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Weed flora dynamics and maize yield under different fertilizer types and spacing regimes

Francis A. Nwagwu, Emmanuel B. Effa [*], Ephraim O. Osai

Department of Crop Science, Faculty of Agriculture, Forestry and Wildlife Resources Management, University of Calabar, PMB 1115, Calabar, Nigeria

Abstract

Tackling the food security challenges confronting the African Continent requires a holistic approach that will address the major problems affecting crop production, including weed interference. Improvement in other factors affecting crop production such as soil fertility, moisture, pests and disease control can be confounded if weeds are not adequately managed. The influence of different fertilizer types and intra-row spacing regimes on weed flora dynamics and the yield of maize were investigated during the 2013 and 2014 early cropping seasons in Calabar, Nigeria. The experiment was a 4 x 3 factorial, comprising of four fertilizer types (poultry manure, - 5 t ha^{-1}; NPK 15:15:15- 600 kg ha^{-1}; organomineral fertilizer – 4.2 t ha^{-1} and no fertilizer – control) and three intra-row regimes (20, 25 and 30 cm) laid out in a Randomized Complete Block Design with three replications. Plot size was 2 m x 3 m with a 1 m margin round each plot. NPK consistently increased weed dry weight; weed density and weed flora distribution, while poultry manure increased yield components, compared to other treatments. Organomineral fertilizer however resulted in the highest maize grain yields of 2.63 t ha^{-1} in 2013. Spacing had no significant effect on weed dynamics, but the 75 cm x 20 cm spacing, gave the highest grain yield. The interaction of NPK x 75 cm x 25 cm spacing gave the highest weed dry weight and weed density, sedge populations as well as yield components. Organomineral fertilizer (OMF) seemed to favour reduced weed proliferation at all spacing regimes. Fertilizing maize with 4.2 t ha^{-1} OMF at 75 cm x 20 cm spacing produced best yields while suppressing weeds.

Keywords: Fertilizer, Weed suppression, Spacing, Maize

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[*] Corresponding author. *E-mail address:* emmaeffa@yahoo.com

1. Introduction

The prolific nature of weeds has elevated weed infestation to a major stress factor in maize production agronomy. Weeds compete severely with maize if they establish within the first 3-5 weeks of planting (Liebman and Dyck, 1993). Plant growth resources such as soil moisture, mineral nutrients, and solar radiation are greatly competed for. This leaves crops stressed with a resultant decline in yields (Chikoye et al., 2004). According to Singh and Singh (2006), weed density decreases as crop density increases. Del-Pino and Covarelli (1999) reported that two-week weed free duration from 3 weeks after emergence is adequate for an acceptable maize grain yield. Several workers have reported the critical weed control period in maize between 1 – 10 leaf stage (Ferrero et al., 1996), 6-13 leaf stage (Alford et al., 2004). According to Mahmoodi and Rahimi (2009), managing weeds at 4-7, 6-8 and 9-12 leaf stages resulted in yield loss prevention of 3.5, 10 and 20% respectively. Oyewole and Ibikunle (2010) observed that surmounting Africa's food insecurity lies in addressing among other obstacles, the problem associated with obnoxious weed interference.

Alternative weed control techniques must be evolved with the inadequacy of current, measures in controlling weeds due to drudgery, cost implication, labour intensiveness and the need for repletion which reduce effectiveness. Weed management has evolved into an advanced technology and scientifically controlled operation that draws from knowledge of soil-crop management systems, and other environmental variables associated with crop production. Management of crop fertilization may be an important component of weed management systems (Blackshaw et al., 2005), since weed flora dynamics change according to nutrient availability or source of nutrients. Baitilwake et al. (2011) reported that manure improves soil fertility, but also serves as source of weeds seeds. On the other hand, Baig et al. (2001), noted that poultry manure can be used as a good weed control agent due to its phytotoxic properties, perhaps arising from its saw dust component. Haider and Sidahmed (2006) reported that chicken manure was effective in reducing growth of *Orobanche ramose*. Egbe et al. (2012) reported that weed biomass was highest in the control and NPK fertilized plots, while Shiyam et al. (2011) observed that weed dry weight increased with increasing NPK rates whereas sawdust mulch smothered weeds.

Optimal spacing enables crops attain maximum leaf area index which reduces weed competitiveness and frequency of weeding. Smith and Ojo (2007) reported optimum okra yields with narrow intra-row spacing (30 cm) and one early manual weeding (3 WAS). Hokmalipour et al. (2010) reported that increasing density increased yield per ha^{-1} and decreased yield and yield components of maize per plant. According to Abuzar et al. (2011), intra-row spacing of 22.70 cm or 60,000 stands hectare resulted in highest maize yields compared to higher or lower spacing regimes. In view of contrasting results in different locations, this study was conducted to examine how fertilizer types and intra-row spacing regimes would influence weed flora dynamics and the performance of maize in Calabar, South eastern Nigeria.

2. Materials and methods

A two - year field experiment was conducted at the University of Calabar Teaching and Research Farm, Calabar South eastern Rainforest zone of Nigeria, (4.5^o – 5.2^o N, 8.0^o – 8.3^o E, 39 m above sea level) during the

2013 and 2014 early planting seasons. Before land preparation, soil samples were taken at 0 – 20 cm depths from the experimental sites. Soil samples were analysed for physico – chemical properties, while poultry manure was analysed for chemical properties using standard procedures outlined in IITA (1990) (Table 1).

Table 1. Physico-chemical properties of the soil at the experimental site and nutrient composition of poultry manure and organomineral fertilizer

Chemical composition	**Soil analysis**		**Poultry manure**		**Organomineral fertilizer**	
	2013	2014	2013	2014	2013	20134
pH	4.6	4.6			6.2	6.2
Organic carbon (%)	1.35	1.29			2.18	2.18
Total Nitrogen (%)		0.11	3.15	1.36	0.25	0.25
Available P (mg/kg)	0.08	21.12	1.22%	1.10%	500	500
K (Cmol/kg)	53.5	0.07	1.10%	0.94%	0.2	0.2
Ca (Cmol/kg)	0.09	4	2.96%	5.44%	7.2	7.2
Mg (Cmol/kg)	3	0.6	1.68%	0.80%	4.4	4.4
Na (Cmol/kg)	2	0.05				
Al^{+++} (Cmol/kg)	0.06	0.56				
H^{+} (Cmol/kg)	1.28	0.88				
ECEC (Cmol/kg)	0.4	6.16				
BS %	6.83	77				
Clay %	75	9				
Silt %	13	9				
Sand %	7.7	82				
Soil texture	79.3	Sandy loam				

Manual land preparation was followed by plot demarcation into 2 m x 3 m sized beds. Each plot was separated by 1 m wide paths. The experimental design followed a 4 x 3 factorial disposition in RCBD of 3 replications. The factors included four types of fertilizer (NPK 15:15:15 (0.6 t ha^{-1}), organomineral fertilizer (4.6 t ha^{-1}), poultry manure (5 tha^{-1}) and the non fertilized control), and three intra row spacing regimes (75 x 20 cm, 75 x 25 cm, 75 x 30 cm). Poultry manure (PM) was soil incorporated one week before sowing, NPK and organomineral fertilizers (OMF) were ring applied 2 weeks after sowing. Seeds of Oba Super 2 hybrid maize were sown on 29th May in both seasons, using the intra-row spacing above. Two seeds were sown and later thinned to one seedling per hill at 2 WAS at 75 x (20, 25 and 30 cm) to give stand densities of 66, 667; 53, 333 and 44, 4444 plants ha^{-1} respectively. From net plots 1.2 m x 1.0 m, randomly tagged maize plants were sampled every two weeks for plant height, number of leaves, leaf area index, and grain yield (t ha^{-1}) of maize. The weeds within 0.5 m^2 quadrat were harvested, separated into species and morphological groups and recorded. All the harvested weeds were oven dried at 70^{o} C to a constant weight and expressed on hectare basis. Weed density was determined by placing a 1 m x 0.5 m quadrat randomly on each plot and counting all the weeds enclosed within the quadrat. Data obtained was subjected to analysis of variance using Genstat Version 8.1 and significant means compared using Tukey's test at 95 % confidence level.

3. Results and discussion

The analysis of soil in both years indicated a pH of 4.6, organic carbon 1.35 and 1.25 % and total nitrogen 0.08 and 0.11 % respectively. PM on the other hand contributed 3.15 and 1.36 % Total N, while the pH of 6.2 and organic carbon 2.18 % of organomineral fertilizer were the same for both seasons (Table 1). The soil texture was sandy loam, with base saturation of 75 and 77 % respectively. Other characteristics are as presented in Table 1.

3.1. Fertilizer effects

The effects of types of fertilizer and spacing regime on weed density (0.5 m^{-2}) and weed dry matter (g 0.5 m^{-2}) are presented in Table 2. Fertilizer types did not affect weed density at different sampling periods in both years, except at 7 WAS in 2014 when NPK application resulted in significantly ($P < 0.05$) greater weed populations than either of the unfertilized control, PM or OMF. At 7 WAS in 2013 alone, weed density in PM treated plots was statistically at par with that in NPK treated plots and significantly higher than that in the control and OMF treated plots. NPK application resulted in a percentage weed density increase of 141.78 %, 111.02 % and 40.98 % above OMF, the unfertilized control and PM treated plots, weed density therefore was increased by the order of NPK > Pm > Control > OMF or 260.4 > 184.7 > 123.4 > 107.7 m^2 respectively. Weed dry weight (g 0.5 m^{-2}) was significant at 3 and 7 WAS in the 2013 season only, with NPK increasing weed dry weight above other fertilizer treatments, which were statistically at par ($P > 0.05$) with each other. Non significant effects of fertilizer types were observed in the 2013 season for broadleaves, grasses and sedges (Table 3).

In 2014 however, NPK application resulted in significantly higher weed populations across the morphological groups. Poultry manure application resulted in significant increase in plant height, number of leaves, leaf area and leaf area index at 9 WAS above other fertilizers (Table 4), whereas other treatments were statistically similar but significantly higher than plants in unfertilized control plots. Weed density (0.5 m^{-2}) was significantly higher in NPK treated plots and statistically at par ($P > 0.05$) among all other fertilizer treated plots (Table 5). In 2013, organomienral fertilizer resulted in significantly higher ($P<0.05$) maize yields than NPK and Pm which in turn resulted in higher yields than the unfertilized control. In 2014 however, all fertilizer types except the control produced statistically similar yields.

3.2. Intra-row spacing effects

Significant spacing effects were observed only for leaf area index in 2013 and grain yield in both seasons (Tables 4 and 5). At 20 x 75 cm, LAI and grain yield (t ha^{-1}) in the two seasons were significantly ($P < 0.05$)

increased compared to other spacing regimes. In 2014 however, grain yield was statistically similar (P>0.05) for 20 x 75 and 25 x 75 cm² spacing respectively.

Table 2. Effects of fertilizer type and spacing on weed density and weed dry weight at different growth stages

	WEED DRY WEIGHT (g m⁻²)				WEED DENSITY (g m⁻²)			
	2013		2014		2013		2014	
	Weeks after planting				Weeks after planting			
Treatment	3	7	3	7	3	7	3	7
Fertilizer								
Control	19.04b	22.11ab	12.26a	13.34a	42.78a	123.4b	28.80a	42.44a
NPK	117.07a	29.80a	11.48a	12.68a	109.11a	260.4a	23.60a	35.44a
PM	20.80b	26.48ab	11.82a	12.75a	70.44a	184.7ab	24.80a	39.11a
OMF	24.00b	11.52b	12.08a	13.32a	61.5a	107.7b	30.60a	42.44a
Spacing (cm)								
20 x 75	38.25a	15.21a	12.11a	13.18a	65.83a	142.5a	27.70a	42.00a
25 x 75	40.51a	27.93a	11.76a	12.90a	69.50a	163.2a	26.10a	39.50a
30 x 75	50.93a	24.29a	11.86a	12.98a	77.58a	201.5a	27.00a	38.08a
Fertilizer x Spacing Interaction								
No Ft + 75 x 20	8.10d	10.53a	11.25a	12.85a	23.67a	75.30c	32.30a	35.33a
No. Ft. + 75 x 25	5.77d	36.50a	12.22a	12.78a	59.33a	123.3ab	31.30a	37.00a
No. Ft. + 75 x 30	43.3bcd	19.30a	11.72a	13.33a	45.33a	171.7ab	22.70a	37.67a
NPK + 75 x 20	88.63bc	22.67a	12.82a	13.94a	93.00a	197.7ab	18.00a	37.33a
NPK + 75 x 25	171.10a	29.43a	11.37a	12.25a	116.67a	338.00a	23.30a	30.67a
NPK + 75 x 30	91.50b	37.30a	11.83a	12.95a	117.67a	245.7ab	29.30a	38.33a
PM + 75 x 20	29.93bcd	15.07a	12.30a	12.92a	91.00a	171.7ab	30.70a	39.00a
PM + 75 x 25	21.17bcd	37.07a	11.24a	12.47a	47.67a	233.33ab	20.70a	37.33a
PM + 75 x 30	11.30cd	27.30a	11.92a	12.87a	72.67a	149.00ab	23.00a	41.00a
OM + 75 x 20	26.33bcd	12.57a	12.06a	13.03a	55.67a	125.30ab	29.70a	39.00a
OM + 75 x 25	5.73d	8.73a	12.22a	13.14a	54.33a	111.30b	29.00a	53.00a
OM + 75 x 30	39.93bcd	13.27a	11.97a	12.78a	74.67a	86.30c	33.00a	52.67a

Means in a column followed by the same letter(s) are not significantly different by Tukey's Test at 5 % level of probability

3.3. Interactions

Significant interactions between intra-row spacing and types of fertilizer were observed at 3 WAS for weed dry weight and 7 WAS for weed density respectively in 2013 season alone (Table 2) at interaction of N.P.K. + 75 x 25 cm spacing. The population of broadleaf weeds was significantly (P>0.05) higher at Pm + 75 x 25 cm interaction in 2014, while OM + 75 x 20 cm resulted in higher (P>0.05) sedge populations compared to other combinations (Table 3). No interactions were observed during 2013 season. Among vegetative parameters, plant height, number of leaves, leaf area and leaf area index were also significantly (P < 0.05) highest at NPK

+ 75 x 25 cm interaction in 2013 planting season only (Table 4). Organomineral fertilizer treatments at 75 x 20 cm spacing resulted in the lowest values of the above mentioned growth attributes.

Table 3. Effects of fertilizer type and spacing on broadleaf, grass and sedge population m^{-2}

	Broadleaves		Grass		Sedges	
	2013	2014	2013	2014	2013	2014
Treatment	3 WAS		3 WAS		3 WAS	
Fertilizer						
Control	4.78a	10.6c	5.50a	17.3b	13.00a	6.85a
N.P.K.	6.00a	20.0a	5.00a	34.5a	14.00a	7.38a
PM	7.89a	13.8b	5.44a	37.7a	12.30a	7.04a
OMF	5.78a	13.2b	3.56a	14.2c	16.30a	5.62ab
Spacing (cm)						
20 x 75	5.92a	14.5a	4.56a	26.9	13.80a	6.56a
25 x 75	6.83a	14.2a	4.58a	16.1	14.80a	6.45a
30 x 75	5.67a	14.4a	5.58a	34.8	13.20a	7.16a
Fertilizer x spacing Interaction						
No. fert. + 75 x 20 cm	3.67ab	7.7c	4.33a	10.5c	7.70ab	6.08a
No. fert. + 75 x 25 cm	3.33ab	12.3c	4.33a	14.0c	17.30ab	7.07a
No. fert. + 75 x 30 cm	7.33ab	11.7c	2.00a	27.5bc	14.00ab	7.40a
NPK + 75 x 20 cm	4.67ab	18.0ab	3.69a	27.5bc	10.30ab	6.79a
NPK + 75 x 25 cm	6.00ab	25.0a	6.00a	32.5bc	13.70ab	7.45a
NPK + 75 x 30 cm	7.33ab	17.0ab	5.33a	43.5ab	18.00ab	7.72a
PM + 75 x 20 cm	9.00ab	19.3ab	4.67a	52.5a	20.00ab	7.45a
PM + 75 x 25 cm	12.00a	10.0c	4.67a	10.5c	7.30b	6.26a
PM + 75 x 30 cm	2.67b	12.0c	7.00a	50.0a	9.70ab	7.42a
OM + 75 x 20 cm	6.33ab	13.0c	5.67a	17.0c	17.00ab	5.73a
OM + 75 x 25 cm	6.00ab	9.7c	3.33a	17.5c	20.70a	5.02a
OM + 75 x 30 cm	5.33ab	17.0ab	8.00a	18.0c	11.30ab	6.09a

Means in a column followed by the same letter(s) are not significantly different by Tukey's Test at 5 % level of probability

3.4. Discussion

Increase in weed density, weed dry weight and relative populations of sedges, grasses and broad-leafed weeds occasioned by NPK application could be attributed to the stimulation of rapid weed growth and increased seed vigour of weed propagules from the nutrient flush accompanying NPK treatment. Higher plant growth observed among PM treated plots could be due to the weed suppressing effects of PM to the advantage of the crop. According to Shiyam et al. (2011) sawdust application suppressed weed growth in plantain/cocoyam intercrop. The authors further reported that weed dry weight was highest at the highest rate of NPK application (400 kg ha^{-1}) irrespective of mulching with sawdust. Makinde (2007) reported that organomineral fertilizer at 4.5 t ha^{-1} gave the greatest maize yields, because of higher nutrient supply to plants. Similarly, Akanbi et al. (2000) observed increase in Amaranth yield contributing components with increase in rates of maize stover amended with organic manure. Ipinmoroti et al. (2002) also reported increase in plant height and leaf area of tea with increase in OMF rates. In this study, similar results were recorded.

Table 4. Effects of types of fertilizer and intra row spacing on maize growth parameters at 9 WAS

	Plant height		No of leaves		Leaf area (cm^2)		Leaf area index	
	2013	2014	2013	2014	2013	2014	2013	2014
Fertilizer								
Control	128.2c	99.40c	11.53b	9.35ab	329.8b	358.50b	0.18b	0.20b
NPK	173.8b	104.5b	12.83ab	9.85b	473.6b	353.90b	0.25a	0.21b
PM	210.5a	119.40a	13.47a	10.11a	518.7a	418.90a	0.28a	0.24a
OMF	178.3b	126.50a	11.31b	9.92ab	479.6b	411.90a	0.26a	0.23a
Spacing								
20 x 75	168.5	118.00	12.83	9.601	443.0	375.80	0.29a	0.25
25 x 75	171.9	112.20	11.29	9.893	441.0	397.60	0.23b	0.21
30 x 75	177.7	107.10	12.77	9.944	466.7	383.00	0.21b	0.21
Fertilizer x spacing Interaction								
No Ft + 75 x 20	153.8ab	81.80	12.67ab	9.49	420.1ab	370.40	0.27ab	0.26
No. Ft. + 75 x 25	209.5a	97.20	13.58a	10.07	503.0a	381.30	0.26ab	0.23
No. Ft. + 75 x 30	158.2ab	88.20	12.25ab	9.99	498.1a	356.70	0.22abc	0.16
NPK + 75 x 20	197.6ab	109.80	13.42a	9.23	502.1a	323.80	0.33a	0.21
NPK + 75 x 25	217.6a	115.30	13.67a	9.51	552.0a	400.40	0.29a	0.21
NPK + 75 x 30	216.4a	119.20	13.33a	9.31	502.1a	458.80	0.22abc	0.21
PM + 75 x 20	174.5ab	130.80	11.75ab	9.99	473.1ab	408.60	0.31a	0.27
PM + 75 x 25	158.8ab	133.00	9.42b	10.14	471.2ab	402.50	0.24abc	0.21
PM + 75 x 30	201.7ab	94.30	12.75a	10.21	495.2a	445.70	0.24abc	0.23
OM + 75 x 20	148.2ab	149.70	13.33a	9.68	377.0bc	400.50	0.25ab	0.26
OM + 75 x 25	101.6c	102.90	8.50b	9.84	240.2c	406.30	0.12c	0.21
OM + 75 x 30	134.7bc	126.90	12.75a	10.25	372.3bc	476.10	0.16bc	0.21

Means in a column without letter(s) are not significantly different by Tukey's Test at 5 % level of probability

The interactions were however not consistent for both years, although the NPK + 75 x 25 cm resulted in higher yield components increase. On the other hand OMF treated plots, either with 75 x 25 cm or 75 x 30 cm spacing recorded the lowest weed density and weed dry matter values. The reduced prevalence of weeds may have contributed to better yields among OMF treated plants.

4. Conclusion

Maize growth is well supported by organomineral fertilizer treatment at 4.2 t/ha^{-1}, which supplied 18 kg N, 1.8 kg P and 27 kg k ha^{-1}. NPK tended to increase the population of weeds as well as weed dry matter while the closest intra-row spacing of 20 x 75 cm resulted in the highest grain yields in this study.

Table 5. Effect of fertilizer types and intra row spacing on weed flora count and maize grain yield in two seasons

	Weed flora		Grain yield t ha^{-1}	
Treatment	2013	2014	2013	2014
Fertilizer				
Control	7.67b	8.56b	1.56c	1.03b
NPK	10.22a	10.89a	2.25b	1.27a
PM	8.22b	9.00b	2.25b	1.35a
OMF	8.67b	7.22b	2.63a	1.47a
Spacing				
20×75	8.00	7.33	2.56a	1.40a
25×75	8.92	10.26	2.01b	1.34a
30×75	9.97	9.17	1.95c	1.11b
Fertilizer x Spacing Interaction				
No Ft + 75 x 20	6.33	7.33	3.24	1.18
No. Ft. + 75 x 25	8.00	10.67	1.66	1.05
No. Ft. + 75 x 30	8.67	7.67	1.85	0.85
NPK + 75 x 20	8.33	10.00	2.55	2.06
NPK + 75 x 25	12.00	11.33	1.86	1.33
NPK + 75 x 30	10.33	11.33	2.35	1.02
PM + 75 x 20	8.33	6.33	3.15	1.11
PM + 75 x 25	8.00	11.33	2.84	1.63
PM + 75 x 30	9.00	9.33	1.88	1.30
OM + 75 x 20	7.00	5.67	1.28	1.22
OM + 75 x 25	7.67	7.67	1.69	1.35
OM + 75 x 30	9.33	8.33	1.71	1.23

Means in a column without letter(s) are not significantly different by Tukey's Test at 5 % level of probability

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