Journal of Agricultural Sciences (Belgrade)
Vol. 66, No. 4, 2021
Pages 335-350

https://doi.org/10.2298/JAS2104335E
UDC: 632.954(669)
Original scientific paper

-

ENHANCING THE WEED CONTROL EFFICACY OF TWO PRE-EMERGENCE HERBICIDES IN MAIZE/JACK BEAN AND MAIZE/GROUNDNUT INTERCROPS IN DERIVED SAVANNA

Enor Eni[1], Olusegun R. Adeyemi[1*], Segun Toyosi O. Lagoke[1] and Osebekwin E. Asiribo[2]

[1]Department of Plant Physiology and Crop Production, Federal University of Agriculture Abeokuta, Nigeria
[2]Department of Statistics, Federal University of Agriculture Abeokuta, Nigeria

Abstract: The inability of pre-emergence herbicides alone to give season-long weed control in maize production justifies the need for supplementary weed control. Field trials were conducted to evaluate intercropped groundnut and jack bean for enhanced weed control efficacy of two pre-emergence herbicides in maize production in 2013/2014 and 2015 cropping seasons at the Federal University of Agriculture, Abeokuta, Nigeria. The experiment was arranged in split-plot fitted in a randomized complete block design with three replications. Main plots consisted of eight weed control treatments of a commercially formulated mixture of prometryne + metolachlor (Probaben[R]); prometryne + acetochlor (Super Union[R]) each at 2.4 kg a.i ha^{-1}, 1.6 kg a.i ha^{-1} with and without supplementary hoe-weeding, two hoe-weedings and a weedy check. Sub-plot treatments consisted of eight cropping patterns (sole maize, maize-jack bean and maize-groundnut intercrops, each at two spacings [100 x 37.5 cm and 75 x 50 cm] and sole crops of jack bean and groundnut). All the weed control methods significantly reduced ($p<0.05$) weed dry matter compared to the weedy check by 10–81%. Maize grain yields (1.4–5.2 t ha^{-1}) were similar for all plots with the weed control methods, except in the 2015 late season, but significantly depressed (21–48%) on those weed-infested throughout. Intercropped jack bean and groundnut with maize significantly suppressed weed growth relative to sole crops of maize, jack bean or groundnut by 20–67%. Therefore, the efficacy of pre-emergence herbicides in this study was enhanced by intercropping of maize with jack bean and groundnut at the spacings of 75 x 50 cm and 100 x 37.5 cm in the early seasons.

Key words: intercropping, jack bean, pre-emergence herbicide, weed control.

[*]Corresponding author: e-mail: adeyemior@funaab.edu.ng

Introduction

Maize (*Zea mays L.*) ranks third after wheat and rice among the world's most traded cereal crops and first in Africa, but more maize is currently produced annually than any other crop (FAOSTAT, 2014). Nigeria is the largest producer of maize in Africa, with 7.2 million tonnes (USDA, 2017). Virtually all parts of maize are utilized for various purposes ranging from direct human consumption and animal feed to raw materials in industries (IITA, 2009; Nuss and Tanumihardjo, 2010; Sule-Enyisi et al., 2014).

In spite of the great potentials of maize, both as a consumer crop and an industrial crop, its production in Nigeria is constrained by several factors, which include the use of low-yielding varieties, problems of low soil fertility, drought, diseases, pests and weed infestation, price fluctuation and inadequate storage facilities (IITA, 2000; Ojo, 2000). In 2019, the average yield of maize in Nigeria was 1.69 tonnes per ha (Knoema.com, 2019) compared with the global average yield of 4.3 t ha^{-1} and 8.6 t ha^{-1} of the United States.

Weeds appear to have the most deleterious effects on maize of all the constraints militating against its production and causing 69% to 92% loss in grain yield in the savanna agro-ecological zones of Nigeria (Adigun and Lagoke, 2003; Eni et al., 2012; Lagoke et al., 2014).

The use of a single method of weed control usually has several limitations (Jhala et al., 2014). It has been observed by several authors (Akobundu, 1987; Badmus et al., 2006; Eni et al., 2012; Lagoke et al., 2014; Adeyemi et al., 2019) that the use of one method of weed control was unable to give season-long control of weeds, hence the use of supplementary hoe-weeding, post-emergence herbicide application or/and cover crops to pre-emergence herbicide application is justified. The use of low growing legume cover crops to supplement other control measures for season-long weed control has been suggested by various workers (Akobundu, 1987; Yenish et al., 1996; Udensi et al., 1999; Badmus et al., 2006; Ojelade, 2004; Giwa, 2007).

The use of jack bean to suppress weed growth in maize production is currently under-exploited. The complementary use of the spatial arrangement of maize could be considered as it would affect cover crop spread and total light transmission to the weeds and consequently their smothering. Therefore, there is the need to determine the most appropriate combinations of maize spacing, cover crop and weed control treatment for effective season-long weed control and acceptable maize growth and productivity.

The use of a single herbicide and mixtures of herbicides like atrazine, prometryne, diuron, metolachlor, alachlor and pendimethalin has been reported in maize production in Nigeria (Akinyemiju, 1993; Osikanlu, 1996; Adigun and Lagoke, 1999). However, there is a paucity of information on the enhancement of the effectiveness of some commercially formulated mixtures of pre-emergence herbicides with cover crops, especially groundnut and jack bean, to substitute supplementary hoe-weeding. Therefore, the objective of this study was to evaluate the weed control efficacy of pre-emergence herbicide mixtures of prometryne, metolachlor and acetochlor in maize production as influenced by intercropped groundnut and jack bean as legume cover crops and row spacing.

Material and Methods

Field trials were conducted to evaluate intercropped groundnut and jack bean for enhanced weed control efficacy of pre-emergence herbicide use in maize production in the late seasons of 2013 and 2015 and early seasons of 2014 and 2015 at the Federal University of Agriculture, Abeokuta. Details of the physico-chemical properties and weed flora are contained in Tables 1 and 2. In all the trials, the land was ploughed and harrowed at the two-week interval. The experiment was arranged in split-plot fitted in a randomized complete block design with three replications. Main plots consisted of eight weed control methods (WCMs): Probaben^{R} (prometryne + metolachlor, 200+200 g of a.i. per L) and Super Union^{R} (prometryne+acetochlor, 130+380 g of a.i. per L) each applied at 2.4 kg a.i ha, 1.6 kg a.i/ha and each at 1.6 kg a.i/ha followed by supplementary hoe-weeding at 6 WAP, two hoe-weedings at 3 and 6 WAP and a weedy check. Sub-plot treatments consisted of eight cropping patterns (CPs) – sole maize, maize-jack bean and maize-groundnut intercrops, each at two spacings (100 x 37.5 cm and 75 x 50 cm) and sole crops of jack bean and groundnut.

Table 1. Soil physico-chemical characteristics at the experimental sites at Alabata Road, Abeokuta, Nigeria.

Soil composition	2013L	2014E	2015E	2015 L
Particle size analysis				
Sand (%)	83.8	82.8	70.8	82.8
Silt (%)	8.5	4.4	17.4	4.4
Clay (%)	9.2	12.8	11.8	12.4
Textural class	sandy-loam	sandy-loam	sandy-loam	sandy-loam
Chemical composition				
Organic carbon (%)	1.89	4.19	3.83	2.99
Available P (mg/kg)	1.90 ppm	40.89	41.26	41.92
Total N (%)	1.12	0.14	0.15	0.16
Exchangeable K (Cmol/g)	0.74	0.54	0.62	0.6

E = Early season, L= Late season.

Three seeds of maize were planted per hill at the spacing indicated according to the treatment structure and thinned to 2 plants per stand three weeks later to give a total population of 53,333 plants/ha. The gross plot size was 6 m x 3 m while 4.5 m x 2.0 m and 4 m x 2.25 m were the net plot sizes for maize spaced at 75 x 50 cm and 100 x 37.5 cm, respectively. Maize genotype Oba Super 2, a single cross hybrid, groundnut local variety *Jawanda* and an unnamed variety of jack bean sourced from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were planted.

Table 2. Common weed flora composition and levels of weed species occurrence before soil cultivation at the experimental sites at Alabata Road, Abeokuta, Nigeria.

Weed species	Level of infestation			
Broadleaves	2013L	2015L	2014E	2015E
Mucuna utilis (Wight) Burck.	+	-	++	-
Meremia aegyptia L.	++	++	+++	+
Talinum triangulare (Jacq.) Willd.	++	+	+	-
Tridax procumbens L.	++	++	+++	+
Ageratum conyzoides	_	-	++	+
Euphorbia heterophylla L.	+++	+++	+	++
Euphorbia hirta L.	++	+	+	-
Aspilia africana (Pers.) C.D. Adams.	+	+	+	+
Centrosema pubescens Benth.	+	+	-	+
Unknown pulse	+	+	++	+
Grasses				
Andropogun gayanus (Kunth.)	+	+	+	++
Panicum maximum Jacq.	+++	+++	++	+++
Rottboellia cochinchinensis (Lour.) W.D. Clayton	+	+	+	+
Eleusine indica (Gaertn.)	+	+	-	+
Digitaria horizontalis (Willd)	+	+	+	+
Physalis angulata L.	+	-	+	-
Sedges				
Cyperus esculentus L.	+	+	-	+
Cyperus rotundus L.	+	+	-	+
Spiderwort				
Commelina bengalensis L.	++	+	+	-

E = Early season; L = Late season; +++ = High infestation (60–90% occurrence); ++ = Moderate infestation (30–59% occurrence); + = Low infestation (1–29% occurrence).

Inorganic fertilizer was applied to maize at the rate of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare. All herbicide treatments were applied pre-emergence one day after planting in a spray volume of 230 l/ha using a CP3 knapsack sprayer with a green deflector nozzle at a pressure of 2.1kg/cm^2. Hoe-weeding was carried out on appropriate plots at 3 and 6 weeks after planting (WAP) using a West

African hand hoe. The weeding operation was proceeded by weed cover score assessment and sampling. Data collected included the grain yield of maize, weed cover score and weed dry matter production. All data collected were subjected to analysis of variance, and treatment means were compared using Duncan Multiple Range Test ($p<0.05$).

The statistical package used was GENSTAT 12th Edition, following the procedure of www.vsn.co/software/genstat/htmhelp/server/HCITEGEN.

Results and Discussion

The cropping patterns (CPs) affected weed infestation in this study (Tables 3 to 7). The groundnut and jack bean components in a mixture with maize reduced weed infestation compared to sole crops of maize, groundnut and jack bean. Weed infestation at 9 WAP, as reflected in weed cover score and broadleaf weed dry matter production, was, in most cases, lower in the intercrops at both spacings compared to the corresponding sole maize, sole jack bean and sole groundnut. Moreover, at 12 WAP, the weed cover score was generally lower on plots of groundnut intercropped with maize at both spacings compared with the sole maize in 2015 early and late wet seasons (Table 3). In all cases, plots of maize intercropped with groundnut consistently produced lower broadleaf weed dry matter compared with the respective maximum in each trial. Total weed infestation at harvest was also lower in the maize/groundnut mixture than the corresponding sole maize and sole groundnut (Tables 4 to 6).

The additional shade caused by maize stands in the mixture, which enhanced the smothering effect of jack bean and groundnut canopies, was probably responsible for better suppression of weeds in the mixture compared with the sole crops. The results corroborate those of Badmus et al. (2006), Lagoke et al. (2014), Adebomi (2008) and Williams (2010), who reported reduced weed infestation in maize–groundnut mixtures compared with the sole maize crop. Bilalis et al. (2010) also reported reduced weed infestation in intercrops compared with their sole crops.

However, at 12 WAP and harvest, weed infestation was only higher on the plots with sole maize at 100 x 37.5 cm spacing than the corresponding intercrop with jack bean. The higher weed infestation in sole maize than in the intercrop with jack bean at 100 x 37.5 cm can be attributed to the wider inter-row spacing than at 75 x 50 cm, which allowed for more light transmission to lower strata for weed growth. Maize in narrow rows was reported to shade soil surface and consequently smother weeds beneath the canopy earlier than those in wider rows (Jhala et al., 2014; Simić et al., 2020). Weed infestation was, however, observed to be consistently similar on plots of jack bean intercropped with maize at the two spacings, indicating that both intercrop combinations controlled weed similarly, probably due to the greater role of the cover crop in suppressing weeds than maize.

Table 3. Effects of weed control treatments and cropping patterns on weed cover score* at 9 and 12 WAP at Abeokuta.

Treatment	9 WAP				12 WAP			
	2013L	2014E	2015E[1]	2015L[2]	2013L	2014E	2015E	2015L
Weed Control Method (WCM)								
Probaben[R] at 2.4 kg a.i ha^{-1}	3.20bc	4.10b	2.10b	5.40b	5.80bc	4.10b	3.40bc	6.10b
Probaben[R] at 1.6 kg a.i ha^{-1}	3.70b	3.90bc	1.90bc	5.50b	6.70ab	3.80bc	3.60bc	6.20b
Probaben[R] at 1.6 kg a.i ha^{-1} fb[3] SHW[4]	2.10cd	2.20e	1.10d	1.50c	4.80cd	2.70de	1.80e	2.10c
Super Union[R] at 2.4 kg a.i ha^{-1}	3.40b	3.20cd	1.80bcd	5.60b	6.90ab	3.40bcd	2.90cd	6.30b
Super Union[R] 1.6 kg a.i ha^{-1}	4.10b	3.10cd	2. 20b	5.20b	6.80ab	3.40bcd	3.90b	6.30b
Super Union[R] 1.6 kg a.i ha^{-1} fb[3] SHW[4]	1.90d	1.70e	1.20d	1.60c	4.50cd	2.40e	2.10de	1.90c
Hoe-weeding at 3 and 6 WAP[5]	1.60d	2.30de	1.30cd	1.40c	4.30d	2.90cde	2.00de	1.80c
Weedy check	6.10a	7.20a	6.10a	7.30a	8.10a	7.60a	7.80a	7.50a
SE ± (WCM)	0.38	0.28	0.23	0.34	0.43	0.29	0.32	0.26
Cropping Pattern (CP)								
75 x 50 cm Sole maize	4.20a	4.30a	2.50a	4.30bcd	7.70a	4.50a	3.60bc	4.70bcd
75 x 50 cm Maize + Jack bean	3.00b	2.30d	2.10bc	3.50de	4.50e	2.60c	3.10d	4.2cd
75 x 50 cm Maize + Groundnut	2.80b	2.80cd	1.80c	3.80cde	5.70cd	3.40b	2.80d	4.40bcd
Sole jack bean	2.90b	3.00bc	2.50a	4.20bcd	4.90de	3.30b	3.80ab	4.90bc
Sole groundnut	3.40b	4.20a	1.90c	5.20a	5.90c	5.10a	3.00d	6.10a
100 x 37.5 cm Maize + Jack bean	3.20b	2.90bc	2.50ab	3.20e	5.70cd	3.10bc	3.60bc	4.10d
100 x 37.5 cm Maize + Groundnut	3.30b	3.50b	1.80c	4.50abc	6.50bc	3.60b	3.10cd	4.90bc
100 x 37.5 cm Sole maize	3.30b	4.80a	2.70a	4.90ab	7.00ab	4.80a	4.30a	4.90b
SE ± (CP)	0.19	0.19	0.12	0.29	0.29	0.20	0.18	0.23
SE ± Interaction (WCM x CP)	0.62	0.59	0.40	0.84	0.88	0.60	0.57	0.66

[1]E = Early season; [2]L = Late season; [3]fb = Followed by; [4]SHW = Supplementary hoe-weeding; [5]WAP = Weeks after planting; [6]Means followed by the same letter(s) within the same column and treatments are not significantly different at the 5% level of probability using Duncan's New Multiple Range Test (DNMRT); [7]Probaben[R] = Prometryne (20%) + Metolachlor (20%); [8]Super Union[R] = Prometryne (13%) + Acetochlor (38%); *Weed cover score was based on visual observations using a scale of 1–10, where 1 = no weed cover and 10 = complete weed cover.

In this study, weed infestation was observed to be consistently similar on plots of maize/groundnut and maize/jack bean intercrops at both spacings, indicating that all the intercrop combinations similarly suppressed weeds.

The weed control methods (WCMs) also affected the level of weed infestation in this study (Tables 3 to 7). All the weed control methods generally reduced weed infestation, especially at the early stage of crop growth compared with the weedy check. Weed cover scores at 9 and 12 WAP were consistently lower in the supplementary hoe-weeded plots and those hoe-weeded twice than those with the application of herbicides alone, indicating that additional hoe-weeding at 6 WAP to the application of pre-emergence herbicides was still required to give satisfactory season-long weed control (Table 3). Various authors have earlier reported the inability of pre-emergence herbicides alone to give season-long weed control in maize production in various agroecological zones of Nigeria (Bakut, 1985; Akobundu, 1987; Adigun and Lagoke, 2003; Williams, 2010; Lagoke et al., 2014; Adeyemi et al., 2019). Akobundu (1987) indicated that pre-emergence herbicide application gave early weed control of emerging weed seedlings but lost effectiveness later due to depletion in the soil, thereby allowing late-emerging weeds to re-infest plots.

In this study, the herbicide treatments also reduced broadleaf weed dry matter production compared to the weedy check at 9 WAP with the exception of the pre-emergence application of Super union^{R} alone in 2013 late and 2015 early seasons (Table 4). This confirms that the weed control methods gave various levels of early weed control until 9 WAP. Furthermore, broadleaf weed dry matter production at 12 WAP was generally lower with the similar values of the supplementary hoe-weeded plots and those hoe-weeded twice, compared to the other weed control treatments. It is, therefore, apparent that the late supplementary hoe-weeding at 6 WAP to either pre-emergence herbicides or one hoe-weeding at 3 WAP is critical for improved season-long weed control in maize production despite intercropped legume cover crops.

The pre-emergence application of both Probaben^{R} and Super Union^{R} alone was observed to give moderate weed control, which was, however, lower than the maximum obtained from the two hoe-weedings in this study. These results suggest that the pre-emergence application of the herbicides alone was also effective in controlling weeds, especially more in the early than in the late season. These results also suggest that the application of pre-emergence herbicides could be as effective as hoe-weeding in the management of weeds in maize production as earlier indicated by Adigun and Lagoke (2003), Chikoye et al. (2005), Olatunji et al. (2016).

At equal rates, without supplementary hoe-weeding, the two herbicide treatments consistently resulted in similar weed infestation as reflected in weed cover scores, broadleaf and grass weed dry matter production, as well as total weed dry matter production at harvest when compared with each other. This also translated into similar crop yield parameters in the two herbicide treatments.

Table 4. Effects of weed control treatments and cropping patterns on broadleaf weed dry matter production (kg ha^{-1}) at 9 and 12 WAP at Abeokuta.

Treatments	9 WAP				12 WAP			
	2013L	2014E	2015E[1]	2015L[2]	2013L	2014E	2015E	2015L
Weed Control Method (WCM)								
Probaben[R] at 2.4 kg a.i ha^{-1}	464c	727a	295bc	591bc	762	514a	268abc	513b
Probaben[R] at 1.6 kg a.i ha^{-1}	549bc	404b	296bc	750b	511	328ab	324abc	661ab
Probaben[R] at 1.6 kg a.i ha^{-1} fb[3] SHW[4]	372c	225b	206c	626bc	439	350ab	221bc	216c
Super Union[R] at 2.4 kg a.i ha^{-1}	550bc	272b	247c	787b	714	219b	391ab	779ab
Super Union[R] 1.6 kg a.i ha^{-1}	844ab	319b	447ab	651bc	576	304ab	416abc	527b
Super Union[R] 1.6 kg a.i ha^{-1} fb[3] SHW[4]	537bc	123b	241c	624bc	460	285b	273abc	215c
Hoe-weeding at 3 and 6 WAP[5]	342c	239b	215c	234bc	429	406ab	176c	178c
Weedy check	954a	662a	608a	1256a	999	308ab	456a	885a
SE ± (WCM)	99.2	83.5	56.9	136.6	127.9ns	70.5	71.1	92.2
Cropping Pattern (CP)								
75 x 50 cm Sole maize	1070a	330c	305bc	835ab	677	305bc	330b	449bc
75 x 50 cm Maize + Jack bean	356b	381bc	238bc	444c	305	154c	297b	358c
75 x 50 cm Maize + Groundnut	452b	171c	163c	396c	513	292bc	191b	429bc
Sole jack bean	546b	644a	368b	956a	596	229bc	493a	720a
Sole groundnut	633b	590ab	243bc	820ab	702	793a	226b	689a
100 x 37.5 cm Maize + Jack bean	420b	220c	333bc	668abc	600	272bc	229b	371c
100 x 37.5 cm Maize + Groundnut	530b	287c	218bc	581bc	568	280bc	256b	346c
100 x 37.5 cm Sole maize	607b	347c	688a	819ab	925	391b	502a	609ab
SE ± (CP)	90.7	75.9	62.4	95.5	108.1ns	58.4	53.3	76.7
SE ± Interaction (WCM x CP)	259.6ns	217.4ns	174.5ns	287.2ns	313.3ns	169.8ns	157.9ns	222.9ns

[1]E = Early season; [2]L = Late season; [3]fb = Followed by; [4]SHW = Supplementary hoe-weeding; [5]WAP = Weeks after planting; [6]Means followed by the same letter(s) within the same column and treatments are not significantly different at the 5% level of probability using Duncan's New Multiple Range Test (DNMRT); [7]Probaben[R] = Prometryne (20%) + Metolachlor (20%); [8]Super Union[R] = Prometryne (13%) + Acetochlor (38%).

Grass weed dry matter production was similarly controlled by the weed control methods at 9 WAP but not at 12 WAP in most cases, indicating the weed control methods reduced grass weed infestation more at 9 WAP compared to 12 WAP (Table 5). This may be attributed to the weed control treatments losing their efficacy on grasses over time. Metolachlor and acetochlor have been reported to lose their persistence in the soil and efficacy over time, depending on environmental factors such as soil moisture content (Zimdahl and Clark, 1982; Thomas et al., 1999). Even at harvest, the plots treated with various weed control methods still produced lower weed dry matter than those left weed-infested throughout, confirming their effectiveness in ensuring various levels of control during the life cycle of the crops.

Table 5. Effects of weed control treatments and cropping patterns on grass dry matter production (kg ha^{-1}) at 9 and 12 WAP at Abeokuta.

Treatments	9 WAP				12 WAP			
	2013L	2014E	2015E[1]	2015L[2]	2013L	2014E	2015E	2015L
Weed Control Methods (WCM)								
Probaben[R] at 2.4 kg a.i ha^{-1}	160b	200bc	55.0b	93.0	252	05.0b	64.0	228
Probaben[R] at 1.6 kg a.i ha^{-1}	85b	223bc	123b	243	69.0	96.0b	181	101
Probaben[R] at 1.6 kg a.i ha^{-1} fb[3] SHW[4]	63b	59.0c	80.0b	65.0	185	35.0b	77.0	39.0
Super Union[R] at 2.4 kg a.i ha^{-1}	96b	485b	166b	75.0	395	40.0b	118	317
Super Union[R] 1.6 kg a.i ha^{-1}	141b	224bc	162b	143	146	76.0b	138	198
Super Union[R] 1.6 kg a.i ha^{-1} fb[3] SHW[4]	96b	121bc	31.0b	20.0	84.0	19.0b	24.0	47.0
Hoe-weeding at 3 and 6 WAP[5]	66b	92bc	110b	98.0	194	41.0b	92.0	103
Weedy check	719a	1135a	558a	282	823	358a	660	461
SE ± (WCM)	104.7	119.0	75.8	66.5ns	155.0ns	59.5	137.6ns	130.5ns
Cropping Pattern (CP)								
75 x 50 cm Sole maize	327	327	226	08.0	300	85.0	86.0	05.0
75 x 50 cm Maize + Jack bean	175	148	138	16.0	366	84.0	166	25.0
75 x 50 cm Maize + Groundnut	129	405	72.0	261	151	130	145	293
Sole Jack bean	116	203	186	107	214	35.0	262	311
Sole groundnut	148	365	169	194	239	192	138	280
100 x 37.5 cm Maize + Jack bean	109	244	191	114	307	39.0	236	292
100 x 37.5 cm Maize + Groundnut	299	477	124	76.0	391	48.0	107	98
100 x 37.5 cm Sole maize	124	367	177	242	179	54.0	212	188
SE ± (CP)	99.9ns	101.9ns	69.9ns	77.6ns	113.5ns	39.8ns	55.2ns	94.1ns
SE ± Interaction (WCM x CP)	284.2ns	294.7ns	199.9ns	215.7ns	337.9ns	121.0ns	200.7ns	281.1ns

[1]E = Early season; [2]L = Late season; [3]fb = Followed by; [4] SHW = Supplementary hoe-weeding; [5]WAP = Weeks after planting; [6]Means followed by the same letter(s) within the same column and treatments are not significantly different at the 5% level of probability using Duncan's New Multiple Range Test (DNMRT); [7]Probaben[R] = Prometryne (20%) + Metolachlor (20%); [8]Super Union[R] = Prometryne (13%) + Acetochlor (38%).

Table 6. Effects of weed control treatments and cropping patterns on weed dry matter production at harvest (kg ha^{-1}) at Abeokuta.

Treatments	Weed dry matter production at harvest (kg ha^{-1})		
Weed Control Method (WCM)	2014L	2015E[1]	2015L[2]
Probaben[R] at 2.4 kg a.i ha^{-1}	795b	768b	3299ab
Probaben[R] at 1.6 kg a.i ha^{-1}	583bc	840b	3293ab
Probaben[R] at 1.6 kg a.i ha^{-1} fb[3] SHW[4]	370c	461b	1075c
Super Union[R] at 2.4 kg a.i ha^{-1}	559bc	789b	2828b
Super Union[R] 1.6 kg a.i ha^{-1}	509bc	868b	3156b
Super Union[R] 1.6 kg a.i ha^{-1} fb[3] SHW[4]	300c	659b	662c
Hoe-weeding at 3 and 6 WAP[5]	423c	741b	1086c
Weedy check	1356	525a	3722a
SE ± (WCM)	94.2	153.6	156.5
Cropping Pattern (CP)			
75 x 50 cm Sole maize	574b	622c	2340bc
75 x 50 cm Maize + Jack bean	421b	602c	2033
75 x 50 cm Maize + Groundnut	548b	948ab	1734d
Sole jack bean	613b	1106a	2813b
Sole groundnut	1069a	1039a	3628a
100 x 37.5 cm Maize + Jack bean	429b	447c	1733d
100 x 37.5 cm Maize + Groundnut	600b	718bc	2324bc
100 x 37.5 cm Sole maize	642b	1168a	2514bc
SE ± (CP)	75.3	104.3	188.9
SE ± Interaction (WCM x CP)	220.5ns	315.7ns	523.7

[1]E = Early season; [2]L = Late season; [3]fb = Followed by; [4] SHW = Supplementary hoe-weeding; [5]WAP = Weeks after planting; [6]Means followed by the same letter(s) within the same column and treatments are not significantly different at the 5% level of probability using Duncan's New Multiple Range Test (DNMRT); [7]Probaben[R] = Prometryne (20%) + Metolachlor (20%); [8]Super Union[R] = Prometryne (13%) + Acetochlor (38%).

The interaction of weed control treatments and the cropping pattern was significant on total weed dry matter production at harvest in the 2015 late season (Table 7). The sole groundnut plots treated with Probaben[R] at both rates produced the maximum weed dry matter, which was significantly higher than all the intercropped plots and sole maize treated with Probaben[R] and Super Union[R] each at 1.6 kg a.i/ha fb SHW and those hoe-weeded twice. The plots with maize at the 75 x 50 cm spacing intercropped with groundnut and at the 100 x 37.5 cm spacing intercropped with jack bean treated with the two herbicides each at 1.6 kg a.i/ha alone also produced significantly lower weed dry matter than the maximum of plots with sole groundnut given Probaben[R] at both rates and comparable to the minimum.

Table 7. The interaction of weed control treatments and the cropping pattern on weed dry matter production at harvest (kg ha^{-1}) in the 2015 late season at Abeokuta.

Weed Control Methods	Cropping Pattern			
	75 cm Sole maize	75 cm Maize + Jack bean	75 cm Maize + Groundnut	Sole jackbean
Probaben^{R} at 2.4 kg a.i ha^{-1}	2612.0d-n	3291.0b-j	2662.0d-m	4908.0ab
Probaben^{R} at 1.6 kg a.i ha^{-1}	3275.0b-j	3579.0b-g	1895.0f-r	3891.0b-e
Probaben^{R} at 1.6 kg a.i ha^{-1}fb[3] SHW[4]	1058.0 l-r	541.7qr	658.3o-r	891.7m-r
Super Union^{R} at 2.4 kg a.i ha^{-1}	3512.0b-g	2316.0e-q	2391.0e-p	2675.0d-m
Super Union^{R} 1.6 kg a.i ha^{-1}	2475.0e-o	2875.0d-l	1025.0m-r	4366.0a-d
Super Union^{R} 1.6 kg a.i ha^{-1}fb[3] SHW[4]	987.0m-r[6]	154.2r	1137.0k-r	454.2r
Hoe-weeding at 3 and 6 WAP[5]	866.7m-r	587.5pqr	795.8n-r	954.2m-r
Weedy check	3937.0b-e	2925.0d-k	3308.0b-j	4366.0a-d
Weed Control Methods	Sole groundnut	100 cm Maize + Jack bean	100 cm Maize + Groundnut	100 cm Sole maize
Probaben^{R} at 2.4 kg a.i ha^{-1}	5754.0a	1650h-r	2325.0e-q	3187.0b-j
Probaben^{R} at 1.6 kg a.i ha^{-1}	5683.0a	1554j-r	3450.0b-i	3016.0c-j
Probaben^{R} at 1.6 kg a.i ha^{-1}fb[3] SHW[4]	1875.0f-r	895.8m-r	683.3o-r	1995.0f-r
Super Union^{R} at 2.4 kg a.i ha^{-1}	3483.0b-h	1637.5i-r	4125.0a-e	2487.0e-o
Super Union^{R} 1.6 kg a.i ha^{-1}	4804.0abc	3241.0b-j	2491.0e-o	3970.0b-e
Super Union^{R} 1.6 kg a.i ha^{-1}fb[3] SHW[4]	941.0m-r	529.1qr	258.3r	837.5m-r
Hoe-weeding at 3 and 6 WAP[5]	1491.0j-r	1750.0g-r	1566.0j-r	675.0o-r
Weedy check	4995.0ab	2608.0d-n	3695.0b-f	3941.0b-e
SE $\pm$ 523.7				

[1]E = Early season; [2]L = Late season; [3]fb = Followed by; [4]SHW = Supplementary hoe-weeding; [5]WAP = Weeks after planting; [6]Means followed by the same letter(s) within the same column and treatments are not significantly different at the 5% level of probability using Duncan's New Multiple Range Test (DNMRT); [7]Probaben^{R} = Prometryne (20%) + Metolachlor (20%); [8]Super Union^{R} = Prometryne (13%) + Acetochlor.

Maize grain yields (1.4–5.2 t ha^{-1}) were similar for all WCM, except in the 2015 late season, but significantly depressed (21–48%) in those weed-infested throughout. Maize intercropped with groundnut and jack bean produced similar cob and grain yields compared to corresponding sole maize in the early seasons. However, lower yields were recorded in the intercrop than in the corresponding sole crop in the late seasons (Table 8). This was probably because the adequate growth resources of the early season ameliorated the effect of interspecific competition.

Table 8. Effects of weed control treatments and the cropping pattern on maize cob and grain yields at Abeokuta.

Treatments	Cob yield (kg ha^{-1})				Grain yield (kg ha^{-1})			
	2013L	2014E[1]	2015E	2015L[2]	2013L	2014E	2015E	2015L
Weed Control Methods (WCMs)								
Probaben^R at 2.4 kg a.i ha^{-1}	2524abc	5556a	4624bc	892cd	2052ab	4141a	3742bc	657cd
Probaben^R at 1.6 kg a.i ha^{-1}	2428abc	5685a	5707ab	1096bc	1931abc	4128a	4263ab	822bc
Probaben^R at 1.6 kg a.i ha^{-1} fb[3] SHW[4]	2750ab	5611a	5787ab	1927a	2205ab	4298a	4634ab	1439a
Super Union^R at 2.4 kg a.i ha^{-1}	1776cd	4408ab	4842bc	1220bc	1386cd	3239ab	3865bc	950c
Super Union^R 1.6 kg a.i ha^{-1}	2282bc	3685bc	5041bc	1132bc	1817bc	2708bc	4011ab	862c
Super Union^R 1.6 kg a.i ha^{-1} fb[3] SHW[4]	2652ab	5000ab	53594ab	1853a	2216ab	3716ab	4412ab	1496a
Hoe-eeding at 3 and 6 WAP[5]	3086a[6]	5070a	6549a	1471ab	2567a	3869a	5236a	1112ab
Weedy Check	1337d	2630c	3654c	4896d	1072d	1988c	2709c	349d
SE ± (WCM)	228.4	417.6	432.6	147.1	191.2	341.7	393.0	129.5
Cropping Patterns (CPs)								
75 x 50 cm Sole maize	2761a	4646ab	591	1823a	2227a	3549ab	4395	1406 a
75 x 50 cm Maize + Jack bean	1957b	4837ab	5336	1031bc	1564b	3516ab	4256	796bc
75 x 50 cm Maize + Groundnut	1975b	5445a	5006	927c	1587b	3924a	4026	673c
100 x 37.5 cm Maize + Jack bean	2257ab	5174a	5046	900c	1817ab	4050a	4067	703c
100 x 37.5 cm Maize + Groundnut	267a	3972b	4763	1381abc	2127a	3011b	3501	1043abc
100 x 37.5 cm Sole maize	2504a	4160b	5458	1499ab	2037a	3016b	4409	1144ab
SE ± (CP)	176.8	295.6	297.2	181.5	148.9	239.7	245.9ns	141.7
SE ± Interaction (WCM x CP)	510.5	869.9	880.8	491.2	429.3	706.9	746.3ns	388.1

[1]E = Early season; [2]L = Late season; [3]fb = Followed by; [4]SHW = Supplementary hoe-weeding; [5]WAP = Weeks after planting; [6]Means followed by the same letter(s) within the same column and treatments are not significantly different at the 5% level of probability using Duncan's New Multiple Range Test (DNMRT); [7]Probaben^R = Prometryne (20%) + Metolachlor (20%); [8]Super Union^R = Prometryne (13%) + Acetochlor (38%).

Maize cob and grain yields were higher in maize/groundnut intercrop at 75 x 50 cm than at 100 x 37.5 cm in the early seasons, while the reverse was the case in the late seasons. This could be attributed to the limited available resources and interspecific competition in the late season, which probably could not sustain the higher plant density of maize at the 75 x 50 cm intercrop since the closer inter-row spacing had higher maize and groundnut plant densities per unit area. Maize yield is known to be influenced by plant densities (Fanadzo, 2007; Vega et al., 2001; Olaniyan and Lucas, 2002; Shrestha et al., 2018; Simić et al., 2012). The meteorological records during the trial periods suggest that the late-season maize, especially in 2015, might have experienced some drought during the period of grain filling.

Conclusion

Jack bean and groundnut intercropped with maize significantly suppressed weed growth compared to sole crops of maize, consequently maize intercropped with groundnut and jack bean produced similar cob and grain yields compared to corresponding sole maize in the early seasons. However, the weed-suppressive effect of intercropped jack bean/groundnut did not reflect in the cob and grain yields of maize in the late wet season because of the limited resources in the late season.

Intercropping of maize with either jack bean or groundnut at 75 x 50 and 100 x 37.5 cm spacings enhanced the efficacy of prometryne pre-emergence herbicides when combined with either metolachlor or acetochlor and increased maize cob and grain yields, hence, it can be recommended for optimal yield.

References

Adebomi, O.O. (2008). Effect of intercropped groundnut (*Arachis hypogaea* L.) density on the performance of weed control treatments in maize (*Zea mays* L.) production B.Sc. Project, Department of Plant Physiology and Crop Production, University of Agriculture, Abeokuta, Ogun State, Nigeria.

Adeyemi, O.R., Hosu, D.O., Olorunmaiye, P.M., Soretire, A.A., Adigun, J.A., & Ogunsola, K.O. (2019). Weed Control Efficacy of Hoe Weeding and Commercially Formulated Mixture of Metolachlor and Prometryn Herbicide under Maize Production in Soil Amended with Biochar. *Agricultura Tropica et Subtropica*, *52* (2), 73-78.

Adigun, J.A., & Lagoke, S.T.O. (1999). Weed control in maize with various herbicide combinations in the Northern Guinea Savanna of Nigeria. *Nigerian Journal of Botany, 12*, 79-84.

Adigun, J.A., & Lagoke, S.T.O. (2003). Weed management with various herbicide combinations in a maize-groundnut intercrop. *Nigerian Journal of Plant Protection, 20*, 12-23.

Akinyemiju, O.A. (Ed.) (1993). Herbicide control of water hyacinth: A pilot demonstration at Ere Fishing Channel, Ogun State, Nigeria. A report submitted to Agricultural Development Project, January 1993.

Akobundu, I.O. (1987). *Weed Science in Tropics: Principle and Practice.* John Wiley and Sons.

Badmus, A.A., Lagoke, S.T.O., Adigun, J.A., & Okeleye, K.A. (2006). Effects of intercropped groundnut and weed control methods on maize production in south western Nigeria. *ASSET Series*, *6* (1), 289-269.

Bakut, H.B. (1985). Effects of period of weed interference and weed control in maize/pepper mixture. Unpublished M.Sc. Thesis, A.B.U., Zaria, Nigeria.

Bilalis, D., Papastylianou, P., Konstantas, A., Patsiali, S., Karkanis, A., & Efthimiadou, A. (2010). Weed-suppressive effects of maize-legume intercropping in organic farming. *International Journal of Pest Management, 56* (2), 173-181.

Chikoye, D., Udensi, E., & Fontem, L.A. (2005). Evaluation of a new formulation of atrazine and metolachlor mixture for weed control in maize in Nigeria. *Crop Protection*, *24*, 1016-1020.

Eni, E.I., Phillip, B.B., Lagoke, S.T.O., & Adigun, J.A. (2012). The economic performance of maize-groundnut intercrop in response to weed control methods and cropping patterns. *Nigerian Journal of Weed Science,* 25, 49-59.

Fanadzo, M. (2007). Weed management by small-scale irrigation farmers – the story of Zanyokwe. *SA Irrigation, 29* (6), 20-24.

FAOSTAT (2014). http://www.faostat.fao.org/site/567/desktopdefault.aspx (accessed on February 20, 2015).

Giwa, M.B. (2007). Effect of groundnut (*Arachis hypogaea* L.) intercrop on weed control in maize (*Zea mays* L.) production. B.Sc. Project, Department of Plant Physiology and Crop production. University of Agriculture, Abeokuta.

IITA. (2000). International Institute of Tropical Agriculture. *Maize Improvement Programme Research Report,* Ibadan, Nigeria.r4dreview.iita.org/maize (accessed on July 15, 2013).

IITA (2009). http://www.iita.org/maize (accessed on February 20, 2012).

Jhala, A.J., Knezevic, S.Z., Ganie, Z.A., & Singh, M. (2014). Integrated Weed Management in Maize In: Chauhan, B. S. and Mahajan, G. (eds.), *Recent Advances in Weed Management,* (pp. 177-196). Springer Science+Business Media, New York, USA.

Knoema.com (2019). World Data Atlas/topics/Agriculture/Crops/yield.

Lagoke, S.T.O., Eni, E., Adigun, J.A., & Phillip, B.B. (2014). Influence of intercropped groundnut (*Arachis hypogaea* L.) on the performance of weed control treatments in maize production. *International Journal of Agronomy and Agricultural Reasearch, 5* (6), 1-8.

Nuss, E.T., & Tanumihardjo, S.A. (2010). Maize: a paramount staple crop in the context of global nutrition. *Comprehensive Reviews in Food Science and Food Safety, 9*, 417-436.

Ojelade, O.B. (2004). Use of groundnut (*Arachis hypogaea* L.) for enhanced weed management in maize (*Zea mays* L.). Postgraduate Diploma Project Report, Department of Plant Physiology and Crop production, University of Agriculture, Abeokuta. 67 pp

Ojo, S.O. (2000). Factor Productivity in Maize Production in Ondo state, Nigeria. *Applied Tropical Agriculture, 15* (1), 57-63.

Olaniyan, A.B., & Lucas, E.O. (2002). Effect of periodic reduction in density of planting on yield of maize genotypes in south western Nigeria. *Research Crops Journal, 3* (2), 315-321.

Olatunji, A., Adejoro, S.A., Ayelari, O.P., & Aladesanwa, R.D. (2016). Evaluation of Selected Weeding Methods for Weed Control and Performance of Maize in South Western Nigeria. *Applied Tropical Agriculture, 21* (1), 15-23.

Osikanlu, Y.O.K. (1996). The effects of tillage and weed control methods on the Southern leaf blight and performance of maize in the rainforest zone of Western Nigeria. *Nigerian Journal of Science, 30*, 1-7.

Shrestha, J., Yadav, D.N., Amgain, L.P., & Sharma, J.P. (2018) Effects of Nitrogen and Plant Density on Maize (Zea mays L.) Phenology and Grain Yield. *Current agriculture research Journal, 6* (2), 175-182.

Simić, M., Dolijanović, Ž., Maletić, R., Stefanović, L., & Filipović, M. (2012). Weed suppression and maize productivity by different arrangement patterns. *Plant, Soil and Environment, 58* (3), 148-153.

Simić, M., Dragičević, V., Babić, M., Brankov, M., & Filipović, M. (2020). Integrated effects of nitrogen form, row spacing, and herbicide treatment on maize. *Agronomy Journal, 112*, 748-757.

Sule-Enyisi, I., Umoh, U.J., Whong, C.M.Z., & Alabi, O. (2014). Chemical and nutritional value of maize and maize products obtained from selected markets in Kaduna State, Nigeria. *African Journal of Food Science and Technology, 5* (4), 100-104.

Thomas, C.M., Shaw, D., & William, W. (1999). Relative dissipation of acetochlor, alachlor, metolachlor, and SAN 582 from three surface soils. *Weed Technology*, *13* (2), 341-346.

Udensi, U.E., Akobundu, I.O., Ayeni, A.O., & Chikoye, D. (1999). Management of Cogon grass (*Imperata cylindirica*) with velvet bean (*Mucuna pruriens var. ulitis*) and herbicides. *Weed Technology, 13* (2), 201-208.

USDA (2017). Foreign Service: Peanut Area, Yield and Production. Retrieved on 20th April, 2017 from http://en.wikipedia.org/wiki/peanut.

Vega, C.R.C., Andrade, F.H., Sadras, V.O., Uhart, S.A., & Valentinuz, O.R. (2001). Seed number as a function of growth. A comprehensive study in soybean, sunflower and maize. *Crop Science, 41*, 748-754.

Williams, O.A. (2010). Effect of intercropped groundnut (*Arachis hypogaea* L.) and mucuna (*Mucuna utilis*) on weed control in maize (*Zea mays* L.) production. Ph.D. Thesis. Department of Plant Physiology and Crop production, University of Agriculture, Abeokuta, Nigeria.

Yenish, J.P., Worsham, A.D., & York, A.C. (1996). Cover crops for herbicide replacement in no tillage corn. *Weed Technology, 10*, 815-821.

Zimdahl, R.L., & Clark, S.K. (1982). Degradation of three acetanilide herbicides in soil. *Weed Science, 30*, 545-548.

Received: May 28, 2020
Accepted: July 12, 2021

POVEĆANJE EFIKASNOSTI SUZBIJANJA KOROVA DVA HERBICIDA PRIMENJENIH PRE NICANJA KOD ZDRUŽENIH USEVA KUKURUZA/PASULJA I KUKURUZA/KIKIRIKIJA U PRELAZNOM POJASU SAVANE

Enor Eni[1], Olusegun R. Adeyemi[1*], Segun Toyosi O. Lagoke[1] i Osebekwin E. Asiribo[2]

[1]Odsek za fiziologiju biljaka i ratarstvo, Federalni poljoprivredni univerzitet u Abeokuti, Nigerija
[2]Odsek za statistiku, Federalni poljoprivredni univerzitet u Abeokuti, Nigerija

R e z i m e

Nemogućnost herbicida, u ranoj primeni pre nicanja glavnog useva, da sami obezbede suzbijanje korova tokom cele sezone u proizvodnji kukuruza opravdava potrebu za dodatnim suzbijanjem korova. Sprovedena su ispitivanja metodom poljskog ogleda da bi se procenila združena setva kikirikija i pasulja radi poboljšane efikasnosti suzbijanja korova dva herbicida pre nicanja u proizvodnji kukuruza tokom vegetacione sezone 2013/2014. i 2015. na Federalnom poljoprivrednom univerzitetu u Abeokuti (Nigerija). Eksperiment je postavljen kao podeljena parcela uklopljena u randomizirani potpuni blok dizajn sa tri ponavljanja. Glavne parcele su se sastojale od osam tretmana za suzbijanje korova komercijalno formulisaneherbicidne preparate na generičkoj osnovi prometrina + metalohlora (Probaben^R); prometrina + acetohlora (Super Union^R) svaki po 2,4 kg a.s ha^{-1}, 1,6 kg a.s ha^{-1} sa i bez dodatnog okopavanja, dva okopavanja i apsolutne kontrole bez uklanjanja korova. Tretmani potparcela sastojali su se od osam sistema gajenja (kukuruz kao jedini usev, združena setva kukuruza i pasulja, kukuruza i kikirikija, svaki sa dva međuredna rastojanja [100 x 37,5 cm i 75 x 50 cm] i usevi pasulja i kikirikija kao jedinih useva bez združivanja). Sve metode suzbijanja korova značajno su smanjile ($p<0,05$) suvu materiju korova u poređenju sa kontrolom bez uklanjanja korova za 10–81%. Prinosi zrna kukuruza (1,4–5,2 t ha^{-1}) bili su slični na svim parcelama sa metodama suzbijanja korova, osim u kasnoj vegetacionoj sezoni 2015. godine, ali su značajno smanjeni (21–48%) u poredjenju sa kontrolom. Združena setva pasulja i kikirikija sa kukuruzom značajno (20–67%) je smanjila zakorovljenost u odnosu na useve kukuruza, pasulja ili kikirikija gajenih bez združivanja. Efikasnost herbicida primenjenih posle setve, a pre nicanja u ovom istraživanju je, stoga, poboljšana združenom setvom kukuruza sa pasuljem i kikirikijem na rastojanjima od 75 x 50 cm i 100 x 37,5 cm u ranim sezonama.

Ključne reči: združena setva, pasulj, herbicidi pre nicanja glavnog useva, suzbijanje korova.

Primljeno: 28. maja 2020.
Odobreno: 12. jula 2021.

[*]Autor za kontakt: e-mail: adeyemior@funaab.edu.ng