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WEED COMPETITION IN MAIZE (*Zea mays* L.) AS A FUNCTION OF THE TIMING OF HAND-HOEING WEED CONTROL IN THE SOUTHERN GUINEA SAVANNA ZONE OF NIGERIA

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Field studies were conducted in 2010 and 2011 at the Teaching and Research Farm of the University of Ilorin, Nigeria (9°29’ N, 4°35’ E) to evaluate the effect of early weed competition on the growth and yield of maize. The experiment was designed as a randomized complete block (RCBD) with a split-plot arrangement and three replications. The main plots consisted of three weed control treatments included weedy (no herbicide), grass weeds (pre-emergence atrazine) and broadleaf weeds (pre-emergence metolachlor), while the sub-plots consisted of six durations of weed infestation (3, 4, 5, 6, 7 and 8 weeks after emergence). The pre-emergence herbicides had a greater effect on weed density and weed dry weight. Weed seedling emergence and weed dry weight increased significantly with an increase in the duration of weed interference. The grasses and broadleaf weeds had a similar influence on the growth and grain yield of maize. Three to five weeks of weed interference gave similar grain yields, which were significantly higher than those obtained in plots that had 6–8 weeks of weed interference. These results suggest that the maize crop must be kept free of weeds for 6–8 weeks after the application of pre-emergence herbicide to minimize weed–crop competition and harvest a good grain yield.

Key words: maize, atrazine, metolachlor, weed interference

Introduction

Weeds are one of the most important factors in maize production, causing severe yield losses worldwide, with an average of 12.8% when weed control is applied and 29.2% without weed control (Oerke and Steiner, 1996). Yield loss due to weeds is estimated to be 38% in Africa as a whole and 64–75% in the Guinea savanna zone of Nigeria (NACWC, 1994), varying from 40 to 100% in Nigeria (Fadayomi, 1991). Therefore, weed control is an important management practice for maize production, which must be carried out to ensure optimum grain yield.

Weed control in maize is carried out by mechanical and/or chemical methods. Weeds between plant rows are generally removed by mechanical cultivation, while weeds within the rows are controlled by hand hoeing or by herbicides. Although both methods are effective in controlling weeds, they increase production costs and have some disadvantages or side effects when applied intensively (Dogan et al., 2004).

Controlling weeds based on critical periods for weed control (CPWC) is the most appropriate way to optimize weed control applications. With the aid of CPWC it is possible to make decisions on the need for and timing of weed control, and to control weeds only when efficient weed control is required (Knezevic et al., 2002). When studying the agronomic aspects of maize Cumberland et al. (1971) theorised on the existence of a "critical stage" in the life of a maize plant. This "critical stage" was between 4 and 6 weeks after emergence, and competition at this stage had a major effect on potential yield. Others have found that the critical period fell between 4 and 8 weeks after emergence, with the starting time of the period showing more variation than the end time (Hall et al., 1992). It has been observed that if weeds are not controlled, there is a critical crop–weed competition period with grain losses reaching between 35 and 70% (Ford and Pleasant, 1994).

The magnitude of losses in grain yield due to weed infestation in maize depends on the composition of the weed flora, weed density and the stage of crop growth at which weed–crop competition occurs (Maqsood et al., 1999). To provide more precise information, CPWC should be determined specifically for a particular region by considering the weed composition and climatic conditions (Wu et al., 2008). Therefore, this study aimed to estimate the effect of the timing of weed removal and the duration of weed morphological groups in maize.

Materials and methods

Site description

This study was conducted at the University of Ilorin Teaching and Research Farm during the 2010 and 2011 growing seasons. The farm is located at Bolorunduro, Ilorin, in the southern Guinea savanna ecological zone of Nigeria (9°29' N, 4°35' E), and is 307 m above sea level. The area had a peak of rainfall in July that decreased gradually thereafter and a daily temperature range of 20–35°C. The soil was a sandy clay loam, classified as a Plinthustaffs, with approximately 74.12% sand, 5.54% silt and 20.69% clay, organic matter 2% and pH 5.5.

Experimental layout

The experiment was designed as a randomized complete block (RCBD) with a split-plot arrangement and three replications. The main plots consisted of three weed control treatments: (1) pre-emergence application of atrazine [(6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2,4-diamine) (370 g/L)] at 2.0 kg ai/ha to control broadleaf weeds and allow grass weeds to dominate; (2) pre-emergence application of metolachlor (Dual®) [(2-chloro-N-(2-ethyl-6-methyl-phenyl)-N-(2-methoxyl-1-methyl ethyl) acetamide) (290 g/L)] at 2.0 kg ai/ha to control grass weeds and allow broadleaf weeds to dominate; and (3) no weed control, allowing the natural weed spectrum to become established. The sub-plots consisted of six durations of weed infestation: (1) weed competition for the first 3 weeks after emergence; (2) weed competition for the first 4 weeks after emergence; (3) weed competition for the first 5 weeks after emergence; (4) weed competition for the first 6 weeks after emergence; (5) weed competition for the first 7 weeks after emergence; and (6) weed competition for the first 8 weeks after emergence.

Field establishment

The vegetation cover of the experimental sites was slashed to ground level prior to carrying out the tillage operations. Thereafter, in 2009 the appropriate plots were disc ploughed on 3rd July, and harrowed and ridged on 10th July. In 2010, the plots were disc ploughed on 10th June, while harrowing and ridging were done one week later. Maize (*Zea mays* L., variety Suwan 1), was sown with three seeds per hole at a spacing of 1.3 m × 0.3 m, and the seedlings were later thinned to two plants per stand to give an approximate plant density of 61,538 plants/ha.

All the herbicide treatments were applied pre-emergence, using a CP3 knapsack sprayer, fitted with a polyjet nozzle at a delivery rate of 250–300 L/ha, immediately after sowing the maize seeds. NPK fertilizer (20:10:10) was applied in two splits, at a rate of 200 kg/ha 3 weeks after planting (WAP) and 100 kg/ha at 7–8 WAP.

Data collection

Data on weed seedling emergence (weed density) were monitored in two fixed quadrats (0.5 m^2) at 4, 6 and 8 WAP in each sub-plot. The weed species from each quadrat in each sub-plot were counted, pulled out and identified at the species level using the weed identification manual of Akobundu and Agyakwa (1998), then separated into broadleaf weeds, grasses and sedges. Thereafter, the number of weeds within each category was counted. Samples from the same plot were bulked and oven-dried for 24 hours at 80°C to constant weight.

The number of maize plants per plot was estimated at 6 WAP, the plant height, leaf area and leaf area index at 8 WAP and grain yield at harvest.

Data analysis

All the data collected in both years were analysed using Genstat Discovery Edition 3, and means were separated using the Least Significant Difference (LSD) test at $p \leq 0.05$.

Results and discussion

The Dual treatment provided excellent control of the grass weeds, especially in the 2011 season. The predominant grass weeds were *Brachiaria deflexa* (Schmach) C. E. Hubbard, *Digitaria horizontalis* Willd., *Eleusine indica* Gaertn., *Rottboellia cochinchinensis* (Lour.) Clayton and *Cynodon dactylon* L. in both years. Similarly, atrazine controlled most of the broadleaf weeds except for a few, such as *Euphorbia heterophylla* Linn., *Tridax procumbens* L. and *Cleome viscosa* L.

The effects of weed control and duration of weed interference on weed seedling emergence at 4, 6 and 8 WAP are presented in Table 1. The highest weed density was recorded in the unweeded control plots except at 4 WAP in both years and 8 WAP in 2011, when similar weed populations were obtained in atrazine-treated plots as in the unweeded control plots. The plots treated with Dual had similar weed density to the atrazine-treated plots in 2010, while in 2011, the Dual-treated plots had a significantly lower weed population compared to that obtained with atrazine. Weed seedling emergence increased significantly with an increase in the duration of weed interference in maize, while it decreased significantly with the increasing removal of weeds. This agrees with Shinggu et al. (2009), who reported that weed interference had a significant effect on weed growth and weed dry matter in a maize/cowpea intercropping system.

The population of weed morphological types was significantly affected by the weed control treatments (Table 2). The unweeded control plots had significantly more weed types than in the herbicide-treated plots, but the combined population of broadleaf weeds and grasses in the Dual- and atrazine-treated plots, respectively, showed a numerical similarity to that recorded from the control plots in both years. The effect of the duration of weed interference on the weed types followed a pattern similar to that observed for weed seedling emergence.

The effects of weed control and duration of weed interference on weed dry matter are presented in Table 3. The highest weed biomass was obtained in the untreated control plots except at 6 and 8 WAP in the 2011 season. The grass weeds in the atrazine-treated plots and the broadleaf weeds in the Dual-treated plots grew at similar rates, but in both cases where significant differences were observed, these weed types were adversely affected by the herbicides. The combined weights of grass and broadleaf weeds were similar to when they were growing together in the untreated plots. Weed biomass increased significantly with an increase in the duration of weed interference and decreased gradually with the length of the weed-free period.

The number of maize plants was not affected significantly by the varying durations of weed interference and weed control treatment during maize growth (Table 4), ranging between 62 and 76. It is evident that weed infestation did not significantly affect the maize plant stand. This is in agreement with the findings of Maqsood et al. (1999) and James et al. (2000).

The effect of the weed control treatments on plant height was significant. The untreated plots had significantly lower plant height compared to the atrazine and Dual-treated plots. The latter plots had statistically similar plant height. Similarly, where weed competition was allowed for the first 3 to 5 weeks, the plant height increased significantly, but decreased beyond 6 weeks of weed interference (Table 4). These results confirmed earlier reports that weed–crop competition from 6–8 weeks after emergence was very critical for plant height (Cumberland et al., 1971; Atkinson, 1978; Singh et al., 1985; Hall et al., 1992; Maqsood et al., 1999).

Plots treated with pre-emergence herbicides had similar maize grain yields, which were significantly higher than what was obtained in the unweeded control plots in both years (Table 5). These results were in contrast to the findings of James et al. (2000), who reported that grasses had a greater effect on maize grain yield than broadleaf weeds. Three to five weeks of weed interference produced similar grain yields, which were significantly higher than those obtained in plots having 6–8 weeks of weed interference. In other words,

Table 1
Influence of weed control treatments and duration of weed interference on weed seedling emergence (seedlings/m^2)

Treatment	Weed seedling population in 2010			Weed seedling population in 2011		
	4WAP	6WAP	8WAP	4WAP	6WAP	8WAP
Weed control (WC)						
Dual	28	60	82	21	23	15
Atrazine	65	41	69	65	64	23
No weed control	96	91	117	70	93	25
Sed	20.78	11.16	8.07	10.64	12.50	3.22
LSD (0.05)	41.16	23.01	22.42	21.62	25.41	7.81
Duration of weed interference (WI)						
3 weeks	22	14	11	30	16	7
4 weeks	66	13	7	46	18	5
5 weeks	68	9	6	52	28	0
6 weeks	64	108	14	64	77	3
7 weeks	78	109	6	60	102	8
8 weeks	84	130	493	61	116	102
Sed	13.29	16.18	26.18	7.05	17.68	15.38
LSD (0.05)	26.96	33.09	53.09	15.23	36.74	32.08
Interaction						
WC × WI	NS	NS	NS	NS	NS	NS

WAP = weeks after planting; NS = non-significant

Table 2
Influence of weed control treatments and duration of weed interference on the population of weed morphological types (seedlings/m^2)

Treatment	Weed types in 2010				Weed types in 2011			
	4 WAP		8 WAP		4WAP		8 WAP	
Weed control (WC)	BL	GR	BL	GR	BL	GR	BL	GR
Dual	20	8	35	47	17	4	9	6
Atrazine	17	48	26	33	14	51	14	9
No weed control	35	61	52	66	31	39	10	15
Sed	4.76	5.93	4.90	7.54	3.65	9.73	1.77	3.97
LSD (0.05)	10.53	11.75	10.86	16.48	7.42	19.73	NS	NS
Duration of weed interference (WI)								
3 weeks	12	10	6	5	20	10	5	2
4 weeks	34	32	2	5	20	26	2	3
5 weeks	27	41	3	3	31	21	0	0
6 weeks	40	24	4	10	20	44	1	2
7 weeks	35	43	1	5	18	42	5	3
8 weeks	15	69	212	281	17	44	53	49
Sed	5.16	13.76	22.50	15.61	14.18	17.31	21.66	11.34
LSD (0.05)	11.42	28.47	47.81	32.84	NS	NS	44.31	24.21
Interaction								
WC × WI	NS	NS	NS	NS	NS	NS	NS	NS

WAP = weeks after planting; BL = broadleaf weed seedlings; GR = grass weed seedlings; NS = non-significant

Table 3

Influence of weed control treatments and duration of weed interference on weed biomass (g/m^2)

Treatment	Weed biomass in 2010			Weed biomass in 2011		
	4WAP	6WAP	8WAP	4WAP	6WAP	8WAP
Weed control (WC)						
Dual	14.98	26.64	2.22	11.21	31.24	1.35
Atrazine	12.64	16.29	1.65	15.49	34.19	0.57
No weed control	31.32	26.84	4.16	20.46	33.52	1.31
Sed	7.59	3.87	0.63	3.21	7.67	0.35
LSD (0.05)	16.48	8.45	1.76	6.53	NS	NS
Duration of weed interference (WI)						
3 weeks	1.18	0.25	0.66	1.07	0.32	0.21
4 weeks	18.37	0.28	0.81	7.23	0.63	0.95
5 weeks	22.53	0.35	1.26	17.46	0.81	0
6 weeks	21.76	53.67	0.80	22.24	50.68	0.39
7 weeks	24.87	44.98	0.64	23.95	76.53	0.84
8 weeks	23.55	40.07	11.74	20.54	69.09	3.98
Sed	1.54	26.89	0.85	4.54	10.84	0.50
LSD (0.05)	4.01	54.54	1.71	9.23	22.03	1.02
Interaction						
WC × WI	NS	NS	NS	NS	NS	NS

WAP =weeks after planting; NS = non-significant

Table 4

Influence of weed control treatments and duration of weed interference on crop growth and grain yield

Treatment	2010				2011			
	Plant/plot	PH (cm)	LAI	GY (t/ha)	Plant/plot	PH (cm)	LAI	GY (t/ha)
Weed control (WC)								
Dual	75	144	4.69	1.398	73	141	5.56	1.353
Atrazine	68	142	5.65	1.410	70	148	5.34	1.250
NWC	67	115	4.71	0.376	69	126	3.86	0.661
Sed	5.14	2.452	0.213	0.153	5.25	3.16	0.422	0.158
LSD (0.05)	NS	5.762	0.759	0.342	NS	8.226	0.858	0.322
Duration of weed interference (WI)								
3 weeks	75	148	5.41	1.573	62	151	6.32	1.611
4 weeks	70	142	5.47	1.428	70	155	5.26	1.400
5 weeks	69	145	4.76	1.417	72	143	5.11	1.100
6 weeks	70	137	4.58	0.800	74	137	4.84	0.956
7 weeks I	75	135	3.72	0.661	76	121	4.38	0.772
8 weeks	70	125	5.84	0.394	71	116	3.75	0.689
Sed	7.26	2.876	0.667	0.195	7.43	4.571	0.597	0.124
LSD (0.05)	NS	7.624	1.353	0.432	NS	11.392	1.214	0.355
Interaction								
WC × WI	NS	NS	NS	NS	NS	NS	NS	*

WAP = weeks after planting; NWC = no weed control; PH = plant height, LAI = leaf area index; GY = grain yield; NS = non-significant

Table 5
Interactive effect between weed control and duration of weed interference on grain yield (t ha^{-1}) in the 2011 cropping season

Weed control	Duration of weed interference					
	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks
Dual	1.783	1.483	1.350	1.200	1.050	1.250
Atrazine	1.933	1.783	1.400	0.967	0.800	0.617
NWC	1.117	0.933	0.700	0.550	0.467	0.200
Sed			0.288			
LSD(0.05)			0.572			

NWC = no weed control

the grain yield decreased significantly with an increase in the duration of weed interference. The above findings agree with those of Shad (1988), who reported that weeding operations conducted from 6 to 8 weeks after planting may not give an economic increase in yield, while Maqsood et al. (1999) observed that maize infested with weeds for the first 6–8 weeks of growth may have a drastic decrease in the grain yield. In a similar manner, Shinggu et al. (2009) observed that keeping the crop weed-free till 6 WAP and beyond gave better crop performance. The significantly lower grain yield recorded in the case of weed interference for more than 6 weeks of maize growth may be due to the higher weed density and biomass, and probably to competition for nutrients, moisture, etc. These results suggest that the weed morphological groups did not significantly affect the growth or grain yield of maize and that the maize crop must be kept free of weeds from 6–8 weeks after the application of pre-emergence herbicide in order to eliminate the weed–crop competition that will significantly reduce the grain yield of maize.

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