

EFFECT OF PLANT DENSITY, FERTILIZER RATE AND WEED CONTROL ON GRAIN YIELD OF MAIZE (ZEA MAYS L.)

**Takim, F. O., Philips. E. O. and Olayiwola, O.I*

Department of Agronomy, Faculty of Agriculture,
University of Ilorin, Nigeria

*Corresponding Author's e-mail: fotakimson@unilorin.edu.ng

Abstract

Field experiments were established to evaluate the effects of fertilizer (NPK) rates, contrasting plant densities and weed control on weed infestation and yields of maize in the Southern Guinea savannah of Nigeria. The first trial (trial I) was laid as a split-split-plot in three replications using three maize varieties (LNT-P-Y, BR9928DMRSR-Y and PVA8-Y), three plant densities: 53,333 plants ha⁻¹ (a row on a ridge with 1 plant/stand at 75x25cm), 106,666 plants ha⁻¹ (a row on a ridge with two plants/stand at 75x25cm) and 106,666 plants ha⁻¹ (2 rows on a ridge with plant/stand at 75x25cm) and three NPK 20:10:10 rates (100:50:50, 150:75:75 and 200:100:100). Two best interactions between plant density and fertilizer rate were selected from trial I and laid as main plots in a split-plot design where six weed control methods were the sub-plots in trial II. The results showed that high fertilizer dose and low densely populated maize increased weed seedling population and biomass production. Maize plant density significantly influenced grain yield of maize, seeding at 106,000 plants/ha (2seeds/hill at single row/ridge) with application of NPK at 150:75:75 gave 6.33 tonnes/ha of BR 9928DRM SRY, 6.67 tonnes/ha of LNT-P-Y C₂ and 6.47 tonnes/ha of PVA8. Pre-application of Primextra Gold^(R) at 2.5kg ai/ha and post-application of Guardforce^(R) at 1.25kg ai/ha gave significantly higher grain yield, 4.89 tonnes/ha. It can be concluded in this study that seeding maize at two seeds per hill (106,666 plants/ha) with the applications of NPK fertilizer at 150:75:75, pre-Primextra Gold^(R) at 2.5kg ai/ha and post-Guardforce^(R) at 1.25kg ai/ha will lead to 100% increase in maize grain yield.

Key Words: Double Density, Fertilizer Rate, Primextra, Maize Yield

Introduction

There is an increased interest in maize production in the Savannah of West and Central Africa region because of the relatively higher incidence of solar radiation and lower incidence of pest and diseases during the maize growing season (Badu-Apraku *et al.*, 2006). There is gradual decline in maize yield which is likely attributed to: rapid reduction in soil fertility caused by intensive use of land and reduction of fallow period (DIPA, 2006), use of inappropriate plant spacing which determines plant population and final yield (Zeidan *et al.*, 2006), weeds infestation which is one of the main causes of low yields in maize and may condense yield up to 20 to 50% and inadequate high yielding maize varieties adapted to each agro-ecological zone (Kim, 1997).

Seeding maize at appropriate plant spacing is one of the bases for higher yield, whereas intra-row spacing at sub-optimum is a major constraint to attaining the yield potential of the crop (Alofe *et al.* 1988). There is no single recommendation for all environments and all maize varieties because optimum spacing for optimum maize yield could vary depending on factors such as variety and type, soil fertility, planting date and planting pattern among others

(Sangoi, 2000). Iken and Anusa (2004) recommended an optimum plant population of 53,333 plants/ha for maximum yield of maize. Their report indicated that this is obtainable using a spacing of 75cm x 25cm at one plant per stand or 75cm x 50cm at two plants per stand. Azam *et al.* (2007) reported that spacing of 75cm x 35cm resulted in increased grain yield of maize while 75cm x 15cm gave maximum cob weight but such conflicting reports have led to a renewed interest in the effects of high plant densities on yield of cereals. Various studies indicate that optimum fertilizer and plant populations provide better crop growth and yield which will increase food production and safeguard the environment for future generation (Buah *et al.*, 2009). Therefore,, developing plant varieties that are better users of available nutrients coupled with appropriate soil management practices remains a reliable method of combating problems of nutrient deficiencies in the Savannah lands like Nigeria.

Simić *et al.* (2012) reported that it is possible to control weed infestation level if maize is grown with increased spatial uniformity. Modification of crop density and pattern can reduce weed emergence and/or increase crop competitive ability (Salam *et al.*, 2010) while the modification of crop spatial arrangement can increase maize grain yield (Robles *et al.*, 2012). Chauhan (2013) reported that cultural weed management strategies need to be developed to maintain or increase the sustainability of direct seeded systems. Additionally, the use of weed-competitive cultivars, narrow row spacing, and high seeding rates are some of the non-chemical strategies that could help in suppressing weeds by closing the canopy quickly and increasing shade on the weeds (Chauhan, 2012) as competition for light is an important factor in crop-weed interference. In this vein, the current work was designed to determine the appropriate plant population, fertilizer application rate and weed control strategy that will improve the yield of maize in the Nigerian southern Guinea savannah.

Materials and Methods

Sites Description

The experiments were conducted during the 2014, 2015 and 2016 growing seasons at the University of Ilorin Teaching and Research Farm located at Bolorunduro Ilorin (at 008° 27' 23.9" N and 004° 39' 42.9" E) , Oyo State Agricultural Development Project demonstration field at Saki West and farmer's fields (at 008° 40' N 003° 24' E). Both sites are in the southern Guinea savannah agro-ecology of Nigeria.

Experiment I

The first experiment was aimed at identifying high yielding varieties, appropriate plant population and NPK fertilizer application rate most suited for the ecology. It was laid in randomized complete block design (RCBD) with split-split-plot arrangement and three replications. Maize varieties (LNTP-Y, BR9928DMRSR-Y and PVA8-Y) were the main plots, the sub-plot comprised of three plant densities/patterns: 53,333 plants ha⁻¹ (normal density maize; one row on a ridge, one plant per stand at 75x25cm), 106,666 plants ha⁻¹ (double density maize; on row one a ridge, one plant per stand at 75x25cm), and 106,666 plants ha⁻¹ (double density maize; two rows on a ridge, one plant per stand at 75x25cm with

triangular stand display) while the sub-sub-plots were NPK 20:10:10 fertilizer application rate (100:50:50, 150:75:75 and 200:100:100).

The land was mechanically ploughed and harrowed twice. Seeding was done on flat land and the plot size was 10 m x 5 m (50 m²) while the distance between adjacent plots and blocks was kept at 1.0 m apart each. NPK fertilizer (20:10:10) was applied at two weeks after sowing (WAS) and urea (46%) at 50% tasselling.

Primextra Gold[®] a proprietary mixture of metolachlor (290 g/L) and atrazine (370 g/L) was applied as pre-emergence at 2.5kg ai/ha immediately after seeding using a CP3 knapsacks sprayer filter with a polyjet nozzle with a delivery rate of 250-300 l/ha and supplementary hoeing at 4-5 WAS.

Experiment II

This experiment was aimed at identifying the appropriate weed control strategy that will suppress weed infestation in different seeding and NPK fertilizer application rates, to improve maize yield. The trial was laid in a Randomized Complete Block Design (RCBD) with split-plot arrangement and three replications. The main plots comprised of plant density/fertilizer rate: normal density maize; one row on a ridge, one plant per stand at 75x25cm plus NPK 20:10:10 fertilizer application rate at 100:50:50 and double density maize; two rows on a ridge, one plant per stand at 75x25cm plus NPK 20:10:10 fertilizer application rate at 150:75:75 while weed control strategy (weedy check, two hoe weeding at 3 and 6 WAS, pre-emergence application of Primextra Gold[®] at 2.5kg ai/ha and post-emergence application of Guardforce[®] (Nicosulfuron 40g/L) at 1.25kg ai/ha, pre-emergence application of Primextra Gold[®] at 2.5kg ai/ha and supplementary hoe weeding at 6WAS, pre-emergence application of Primextra Gold[®] at 2.5kg ai/ha and post-emergence application of Guardforce[®] at 1.25kg ai/ha made up the sub-plots. Seeding (variety: LNTP-Y) was done after ploughing and harrowing in July, 2016. The plot size and other post planting operations were the same as for experiment I

Data Collection

In experiment I and II: weed seedlings emerged within discreet quadrats (1 m²) at 3, 6, 9 and 12 WAS and were counted, pulled for identification to species level with the aid of a weed handbook titled *West African Weeds* by Akobundu and Agyakwa (1998). Weed biomass was determined using a weighing balance after subjecting the sampled weeds to oven drying. Leaf area (0.75 x leaf length x maximum breadth) at 5 and 10 WAS, plant height (cm) at 4, 8 and 12 WAS, ear height (cm), cob length (cm), cob number per plot and grain yield were estimated at harvest.

Data Analysis

Data collected were subjected to analyses of variance using the Genstat 5.32 statistical packages. Significant means were separated using Least Significant Difference (LSD) test at 5% probability level.

The composition of the weed flora was analyzed by calculating the Relative Abundance (RA) of each species within each experimental field as follows:

$$RA = (RD + RF) / 2$$

Where Relative Density (RD) = number of a weed species per unit area (within a quadrat) in the plot divided by the total number of weed species within the same unit area (quadrat); and Relative Frequency (RF) proportion of quadrat in which the species was present per experimental unit divided by the total frequency of all species in the experimental unit (Fadayomi and Takim, 2009).

Results

Thirty-three weed species belonging to 28 genera and 12 families were collected across the trial fields (See Table 1). Over half (61%) of the weeds were broadleaved species, 21% were grasses while 18% were sedges. In terms of relative abundance showed that 56.64% of the field was dominated with broadleaves weeds, 36.72% were grasses and 6.64% were sedges. Ten weed species made up 68.40% of the total weed relative abundance and were therefore the prevalent weed species. These were: *Digitaria horizontalis* Willd. (13.19%), *Diodia scandens* Sw. (11.00%), *Eleusine indica* Gaertn. (8.54%), *Tridax procumbens* L. (6.67%) *Oldelandia corymbosa* L. (5.65%) *Fimbristylis littoralis* Gaudet (5.21%), *Imperata cylindrica* L. (5.02%), *Triumfetta cordifolia* A. Rich. (4.92%), *Brachiaria deflexa* Schumacher. (4.26%) and *Phyllanthus amarus* Schum. and Thonn. (3.94%). There was inconsistency in the pattern of weed species across maize plant densities while the trend of weed seedling emergence across fertilizer rates showed that, high fertilizer rate relatively increased the emergence of weed seedlings.

Weed seedlings emerged throughout the growing season with a peak period at 6 WAS (See Table 2). Neither weed density nor weed biomass was significantly influenced by maize varieties except at 3 WAS where LNTP-Y seeded plots had higher weed seedling emergence (98 seedlings/m²). The population of maize plants per plot did not affect the emergence of weed seedlings but significantly influenced weed biomass production. The plots where maize was seeded at the recommended rate (53,333 plants/ha) had high weed biomass, 47.14 g/m² and 35.28 g/m² at 6 and 9 WAS, respectively. Fertilizer application at different rates significantly influenced weed seedlings emergence and weed biomass production. The higher rate of fertilizer application encouraged more weed seedlings emergence which translated to high weed biomass produced, 58.57 g/m² and 37.31 g/m² at 6 and 9 WAS, respectively.

Table 3 shows that maize varieties evaluated had a relatively similar yield components and significantly differed in grain yield with variety PVA8Y yielded the lowest, 2.56 tonnes/ha and 3.48 tonnes/ha at Ilorin and Saki, respectively while LNTP-Y and BR9928DMR SRY had similar grain yield ranged from 3.02—5.63 tonnes/ha. While the double density plots had 100% significantly increased in grain yield as compared to 1.65 tonnes/ha obtained at Ilorin and Saki.

Table 1: Mean weed species composition as influenced by seeding and fertilizer rate in a maize field (experiment I)

FAMILY	WEED SPECIES	M G	Plant density			Fertilizer rate			Relative Abundance (%)
			2DDM2 R	DDM2 R	NDM1 R	200:100:10 0	100:50:5 0	150:75:7 5	
Asteraceae	<i>Ageratum conyzoides</i> L.	B	0.73	0.72	1.17	1.56	2.36	2.68	1.54
	<i>Tridax procumbens</i> L.	B	6.00	5.27	9.47	7.39	6.13	5.39	6.67
Cleomaceae	<i>Cleome viscosa</i> L.	B	0.76	1.39	2.18	1.35	2.22	1.84	1.62
Commelinaceae	<i>Commelina benghalensis</i> L.	B	0.62	2.59	1.27	2.37	1.94	1.48	1.71
Convolvulaceae	<i>Ipomoea involucre</i> P.Beauv	B	2.73	1.27	1.87	2.18	1.94	1.81	1.97
Cyperaceae	<i>Cyperus rotundus</i> L.	S	0.11	0.12	0.07	0.13	0.23	0.39	0.16
	<i>C. iria</i> L.	S	0.15	0.12	0.24	0.10	0.24	0.18	0.17
	<i>C. esculentus</i> L.	S	0.07	1.56	0.84	0.62	0.83	1.16	0.84
	<i>Frimbristylis littoralis</i> Gaudet	S	9.20	5.36	3.86	5.13	4.06	3.63	5.21
Euphorbiaceae	<i>Kyllinga bulbosa</i> Beauv.	S	0.22	0.15	0.07	0.03	0.18	0.11	0.12
	<i>Mariscus alternifolius</i> Vahl.	S	0.11	0.07	0.26	0.13	0.17	0.075	0.12
	<i>Croton lobatus</i> L.	B	2.25	2.72	1.47	2.77	2.67	1.09	2.16
	<i>Euphorbia hyssopifolia</i> L.	B	0.29	0.52	0.17	0.55	0.31	0.22	0.35
	<i>E. hirta</i> L.	B	1.34	0.24	0.34	0.69	0.72	0.18	0.58
	<i>E. heterophylla</i> L.	B	2.58	3.39	2.65	2.63	3.02	3.47	2.95
	<i>Phyllanthus amarus</i> Schum.& Thonn.	B	9.71	2.28	2.88	3.18	3.02	2.56	3.94
	<i>Hyptis suaveolens</i> Poit.	B	4.98	3.64	1.72	6.32	2.91	3.39	3.82
	<i>Chamaecrista mimosoides</i> L.	B	0.36	0.63	1.17	0.83	1.25	1.09	0.89
	<i>Desmodium scorpiurus</i> (Sw.) Desv.	B	0.36	0.72	0.94	1.17	1.01	0.79	0.83
Malvaceae	<i>Tephrosia bracteolata</i> Guill. & Perr.	B	0.87	4.96	3.79	3.32	3.54	3.20	3.28
	<i>Sida acuta</i> Burm. f.	B	0.07	0.34	0.17	0.06	0.13	0.11	0.16
	<i>S. cordifolia</i> L.	B	0.47	0.43	0.54	0.41	0.52	0.45	0.47
Poaceae	<i>Andropogon gayanus</i> Kunth	G	0.73	1.79	1.74	2.32	2.98	2.52	2.01
	<i>Brachiara deflexa</i> (Schumach.)	G	5.45	0.87	4.83	4.81	4.40	5.20	4.26
	<i>Cynodon dactylon</i> (L.) Pers.	G	0.15	0.88	1.44	1.97	2.98	2.15	1.59
	<i>Digitaria horizontalis</i> Willd.	G	16.22	14.63	10.43	14.27	10.24	13.39	13.19
	<i>Eleusine indica</i> Gaertn.	G	4.87	12.51	9.39	9.17	7.20	8.14	8.54
	<i>Imperata cylindrica</i> L.	G	4.36	5.32	4.89	5.47	4.68	5.39	5.02
	<i>Setaria barbata</i> (Lam.) Kunth	G	0.22	2.08	2.15	2.70	2.15	3.09	2.06
	<i>Dioda scandens</i> Sw.	B	10.18	11.95	16.84	9.83	8.38	8.82	11.00
Rubiaceae	<i>Mitracarpus villosus</i> (Sw.) DC	B	1.38	1.68	1.85	2.32	2.84	2.86	2.16
	<i>Oldelandia corymbosa</i> L.	B	5.93	6.28	4.93	6.96	3.54	6.26	5.65
Tiliaceae	<i>Triumfetta cordifolia</i> A. Rich.	B	6.55	3.48	4.32	4.22	6.56	4.41	4.92

MG= morphological group, B=broadleaf, G=grass, S= sedge, 2DDM2R = Double density maize two rows on a ridge one plants per stand at 75 x 25 cm, DDM2R = Double density maize one row, two plant per stand at 75 x 25cm, NDM1R = Normal density maize one row, one plant per stand at 75 x 25cm

Table 2: Influence of variety, planting density and fertilizer rate on mean weed density and mean biomass production

Treatment	Weed density (seedling/m ²)			Weed biomass (g/m ²)	
	3 WAS	6 WAS	9 WAS	6 WAS	9 WAS
Variety					
BR9928DMRSRY	83	104	57	38.92	33.06
LNTPYC2	98	127	63	46.15	28.13
PVA8Y	74	95	58	42.57	30.18
Sed	5.52*	11.17	3.83	9.41	4.35
Plant Density					
2DDM2R	90	115	64	42.08	25.93
DDM2R	81	106	61	36.53	30.17
NDM1R	84	105	53	49.14	35.28
Sed	5.25	7.02	4.46	3.48	2.39*
Fertilizer Rate					
200:100:100	129	162	80	58.57	37.31
100:50:50	49	65	41	31.16	20.64
150:75:75	77	99	57	37.95	33.32
Sed	6.07*	7.66*	7.29*	7.01*	5.14*

2DDM2R = Double density maize two rows on a ridge one plants per stand at 75 x 25 cm, DDM2R = Double density maize one row, two plant per stand at 75 x 25cm, NDM1R = Normal density maize one row, one plant per stand at 75 x 25cm, *= significant at 95% probability level, WAS = weeks after sowing.

2.45 tonnes/ha at Saki from plots seeded to recommend maize population. There was significantly reduction in grain yield at the highest rate of fertilizer application. The application of NPK at 150:75:75 to plots where maize was seeded one row per ridge of two plants per stand (DDM2R) gave an average maize grain yield of 6tons/ha across the varieties (Table 4) followed by plots where NPK was applied at 100:50:50 (recommended rate). The grain yield obtained from the latter plots ranged between 4.50-5.83 tons/ha and these yields were relatively higher to what was obtained from similar plots where NPK was applied at 200:100:100. The doubling of the recommended fertilizer rate had relatively higher grain yield on plots where maize was seeded at normal density (53,333plants/ha).

Table 3: Effect of Variety, Plant Density and Fertilizer Rate on Yield and Yield Components of Maize

	Plant Height (cm)	Plants/ha	Ilorin No of cobs (cobs/ha)	Grain yield (t/ha)	Plant Height (cm)	Plants/ha	Saki No of cobs (cobs/ha)	Grain yield (t/ha)
Variety(V)								
BR9928DMR SRY	102	83796	77315	3.02	142	77944	74844	4.91
LNTPYC2	86	84738	82815	3.11	147	77963	73984	5.63
PVA8Y	88	81759	80779	2.56	145	76759	73833	3.48
Sed	5.49	1634.6	1846.4	0.15*	4.65	1091.7	3378.0	0.30*
Plant Density (D)								
2DDM2R	96	100170	99407	3.54	148	102130	95000	5.48
DDM2R	92	104104	102833	3.50	144	100074	98407	6.09
NDM1R	89	46019	38667	1.65	143	30463	29815	2.45
Sed	3.17	1679.5*	2075.3**	0.20*	4.29	11431.1*	3961.0*	0.19*
Fertilizer Rate (F)								
200:100:100	90	80741	75093	2.68	144	72500	69444	4.39
100:50:50	92	82238	81611	2.93	145	80463	78056	4.37
150:75:75	94	87315	84204	3.09	145	79704	74722	5.24
Sed	4.20	1508.2*	2605.8	0.20*	4.06	2323.4	2132.3	0.20**

2DDM2R = Double density maize two rows on a ridge one plants per stand at 75 x 25 cm, DDM2R = Double density maize one row, two plant per stand at 75 x 25cm, NDM1R = Normal density maize one row, one plant per stand at 75 x 25cm, *= significant at 95% probability level **= significant at 99% probability level

Table 5 shows the results obtained from experiment II, 103,633 plants/ha were estimated at harvest from DDM2R plots compared to 48,944 plants/ha estimated from plots where normal density of maize (NDM1R) was seeded. The maize population at DDM2R plots translated to higher grain yield of 3.94 tonnes/ha compared to 0.98 tonnes/ha obtained at NDM1R plots. The weed control strategy significantly affected yield and yield components estimated. Weed check plots had significantly low maize plant density, plant height, leaf area and subsequently no grain yield. The other weed control strategies had similar yield components and significantly differed in grain yield. The plots where Primextra and Guardforce herbicides were applied as pre-emergence and post-emergence, respectively had the highest maize grain yield, 4.89tonnes/ha followed by 3.92 tonnes/ha obtained at plots that had pre-emergence application of Primextra + supplementary hoe weeding at 5 WAS and these latter plots was similar to 2 hoe weeded plots that 3.85 tonnes/ha was recorded.

The performance of maize on farmer's fields seeded using two planting densities; fertilizer application rates and weed control strategy— pre-application of Primextra and post-application of Guardforce showed that doubling maize plant density and NPK at 150:75:75 gave higher maize grain yields ranging from 5.62 tons/ha to 7.67 tons/ha compared to 2.58-3.11 tons/ha obtained from plots with 53,333 plants/ha and NPK applied at 100:50:50 (See Table 5).

Table 4: Interactions of Variety, Plant Density and Fertilizer Rate on Maize Grain Yield (tonnes/ha)

Variety	Plant density	Fertilizer (NPK) Rate		
		200:100:100	100:50:50	150:75:75
BR9928DMR SRY	2DDM2R	5.50	5.33	5.50
	DDM2R	3.50	5.83	6.33
	NDM1R	4.67	3.33	3.27
LNTPYC2	2DDM2R	4.17	4.50	5.17
	DDM2R	4.33	4.50	6.67
	NDM1R	3.67	2.33	4.33
PVA8Y	2DDM2R	4.50	4.67	4.23
	DDM2R	5.17	5.50	6.47
	NDM1R	3.83	3.67	3.30
Sed		0.641		

2DDM2R = Double density maize two rows on a ridge one plants per stand at 75 x 25 cm, DDM2R = Double density maize one row, two plant per stand at 75 x 25cm, NDM1R = Normal density maize one row, one plant per stand at 75 x 25cm.

Table 5: Effect of Weed Control Strategy on Establishment and Yield of Maize under Two Plant Densities and Fertilizer Rates

Treatment	Plant Population	Plant height	Leaf Area	No of leaves	Grain yield (t/ha)
Plant Population/Fertilizer Rate (PPFR)					
DDM2R+ NPK (150:75:75)	103633	124.1	346	10	3.939
NDM1R + NPK (100:50:50)	48944	129.1	389	10	0.978
Sed	366.70**	8.00	55.30	0.29	0.091**
Weed Control (WC)					
Weedy check	70500	72.5	200	9	0.000
2 HW @ 3& 5 WAS	78178	142.3	433	10	3.847
Pre Primextra + Post Guardforce	78578	136.2	377	10	4.895
Pre Primextra and SHW@5WAS	77611	142.8	458	10	3.917
Pre Primextra	75700	142.6	412	10	1.267
Post Guardforce	77167	123.0	327	10	0.828
Sed	1281.40**	6.90**	47.90**	0.49	0.230**

HW=hoe weeding, WAS=weeks after planting, SHW=supplementary hoe weeding, **= significant at 99% probability level.

Discussion

The results clearly indicated that successive increase in fertilizer rate from recommended rate for the study area (400 kg NPK ha⁻¹) had influence on weed seedling emergence. While no

significant difference was observed on weed seedling population, the trend shows an increase in weed seedling population as the fertilizer rate increased. High weed seedlings in densely populated maize plots with high NPK application but this trend was not consistent with low maize density. Robles *et al.* (2012) reported that despite higher plant spacing variation, radiation interception was initially favoured by earlier canopy closure with twin row planting, but the relative radiation-interception advantage declined as plant density increased and at a later vegetative stage. Production of weed biomass was significantly affected by fertilizer rate. Plots that had NPK at 200:100:100 produced significantly higher weed biomass. Weed biomass (dry weight) is a better measure of effect of field management on weeds since such values combine weed density and size. Weed numbers can be halved, but if their weight is doubled, crop/weed competitive relationships may be unaltered.

The tallest maize plants were obtained in densely populated plots. This phenomenon explains that as the number of plants increased in a given area the competition among the plants for nutrients uptake and sunlight interception also increased (Sangakkara *et al.* 2004). There was a relatively increase in maize height as the amount of fertilizer applied was increased. Maize plant density significantly influenced grain yield of maize. Seeding at 106,666 plants/ha (2 seeds/hill at single row/ridge) gave relatively higher grain yield, 6.09 tonnes/ha. This result was supported by Robles *et al.*, (2012) who reported that twin rows yielded significantly more than single rows at any plant density. Sangoi (2000) explained that maize is the most sensitive grass species to variations in plant density, such that for each production system, there is a population that maximises the utilisation of available resources thereby allowing the expression of maximum attainable yield in that environment. Mashingaidze *et al.* (2004) further stated that maize yield is known to increase with increased plant population until the increase in yield attributable to the addition of plants is less than the decline in mean yield per plant due to increased inter-plant competition.

Experiment II showed the advantages of weed control in maize and the application of two treatments with the use of herbicides. This is undoubtedly the effective means of eliminating the competitive effect of weeds at the early developmental stages of maize and before canopy closure. Also the intermittent drought (which unfortunately occur more and more frequently in the Nigerian Southern Guinea Savannah GS), single herbicide application (mainly pre-emergence treatment) did not eliminate weeds infestation in the long time. Takim (2015) reported that pre-emergence application of terbutylazine could not provide season long weed control due to short persistence, fairly immobile and rapidly degradation in the soil and these characteristics are common to most pre-emergence herbicides. Therefore, too long period of waiting with a single treatment is irrational, since maize yields potential decreases drastically after the critical period of weed interference (3-5-leaf stage of maize) depending on the conditions in the field (Dogan *et al.* 2004).

In this situation, the possibility of carrying out two independent treatments on dates adapted to the current need and situation in the field makes it easier for the farmer to make the right

decision in the choice of optimum weed control strategy in maize. Knezevic *et al.* (2003) reported a significant yield increase in maize due to the application of split and lowered doses of herbicides. The high maize grain yield obtained in plots treated with pre Primextra and post Guardforce was due to low level of weed interference. Although the two hoe weeded and pre Primextra and supplementary hoe weeded plots had reasonable high yields, this method of weed control is tedious and time-consuming.

Therefore in this study, it can be concluded that seeding maize at 2 seeds per hill (to give an approximate population of 106,666 plants/ha) with application of NPK fertilizer at 150:75:75, pre-emergence application of Primextra Gold^(R) at 2.5 kg ai/ha and post-emergence application of Guardforce^(R) (Nicosulfuron 40 g/L) at 1.25 kg ai/ha three weeks after planting will lead to 100% increase in maize grain yield in the Nigerian Southern Guinea Savannah.

References

- Akobundu, I.O. and Agyakwa, G.W. (1998). A handbook of West Africa weeds. International Institute of Tropical Agriculture, Ibadan, Nigeria. pp 521.
- Alofe, C. O., Kim, S. K., Efron, Y., Fajemisin, J. M., Khadr, F. H. and Kang, B. T. (1988). Effect of nitrogen and plant density on grain performance of hybrid maize in the forest and derived savanna zone of Nigeria. National Conference on maize, Ile-Ife Abstract pp. 17
- Azam, S., Ali, M., Amin, M., Bibi, S. and Arif, M. (2007). Effect of plant population on maize hybrids. *Journal of Agricultural and Biological Science*, 2(1): 104 – 111.
- Badu-Apraku, B., Menkir, A., Fakorede, M.A.B., Fonten Lum, A. and Obeng-Antwi, K. (2006). Multivariate analyses of the genetic diversity of forty-seven Striga resistant tropical early maturing maize inbred lines. *Maydica* 51:551-559.
- Buah, S. S .J., Abatania, L. N. and Aflakpui, G. K. S. (2009). Quality Protein Maize Response to Nitrogen Rate and Plant Density in the Guinea Savanna Zone of Ghana, *West African Journal of Applied Ecology*. 6:9-21.
- Chauhan, B. S. (2012). Weed ecology and weed management strategies for dry seeded rice in Asia. *Weed Technology*, 26: 1-13.
- Chauhan, B. S. (2013). Shade reduces growth and seed production of *Echinochloa colona*, *Echinochloa crusgalli*, and *Echinochloa glabrescens*. *Crop Protection*, 43: 241-245.
- Directorate of Information and Publications of Agriculture (DIPA) (2006). Handbook of Agriculture: Facts and Figures for farmers, students and all interested in farming. Directorate of Information and Publications of Agriculture. Indian Council of Agricultural Research, New Delhi, pp.435.
- Dogan, M.N., Unay, A., Boz, O. and Albay, F. (2004). Determination of optimum weed control timing in maize (*Zea mays* L.). *Turkish Journal of Agriculture*,. 28, 349-354.

- Fadayomi, O. and Takim, F.O. (2009). Residual effects of legume cover plants on soil weed seed bank and weed growth in a subsequent maize crop. *Nigerian Journal of Weed Science* 22: 15-22.
- Iken, J. E. and Anusa, A. (2004). Maize Research and Production in Nigeria. *African Journal of Biotechnology*, 3(6): 302-307.
- Kim, S. K. (1997). Achievement, challenges and future direction of hybrid maize research and product. In B. Badu-Apraku, Akoroda M.O., Oedraw M. and QuinF.M(eds). *Proceedings of Required Maize Workshop May 99- June 2, 1995. IITA Cotonou, Benin Republic*
- Knezevic, M., Durkic, M., Knezevic, I. and Loncaric, Z. (2003). Effects of pre- and post-emergence weed control on weed population and maize yield in different tillage systems. *Plant Soil Environment* 49(5): 223-229.
- Mashingaidze, A.B., Lotz, L. A. P., Van der Werf, W., Kropff, M. J. and Chipomho, J. (2004). Narrow rows reduce density, biomass and seed production of weeds and increase maize yields. *Tropical Resource Manager*. 57: 89- 112.
- Robles, M., Ciampitti, I. A. and Vyn, T. J. (2012). Responses of maize hybrids to twin-row spatial arrangement at multiple plant densities. *Agronomy Journal*, 104: 1747-1756.
- Salam, M. A., Sarder, M. S. A. Ullah, M. J. Kawochar, M. A. and Islam, M. K. (2010). Effect of different spacing and levels of nitrogen fertilizer on the yield attributes and yield of hybrid maize. *Journal of Experimental Bioscience*, 1(2): 57-61.
- Sangakkara, U. R., Bandaranayake, P. S. R. D., Gajanayake, J. N. and Stamp, P. (2004). Plant populations and yield of rainfed maize grown in wet and dry seasons of the tropics. *Maydica*. 49: 83-88.
- Sangoi, L. (2000). Understanding plant density effects on maize growth and development: an important issue to maximise grain yield. *Ciência Rural* 31(1): 159-168.
- Simić, M., Dolijanović, Z., Maletić, R., Stefanović, L. and Filipović, M. (2012). Weed suppression and crop productivity by different arrangement patterns of maize. *Plant Soil Environment*, 58(3): 148-153.
- Takim, F. O. (2015). Efficacy of selected herbicide formulations on sugarcane field weeds in Southern Guinea Savanna of Nigeria. *Journal of Agricultural Research and Development*. 14(1): 60-73.
- Zeidan, M. S., Amany, A. and Balor El-Kramany, M. F. (2006). Effect of N-Fertilizer and plant Density on Yield and Quality of maize in Sandy Soil. *Research Journal of Agriculture and Biological Sciences*, 2(4): 156-161.