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Effects of Weed Management on Soil Microbiological Properties in Groundnut Production

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

To quantify the efficacy of effective weed control methods and spacing of groundnut on soil microbiological properties, a field experiment was conducted between 2009 and 2010 at the Teaching and Research Farm of the University of Agriculture, Abeokuta, a sub-humid region of southwestern Nigeria. Treatments were five levels of weed control (codal gold 1.6 kg a.i/ha, codal gold 1.6 kg a.i/ha + hoe weeding, codal gold 2.4 kg a.i/ha, hoe weeding and a control (weedy check); two levels of spacing (15 cm and 25 cm) and eight levels of weeding intervals on soil microbial biomass, nodulation, the biomass of root and shoot as well as yield of groundnut in a split-plot design fitted into a randomized complete block design. The results indicated that both levels of spacing have no significant effect on the soil microbiological parameters, groundnut biomass production, nodulation and yield. So, the levels of weed control have no significant effect on groundnut biomass production and nodulation but showed a significant effect on microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), total fungal count, pod count and pod weight of groundnut with plots kept weedy throughout the experiment at 25 cm intra row spacing having 34 % MBC more than plots kept weed free throughout the experiment at the same spacing.

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Keywords: Herbicides; microbial biomass; nodulation; groundnut biomass; weeding; spacing.

1. INTRODUCTION

Groundnut *(Arachis hypogeal* L.) is of great importance among the world food crops and has been an important cash crop of the Nigerian savannah ecological region, as well as a significant source of foreign exchange for the country [1-6]. Globally, groundnut is grown on 26.4 million hectares in about 100 countries, with a total production of 36.1 million tons and an average productivity of 1.4 million tons per hectare [7]. The strong world demand for groundnut oil and other groundnut products determines the economic significance of the crop [8,9]. Groundnut production is well developed in countries with well-functioning agriculture. Differences in applied technology and management are major factors contributing to regional differences in yield and production.

Weeds are a major constraint to efficient groundnut production, they are known to cause between 34 % and 88 % yield reduction in pod yield [10]. Ayomide [11] reported a 51 % reduction in pod yield of groundnut when weed growth was unrestricted throughout the life cycle of the crop in the northern guinea savannah of Nigeria. According to Devi Dayal [12]; Jat et al. [13], the critical period of weed interference in groundnut is between 3-7 WAP. Weeds compete with crops for light, water and nutrient ions in the soil. Weeds are aggressive, competitive and adaptable and have a marked effect in reducing crop yield [14]. Crops are generally more sensitive to limitations in light, water and nutrients at the three growth stages; early growth, flowering, fruiting and ripening. The damage done by weeds during early growth when both weeds and crops are young is most common and serious, they remove water and nutrients from the plants directly, resulting in a weak, stunted crop giving little or no yield at all [15].

Therefore, the effect of herbicides on legume nitrogen fixation is of great importance and many studies have indicated different effects of herbicides on nodulation and dinitrogen fixation [16]. In most cases, it was found that applied herbicide doses are safe for both nodulation and maintaining full nitrogen. Islam et al. [17] reported that metribum reduced soybeans nodulation and nitrogen fixation by (ARA) by 50% [18] that linuron did not decrease the nitrogen fixation rate while Bentazon affected the growth and reproduction of soil bacteria and micromycetes independence on the concentration and species of microorganism [19]. The physiological and biochemical activities of bacteria with respect to nitrogen fixation, nitrification and CO_2 production were negatively influenced by high concentrations of the herbicides [20].

Therefore, this study was set to estimate the effect of weed interference and plant population density on soil microbial ecology in groundnut rhizosphere and to determine the effect of weed inference and plant population density on the groundnut growth and yield [21].

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil

Field studies conducted at the University of Agriculture, Abeokuta. The experimental site falls within the derived agro ecological zone of southwestern Nigeria. It is on latitude $7^0$25'N and longitude $3^0$25'E with an altitude of 159 m above sea level. The area has s bi-modal rainfall pattern with peaks in June and September and a mean annual rainfall of about 1200 mm.

2.2 Land Preparation and Planting

The land was ploughed twice and harrowed once. The land was divided into three replicates with each replicate having 16 plots of 3 m × 4.5 cm dimensions. Each replicate was split into two halves of 8 plots, and groundnut seeds were planted with a spacing of 75 cm × 25 cm on the first half and a spacing of 75 cm × 15 cm was used on the second half. All three replicates were subjected to the same treatments.

2.3 Experimental Design

The experiment was arranged in a split plot layout fitted into a randomized complete block design with three replicates. The experiment was subjected to 2 main plot treatments and 8 subplot treatments.

2.4 Experimental Setup and Treatments

The treatments consisted of three factors, intra-row spacing (25 cm and 15 cm), weeding interval and weed control methods.

The eight levels of weeding interval include:

1. Weed-free for 3 WAS followed by subsequent weed infestation for the rest of the experiment
2. Weed-free for 6 WAS followed by subsequent weed infestation for the rest of the experiment
3. Weed-free for 9 WAS followed by subsequent weed infestation for the rest of the experiment
4. Weed throughout the experiment
5. Weedy for 3 WAS and subsequently kept weed free for the rest of the experiment
6. Weedy for 6 WAS and subsequently kept weed free for the rest of the experiment
7. Weedy for 9 WAS and subsequently kept weed free for the rest of the experiment
8. Weed throughout the experiment

The five levels of weed control method include:

1. Codal (herbicide) at 1.6 kg a.i/ha
2. Codal (herbicide) at 2.4 kg a.i/ha
3. Codal (herbicide) at 1.6 kg a.i/ha + hoe weeding
4. Hoe weeding at 3 WAS and 6 WAP
5. Weedy check

2.5 Test Crop

The groundnut variety that was planted was RMP 91 which was obtained from the Institute of Agricultural Research (IAR), Samaru.

2.6 Data Collection and Laboratory Analysis

Data was collected on plant height, canopy spread, nodule count, and number of effective and non-effective nodules, fresh and dry weight of the biomass.

2.7 Determination of Microbial Biomass C

Composite moist soil sample throughout mixed was taken and sub samples from each plot. The soil was sieved to remove stones, coarse roots and visible litter. Two sub samples of 10$\pm$ 0.01 g of soil were put into a 50 ml beaker and a third sample of 10$\pm$0.01 g of soil was also put into a 125 ml water-tight bottle. The sample in the bottle was extracted and the first sample was fumigated. The water content of the sample in the beaker was determined. The beaker was then placed in a vacuum desiccator containing 30 ml alcohol-free chloroform evaporates. The tap on the desiccator was closed and the soil was in the dark for 5 days at 25 ^{0}C. After 5 days, the soil was transferred to a watertight 125 ml extraction bottle 50 ml. 0.5 M of K_2SO_4 was added to the bottle and it was stored for 30 minutes. The extract was filtered through a No 42 Whatman filter paper and the filtrate was retained for analysis.

Microbial biomass C = (Extract C_{t1} – Extract C_{t0}) × 2.64

2.8 Determination of Microbial Biomass N

Microbial biomass N can be determined by analyzing for total N in the extract after digestion microbial N = (Extract N_{tl} – Extract N_{t0}) × 1.46.

2.9 Determination of Microbial Biomass P

Microbial biomass P was estimated using a procedure whereby inorganic P was extracted by 0.05 M sodium bicarbonate at pH 8.5. The Extract P was determined by the ammonium molybdate-ascorbic acid method.

Microbial biomass P = (Extract P_{t1} – Extract P_{t0}) × 2.5.

2.10 Total Fungi Count and Total Viable Count

The method used in the laboratory determination of the total fungi was the plate count method and serial dilution techniques which included sterilization of the media and glass ware, inoculation, incubation and counting of the colonies.

2.11 Sterilization of Media and Glass Ware

The agar media include nutrient agar for the isolation of bacteria and potato dextrose-agar for the isolation of fungi were sterilized in an autoclave at 121^{o}C for 15 minutes. The glass wares used i.e. petri dishes, test tubes and pipettes were sterilized at 160 ^{o}C for 2 hours in the oven.

2.12 Inoculation

Ten grammes of the soil sample for each of the plots were taken and placed in a conical flask, mixed with 90 m/s of water and shaken for 15

minutes. Nine millimeters of sterilized water were placed in 8 tests and labelled as 10^1, 10^2, 10^3, 10^4, 10^5, 10^6, 10^7, 10^8. An appropriate series of eight-fold dilutions were prepared using 1 ml of soil suspension from the conical flask to a series of eight test tubes. Aliquot of 1 ml were also transferred and placed in the series of the eight petri-dishes before the media were added and swirled to mix. For the bacteria, 28 g/l of nutrient agar medium was used while 39 g/l of potato dextrose agar medium was used for fungi. The agar media in the petri-dishes were left to solidify and then they were inverted before being placed in the incubator.

2.13 Incubation

The nutrient agar petri-dishes were incubated at 37 ^{0}C while potato dextrose agar petri-dishes were incubated at 25 ^{0}C.

2.14 Counting of Colonies

The colonies counting for bacteria were done after 36 hours of incubation while fungi were counted after 48 hours of incubation and the numbers were recorded. The colony forming units ($Cfug^{-1}$) of soil were calculated as

Population of dry soil (g^{-1}) = Average count × dilution / Dry weight of moist soil (1 g)

2.15 Particle Size Analysis

Particle size analysis was carried out on the soil sample. The mechanical analysis of sand, silt, and clay was determined using the Hydrometer method. 50 g of soil was dispersed using Calgon and left for 24 hours. This was poured into a 100 m/s measuring cylinder and made up to the mark.

The first hydrometer reading was taken after 2 hours for clay particles

The hydrometer reading of Blank was taken for the reading separately. The percentage of sand, silt, and clay in the fraction are calculated as follows:

1st reading indicates silt and clay fraction
2nd reading indicates clay fraction

Therefore, silt = 1st treading – 2nd reading

Since sand + silt – clay = 100

Therefore, sand = 100- 1st hydrometer reading

2.16 Soil pH

pH of the soil was determined by using a glass electrode pH meter. A soil solution of ratio 1:1 was used by weighing 10 g of soil into sample bottle and adding 10 m.s of distilled water. The solution was shaken with mechanical shaker for 30 minutes at 250 revolution per minute. The solution was allowed to settle for 15 minutes and the reading was taken using a pH meter.

2.17 Determination of % Organic Carbon

This was determined using Walkey-Blakey method. One gramme of 0.5 mm sieved soil was weighed into a flat bottom flask. Ten millimeter of potassium dichromate ($K_2Cr_2O_7$) was added. This was swirled to mix before 20 m/s of concentrated H_2SO_4 was added. After the addition of the concentration H_2SO_4 heat was generated to drive the reaction to completion. The flask was allowed to stand for 30 minutes before the solution was diluted with 100 ml of diluted water, two drops of ferroin indicator was added to the whole mixture and titrated against 0.5 N Iron Sulphate (Fe_2SO_4). The end point was through the development of the maroon colour and the percentage of organic carbon was determined mathematically.

$$\% \text{ Organic Carbon} = \frac{(B-T) \times 0.5N \times 0.003 \times 1.33 \times 100}{\text{Weight of soil (g)}}$$

Where:

B – Blank titre value
T – Sample titre value
0.5 – Normality of $FeSO_4$ used
0.003 – Milli equivalent of carton

2.18 Available Phosphorus

The available phosphorus was determined from the soil Bray – 1 method. Five gramme of sieved soil samples was placed in a clean plastic bottle, 25 ml of a mixture of ammonium fluoride and hydrochloric acid was added to it and was placed on a mechanical shaker for 30 minutes, and it was allowed to settle for some time before it was filtered using funnel and filter paper into another bottle. The available phosphorus was determined in the extract using a spectrophotometer

2.19 Total Nitrogen

About 0.2 g of ground soil was weighed and a 4.4 ml digestion mixture was added to each tube

and digested at 360 ^{o}C for 2 hours until the solution was colorless. The solution was allowed to cool, then 50 ml of water was added consciously and allowed to cool, more water was added to the solution to make up 100 ml after cooling it. The solution was allowed to settle; the clear solution was used for the analysis.

$$\text{Total N (\%)} = \frac{(\text{T x } 0.1 \text{ x } 0.001 \times \frac{\text{S}}{\text{A}})}{\text{W}} \times \frac{100}{1}$$

*- conversion factor from mg to g
T- Corrected titre (ml)
S- Final digest solution volume (ml)
A- Aliquot volume (ml)
W – Sample weight (g)

2.20 Exchangeable Cation

The exchangeable cation of the soil was analyzed using an Atomic Absorption Spectrometer to determine cations like Mg^{2+}, Ca^{2+} and Na^{+} K^{+} by flame photometer after extraction with Ammonium acetate.

$$\text{Saturation \%} = \frac{\text{Ca} + \text{Mg} + \text{K} + \text{Na} \times 100}{\text{CEC}}$$

2.21 Exchangeable Acidity

Exchangeable acidity was determined using titration methods. 5 g of 2 mm sieved soil was weighed into a sample bottle, 25 ml of KCl was added into it, shaken for 1 hour and allowed to settle.

The filtrate was transferred into a conical flask 25 m/s of KCl was added to the filtrate, and 5 drops of phenolphthalein indicator were added into it and titrated with 0.1 M NaOH solution. This was also carried out on the blank

Exchangeable acidity = End point – Blank value

2.22 Data Analysis

Data collected were subjected to correlation analysis and Analysis of Variance (ANOVA) according to the procedures outlined by Steel and Torrie (1960). `The means were separated using the Least Significant Difference (LSD).

3. RESULTS AND DISCUSSION

Table 1 showed that the soil was sandy loamy from the particle size analysis, the pH of the soil was 6.8; hence the soil was slightly acidic. Cation exchangeable capacity was 4.01 and the carbon to Nitrogen ratio was 9.86. The soil was very low in total nitrogen and available phosphorus.

Table 2 showed that at 25 cm and 15 cm spacing, there were no significant differences recorded at $p \leq 0.05$ for fresh nodule weight, dry nodule weight, number of nodules, and number of non-effective nodule, but there were significant differences in number of effective nodules at $p \leq 0.05$ and 15 cm spacing indicated the highest the highest mean and 25 cm spacing indicated the least mean.

Table 3 shows the various weed control methods, number of effective nodule and non-effective nodule but there were significant difference in fresh weight with codal at 1.6 kg/a.i showed highly significant response on fresh nodule weight followed by codal at 2.4 kg/a.i and the least significant was showed by weedy check.

Table 4 showed that at 15 cm and 25 cm spacing, there were no significant difference at $p \leq 0.05$ on fresh shoot weight, dry shoot weight and dry root weight.

In Table 5, there were no significant differences recorded at $p<0.05$ on fresh shoot weight, dry root weight but there were significant on fresh root weight and dry root weight with codal at 1.6 kg/a.i showed highly significant response on both fresh root weight and dry root weight and the least significant difference was showed by the hoe weeding.

Table 6 shows the effect of weed interference on microbial parameter. There was no significant difference recorded at p<_0.05 on microbial biomass phosphorus (MBP)and total viable count **(TVC),** even though plots kept weedy for nine weeks has the highest value for TVC. For microbial biomass carbon (MBC),there was no significant difference between means of plots kept weed free for 6 weeks, 9 weeks throughout the experiment and plots kept weedy for 6 weeks plots kept weedy for 6 weeks has the highest value , while plots kept weedy for 3 weeks has the least plots kept weed free for 6,9 WAS those kept weedy for 6 weeks had the similar values of MBN, but were comparable to plots kept weed free for 33 weeks, throughout and weedy throughout .But these gave significantly higher MBN than plots kept weedy for 3 and 9 weeks. Also plots kept weedy throughout had higher MBN than those kept weedy for 3 weeks. Plots

kept weedy for 6 weeks gave highest significant response for total fungal count (TFC), but was comparable to values obtained from the other treatments except for plots kept weedy for 9 weeks which was about 38.3% lower and showed the least significant response.

Table 1. Mean values of the routine soil analysis

Parameter	
% Sand	81.6%
% Silt	10.2%
% Clay	8.2%
Texture class	Sandy loamy
Ph	6.80
Exchangeable acidity	1.30
Ca^{2+} ($Cmolkg^{-1}$)	0.61
Mg^{2+} ($Cmolkg^{-1}$)	1.13
K^{+} ($Cmolkg^{-1}$)	0.72
Na^{+} ($Cmolkg^{-1}$)	0.25
CEC ($Cmolkg^{-1}$)	4.01
Carbon –Nitrogen ratio	9.86
Total Nitrogen	0.21
Organic carbon	2.07
Available phosphorus (mg/kg)	0.16

Table 2. Effect of spacing on groundnut nodulation (Mean Values)

Spacing W	Fresh nodule weight (g/plant)	Dry nodule weight (g/plant)	Number of nodules	Number of effective nodules	Number of non-effective nodules
25 cm	1.06	9.74	36.90	2.20b	28.30
15 cm	1.32	9.12	36.05	11.00a	32.90
LSD (0.05)	NS	NS	NS	NS	

Table 3. Effect of weed control method on groundnut nodulation (Mean Values)

Treatment W	Fresh nodule weight (g/plant)	Dry nodule weight (g/plant)	Number of nodules	Number of effective nodules	Number of non-effective nodules
Codal	1.43a	1.39	40.38	5.00	34.13
1.6 kg/a.i					
Codal	1.51a	22.67	24.88	3.63	21.00
2.4 kg/a.i					
Codal	1.16ab	1.31	25.25	5.50	28.88
1.6 kg/a.i + hoe weeding					
Hoe weeding	0.96b	0.82	25.13	4.00	28.63
Weedy check	0.90b	0.95	66.75	14.86	40.38
LSD (0.05)		NS	NS	NS	NS

Means not followed by the same alphabet within the same column are statistically significant at $p \leq 0.05$

Table 4. Effect of spacing on groundnut biomass production (Mean Values)

Spacing	Fresh shoot weight (g/plant)	Dry shoot weight (g/plant)	Fresh root weight (g)	Dry root weight (g)
25 cm	119.74	13.73	3.65	0.43
15 cm	123.96	14.13	3.61	0.42
LSD (0.05)	NS	NS	NS	NS

Means not followed by the same alphabet within the same column are statistically significant at $p \leq 0.05$

Table 5. Effect of weed control methods on groundnut biomass production (Mean Values)

Treatment	Fresh shoot weight (g/plant)	Dry shoot weight (g/plant)	Fresh root weight (g)	Dry root weight (g)
Codal 1.6 kg/a.i	140.00	16.85	4.95a	0.55a
Codal 2.4 kg/a.i	136.51	14.76	4.02ab	0.48b
Codal	130.37	13.47	3.71ab	0.49b
1.6 kg/a.i + hoe weeding				
Hoe weeding	100.29	11.87	2.89b	0.28ab
Weedy check	102.12	12.93	2.59b	0.13ab
LSD (0.05)				

Means not followed by the same alphabet within the same column are statistically significant at p≤0.05

Table 6. Effect of weeding interval on microbial parameters (Mean Values)

Treatment	Microbial biomass (Carbon) (mg/kg)	Microbial biomass (Nitrogen) (mg/kg)	Microbial biomass (Phosphorus) (mg/kg)	Total viable count ($cfug^{-1}$) (10^6)	Total fungal count ($cfug^{-1}$) (10^6)
Weed free					
For 3 weeks	2.19bed	0.14bc	11.28	16.38	0.85ab
Weed free					
For 6 weeks	2.63ab	0.17a	12.16	14.77	0.93ab
Weed free					
For 9 weeks	2.86a	0.17a	11.73	18.86	0.93ab
Weed free					
Throughout	2.53abc	0.14abc	11.05	18.05	0.98ab
Weed free					
For 3 weeks	1.80d	0.11c	10.34	14.77	0.90ab
Weedy for					
For 6 weeks	3.06a	0.18a	11.16	13.83	1.15a
Weedy for					
For 6 weeks	1.99cd	0.12bc	13.28	15.08	0.71b
Weedy					
Throughout	2.52bc	0.16ab	12.91	17.68	0.90ab
LSD				**NS**	**NS**

Table 7 shows that there was no significant difference in the biomass carbon at 25 cm and 15 cm spacing for plots kept weed for 3 weeks 9 weeks and on ploys kept weedy for 3, 6, and 9 weeks at p<_0.05. for plots kept weed free for 6 weeks, 15 cm spacing gave about 29 % MBC more than 25 cm spacing, .the same was also observed for plots kept weed free throughout the experiment gave highest value this was about 35 % higher than the value recorded for plots kept weedy for 6 weeks, which gave the least significant value .At 15 cm spacing, plots kept weedy for 6 weeks showed the highest level of significant. Similarly, plots kept weedy for 3 weeks gave the least significant value.

Table 8 shows that at $p \leq 0.05$ only plots kept weedy throughout the experiment showed significant response to spacing with 25 cm spaced plots giving 44.9 % more MBN than 15 cm spaced plots. All other weeding interval treatment showed no significant difference to spacing. This did not differ significant from plots kept weed free for 9 weeks and plots kept weedy for 6 weeks. On the other hand, plots kept weedy for 6 weeks had the significant from highest value at 15cm spacing at $p \leq 0.05$. This did not differ significantly from plots kept weed free for weeks, 9 weeks and throughout the experiment.

In Table 9, there was no significant in MBP at p<_0.05 on the interaction between spacing and

weed interaction. This shows that the interaction between plant density and weed interference was not significant on the soil microbial biomass phosphorus, even though plots kept weed free throughout the experiment gave relatively low value at 25 cm spacing compared to pots kept weed free for 9 weeks. Also plots kept weedy for 3 weeks relatively low values at spacing compared to plots kept weedy for 9 weeks.

Table 10 shows the interaction between weeding interval treatment and treatment did not significantly affect total viable count at, this complement the result in Table 2 which showed that spacing had no effect on the total viable count (TVC), plots kept weedy for six weeks, which gave the least, but similar to the weeding interval treatment, while plots kept weed free for 9 weeks showed the significantly highest value at 15 cm spacing at p<_0.05, but did not differ significant from plots kept weed free for 3 weeks 6 weeks and throughout the experiment as well as plots kept weedy for 6 weeks and throughout the experiment .this shows that weed interference had significant for the six weeks after planting lowered the total viable count in the rhizosphere soil under 25 cm spacing.

Table 7. Effect of the interaction between spacing and weed interference on MBC (Mean Values)

Treatments	25 cm	15 cm	LSD (0.05)
Weed free 3 WAS	2.28abc	2.11bc	NS
Weed free 6 WAS	2.18bcb	3.08aa	
Weed free 9 WAS	3.01ab	2.72ab	NS
Weed free Throughout	2.02cb	3.03aa	
Weedy 3 WAS	1.99c	1.61c	NS
Weedy 6 WAS	2.91ab	3.20a	NS
Weedy 9 WAS	2.20bc	1.79c	NS
Weedy throughout	3.08aa	1.95bcb	NS
LSD (0.05)			

Table 8. Effect of the interaction between spacing and weed interference on MBN (Mean Values)

Treatments	25 cm	15 cm	LSD (0.05)
Weed free 3 WAS	0.1387B	0.1317bcd	NS
Weed free 6 WAS	0.1460b	0.1900ab	NS
Weed free 9 WAS	0.1750ab	0.160abcd	NS
Weed free Throughout	0.1167b	0.1677abc	NS
Weedy 3 WAS	0.1170b	0.1027d	NS
Weedy 6 WAS	0.1680ab	0.1930a	NS
Weedy 9 WAS	0.1240b	0.1093cd	NS
Weedy throughout	0.2117aa	0.1167cdb	NS
LSD (0.05)			

Table 9. Effect of the interaction between spacing and weed interference on MBC (Mean Values)

Treatments	25 cm	15 cm	LSD (0.05)
Weed free 3 WAS	10.46	12.10	NS
Weed free 6 WAS	11.19	13.13	NS
Weed free 9 WAS	13.44	10.01	NS
Weed free Throughout	9.35	12.75	NS
Weedy 3 WAS	11.39	9.29	NS
Weedy 6 WAS	11.93	10.40	NS
Weedy 9 WAS	12.18	14.34	NS
Weedy throughout	12.94	12.88	NS
LSD (0.05)	NS	NS	

Table 10. Effect of the interaction between spacing and weed interference on MBC (Mean Values)

Treatments	25 cm	15 cm	LSD (0.05)
Weed free 3 WAS	14.57ab	18.20ab	NS
Weed free 6 WAS	14.93ab	14.60abc	NS
Weed free 9 WAS	15.90ab	21.80a	NS
Weed free Throughout	19.70ab	16.40abc	NS
Weedy 3 WAS	19.87ab	9.67c	NS
Weedy 6 WAS	12.00b	15.67c	NS
Weedy 9 WAS	17.57ab	12.60bc	NS
Weedy throughout	20.90a	14.47abc	NS
LSD (0.05)			

Table 11 shows that total fungal count did not show significant response to the interaction between weed treatment and spacing at $p \leq 0.05$. Also, there was significant difference between all the weeding interval at 15 cm spacing, though plots kept weed free for 6 weeks and plots kept weedy for 6 weeks gave higher values compared to other weeding interval treatment at 25 cm spacing plots kept weedy for 9 weeks but did not differ significant from all other weeding interval treatments.

Tables 12 and 13 show the effect of plant population density on groundnut biomass production from Table 12, it can be shown that at and 15 cm spacing there was no significant difference recorded at $P \leq 0.05$ for fresh shoot, dry shoot weight, fresh root weight and dry shoot weight. Table 13 shows that all the weeding interval treatment recorded no significant differences at $p \leq 0.05$ for fresh shoot weight, dry shoot weight, fresh root weight dry root weight. though plots kept weedy for 3 weeks gave higher value for fresh shoot weight, while plots kept weed free for 6 weeks gave higher value for dry shoot weight similarly plots kept weed for 6 weeks gave higher values for fresh root weight compared to other treatments.

From the results of Tables 12 and 13, it confirms that the interaction between spacing and weeding interval has no significant effect on groundnut biomass production.

Table 14 shows the effect of spacing on groundnut nodulation. At 25 cm and 15 cm spacing, there were no significant differences recorded at $p \leq 0.05$ for nodule count, number of effective nodule and number of non-effective nodule. Nodule count at 25 cm spacing was 12.3 % higher than that at 15 cm spacing. While Table 15 shows the effect of weed interference on groundnut nodulation. For the various weeding intervals there were no significant differences recorded at $p \leq 0.05$ for nodule count, number of effective and non-effective nodules and this was about 34 % higher than the nodule counts for plots kept free for 6 weeks which gave the least number of nodules. The same thing applied for number of effective nodules, while the reverse was the case with number of non-effective nodules.

Table 16 shows the effect of spacing on groundnut pod count and pod weight. At 25 cm spacing and 15 cm spacing, there were no significant different at $p \leq 0.05$ on pod count and pod weight, although the pod counts at 25 cm spacing was 21.6 % greater than 15 spaced plots. Conversely, pod weights at 25 cm spacing gave 20.7 % higher value than those at 15 cm spacing.

Table 17 shows the effect of weed interference on groundnut pod count and pod weight. Plots kept weedy for just three weeks showed the highest level of significance at $p \leq 0.05$ for pod count, followed by plots kept weedy for six weeks, plots kept weedy throughout the experiment showed the level of significance at $p \leq 0.05$ for pod count, even though there were no significant difference between this plot and plots kept weed free for three weeks and all the other plots except for plots kept weedy for six weeks and nine weeks after planting. Plots kept weedy for three weeks gave the highest value at $p \leq 0.05$ for pod weight, this did not differ significantly from all the other plots except for plots kept weed free for three weeks and plots kept weedy throughout the experiment which had the least value.

Table 18 show that at 25 cm spacing plots weedy for six weeks had the highest value at $P \leq 0.05$

for pod count but did not differ significant from other treatments except for plots kept weedy throughout the experiment which gave the least number of pods there was no significant difference between all the weeding interval treatment at 15 cm spacing, nevertheless plots kept weedy for 3 weeks gave very high number of pods compared to the values recorded for other treatment while plots kept weedy throughout gave the least number of showed no significant difference on pod count at $p \leq 0.05$, though some of the treatment gave numerically values of pod counts at 25 cm than at 15 cm.

Table 11. Effect of the interaction between spacing and weed interference on MBC (Mean Values)

Treatments	25 cm	15 cm	LSD (0.05)
Weed free 3 WAS	0.90ab	0.80	NS
Weed free 6 WAS	0.75ab	1.10	NS
Weed free 9 WAS	0.80ab	1.05	NS
Weed free Throughout	1.00ab	0.95	NS
Weedy 3 WAS	0.80ab	1.00	NS
Weedy 6 WAS	1.20a	1.10	NS
Weedy 9 WAS	0.72b	0.70	NS
Weedy throughout	0.85ab	0.95	NS
LSD (0.05)			

Table 12. Effect of spacing on groundnut biomass production (Mean Values)

Treatment	Fresh shoot weight	Dry shoot weight	Fresh root weight	Dry root weight
25 cm	145.68	30.58	3.89	0.83
15cm	147.59	33.91	3.64	0.83
LSD (0.05)	NS	NS	NS	NS

Table 13. Effect of weeding interval on groundnut biomass production (Mean Values)

Treatment	Fresh shoot weight	Dry shoot weight	Fresh root weight	Dry root weight
Weed free 3 WAS	138.04	28.14	3.52	0.85
Weed free 6 WAS	147.82	31.50	5.40	0.87
Weed free 9 WAS	150.98	35.13	3.53	0.77
Weed free Throughout	130.99	31.69	3.66	0.85
Weedy 3 WAS	168.76	36.31	3.31	0.84
Weedy 6 WAS	163.24	37.09	3.82	0.88
Weedy 9 WAS	117.59	27.49	3.05	0.73
Weedy throughout	157.68	30.59	3.80	0.87
LSD (0.05)	NS	NS	NS	NS

Table 14. Effect of spacing on groundnut nodulation (Mean Values)

Treatment	Nodule count	Effective count	Non – Effective count
25 cm	88.58	72.50	27.50
15 cm	77.67	71.67	28.33
LSD (0.05)	NS	NS	NS

Table 15. Effect of weeding interval on groundnut nodulation (Mean Values)

Treatment	Nodule count	Effective count	Non – Effective count
Weed free 3 WAS	68.67	65.00	35.00
Weed free 6 WAS	81.83	76.67	23.33
Weed free 9 WAS	78.00	68.33	31.67
Weed free Throughout	104.17	81.66	18.33
Weedy 3 WAS	82.00	73.33	26.67
Weedy 6 WAS	83.50	71.67	28.33
Weedy 9 WAS	82.00	66.67	33.33
Weedy throughout	84.83	73.33	26.67
LSD (0.05)			

Table 16. Effect of spacing on groundnut yield parameters (Mean Values)

Treatment	Pod count	Pod weight
25 cm	187.17	139.83
15 cm	146.83	110.90
LSD (0.05)		

Table 17. Effect of weeding interval on groundnut yield parameters (Mean Values)

Treatment	Pod count	Pod weight
Weed free 3 WAS	36.00b	21.47bc
Weed free 6 WAS	113.00ab	85.28abc
Weed free 9 WAS	113.50ab	80.69abc
Weed free Throughout	207.50ab	158.62abc
Weedy 3 WAS	328.00a	252.62ab
Weedy 6 WAS	285.33a	213.62ab
Weedy 9 WAS	236.83ab	181.47abc
Weedy throughout	15.18b	9.54c
LSD (0.05)		

Table 18. Effect of the interaction on pod count (Mean Values)

Treatment	25 cm	15 cm	LSD (0.05)
Weed free 3 WAS	36.67ab	36.33	NS
Weed free 6 WAS	128.00ab	98.00	NS
Weed free 9 WAS	134.00ab	93.00	NS
Weed free Throughout	200.33ab	214.67	NS
Weedy 3 WAS	335.00ab	321.00	NS
Weedy 6 WAS	364.33a	206.33	NS
Weedy 9 WAS	282.00ab	191.67	NS
Weedy throughout	18.00b	13.67	NS
LSD (0.05)			

4. CONCLUSION

Spacing as a factor showed no significant difference in all the microbial parameters. Hence planting groundnuts at 25 cm and 15 cm spacing will have an equal effect on soil microbial and activities. Leaving weeds unchecked may show no significant effect on microbial biomass phosphorus and total viable count, but weed competition has a significant effect on microbial biomass carbon, microbial biomass nitrogen and total fungal count.

The interaction between spacing and weed interference showed a more significant effect on the microbial biomass carbon, with plots kept weedy throughout showing the highest level of significance at 25 cm spacing. Hence planting

groundnut at 25 cm without any weed control will show the highest significant effect on MBC. The high mean value in the fresh shoot and root weights as shown in the result implies that effective *rhizobia* were produced in roots and high nitrogen was produced by symbiotic nitrogen fixation. The high mean value in soil microbial biomass as shown in the result implies that the application of weed control methods to the soil in groundnut production generally result in increase in microbial activity and the biomass.

The problems caused in Nigeria agricultural systems are becoming increasingly and very difficult to manage, since the farming system in the country depends mostly on hand-tools and local crop varieties therefore the use of active herbicides (i.e Codal at 1.6 kg a.i/ha) can enhanced groundnut biomass production nodulation as well as yield.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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