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Screening of Herbicides for Weed Control in Soybeans (Glycine max) in Derived Savanna Agroecology of Nigeria

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Abstract

Weed stress significantly hampers soybean (*Glycine max* L.) production in sub-Saharan Africa, a vital source of protein and plant oil. Two studies evaluated herbicide formulations for pre and post-emergence weed control in soybeans within the Derived savanna. at Ibadan and Ilora sites in a Randomized Complete Block Design (RCBD), replicated three times. The experiments involved random sampling of initial weed flora composition before land preparation. Pre-emergence treatments featured trifluralin (580, 700, 820 g a.i ha^{-1}) and metolachlor (1440 g a.i ha^{-1}). Post-emergence treatments included clethodim (48, 72, 96 g a.i ha^{-1}), quizalofop-P-ethyl (10, 15, 20 g a.i ha^{-1}), and oxyfluorfen (960, 1200, 1440 g a.i ha^{-1}) applied 5 weeks after sowing. Agronomic data were collected on soybeans, weed growth, and weed flora composition. The frequent weeds identified were *Mitracarpus villosus* in metolachlor-treated plots and *Commelina* bengalensis in trifluralin-treated plots at 820 g a.i ha^{-1}. *Tithonia diversifolia* and *Commelina banghalensis* were the common post-herbicide application weeds. Trifluralin (580-820 g a.i ha^{-1}) and post-emergence herbicides (clethodim and quizalofop–P-ethyl) increased soybean canopy, seed pods, and yield by 50-90%, with 70-90% weed growth reduction, ensuring significant weed control (76-96%). Trifluralin effectively suppressed weed growth at 7 weeks after sowing, resulting in a noteworthy grain yield. Clethodim and quizalofop–P-ethyl demonstrated superior and comparable weed control to fluazifop-p-butyl (225 g a.i ha^{-1}) and weed-free treatment, respectively, at harvest. Early trifluralin-based pre-emergence weed control led to a 53% increase in grain yield (2.58 t ha^{-1}) compared to post-emergence herbicides (1.38 t ha^{-1}). This study underscores effective herbicide strategies for soybean cultivation in the Derived savanna, contributing to enhanced productivity and weed management.

Introduction

Soybean (*Glycine max* (L.) Merr.) production is limited by weed infestation, which reduces growth and grain yield (Stefanic *et al*., 2022). Sodangi *et al*., (2011) associated low soybean yield with weed infestation and poor soil fertility. On a global basis, 37% of attainable soybean production is endangered by weed competition, compared to 11, 11, and 1% by pathogens, animal pests, and viruses, respectively (Oerke, 2006). Weeds aggravate multiple stress, causing biochemical and physiological modifications in competing crop plants (Rockenbach *et al*., 2018). Weeds are considered the most harmful pest to agricultural production, with a significant increase in the cost of crop production (Gharde *et al.,* 2018). Weeds infestation in soybean plants leads to quick crop plant suppression, resulting in marked yield reduction of 5-90% in different agro-ecologies (Aluko *et al*., 2012; Nathanael *et al*., 2013; Imoloame, 2014; Pereira *et al*., 2015). The presence of weeds at soybean harvest could

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contaminate soybean seeds, and reduce seed quality, and harvest efficiency (Werner *et al*., 2014).

Weed control in sub-Saharan Africa is mainly by hand-hoeing, which is laborious, expensive, and ineffective thereby making effective control of weeds in the field during the peak periods of the rainy season almost impossible (Adigun and Lagoke, 2003; Imoloame, 2014). Using herbicides for weed control in soybean production has been proven efficient (Peer *et al*., 2013; Song *et al*., 2020). Herbicide application is supposedly a feasible option for timely weed control. Many herbicides are labeled for use in soybeans which can be applied as pre-plant incorporation, pre-emergence, post-emergence, and post-directed (Spasic, 2018). Herbicide formulations in this study were developed to widen the selection window of herbicides for effective weed control in soybeans. Hence, the objective of this study was to evaluate the efficiency of these candidate herbicide formulations for pre and post-emergence weed control in soybeans in the derived savanna of Nigeria.

Materials and Methods

This study was conducted at the Institute of Agricultural Research and Training (IAR&T), Obafemi Awolowo University out-stations in the Derived savanna agro-ecology [(Ibadan 7° 38'N, 3°84'E 182m altitude (alt.) and Ilora 07° 81'N, 03° 82'E) of southern Nigeria in 2014 and 2015 cropping seasons. The weed flora compositions at the study sites were sampled randomly before land preparation, using a 1 m × 1 m quadrat. Weeds samples collected were identified and classified (Table 1). The cropping history of the locations was also recorded from 2010 to 2015 (Table 2).

Pre-experiment site weed composition

The weed spectrum of experimental sites was composed of about 20% grass and 80% broadleaved weeds in both locations (Table 1). The weed flora composition in both locations was similar. The weeds cut across different plant families (7), mostly annual weeds (80%), with *Asteraceae* more prominent in both locations (Table 1).

The experimental land was ploughed and harrowed before sowing. Soybean variety TGX 1448-2E was used in this study and was obtained from the Institute of Agricultural Research and Training (IAR&T). It was sown in plots of 3 m × 3 m, with an inter-row spacing of 50 cm and intra-row spacing of 10 cm. Herbicides were presented for evaluation by Rainbow Company Nigeria. Company-recommended rates of herbicides were: trifluralin (700 g a.i ha^{-1}), clethodim 240 g L^{-1} EC (72 g a.i ha^{-1}); quizalofop-p-ethyl 200 g L^{-1} EC (15 g a.i ha^{-1}); and oxyfluorfen 240 g L^{-1} EC (1200 g a.i ha^{-1}). Trifluralin was applied at rates of 580, 700, and 820 g a.i ha^{-1}, and metolachlor was applied at 1440 g a.i ha^{-1} as the reference treatment. These herbicides were randomly assigned to plots with a water volume of 200 L ha^{-1} after sowing for pre-emergence weed control in a Randomized Complete Block Design (RCBD), replicated three times.

Clethodim 240 g L^{-1} EC (48, 72, and 96 g a.i ha^{-1}), quizalofop-p-ethyl 200 g L^{-1} EC (10, 15, and 20 g a.i ha^{-1}), oxyfluorfen 240 g L^{-1} EC (960, 1200 and 1440 g a.i ha^{-1}) were evaluated for post-emergence weed control at 5 WAS, with fluazifop-P-butyl 225 g a.i ha^{-1} (Fusilade forte® 150 EC) serving as the reference post-emergence treatment. The concentrations of herbicides were varied to ascertain the optimum effective dose of herbicides for weed control. Herbicide formulations were randomly assigned to plots, applied with a water volume of 200 L ha^{-1}, and arranged in a Randomized Complete Block Design (RCBD) with three replicates.

Data were collected from 5 tagged plants in each plot in pre- and post-emergence herbicide studies. The soybean canopy cover was visually rated on a scale of 1 – 10, where 1 represented the lowest canopy coverage and 10 represented the highest. The number of pods /plant was counted on the tagged plants and the average was recorded. Grain yield/hectare was measured by harvesting and threshing the soybean pods in the sample area (1 sqm) in the middle of each plot. The grains were weighed and extrapolated to yield/hectare.

Table 1: Weed spectrum before land preparation of the experimental sites in derived savanna agroecology of southern

Weed family	Weed spp	Morphology	Life cycle	Ibadan	Ilora
Asteraceae	*Tridax procumbens* L.	B	A	p	p
"	*Aspillia africana* C. D. Adams	B	A	p	p
"	*Tithonia diversifolia* (Hemsl) A. Gray.	B	A	p	p
"	*Agerantum conyzoides* L.	B	A	p	p
"	*Hyptis suaveolens* (L.) Poit	B	A	a	p
Leguminosae-Mimosoideae	*Mimosa invisa* Mart. Ex Colla	B	A	p	a
Leguminosae-Papilinoideae	*Crotalaria retusa* L.	B	A	p	a
"	*Desmodium scorpiurus* Sw. Desv.	B	A	a	p
Poaceae	*Megathysus maximum* Jacq.	G	P	p	p
"	*Hackelochloa granularis* L. Kuntze	G	P	a	p
Rubiaceae	*Mitracarpus villosus* (Sw.) DC.	B	A	p	p
Verbenaceae	*Stachytarpheta cayennensis* (Rich.) Vahl	B	A	p	a
"	*Stachytarpheta jamaicensis* (L.) Vahl	B	A	p	a

P – Perennial, A- annual, G- grass, B- broadleaf, a = absent, p = present

Table 2: Cropping history and weed control methods in the Derived savanna agroecology of southern Nigeria (2010 – 2015)

Year	Ibadan		Ilora	
	Crops	Weed control methods	Crops	Weed control methods
2010	Kenaf	Pendimethalin + HW	Maize	Atrazine + HW
2011	Kenaf	Pendimethalin + HW	Cowpea	Metolachlor + HW
2012	Maize	Atrazine + HW	Kenaf	Pendimethalin + HW
2013	Cajanus	Metolachlor + HW	Maize	Atrazine + HW
2014	Soybean	Evaluation of herbicide + HW	Soybean	Evaluation of herbicides + HW
2015	Soybean	Evaluation of herbicide + HW	Soybean	Evaluation of herbicides + HW

HW – Hoe weeding

Weed weight was measured at soybean harvest by taking weed samples from a 1 × 1 m quadrat in the plot's middle. The weed samples were identified and oven-dried at 80° C for 48 hours. The dried weed samples were weighed with a sensitive weighing scale Model HC Shanghai Huachao Industrial Co. Limited China. Weed control efficiency (WCE %) and relative yield loss (%) were calculated from equations 1 and 2, respectively according to Mani *et al*., (1973) and Gill and Kumar, (1969).

$$WCE\% = \{(W_{wy} - W_t)/W_{wy}\} \times 100 \quad (1)$$

Where: WCE is weed control efficiency; W_{wy} is the weed weight in the weedy plot; W_t is the weed in the treated plot.

$$RYL = \{(Y_{ht} - Y_t)/Y_{ht}\} \times 100 \quad (2)$$

where: RYL is the relative yield loss; Y_{ht} is the highest yield; Y_t is the yield from treatment

Data collected were statistically analyzed using Statistical Analysis System (SAS) 2001 GLM and means separated with Duncan's Multiple Range Test (DMRT) at $p \leq 0.05$.

Results

Effect of Herbicides on weed composition

At 5 weeks after application of treatments (WAA), plots with pre-emergence herbicides in Ibadan had weeds from seven families and nine species (Table 3). *Tithonia diversifolia, Commelina benghalensis*, and *Mitracarpus villosus* were the major weeds in these plots. *Tithonia diversifolia plants* were major weeds when 0.58 kg trifluralin a.i ha^{-1} was applied. However, increased trifluralin concentration to 0.70 kg a.i ha^{-1} and 0.82 kg a.i ha-1 successfully reduced these weed plants to minor weeds. On the contrary, *Commelina benghalensis* plants were major weeds in plots treated with 0.82 kg trifluralin a.i ha^{-1} and minor weeds in lower concentrations. Applying 0.70 kg of trifluralin a.i ha^{-1} in Ibadan resulted in only less frequent weeds. *Mitracarpus villosus,* which was observed to be a minor weed in trifluralin-treated plots, was a major weed in the metolachlor-treated plots and the weedy checks. However, *Tithonia diversifolia* and *Commelina benghalensis* were major weeds in trifluralin-treated plots and minor in metolachlor-treated plots.

Plots treated with pre-emergence herbicides in Ilora had weeds belonging to eight families and ten species at 5 WAA (Table 4). The frequent weeds in these plots were *Aspilia africana, Tithonia diversifolia, Commelina benghalensis, and Cyperus rotundu*s. *Aspilia africana* plants were the less frequent and frequent weeds in plots treated with 0.58 kg trifluralin a.i ha^{-1} and 0.82 kg trifluralin a.i ha^{-1}, respectively. *Tithonia diversifolia* plants were the frequent weeds in all plots where pre-emergence herbicides were applied. *Commelina benghalensis* plants were the less frequent weeds in plots treated with 0.70 kg trifluralin a.i ha^{-1} and frequent weeds in plots treated with 0.58 kg trifluralin a.i ha^{-1} and 0.82 kg trifluralin a.i ha^{-1}. *Cyperus rotundus* plants were frequent weeds in plots treated with 0.58kg trifluralin a.i ha^{-1} and the weedy checks. However, this weed species was less frequent weed in plots treated with 0.70 kg trifluralin a.i ha^{-1} and 0.82 kg trifluralin a.i ha^{-1}.

Twenty-two weed species belonging to nine families were in plots treated with post-herbicides in Ibadan at soybean harvest (Table 5). *Tithonia diversifolia, Cyperus rotundus, Mimosa invisa, Desmodium scorpiurus, Megathysus maximum, Mitracarpus villosus, and Oldenlandia corymbosa* were frequent weeds on these plots. *Tithonia diversifolia* plants were frequent weeds in plots treated with 48 g clethodim a.i ha^{-1} and 72 g clethodim a.i ha^{-1}. On the contrary, this weed emerged as a less frequent weed in plots treated with 96 g clethodim a.i ha^{-1}. In oxyfluorfen-treated plots, *Tithonia diversifolia* plants were less frequent weeds on plots treated with 960g oxyfluorfen a.i ha^{-1} and 1200 g oxyfluorfen a.i ha^{-1}. Conversely, they were frequent weeds in plots treated with 1440g oxyfluorfen a.i ha^{-1}. Similarly, *Tithonia diversifolia* plants were major weeds in plots treated with 10g quizalofop-p-ethyl a.i $ha^{-1}$and 20 g quizalofop-p-ethyl a.i ha^{-1}. However, plots treated with 225 g gfusilade a.i ha^{-1} and the weedy checks had *Tithonia diversifolia* as a less frequent weed. *Cyperus rotundus, Mimosa invisa, Desmodium scorpiurus, and Megathysus maximum* were the weeds with high density in plots treated with 20 g quizalofop-p-ethyl a.i ha^{-1}, 15g quizalofop-p-ethyl a.i ha^{-1}, 48 g clethodim a.i ha^{-1} and the weedy check, respectively. *Mitracarpus villosus* plants were major weeds in plots treated with 96 g clethodim a.i ha-^{1}, 15 g quizalofop-p-ethyl a.i ha^{-1}, and the weedy checks. Also, *Oldenlandia corymbosa* plants had high density in plots treated with 48g clethodim a.i ha^{-1}, 10g quizalofop-p-ethyl a.i ha^{-1}, and 225g fluazifop-p-butyl a.i ha^{-1}.

Table 3: Weed spectrum and prevalence at 5 WAA of pre-emergence herbicide in 2014 and 2015 cropping seasons at Ibadan, Nigeria

Weed family	Weeds Spp	Morphology	Life cycle	Pre-emergence herbicides (PREH)				WF	WC
				1	2	3	4		
Asteraceae	*Acanthospermum hispidum* DC	B	A	-	-	-	b	-	-
Asteraceae	*Tithonia diversifolia* (Hemsl) A. Gray.	B	A	a	b	b	b	-	-
Commelinaceae	*Commelina benghalensis* L.	Sp	P	-	b	a	b	-	b
Cyperaceae	*Cyperus rotundus* L.	S	P	b	b	b	b	-	b
Fabaceae-Mimosoideae	*Mimosa invisa* C. Martius	B	A/P	b	-	-	-	-	-
Fabaceae-Papilinoideae	*Desmodium scorpiurus* Sw. Desv.	B	A/P	-	b	b	-	-	b
Poaceae	*Megathysus maximum (Jacq.)*	G	A	-	b	-	b	-	-
Portulacaceae	*Talinum fruticosum* (L.) Juss	B	A/P	-	-	b	-	-	-
Rubiaceae	*Mitracarpus villosus* (Sw.) DC.	B	A	b	-	b	a	-	a

a – frequent weed, b – less frequent, B- broadleaf, G- Grass, Sp- Spiderwort, S – Sedge, P – Perennial, A – Annual, $PREH_1$ – Trifluralin – 0.58 kg a.i ha^{-1}, $PREH_2$ – Trifluralin 0.70 kg a.i ha^{-1}, $PREH_3$ – Trifluralin – 0.82 kg a.i ha^{-1}, $PREH_4$ – Metolachlor 1.44 kg a.i ha^{-1} (reference treatment, WF – Weed-free, and WC – Weedy check, WAA - Weeks After Application

Table 4: Weed spectrum and prevalence at 5 WAA of pre-emergence herbicide in 2014 and 2015 seasons at Ilora, Nigeria

Weed family	Weeds Spp	Morphology	Life cycle	Pre-emergence herbicides (PREH) 1	2	3	4	WF	WC
Amaranthaceae	*Achyranthes aspera*	B	A	-	-	b	-	-	b
Asteraceae	*Aspilia africana* C. D. Adams	B	A	b	a	-	-	-	-
Asteraceae	*Tithonia diversifolia* (Hemsl) A. Gray.	B	A	a	a	a	a	-	a
Asteraceae	*Tridax procumbens L.*	B	A	-	b	-	-	-	-
Commelinaceae	*Commelina benghalensis* L.	Sp	P	a	b	a	b	-	b
Cyperaceae	*Cyperus rotundus L.*	S	A/P	a	b	b	-	-	a
Fabaceae - Papilinoideae	*Desmodium scorpiurus* Sw. Desv.	B	A	-	-	-	-	-	b
Lamiaceae	*Hyptis suaveolens* (L.) Poit	B	A	-	-	b	-	-	-
Poaceae	*Hackelochloa granularis* L. Kuntze	G	A	-	b	b	b	-	b
Rubiaceae	*Mitracarpus villosus* (Sw.) DC.	B	A	-	-	-	-	-	b

a – frequent weed, b – less frequent weed, B- broadleaf, G- Grass, Sp- Spiderwort, S – Sedge, P – Perennial, A – Annual, $PREH_1$ – Trifluralin 0.58 kg a.i ha^{-1}, $PREH_2$ – Trifluralin 0.70 kg a.i ha^{-1}, $PREH_3$ – Trifluralin 0.82 kg a.i ha^{-1}, $PREH_4$ – Metolachlor 1.44 kg a.i ha^{-1} (reference treatment), WF – Weed-free, and WC – Weedy check, WAA - Weeks after application

Table 5: Weed spectrum at soybean harvest in 2014 and 2015 cropping seasons at Ibadan, Nigeria.

Weed family	Weed Spp	Morphology	Life cycle	Post-emergence herbicides (POEH)										WF	WC
				1	2	3	4	5	6	7	8	9	10		
Asteraceae	*Acanthospermum hispidum DC.*	B	A	b	-	-	-	-	-	-	-	-	b	-	b
Asteraceae	*Aspilia bussei O.Hoffm & Muschl.*	B	A	-	-	-	-	-	-	-	-	b	-	-	-
Asteraceae	*Tithonia diversifolia* (Hemsl) A. Gray.	B	A	a	a	b	b	b	a	a	-	a	b	-	b
Cleomaceae	*Cleome viscosa L.*	B	A	b	-	-	b	b	b	-	-	-	b	-	-
Commelinaceae	*Commelina benghalensis L.*	Sp	P	b	b	-	b	-	b	b	b	-	b	-	-
Convolvulaceae	*Cyperus esculentus*	S	P	-	b	-	-	-	-	b	b	-	-	-	-
Cyperaceae	*Cyperus rotundus* L.	S	P	b	b	b	b	-	b	b	b	a	b	-	-
Cyperaceae	*Ipomea involucrata P.Beauv.*	B	A/P	b	-	-	-	-	-	-	-	-	-	-	-
Cyperaceae	*Kyllinga bulbosa P.Beauv.*	S	P	-	-	-	-	-	-	-	b	-	-	-	b
Cyperaceae	*Kyllinga erecta Schumach*	S	P	b	-	-	-	b	-	-	-	-	-	-	-
Cyperaceae	*Kyllinga pumila Michx*	S	A/P	-	-	-	-	-	-	-	b	-	-	-	-
Cyperaceae	*Kyllinga squamulata Vahl*	S	A/P	b	-	b	-	b	-	b	b	-	-	-	-
Cyperaceae	*Mariscus longibracteatus Chermezon*	S	P	-	-	-	-	b	-	-	-	-	-	-	b
Euphorbiaceae	*Phyllanthus amarus (Schum & Thonn)*	B	A	b	-	-	-	-	-	-	-	-	-	-	-
Fabaceae -Mimosoideae	*Mimosa invisa* C. Martius	B	P	-	b	-	-	-	-	-	a	b	-	-	-
Fabaceae -Mimosoideae	*Mimosa pudica L.*	B	P	-	-	-	-	-	-	-	-	b	-	-	-
Fabaceae -Papilinoideae	*Desmodium scorpiurus* Sw. Desv.	B	A/P	a	-	-	b	b	b	b	b	b	b	-	-
Poaceae	*Eragotis tenella (L.) P.Beauv. ex Roem. & Schult.*	G	A	-	b	-	b	b	-	b	-	-	-	-	-
Poaceae	*Megathysus maximum (Jacq.)*	G	A	-	b	b	b	b	b	b	-	-	-	-	A
Portulacaceae	*Talinum fruticosum* (L.) Juss	B	P	b	-	b	-	-	-	-	-	-	b	-	-
Rubiaceae	*Mitracarpus villosus* (Sw.) DC.	B	A	b	b	a	-	b	-	b	a	b	b	-	A
Rubiaceae	*Oldenlandia corymbosa L.*	B	A	a	b	b	-	-	-	a	b	-	a	-	-

a – frequent weed, b – less frequent weed, B- broadleaf, G- Grass, Sp- Spiderwort, S – Sedge, P – Perennial and A – Annual, $POEH_1$ – Clethodim 48g a.i ha^{-1}, $POEH_2$ – Clethodim 72g a.i ha^{-1}, $POEH_3$ – Clethodim 96g a.i ha^{-1}, $POEH_4$ – Oxyfluorfen 960g a.i ha^{-1}, $POEH_5$ – Oxyfluorfen 1200 g a.i ha^{-1}, $POEH_6$ – Oxyfluorfen 1440g a.i ha^{-1}, $POEH_7$ – Quizalofop-p-ethyl 10g a.i ha^{-1}, $POEH_8$ – Quizalofop-p-ethyl 15g a.i ha^{-1}, $POEH_9$ – Quizalofop-p-ethyl 20g a.i ha^{-1} , $POEH_{10}$ – Fluazifop-p-butyl 225g a.i ha^{-1} (reference treatment), WF – Weed-free and WC– Weedy check

Plots treated with post-emergence herbicide in Ilora had ten weed species (Table 6). *Tithonia diversifolia, Commelina benghalensis,* and *Hackelochloa granularis* were the major weeds in these plots. *Tithonia diversifolia* plants were frequent in all the plots treated with post-emergence herbicides in Ilora except those with 960g oxyfluorfen a.i ha^{-1}. *Commelina benghalensis* and *Hackelochloa granularis* had high density in plots treated with 72g clethodim a.i ha^{-1} and 10g quizalofop-p-ethyl a.i ha^{-1}, respectively.

Table 6: Weed spectrum at soybeans in 2014 and 2015 cropping seasons at Ilora, Nigeria.

				Post-emergence herbicides (POEH)											
Weed family	Weed Spp	Morphology	Life cycle	1	2	3	4	5	6	7	8	9	10	WF	WC
Amaranthaceae	*Achyranthes aspera* L.	B	A	-	-	-	-	-	-	-	-	b	b	-	-
Asteraceae	*Aspilia africana* C. D. Adams	B	A	b	-	b	-	b	-	-	b	b	b	-	b
Asteraceae	*Tithonia diversifolia* (Hemsl) A. Gray.	B	A	a	a	a	b	a	a	a	a	a	a	-	a
Asteraceae	*Tridax procumbens* L.	B	A	-	-	-	-	-	-	-	b	b	-	-	-
Commelinaceae	*Commelina benghalensis* L.	Sp	P	b	a	-	-	-	-	b	b	b	b	-	b
Cyperaceae	*Cyperus rotundus* L.	S	A/P	-	-	-	-	b	-	-	-	-	-	-	b
Fabaceae -Papilinoideae	*Desmodium scorpiurus* Sw. Desv.	B	A	b	b	-	b	-	-	b	b	-	b	-	-
Lamiaceae	*Hyptis suaveolens* (L.) Poit	B	A	-	-	-	-	-	-	-	-	b	-	-	-
Poaceae	*Hackelochloa granularis* L. Kuntze	B	A	-	-	-	-	b	b	a	b	b	-	-	b
Rubiaceae	*Mitracarpus villosus* (Sw.) DC	B	A	-	-	-	-	-	-	-	b	b	b	-	-

a – frequent weed, b – less frequent weed, B- broadleaf, G- Grass, Sp- Spiderwort, S – Sedge, P – Perennial and A – Annual, $POEH_1$ – Clethodim 48g a.i ha^{-1}, $POEH_2$ – Clethodim 72g a.i ha^{-1}, $POEH_3$ – Clethodim 96g a.i ha^{-1}, $POEH_4$ – Oxyfluorfen 960g a.i ha^{-1}, $POEH_5$ – Oxyfluorfen 1200 g a.i ha^{-1}, $POEH_6$ – Oxyfluorfen 1440g a.i ha^{-1}, $POEH_7$ – Quizalofop-p-ethyl 10g a.i ha^{-1}, $POEH_8$ – Quizalofop-p-ethyl 15g a.i ha^{-1}, $POEH_9$ – Quizalofop-p-ethyl 20g a.i ha^{-1}, $POEH_{10}$ – Fluazifop-p-butyl 225g a.i ha^{-1} (reference treatment), WF – Weed-free and WC– Weedy check

Effect of Herbicides on weed growth and soybean performance

Weed growth and soybean performance were influenced by applied pre-emergence herbicides (Table 7). Dry weights of weeds from plots treated with pre-emergence herbicides (PREH) were statistically at par with each other and weed-free (WF) but all had significantly lower weed dry weight (WDW) than weedy check (81.47 g m^{-2}). Weed control efficiency (WCE) of these weed control treatments maintained an inverse relationship with WDW but a similar trend with the latter. Notably, variations in WDW and WCE from trifluralin-treated plots with an increase in the active ingredient rate applied were insignificant (Table 7). Soybeans in plots treated with 580 g of trifluralin a.i ha^{-1} had the maximum canopy coverage score (8.67) though compared significantly with scores from WF (7.67) and other herbicidal-treated plots (Table 7). Numerically, seed pods produced by soybean in metolachlor-treated plots were highest (55.33) and significantly superior to the number recorded from plots treated with 700 g of Trifluralin a.i ha^{-1} (34.67) and unweeded control (22.33). However, decreasing the application rate of Trifluralin from 700 to 580 g a.i ha^{-1} had no significant effect on the number of seed pods produced by soybean (Table 7). The grain yield obtained from soybean in WF plots (3.67 t ha^{-1}) and corresponding relative yield loss incurred (11.35%) were the highest and least, respectively but compared significantly with yield and percentage losses from plots treated with Trifluralin applied at 580 g ha^{-1} (2.45 t ha^{-1}; 40.90%) and 700 g a.i ha^{-1} (2.27 t ha^{-1}; 45.25%). Meanwhile, differences in grain yield and relative yield loss from soybeans in all PREH treatments were not significant (Table 1). Significantly least grain yield (0.98 t ha^{-1}) and highest relative yield loss (76.37%) were recorded from weedy check plots. The response of weed and soybean to applied post-emergence herbicides (POEHs) was significant (Table 8). The WDW and WCE from WF plots were least (0 g m^{-2}) and highest (100%), respectively though compared favourably with values from all POEHs treated plots except oxyfluorfen (at all application rates) and fluazifop-P-butyl applied at 225 g a.i ha^{-1}. Howbeit, differences in WDW and WCE from all POEHs treated plots were not significant however, oxyfluorfen (at all application rates) consistently had the highest and lowest values, respectively (Table 8). The canopy coverage score for soybean in the WF plot was highest (8.67) and significantly superior over scores from other POEH treatments except for clethodim at 72 g a.i ha^{-1} (7.67) and fluazifop-P-butyl at 225 g a.i ha^{-1} (7.67). Meanwhile, variations in canopy coverage scores for soybeans in these two POEH treatments and plots treated with 10 g of quizalofop-P-ethyl ha^{-1} (7.00) were not significant. Application of quizalofop-P-ethyl at 10 or 20 g a.i ha^{-1}had significantly comparable effects on soybean canopy development (Table 2). Similarly, canopy coverage scores of soybeans in plots treated with 1.2 kg of Oxyfluorfen a.i ha^{-1} (5.33), 48 or 96 g of clethodim a.i ha^{-1} (5.33; 6.00), 15 or 20 g of quizalofop-P-ethyl a.i ha^{-1} (5.67; 6.00) were statistically at par. However, the application of oxyfluorfen at the rate of 960 g a.i ha^{-1} or 1.44 kg a.i ha^{-1} resulted in the lowest canopy coverage score of soybeans among the POEH treatments (4.67) which did not differ significantly from scores recorded from plots treated with 15 g quizalofop-P-ethyl a.i ha^{-1}, 1.2 kg oxyfluorfen a.i ha-1and 48 g–clethodim a.i ha^{-1}(Table 8). The highest number of seed pods was on soybean in plots kept weed-free (79.00) which compared significantly with the quantity from only plots treated with 15 g quizalofop-P-ethyl a. i ha^{-1} (67.00). Moreover, the effect of quizalofop-P-ethyl applied at 15 g ha^{-1} on this soybean trait did not differ significantly from other POEH except xyfluorfen (at all evaluated application rates), quizalofop-P-ethyl at 20 g a.i ha^{-1} and Clethodim at 48 g a.i ha^{-1}(Table 8). The number of seed pods per soybean plant in plots treated with these later mentioned POEHs were statistically at par. Notably, the significantly highest grain yield (3.36 t ha^{-1}) and least relative yield loss (3.36%) were recorded from soybeans in WF plots. The applied POEH varied significantly in their effects on grain yield and relative yield loss from soybeans. The grain yield of soybeans in POEH-treated plots ranged between 0.82 t ha^{-1} (oxyfluorfen applied at 1.44 kg ha^{-1}) and 2.06 t ha^{-1}(quizalofop-p-ethyl applied at 15g ha^{-1}).

Table 7: Effects of pre-emergence herbicide on weed growth and soybean performance in 2014 and 2015 cropping seasons at Ibadan and Ilora.

Treatments	CC (Scale:1 - 10)	Seedpods ($plant^{-1}$)	GY ($t\ ha^{-1}$)	Relative Yield loss (%)	WDW ($g\ m^{-2}$)	WCE (%)
Trifluralin 580g a.i ha^{-1}	8.67a	45.67ab	2.45b	40.90b	7.20b	91.58a
Trifluralin 700g a.i ha^{-1}	7.67a	34.67b	2.27b	45.25b	10.51b	87.71a
Trifluralin 820g a.i ha^{-1}	7.67a	54.67a	2.71ab	29.54bc	19.82b	76.80a
Metolachlor 1440g a.i ha^{-1}	8.00a	55.33a	2.73ab	33.73bc	13.89b	83.42a
Weed-free	7.67a	53.00a	3.67a	11.35c	0.00b	100.00a
Weedy check	3.67b	22.33c	0.98c	76.37a	81.47a	4.67b

CC – canopy coverage at 10 weeks after sowing, GY – Grain yield, RYL – Relative yield loss, WDW – weed dry weight at 7 weeks after sowing, WCE – weed control efficiency at 7 weeks after sowing. The means with the same alphabet(s) are similar across each column at P = 5%

Table 8: Effects of post-emergence herbicide on weed growth and soybean performance in 2014 and 2015 cropping seasons at Ibadan and Ilora

Treatments	CC (Scale: 1-10)	Seed pods ($plant^{-1}$)	GY ($t\ ha^{-1}$)	Relative yield loss (%)	WDW ($g\ m^{-2}$)	WCE (%)
Clethodim 48g a.i ha^{-1}	5.33de	48.33bc	1.28cd	59.24bc	11.86bc	87.02ab
Clethodim 72g a.i ha^{-1}	7.67ab	61.33b	1.87b	40.45d	17.32bc	81.05ab
Clethodim 96g a.i ha^{-1}	6.00cd	52.00b	1.67bc	46.82cd	16.38bc	82.09ab
Oxyfluorfen 960g a.i ha^{-1}	4.67e	39.00c	0.87d	72.29b	28.35b	68.98b
Oxyfluorfen 1200g a.i ha^{-1}	5.33de	35.33c	0.86d	72.61b	30.98b	66.10b
Oxyfluorfen 1440g a.i ha^{-1}	4.67e	40.00c	0.82d	73.89b	26.46b	71.06b
Quizalofop–P-ethyl 10g a.i ha^{-1}	7.00bc	51.33b	1.32c	57.96bc	22.38bc	75.52ab
Quizalofop-P-ethyl 15g a.i ha^{-1}	5.67de	67.00ab	2.06b	34.39d	23.29bc	74.52ab
Quizalofop-P-ethyl 20g a.i ha^{-1}	6.00cd	43.33c	1.16cd	63.06bc	15.76bc	82.76ab
Fluazifop-p-butyl 225g a.i ha^{-1}	7.67ab	59.67b	1.85b	41.08d	25.86b	71.71b
Weed-free	8.67a	79.00a	3.14a	3.36e	0.00c	100.00a
Weedy check	2.67f	14.67d	0.16e	94.90a	82.72a	9.51c

CC – canopy coverage at 10 weeks after sowing, GY – Grain yield, RYL – Relative yield loss, WDW – weed dry weight, WCE – weed control efficiency. The means with the same alphabet(s) are similar across each column at P = 5%

Application of quizalofop-P-ethyl at 15 g a.i ha^{-1} and oxyfluorfen at 1.44 k g a.i ha^{-1} resulted in the least (34.39%) and highest (73.89%) relative yield loss incurred from POEH treated plots, respectively. Meanwhile, weed growth and soybean performance in the weedy check were significantly highest and least, respectively.

Discussion

Weed flora composition as influenced by herbicide rates

This study corroborates earlier reports by Olubode and Ibrahim (2023) and Kareem *et al*. (2021) concerning the general dominance of *Tithonia diversifolia* and *Commelina benghalensis* in Ibadan. However, the non-dominance of *Commelina benghalensis* in plots treated with post-emergence herbicide in Ibadan suggests that this weed may be better managed after emergence. The possession of underground tuber by this species makes pre-emergence chemical control difficult. The decreasing dominance of *Tithonia diversifolia* with increasing concentrations of trifluralin suggests that applying the average label concentration and high label concentration of this herbicide may be effective for controlling this weed. However, the study further suggests that the efficacy of Trifluralin's average and high-level concentrations is weed species-dependent since plots treated with the high label concentration of Trifluralin had *Commelina benghalensis* as a major weed. It is opined that weeds having perennating structures may resist the weed control mechanism of trifluralin since it controls weeds by inhibiting seed germination and the formation of new radicle and hypocotyl cells (González-Torralva, and Norsworthy, 2021).

The pronounced efficacy of Trifluralin in sustaining *Mitracarpus villosus* as a minor weed and the inability of metolachlor, which showed superior ability in managing *Tithonia diversifolia and Commelina benghalensis*, is a justification to recommend the adoption of integrated herbicide management in a heterogeneous weed population. The inability of pre-emergence herbicides to effectively control *Tithonia diversifolia* in Ilora could be due to its production of many seeds. *Tithonia diversifolia* produces approximately 80,000 to 160,000 seeds m^{-2} yearly, with about 18 to 56% germination rates (Ajao and Moteetee, 2017)

It is beneficial to unravel the reasons for the absence of major weeds in plots treated with 0.70 kg Trifluralin a.i ha^{-1} in Ibadan. It may be logical to assume that the weed species on these plots were susceptible to this concentration of Trifluralin. More so, the absence of a moderately dominant weed attributes the emergence of these minor weeds solely to herbicide treatment. However, the presence of *Tithonia diversifolia* and *Commelina benghalensis* as minor weeds could be due to the non-uniform distribution of *Tithonia diversifolia* seeds and *Commelina benghalensis* rhizomes in the soil or interspecific competition from other weeds. This could justify the seeming efficacy of Trifluralin in controlling *Cyperus rotundus* against previous reports of its inability to control sedges by Sitangshu and Majumdar (2013).

Clethodim herbicide did not repeatedly reduce the dominance of *Tithonia diversifolia* plants in Ibadan and Ilora plots. Hence, the efficacy of these herbicide rates in controlling *Tithonia diversifolia* is not reliable. This assertion is consistent with the report of USEPA (2021) that clethodim herbicide does not control broadleaf weeds. Therefore, it is opined that the seeming efficacy of clethodim in controlling some broadleaf weeds in this study may have emanated from the interspecific competition from the major weeds on the plots. However, it may have contributed to the low density of grasses on plots where it was applied. Notably, among the post-emergence herbicide treatments in this study, oxyfluorfen was the only herbicide that had only major weed. The repeated instances of the absence of major weeds emanating from plots treated with the low label concentration of oxyfluorfen indicate the efficiency of this herbicide in managing most weeds found in Ibadan and Ilora. However, management of *Tithonia diversifolia* plots with this herbicide may not be effective.

Weed Growth and Soybean Performance

Soybean production is mainly limited by weed infestation sequel to its slow initial growth which makes it a poor competitor with weeds at the early growth stage (Arsenijevic *et al*., 2022). This is reflected significantly in the highest relative yield loss, lowest canopy coverage, yield, and yield-related traits of soybean in weedy check plots due to the least WCE of the treatment. This observation aligns with the earlier reports of Rupareliya *et al*. (2020), Ribeiro *et al*. (2021), and Arsenijevic *et al*. (2022). Uninterrupted early weed-soybean rivalry in unweeded control plots increased weed density in the treatment (inferred from its highest weed dry weight) which could have induced stress, biochemical and physiological alteration in soybean resulting in reduced growth and yield potential (Ribeiro *et al*., 2021; Arsenijevic *et al*., 2022). Specifically, Patel *et al*. (2019) and Rupareliya *et al*. (2020) asserted that weed density in soybean and its attended competition within 42 days after sowing are preponderant to yield loss. The present huge relative yield loss of 76.37% incurred from the weedy check is within the range of 31 and 84% reported by Kachroo *et al*. (2003) for percentage reduction in soybean yield due to uncontrolled weed growth. This has huge economic implications, connotes the wastage of resources invested in the production of the crop, and poses a threat to the future availability of the crop. Since the critical period of weed competition in soybean is between 3 and 6 WAS (Patel *et al*., 2019), observation of significantly higher WCE from all weed control treatments at 7 WAS indicates the effectiveness of the treatments in reducing weed population and consequently early season soybean-weed competition. This may be due to the ability of PREHs to suppress weed growth and control perennial troublesome weed species with an extended emergence window (Raphael *et al*., 2013). Thus enabling soybeans in WF and PREH-treated plots to optimize available soil nutrients, water, light, space, CO_2, and other growth resources for the production of a higher number of leaves and branches than soybeans in weedy check. Subsequently, these leaves and branches spread to form wider canopy coverage recorded from weed control treatments at 10 WAS. Plant growth characteristics have been reported to be enhanced by low weed density per square meter of crop (Ferdous *et al*., 2017). Howbeit, significantly comparable canopy coverage of soybean in WF and PREH-treated plots suggests that all the PREHs influenced soybean growth and consequently canopy development to the same extent as WF. This further highlights the relationship between weed control and canopy development in soybeans. Wider canopy coverage of soybean from all the weed control treatments enhanced light interception and simultaneously inhibited light penetration to the soil surface. This smothered weed growth by preventing weed seed germination and weed seedling establishment. Subsequently, soybeans in these plots had enhanced WCE and optimal nutrient uptake with resultant numerically higher pods per plant. This observation corroborates the assertion of Adhikary *et al*. 2016 and Shittu *et al*. (2022) that high WCE and enhanced nutrient uptake resulting from limited weed infestation translates to the production of more pods per plant. In addition, an increase in photosynthetic activities of soybeans in the WF and PREH treatments sequel to higher light interception by their wider canopy may have contributed to their better pod yield in comparison to the weedy check. Amaregouda *et al*. (2013) reiterated that soybean growth and pod yield can be boosted by strategic weed management measures. Although all the PREHs controlled weed and influenced the canopy development of soybean to the same extent as WF, the significantly comparable grain yield and weed index from soybean in WF with only plants from plots treated with metolachlor and 820 g of trifluralin a.i ha^{-1} implies that label and sub-label concentration of trifluralin is as effective as WF and metolachlor on weed and soybean growth but not on grain yield. This submission affirms the assertion of Daneshvari *et al*. (2021) that increasing the applied concentration of trifluralin will maintain crop yield. Trifluralin is a selective PREH in the dinitroaniline chemical family, effective for use in controlling annual grasses and broad-leaf weeds in crops including legumes (Adjesiwor *et al*. 2020). Since increasing the applied concentration of trifluralin had no influence on its effectiveness on weed and grain yield of soybean, adoption of trifluralin at 580 g ha^{-1} may be an efficient and cost-effective alternative to metolachlor and WF for soybean production. Metolachlor is a long-existing recommended PREH for controlling weeds in soybeans which might become scarce due to high demand at a critical period of sowing season. Moreover, achieving WF through hoe-weeding is labour-intensive, and can result in soil erosion, crop stand loss, and drudgery while being limited by labour shortages during peak periods (Moss, 2019).

Post-emergence herbicides have been considered useful in mitigating soybean weeds (Kaur *et al*., 2019). Hence, significantly least WCE and performance of soybean in unweeded control plots reflected the effectiveness of the weed control treatments. This finding concurs with the results of several published reports in the literature (Kaur *et al*., 2019; Patel *et al*., 2019; Suhaip *et al*., 2020). However, the absence of significant difference in WDW and WCE of all POEHs treated plots suggests that the efficacy of the POEH in controlling weed was the same irrespective of type or concentration of application. This may be attributed to the fact that they are all systemic, selective, and efficient in controlling grasses mostly in soybeans (Sudhakara *et al*., 2014; Yadav *et al*., 2017; Kaur *et al*., 2019; Suhaip *et al*., 2020; Hasanuddin *et al*., 2022). Also, Ariunaa *et al*. (2016) reiterated that weed can be effectively controlled with a lower concentration of herbicides. Generally, grasses have a higher superior competitive advantage over soybeans due to their morphology and therefore pose more threat to its growth and yield than broadleaves (Ariunaa *et al*. 2016). The ability of the POEHs to eliminate or suppress the growth of grasses (the major or dominant weed) on the treated plots may have made the WDW and WCE of the treatments at par due to the presence of only minor weeds (broad leaves or sedges) on the plots. The WDW and WCE from WF been statistically at par with only quizalofop-P-ethyl and clethodim (at all applied rates) treated plots denote the effectiveness of the POEHs (independent of dosage applied) in maintaining a weed status on plots like weed-free treatment. This may be unconnected to the similarity in the mode of action of the two POEHs (Ma *et al*., 2016; Blanchi *et al*., 2020). They inhibit the activity of the acetyl-COA carboxylase enzyme which is necessary for fatty acid synthesis in grassy weeds, thus suppressing their growth. The widest canopy coverage, the highest number of seed pods, and significantly highest grain yield from WF plots in comparison to POEHs treated and weedy check plots show that soybean can exhibit its optimum growth and yield potential in the absence of weed competition throughout the season. Howbeit, WF compared significantly with only plots treated with clethodim (72g a.i ha^{-1}) and fluazifop-P-butyl (225g a.i ha^{-1}) for canopy coverage score and quizalofop-P-ethyl (15g a.i ha^{-1}) for several seed pods among all evaluated POEHs suggests that effectiveness of some POEH in controlling weeds like WF does not cumulate to corresponding optimum growth and yield similar to what is obtainable in WF. This may be due to the inability of soybeans in these POEH treatments to recover from the earlier negative impact of weed-soybean competition before herbicide treatments. This finding corroborates the separate submissions of Nordby *et al*. (2007) and Horvath *et al*. (2023) on the boomerang effect of weed interference on crop (including soybean) growth and yield. Keeping plots free of weeds throughout the lifecycle of soybean on the field eliminates weed-soybean rivalry and imminent relative yield loss but it is costly and labor-intensive. The use of herbicides has been asserted to reduce production expenditure and increase the profit index of farmers (Gianessi, 2013). Hence, the adoption of label concentrations of quizalofop-P-ethyl (15 g a.i ha^{-1}), clethodim (72 g a.i ha^{-1}), and fluazifop-P-butyl (225 g a.i ha^{-1}) for post-emergence control of weeds in soybean may be an effective, economic and feasible substitute for WF. Notably, quizalofop-P-ethyl applied at 15g a.i ha^{-1}, clethodim at 72g a.i ha^{-1}, and fluazifop-P-butyl at 225 g a.i ha^{-1} ranked first, second, and third after WF for the number of seed pods and grain yield. Moreover, the POEH treatments that resulted in significantly comparable canopy coverage and yield components of soybean influenced these traits to the same extent. The record of significantly better performance of soybean in POEHs treated plots in comparison to weedy check highlights the beneficial role of POEHs in reducing potential relative yield loss that can be incurred from unrestricted weed infestation. For instance, Pandya *et al*., (2005) noted that weeds alone remove about 21.4 kg N and 3.1 kg P ha^{-1}, thereby reducing the amount available for soybean use, initiating competition and declining harvest efficacy. The consistently least canopy coverage scores, seed pod per plant, and grain yield from oxyfluorfen-treated plots at all application rates when compared to other POEHs and WF may be unconnected to its lowest weed control efficiency and consequently higher weed dry weight.

Conclusion

Pre-emergence application of trifluralin rates suppressed weed growth effectively at 7 WAS with significant grain yield. Similarly, clethodim (48, 72, and 96 g a.i ha^{-1}) and quizalofop–P-ethyl (10, 15, and 20 g a.i ha^{-1}) gave superior and comparable weed control efficiency (WCE) with fluazifop-p-butyl 225 g a.i ha^{-1} (control) and weed-free control at crop harvest. Early weed control with Trifluralin rates (pre-emergence) gave about 53% superior grain yield (2.58 t/ha) compared to the average soybean grain yield (1.38 t ha^{-1}) from the post-emergence herbicide rates evaluated. Hence, pre-emergence weed control with Trifluralin is effective for early weed control in soybeans. This might be supplemented with post-emergence herbicide [clethodim (48 g a.i ha^{-1}) and quizalofop–P-ethyl (10 g a.i ha^{-1}] application for season-long weed suppression.

References

Ajao, A. A., and Moteetee, A. N. (2017). *Tithonia diversifolia* (Hemsl) A. Gray.(Asteraceae: Heliantheae), an invasive plant of significant ethnopharmacological importance: A review. *South African Journal of Botany*, 113, 396-403.

Adhikary, P., Patra, P.S. and Ghosh, R. (2016). Influence of weed management on growth and yield of groundnut in Gangetic Plains of West Bengal. *Indian Legume Research* 39(2): 274-278.

Adigun, J. A. and Lagoke, S. T. O. (2003). Assessment of critical period of weed interference in transplanted rainfed and irrigated tomatoes in the Nigerian Northern Guinea Savanna. Nigerian *Journal of Plant Protection* 21: 89-100.

Adjesiwor A.T., Claypool, D.A. and Kniss, A.R. 2020. Dry bean response to pre-emergence Flumioxazin. *Weed Technology* 34: 197-201

Aluko, O.A., Chikoye, D. and Smith, M.A.K. 2012. Effects of tillage, plant spacing, and soybean genotypes on speargrass [*Imperata cylindrica* (L.) Reauschel] suppression. *African Journal of Agricultural Research* 7 (7): 1068 – 1072.

Amaregouda, A., Jadhav, J., Chetti, M.B.andNawalagatti. 2013. Effect of weedicides on physiological parameters, growth, yield, and yield components of soybean (*Glycine max*. L.) and weed growth. *Journal of Agriculture and Allied Sciences* 2(4):12-15

Ariunaa, O., Otgonsuren, M., Bayarsukh, N. 2016. Effect of chemical weed control of soybean (*Glycine max* L.) field in Mongolia. *International Journal of Advanced Research in Biological Sciences* 3(1): 192-198

Arsenijevic, N., Dewerff, R., Conley, S., Ruark, M., Werle, R. 2022. Influence of integrated agronomic and weed management practices on soybean canopy development and yield. *Weed Technology* 36:73-78

Blanchi, L., Anunciato, W., Gazola, T., Perissato, S.M., Dias, C.R., Tropaidi, L., Carbonari, C.A., Vellni, D., Edivaldo. 2020. Effects of glyphosphate and Clethodim alone and in the mixture in sour *Digitaria insularis*. *Crop Protection* 138:105322

Daneshvari, G., Yousefi, A.R., Mohammed, M., Banibairami, S., Shariati, R., Rahdar, A., Kyzas, G.Z. 2021. Release formulation of Trifluralin herbicides by interfacial polymerization as a tool for environmental hazards. *Biointerface Research in Applied Chemistry* 11(6), 13866-13877

Ferdous, J., Ali, M.H., Islam, M.S., Chowdhury, I.F., Haque, M.N. and Masum, S.M. 2017. Growth and yield of soybean as affected by irrigation and weed control methods. Bangladesh *Journal of Weed Science* 6:17-26

Gharde, Y., Singh, P. K., Dubey, R. P., & Gupta, P. K. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection*, *107*, 12-18.

Gill, H. S. 1969. Weed index-a new method for reporting weed control trials. "Weed Index—Indian Journal of Agronomy, 14 (2), 96-98.

Gianessi, L.P. 2013. Increasing importance of herbicides in worldwide crop production. *Pest Management Science* 69 (10), 1099-1105

González-Torralva, F., and Norsworthy, J.K. 2021. Understanding resistance mechanisms to trifluralin in an Arkansas Palmer amaranth population. *Genes*, *12*(8), 1225. doi:10.3390/genes12081225

Hasanuddin, H., Erida, G, Hafsah, S., Marllah, A., Agustiawan, Y., Aryani, D.S. 2022. Application of oxyfluorfen and pendimethalin to control weeds on soybean plantation. IOP Conference Series: Earth and Environmental Sciences 95: 012066

Horvath, D.P., Clay, S.A., Swanton, J.C., Anderson, J.V., Chao, W.S. 2023. Weed-induced crop yield loss: a new paradigm and new challenges. Food Security 28: 567-582

Imoloame, E.O. 2014. The effect of different weed control methods on weed infestation growth and yield of soybean (Glycine max) in Southern Guinea Savannah of Nigeria. *Global Journal of Science Frontier Research* 13(6), 20-33.

this is not citedJong-Seok S., Ji-Hoon C., Kyu J. L.,Jin-Won K., Do-Soon K., Jihyung K., Ji-Hoon I. and Do-Soon K., 2020. Herbicide-Based weed management for Soybean production in the Far Eastern Region of Russia. Agronomy 2020, 10 (11), 1823

Kachroo, D., Dixit, A.K. and Bali, A.S. 2003. Weed management in oilseed crops: A review. *Journal of Research*-SKVAST 2(1), 1-12

Kareem, K. T., Adegbite, A. A., Nsa, I. Y., Olayinka, R. B., Egberongbe, R. K., & Alamu, O. O. (2021). Synthetic mulches reduce the incidence of aphid-borne viruses and weeds in cowpea fields (effect of mulches on aphid-borne viruses). *Archives of Phytopathology and Plant Protection, 54*(17-18), 1305-1322.

Kaur, T., Kaur, M., Bhullar, M.S. 2019. Management of grass weeds with quizalofop in soybean [*Glycine max* (L.) Merrill]. Phytoparasitica 47(1),155-162

Ma, L., Lu, H., Qu, H., Xu, Y., Wang, P., Sun, M., Zhou, Z., Liu, D. 2016. Chiral quizalofop-ethyl and its metabolite quizalofop-acid in soils: Enantioselective degradation, enzymes interaction and toxicity to *Eisenia foetida*. *Chemosphere* 152: 173-180

Mani V.S., Malla M.L., Gautam K.C., Bhagwndas 1973. Weed killing chemicals in potato cultivation. *Indian Farm*. 22:17-18. 8

Moss, S. 2019. Integrated weed management (IWW): why are farmers reluctant to adopt non-chemical alternatives to herbicides? *Pest Management Science* 75, 1205-1211

Nathanael, D.F., Chris, M.B., David, E.S. 2013. Soybean Yield Loss Potential Associated with Early-Season Weed Competition across 64 Site-Years. Weed Science: July-September 2013, Vol. 61, No. 3, pp.500-507.

Nordby, E.D., Alderks, D.L., Nafziger, E.D. 2007. Competitiveness with weeds of soybean cultivars with different maturity and canopy width characteristics. *Weed Technology* 21(4), 1082-1088

Oerke, E.C. 2006. Crop losses to pests. *Journal of Agricultural Science.* 144,31–43

Olubode, O., and Ibrahim, B. (2023). Attributes and ecological potentials of dumpsite flora in the peri-urban area of Ibadan, Nigeria. *Journal of Agriculture and Ecology Research International, 24*(3), 39-53.

Pandya, N., Chouhan G.S., Nepalia, V. 2005. Effect of varieties, crop geometrics, and weed management on the nutrient uptake by soybeans (*Glycine max*) and associated weeds. Indian Journal of Agronomy 50(3), 218-220

Patel, A., Spare, N., Malgaya, G., Dharmendra. 2019. Effects of post-emergence herbicides on growth and yield of soybean. *Journal of Plant Development Sciences* 11(2), 89-92

Peer, F.A., BadrulLone, B.A., Qayoom, S., Ahmed, L., Khanday, B.A., Singh, P. and

Singh, G. (2013). Effect of weed control methods on yield and yield attributes of soybean. African Journal of Agricultural Research. Volume 8: 6135 - 6141.

Pereira, F.A.R., Bono, J.A.M., Neto, J.F.R., Silveira, D.S., Berselli, C., Carvalho, T. (2015). Period of competition between weeds and soybean crops in Cerrado. African Journal of Agricultural Research. Volume 10, 3644 - 3649

Raphael, V., Andre, R., Pablo, A.K., Lenandro, V., Ana, C., Camara, F and Franciele, M. 2013. Weed management in soybean- issues, and practices. Available at: https://www.intech-open.com/books/soyeans-pest-resistance/weed-in-soybeans-issues-and-practices

Ribeiro, V.H., Maia, S.G., Armeson, J.N., Oliveira, C.M., Read, W.H., Ana, J., Dossantos, B.J., Werle, R. 2021. Influence of pre-emergence herbicides on soybean development, root nodulation, and symbiotic Nitrogen fixation. *Crop Protection* 144, 105576

Rockenbach, A. P.; Rizzardi, M. A.; Nunes, A. L.; Bianchi, M. A.; Caverzan, A.; Schneider, T. 2018. Interferência entre plantas daninhas e a cultura: alterações no metabolismo secundário. Revista Brasileira de Herbicidas, v.17, p.59-70 https://doi.org/10.7824/rbh.v17i1.527

Rupareliya, V.V., Mathukla, R.K., Gohil, B.S., Javiya, P.P. 2020. Effect of post-emergence herbicides and their mixture on growth, yield, and quality of soybeans (*Glycine max* L) pharmacognosy and phytochemistry 9(6), 1161-1164

Spasic R. (2018). Pesticides in Agriculture and Forestry in Serbia; Plant Protection Society of Serbia: Belgrade, Serbia, p. 896.

Shittu, E.A., Fagbam, A.S., Garba, A.A., Sabo, M.U., Bello, T.T. 2022. Influence of supplementary hoe-weeding on the efficacy of pre-emergence herbicides on groundnut (*Arachis hypogaea* L) weed management in Bauchi, Nigeria. *International Journal of Pure and Applied Science Research* 12(5), 152-177

Sitangshu, S., & Majumdar, B. (2013). Herbicidal effect on weed growth, crop yield, and soil microbes in olitorius jute (Corchorus olitorius L.). *Journal of Tropical Agriculture, 51(1), , 51*(1), 23-29.

Sodangi, I.A., Gworgwor, N.A. and Joshua, S.D. (2011). Effects of Inter-row, spacing and NPk fertilizer in weed suppression by soybean (Glycine Max) in Sudan Savanna of Nigeria. Nigerian Journal of Weed Science, 24, 33-40

Stefanic, E.; Rasic, S.; Lucic, P.; Tolic, S.; Zima, D.; Antunovic, S.; Japundži´c-Palenki´c, B.; Stefanic, I 2022. Weed Community in Soybean Responses to Agricultural Management Systems. Agronomy 2022, 12, 2846. https://doi.org/10.3390/agronomy12112846

Sudhakara, T.M., Sridhara, S., Reddy, V., Kishore, M.J., Ragothuma. 2014. Bio-efficacy of clethodim in soybean and their residual effect on succeeding green gram. *Indian Journal of Plant Protection* 42(2), 169-174

Suhaip, A.M., Dafaallah, A.B., Zaroug, M.A. 2020. Efficacy and selectivity of oxyfluorfen 240 EC for weed control in soybean (*Glycine max*. L. Merr.) Gezira state, Sudan. *University of Bakht Alnuda Refereed Quarterly Scientific Journal* 3, 97-109

Song, J. S., Chung, J. H., Lee, K. J., Kwon, J., Kim, J. W., Im, J. H., & Kim, D. S. (2020). Herbicide-based weed management for soybean production in the Far Eastern region of Russia. *Agronomy*, *10* (11), 1823.

Werner, E.L., Curran, W.S., Lingenfelter, D.D. 20 14. Management of eastern black nightshade in agronomic crops: an integrated approach. Pennsylvania: Penn State Extension. (Agronomy Facts 58). 6 p

Yadav, R., Bhullar, M.S., Kaur, S., Kaur, T. 2017. Weed control in conventional soybean with pendimethalin followed by Imazethapyr + imazamox/quizalofop-p-ethyl. *Canadian Journal of Plant Science* 97: 654-664.