventional tillage through pulverization (small hand hoe and cutlass) of clods into smaller fragments. For rice establishment minimum tillage was achieved through reduced disturbance of soil manually (hand hoe), while conventional tillage was conducted manually (hoe, feet and hand) but with increased intensity of soil disturbance until it turned into slurry for reduced infiltration and percolation of water (puddling). Seeds for the soybean varieties were sourced from Institute of

Food Security, Environmental Resources and Agriculture Research (IFSERAR) of FUNAAB, while those of the rice varieties were sourced from Africa Rice Centre, Ibadan sub-station. The fruit of the fluted pumpkin was locally sourced. Fluted pumpkin seedlings were raised in a nursery for three weeks before they were transplanted to the field. A dry bed nursery was established at the beginning of each rice cycle near the field. The size of the bed was 1 m × 5 m. The top soil was softened and watered. Rice seeds were sown on the date of seeding the dry direct seeded on the field and watered regularly for 3 weeks after which they were transplanted. The nursery of the lowland rice was established on 1th and 20th June 2011 at Abeokuta and Ibadan, respectively. While that of upland rice was established on 27th September, and 5th October, 2011 at Abeokuta and Ibadan, respectively.

2.4 Planting Operations

Three seeds of soybean per hole were planted on 15th January, 2011 in Abeokuta and 20th January, 2011 at Ibadan at spacing's corresponding to the treatment combination, which was later thinned to two plants per stand at two weeks after sowing. The population of the fluted pumpkin was 10,000 plants per hectare at one seedling per stand. The vines of the fluted pumpkin were trained to climb platforms erected to facilitate its creeping habit.

The lowland rice trials were established in Abeokuta on 1st June, 2011 and at Ibadan on 7th June, 2011. The upland rice trials were established on 27th September, 2011 at Abeokuta and 5th October, 2011 at Ibadan. For the direct seeded, three seeds were sown and thinned to two seedlings per stand two weeks after sowing, while two 3 weeks old seedlings were transplanted for the transplanted treatment.

Weeding in soybean field was done manually (hoe) at 3, 6, and 10 weeks after planting (WAP). In rice plots Riceforce® (a selective pre-emergence herbicide) with oxidiaxon as active ingredient at 0.25 kg l^{-1} was applied on the day of establishing the direct seeded plots at the rate of 3 kg a.i. per hectare while OrizoPlus® (360 g of propanil and 200 g of 2, 4-D acid a.i./litre), a selective post-emergence herbicide was applied at the average recommended rate of 10 kg a.i. per hectare at 18 DAT. Off-type rice varieties were selectively removed manually during the life cycle of the rice.

2.5 Sampling and measurements

Pre-planting soil physico-chemical properties were determined for each crop cycle. A composite soil samples were randomly taken from a depth of 0-20 cm. Rice grain yield and yield components was determined at harvest maturity from ten representative hills per net plot. Leaf fresh mass of fluted pumpkins was determined at two-week intervals after four weeks of transplanting up to the 16th week.

Productivity of the cropping system was evaluated based on total productivity of the sequence, production efficiency, economic efficiency, land utilization index, profitability, returns (gross and net), benefit and cost ratio. To evaluate the productivity of rice in the sequence, productivity of paddy was converted to milled rice (National Cereals Research Institute, 1992), while productivity of non-rice component in the sequence was converted to rice grain equivalent yield on price basis.

Rice grain equivalent yield (RGEY)=yield of non rice crop × price of non rice crop/price of rice (Manjunath & Korikanthimah, 2004).

Prices as at third quarter 2011, of milled imported rice was N 202.34 kg^{-1} (market price of 'NERICA®' was assumed to be equal to those of imported milled rice (Adigbo et al., 2010), and soybean was N 180.00 kg^{-1}. This was obtained from Ogun State Agricultural Development Programe (OGADEP), Abeokuta, Ogun State. Farm gate price of fluted pumpkin (N100 kg^{-1}) was used for computation. Production efficiency was computed by dividing the total grain production (ha^{-1}) in a sequence with total duration (days) of crops in a sequence (Tomar et al., 1990). Benefit: cost ratio was calculated for the different practices in each sequence by diving the net returns by the cost of cultivation per sequence (Prasad et al., 2011).

Land utilisation index=(Ta+Tb+Tc)/365×100 (Tomar et al., 1990);
where; Ta, Tb and Tc represent total duration (days) of crops a, b and c in the sequence

Profitability=net returns per hectare in the sequence/365 days (Prasad et al., 2011).

Economic efficiency (EE)=Net returns of sequence (Naira per hectare)/duration of sequence (days) (Patil et al., 1995). Duration indicated the sum total of the number of days all crops in a sequence attained maturity.

Total grain production is the sum total of all grain in a sequence, i.e. rice grain equivalent yield (RGEY) plus milled rice equivalent (MRE) of lowland and upland rice. Gross return was the total income from the sales of all the crops in a sequence i.e. price of milled rice multiplied by total grain production (kg ha^{-1}). Net return was gross return less cost of cultivation. Cost of cultivation indicated the amount of money incurred in the producing all the crops in each sequence based on different operations performed and materials used for raising the crops in each sequence.

2.6 Statistical Analysis

Data collected were subjected to mixed model Analysis of Variance (ANOVA) using the GenStat 12th Edition and the differences among treatment means were separated using least significant difference (LSD) at 5 % probability level where F values were significant.

3 RESULTS

Before the establishment of soybean in the inland valley of Abeokuta, the soil pH was 6.50, with organic content of 51.4 g kg^{-1}. The nutrient composition was 1.80 g kg^{-1} (total nitrogen), and 6.91 mg kg^{-1} (available phosphorus). The textural class was loamy sand. At the commencement of lowland rice, soil pH was 6.75, with organic content of 53.1 g kg^{-1}. The nutrient composition was 0.90 g kg^{-1} (total nitrogen), and 10.69 mg kg^{-1} (available phosphorus). The textural class was sandy loam. Soil property as at the time of establishing upland rice was soil pH 6.95, with organic content of 58.8 g kg^{-1}. The nutrient composition was 2.50 g kg^{-1} (total nitrogen), and 10.76 mg kg^{-1} (available phosphorus). The textural class was sandy loam. Soil pH at the establishment of soybean at Ibadan was 5.50, while soil organic content and total nitrogen was 32.2 g kg^{-1} and 1.90 g kg^{-1}, respectively. The soil was sandy clay loam. Prior to the establishment of lowland rice, the soil pH was close to neutral (6.85), with organic matter content of 49.10 g kg^{-1}. Nutrient composition was: 0.60 g kg^{-1} total nitrogen and 4.49 mg kg^{-1} available P; the textural class was the same as that of soybean establishment. Soil properties at the start of upland rice in the sequence were 7.05 pH, 66.70 g kg^{-1} organic matter and 2.90 g kg^{-1} total nitrogen. Available P was 8.1 mg kg^{-1}. The soil was sandy loam (Table 3).

Table 3: Soil physico-chemical properties of the experimental site, in soybean-lowland-upland-rice at Abeokuta and Ibadan

Parameters and methods of determination	Units	ABEOKUTA Soil A	Soil B	Soil C	IBADAN Soil A	Soil B	Soil C
pH (in water, 1:1),pH meter (McLean, 1982)	-	6.50	6.75	6.95	5.50	6.85	7.05
Organic matter, Walkey-Black method (Allison, 1965)	g kg^{-1}	51.4	53.1	58.8	32.2	49.1	66.7
Total nitrogen, modified micro Kjeldahl method (Jackson, 1962)	g kg^{-1}	1.80	0.90	2.50	1.90	0.60	2.90
Available phosphorus (Bray and Kurtz, 1945)	mg kg^{-1}	6.91	10.69	10.76	6.52	4.49	8.1
Exchangeable, flame photometry							
- Potassium	cmol kg^{-1}	0.21	0.24	0.11	0.71	0.41	0.09
- Sodium	cmol kg^{-1}	0.5	0.62	0.20	0.16	0.84	0.22
Particle size (Bouyoucos, 1962)							
- Sand	g kg^{-1}	778	734	750	580	544	730
- Clay	g kg^{-1}	56	125	120	220	245	130
- Silt	g kg^{-1}	166	141	130	200	211	140
Textural class	-	Loamy sand	Sandy loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy loam

Legend: A – At soybean establishment, B – At lowland rice establishment, C – At upland rice establishment, % - percent, cmol kg^{-1} - centimoles of cations per kilogram, mg kg^{-1} - milligramme kilogramme^{-1}, g kg^{-1} – gramme kilogramme^{-1}

3.1 Grain yield and yield components of soybean at Abeokuta and Ibadan

Tillage practices had no significant effect on all the yield components and grain yield of soybean in Abeokuta (Table 4). Similar trend was observed in Ibadan (Table 5). Soybean variety TGx 1448-2E had significantly ($P < 0.05$) higher mass of pod plot^{-1}, mass of seed plot^{-1} and grain yield than cultivar TGx 1740-2F in Abeokuta, except mass of seed pod^{-1} where, soybean cultivar TGx 1740-2F was observed to have significantly ($P < 0.05$) higher mass of seed pod^{-1} than cultivar TGx 1448-2E. However, in Ibadan there was no significant varietal variability on all the yield components and grain yield. In Abeokuta and Ibadan increasing plant density resulted in a significant ($P < 0.05$) increase in stover mass plot^{-1}. However, a converse trend was observed on 100 seed mass (Abeokuta) and mass of seed pod^{-1} (Ibadan).

Table 4: Effect of tillage and row spacing on the yield components and grain yield of soybean cultivars in the inland valley at Abeokuta, 2011

Tillage (T 1df)	Mass of pod plot^{-1} (g)	Mass of pod plant^{-1} (g)	Mass of seed plot^{-1} (g)	Mass of seed plant^{-1} (g)	Mass of seed pod^{-1} (g)	Threshing percentage (%)	Stover mass plot^{-1} (kg)	100 seed mass (g)	Harvest index	Grain yield (kg ha^{-1})
Minimum	1602	26.28	822.9	4.026	0.264	51.89	4.49	11.21	44.4	772.9
Conventional	1520	29.94	784.8	4.292	0.274	51.90	4.34	10.54	46.7	737.6
LSD (0.05)	347.4	19.745	146.82	0.9701	0.0518	3.075	1.174	0.683	18.92	138.79
Variety (V 1df)										
TGx1448-2E	1651	27.35	836.0	3.968	0.263	51.00	4.31	11.08	44.1	785.2
TGx1740-2F	1471	28.87	771.7	4.349	0.275	52.79	4.53	10.67	47.0	725.3
LSD (0.05)	152.4*	3.580	33.70*	0.7042	0.0409*	3.720	0.601	0.793	9.41	32.66*
Spacing (S 2df)										
60 cm × 5 cm	1590	30.35	804.9	4.210	0.175	50.84	6.35	7.28	48.3	756.6
60 cm × 10 cm	1556	28.25	796.5	4.122	0.266	51.61	3.89	11.09	46.0	747.8
60 cm × 15 cm	1539	25.73	810.2	4.144	0.367	53.23	3.02	14.25	42.4	761.4
LSD (0.05)	138.4	3.793	28.93	0.3521	0.0542	5.043	0.673*	0.972*	7.05	26.98
T × V(1df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
T × S (2df)	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns
V × S (2df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
T × V × S (2df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Legend: * - significant at 5 % level, ** - significant at 1 % level.

Table 5: Effect of tillage and row spacing on the yield components and grain yield of soybean cultivars in the inland valley at Ibadan, 2011

Tillage (T 1df)	Mass of pod plot^{-1} (g)	Mass of pod plant^{-1} (g)	Mass of seed plot^{-1} (g)	Mass of seed plant^{-1} (g)	Mass of seed pod^{-1} (g)	Threshing percentage (%)	Stover mass plot^{-1} (kg)	100 seed mass (g)	Harvest index	Grain yield (kg ha^{-1})
Minimum	1706	19.51	843	4.14	0.32	49.60	4.26	14.70	43.4	793
Conventional	1655	18.22	827	3.86	0.27	49.84	4.72	12.05	38.9	777
LSD (0.05)	141.9	6.200	258.5	0.535	0.058	12.49	2.019	6.058	11.57	243.5
Variety (V 1df)										
TGx1448-2E	1723	19.07	874	3.75	0.30	50.97	4.36	12.89	38.8	821
TGx1740-2F	1638	18.66	796	4.25	0.29	48.47	4.62	13.86	43.5	749
LSD (0.05)	292.1	5.282	114.0	0.514	0.060	4.825	0.364	2.628	6.63	104.8
Spacing (S 2df)										
60 cm × 5 cm	1690	19.20	868	4.21	0.27	51.27	6.79	12.66	44.7	816
60 cm × 10 cm	1705	18.67	870	4.05	0.30	51.40	3.72	14.30	41.9	820
60 cm × 15 cm	1646	18.72	766	3.74	0.33	46.48	2.96	13.17	36.9	720
LSD (0.05)	176.8	3.489	108.4	0.635	0.0354*	4.800	0.816*	2.096	6.32	103.2
T × V(1df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
T × S (2df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
V × S (2df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
T × V × S (2df)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Legend: * - significant at 5 % level.

3.2 Grain yield and yield components of lowland rice ('NERICA L-42') at Abeokuta and Ibadan

Rice grown under conventional tillage performed better (significant at $P < 0.05$) than minimum tillage only in Abeokuta on panicle mass (Table 6). There were no significant differences between the tillage practices among other yield and yield component parameters examined. Dry dibble method resulted in significantly higher ($P < 0.05$) numbers of grains per panicle in Abeokuta than the transplanted rice, while there were no significant differences on other yield components at both locations (Tables 6 and 7). Stover mass increased significantly ($P < 0.05$) with lower plant densities at both locations, conversely at Ibadan number of panicles per m^2 increased significantly ($P < 0.05$) with increasing plant density. There were no significant differences among other reproductive parameters with varying plant densities.

Table 6: Effect of tillage, seeding method and spacing on reproductive growth parameters of lowland rice ('NERICA® L-42') grown during the main season after soybean in the inland valley at Abeokuta in 2011

Treatments	Panicle mass (g)	Panicle length (cm)	Number of panicles m^{-2}	Number of grains panicle^{-1}	1000 seed mass (g)	Harvest Index (%)	Grain Yield (t ha^{-1})	Stover mass (t ha^{-1})
Tillage (T 1df)								
Minimum	18.81	25.66	138	135	24.97	42.55	3.03	6.00
Conventional	21.44	26.57	139	128	25.54	44.78	3.05	5.96
LSD (0.05)	2.30	2.73	36.64	18.08	3.73	14.51	0.78	0.42
Seeding Method (1df)								
Dry Dibble	19.62	25.50	138	136	25.67	43.74	3.04	5.94
Transplanted	20.63	26.73	139	127	24.84	43.59	3.04	6.01
LSD (0.05)	1.09	2.71	27.21	21.39	3.68	5.60	0.13	0.48
Spacing (S 2df)								
15 × 15	19.87	26.03	143	130	24.75	42.49	3.01	5.41
20 × 20	19.81	25.88	136	136	25.51	42.25	3.07	6.00
25 × 25	20.70	26.43	137	129	25.50	46.27	3.05	6.52
LSD (0.05)	1.08	2.22	16.91	12.28	2.29	4.69	0.33	0.45
INTERACTIONS								
T×M (1 df)	ns	ns	ns	ns	ns	ns	ns	ns
T×S (2 df)	ns	ns	ns	ns	ns	ns	ns	ns
M×S (2 df)	*	ns	*	ns	ns	ns	ns	ns
T×M×S (2 df)	*	ns	ns	ns	ns	ns	ns	ns

Legend: g – gramme(s), cm – centimetre(s), m^2 – square metre(s), % - percent, t/ha – tonnes per hectare, ns – not significant, LSD - Least significant differences of means (5 % level), T – Tillage, S - Spacing, M - Seeding method, * - significant at 5 % level.

Table 7: Effect of tillage, seeding method and spacing on reproductive growth parameters of lowland rice ('NERICA® L-42') grown during the main season in the inland valley at Ibadan in 2011

Treatments	Panicle mass (g)	Panicle length (cm)	Number of panicle m^{-2}	Number of grains panicle^{-1}	1000 seed mass (g)	Harvest index (%)	Grain yield (t ha^{-1})	Stover mass (t ha^{-1})
Tillage (T 1df)								
Minimum	15.61	23.66	141	123	25.76	43.0	2. 9	6.30
Conventional	15.31	25.03	138	143	26.53	49.0	3.18	6.58
LSD (0.05)	4.21	1.80	35.53	33.55	0.85	14.75	1.23	0.93
Seeding Method (M 1df)								
Dry Dibble	15.01	23.62	139	133	25.98	45.2	3.06	6.53
Transplanted	15.91	25.07	140	133	26.31	46.8	3.01	6.35
LSD (0.05)	2.34	1.79	22.21	20.16	2.97	5.50	0.47	0.55
Spacing (S 2df)								
15 × 15	14.55	24.88	161.4	133.0	27.79	45.0	2.75	6.00
20 × 20	15.72	23.56	128.3	136.4	25.56	45.1	3.12	6.37
25 × 25	16.12	24.60	129.0	130.1	25.09	48.0	3.24	6.96
LSD (0.05)	1.76	1.66	17.08	16.32	1.99	5.97	0.40	0.40
INTERACTIONS								
T×M (1df)	ns	ns	ns	ns	ns	ns	ns	ns
T×S (2df)	ns	ns	ns	ns	ns	ns	ns	ns
M×S (2df)	ns	**	ns	*	ns	ns	ns	ns
T×M×S (2df)	ns	ns	ns	ns	ns	ns	ns	ns

Legend: g – gramme(s), cm – centimetre(s), m^2 – square metre(s), % - percent, t/ha – tonnes per hectare, ns – not significant, LSD - Least significant differences of means (5 % level), T – Tillage, S - Spacing, M - Seeding method, * - significant at 5 % level, ** - significant at 1 % level.

3.3 Grain yield and yield components of upland rice ('NERICA 2') at Abeokuta and Ibadan

There were no significant differences at both location between the tillage practices on yield and yield components (Tables 8 and 9). Dry dibble method seeded rice plants produced significantly higher numbers of panicles per m^2 in Abeokuta than the transplanted rice plant. Similar pattern was observed on the number of grains per panicles at Ibadan. Reduced plant density at Ibadan resulted in a significant increase ($P < 0.05$) in panicle mass, number of grains per panicle and grain yield. However, at Abeokuta none of the yield components was significantly affected by plant densities.

Table 8: Effects of tillage, seeding method and spacing on reproductive growth parameters of upland rice ('NERICA® 2') grown after lowland rice during the late season in the inland valley at Abeokuta in 2011

Treatments	Panicle mass (g)	Panicle length (cm)	Number of panicles m^{-2}	Number of grains panicle^{-1}	1000 seed mass (g)	Harvest index (%)	Grain yield (t ha^{-1})
Tillage (T 1df)							
Minimum	14.84	21.60	87	93	23.80	59.4	1.62
Conventional	14.59	22.36	89	92	23.61	60.2	1.76
LSD (0.05)	5.69	0.67	7.53	11.89	5.31	6.62	0.83
Seeding Method (M 1df)							
Dry Dibble	14.85	21.96	90	93	24.24	59.9	1.75
Transplanted	14.58	22.01	86	91	23.17	59.7	1.64
LSD (0.05)	1.36	3.03	4.00	3.87	1.66	3.23	0.11
Spacing (S 2df)							
15 × 15	14.56	22.01	87	93	23.57	60.5	1.68
20 × 20	14.32	21.80	87	91	24.54	59.5	1.66
25 × 25	15.28	22.13	90	93	23.01	59.5	1.75
LSD (0.05)	1.46	1.40	6.24	6.87	2.32	5.61	0.20
INTERACTIONS							
T×M (1df)	ns	ns	ns	ns	ns	ns	*
T×S (2df)	ns	*	*	ns	ns	ns	ns
M×S (2df)	ns	ns	ns	ns	ns	ns	ns
T×M×S (2df)	ns	ns	ns	ns	ns	ns	ns

Legend: g – gramme(s), cm – centimetre(s), m^2 – square metre(s), % - percent, t ha^{-1} – tonnes per hectare, ns – not significant, LSD - Least significant differences of means (5 % level), T – Tillage, S - Spacing, M - Seeding method, * - significant at 5 % level.

Table 9: Effects of tillage, seeding method and spacing on reproductive growth parameters of upland rice ('NERICA® 2') grown after lowland rice during the late season in the inland valley at Ibadan in 2011

Treatments	Panicle mass (g)	Panicle length (cm)	Number of panicles m^{-2}	Number of grains $panicle^{-1}$	1000 seed mass (g)	Harvest index (%)	Grain yield (t/ha)
Tillage (T 1df)							
Minimum	12.68	21.65	92	98	23.19	62.0	1.73
Conventional	12.25	21.79	91	99	23.75	61.8	1.67
LSD (0.05)	1.36	2.28	46.18	5.64	3.80	12.60	0.26
Seeding Method (M 1df)							
Dry Dibble	12.54	21.81	96	100.7	23.70	61.8	1.70
Transplanted	12.39	21.63	87	95.3	23.24	62.0	1.70
LSD (0.05)	1.46	1.66	12.36	5.34	1.88	5.76	0.11
Spacing (S 2df)							
15 × 15	11.58	21.24	89	89	22.95	62.9	1.50
20 × 20	12.26	22.05	89	97	23.86	60.9	1.77
25 × 25	13.56	21.88	96	108	23.61	61.9	1.84
LSD (0.05)	1.04	1.73	10.94	5.60	1.79	7.80	0.26
INTERACTIONS							
T×M (1df)	ns	ns	ns	ns	ns	ns	*
T×S (2df)	ns	ns	*	ns	ns	ns	ns
M×S (2df)	ns	ns	ns	ns	ns	ns	ns
T×M×S (2df)	ns	ns	ns	ns	ns	ns	ns

Legend: g – gramme(s), cm – centimetre(s), m^2 – square metre (s), % - percent, t ha^{-1} – tonnes per hectare, ns – not significant, LSD - Least significant differences of means (5 % level), T – Tillage, S - Spacing, M - Seeding method, * - significant at 5 % level.

3.4 Economic productivity and profitability of soybean-lowland rice-upland rice

At Abeokuta, productivity of fluted pumpkin (0.99 t ha^{-1}) expressed as rice grain equivalent yield (RGEY) was the highest ($P < 0.05$), while the least significant RGEY (0.62 t ha^{-1}) was observed when soybean 'TGx 1448-2E' was cultivated under conventional tillage at the spacing of 60 cm × 5 cm. Conversely, for lowland and upland rice in the sequence the least significant productivity was observed in the plots preceded by fluted pumpkin under conventional tillage practises, transplanted at a spacing of 20 cm × 20 cm. The highest milled lowland rice productivity (2.50 t ha^{-1}) was observed when directly seeded under conventional tillage at the least plant population density (25 cm × 25 cm). However, the highest ($P < 0.05$) milled rice productivity (1.47 t ha^{-1}) of upland rice was observed under conventional tillage, transplanted at the spacing of 15 cm × 15 cm. Sequence that consisted of soybean 'TGx 1448-2E', 'NERICA L-42' and 'NERICA 2' under conventional tillage, at the spacing of 60 cm × 15 cm and 25 cm × 25 cm (soybean and rice cultivars respectively) recorded the highest total productivity (4.57 t ha^{-1}) and production efficiency (15.69 kg ha^{-1} day^{-1}). The sequence that consisted of fluted pumpkin, 'NERICA L-42' and 'NERICA 2' cultivated under conventional tillage that was transplanted at a spacing of 20 cm × 20 cm had significantly the least total productivity (3.69 t ha^{-1}), production efficiency (11.40 kg ha^{-1} day^{-1}), profitability (N 729 ha^{-1} day^{-1}) and conversely the highest land utilization index (88.58 %). The highest ($P < 0.05$) profitability (N 1404 ha^{-1} day^{-1}) was observed in the sequence that consisted of soybean 'TGx 1448-2E', under minimum tillage, at a spacing of 60 cm × 15 cm and 25 cm × 25 cm in soybean, lowland and upland rice respectively with the least plant population densities. The least land utilization index (77.63 %) was observed in the sequence that consisted of soybean 'TGx 1448-2E', under minimum tillage, at a spacing of 60 cm × 10 cm and 20 cm × 20 cm in soybean, lowland and upland rice respectively (Table 10).

At Ibadan, the highest RGEY (1.04 t ha^{-1}) was observed when the fluted pumpkin was established in the control plot preceding rice in the sequence. However, the least RGEY (0.5 t ha^{-1}) was observed when soybean 'TGx 1448 -2E' was established under minimum tillage at the spacing of 60 cm × 5 cm. As observed in Abeokuta, the treatment combinations that had the least significant productivity of milled lowland and upland rice was also observed at Ibadan. Similar pattern of cropping sequence and treatment combinations were observed on the least total productivity, production efficiency, profitability and the highest LUI was repeated at Ibadan. The highest productivity (2.70 t ha^{-1}) of milled lowland rice was observed when it was transplanted and established under conventional tillage at the spacing of 25 cm × 25 cm. In upland rice, the highest productivity of milled rice was obtained when 'NERICA 2' was cultivated under minimum tillage and directly seeded at the spacing of 15 cm × 15 cm. The highest total productivity (4.75 t ha^{-1}) was achieved in the sequence when soybean 'TGx 1740-2F', lowland and upland rice cultivars were established under minimum tillage, with both rice cultivars directly seeded at the spacing of 25 cm × 25 cm, while soybean was spaced at 60 cm × 15 cm. Similar cropping sequence gave the highest production efficiency (15.84 kg ha^{-1} day^{-1}). The highest profitability (1531 ha^{-1} day^{-1}) was observed in the sequence of soybean ‘TGx 1448-2E’ at the spacing 60 cm × 5 cm, lowland and upland rice directly seeded at the spacing 15 cm × 15 cm under minimum tillage. Cultivar TGx 1448-2E at a spacing of 60 cm × 10 cm, succeeded by lowland and upland rice at a spacing of 20 cm × 20 cm, directly seeded gave the least LUI (77.63 %) (Table 11).

The least significant net returns, benefit/cost ratio and economic efficiency at both locations was recorded in the sequence fluted pumpkin, lowland and upland land rice that was transplanted, established under conventional tillage at a spacing of 20 cm × 20 cm. The sequence of ‘TGx 1448-2E’ soybean at the spacing 60 cm × 15 cm, lowland and upland rice at the spacing of 25 cm × 25 cm directly seeded and established under minimum tillage in Abeokuta produced the highest net returns (N 512, 488). At Ibadan, the sequence of ‘TGx 1448-2E’ soybean at the spacing of 60 cm × 5 cm and lowland and upland rice at a spacing of 15 cm × 15 cm that was directly seeded and established under minimum tillage resulted in the highest net return (N 558,647). Similar pattern of treatment combinations in the cropping sequence was observed on the highest benefit/cost ratio at both locations. In Abeokuta soybean ‘TGx 1448-2E’ conventionally established at the 60 cm × 15 cm spacing, lowland and upland rice at a spacing of 25 cm × 25 cm that were conventionally tilled and directly seeded was the most economically efficient (N 1,754 ha^{-1} day^{-1}). The sequence of ‘TGx 1448-2E’ at the 60 cm × 5 cm spacing, lowland and upland rice at a spacing of 15 cm × 15 cm all crops minimally tilled and directly seeded was the most economically efficient (N 1858 ha^{-1} day^{-1}) at Ibadan (Table 12).

Table 10: Total productivity, duration, production efficiency, profitability, and land utilization index of the sequence at Abeokuta in 2011/2012 cropping season.

Treatments			Productivity (t ha^{-1})				Duration	Production	Profitability ₦	Land
SOY	LR	UR	RGEY	MRE LR	MRE UR	TOTAL	(days)	efficiency (kg ha^{-1}day^{-1})	ha^{-1}day^{-1})	utilization index (%)
$T_1V_1R_1$	$T_1S_1R_1$	$T_1S_1R_1$	0.71	2.27	1.29	4.27	303.3	14.08	1348	83.11
$T_1V_1R_2$	$T_1S_1R_2$	$T_1S_1R_2$	0.65	2.28	1.10	4.03	283.3	14.21	1178	77.63
$T_1V_1R_3$	$T_1S_1R_3$	$T_1S_1R_3$	0.71	2.48	1.22	4.41	302.0	14.60	1404	82.74
$T_1V_2R_1$	$T_1S_2R_1$	$T_1S_2R_1$	0.67	2.31	1.33	4.30	290.0	14.84	1345	79.45
$T_1V_2R_2$	$T_1S_2R_2$	$T_1S_2R_2$	0.72	2.16	1.16	4.03	303.0	13.31	1195	83.01
$T_1V_2R_3$	$T_1S_2R_3$	$T_1S_2R_3$	0.67	2.34	1.16	4.16	292.3	14.24	1248	80.09
$T_2V_1R_1$	$T_2S_1R_1$	$T_2S_1R_1$	0.62	2.12	1.25	3.99	289.3	13.78	1081	79.27
$T_2V_1R_2$	$T_2S_1R_2$	$T_2S_1R_2$	0.70	2.34	1.44	4.48	302.0	14.83	1379	82.74
$T_2V_1R_3$	$T_2S_1R_3$	$T_2S_1R_3$	0.63	2.50	1.45	4.57	291.3	15.69	1400	79.82
$T_2V_2R_1$	$T_2S_2R_1$	$T_2S_2R_1$	0.68	2.16	1.47	4.31	303.7	14.18	1261	83.20
$T_2V_2R_2$	$T_2S_2R_2$	$T_2S_2R_2$	0.63	2.34	1.43	4.40	289.3	15.21	1315	79.27
$T_2V_2R_3$	$T_2S_2R_3$	$T_2S_2R_3$	0.68	2.46	1.29	4.43	300.3	14.76	1340	82.28
Tel. (F)	$T_2S_2R_2$ (F)	$T_2S_2R_2$ (F)	0.99	1.69	1.01	3.69	323.3	11.40	729	88.58
	LSD (0.05)		0.078	0.47	0.33	0.59	6.611	1.911	327.9	1.811

Legend: T – tillage: T_1 – minimum, T_2 – conventional; V – soybean varieties: V_1 – TGx 1448-2E, V_2 – TGx 1740-2F; R – seeding rates: for soybean = R_1 – 60 cm X 5 cm, R_2 – 60 cm X 10 cm, R_3 – 60 cm X 15 cm; For rice = R_1 – 15 cm X 15 cm, R_2 – 20 cm X 20 cm, R_3 – 25 cm X 25 cm; S – seeding method: S_1 – dry dibble, S_2 – transplanting; F – inorganic fertilizer, Tel. – *Telfairia occidentalis* (fluted pumpkin), SOY – soybean, LR – lowland rice, UR – upland rice, t – tonnes, ha - hectare, kg – kilogrammes, ₦ – Nigerian naira.

Table 11: Total productivity, duration, production efficiency, profitability, and land utilization index of the sequence at Ibadan in 2011/2012 cropping season.

Treatments				Productivity (t ha^{-1})			Duration	Production	Profitability (	Land
SOY	LR	UR	RGEY	MRE LR	MRE UR	TOTAL	(days)	efficiency (kg ha^{-1}day^{-1})	₦ ha^{-1}day^{-1})	utilization index (%)
$T_1V_1R_1$	$T_1S_1R_1$	$T_1S_1R_1$	0.50	2.42	1.69	4.60	300.7	15.30	1531	82.37
$T_1V_1R_2$	$T_1S_1R_2$	$T_1S_1R_2$	0.63	2.12	1.26	4.01	283.3	14.13	1166	77.63
$T_1V_1R_3$	$T_1S_1R_3$	$T_1S_1R_3$	0.63	2.20	1.37	4.19	300.7	13.93	1281	82.37
$T_1V_2R_1$	$T_1S_2R_1$	$T_1S_2R_1$	0.58	2.47	1.40	4.45	290.3	15.33	1427	79.54
$T_1V_2R_2$	$T_1S_2R_2$	$T_1S_2R_2$	0.68	1.92	1.09	3.69	303.0	12.19	1005	83.01
$T_1V_2R_3$	$T_1S_2R_3$	$T_1S_2R_3$	0.59	2.10	1.11	3.79	290.3	13.07	1040	79.54
$T_2V_1R_1$	$T_2S_1R_1$	$T_2S_1R_1$	0.53	2.47	1.43	4.43	289.0	15.32	1327	79.18
$T_2V_1R_2$	$T_2S_1R_2$	$T_2S_1R_2$	0.61	2.61	1.20	4.42	300.7	14.70	1347	82.37
$T_2V_1R_3$	$T_2S_1R_3$	$T_2S_1R_3$	0.60	2.26	1.26	4.12	290.7	14.17	1149	79.63
$T_2V_2R_1$	$T_2S_2R_1$	$T_2S_2R_1$	0.61	2.10	1.11	3.81	302.3	12.61	988	82.83
$T_2V_2R_2$	$T_2S_2R_2$	$T_2S_2R_2$	0.53	2.33	1.30	4.16	288.0	14.46	1182	78.90
$T_2V_2R_3$	$T_2S_2R_3$	$T_2S_2R_3$	0.73	2.70	1.32	4.75	300.3	15.84	1520	82.28
Tel. (F)	$T_2S_2R_2$ (F)	$T_2S_2R_2$ (F)	1.04	1.70	0.96	3.70	323.3	11.43	733	88.58
	LSD (0.05)		0.20	0.64	0.34	0.80	7.53	2.74	444.3	2.06

Legend: T – Tillage: T_1 – Minimum, T_2 – Conventional; V – Soybean varieties: V_1 – TGx 1448-2E, V_2 – TGx 1740-2F; R – Seeding rates: for soybean = R_1 – 60 cm X 5 cm, R_2 – 60 cm X 10 cm, R_3 – 60 cm x 15 cm; For rice = R_1 – 15 cm x 15 cm, R_2 – 20 cm x 20 cm, R_3 – 25 cm x 25 cm; S – seeding method: S_1 – dry dibble, S_2 –transplanting; F – inorganic fertilizer, Tel. – *Telfairia occidentalis* (fluted pumpkin), SOY – soybean, LR – lowland rice, UR – upland rice, t – tonnes, ha - hectare, kg – kilogrammes, ₦ – Nigerian naira.

Table 12: Economics of the rice-based cropping sequence in Abeokuta and Ibadan in 2011/2012 cropping season.

Treatments			Total productivity (t ha^{-1})		Cost of Cultivation (₦ ha^{-1})	Gross Return (₦ ha^{-1})		Net Return (₦ ha^{-1})		Benefit: Cost Ratio		Economic Efficiency (ha^{-1} day^{-1})	
SOY	LR	UR	Ab.	Ib.		Ab.	Ib.	Ab.	Ib.	Ab.	Ib.	Ab.	Ib.
$T_1V_1R_1$	$T_1S_1R_1$	$T_1S_1R_1$	4.27	4.60	384,100	864048	930837	491858	558647	1.32	1.50	1621	1858
$T_1V_1R_2$	$T_1S_1R_2$	$T_1S_1R_2$	4.03	4.01	379,780	814716	810583	429836	425703	1.12	1.11	1514	1498
$T_1V_1R_3$	$T_1S_1R_3$	$T_1S_1R_3$	4.41	4.19	372,190	892268	847388	512488	467608	1.35	1.23	1696	1556
$T_1V_2R_1$	$T_1S_2R_1$	$T_1S_2R_1$	4.30	4.45	387,100	870753	900499	491063	520809	1.29	1.37	1693	1794
$T_1V_2R_2$	$T_1S_2R_2$	$T_1S_2R_2$	4.03	3.69	384,880	816186	747035	436056	366905	1.15	0.96	1439	1213
$T_1V_2R_3$	$T_1S_2R_3$	$T_1S_2R_3$	4.16	3.79	379,690	842621	766752	455521	379652	1.18	0.98	1558	1310
$T_2V_1R_1$	$T_2S_1R_1$	$T_2S_1R_1$	3.99	4.43	411,100	806486	896062	394606	484182	0.96	1.18	1364	1675
$T_2V_1R_2$	$T_2S_1R_2$	$T_2S_1R_2$	4.48	4.42	406,780	906331	894434	503391	491494	1.25	1.22	1666	1633
$T_2V_1R_3$	$T_2S_1R_3$	$T_2S_1R_3$	4.57	4.12	402,940	925130	833661	511030	419561	1.23	1.01b	1754	1442
$T_2V_2R_1$	$T_2S_2R_1$	$T_2S_2R_1$	4.31	3.81	414,100	871316	771786	460216	360686	1.12	0.88	1516	1193
$T_2V_2R_2$	$T_2S_2R_2$	$T_2S_2R_2$	4.40	4.16	411,880	890388	841735	479948	431295	1.17	1.05	1658	1500
$T_2V_2R_3$	$T_2S_2R_3$	$T_2S_2R_3$	4.43	4.75	410,440	895953	961448	489173	554668	1.20	1.36	1632	1850
Tel. (F)	$T_2S_2R_2$	$T_2S_2R_2$	3.69	3.70		746093	747712	265993	267612	0.55	0.56	822	828
	(F)	(F)			480,100								
	LSD (0.05)		0.59	0.80	3213.8	119142.3	161979	746093	162185.2	0.298	0.412	392.4	552.5

Legend: T – Tillage: T_1 – Minimum, T_2 – Conventional; V – Soybean varieties: V_1 – TGx 1448-2E, V_2 – TGx 1740-2F; R – Seeding rates: for soybean = R_1 – 60 cm X 5 cm, R_2 – 60 cm X 10 cm, R_3 – 60 cm x 15 cm; For rice = R_1 – 15 cm x 15 cm, R_2 – 20 cm x 20 cm, R_3 – 25 cm x 25 cm; S – seeding method: S_1 – dry dibble, S_2 – transplanting; F – inorganic fertilizer, Tel. – *Telfairia occidentalis* (fluted pumpkin), SOY – Soybean, LR – lowland rice, UR – upland rice, ha - hectare, ₦ – Nigerian naira, t – tones.

4 DISCUSSION

Intensive cropping system through sequential cropping could be constrained by growth factors; selection of appropriate cropping mixture in the right environment could ameliorate the negative effect of increased utilization of growth resources (Malézieux et al., 2009). Available literature had indicated varietal variability on yield components of soybean (Baruah et al., 2014); this was more pronounced in Abeokuta than in Ibadan. This suggests that genotypic differences could have been mediated by environmental factors. Biological nitrogen fixation is an energy consuming process (Serraj et al., 1999). This process is limited by nutrient elements, especially phosphorus (Harold et al., 1990). In legumes in symbiotic relation with microorganism. Oxidative phosphorylation and availability of reducing compounds such as nicotinamide adenine dinucleotide phosphate (NADP) could be grossly constrained where P is limiting (Streeter, 1991). This is especially germane in the tropics, where P is chelated with Al or Fe, due to the acidic nature of such soils (Sample et al., 1980) Though P content in both locations could be characterized as low (Agbede, 2009), in absolute terms soil P content in

Abeokuta was observed to be higher than in Ibadan at the start of establishing soybean. This could have explained the significant varietal differences in Abeokuta than Ibadan. This varietal variability was also reflected on mass of pod per plot, mass of seed per plot and seed per pod suggesting that these yield components were the ones that contributed predominantly to the grain yield of soybean in Abeokuta (Pande et al., 1985).

Tillage did not have any significant effect on the yield components and performance of the component crops in the sequence except on panicle mass in the lowland rice (Abeokuta) and panicle length in lowland (Ibadan) and upland rice (Abeokuta). Both locations recorded an increase in soil organic matter in the sequence. However, the proportion of increase was more pronounced at Ibadan than Abeokuta. Puddling is a predominant tillage practice under conventional tillage to ensure comparatively higher water balance (low seepage and percolation) (McDonald et al., 2006) through increase *in situ* water storage capacity, increase in nutrient form, availability and loss (Wade et al., 1998). Suppression of weed infestation had also been observed (Garrity et al., 1992). Conventional tillage is capable of positively affecting the rate of mineralization and decomposition of organic residues incorporated into the soil after each sequence. Increase in those yield components could have suggested release of essential nutrients for assimilate partitioning at the most critical growth stage of rice. However, decomposition and mineralization rate as reflected in soil organic content and nitrogen availability in lowland could have suggested slower rate due to anaerobic soil condition and its implications on the activities of soil microbes. The threefold increase in soil organic matter especially at Ibadan during the establishment of upland rice could be explained by the pH of the soil which is close to neutral that could hasten microbial activities for organic residue mineralization or the textural composition of the soil preceding upland rice which could positively affect soil nutrient reservoir. Similar pattern were observed on the dynamics of nitrogen in the soil at both locations.

Increased stover mass per plot observed at both locations with increased soybean density and a depression on 100 grain mass (Abeokuta) and seed mass per pod (Ibadan) suggested a compensatory relationship between vegetative and reproductive growth. With increased plant density there would be increased competition for growth resources and metabolite that must be optimized for maximum grain yield for a given genotype in a given environment. At both locations most yield components of lowland rice increased with a reduction in plant density, except number of panicle per m^2 (both locations) and 1000 seed mass (Ibadan). Total nitrogen at both locations was classified as low in Nigeria according to Agbede, (2009), incorporation of soybean residue and the application of organic manure, which are slow releasing with the physico-chemical changes reported in lowland ecology (Ponnamperuma, 1972), could have limited availability of essential nutrients, especially nitrogen at both locations. Inland valley are characterized by a predominance of reduction reaction (reduced soil pH and redox potential) with concomitant effect on nutrient availability, microbial activity and changes in structural integrity of soil particles (Ponnamperuma, 1972). In lowland rice increased number of panicles per m^2 at both locations and 1000 grain mass (Ibadan) with increasing plant densities could have resulted from the increased number of tillers per m^2, increased number of tillers per hill and or increased hill per m^2 (Huang et al., 2011). Huang et al., (2011) posited that number of tillers per hill are determined by the tillering rate and duration and metabolic process (nitrogen and carbon land assimilation). Rainfall distribution at Ibadan in June, 2011 was more than what was obtained in Abeokuta, which could have contributed more to the relative better performance of yield components observed at Ibadan with increasing plant density. Upland rice had all its yield components increased with decreasing plant densities at both locations. This could have suggested that preceding lowland rice, with altered physico-chemical soil condition in a submerged soil could have depleted nutrient availability; hence increasing succeeding upland rice plant population in the inland valley would have exacerbated increased competition for nutrients in the soil.

Most yield components of transplanted lowland rice recorded better performance than dry dibble method in both locations, though not significant, except significantly higher number of grains per panicle that was achieved in Abeokuta under dry dibble method than transplanting. Earlier reported literature indicated that dry dibble method increased number of panicle per m^2, which increased the sink strength (Huang et al., 2011). But increased panicle sterility that was observed in dry dibble could have compromised its comparatively superior performance in the lowland rice (Farooq et al., 2011). Other factors reported included the prevalence of weed, reduced water use efficiency and nutrient availability (Farooq et al., 2011). The trend in the upland rice was that dry dibble gave better yield components than transplanted method especially on number of panicle per m^2 and grain yield (Abeokuta) and number of grains per panicle (Ibadan). Other reports had reported comparatively similar yield of dry dibble and transplanted seeding method (Kukal and Aggarwal, 2002). This could have been a result of its positive effect on yield components mediated by environmental conditions.

The high production efficiency in Abeokuta for the sequence soybean ‘TGx 144-2E’, spaced at 60 cm × 15 cm, conventionally tilled, with lowland and upland rice conventionally tilled and directly seeded at the spacing of 25 cm × 25 cm could be as a result of its high total productivity, explained by the high productivity of milled lowland rice. This information is corroborated by earlier studies that indicated a comparatively higher performance of lowland than upland rice in most rice growing ecologies (Grist, 1986). However, reduced land use index (LUI) observed in the sequence soybean ‘TGx 144-2E’, spaced at 60 cm × 10 cm, minimally tilled with lowland and upland rice minimally tilled and directly seeded at the spacing 20 cm × 20 cm could be as a result of a reduced duration of the sequence in a year. Similar pattern was equally observed at Ibadan. This suggests that the sequence was not able to optimally utilize available growth resources. It had been reported that directly seeded rice flower earlier than transplanted (Santhi et al., 1998), which could have explained the short growing season observed. In Ibadan high production efficiency was recorded in the sequence soybean ‘TGx 1740-2F’, planted at a spacing of 60 cm × 15 cm, conventionally tilled with lowland and upland cost irice conventionally tilled and transplanted at a spacing of 25 cm × 25 cm. Similar pattern with respect to total productivity and productivity of milled lowland rice as observed in Abeokuta was reported here. In Abeokuta, the economic efficiency in the sequence that consisted of soybean variety TGx 1448-2E, spaced at 60 cm × 15 cm, conventionally tilled, lowland and upland rice conventionally tilled and directly seeded at the spacing 25 cm × 25 cm could have been a result of its high gross returns and high total productivity. However, at Abeokuta high profitability of the sequence soybean variety TGx 1448-2E, spaced at 60 cm × 15 cm, minimally tilled with lowland and upland rice minimally tilled and directly seeded spaced at 25 cm × 25 cm indicated its high benefit-to-cost ratio. In Ibadan, high economic efficiency was observed in the sequence of soybean variety TGx 1448-2E, spaced at 60 cm × 5 cm, minimally tilled, with lowland and upland rice minimally tilled and directly seeded, spaced at 15 cm × 15 cm. High benefit-to-cost ratio and net return would have explained this higher economic efficiency observed at Ibadan. This was also reflected on its profitability of that sequence.

5 CONCLUSION

In Abeokuta, lowland rice had significantly higher panicle mass (21.44 g) with conventional than minimum tillage, while at Ibadan significantly longer panicle (25.03 g) was observed. Significantly longer panicle (22.36 g) was obtained at Abeokuta for upland rice under conventional than minimum tillage. Lowland rice had significantly higher number of grains panicle^{-1} under dry dibble than transplanted rice (Abeokuta). Upland rice had significantly higher number of panicles m^{-2} and grain yield under dry dibble than transplanted rice (Abeokuta). However, at Ibadan significantly higher numbers of grains panicle^{-1} was recorded for dry dibble than transplanted rice. Soybean had significantly higher stover mass plot^{-1} at both locations with spacing, while significant effect was observed on mass of seed pod^{-1} and 100 grain mass (Abeokuta). Number of panicles m^{-2} increased with higher lowland rice density (both locations) and 1000 seed mass (Ibadan). Conversely panicle mass, number of grains panicle^{-1} and grain yield recorded significant depression with increasing upland rice (Ibadan). In Abeokuta soybean ‘TGx 1448-2E’ conventionally established at the 60 cm × 15 cm spacing, lowland and upland rice at a spacing of 25 cm × 25 cm that were conventionally tilled and directly seeded was the most economically efficient (₦ 1,754 ha^{-1} day^{-1}). At Ibadan the sequence of ‘TGx 1448-2E’ soybean at the spacing of 60 cm × 5 cm and lowland and upland rice at a spacing of 15 cm × 15 cm that was directly seeded and established under minimum tillage was the most economically efficient (₦ 1,858 ha^{-1} day^{-1}).

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