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INFLUENCE OF PLANT SPACING ON WEED SUPPRESSION AND MAIZE PERFORMANCE IN THE HUMID FOREST AGRO-ECOLOGY OF SOUTHEASTERN NIGERIA

Udensi, E.U. and Omovbude, S.
Department of Crop and Soil Science, University Of Port Harcourt,P.M.B 5323, Port Harcourt, Rivers State, Nigeria
Corresponding Author Email: ueudensi@yahoo.co.uk.

ABSTRACT
Field experiment was conducted at the Department of Crop and Soil Science Demonstration Plot, Faculty of Agriculture, University of Port Harcourt, Nigeria between April and October, 2017 to evaluate the effect of maize plant spacing on weed suppression and maize performance in the humid forest agro-ecology of South-Eastern Nigeria. The treatment consisted of five plant spacing: 50 cm x 25cm, 75cm x 25cm, 100 cm x 25 cm, 75cm x 50 cm and 100 cm x 50cm which was equivalent to five population densities (80,000; 53,333; 40,000, 26,667 and 20,000 plants /ha). The treatments were arranged in a Randomized Complete Block Design (RCBD), and replicated four times. Data collected on weeds were weed density and biomass, while maize data were count at emergence, height, leaf area index, stands at harvest, total plant weight at harvest, cob number, cob dry weight and grain yield. Result showed that spacing had no significant (P ☐ 0.05) effect on weed density but had on weed biomass. Plant spaced at 100 cm x 25cm had the highest weed biomass (190.53g/m2) but did not differ significantly from other plant spacing except for 75 x 50 cm. Spacing had significant (P ☐ 0.05) effect on all agronomic maize data assessed, except for plant height, cob dry weight and grain yield. Though there were no significant differences in grain yield among the different plant spacing, plants spaced at 75 cm x 25cm had the highest grain yield (1704 kg/ha) followed by 50 cm x 25 cm (1666.7kg/ha) plant spacing. In order to attain better weed control and high maize performance, farmers are encouraged to plant maize at a spacing of 75cm x 25cm or at closer spacing of 50 cm x 25cm with one plant per hill.

Keywords: Maize, weed suppression, spacing and weed control

Introduction

Maize (*Zea mays* L.), commonly called "corn" is a member of the Poaceae family. It ranked second after cassava as the most cultivated crop in terms of harvested area (5.8million ha), in Nigeria (FAOSTAT, 2014). Nigeria is among the top ten (10) maize producers in Africa and is ranked second after South Africa, with an estimated quantity of about 10.8 million t produced in 2014 (FAOSTAT, 2014). It is widely cultivated in many regions of Nigeria, ranging from coastal swamps of the south to the dry savanna lands of the north (Remison, 2004). Presently, the savanna regions of Africa have the comparative advantage and the greatest potential of its productivity due to lower incidence of pest and diseases, and higher solar radiation (Badu – Apraku *et al*., 2000). The production of maize is very popular in Nigeria among arable crops farmers because of its high socio-economic value and importance in tackling food insecurity and poverty (Bamire *et al*., 2010). Remison (2005) grouped the uses of maize into three viz; staple human food, feed for livestock and industrial raw materials. Maize as staple human food is eaten either boiled or roasted, and as corn meal. It is also used locally in Nigeria for the preparation of maize breakfast dish called "Ogi' or "Akamu" (IITA, 1982). As feed for livestock, it is used directly, after milling, for feeding animals like poultry, sheep, pig and cattle. As industrial raw materials, the products are used for the manufacturing of starch, asbestos, ceramics, plastics, oilcloths, linoleum, soaps, varnishes, paints, shoe polish, tobacco, jams, jellies, chemicals, dyes, explosive, paper, paperboard and wall board. As industrial raw material, maize is also used in the production of flour, beer, malt drinks, and a component in the production of animal feed (IITA, 1982, Remison, 2005).

Despite its usefulness and high production volumes, Nigeria's average maize yield of 1.8 t/ha (FAOSTAT, 2014) is one of the lowest among the top 10 maize producers in Africa. Though some African countries (e.g., Ethiopia with >3 t/ha) have made significant productivity gains, the average yield of maize in Sub Sahara Africa, SSA (estimated at <1.8 t/ha) is still far below the global average yield of maize (~5 t/ha) and considerably below the 4.4-5.4 t/ha on-farm trial. Smallholder farmers are the major producers of maize in Nigeria, each cultivating an average of 0.65ha (Anon 2017a). Studies, had demonstrated that inadequate plant spacing is among of the factors that is responsible for crop yield reduction in Nigeria. IITA, (1982) reported that maize yield in the field depends to an extent on the number of plants per unit area and that, it is fundamental to establish the optimum rate of planting for the region where it is cultivated. Generally, irrespective of the variety, the use of appropriate plant spacing that will give the optimum plant population has been established by various researchers (Remison and Lucas, 1982; Lucas and Remison, 1984).

The use of closer spacing with higher plant population density is of benefit to crops growth and competition against weed competition. Weed competition is one of the greatest challenges in maize production, and labour for weeding is one of the most important factors limiting yield. Andrade *et al*. (2002) noted that narrow spacing with higher plant population density accelerates the promptness of leaf canopy closure and increases canopy solar radiation that invariably enhances crop performance and competitive ability for the natural resources of growth. Similarly Bullock *et al*.(1998), noted that narrower rows spacing enabled crops to make use of available light and shade the entire soil surface during the early stage of the crop's life history while the soil is still moist. They further noted that less water is being lost from the soil surface by evaporation through the process. Researchers (Zimdahl, 1999; Mashingaidze, 2004) reported weed suppressive ability and competitiveness of maize at closer spacing, due to better leaf canopy closure and shading of the undergrowth. Most Nigerian farmers plant maize using wider spacing, which often results in scanty plant population density that encourages weed growth, and competitiveness with the consequent reduction in maize yield. In addition, controlling weeds in maize planted at a wider spacing at smallholder farm level might be expensive and can lead to land abandonment especially in areas where land is limited. The need for an appropriate spacing and optimum plant population density that will enhance maize productivity and yield, as well as its competitive ability against weed becomes imperative. Therefore the objective of the present study was to evaluate various plant spacing of maize established and its weed suppression ability and maize performance in the study location.

Materials and Methods

Description of the Experimental site

The experiment was conducted at the Department of Crop and Soil Science Demonstration Plot, Faculty of Agriculture, University of Port Harcourt, Nigeria between April and October 2017. The University of Port Harcourt is located on latitude 04° 54´ 538'N and longitude 006° 55´ 329'E and at an elevation of 17meters above sea level in the humid forest agroecology. It has an average temperature of 27^0C, an average relative humidity of 78%, and average annual rainfall that is between 2500 – 4000 mm, which occurs mostly between March and November (Nwankwo *et. al*, 2010). The experimental site was under continuous cultivation with some crops such as cassava, fluted pumpkin, maize and watermelon for five years before fallowing for one year.

Soil analysis

Prior to the experimentation, representative soil samples were taken randomly from the experimental site at uniform depth of 0-15cm with an auger for physico-chemical properties. The physical properties (Particles size distribution) were determined by the hydrometer method (Gee and Bauder, 1982), while the chemical properties were determined using the procedures as itemized in Adepetu (2000)

Experimental Procedure and Design

The maize seed used for the trial was from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and the variety was Samaz-40 (Yellow)

The treatment consisted of five plant spacing (50 cm x 25cm, 75cm x 25cm, 100 x 25 cm, 75cm x 50 cm and 100 cm x 50cm). The treatments were arranged in a Randomized Complete Block Design (RCBD) replicated four times. The details of the expected plant population density at different spacing is presented in Table 1.

The plot size was 3 m x 3 m with an alleyway of 1 m between plots and 2 m between replicates. The experiment occupied an experimental area of dimension 19 m x 15 m (285 m^2) of approximately 0.03hactares. The land was manually cleared on the 19th of April 2017 and the debris was packed. Three seeds were planted per hole on the 22th of April, 2017. Supply was done at one week after planting (1WAP) and later thinned to one seedling per hill two weeks after planting (2WAP). All plots were weeded manually using hoeing. Fertilizer was not used in this trial, so as to simulate a typical farmer situation where fertilizer is rarely used or may not be available at all for use

Data collection

Weed density and weed biomass

Weed density was determined at harvest by counting from two quadrats of 50cm x 50 cm taken across a diagonally transect in each treatment plot. The weeds were counted and categorized into broadleaves, grasses and sedges which were later summed to give the total weed density per treatment. Dominant weed species per treatment were also assessed. Weed dry weight was determined by oven drying the weed samples at 70^{0}C to constant weight. Both weed density and dry weight values were expressed in grams per square meter (g/m^2).

Maize

The yield components measured were emergence count, leaf area index (LAI) and plant height at 50% tasselling, stands at harvest and ear number, while yield data were separated into biological yield (whole plant), ear yield and grain yield. Data on height, LAI were collected by randomly selecting and tagging of six plants from each treatment plot from the net plot to facilitate the identification. At harvest the shoots from each plot were manually harvested by cutting whole plants at above ground level and weighed with a spring balance for field biological yield determination. The ears obtained from the bundle of each treatment were detached and dehusked, counted to get the ear number. The dehusked ears were sun dried for about eight weeks until near constant weight, to determine the ear dry weight. The dry ears were shelled and the grains were weighed, and weight adjusted at 12 % moisture content using the formula:

Maize grain yield (kg/ha) = Egwt × [(100-M %)/88]-------------------(1)

Where, Egwt = ear grain weight per plot, M = grain moist reading

All maize parameter data were expressed in kilogram per hectare (kg/ha).

Statistical analysis

Data generated were subjected to statistical analysis of variance (ANOVA) and significant treatment means were compared using least significant difference (LSD) at 5% probability level.

Results and Discussion

Soil Physiochemical properties

The physiochemical properties the soil of the experimental site before planting is presented in Table 2. The soil textural class was sandy clay loam with 67.8% sand, deficient of nutrient and acidic, a with pH value of 4.87. Organic carbon (Oc), Total nitrogen (N) Phosphorus (P), Potassium (K), Calcium (Ca) and Magnesium (Mg) had values that were below critical level of soils in Southeastern Nigeria as established by Ibedu *et al.* (1988). The low fertility status of the soil could be attributed to continuous cropping and uptake of nutrient from the soil yearly by crops without sufficient fallow period for the soil to recuperate. It could also be attributed to high rainfall and temperature, which facilitated the leaching of nutrient elements from the soil having being exposed by continuos cropping over the seasons. This agrees with the results of Madueke *et al*. (2012) who noted that soils of south eastern Nigeria are low in nutrients as a result of the high degree and extent of weathering and leaching they have undergone.

Weed suppression

Weed flora and Weed species composition at experimental site at harvest

Weed flora and Weed species composition (percentage) of the different plant spacing at final harvest are presented in Table 3. Fifteen (15) dominant weed species were identified at the experimental site at harvest, out of which 10 were broadleaved, 3 grasses and 2 sedges (Table 3). Weed sensitivity to spacing was higher in *Oldenlandia corymbosa* (LSD= 46.7) and lower in *Ipomoea involucrata* (LSD=0.97). Total weed species contribution by various maize spacing were in order of 75 x 25cm > 100 x 50cm = 50 x 25cm > 100 x 25cm > 75 x 25cm. There were no significant (P>0.05) differences among the different maize spacing on percentage weed species of individual weeds except for *Ipomoea involucrate*, *Peperomia pellucida Mariscus alternifolius* and *Oldenlandia corymbosa* (Table 3). Maize grown at plant spacing of 75cm x 25cm had the highest composition (2%) of *Ipomoea involucrate*) and *Mariscus alternifolius* (4%); 100cm x 25cm had the highest (5%) of *Peperomia pellucida* while 75cm x 50cm had the highest composition (58%) of *Oldenlandia corymbosa*. On the average, the dominant weed species contribution to the total weed density, by the respective plant spacing were as follows:

Weed density and weed biomass

The influence of spacing on weed density and weed dry weight are presented in Table 4. Spacing had no significant (p> 0.05) effect on number of broad leaves and sedges, and total weed density, but had on grasses, and weed biomass (weed dry weight). The number of grassy weeds ranged from 5 to 35 weed/m^2, with maize plant spaced at 75 cm x 25cm, having the highest number of grassy weeds while 100cm x 50 cm had the lowest. Plant spaced at 100cm x 25cm significantly produced the highest weed biomass (190.53g/m^2) when compared to other closer spacing (Table 4). This means that at this spacing maize and weeds sourced their growth resources without interference. The probable reason for the high biomass produced at a wider spacing might be attributed to scanty number of plants, which develop poor canopy for light penetration that stimulated weed growth. On the other hand, low weed biomass recorded under closer spacing might be due to interception of solar radiation by canopy shading which prevents light energy from reaching the weed surface and resulting in effective weed growth suppression. This finding is in agreement with that of Mashingaidze *et al*. (2009) who noted that, narrow rows spacing in maize farms reduced weed biomass (dry weight) and growth of weed. Similarly, (Staggenborg, *et al* .2001) noted that narrow-row corn form canopies more quickly, which reduced weed emergence and vigorous growth.

Maize performance

Maize yield components

The influence of spacing on maize yield components is presented in Table 5. The different spacing had significant (P < 0.05) effect on yield components except plant height. Although there was no significant (P > 0.05) difference among the different spacing on plant height, plant spaced at 50cm x25cm grew taller than other spacings. The probable reason for tallness of plant recorded at plant spaced at 50 cm x 25 might be due to overcrowding, which makes the plant to compete for growth resources such as light, water, nutrients and air. This finding is in agreement with that of Ibeawuchi *et al*. (2005) who noted that okra plants grew taller at closer spacing. In addition, Liu *et al*. (2004) noted that plant spacing variability had no significant effect on plant height, probably as result of lesser or no competition among plants. The highest emergence count was recorded in plant spaced at 50 x 25cm while 100 x 50cm had the lowest (Table 5).

The probable reason for this could be attributed to variation of plant spacing. Stand count also followed similar trend. The number of cobs was more at plant spaced at 50cm x 25cm (Table 5) than other spacing and this might be attributed to higher plant population density. Plant spaced at a closer spacing of 50cm x 25cm had the highest leaf area index. The probable reason for this could be attributed to its higher population density. Jarvela (2004) defined Leaf area index (LAI) as the total one-sided area of leaf tissue per unit ground surface. Leaf area index is one of factors that determine the quantity of light energy that is intercepted by plant canopy, and it differs greatly with canopy structure from species to species (Antonarakis *et al.,* 2004). The leaf area index (LAI) is the ratio of total projected leaf area (one side only) per unit ground area, and is widely used to characterize the canopy light climate and interception (Anon, 2017b). Anon (2017b) noted that a canopy where LAI that has the value of one (1) indicates that it has a leaf area equal to the soil surface area on which it grows, but this does not mean all photosynthetically active radiation (PAR) is intercepted because some leaves overlap, leaving gaps. In addition, not all the leaves are positioned at right angles to incident radiation. A crop under favorable growing conditions increases LAI rapidly during early development to a maximum of 3 to 7 (Anon, 2017b).

Maize biological, ear and grain yields

Effect of plant spacing on maize biological plant yield, ear and grain yield are presented in Table 6. Plant spacing had significant effect on biological yield of maize .The biological yield ranged from 17,963 to 34,074kg/ha, with plant spaced at 50cm x 25cm having the highest biological yield while 100cm x 25cm had the lowest. Whole plant yield or biological yield is a chief factor because of interest of straw or stover in addition to grain by farmers (Tigabun and Asfaw, 2016). This result is in agreement with that of Iqtidar *et al*. (2003) who noted that different row spacing had effect on biological yield of wheat. The influence of spacing on ear yield and grain yield were not significant (Table 6). Although the effect on yield was not significant, the highest grain yield (1704 kg/ha) was recorded at recommended spacing of 75cm x 25 cm closely followed by 50cm x 25cm (1666.7Kg/ha). Plants spaced at the recommended spacing of 75cm x25cm had increase of 2.2 % in yield when compared to plants spaced at 50cm x 25cm. The probable reason for the non-significant differences among the various spacing in yield might be attributed to lesser or no strong competition by plants for growth resources such as light, moisture, nutrients and air.

Conclusion

This study suggests that farmers should be encouraged to plant maize at recommended spacing of 75cm x 25cm with one plant per hill as the minimum and standard to boost yield and reduce the effect of weed pressure and weeding frequency; especially where herbicide use is constrained by availability and cost. The current study advocates for the development of maize varieties that can be grown at closer spacing of 50cm x 25cm or less for greater weed suppression benefits with little or effect of intra-specific competition. This will go a long way to remove the bottlenecks that are associated with hoe weeding and herbicide use by farmers.

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Table 1: Plant densities at different plant spacing

Plant spacing (cm)	Plant density(plants/ ha)
50 x 25	80,000
75 x 25	53, 333
100 x 25	40,000
75 x 50	26,667
100 x 50	20,000

Table 2: Physiochemical properties of the experimental site before planting

Soil properties	Value	Critical Level*
Physical properties		
Sand (%)	67.8	–
Silt (%)	13.6	–
Clay (%)	18.6	–
Textural class	Sandy clay loam	-
Chemical properties		
pH (H_20)	4.87	–
Total organic carbon (%)	0.96	1.16
Total nitrogen (%)	0.08	0.15
Available P (mg/kg)	7.60	8.50
Cation exchange capacity (cmol/kg)		
Ca	1.01	1.50
Mg	0.24	0.28
Na	0.01	–
K	0.11	0.16

*Ibude *et al*. (1988)

Table 3: Dominant weed flora and species composition (%) of the different plant spacing at final harvest

s/n	Weed species	Life form[1]	Plant Spacing 50 x 25cm	75 x 25cm	100 x 25cm	75 x 50cm	100 x 50cm	LSD[2] P=0.05
1	*Talinum triangulare*	PBL	0a	1a	2a	3a	1a	4.91
2	*Commelina benghalensis*	ABL/ PBL	5a	4a	3a	3a	8a	6.52
3	*Cleome rutidosperma*	ABL	0a	1a	3a	3a	6a	10.95
4	*Eleutheranthera* Spp	ABL	1.7a	7a	3a	4a	9a	15.04
5	*Physalis angulate*	ABL	4a	3a	0a	0a	1a	4.89
6	*Ipomoea involucrate*	ABL	1b	2a	1ab	1b	1b	0.97
7	*Linderma* Spp	ABL/ PBL	3a	5a	7a	4a	7a	12.42
8	*Spermacoce ocymoides*	PBL	3a	5a	2a	2a	1a	5.85
9	*Peperomia pellucida*	ABL	5b	3b	23a	0b	0b	15.74
10	*Cyperus* Spp	PS	8a	18a	4a	10a	9a	25.64
11	*Mariscus alter nifolius*	PS	0b	4a	2ab	1b	1ab	2.44
12	*Panicum maximum*	PG	0a	4a	1a	2a	1a	6.56
13	*Eleusine indica*	AG	4a	4a	5a	0a	0a	5.90
14	*Panicum laxum*	PG	7a	7a	1a	2a	0a	13.57
15	*Oldenlandia corymbosa*	ABL	24ab	7a	12ab	58a	36ab	46.7
	Total percentage (%) dominant weed species		**81**	**75**	**69**	**93**	**81**	

[1]ABL=Annual broad leaf; PBL=Perennial broad leaf; AG= Annual grass, PG= perennial grass; PS= Perennial sedge

[2]Values followed by the same letter(s) within the same column do not differ significantly at 0.05 level of probability using LSD Test

Table 4: Influence of plant spacing on weed density (no./m^2) and weed biomass (g/m^2)

Spacing (cm)	Broadleaves	Grasses	Sedges	Total weed density	Weed biomass
50 x 25	71a	9ab	12a	92a	112.27a
75 x 25	55a	35a	16a	106a	166.87a
100 x 25	97a	28ab	8a	135a	190.53a
75 x 50	89a	9ab	14a	112a	50.07b
100 x 50	55a	5b	10a	70a	155.12ab
LSD(P=0.05)	NS	26.8	NS	NS	117.17

Values followed by the same letter(s) within the same column do not differ significantly at 0.05 level of probability using LSD Test
NS = Not significant at 5%

Table 5: Influence of plant spacing on maize yield components

Plant spacing (cm)	Emergence count (no/ha) at 2WAP	Stand count (no/ha) at harvest	Plant height (cm) at 50% tasselling	Leaf area index at 50% tasselling	No. of cob/ha
50 x 25	71,111a	60,000a	179.9a	3.40a	56,296a
75 x 25	48,889b	49,259ab	170.1a	2.26b	44,444a
100 x 25	38,889bc	36,296bc	171.1a	1.83b	30,370b
75 x 50	26,667cd	27,407c	167.5a	1.16c	27,037bc
100 x 50	19,259d	18,889c	165.0a	1.00c	17,037c
LSD(P=0.05)	13,215	17,520	NS	0.6146	13,176

Values followed by the same letter(s) within the same column do not differ significantly at 0.05 level of probability using LSD Test NS= Not significant at 5%

Table 6: Influence of plant spacing on biological, ear and grain yield

Plant spacing (cm)	Biological yield (Kg/ha)	Cob yield (Kg/ha)	Grain yield (Kg/ha)
50 x 25	34,074a	2333.3a	1666.7a
75 x 25	24,815ab	2222.2a	1704a
100 x 25	17,963b	2444.4a	1629.6a
75 x 50	19,630b	2074.1a	1518.5a
100 x 50	18,519b	2185.2a	1629.6a
LSD(P=0.05)	10,210	NS	NS

Values followed by the same letter(s) within the same column do not differ significantly at 0.05 level of probability using LSD Test. NS= Not significant at 5%