Control of speargrass (*Imperata cylindrica* (L) Raeuschel) with glyphosate and fluazifop-butyl for soybean (*Glycine max* (L) Merr) production in savanna zone of Nigeria

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Abstract: A field trial was conducted in 1996 and 1997 to control speargrass (*Imperata cylindrica* (L) Raeuschel) for soybean production. The treatments comprised four levels of glyphosate, 1.08, 1.44, 1.80 and 2.16 kg ha^{-1}, applied pre-tillage and followed by one hoe-weeding (HW) at 6 weeks after planting (WAP); fluazifop-butyl, 0.125, 0.25 and 0.375 kg ha^{-1}, at 3WAP; 1HW at 3WAP; 2HW at 3 and 6WAP; and an unweeded control. Glyphosate and fluazifop-butyl controlled 57–85% and 51–83% respectively of *I cylindrica* compared with 64–67% by traditional hoe-weeding. The highest grain yield (1.88 t ha^{-1}) was obtained from plots treated with glyphosate (1.44 kg ha^{-1}) + 1HW. The highest profit, however, was obtained with fluazifop-butyl. It was unprofitable to apply glyphosate at rates higher than 1.44 kg ha^{-1} to control *I cylindrica* at 30 cm foliage.

Keywords: savanna; *I cylindrica*; soybean; glyphosate; pre-tillage; fluazifop-butyl; hoe-weeding

INTRODUCTION

Speargrass (*Imperata cylindrica* (L) Raeuschel) is the most widespread perennial weed in soybean-producing areas (savanna, derived savanna and forest) of Nigeria. It is a common weed of soybean in Benue State, which accounts for about 90% of the total national production.[1–3] Speargrass caused 28.5–52.6% grain yield reduction when soybean was left unweeded.[4] The weed is a problem more in the savanna region where the climax vegetation of bush fallow consists mainly of grasses. The spread of *I cylindrica* in the savanna is favoured by the annual bush fires which stimulate the weed to produce seeds, and by the mechanical cultivation that tends to cut rhizomes into pieces which regenerate and rapidly give rise to new infestation.[5,6]

Soybean farmers in the study area (Benue State, Nigeria) control *I cylindrica* by cultural methods (hoe-weeding, burning and fallowing). Hoe-weeding, which is the most common method used, tends to cut the rhizomes into segments which easily regenerate. Burning of *I cylindrica* during fallow periods does not control the weed effectively, because only the shoots are burnt while the underground rhizomes are left intact and produce new shoots. Besides, burning eradicates most annual weeds and confers competitive advantage on rhizomatous perennials, thereby enhancing colonisation by *I cylindrica* which dominates the climax vegetation.[7] Thus the types of tools available to peasant farmers are generally inadequate to cope with the increasing problem of speargrass; hence the need to use effective and profitable systemic herbicides by medium- and large-scale farmers to control speargrass.

Glyphosate (*N*-(phosphonomethyl) glycine), a broad-spectrum, systemic and non-selective herbicide, has the potential for the control of *I cylindrica* under crop and non-crop situations in the tropics.[8] It is used as a directed treatment with rope–wick applications over the top of soybeans where it is applied to perennial and other weeds that grow taller than soybean.[9] The herbicide can also be used effectively for pre-tillage control of perennial weeds. Avav and Okereke[10] achieved 96–98% control of *I cylindrica* with glyphosate applied pre-tillage at 25–30 cm foliage for profitable soybean grain production. However, small-scale farmers, who produce the bulk of the soybean in Benue State, usually lack the knowledge and capital to use glyphosate which can effectively solve the problem of *I cylindrica*.

Fluazifop-butyl ((+)-butyl 2-[4-[[5-(triflouromethyl)-2-pyrindinyl]oxy]phenoxy] propanoic acid) is a selective, post-emergence and systemic herbicide for the control of annual and perennial grasses in several broad-leaved crops and fallow of non-crop land.[5] The herbicide is characterised by high phytotoxicity that makes it possible for it to be applied at low and economic rates for weed control.[11] Fluazifop-butyl may be used with herbicides that control broad-

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Table 1. Treatments used in trial in 1996 and 1997

T_1	Glyphosate (1.08 kg ha^{-1}) PRET + 1HW at 6WAP
T_2	Glyphosate (1.44 kg ha^{-1}) PRET + 1HW at 6WAP
T_3	Glyphosate (1.80 kg ha^{-1}) PRET + 1HW at 6WAP
T_4	Glyphosate (2.16 kg ha^{-1}) PRET + 1HW at 6WAP
T_5	Fluazifop-butyl (0.125 kg ha^{-1}) at 3WAP
T_6	Fluazifop-butyl (0.25 kg ha^{-1}) at 3WAP
T_7	Fluazifop-butyl (0.375 kg ha^{-1}) at 3WAP
T_8	1HW at 3WAP
T_9	2HW at 3 and 6WAP
T_{10}	Unweeded control

HW, hoe-weeding; PRET, pre-tillage; WAP, weeks after planting.

leaf weeds to enhance broad-spectrum weed control in soybean.[3,12] Hence an experiment was conducted to compare the efficacy and economics of pre-tillage application of glyphosate with post-emergence application of fluazifop-butyl for controlling *I cylindrica* for soybean production.

MATERIALS AND METHODS

The experiment was conducted in 1996 and 1997 at the Experimental Station of the University of Agriculture, Makurdi (07°41′N, 08°37′N, and 400 m above mean sea level). The soil had 52.3% sand, 30.7% clay, 16.5% silt with organic matter 0.5% and pH 5.9. The total rainfall during the trial, ie 11 July–27 November 1996 and 9 July–29 November 1997, was 725.3 and 740.5 mm respectively. The mean monthly temperature was 27.5 °C, while the total evapotranspiration (Thornthwaite) was 380.2 and 415.6 mm respectively. The experimental sites were naturally infested with *I cylindrica* at density 152 (1996) and 111 (1997) stands per square metre determined with a 1 m × 1 m quadrant.

Glyphosate was applied as Roundup (Soluble 360 g ai l^{-1}) and fluazifop-butyl as Fusilade Super 125EC. The treatments comprised four levels of glyphosate, 1.08, 1.44, 1.80 and 2.16 kg ha^{-1}, which were applied pre-tillage and followed by one hoe-weeding (HW) at 6 weeks after planting (WAP); fluazifop-butyl at 0.125, 0.25 and 0.375 kg ha^{-1} applied post-emergence at 3WAP; 1HW at 3WAP; 2HW at 3 and 6WAP; and an unweeded control. The treatments are summarised in Table 1. The experimental design was a randomised complete block (RCB) with four replications and plot size 6 m × 4 m.

The herbicides were applied using a knapsack sprayer with a deflector-type impact nozzle and spray volume 200 l ha^{-1}. Glyphosate was applied at 30 cm foliage of *I cylindrica* and the land was ploughed and harrowed 14 days after application (DAP). Single superphosphate fertiliser was applied at the rate of 40 kg P_2O_5 ha^{-1} as basal treatment based on results of soil analysis. An early-maturing soybean variety, TGX 923-2E, was planted in early July each year by drilling 50 kg ha^{-1} of seeds in 50 cm rows (about 454 545 seeds per hectare at about 0.11 g per seed). The seedlings were thinned to maintain intra-row spacing, 5 cm 2WAP, to give a population of 400 000 plants per hectare. Fluazifop-butyl was applied at 3WAP, while weeding was done with the hoe according to the treatments.

The pod number was estimated at harvest by taking the average of the pods from five randomly selected plants per plot. The plant stand per square metre was also estimated at harvest. The grain yield was recorded from a net plot of 4 m × 2 m. The 100-seed weight was estimated by counting out three batches of 100 seeds from the air-dried product and weighing. The seed weight was calculated from the average of the batches. Weed density and fresh weight were estimated after crop harvest, using a 1 m × 1 m quadrant to estimate the extent of control of *I cylindrica* when compared with control treatment. The control (%) of *I cylindrica* was determined using the formula

$$C = \frac{A - B}{A} \times 100$$

where A is the mean density of weed in unweeded plots (m^{-2}), B is the density of weed after treatment (m^{-2}) and C is the control (%).

Analysis of variance was done and treatments were compared using Duncan's new multiple-range test (DNMRT) at $P = 0.05$ as described by Duncan[13] and Obi.[14]

The economic return was computed based on the cost of weed control only, since the costs of land preparation, seeds, planting, fertiliser and harvesting were the same in all plots. Economics are expressed in Nigerian naira ₦.

RESULTS AND DISCUSSION

Glyphosate at 2.16 kg ha^{-1} applied pre-tillage followed by 1HW at 6WAP gave the best control of *I cylindrica* which was comparable with post-emergence application of fluazifop-butyl at 0.375 kg ha^{-1} (Table 2). Glyphosate and fluazifop-butyl controlled 57–85% and 51–83% respectively of *I cylindrica* compared with 64–67% by traditional hoe-weeding. This finding contradicts that of Avav and Okereke,[10] who reported that hoe-weeding controlled 47–58% of the weed, which was lower than the control of 75% described by Yonce and Scroch[15] as commercially acceptable. The relatively lower level of control of the weed by hoe-weeding compared with the systemic herbicides may be due to the fact that mechanical cultivation tends to cut the rhizomes into pieces which regenerate and give rise to new infestation.[5,6] Consequently, the number of hoe-weedings may only retard the growth of *I cylindrica* but may not always reduce its density significantly. The fresh weight of the weed was affected by the herbicides and hoe-weeding in the same pattern as the weed density (Table 2).

The soybean population was not significantly influenced by the herbicides and weeding frequency (Table 3). The highest pod number for glyphosate (56

Table 2. Effect of glyphosate and fluazifop-butyl on growth of *I cylindrica*

Treatment	Plant density (m^{-2})			Control (%)[a]			Fresh weight ($g\,m^{-2}$)		
	1996	1997	Mean	1996	1997	Mean	1996	1997	Mean
T_1	42[b]	33[b]	38	60	54	57	221.0[b]	226.0[b]	223.5
T_2	22[c]	20[c]	21	79	72	76	180.5[c]	178.4[c]	179.5
T_3	18[cd]	15[c]	17	83	79	81	142.3[c]	139.5[c]	140.9
T_4	14[d]	12[d]	13	87	83	85	133.6[c]	129.8[c]	131.7
T_5	53[b]	35[b]	44	50	51	51	280.1[b]	287.4[b]	283.8
T_6	47[b]	32[b]	40	55	56	56	252.2[b]	249.2[b]	250.7
T_7	17[d]	14[c]	16	84	81	83	150.4[c]	144.0[c]	147.2
T_8	34[b]	29[b]	32	68	60	64	200.3[b]	198.2[c]	199.3
T_9	33[b]	25[b]	29	69	65	67	181.5[c]	179.4[c]	180.5
T_{10}	105[a]	72[a]	89	—	—	—	430.2[a]	425.0[a]	427.6

[a] Control was based on weed density in unweeded plots, 105 m^{-2} (1996) and 72 m^{-2} (1997), and was calculated as in text.

Means within a column followed by the same letter(s) do not differ significantly according to DNMRT at $P = 0.05$.

pods per plant) was obtained at 2.16 kg ha^{-1} + 1HW; fluazifop-butyl at 0.375 kg ha^{-1} (55 pods); while 57 pods were obtained when soybean was weeded twice at 3 and 6WAP. The 100-seed weight did not differ among the weed control treatments, but was significantly reduced in plots in which weeds were not controlled.

The highest grain yield was obtained from plots treated with glyphosate (1.44 kg ha^{-1}) applied pre-tillage + 1HW, followed by fluazifop-butyl (0.375 kg ha^{-1}) and 2HW (Table 3). The highest profit, however, was obtained with fluazifop-butyl (Table 4). It was unprofitable to apply glyphosate at rates higher than 1.44 kg ha^{-1} to control *I cylindrica* with 30 cm foliage. This result corroborates that of Avav and Okereke.[10] The 2HW at 3 and 6WAP also

Table 3. Effect of glyphosate and fluazifop-butyl on yield of soybean

Treatment	Stand count (m^{-2})			Pods (per plant)			100-Seed weight (g)			Grain yield (t ha^{-1})		
	1996	1997	Mean	1996	1997	Mean	1996	1997	Mean	1996	1997	Mean
T_1	19[a]	20[a]	20	49[ab]	45[b]	47	11.4[a]	11.2[a]	11.3	1.35[b]	1.10[b]	1.23
T_2	18[a]	19[a]	19	50[a]	50[a]	50	11.5[a]	11.1[a]	11.3	1.92[a]	1.83[a]	1.89
T_3	18[a]	18[a]	18	46[b]	48[b]	47	11.4[a]	11.3[a]	11.4	1.75[a]	1.72[a]	1.74
T_4	20[a]	19[a]	20	56[a]	55[a]	56	11.6[a]	11.8[a]	11.7	1.84[a]	1.80[a]	1.82
T_5	18[a]	18[a]	18	47[b]	48[b]	48	11.7[a]	11.5[a]	11.6	1.52[b]	1.43[b]	1.48
T_6	19[a]	18[a]	19	52[a]	49[b]	51	11.8[a]	11.9[a]	11.9	1.75[a]	1.65[a]	1.70
T_7	19[a]	20[a]	20	56[a]	54[a]	55	11.7[a]	11.6[a]	11.7	1.82[a]	1.75[a]	1.79
T_8	20[a]	18[a]	19	51[a]	53[a]	52	11.5[a]	11.5[a]	11.5	1.45[b]	1.38[b]	1.42
T_9	19[a]	18[a]	19	58[a]	55[a]	57	11.6[a]	11.7[a]	11.7	1.76[a]	1.76[a]	1.76
T_{10}	17[a]	18[a]	18	39[c]	34[c]	37	9.4[b]	9.9[b]	9.7	0.85[c]	0.73[c]	0.79

Means within a column followed by the same letter(s) do not differ significantly according to DNMRT at $P = 0.05$.

Table 4. Economics of using glyphosate and fluazifop-butyl for control of *I cylindrica* for soybean production based on 1997 prices

Treatment	Cost of control (₦ ha^{-1})[a]	Grain yield (t ha^{-1})	Revenue (₦ ha^{-1})[b]	Profit (₦ ha^{-1})
Glyphosate (1.08 kg ha^{-1}) + 1HW	6000	1.23	46750	40750
Glyphosate (1.44 kg ha^{-1}) + 1HW	7400	1.88	71440	64040
Glyphosate (1.80 kg ha^{-1}) + 1HW	8800	1.74	66120	57320
Glyphosate (2.16 kg ha^{-1}) + 1HW	10200	1.82	69160	58960
Fluazifop-butyl (0.125 kg ha^{-1})	1000	1.48	56240	55240
Fluazifop-butyl (0.25 kg ha^{-1})	2000	1.70	64600	62600
Fluazifop-butyl (0.375 kg ha^{-1})	3000	1.79	68020	65020
1HW at 3WAP	1800	1.42	53960	52160
2HW at 3 and 6WAP	3600	1.75	66500	62900
Unweeded control	—	0.78	29640	29640

[a] Cost was based on cost of ₦1400 per 0.36 kg glyphosate, ₦1000 per 0.125 kg fluazifop-butyl and ₦1800 per hoe-weeding. £1.00 = ₦128.00 and US$1.00 = ₦84.00. ₦ = Nigerian naira.

[b] Soybean sold at ₦38000 per tonne in 1997.

gave profitable grain yield comparable with the herbicides. In view of the increasing problem of *I cylindrica* in the savanna zone, which defies traditional hoe-weeding, the weed can be controlled economically by applying fluazifop-butyl (0.25–0.375 $kg\,ha^{-1}$) or pre-tillage application of glyphosate (1.44 $kg\,ha^{-1}$) + 1HW at 6WAP. Ashton and Monaco[11] recommended the application of fluazifop-butyl at 0.125 $kg\,ha^{-1}$ for effective weed control in soybean.

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