J. Agric. Food. Tech., 2(3)41-48, 2012

ISSN 2090 – 424X
Journal of Agriculture and Food Technology
www.textroad.com

Comparative Evaluation of Seven Different Spacing Treatments on Weeding Regimes, Tuber Yield, Stem and Leaf Biomasses of Cassava (*Manihot esculenta* L)

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ABSTRACT

The effect of seven spacing treatments on weeding regimes, tuber yield, stem and leaf biomasses of cassava (*Manihot esculenta*, L) was investigated at Akure in the rainforest zone of Nigeria. The seven spacing treatments were 100x100cm (10,000 plants), 90x70cm (15,000 plants/hectare), 100cmx50cm (20,000 plants/ha), 70x50cm (28,600 plants/ha), 80x50cm (25,000 plants/ha), 65x50cm (30,500 plants/ha), 65x50cm (30,500 plants/ha) and 50x50cm (40,000 plants/ha) with four replications, arranged in a randomized complete design (RCB). A spacing treatment of 100cmx100cm which was conventionally used by farmers served as the control treatment. The results showed that these spacing treatments significantly (P<0.05) influenced the cassava growth parameters, tuber yield, stem and leaf biomasses and weeding regimes. For the growth parameters, 100x100cm spacing treatment had the highest values of plant height, stem girth and leaf area followed by 100x50cm and 70x50cm. 100x100cm spacing increased the plant height, leaf area and stem girth by 13%, 4.5% and 12% compared to that of 100x50cm spacing. For tuber yield, stem and leaf biomasses of cassava, 100x100cm spacing had second best value for tuber yield and least value of leaf biomass with the highest weeding regime (four times) compared to others. 90x70cm spacing ranked third in term of tuber yield, tuber diameter and population while 100x50cm spacing had the highest tuber weight (57.7t/ha) and second best tuber diameter compared to others. 80x50cm 70x50cm spacing ranked fourth and fifth in terms of tuber weight and diameter performance respectively. Generally, 100x50cm spacing had good and balanced potentials for cassava root tubers, leaf and stem biomasses. Both 65x50cm and 50x50cm spacing had the least tuber yield performance but had good potentials for stem and leaf biomasses and reduced cost of weeding by 50% compared to 100x100cm. The 50x50cm spacing treatment had the highest gross income, net income gain and BC ratio of 6.343 with the highest contributions from sales of cassava stem cuttings and huge leaf biomass compared to BC 2.92 in 100x100cm spacing treatments respectively. In these experiments, 100cmx50cm, spacing was recommended for tuber yield while 50x50 cm spacing was recommended for leaf and stem biomasses.

Key words: Spacing, weeding, cassava tuber, leaf and stem biomasses.

1. INTRODUCTION

Cassava (*Manihot esculentum*) is a major tuber crop grown by farmers for income and as staple foods. In recent times, it has become an important crop for making industrial starch, tapioca, cassava chips and other processed products in Nigeria which helped to enhance export drive for increased foreign exchange, provision of employment opportunities and for meeting local consumption [1].

In spite of the above mentioned importance of the crop to economic development, the optimum yields of cassava to meet the needs of the society, have not been attained and the fundamental problems are that the present level cultivation of the crops is low and cannot meet up with the local consumption talk less of the cassava processing industries and export drive, coupled with the continued decline in soil fertility and weed competition.

In order to sustain the demand for cassava to meet both local and export needs of the nation, there is need to increase the present cassava plant population per hectare from the present 10,000 plants to between 16,000 and 40,000 plants per hectare as well as maintaining soil fertility.

Interestingly, massive production of cassava at higher plant population will provide substantial leaf biomass for animal production as well as increasing the number of stem cutting available for sustainable cultivation of cassava. A farmer can make between ₦100,000 and ₦300,000 from sales of cassava stem cutting only, in addition to the sales of the tubers [2].

Having reviewed literature critically, except [3, 4, 5] who worked on the morphology of cassava and plant population densities in cassava/maize mixture, there is scarcity of research reports on determining the best of optimum plant population of cassava that will give good performance of tuber yield, stem cutting and leaf biomass using appropriate spacing, thus, there is justification to look into this research for future development.

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The objective of this research are to determine the optimum plant population of cassava using seven spacing treatment that will give the highest tuber yield, leaf biomass and stem cuttings and best weeding regimes for cassava sole cropping in Akure, Ondo State, Nigeria and to determine the economic benefit cost of cassava production under these spacing treatments.

2. MATERIALS AND METHODS

2.1 Description of the study area

The experiment was carried out at Akure in the rainforest zone of Nigeria between August 2004 and September 2005 and was repeated between March 2006 and April 2007 to validate the results. The soil is sandy clay loam, skeletal, kaolinitic, isohyperthermic oxic paleustalf (Alfisol) [6]. The annual rainfall is between 1100 and 1500mm while the average temperature is 24^{o}C. The land had been under continuous cultivation for 5 years.

2.2 Soil sampling and analysis before panting

Thirty core samples were collected randomly from 0-15cm depth on the site using soil auger, mixed thoroughly and the bulk sample was taken to the laboratory, air dried and sieved to pass through a 2 mm screen for chemical analysis. The soil pH (1:1 soil/ water) and (1:2 soil/0.01M $CaCl_2$) solution was determined using a glass calomel electrode system [7] while organic matter was determined by the wet oxidation chromic acid digestion method [8].

The total nitrogen was determined by the micro kjedahl method [9] while available soil phosphorous was extracted by the Bray P1 extractant and measured by the Murphy blue colouration on spectronic 20 [10] while K, Ca, Na were determined with flame photometer while Mg was determined with an atomic absorption spectrophotometer [11].

The exchangeable acidity (H^+ and $A1^{3+}$) were determined using 0.01M HCl extracts and titrated with 0.1M NaOH [12] while the micronutrient (Mn, Cu, Fe and Zn) were extracted with 0.1M HCl [13] and read on Perkin Elmer atomic absorption spectrophotometer. The mechanical analysis of the soil was done by the hydrometer method [14].

2.3 Field Experiment

The land was cleared, ploughed, harrowed, ridged and laid out into plots. Each individual plot size is 12x17m^2 (204m^2) totaling 30 plots. There were discards of 1mx1m between and within plots for easy accessibility and for carrying out other cultural practices without trampling on the cassava plants. There were seven spacing treatments namely; 90cmx70cm, (15,000 plants/ ha), 100x50cm (20,000 plant/ha), 70x50cm (28,600 plant/ha), 80x50cm (25,000 plant/ha), 65cmx 50cm (30,800 plants/ha) and 50cmx50cm (40,000 plants/ha with four replications and arranged in a randomized complete block design (RCB). A spacing treatment of 100cmx100cm which was conventionally used by farmers served as the control treatment. Six tonnes/ha of poultry manure was applied basally to the field to supply initial nutrients and allowed 7days to decompose. Planting of viable cassava stem cuttings of 30572 variety into different plots based on the above mentioned spacing started on September 6 and ended on September 13, 2004. Specific labels sharing these spacing treatments were placed on the plots for easy identification and data collection.

The plots were sprayed with pre-emergence herbicides Atrazine and Gramozone to kill weed seeds. The stem cuttings sprouted and the first weeding took place after two months of sprouting. Another three weeding were done for 100cmx100cm while 65cmx50cm, 50cmx50cm and 80cmx50cm spacing treatments had only one extra weeding after the first weeding. At 3 months after sprouting, Avesthrin (Cypermethrin 10% EC) was sprayed at 10ml per 10l of water to control white flies responsible for the widespread of cassava mosaic disease.

Field data collection on the growth parameters (plant height, leaf area and stem girth) were done every week starting from the 3rd week after sprouting till four months after sprouting. Another spraying of Avesthrin (a.i Cypermethrin 10% E.C) to control white flies was done at 6 months after sprouting. The bushes adjourning the cassava plantation was cut back to prevent rodent and grass cutter attack of cassava plants.

At 11 months after sprouting on the field, sampling harvest was done on August 22, 2005 using 3mx3m for each following parameters were determined which include tuber weight (kg), tuber diameter (cm), tuber population per plant, leaf biomass (weighed of 50 leaves (kg), and number of leaves per plant, weight of plantable stem cuttings (g), number of weeding regimes, estimate cost of weeding (₦12,000 per hectare), weight of litter fall and number of good stem cuttings.

2.4 Statistical analysis

The average data for the 2 years on the growth parameters, tuber, stem and leaf yield parameters of the two experiments were analysed and subjected to ANOVA F-test and their means were separated using Duncan Multiple Range Test at 5% level of significance [15].

3. RESULTS

3.1 Soil chemical composition before planting of cassava

The chemical properties of the soil before planting of cassava are presented in Table 1. Based on the established critical levels for soils in South west Nigeria, the soil was slightly acidic with pH 5.6 and low in organic matter compared to the critical level of 3% O.M [16]. The total nitrogen is less than 0.15% which is considered optimal for most crops [17].

Table 1: Chemical analysis of the soil before planting

Soil parameters	Values
Soil pH (H_2O)	5.60
Soil pH O.M $CaCl_2$	5.20
Organic matter (%)	0.45
Nitrogen (%)	0.09
Available P (mg/kg)	5.80
K^+ (mmol/kg)	0.15
Ca^{2+} (mmol/kg)	0.11
Mg^{2+} (mmol/kg)	0.09
Na^+ (mmol/kg)	0.08
H^+ (mmol/kg)	4.30
Al^{3+} (mmol/kg)	1.49
Fe (mg/kg)	8.50
Zn (mg/kg)	3.80
Mn (mg/kg)	1.84
Cu (mg/kg)	2.20
Sand (%)	79.5
Silt (%)	14.8
Clay (%)	5.70
Bulk density (mgm^{-3})	1.60
% Porosity	41.81

The available P was less than 10mg/kg P considered as adequate for crop production [16]. The exchangeable K, Ca, Mg and Na were lower than 0.2mmol/kg critical levels [18] while the soil bulk density is high (1.60mgm^{-3}).

3.2 Effect of different spacing treatment on the growth parameters of cassava.

There were significant increases ($p<0.05$) in the plant height, leaf area and stem girth of cassava under different spacing treatments (Table 2). The spacing 100x100cm treatment gave the highest values of cassava plant height, leaf area and stem girth followed by 100x50cm and 70x50cm respectively. For instance, 100x100cm spacing treatment increased the plant height, leaf area and stem girth of cassava by 13%, 4.5% and 12% respectively compared to 100x50cm spacing. The 65x50cm and 50x50cm spacing treatments had the least values of cassava plant height, leaf area and stem girth.

Table 2 Effect of different spacing treatments on the growth parameters of cassava

Treatment spacing (cm)	Plant height (cm)	Leaf area (cm^2)	Stem girth (cm)
100x100	79.66e	327.02g	6.12e
90x70	59.40a	258.95a	5.40d
100x50	69.70d	312.12f	5.40d
80x50	63.95b	294.12d	5.18bc
70x50	67.13c	305.00e	5.09b
65x50	64.06b	274.35b	4.93b
50x50	67.26c	279.93c	4.61a

Treatment means within each group followed by the same letters are not significantly different from other using Duncan Multiple Range Test at 5% level.

3.3 Effect of different spacing treatments on the tuber, stem and leaf biomass yield of cassava.

There were significant increases ($p<0.05$) in the tuber, stem and leaf biomass yield of cassava under different spacing treatments (Table 3). For 100x100cm spacing, the plant population is 10,000 plants. The tuber weight is 54.4 t/ha while the tuber diameter and population values were 5.1cm and 7 respectively. The implication is that the convectional spacing employed by farmers would give an average of 54.4 t/ha tuber but the cost of weeding was at the highest at ₦48,000 which might not give much profit margin (Table 4). The weight of 50 leaves sampled and leaf population were 0.11kg and 103 in 100x100cm compared to 0.25kg and 405 in 50x50cm spacing showing that the leaf biomass was the least of all the spading treatments.

Table 3 Effect of different spacing treatments on the tuber, stem and leaf yield of cassava

Spacing treatment	Estimated plant population per hectare	Tuber weight per 3cmx3cm plot size (kg)	Tuber weight per hectare (tonnes/ ha)	Tuber diameter (cm)	Number of tubers per plant	Leaf biomass		Weight of plantable stem cuttings	Number of good stem cuttings	Number of weeding regimes
						Weight of 50 leaves (kg)	Number of leaves			
100x100cm	10,000	49f	54.4f	5.1	7c	0.11a	103a	1.06d	22d	4
90x70cm	15,000	47e	52.2e	4.6	5b	0.13b	176c	0.76b	20b	3
100x50cm	20,000	52g	57.7g	4.9	4a	0.15c	155b	0.75b	21c	3
70x50cm	28,600	30c	33.3c	3.1	4.6a	0.12ab	105a	1.30f	22d	3
65x50cm	30,800	26b	28.8b	2.6	7c	0.2e	244d	1.1de	28f	2
80x50cm	25,000	45d	50d	4.5	9d	0.17d	366e	0.91c	25e	3
50x50cm	40,000	24a	26.6a	1.8	5f	0.25f	405f	0.58a	19a	2

Treatment means within each group followed by the same letters are not significantly different from other using Duncan Multiple Range Test at 5% level.

Farmers employing this spacing might not make much money from the export of the leaf biomass, also, the litter fall on the ground was 50g thick compared to 250g of 50x50cm. The litter fall on the ground was the least signifying fastest rate of erosion and soil fertility decline than other treatments. In addition, good stem cuttings were obtained from the plots for the planting season.

For 90x70cm spacing treatment, it ranked third in term of tuber weight (52.2t/ha) tuber diameter (4.6cm) and tuber population (5). It has a population of 15,900 plants per hectare and the weeding rate was three time at ₦12,000 each (₦36,000:00). The implication is that farmers adopting this spacing for cassava would save at least ₦12,000 from weeding cost compared to 100x100cm, thereby, enhancing higher profit margin.

In addition, the weight of 50 leaves 0.13kg and leaf population is 176, showing higher leaf biomass than the conventional spacing 100x100cm. The litter fall is 121.1g showing that the thickness might influence the rate of erosion and increased soil fertility maintenance. Nevertheless, it has lower weight of plant able stem cuttings than 100x100cm spacing.

The 100x50cm spacing treatment, it had the highest tuber weight (57.7t/ha) and second best tuber diameter compared to others. It also had plant population of 20,000 plants per hectare, hence increasing the plant population and also reduced the weeding regimes to three compared to four or more weeding regimes in 100x100cm spacing which led to reducing the cost of weeding by ₦12,000.

In term of leaf biomass, the weight of 50 leaves was 0.15kg and leaf population of 155 which were higher than that of the convectional spacing of 100x100cm used by farmers showing that they would make additional income from sales of leaves as source of feed to animals. The litter fall weight was 155.4g showing that the spacing had great potential in reducing soil erosion fertility decline.

Table 4 Effect of different spacing treatments on the weeding regimes, cost of weeding and litter fall (g) of cassava

Spacing treatments control	Estimated plant population per hectare	Number of weeding regimes	Estimated cost of weeding	Weed flora	Soil erosion/fertility litter fall (g)
100x100	10,000	4c	48,000	Elephant grass, spear grass, *Tridax procumbens*	50.0a
90x70	15,900	3b	36,000		112.1b
100x50	20,000	3b	36,000		155.4c
70x50	28,600	3b	36,000		199.6e
65x50	30,800	2a	24,000		200.8e
80x50	25,000	3b	36,000		180.0d
50x50	40,000	2a	24,000		250.0f

Treatment means within each group followed by the same letters are not significantly different from other using Duncan Multiple Range Test at 5% level.

In term of stem biomass, it had on average of 21 good stem cuttings per sampled plants showing that farmers would also make money from sales of stem cuttings (i.e. planting materials). Generally, the 100x50cm had good potentials for root tuber, leaf biomass and stem biomass yield.

For 70x50cm spacing treatment, the plant population is 28,600 plants per hectare. It was fifth in performance in term of tuber weight (33.3t/ha) and tuber diameter (3.1cm). Thus, the increased cassava population also reduced the weeding cost by ₦12,000 for farmers.

The leaf biomass for 50leaves (0.12kg) and leaf population were slightly higher than that of 100x100cm spacing. Nevertheless, the weight of litter fall of 199.6g showed that it had great potential in reducing rate of erosion. In addition, this spacing treatment had the highest weight of plantable stem cuttings (22) per sampled plants.

For 80x50cm spacing treatment, the plant population is 25,000 per hectare and it was fourth in performance in term of tuber weight 50 tonnes/hectare and tuber diameter of 4.5cm compared to that of 100x100cm, 100x50cm and 90x70cm spacing. This showed great potentials in producing good tuber yield, interestingly it had the highest number of tubers (9) per plant. The spacing also reduced the cost of weed by ₦12,000 compared to the convectional spacing of 100x100cm used by the farmers.

In terms of leaf biomass, the weight of 50 sampled leaves and leaf population were 0.17g and 366 respectively showing its potential in producing cassava leaves for export or as source of feed to animals or for food consumption.

The weight of litter fall was 180kg showing that the higher plant population reduced the rate of erosion. In term of stem biomass, it had on average 25 good stem cuttings per sampled plants and third best weight of plantable stem cutting implying that farmers using this spacing for cassava would receive additional income from sales of stem cuttings.

For 65cmx50cm spacing, the plant population is 30,800 plants per hectare and its performance was sixth in terms of tuber weight 28.8 tonnes/hectare (26kg/9m^2) and tuber diameter of 2.6cm. This implied that it might not be good for cassava tuber yield production, however, in term of leaf biomass, it had second best weight of sampled 50 leaves (0.2kg) and an average leaf population of 244.

For the stem biomass, the number of good stem cuttings were 28 per sampled plants and farmers would make additional income from sales of stem cutting. However, the major problem was that the stems were thin in nature caused as a result of etiolation. In term of soil fertility maintenance, the litter fall weight was 200.8g which effectively checked the rate of erosion and weed growth.

The weeding rate was done two times before total covering of the land by the plants. The implication is that this spacing had reduced the cost of weeding from ₦48,000 in 100x100cm spacing to ₦24,000 which is 50% reduction. This is a significant achievement considering the fact that the low cassava tuber yield would have been compensated for by cost of production, high returns on stem cuttings and leaf biomass.

For 50x50cm spacing treatment, the plant population is 40,000 plants per hectare and its performance was the least in term of tuber weight (26.6 tonnes/ha or 24kg/9m^2) and tuber diameter of 1.8cm. In term of leaf biomass, it had the highest weight of sampled 50 leaves (0.25kg) and leaf population of 405 implying that this spacing treatment would be the best for farmers wishing to produce cassava for leaves export or as source of feed to animals.

It also had the highest weight of cassava leaf litter fall (250g) showing that it reduced most the rate of erosion and soil fertility decline. This was evident on the field as it had little or no weed growth. This led to low weeding rate of two compared to four or more weeding rates in 100x100cm spacing and a benefit cost gain of ₦24,000 from weeding exercise alone.

In term of stem biomass, it had the least number of good stem cuttings of 19 and weight of plant able stem cuttings (0.58g) because of high population and etiolation. This spacing is also good for those who are interested in setting up cassava starch and tapioca production enterprise because the large number of small sized tubers available which are not lignified.

3.4 Economic cost benefit for tuber, stem and leaf biomass yield under different spacing treatments

Table 5 presents the yields of tuber, stem and leaf of cassava, the gross income derived from them, the variable cost, net income and benefit cost ratio under different spacing treatments. 100x100cm spacing treatment had the least net income gain of ₦567,800 and benefit cost (BC) ratio of 2.92 compared to net income gain of ₦1448,200 and BC ratio of 6.343 in 50x50cm spacing (40,000 plants).

The highest contribution to the BC ratio and net gain income in 50x50cm spacing came from the sales of stem cuttings and huge leaf biomass which are at present considered as negligible contributions financially by majority of farmers. For-instance, in 50x50cm spacing, leaf biomass/hectare gave about 10t/ha and 1 million naira from sales compared to ₦110,000 in 100x100cm spacing.

Therefore, the higher the BC ratio of an enterprise such as cassava farming, the more profitable it is to the farmers. Interestingly, the lower tuber yields in 50x50cm, 65x50cm spacing had been effectively compensated for by the high stem and leaf yields.

Table 5 The economic cost benefit for cultivation of cassava under different spacing treatments

Spacing treatment	**Estimated plant population per hectare**	**Cassava tuber yield per hectare (t/ha)**	**Cost of tuber per tonne at ₦12,000 tonne**	**Cassava stem cuttings**		**Estimated leaf biomass yield**		**Gross income tuber + stem + leaf yield (₦)**	**Variable costs (₦)**	**Net income (₦)**	**Cost-Benefit Ratio (BC)**
				Yield/ha bundles (50 cuttings each)	Cost of stem per bundle at ₦500	Weight of leaves (kg/ha)	Cost of leaf biomass at ₦100 per kg/ha				
100x100cm	10,000	54.4	652,800	200	100,000	1,100	110,000	826,800	295000	567,800	2.92
90x70cm	15,000	52.2	626,400	320	160,000	2,067	206,700	993,100	279000	714,100	3.56
100x50cm	20,000	57.7	692,400	400	200,000	3,000	300,000	1,192,400	279000	913,400	4.27
70x50cm	28,600	33.3	399,600	580	290,000	3,432	343,200	1,032,600	279000	753,600	3.70
65x50cm	30,800	28.8	345,600	620	310,000	6,160	616,000	1,271,600	271000	1,000,600	4.69
80x50cm	25,000	50.0	600,000	500	350,000	4,250	425,000	1,275,000	279000	996,000	4.56
50x50cm	40,000	26.6	319,200	800	400,000	10,000	1,000,000	1,719,200	271000	1,448,200	6.34

Note: The difference between the variable costs for different spacing is due to the differences in cost of weeding.

The 100x50cm (20,000 plants/hectare) had good financial returns from the tuber, stem and leaf biomass totaling ₦1192400.00, net income gain of ₦913,400 and BC ratio of 4.27 which ranked fourth after 50x50cm, 80x50sm, 65x50cm spacing treatments respectively.

4. DISCUSSION

The initial low soil fertility caused as a result of continuous cultivation of land for five years was solved by the general basal application of 6t/ha of poultry manure to the soil before cultivation of cassava. Therefore, the application of the poultry manure had enhanced growth of cassava in all the spacing treatments.

The low plant population of 10,000 in 100x100cm encouraged quick growth of weeds, thereby increasing the cost of production compared to 65x50cm and 100x50cm spacing. The implication is that the high cost of production would reduce the profit margin of farmers hence, the least value of BC ratio. This observation agreed with the views of [19] who reported faster emergence of weeds in Indian spinach plots with wider spacing because of the high isolation rate which encouraged weed competition and high weed density.

The low plant population in 100x100cm spacing also reflected in the least values of leaf biomass and liter fall. The implication is that the wider planting spacing between cassava plants exposed the soils to torrential rains and run-off which resulted in fastest rate of erosion and probably fertility decline than other spacing treatments. This observation agreed with [20] who reported that low litter fall in yam/maize rotation resulted in low fertility status and increased the rate of erosion.

In addition, the second best yield of cassava tubers, presence of good stem, cuttings and good growth parameters in 100x100cm could be attributed to the low plant population which encouraged maximum exploitation of nutrients by the cassava crops for big tubers (tuber girth or diameter), good leaf area and stem girth values. This work differed from that of [21] who reported reduction in yield components of intercropped cassava-groundnut mixture at that spacing compared to the corresponding sole crop of cassava.

The increased plant population in 90x70cm spacing to 15,000 plants reduced the weeding rate from four in 100x100cm spacing to three. The implication is that farmers adopting this spacing for cassava would save ₦12,000 from weeding cost (25% reduction) and consequently, enhanced higher profit margin. This work differed from that of [22] who did not report weeding regimes in his experiment on cassava-maize intercrop.

The increased plant population of cassava in 90x70cm, 100x50cm, 65x50cm, 80x50cm and 50x50cm can spacing was responsible for higher leaf biomass, litter fall weight, stem cuttings and leaf population compared to the 100x100cm. The implication is that farmers adopting these spacing treatments would make additional income from export of leaf biomass hence, they had the highest BC ratio values and there would be a better crop/livestock enterprise development because of the leaves serving as feeding materials. This observation differed from the previous research work of [23] who did not consider leaf and stem biomass parameters in his experiment on cassava based intercropping system. However, the presence of some etiolated stems of cassava in 65x50cm, 50x50cm spacing could be as a result of intra specific competition among the plants for nutrients, water and air.

The highest tuber weight, moderate tuber diameter, good stem cuttings and leaf biomass in 100x50cm compared to 100x100cm, 80x50cm, 65x50cm could be due to its moderate plant population which reduced intra specific competition between them, thereby resulting into good tuber yields, leaf biomass and stem cutting yields and BC ratio of 4.27. This observation agreed with the work of [4] who reported that 20,000 plants in maize/cassava intercrop gave significant tuber and grain yields of both crops compared to low yields in 30,000 plants/hectare, 40,000 plants per hectare and 50,000 plants per hectare respectively. However, his experiment did not consider leaf and stem biomasses components of the work.

Therefore, the low tuber weight and diameter of cassava in 65x50cm, 50x50cm and 70x50cm could be due to the intra specific competition between the plants as a result of high plant population. This observation agreed with that of [4] who reported that production of small sized cassava roots was associated with increasing population of maize or cassava in the intercrop, between 30,000 and 50,000 plants, thus there will be decline in quantities of commercially acceptable roots.

However, the production of many small sized tubers from these spacing treatments will help to serve as suitable raw material for starch and tapioca industries. This is because of low lignin content. For-instance, the presence of 40,000 or more small sized tubers will go a long way in meeting raw materials needs of cassava processing industries.

In-addition, the 50x50cm and 65x50cm spacing had the highest leaf biomass, and litter fall which would serve as additional source of income for farmers. This is against the backdrop that farmers only derived maximum benefits from cassava tubers alone and neglected the income to be derived from stem cuttings and leaf biomass. For instance, many East African countries such as Democratic Republic of Congo, Tanzania, Kenya and Rwanda used cassava leaves for soup preparation and also to feed their livestock as observed by [24].

Furthermore, the weeding regimes in these spacing treatments reduced from four to two signifying a remarkable reduction of ₦24,000 (50%) in weeding cost. This would definitely reduce the cost of production and increase profit margin analyses for the farmers. This observation agreed with the views of [5] who reported that optimal and higher plant density of cassava/maize mixture covered the ground, thereby, reducing weed density, growth and competition as well as covering the soil against soil erosion.

Also, the highest values of litter fall in 50x50cm and 65x50cm spacing signified the usefulness in checking the rate of erosion and fertility decline. The higher value for litter fall will preserve the soil physical and chemical attributes for continuous productivity of cassava crop by farmers. This differed from that of [25] who reported decrease in soil organic carbon dynamic and nutrients in cassava based intercropping systems at such higher plant population (30,000 and 40,000 plants per hectare).

The 50x50cm spacing had the highest value of BC ratio, gross income, net income gain and this could be due to its highest contributions from sales of stem cuttings and leaf biomass which are at present considered as insignificant by majority of farmers. [26] reported that the higher the BC values of an enterprise, the more profitable it is financially. This should be considered by stakeholders so that maximum financial benefits could be derived from cassava production.

5. Recommendation and Conclusion

From this experiment, the spacing treatments for cassava at 100x50cm (20,000 plants per hectare), 50x50cm (25,000 plants) and 90x70cm (15,900 plants per hectare) compared favourably with the convictional spacing 100x100cm (10,000 plants per hectare) in term of tuber yield, weeding rate reduction, low cost of production, leaf biomass and litter fall while 65x50cm (30,500 plants per hectare) and 50x50cm (40,000 plants per hectare) had great potentials for stem and leaf biomass yield of cassava.

These recommendations are that farmers who are interested in commercial cassava tuber yields should adopt 100x50cm, 90x70cm and 80x80cm spacing while those who are interested in leaf and stem biomass yields should adopt 65x50cm and 50x50cm spacing treatments. This will ensure maximum income benefits from the sales of tubers, stem cuttings and leaf biomass by the farmers compared to the present experience of getting income from cassava tubers alone.

REFERENCES

[1] O.N. Adeniyan, Evaluation of NPK fertilizer and poultry manure for soil fertility enhancements and cassava production in two agro ecologies of South west Nigeria. Nigeria Jour. of Soil Sci., Vol. 18, (2008) 48-53.

[2] APAA, Official Bulletin of Ondo State Accelerated Poverty and Agriculture, Agency Vol. (1) (2007) 6-7.

[3] F. Nweke, Cassava is a cash crop in Africa. IITA (International Institute for Tropical Agriculture), Research 14/15 (1997), 26-27.

[4] B. Osundare, Effect of increasing density in a cassava/maize (Zea Mays L.) population density in a cassava/maize mixture on major soil nutrients and performance of cassava (*Manihot esculenta* Crantz) in Southwestern Nigeria. Nigerian Journal of Soil Sci. (18) (2008) 60-67.

[5] A.Y. Rye, Improving the productivity of cassava/maize mixture through the determination of an optimal maize planting density. Crops Ecology, 5(2) (2007) 222-226.

[6] Soil Survey staff, Soil Taxonomy. A basic system for soil classification for making and interpreting soil surveys. USDA Handbook No 436 (1999), Washington, D.C. USA.

[7] L. Crockford, R. Nowell. Laboratory manual of physical chemistry. Exp 31 and 32, (1956) John Wiley and Sons, New York.

[8] A. Walkley, I.A. Black, An examination of degtajaroff method for determining soil organic matter and a proposed modification of the chromic acid filtration. Soil Sci. 37, (1934) 29-38.

[9] AOAC, Official methods of analysis 12th ed, Association of Official Analytical Chemists, Arlington, VA. (1970).

[10] J. Murphy, J.P. Riley, A modified single solution method for determination of phosphate in natural water. Analytical Chem. Acta. 27 (1962) 31-36.

[11] M.L. Jackson, Soil Chemical analysis Englewood Cliffs N.J. 1958. Prentice Hall (1958) 57-67.

[12] E.O. Mclean, Aluminum P. 927-932 MCA Black (Eds): Methods of soil analysis part 2, Agronomy 9, Amer. Soc. Agron: Madison Wisconsin, U.S.A. (1965).

[13] J.A. Ogunwale, E.J. Udo, A laboratory manual for soil and plant analysis. Agronomy Dept. University of Ibadan, Nigeria (1978) 201-206.

[14] H. Bouycous, Mechanical analysis of soils using hydrometer method. Analytical Chem. Acta. 22 (1951) 32-34.

[15] K.A. Gomez, A.A. Gomez, Statistical procedures for Agricultural Research 2nd edition. John Wiley and Sons, New York (1984).

[16] A.A. Agboola, and R.B. Corey. Soil testing N,P,K for maize in the soil derived from metamorphic and igneous rocks of Western State of Nigeria. Nigeria Jour. of West African Sci. Assoc. 17(2) (1973) 93-100.

[17] R.A. Sobulo, O.A. Osiname, Soils and fertilizer use in Western Nigeria. Tech. Bull. No 11, Institute of Agricultural Research and Training, University of Ife, Nigeria. (1981) 8-9.

[18] O.O. Folorunso, A.A. Agboola, G.O. Adeoye, Use of Fractional recovery (FR) to calculate the K needs of maize (Zea mays). Jour Tech. Educ. 2(1) (1995) 65-75.

[19] M.A.K. Smith, Seedling emergence, growth and yield response of Indian Spanish (Basella spp) to depth of planting soil type and weed competition: In proceeding of the 22nd Annual conference of Horticultural Society of Nigeria, Ibadan, Nigeria (2002) 6-10.

[20] F.K. Salako, G. Tian, G. Kirchhof, Soil Chemical properties and crop yield on an eroded alfisol managed with herbaceous legumes under yam- maize rotation. Nigerian Jour of Soil Sci. (2008) 18: 1-9.

[21] O.P. Aiyelari, H. Tijani-Eniola, Influence of sowing density of groundnut on the performance of cassava and groundnut in an intercropping system. Applied Trop. Agric. 14 (1,2) (2009) 9-15.

[22] C.A. Ogungbe, Investigation of the traditional mixed cropping systems in southwestern Nigeria. Journal of Sustainable Agriculture, 2 (1) (2004) 77-81.

[23] P.O. Olsa, Evaluation of the productivity of cassava-based intercropping systems. Cropping Systems Research, 5 (3) (2006) 41-44.

[24] F.K.N. Cam, Studies on the effects of cassava based intercropping systems on soil fertility in the humid tropics. Soil Fertility Research, 6(6) (2007) 801-807.

[25] B.T. Kutz, Influence of cassava-based intercropping system on soil organic carbon dynamics in the tropical agriculture. Tropical Farming Systems, 3 (2004) 304-309.

[26] J.A. Adegeye, Small scale business, you can start with little or no capital investment. Josadeg Nigeria Limited, Ibadan, Nigeria (2004) ISBN 978-2397-059.