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Impact of Early Season Weed Removal on Weed Seedling Emergence, Fall Armyworm (*Spodoptera frugiperda* L.E.Smith) Infestation and Yield of Maize (*Zea mays* L.) in a Southern Guinea Savanna of Nigeria

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Abstract

Field experiments were conducted at the University of Ilorin Teaching and Research Farm, Ilorin, during the 2019, 2020 and 2021 cropping seasons to evaluate the effect of early weed control strategies on weed emergence, fall armyworm (FAW) damage and grain yield of maize. The weed control treatments were weedy check, 3 weeks of weedy, 4 weeks of weedy, pre-Atrazine, pre-Atrazine+post-Nicosulfuron, pre-Metolachlor, pre-Metolachlor+post-Nicosulfuron, and pre-Primextra. The trial was laid out in a randomised complete block design with three replications. The field was ploughed, harrowed, and ridged before being sown at 1 m x 0.25 m with 80,000 plants per ha. Weed seedling emergence and yield data were collected and subjected to analysis of variance ($p < 0.05$). The most prevalent weed species were *Richardia scabra*, *Digitaria sanguinalis*, *Gomphrena celosioides*, *Cyperus species*, *Chloris pycnothrix*, *Dactyloctenium aegyptium*, *Euphorbia hypericifolia*, *Chromoleana odorata*, *Heterotis rotundifolia*, and *Andropogon gayanus*. Atrazine controlled 94% of broadleaf and 6% of grass species, while metolachlor controlled 89.6% and 20.4% of broadleaves and grasses, respectively. There was a 40–47% low FAW infestation in delayed hoe-weeded and weed-checked plots compared to herbicide-treated plots and a 16.5% increase in atrazine-treated plots. Three (3) weeks weedy yielded 3.63 t/ha of grain yield, a 9.4% and 36.9% increase over plots where herbicides were applied twice (3.29 t/ha) and one (2.29 t/ha), respectively. The result also shows a negative relationship between FAW damage and weed density indicating that as weed density increases, the damage from FAW decreases by 5.42%. Therefore, it is recommended that a delay in weed removal (3 weeks weedy) reduces FAW damage and improves maize grain yield.

Keywords: Fall Armyworm, Delay weeding, Herbicide, Maize, Savanna, Nigeria

Introduction

Maize (*Zea mays* L.) is rated the third most important cereal crop in the world, it is also a crucial crop in Nigeria with a total production of about 10.4 million metric tons in 2017 (FAO, 2017), it is the most commercial crop of great value and is widely considered to have the greatest potential among food crops for attaining food security in West Africa. FAO (2016) reported that Nigeria exported 3,161 metric tons of maize, which provides staple food to many people worldwide and serves as a source of income for many farmers. Despite all the importance of maize, the yield in Nigeria is far below expectations due to several factors such as low soil fertility, unavailability of labour, weed infestation, and insect pest attacks. The most recent and severe pest attack recently reported and confirmed in 28 countries in Africa is the fall armyworm (Cock *et al.*, 2017).

Fall Armyworm (*Spodoptera frugiperda*) is a highly polyphagous migratory pest that can colonize over 80 different plant species but shows a preference for some members of the Poaceae. *S. frugiperda* caterpillars appear to be much more damaging to maize in West and Central Africa than most other African *Spodoptera* species (IITA, 2019). IITA (2016) reported that the caterpillar of FAW appears to be much more damaging to maize in the west and central Africa than most other *Spodoptera* species. Infestations during the mid-to-late-whorl stage of maize development caused yield losses of 15-73% when 55-100% of the plants were infested with FAW.

Fall armyworm (FAW) has infected millions of hectares of maize

fields in Africa. This threatened the food security of more than 300 million people who are smallholder farmers struggling to meet their needs and have enough food for their families (FAO, 2018). It is recently estimated that in the absence of control methods, FAW has the potential to cause losses of an estimated 8.3 to 20.6 m tons of maize per annum (valued at US \$248–687 m) in 12 maize-producing countries in sub-Saharan Africa, which accounts for approximately 20% of the total production in the region (Birhanu *et al.*, 2019).

FAW has been observed feeding on non-crop vegetation (weeds) together with three other lepidopterous defoliators of maize (Penagos *et al.*, 2003). Hailu *et al.*, (2018) reported that maize grown was more attacked by larvae of the FAW when planted as a monoculture compared to when intercropped with cowpea or in the presence of weeds. Weeds may act as alternate or alternative host plants for insects and pathogenic organisms harmful to crop plants thus, making the control of such pathogens and pests more difficult to control (Amadioha *et al.*, 2004). Tindall and Stout (2003) reported the effects of four weedy plant species on the ovipositional behaviour and survivorship of fall armyworm. The study provided evidence that certain weed species can influence fall armyworm behaviour, potentially impacting maize damage. Midega *et al.*, (2015) reported the efficacy of a companion plant, *Desmodium uncinatum* in protecting against FAW and found that weed density and composition in maize fields can influence the present and damage caused by FAW while Khan *et al.*, (2017) concluded that effective weed

management practices can help reduce the incidence of FAW damage to maize crop. This work was therefore designed to evaluate the effect of early weed control strategies on weed emergence, fall armyworm damage, and grain yield of maize.

Materials and Methods

The trial was conducted at the University of Ilorin Teaching and Research Farm, Bolorunduro Ilorin (008°27'23.9"N and 004°39'42.9"E) in the southern Guinea savanna zone of Nigeria. The rainfall pattern is bimodal with peaks in July and September. The annual rainfall ranges between 1200 mm and 1500 mm and temperature ranges between 19°-33°C. The area is characterized by well-drained sandy loam soil. The land used was previously cultivated for cassava and maize between the 2014 to 2018 growing seasons. The experiment was laid out in a Randomized Complete Block Design with three replications.

The weed control treatments were: weedy check; 3 week weedy; 4 weeks weedy; pre-emergence application of Atrazine [6-chloro-N-ethyl-N'-(1-methyl ethyl)-1,3,5-triazine-2,4-diamine) (370 g/L)]; pre-emergence application atrazine plus post-emergence application of Nicosulfuron 40 g/L at 1.25 kg a.i./ha applied at 4 weeks after planting (WAP); pre-emergence application Metolachlor (2-chloro-N-(2-ethyl-6-methyl-phenyl)-N-(2-methoxyl-1-methyl ethyl)acetamide) (290 g/L)); pre-emergence application of metolachlor plus post-emergence application of Nicosulfuron 40 g/L at 1.25 kg a.i./ha applied 4 WAP; pre-emergence Primextra

(proprietary mixture of metolachlor (290 g/L) and (370 g/L) at 2.0 kg a.i./ha. All pre-emergence herbicides were applied at 2.5 kg a.i./ha.

The experimental field (4140 m²) was ploughed, harrowed, and ridged; the plot size was 6 ridges 5 m long (45 m²). Planting operations were done on 6th August 2019, 31st July 2020, and 20th June 2021 using the plant spacing of 1 m x 0.25 m. Thinning was done 2 weeks after planting (WAP) to 2 plants per stand to give an approximate plant population of 80,000 plants/ha. Compound fertiliser NPK 15:15:15 was applied at 100 kg N ha⁻¹, 100 kg P ha⁻¹, and 100 kg K ha⁻¹. All herbicides were applied using a Knapsack sprayer at a delivery rate of 250-300 L/ha.

Weed seedling emergence was monitored in 2 fixed quadrats (0.5 m²) at 6, 9, and 12 WAP in each subplot, hereafter referred to as continuous weed emergence. On each sampling date, weed seedlings were identified to species level using the Weed Identification Manual of Akobundu and Agyakwa (1998) and oven dry to a constant weight to determine dry weed biomass. The total number of plants per plot and the number of plants infested by Fall armyworm were estimated at 2, 4, 6, and 8 WAP while at harvest, the number of plants harvested, and grain yield were taken.

All data collected were transformed and subjected to analysis of variance (ANOVA) using Genstat Discovery Edition 3, where F-ratios were significant ($p \leq 0.05$), and means were separated using the Standard Error of Deviation. A simple regression and correlation analysis was performed to show the relationship between weed

density, FAW damaged and maize grain yield.

Results

Fourteen (14) weed species belonging to 7 families within 12 genera were encountered in maize fields in 2019 (Table 1). In the atrazine-treated plots, 82.6% of the weed community were grasses, 12.4% sedges, and no broadleaves except *Heterotis rotundifolia* which made up 5% of the community. Where Nicosulfuron was applied after atrazine, grasses were 84.2% with *Andropogon gayanus* contributing 39.5%, sedges 11.2% while 4.6% was *H. rotundifolia*. Conversely, plots treated with metolachlor had 58.9% broadleaves weed species with *Chromolaena odorata* and *H. rotundifolia* contributing 31.4% and 22.5%, respectively. Grasses were 22.9% while sedges made up 18.2% of the weed flora. The weed spectrum was similar when Nicosulfuron was applied as post-emergence as a follow-up to the

applied metolachlor, broadleaves (44.8%), grasses 28.6% and sedges (*Cyperus iria*) 17.1% dominated the plots. Pre-emergence application of primextra controlled *C. odorata*, *H. suaveolens*, and *Pennisetum pedicellatum*. The weed community in primextra applied plots composed of 53.6% grasses where *A. gayanus* contributed 22.3%, sedges were 15% and broadleaves constituted 31.32% of the weed spectrum. The weedy plots were mixed weed communities having *C. odorata*, *H. rotundifolia*, and *A. gayanus* as the most prevalent weed species.

In the 2020 growing season, 46 weed species were identified (Table 2). Grasses dominated (86.4%) the weed flora in the atrazine treated-plots, sedges were 10.5% while broadleaves were effectively controlled except *Cyanthium cinereum*. A similar trend was observed when Nicosulfuron was applied as post-emergence to atrazine-treated plots.

Table 1: Importance value index (IVI) of weed species encountered in the continuously sampled quadrat in maize field, 2019

Family	Weed species	MG	LC	AZ	AZ+N	MT	MT+N	PX	W3	W4	WC
Amaryllidaceae	<i>Allium cepa</i> L.	B	A	0	0	0	0	4	4	3	9
Asteraceae	<i>Chromolaena odorata</i> (L.) R.M.King & H. Robinson	B	P	0	0	81	28	0	52	43	55
Cyperaceae	<i>Cyperus iria</i> L.	S	A	19	17	18	18	13	18	19	21
	<i>C. esculentus</i> L.	S	P	0	0	0	0	0	0	0	8
	<i>C. rotundus</i> L..	S	P	18	0	29	0	4	16	20	12
Lamiaceae	<i>Hyptis suaveolens</i> Poit.	B	A	0	0	0	0	0	4	6	4
Leguminosae	<i>Senna occidentalis</i> (L.) Link	B	A	0	0	13	0	3	7	7	10
Melastomataceae	<i>Heterotis rotundifolia</i> (Sm) Jac.	B	P	15	7	58	19	28	39	41	32
Poaceae	<i>Andropogon gayanus</i> Kunth	G	A	121	60	21	14	25	88	90	92
	<i>Bracharia deflexa</i> (Schumach.) C.E. Hubbard	G	A	22	11	4	0	9	18	20	14
	<i>Digitaria horizontalis</i> Willd	G	A	29	23	4	2	12	15	14	11
	<i>Echinochloa stagnina</i> Beauv	G	P	29	14	20	21	12	18	20	23
	<i>Paspalum scrobiculatum</i> L.	G	P	25	12	6	3	2	8	8	10
	<i>Pennisetum pedicellatum</i> Trin.	G	A	21	8	4	0	0	10	9	11

MG = Morphological Groups; LC = Life cycle; B = Broadleaves; G = Grasses; S = Sedges, A = Annual, P = Perennial, AZ= Atrazine, N= Nicosulfuron, MT= Metolachlor, PX= Primextra, W3= 3 Weeks weedy, W4= 4 Weeks weedy, WC= Weed check

Conversely, metolachlor relatively controlled grasses and few sedges while broadleaves were dominant. The weed flora had 2.9% sedges, 5.7% grasses, and 91.4% broadleaves. The most prevalent broadleaves were *Gomphrena celosioides* (14.8%) and *Richardia scabra* (14.2%). A follow-up with Nicosulfuron as post to metolachlor had a 72.3% reduction in weed infestation compared to plots treated with metolachlor alone. Primextra controlled 34 of the 46 weed species encountered in the 2020 season.

Primextra-treated plots had 88.6% and 89.5% reduction in weed infestation as compared to atrazine and metolachlor-treated plots, respectively. The plots comprised 2.5% grasses and 23.5% of *G. celosioides*.

The weed flora in the 2021 season had 20% as members of Poaceae, and 36.4% from 4 families. Broadleaves were 66%, grasses 25% and sedges were 9%. Based on the life cycle of the weed spectrum, 70.5% were annuals and perennials were 29.5%.

Table 2: Importance value index (IVI) of weed species encountered in the continuously sampled quadrat in maize field, 2020

FAMILY	WEED SPECIES	MG	LC	AZ	AZ +N	MT	MT +N	PX	W3	W4	WC
Amaranthaceae	<i>Amaranthus amaranthaceae</i> (L.)	B	A	0	0	0	0	0	5	7	4
	<i>Gomphrena celosioides</i> (L.)	B	A	0	0	72	36	12	14	10	11
	<i>Narcissus papyraceus</i> Ker Gawl	B	P	0	0	0	0	0	5	5	4
Asteraceae	<i>Chromolaena odorata</i> (L.) R.M.King & H. Robinson	B	P	0	0	11	2	1	3	6	4
	<i>Cyanthillium cinereum</i> (L.)	B	P	14	0	0	0	4	9	3	7
	<i>Heliantus annuus</i> (L.)	B	A	0	0	0	0	0	2	3	4
	<i>Tridax procumbens</i> (L.)	B	P	0	0	0	0	0	5	6	5
Balsaminaceae	<i>Impatiens perviflora</i> Dc.	B	A	0	0	7	0	0	0	0	0
Cannabaceae	<i>Cannabis sativa</i> L.	B	A	0	0	17	3	3	4	2	8
Caryophyllaceae	<i>Sagina apetala</i> Ard.	B	A	0	0	9	0	0	5	4	4
Cleomaceae	<i>Cleome monophylla</i> L.	B	A	0	0	18	0	0	6	10	7
	<i>C. viscosa</i> L.	B	A	0	0	0	0	0	4	2	4
Commelinaceae	<i>Commelina benghalensis</i> L.	B	P	0	0	10	0	2	7	6	6
Cyperaceae	<i>Carex divulsa</i> Stokes	S	P	24	0	8	0	0	9	6	6
	<i>Cyprus alopecuroides</i> Rottb.	S	P	0	0	0	0	0	3	2	4
	<i>C. eragrostis</i> Lam.	S	P	11	14	16	4	0	11	10	9
	<i>C. esculantus</i> (L.)	S	P	12	13	11	0	0	5	4	6
Euphorbiaceae	<i>Astaea lobata</i> (L.) Klotzsch.	B	A	0	0	29	9	4	9	11	6
	<i>Euphorbia hyssapifolia</i> (L.)	B	A	0	0	8	0	0	3	4	1
	<i>E. heterophylla</i> (L.)	B	A	0	0	0	0	0	1	4	2
	<i>E. hypericifolia</i> L.	B	P	0	0	20	0	0	5	3	6
Lamiaceae	<i>Hyptis suaveolens</i> (L.)Poi	B	A	0	0	15	11	5	9	6	6
	<i>Leucas aspera</i> (Willd.) Link	B	A	0	0	21	0	0	11	14	9
Leguminosae	<i>Centrosema pubescens</i> Benth	B	A	0	0	14	0	0	6	4	5
	<i>Chamaecrista rotundifolia</i> (Pers.)	B	A	0	0	46	16	0	10	11	13
	<i>Tephrosia villosa</i> (L.) Pers.	B	A	0	0	18	0	2	8	9	6
	<i>Trifolium dubium</i> Sibth	B	A	0	0	0	0	0	0	0	3
Malvaceae	<i>Gossypium hirsutum</i> L.	B	A	0	0	5	0	0	2	6	4
	<i>Sida acute</i> Burm. f.	B	P	0	0	0	0	0	4	2	3
	<i>Urena lobata</i> L.	B	A	0	0	0	0	0	2	7	2
Nyctaginaceae	<i>Boerhavia diffusa</i> L.	B	P	0	0	0	0	0	4	6	7
Passifloraceae	<i>Passiflora foetida</i> L.	B	A	0	0	12	0	0	4	4	2
Phyllanthaceae	<i>Phyllanthus tenellus</i> Roxb	B	A	0	0	0	0	0	2	7	4
	<i>P. amarus</i> L.	B	A	0	0	14	11	0	10	6	7
Poaceae	<i>Chloris pycnothrix</i> Trin.	G	A	84	48	6	0	0	11	7	11
	<i>Dactyloctenium aegyptium</i> (L.) Willd	G	A	53	35	3	0	0	11	11	9
	<i>Digitaria ciliaris</i> (Retz.) Koeler	G	A	12	9	0	0	0	10	11	10
	<i>D. sanguinalis</i> (L.) Scop	G	A	85	38	8	2	6	15	19	12
	<i>Echinochloa crusgalli</i> (L.)	G	A	37	37	0	0	0	13	11	12
	<i>Eragrostis minor</i> Host	G	A	37	21	7	3	6	8	12	10
	<i>E. pilosa</i> (L.)	G	A	19	8	0	0	0	2	4	4
	<i>Pennisetum polystachion</i> (L.)Schult	G	A	45	9	4	0	1	1	2	6
	<i>Seteria pulmilla</i> (Poir)	G	A	16	12	0	0	0	7	7	6
Polygonaceae	<i>Fallopia baldschuanica</i> (Regel)Holub	B	A	0	0	9	2	5	3	6	4
Rubiaceae	<i>Richardia scabra</i> L.	B	A	0	0	69	36	0	11	14	24
Urticaceae	<i>Parietaria judaica</i> L.	B	P	0	0	0	0	0	3	2	3

MG = Morphological Groups; LC = Life cycle; B = Broadleaves; G = Grasses; S = Sedges, A = Annual, P = Perennial, AZ = Atrazine, N = Nicosulfuron, MT = Metolachlor, PX = Primextra, W3 = 3 Weeks weedy, W4 = 4 Weeks weedy, WC = Weed check.

3). The weed community across weedy and herbicide-treated plots was fairly like that of the previous seasons. *Euphorbia hypericifolia* and *Richardia scabra* were the broadleaved species that dominated 9.9% of the atrazine-treated plots while grasses and sedges were 76.8% and 13.3%, respectively. The application of Nicosulfuron as post-emergence in atrazine-treated plots reduced the weed species abundance by 59% as compared to a single application of atrazine. No broadleaved species was encountered, and the weed flora comprised of grasses 82.1% of and 17.9% of sedges. While metolachlor significantly reduced grasses to 5.6% and sedges to 8.2%, broadleaved weed species dominated 86.2% of the weed community treated with metolachlor. A follow-up with Nicosulfuron as post-emergence to metolachlor-treated fields significantly reduced the weed community by 73.4%. Pre-emergence application of primextra effectively controlled members of Poaceae and Cyperaceae except for *C. eragrostis* (15.5%) while 25.6% and

33.3% of the plots were *G. celosioides* and *Chamaecrista rotundifolia*, respectively. The weedy plots generally had a highly diversified mixed weed spectrum comprised of *Richardia scabra*, *Digitaria sanguinalis*, *Gomphrena celosioides*, *Cyperus eragrostis*, *Chloris pycnothrix*, and *Dactyloctenium aegyptium*. Weed control measures significantly influenced weed density and biomass across the seasons. The weed infestation level was very high in 2019, and low in the 2020 and 2021 seasons (Table 4). Generally, single pre-emergence application of the selected herbicides significantly reduced weed density and fresh weed biomass at 3WAP, sharply increased and peaked at 6WAP, and then declined thereafter. A follow-up with a post-emergence application of Nicosulfuron significantly reduced the weed density and biomass between 6 and 9WAP. While weedy check plots had significantly higher weed infestation across the period of assessment thought as plots that were left weedy for 3 or 4 weeks at 3WAP.

Table 3: Importance value index (IVI) of weed species encountered in the discretely sampled quadrats in maize field, 2021

Family	Weed SPECIES	MG	LC	AZ	AZ+N	MT	MT+N	PX	W3	W4	WC
Amaranthaceae	<i>Gomphrena celosioides</i> (L.)	B	A	12	0	90	47	12	25	33	17
Asteraceae	<i>Chromolaena odorata</i> (L.) R.M.King & H. Robinson	B	P	0	0	0	0	0	3	7	4
Cannabaceae	<i>Tridax procumbens</i> (L.)	B	P	0	0	15	0	0	0	0	7
Caryophyllaceae	<i>Cannabis sativa</i> L.	B	A	0	0	26	0	0	12	4	20
Cleomaceae	<i>Sagina apetala</i> Ard.	B	A	0	0	26	0	0	0	0	8
	<i>Cleome monophylla</i> L.	B	A	0	0	17	0	0	8	22	17
	<i>C. viscosa</i> L.	B	A	0	0	0	0	0	4	17	16
Commelinaceae	<i>Commelina benghalensis</i> L.	B	P	0	0	35	0	0	9	6	9
Cyperaceae	<i>Cyperus eragrostis</i> Lam.	S	P	20	0	10	0	10	10	26	12
Euphorbiaceae	<i>Astaea lobata</i> (L.) Klotz sch.	B	A	0	0	16	5	0	13	0	13
	<i>Euphorbia hypericifolia</i> L.	B	P	0	0	0	0	0	8	4	4
Lamiaceae	<i>Hyptis suaveolens</i> (L.) Poit	B	A	0	0	0	0	0	3	9	13
	<i>Leucas aspera</i> (Willd.) Link	B	A	0	0	0	0	9	3	1	12
Leguminosae	<i>Chamaecrista rotundifolia</i> (Pers.)	B	A	11	0	78	16	21	16	25	17
	<i>Tephrosia villosa</i> (L.) Pers.	B	A	0	0	15	0	2	12	9	11
Phyllanthaceae	<i>Phyllanthus amarus</i> L.	B	A	0	0	0	0	0	10	13	8
Poaceae	<i>Chloris pycnothrix</i> Trin.	G	A	40	20	3	0	13	24	22	18
	<i>Dactyloctenium aegyptium</i> (L.) Willd	G	A	85	30	25	0	15	20	25	17
	<i>Digitaria ciliaris</i> (Retz.) Koeler	G	A	0	0	0	0	0	0	5	6
	<i>D. angustifolia</i> (L.) Scop	G	A	89	21	21	0	18	36	30	16
	<i>Echinochloa crus-galli</i> (L.)	G	A	48	19	0	0	0	22	0	13
	<i>Eragrostis minor</i> Host	G	A	0	0	0	0	0	13	0	4
	<i>E. pilosa</i> (L.)	G	A	32	0	0	0	0	7	0	5
Poaceae	<i>Pennisetum polystachion</i> (L.) Schult	G	A	0	0	0	0	0	8	0	10
Polygonaceae	<i>Fallopia baldschuanica</i> (Regel) Holub	B	A	0	0	13	2	2	11	8	10
Rubiaceae	<i>Richardia scabra</i> L.	B	A	25	10	10	58	20	23	33	12

Weed removal did not significantly influence the number of plants per plot (Table 4). The number of plants slightly decreased with age but ranged between 53 and 72 plants per plot. Conversely, weed removal significantly affected the number of FAW-infested plants at all periods of

estimation except at 2WAP in the 2019 season. At 4-6WAP, weedy plots had a significantly lower number of FAW-infested plants compared to herbicide-treated plots while at 8WAP, a significantly lower number of FAW-infested.

Table 4: Effect of time of weed removal on weed density and weed biomass in 2019

Weed control	Weed density (seedling/m ²)			Weed biomass (g/m ²)		
	3 WAP	6 WAP	9 WAP	3 WAP	6 WAP	9 WAP
Atrazine@4l/ha	27	236	108	13.82	205.53	69.62
Atrazine@4l/ha + Nicosulfuron @2l/ha	26	52	12	13.15	38.62	7.76
Metolachlor@4l/ha	23	108	38	16.06	97.15	26.04
Metolachlor@4l/ha +Nicosulfuron @2l/ha	20	2	0	13.17	2.07	0.00
Primextra@4l/ha	15	205	78	7.53	142.32	46.57
3 weeks weedy	150	83	78	35.45	17.08	50.54
4 weeks weedy	141	57	66	39.91	11.06	43.32
Weed check	178	382	148	66.34	317.22	121.84
Sed (0.05)	11.57*	28.82*	14.62*	10.76*	23.40*	9.91*
2020 Growing Season						
Weed control	3 WAP	6 WAP	9 WAP	3 WAP	6 WAP	9 WAP
Atrazine @4l/ha	4	21	14	4.50	11.54	3.23
Atrazine @4l/ha + Nicosulfuron @2l/ha	3	4	3	2.97	3.22	2.43
Metolachlor @4l/ha	5	17	15	1.13	7.23	3.58
Metolachlor@4l/ha+ Nicosulfuron @2l/ha	4	4	3	1.45	3.35	1.33
Primextra @ 4l/ha	4	14	11	0.57	12.16	3.25
3 weeks weedy	14	20	8	14.43	18.42	6.86
4 weeks weedy	17	14	8	14.99	16.76	6.96
Weed check	22	59	21	18.78	99.83	44.22
Sed (0.05)	1.97*	3.34*	1.65*	2.08*	6.25*	4.17*
2021 Growing Season						
Weed control	3 WAP	6 WAP	9 WAP	3 WAP	6 WAP	9 WAP
Atrazine @4l/ha	6	21	15	4.05	12.61	10.34
Atrazine @4l/ha + Nicosulfuron @2l/ha	5	10	8	4.16	4.26	7.67
Metolachlor @4l/ha	6	19	18	4.07	7.44	7.82
Metolachlor@4l/ha+ Nicosulfuron @2l/ha	5	10	6	2.52	4.29	6.04
Primextra @ 4l/ha	5	23	14	2.54	11.72	10.75
3 weeks weedy	45	32	18	5.27	22.18	23.22
4 weeks weedy	52	27	20	8.08	18.15	20.21
Weed check	33	199	78	13.63	131.34	38.28
Sed (0.05)	1.11*	7.58*	1.56*	1.88*	4.36*	1.56*

WAP= weeks after planting, * = significant at $p < 0.05$

plants were obtained from the weedy check plots. Atrazine-treated plots had a relatively higher number of FAW-infested plants compared to other herbicide-treated plots.

The number of plants harvested, and grain yield was substantially influenced by weed removal (Table 5). Weed check plots had significantly lower plant harvested and

Table 5: Effect of weed control measures on the number of infested plants by FAW in 2019

Weed control (W)	Number of plants/plot				Number of infested plants/plot			
	2 WAP	4 WAP	6 WAP	8 WAP	2 WAP	4 WAP	6 WAP	8 WAP
Atrazine @4l/ha	62	62	62	60	17	19	18	18
Atrazine@4l/ha+ Nicosulfuron @2l/ha	69	67	66	66	16	17	16	16
Metolachlor @4l/ha	62	62	61	61	18	18	16	16
Metolachlor@4l/ha+ Nicosulfuron @2l/ha	60	64	61	61	12	16	18	18
Primextra@4l/ha	64	69	67	67	15	23	19	17
3 weeks weedy	64	63	62	56	11	10	16	16
4 weeks weedy	62	62	58	58	12	10	12	18
Weed check	61	61	57	56	10	9	5	15
Sed (0.05)	3.98	3.94	1.31	1.32	1.19	3.21*	1.37*	1.38*
2020 Growing Season								
Weed control (W)	2 WAP	4 WAP	6 WAP	8 WAP	2 WAP	4 WAP	6 WAP	8 WAP
Atrazine@4l/ha	72	74	70	70	28	32	29	28
Atrazine@4l/ha + Nicosulfuron@2l/ha	72	74	69	69	24	20	24	24
Metolachlor@4l/ha	68	69	64	64	23	26	20	20
Metolachlor@4l/ha + Nicosulfuron @2l/ha	66	68	65	65	23	25	22	24
Primextra@4l/ha	65	66	62	62	23	26	26	22
3 weeks weedy	67	69	65	65	5	15	22	21
4 weeks weedy	59	60	53	53	3	12	20	29
Weed check	64	66	60	60	6	10	15	15
Sed (0.05)	4.31	4.49	4.71	4.80*	4.25*	4.51*	4.70*	4.83*
2021 Growing Season								
Weed control (W)	2 WAP	4 WAP	6 WAP	8 WAP	2 WAP	4 WAP	6 WAP	8 WAP
Atrazine @4l/ha	60	59	59	59	27	24	27	24
Atrazine@4l/ha+ Nicosulfuron @2l/ha	61	59	59	59	22	20	22	19
Metolachlor@4l/ha	65	63	63	63	24	21	23	19
Metolachlor@4l/ha + Nicosulfuron @2l/ha	63	58	58	57	25	19	24	18
Primextra@4l/ha	60	56	56	56	20	20	22	16
3 weeks weedy	58	58	57	57	13	14	15	13
4 weeks weedy	60	60	58	58	14	11	16	12
Weed check	59	59	58	58	13	10	10	9
Sed (0.05)	2.82	2.60	2.59	1.13	1.53*	1.46*	1.47*	1.56*

WAP = weeks after planting, * = significant at $p < 0.05$

Table 6: Effect of time of weed removal control on grain yield of maize

	2019 Season			2020 Season			2021 Season		
	Plant stands harvested	Grain yield (t/ha)	Plant stand harvested	Grain yield(t/ha)	Plant stand harvested	Grain yield (t/ha)			
Weed control									
Atrazine@4l/ha	45	2.19	65	2.24	35	2.48			
Atrazine@4l/ha + Nicosulfuron @2l/ha	42	2.92	66	2.98	35	3.56			
Metolachlor@4l/ha	45	2.60	64	1.80	36	2.70			
Metolachlor@4l/ha + Nicosulfuron @2l/ha	42	3.19	65	2.93	35	4.13			
Primextra@4l/ha	45	2.39	62	1.88	37	2.35			
3 weeks weedy	49	2.98	65	3.71	33	4.20			
4 weeks weedy	41	2.90	62	2.68	34	3.52			
Weed check	27	0.56	20	0.51	23	0.88			
Sed (0.05)	1.46*	0.35*	4.60*	0.26*	1.53*	0.18*			

Sed (0.05)1.46*0.35*4.60*0.26*1.53*0.18** = significant at p < 0.01

grain yield across the seasons. In the 2019 season, metolachlor + Nicosulfuron treated plots had significantly higher grain yield, 3.19t/ha although like all other plots except plots treated with single atrazine and primextra, and weedy check plots. The grain yield ranged between 2.19 - 3.19t/ha in plots where weeds were managed while a significantly lower grain yield, 0.56t/ha was obtained from the weedy check plots. Plots left weedy for 3 weeks before weeds removal had a positively higher grain yield, 3.71t/ha in the 2020 cropping season, followed by plots treated with two herbicides (2.93 – 2.98 t/ha) and 4 weeks weedy plots (2.68t/ha). The single herbicide-treated plots were relatively lower in grain yield (1.80-2.24t/ha) while a significantly lower grain yield, 0.51t/ha was obtained from the weedy check plots. In 2021, the

grain yields obtained were higher compared to the previous two seasons. Plots left weedy for three weeks and metolachlor + Nicosulfuron treated plots had a substantially higher grain yield, 4.20t/ha and 4.13 t/ha, respectively, and were closely followed by plots treated with atrazine + Nicosulfuron, and 4 weeks weedy plots (3.52 - 3.56t/ha) while plots treated with a single herbicide had grain yield ranging between 2.35 to 2.70 t/ha. The weedy check plots had a significantly lower grain yield, 0.88t/ha. The relationship between weed density and the number of maize stands damaged by FAW is presented in Fig.1 The result shows a negative relationship between FAW damage and weed density indicating that as weed density increases, the damage from FAW decreases by 5.42%. Similarly, an increase in weed density leads to a slight decrease in maize grain yield.

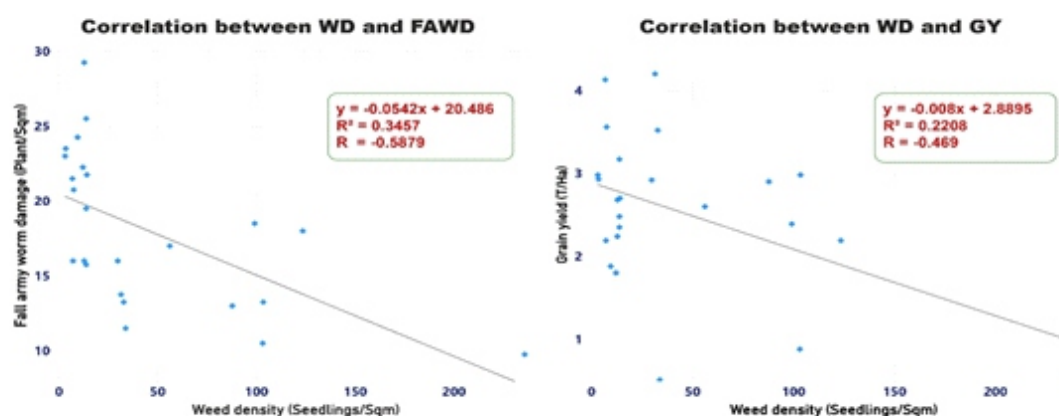


Figure 1. Regression and correlation analysis showing the relationship between weed density, FAW damaged and grain yield

Discussion

The primary food source for many phytophagous insects is weeds, and insects feeding on weeds decrease weed-crop competition by increasing crop access to water, soil nutrients, and sunlight. If an insect's feeding habits are not restricted to the weed alone, some insects may damage crops easily if there are no attractive weeds to feed on (Capinera 2005). A lot of insects seem to be more selective or inconsistent in feeding host preferences, making the host lists extremely deceptive (Schaffner, 2001). Also, in most cases, insects develop very high populations, overrun their food supply, and are forced to feed on crops (Tang *et al.*, 2019). Therefore, if weeds harbour insects that can infest crops, it is important to properly time the application of weed control to prevent the insects from moving to the crop plants. It was reported that fields with diverse weed communities have higher densities of beneficial pest insects than fields with low weed diversity (Storkey and Neva, 2018).

In this study, the fields had a diversified mixed weed spectrum that did not change markedly throughout the 3-year study period (Marshall, 2003). The most prevalent weed species were *Richardia scabra*, *Digitaria sanguinalis*, *Gomphrena celosioides*, *Cyperus species*, *Chloris pycnothrix*, *Dactyloctenium aegyptium*, *Euphorbia hypericifolia*, *Chromoleana odorata*, *Heterotis rotundifolia*, and *Andropogon gayanus*. To determine the principal weed morphological group responsible for FAW populations in maize fields, pre-emergence application of Atrazine controlled 94% of broadleaved

weeds while 81.9% of grass species dominated the field. Application of metolachlor controlled 89.6% of grass weed species and 78.8% of diversified broadleaved species. Weed morphological populations in fields treated with Primextra were relatively similar. The above agrees with the recent reports of Chand *et al.* (2016), Travis *et al.* (2016), and Bhuiyan *et al.* (2018).

This study also showed that weeds positively influenced the number of maize plants infested with FAW; the delayed hoe-weeded and weedy check plots had a relatively low (40–47%) infestation of FAW compared to herbicide-treated plots. The degree of infestation of maize by FAW was also higher in atrazine-treated plots compared with maize grown in plots treated with other herbicides or in plots containing a natural mixture of weed species. Hay-Roe *et al.* (2016) reported that native grasses and weeds are the host natural enemies of FAW, while Baudron *et al.* (2019) observed greater FAW damage on maize crops cultivated immediately after fallowing, which was likely due to the dominance of graminaceous species in short-term fallows. Moraes *et al.* (2020) concluded that the survival and development of FAW during the off-season were higher on weeds like *Sorghum halepense* (L.) and *Eleusine indica* (L.) in maize. It was observed that FAW infests the maize plant via the lower leaves and migrates to the upper leaves, the presence of weeds limit the infestation on the maize plant and thus low damage on the maize plant.

In the present study also, while the application of pre-and post-emergence herbicides on the same plots had a higher

grain yield compared to the use of a single herbicide (Takim *et al.*, 2017), delaying weed removal for 3 weeks had a significant average yield of 3.63 t/ha, which was a 9.37% increase from double herbicide plots, suggesting that early weed interference with maize production could be of little value when minimal weed control practices are employed (Page *et al.*, 2012) and the beneficial effect of weeds in reducing FAW incidence compensates for the negative effect of weed competition (Lima *et al.*, 2009). The percentage of maize plant damage was observed to increase as the weed population increased indicating that weeds may have improved the prevalence of FAW thus a decrease in plant damage from fall armyworms. This result might imply that weeds provide an alternate habitat or food source for the fall armyworms, reducing their impact on maize.

Conclusion

Maize plants damaged by armyworms were 40–47% lower where weed removal was delayed for 3–4 weeks after planting maize compared to maize plants damaged in herbicide-treated plots. There was a 16.5% increase in the level of infestation in atrazine-treated plots compared to other herbicide-treated plots. As a result, increasing the time of weed removal allows the natural host of FAW to dominate, reducing the level of infestation on the maize plant and resulting in an increase in maize grain yield.

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