Influence of Timing and Frequency of Hoe Weeding and Herbicide Application on Maize Yield in Port Harcourt, Nigeria

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Abstract
In a field experiment to evaluate the effect of different weeding strategies on growth and grain yield of maize, eleven treatments comprising a combination of weeding frequencies and timing plus and herbicide usage were used which include: zero weeding (as control), one weeding at 3 weeks after planting (WAP), one weeding at 6 WAP, one weeding at 9 WAP, two weeding at 3+6 WAP, two weeding at 6+9 WAP, three weeding at 3+6+9 WAP, Pre-emergence Atrazine plus one hoe weeding at 6 WAP, Pre-emergence Atrazine plus one hoe weeding at 9 WAP, four hand weeding at 3+6+9+12 WAP and weed-free treatment. Results showed that weed-free treatment gave the highest grain yield of 3.93 t/ha and was not significantly higher than all other treatments except zero weeding, one weeding at 3 WAP and all treatments in which first weeding was delayed to 6 WAP and beyond. One weeding at 3 WAP produced grain yield that was significantly higher than either one weeding at 6 WAP or two weeding at 6+9 WAP, suggesting that the critical period of weed competition in maize in the zone exists before 6 WAP. Weed competition reduced grain yield by 46 - 72% in plots in which first weeding was delayed to 6 WAP and beyond, irrespective of the frequency of weeding thereafter. An economic analysis of labour cost and income from grain sales showed that pre-emergence application of atrazine supplemented with a weeding at 6 WAP followed by two hoe weeding at 3+6 WAP were more profitable than other weeding practices used.

***Key words**: Maize grain yield, hoe weeding, herbicide, Atrazine, critical period of weed interference*

Introduction

Maize (*Zea mays* L.) belonging to the grass family (Poaceae) is ranked first as the most important cereal crop in sub-Saharan Africa and third most widely grown crop in Nigeria, following sorghum and millet. The crop is highly productive and cheap to produce and adapts to a wide range of agro ecological zones (Babatunde *et al*., 2008). The rainforest agro-ecological zone of Nigeria is the major supplier of eating green maize, while the savanna zone in northern Nigeria comprising the (Derived Savanna, Guinea Savanna and Sahel) agro-ecological zones account for the large quantity of the dry grains (Ogunlade *et al*., 2010). Maize is not only an important cereal crop produced in Nigeria on the basis of output but also on the basis of number of farmers that produced it, as well as for its economic value (Olaniyi and Adewale, 2012). In recent years the demand for dry grains has been on the increase probably because in addition to being an important source of food and livestock feed, many agro-based industries in Nigeria rely on maize as a source of raw material for the production of flour, beer, other beverages and pharmaceuticals (Ranum *et al*., 2014; Iken and Amusa, 2004.. An estimated 4.2 million hectares were harvested in 2013 with an average yield of 2 metric t ha^{-1}, mostly by smallholder farmers. The average size of their farm holding is also smaller this could enable them manage their farms and resources more efficiently. The findings agree with (Onoja and Achike, 2008; Kuwornu *et al*., 2013).

Maize farmers face lot of production constrains among which is weed competition (Opaluwa *et al.,* 2015). Weeds compete with the crop for soil nutrients and other environmental resources. Maize is said to be highly susceptible to weed competition particularly at the early stages of growth (Evans *et al.,* 2003). It is required that maize plot be kept weed-free between planting and 6 weeks after planting which is the critical period of weed interference, in other to get optimal yield (Imoloame and Omolaiye, 2017). In Nigeria and most African countries, yield losses as high as 51 to 100% have been recorded in maize production due to weed competition (Paller, 2002). Weeds also provide stable environment for other pests of the crop. Maize cultivation, especially in the humid forest zone of Nigeria where the high rainfall averages 2400 mm per annum, weed competition is seen as the greatest constraints of the crop (Anorvey *et al.,* 2018). It has been observed that the severity of weed infestation increases with increased rainfall (Chikoye *et al.,* 2009). Herbicide usage which gives a better weed control method is expensive and most rural farmers can no longer afford it. Most farmers also get scared of herbicides due to their hazard implications. Again most herbicide recommendations are based on experience in the sub-humid areas and do not effectively applies to the high rainfall condition of the zone (Makinde and Ogunbodede, 2007).

The common method of weed control by smallholder farmers is hand-hoe weeding, which is back-breaking and labour demanding. Although most farmers in the zone understand the importance of weeding in order to achieve good plant growth and yield, there is a great concern over the timing and frequency of such weeding in the crop's life to sustain profitable yield. Weed competition if not controlled at the appropriate time severely reduces maize grain yields (Ismaila *et al.,* 2010; Keramati *et al.,* 2008). Much need to be done in the area of weed control in the high rainfall zone of southeastern Nigeria, more so with the prevalent issues of climate change. Information from other zones can only provide a generalised picture, because of edaphic and other factors. There is therefore the need to conduct this research to aid the traditional farmers in the zone. The objectives of the study were therefore, to determine the most economically viable number and timing of hand weeding for sustained maize production in the zone.

Materials and Methods

The experiment was carried out in the early cropping seasons of 2016 and 2017 at the Research Farm of the Rivers State Institute of Agricultural Research and Training, Onne, near Port 1-larcourt, Nigeria (40 43'N, 70 09'E; 11 m). Onne has a mean annual rainfall of 2400 mm in a monomodal distribution pattern. The soil of the experimental site is described as acid Ultisol derived from coastal sediment of marine origin (IITA, 1994) with the following characteristics: pH (water) 4.7, organic matter 1.79%, total nitrogen 0.19%, phosphorus (Bray-I) 21.3, and exchangeable K, Ca and Mg of 0.26, 2.3 and 2.31 meq I $00g^1$, respectively.

Experimental design

A randomised complete block design with nine treatments replicated three times was used for the trial. The treatments, a combination of weeding frequencies and timing and herbicide were: zero weeding, one weeding at 3 weeks after planting (WAP), one weeding at 6 WAP, one weeding at 9 WAP, two weeding at 3+6 WAP, two weeding at 6+9 WAP, three weeding at 3+6+9 WAP, Pre-emergence Atrazine (PreAtra) plus one weeding at 6 WAP, Pre-emergence Atrazine (PreAtra) plus one weeding at 9 WAP, four weeding at 3+6+9+12 WAP and weed-free. Individual plot size was 6 x 4.5 m.

Table 1: Meteorological data of experimental site

	2016	2017
Month	Rainfall (mm)	Rainfall (mm)
January	13.3	25.3
February	76.2	56.6
March	175.3	195.1
April	94.4	108.4
May	202.6	262.8
June	321.1	381.4
July	373.5	398.4
Total	1256.4	1428

Cultural operations

A one-year fallow land after a crop of cassava was cleared manually (resembling the traditional methods of the zone) towards the end of the dry season (mid February) in 2016 and 2017 for maize planting. Variety used was Oba 98. Planting was done in March each cropping year (at the beginning of the rains). Three grains were planted per hole on the flat each year at a spacing of 0.75 m x 0.25 m and later thinned to one plant per stand, 14 days after planting (DAP) giving a population of 53333 plants/ha. Weeding was based on the design of the experiment. The herbicide treatment was pre-emergence application of 2.5 liters of atrazine (Primextra Gold 720-SC) per hectare, followed by one hand weeding (Pre-Atz+1h); A single dose of fertilizer, NPK (20:10:10) was applied at the rate of 400 kg ha^{-1}, 23 DAP. Observations were made on plant heights at 10 WAP, number of days from planting to 50% tasseling and silking. Other data collected at maize harvest includes number of cobs/plant, weight per cob, grains/cob, 200-grain weight, grain yield, weed density and dry matter (DM) yield and net benefit return. Weed density and yield were determined by the use of a wooden quadrat measuring 1m x 1m. Two quadrats were randomly chosen per plot and all visible weeds within the quadrats counted to assess weed density. All the weeds above the ground within the quadrats were harvested and weighed. Sub samples were taken and oven-dried at 60°C for 48 hours after which the dry weight was taken to determine dry matter yield.

Results

Effect of timing and frequency of weeding on:

Plant and Ear height:

Timing and number of weeding significantly ($p<0.05$) influenced the growth of maize (Table 2). Tallest and shortest plants were recorded in weed-free and zero weeding plots, respectively. Weed-free treatment, followed by four weeding at 3+6+9+12 WAP, application of pre-emergence herbicide plus one weeding at 6 or 9 WAP, three weeding at 3+6+ 9 WAP and two weeding at 3+6 WAP, produced significantly taller plants than other treatments throughout both seasons. Although their height differed very slightly, they did not differ significantly ($p<0.05$) from one another. The result showed that one weeding at 3 WAP produce plants that were shorter in comparison with three weeding at 3+6+9 WAP by 26cm and 28cm in 2016 and 2017, respectively. Interestingly, one weeding at 3 WAP produced plants that were significantly taller than plants of one weeding at 6 WAP, one weeding at 9 WAP and two weeding at 6 and 9 WAP.

Ear height was significantly influenced by the respective weed management systems. Zero weeding, one weeding at 6 WAP, one weeding at 9 WAP and two weeding at 6 and 9 WAP, had the lowest ear height than other treatments.

Number of leaves and leaf area per plant

The treatments had significant effects ($P < 0.05$) on ear height, number of leaves and leaf area of the plant. Values of all the three variables were lowest with zero weeding, followed by treatments in which first weeding was delayed to 6 WAP and beyond. A single weeding at 3 WAP significantly increased the ear height, number of leaves and leaf area by 24.9cm, 1.2 and 51.8 cm^2 in relation to a single weeding at 6 WAP, respectively.

Tasseling and silking

Result in Table 3 shows that date of tasseling and silking were significantly influenced by timing and frequencies of weeding in maize. Early appearance of reproductive characters is a desirable attribute in breeding and crop production. There was early tasseling and silking in the weed-free treatment followed by four weeding at 3+6+9+12 WAP, three weeding at 3, 6 and 9 WAP, herbicide + one weeding at 6 or 9 WAP and two weeding at 3+6 WAP. Despite the slight differences in tasseling and silking dates among the treatments stated above, such differences did not differ significantly from one another in both cropping seasons rather one weeding at 3 WAP significantly delayed tasseling and silking in comparison to the above stated treatments. On the other hand, tasseling and silking were significantly earlier with one weeding at 3 WAP when compared to all other treatments in which first weeding was delayed to 6 WAP and beyond.

Yield components of maize

The number and timing of weeding had significant effect on number of cobs per plant, cob weight, number of grains per cob and seed weight (Table 4). Number of cobs per plant did not differ significantly across the treatments except zero weeding and plots in which first weeding was delayed to 9 WAP most plants did not produce cob on the plant. Plots kept weed-free from planting till harvest and weeding at 3+6+9+12 WAP produced cobs that were significantly heavier than plots left weedy from planting to harvest and those left weedy for 6 to 9 WAP before taking a weeding and left weedy again until harvest. Similar pattern was observed with number of grains per cob and grain weight in both years. Weed-free plot, all plots in which weed was controlled from planting beyond 6 WAP and the pre-herbicide application plus one weeding plots significantly increased number of grains per cob than on plots where there was weed infestation between planting and 6 WAP and beyond,

200-seed weight was significantly affected by period of weed interference in both years (Table 5). Plots kept weed-free until harvest produced seeds that were significantly heavier in both years but which were comparable with four weeding at 3+6+9+12 WAP, application of pre-emergence herbicide plus one weeding at 6 or 9 WAP, three weeding at 3+6+9 WAP and two weeding at 3+6 WAP. However, plants left weedy for the first 6 WAP and weedy until harvest gave significantly lighter grains.

Maize grain yield

Although maize grain yield was higher in the year 2017 than previous year, 2016, they did not differ significantly nor was there any significant interaction effect (Table 4.). Such increase in yield was however expected based on the rainfall data recorded in Table 1 which shows more rain in 2017 than 2016. Maize grain yield in both years was significantly ($p<0.05$) affected by the number and timing of weeding. Highest grain yields ($P < 0.01$) were recorded with weed-free treatment in 2016 and 2017. Immediately following were treatments in which weeds were controlled from planting beyond 6 WAP with the following slight grain yield reduction within same period and includes: four weeding at 3+6+9+12 WAP (0.13, 0.08 t ha^{-1}), PreAtra plus 6 WAP (0.13, 0.28 t ha^{-1}), PreAtra plus 9 WAP (0.19, 0.31 t ha^{-1}), three weeding at 3+6+9 WAP (0.2, 0.4 t ha^{-1}) and two weeding at 3+6 WAP (0.43, 0.52 t ha^{-1}). Weed-free until harvest resulted in maximum grain yields of 3.81 and 3.93 t ha^{-1} in 2016 and 2017, respectively. Plots in which weeding was delayed beyond 3 WAP included one weeding at 6 WAP, 9 WAP, two weeding at 6+9 WAP resulted in significantly low percentage yield reduction (average of two years) of 52.3%. 61.9% and 50.1%, respectively, in relation to the weed-free plot with maximum grain yield. Percentage yield reduction increased with increase in period of weed interference with zero weeding (weedy from planting until harvest) having the highest percentage yield loss of 72.2%.

Weed yield

Zero weeding produced significantly higher percentage of grass in relation to broad-leafed weeds in both seasons (Table 5) while all weed controlled treatments, irrespective of the number and time of such weeding resulted in more broad-leafed than grasses at harvest. Zero weeding also produced significantly higher weed density than all other treatments, followed by one weeding at 3 WAP with a yield reduction of 14%, 6 WAP by 35% and 9 WAP by 55% and two weeding at 6+9 WAP by 31.2%. Weed DM yield in plots weeded at 3 WAP and left weedy until harvest was high, being next to zero weeding.

Table 2: Effect of frequency and timing of hand weeding on maize plant eight, ear height number of leaves and leaf area at 10 weeks after planting (WAP).

Treatment	2016				2017			
	Plant height (cm)	Ear height (cm)	Number of leaf/ plant	Leaf area (cm^2)	Plant height (cm)	Ear height (cm)	Number of leaf/ plant	Leaf area (cm^2)
Zero weeding	119.5	40.1	5.3	197.4	102.6	49.1	6.3	174.6
Weed @ 3 WAP	202.3	90.1	9.4	386.9	2.11.2	94.1	10.6	382.8
Weed @ 6 WAP	165.6	65.2	8.2	335.1	1.75.4	89.2	9.2	368.1
Weed @ 9 WAP	127.3	41.7	6.3	212.2	116.9	43..1	6.8	222.4
Weed @ 3+6 WAP	197.1	93.8	10.8	467.6	2.01.3	105.3	11.8	417.6
Weed @ 6+9 WAP	173.3	69.0	9.4	323.9	1.78.6	94.1	10.4	363.2
Weed @ 3+6+9 WAP	202.2	91.0	12.2	478.6	201.9	111.4	12.4	458.6
PreAtra plus 6 WAP	205.4	103.7	12.1	498.2	214.5	120.7	12.5	511.3
PreAtra plus 9 WAP	204.6	108.6	11.4	496.4	216.3	120.6	12.6	503.2
Weed @ 3+6+9+12 WAP	208.3	112.6	12.4	508.7	218.2	121.4	13.2	528.7
Weed free plot	209.1	115.3	12.6	526.4	219.6	122.6	13.6	534.2
LSD (P<O.05)	18.3	9.11	0.82	21.331	12.68	4.11	0.79	21.331

WAP = Weeks after maize planting; PreAtra = Pre-emergence Atrazine

Table 3. Effect of frequency and timing of hand weeding on tasseling and silking dates of maize (days to initial and 50%)

Weeding frequency and timing	2016 Tasseling (50%)	2016 Silking (50%)	2017 Tasseling (50%)	2017 Silking (50%)
Zero weeding	66.0	73.5	69.5	76.5
Weed @ 3 WAP	58.5	65.0	58.5	65.0
Weed @ 6 WAP	62.5	67.5	66.5	69.5
Weed @ 9 WAP	64.1	70.4	68.3	73.3
Weed @ 3+6 WAP	53.0	57.0	53.0	59.3
Weed @ 6+9 WAP	62.5	69.5	67.0	71.0
Weed @ 3+6+9 WAP	52.0	56.5	57.0	59 0
PreAtra plus 6 WAP	50.6	56.1	53.2	58.3
PreAtra plus 9 WAP	50.6	56.1	53.2	58.4
Weed @ 3+6+9+12 WAP	50.8	56.1	53.2	58.3
Weed free plot	51.0	59.0	57.2	58.2
LSD (P<O.05)	4.53	4.01	4.35	2.83

WAP = Weeks after maize planting; PreAtra = Pre-emergence Atrazine

Table 4. Effect of frequency and timing of hand weeding on yield and yield attributes of maize

Weeding	Number of cobs per plant 2016	Number of cobs per plant 2017	Cob weight (g) 2016	Cob weight (g) 2017	No. of grains per cob 2016	No. of grains per cob 2017	200-Grain weight (g) 2016	200-Grain weight (g) 2017	Grain yield (t/ha) 2016	Grain yield (t/ha) 2017
Zero weeding	0.62	.0.58	42.2	52.2	63	56	20.2	24.2	0.82	1.13
Weed @ 3 WAP	1.0	1.00	121.0	132.4	233	252	39.4	38.9	2.53	2.61
Weed @ 6 WAP	0.92	0.96	91.2	101.2	214	221	34.6	35.2	1.74	1.95
Weed @ 9 WAP	0.84	0.91	84.2	97.3	194	198	30.1	31.6	1.44	1.51
Weed @ 3+6 WAP	1.01	1.00	171.3	148.7	300	313	43.9	44.7	3.38	3.21
Weed @ 6+9 WAP	0.94	0.89	133.1	154.7	244	236	38.2	37.6	1.86	2.03
Weed @ 3+6+9 WAP	1.01	1.01	174.2	183.3	347	263	44.6	46.1	3.61	3.53
PreAtra plus 6 WAP	1.01	1.01	173.8	182.5	359	351	45.4	45.5	3.64	3.45
PreAtra plus 9 WAP	1.01	1.04	178.4	183.1	374	362	46.6	46.8	3.62	3.32
Weed @ 3+6+9+12 WAP	1.02	1.10	187.2	187.9	387	361	46.3	46.8	3.68	3.85
Weed free plot	1.01	1.10	183.5	193.2	382	366	45.3	46.5	3.81	3.93
LSD $_{(0.05)}$	0.05	0.06	7.22	14.22	6.2	8.4	2.2	2.1	0.73	0.73

Table 5. Effect of timing and frequency of weeding on weed density, ratio of borad-leafed to grass and total DM yield in 2016 and 2017.

Treatments	2016			2017			Combined yield	
	B:Grass Ratio	Weed density (cm^2)	Weed Yield (t/ha)	B:Grass Ratio	Weed density (cm^2)	Weed Yield (t/ha)	Mean Weed density (cm^2)	Mean Weed Yield (t/ha)
Zero weeding	1:4	318	3.89	1:4	342	3.83	330	3.86
Weed @ 3 WAP	2:1	262	2.83	1:1	308	2.7	285	2.77
Weed @ 6 WAP	1:3	227	2.42	1:2	202	2.07	214.5	2.25
Weed @ 9 WAP	2:4	194	2.13	1:2	112	1.52	153	1.83
Weed @ 3+6 WAP	2:1	248	2.25	4:1	206	2.04	227	2.15
Weed @ 6+9 WAP	1:1	205	1.84	3:2	231	1.43	218	1.64
Weed @ 3+6+9 WAP	2:1	214	1.79	2:1	176	1.24	195	1.52
PreAtra plus 6 WAP	3:1	207	1.52	3:2	224	1.31	215.5	1.42
PreAtra plus 9 WAP	2:1	225	1.33	4:1	191	1.02	208	1.18
Weed @ 3+6+9+12 WAP	4:1	137	0.43	4:1	152	0.59	144.5	0.51
Weed free plot	0	0	0	0	0	0	0	0
LSD (0.05)		73.5	0.525		56.2	0.641	67.3	6.22
CV (%)		18.3	9.7		14.9	12.6	14.8	12.7

WAP = Weeks after maize planting.; PreAtra = Pre-emergence Atrazine.

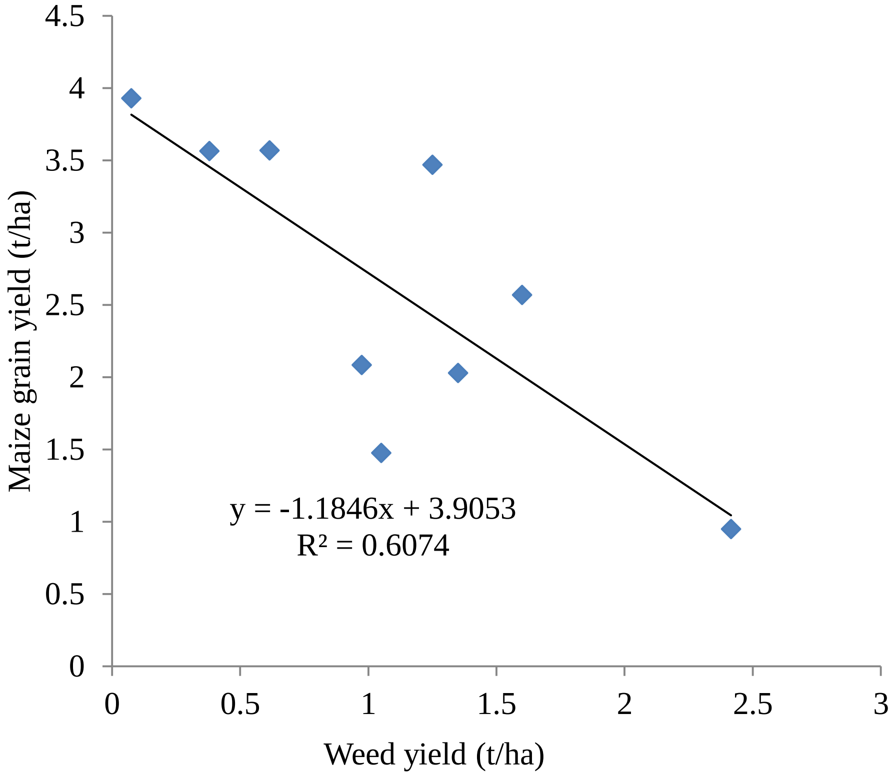

Fig. 1. Relationship between weed yield and maize grain yield as influenced by the weed control strategies

Table 6. Mean effect of timing and frequency of hoe weeding on financial returns from maize produced in Port Harcourt.

Treatment	Labour requirement	Labour Cost	Grain Yield (t/ha)	Gross returns From sales ₦	Net Benefit returns ₦	Percentage Increase Over control	Rating
Zero weeding	0	0	0.98	117600	117600	-	-
Weed @ 3 WAP	85	93500	2.57	308400	214900	182.7	4th
Weed @ 6 WAP	100	110000	1.85	222000	112000	95.2	6th
Weed @ 9 WAP	110	121000	1.48	177600	56600	48.1	10th
Weed @ 3+6 WAP	160	176000	3.3	396000	220000	187.1	3rd
Weed @ 6+9 WAP	160	176000	1.95	234000	58000	49.3	9th
Weed @ 3+6+9 WAP	240	264000	3.57	428400	164400	139.8	5th
PreAtra plus 6 WAP	120	132000	3.55	426000	294000	250.0	1st
PreAtra plus 9 WAP	125	137500	3.47	416400	278900	237.2	2nd
Weed @ 3+6+9+12 WAP	320	352000	3.77	452400	100400	85.4	7th
Weed free plot	350	385000	3.87	464400	79400	67.5	8th
LSD (0.05)	nav	nav	nav	nav	nav	18.42	

Note: All estimates were based on prevailing market price in Port Harcourt environment.
Maize = N120,000.00/tonne.; Labour = N1,100.00/man/day; nav = not available.

Discussion

Maize plant growth characters

The effect of weed interference in maize crop cannot be over emphasized. Weed-free treatment and all the treatments in which weed was controlled from planting to 6 WAP and beyond produced significantly higher plant height, ear height, leaf area and number of leaves per plant in both years. This improvement in character could be attributed to effective prevention of weeds from interfering with the crop for long period in the life circle of the crop, especially at the critical period of crop growth. It enabled the plants to effectively tap the resources of light, moisture, soil nutrients and other assimilates which promoted better crop performance. Plots with prolong weed infestation until harvest resulted in poor growth performance due to intense competition with the crop for growth resources. This agrees with the report of Tunku and Ishaya (2012) that keeping crop weed infested for 6 Weeks and beyond resulted in significant growth depression. Imoloame and Omolaiye (2017) had observed that plots kept weed-free between planting and 6 WAP, which is the critical period of weed interference, produced optimal growth. The finding also agrees with earlier work of Abdin *et al*., (1998) who observed that the reduced height and other development characters of maize in weedy plots was due to severe competition between weeds and maize for environmental resources such as water and nutrients.

The result of the study clearly shows that growth of weed infested maize plants was seriously hampered, producing stunted and slender plants that lacked vigour especially when first weeding was delayed up to 6 WAP and beyond thus allowing the weeds to compete seriously with the crop for growth resources.

Yield and yield components of maize.

Weed-free treatment and all the treatments in which weed was controlled from planting to 6 WAP and beyond significantly increased the number of cobs/pant, produced heavier cob weight, large number of grain/cob and heavier grains than plots that had weed infestation between planting and 6 WAP. This success could be because weeds were removed at critical period of crop growth, thereby enhanced the utilization of growth resources for optimal production of photosynthates for better performance. Similarly, the application of pre-emergence Atrazine plus one weeding at 6 or 9 WAP produced significant yield of maize crop comparable with the weed-free treatment in both years. The less competitive effects of weeds in early and effective weed control plots might have enhanced utilization of growth resources thereby significantly increased number of cobs/plant, cob weight, number of grains/cob and 200- grain weight culminated in producing significantly higher grain yields.

This finding agrees with the reports of Ismaila *et al.,* (2010) and Keramati *et al.,* (2008) that weed competition if not controlled at the appropriate time severely reduces maize grain yields. However, plots left weedy till 6 WAP and beyond gave significantly lower grain yield. This establishes the depressive effect of weeds dominance in crop field especially at the critical growth period of the crop leading to low yield of the crop. Grain yields obtained when first weeding was delayed to 6 WAP, 9 WAP or two weeding at 6+9 WAP or zero weeding were grossly low as compared to one weeding at 3 WAP. The lower weeding efficiency observed in plots of delayed first weeding suggests that the longer weeds are allowed to interfere with maize, the lower will be the weeding efficiency, hence poor grain yield. This agrees with Iyagba et al. (2012) who reported low yield in Okra when it was infested with weeds from planting to 5 WAP.

There was a high negative correlation between weed infestation and maize grain yields (Fig 1). A similar result was obtained by Bidinger *et al*., (1996) who reported that weed competed seriously with the maize crop for soil nutrient and light, thereby causing a serious grain yield depression in treatments with inadequate weed control. Application of pre-emergence atrazine significantly ($P < 0.05$) reduced the weed biomass as effectively as an early hand weeding. A single hand weeding, however, did not control the weeds to enhance plant growth and grain yields. This report indicates that delaying of first weeding beyond 3 WAP offered the weeds a competitive advantage thereby suppressing grain yields seriously. Knezevic *et al*. (2003) had reported that a weed-free duration (5-6 weeks) starting from the 2-leaf stage of soybean is enough to provide acceptable yield in a corn and soybean system. This observation shows that a critical period of weed competition occurs from 3-6 weeks after maize planting. Maize plot must be kept free of weeds within this critical period to enhance higher maize grain yield.

Weed yield
The effects of timing and frequency of weeding significantly influenced weed development in maize crop and showed almost similar trends in both years (Table 5). There were generally more weeds but higher yield in the second year than it was in the first year. This was probably due to higher rainfall in the second year than the first. Chikoye *et al.,* (2009) had reported that the severity of weed infestation increases with increased rainfall. Grass weeds were more dominant in weedy plots while broadleaved weeds mostly dominated the effective weed controlled plots. According to report of Anonymous (2007) grass weeds are more competitive and damaging in a grass-leaf crop than in broad-leaf crops. There was generally high weed incidence in zero weeding and weeding at 3 WAP treatments than the weed-free, four weeding at 3+6+9+12 WAP and three weeding at 3+6+9 WAP treatments. This happening was attributed to prolonged period weeds were allowed to interfere with the crop in the plots resulting in higher weed density and weed dry matter compared to plots kept weed-free until harvest. This finding agrees with that of Iyagba et al. (2012) who reported prolonged weed interference in Okra resulted in higher weed yield in such plots.

Labour management and net return

Timing and frequency of weeding influenced the man-day requirements for maize production (Table 6). One weeding at 3 WAP and weed-free treatments gave the lowest and highest labour requirement, respectively, indicating that labour requirement increased with increased number of weeding. But one weeding at 6 WAP and at 9 WAP increased labour requirement by 18% and 29% in comparison with one weeding at 3 WAP. Similarly, taking two weeding at 6 and 9 WAP increased labour cost over two weeding at 3 and 6 WAP by 27%. An explanation for this finding is that delaying of first weeding to about 6 WAP requires more labour for removal since the weeds must have been well established by then and are heavy. This agrees with Iyagba et al. (2012) who reported a low weed control efficiency in Okra as it was infested with weeds for 5 WAP.

The net benefit derivable from the enterprise was also influenced by the number of weeding per treatment as well as the timing of such weeding. Although no money was spent on weed removal in the zero weeding treatment, the net benefit return was very low (Tables 6). It did not differ much from treatments in which first weeding was delayed to 6 WAP, irrespective of the frequencies of such weeding thereafter. Two weeding at 3+6.WAP gave the highest net return followed by three weeding at 3, 6 and 9 WAP which was not better on average than one weeding at 3 WAP.

Findings from this study show that a hand-hoe weeding at 6 to 9 WAP following an application of 2.5 liters per hectare of pre-emergence atrazine is important in keeping the weed population and yield low as well as producing the highest maize grain yield at the lowest labour cost. This report agrees with Kaiira1 *et al.*, (2014), Takim *et al*. (2012) and El-Metwally *et al.* (2012) that a combination of hand-hoe weeding with a pre- or post-emergence herbicide led to the most effective way for controlling weeds in maize. However, the highest grain yield emanating from three hand weeding (at 3+6+9 WAP), four hand weeding (at 3+6+9+12 WAP) and the complete weed-free treatments attracted a lot of labour, therefore, was not cost-effective to the smallholder farmer. According to Forcella (2000), hand hoeing is efficient in eradication of weeds, but Eddowes and Harpur (2006) observed that pre-emergence herbicide application at 2-3 liter ha^{-1} controls annual weeds in maize in a superior manner compared to other control measures.

Conclusion

The study shows that for maximum growth and yield of maize, plots should be kept weed-free for a minimum of 6 WAP. However, for economic reason and to avoid high frequency of weeding and drudgery, weeding twice at 3+6 WAP or the application of pre-emergence atrazine followed by one weeding at 6 WAP is recommended.

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