Evaluation of atrazine plus isoxaflutole (Atoll®) mixture for weed control in maize

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ABSTRACT

Field experiments were set up in three ecological zones of southwestern Nigeria to evaluate the effectiveness of Atoll® (atrazine + isoxaflutole), a new herbicide mixture, for weed control in maize. Crop injury rating indicated pronounced phytotoxic effect on crops from 1.34 to 1.61 kg a.i. ha^{-1} Atoll in all locations. Acceptable weed control was realized in Atoll treatments except for 0.54 kg a.i. ha^{-1} at Ilorin and Orin-Ekiti. Atoll treatments in Ilorin and Orin-Ekiti controlled weeds more effectively than atrazine soluble concentrate (SC) and atrazine wettable powder (WP). Average yield across the locations was highest in 0.81 kg a.i. ha^{-1} Atoll. Yield losses in weedy checks compared to 0.81 kg a.i. ha^{-1} Atoll ranged between 18.8 and 67.3 per cent in the three locations.

RÉSUMÉ

MAKINDE, J. O. & OGUNBODEDE, B. A.: Des expériences de terrain ont été menées dans trois zones écologiques du Sud-ouest du Nigeria pour évaluer l'efficacité de l'Atoll (atrazine + isoxaflutole), préparation herbicide pour lutter contre la mauvaise herbe nuisible à la culture du maïs. L'évaluation des degats causés aux récoltes a révélé des effets phytotoxiqes prononcés de l'ordre de 1.34 à 1.61 kg a. i. ha^{-1} Atoll dans tous les emplacements. Le traitement à base d'Atoll des cultures a donné des résultats acceptables à l'exception des emplacements comme Ilorin et Orin-Ekiti où le taux a été de 0.54 kg a.i. ha^{-1}. A Ilorin et Orin-Ekiti les traitements à base d'Atoll ont été plus efficaces que le concentré soluble d'atrazine (SC) et la poudre soluble d'atrazine (WP). La moyenne des récoltes la plus élevée à travers ces emplacements a été vérifiée à 0.81 kg a. i. ha^{-1} Atoll. Les pertes en récolte sur les surfaces dominées par les mauvaises herbes, par rapport à 0.81 kg a.i. ha^{-1} Atoll, ont varié entre 18.8 et 67.3 pour cent dans les trois emplacements.

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Introduction

Isoxaflutole is a systemic herbicide for the control of annual broad leaves and some grass species in maize. It is a pre-emergence herbicide for maize and sugarcane. It is a member of the isoxazole herbicide family and a competitive inhibitor of the enzyme p-hydroxyphenylpyruvate dioxygenase (HPPD), which results in blocking carotenoid biosynthesis in susceptible plants (Vrabel *et al*., 1995). Isoxaflutole causes bleaching symptoms in treated plants. Isoxaflutole has been characterized by its low use rate applications (Luscombe *et al*., 1994; Vrabel *et al*., 1995). The herbicide has residual activity for up to 6 weeks after treatment in conventional and no-tillage corn (Bhowmik & Prostak, 1996; Luscombe *et al*., 1994; Mosier *et al*., 1995).

In field studies, soil applications of isoxaflutole at 158 g a.i. ha^{-1}, or less, provided excellent control of many broadleaved weed species (Bhowmik & Prostak, 1996; Luscombe *et al*., 1994; Mosier *et al*., 1995; Sprague, Kells & Penner, 1997). However, control of grass species such as giant foxtail requires higher rates of isoxaflutole for effective

control (Bhowmik & Prostak, 1996; Harvey *et al*., 1995; Luscombe *et al*., 1994).

The objectives of this research were to evaluate atrazine plus isoxaflutole (Atoll®) mixture and recommend appropriate rate(s) of application for weed control in maize in southwestern Nigeria.

Materials and methods

Field experiments were used to evaluate the effectiveness of Atoll (a mixture of atrazine and isoxaflutole) for weed control in maize in 2000 and 2001 at Ilorin (southern Guinea savanna), Ibadan (forest/savanna transition), and Orin-Ekiti (forest) stations of the Institute of Agricultural Research and Training, Ibadan, Nigeria. Land preparation consisted of disc plough and harrow. Formulated mixture of atrazine plus isoxaflutole (Atoll®) was applied pre-emergence at five rates– 0.54, 0.81, 1.08, 1.34, and 1.61 kg a.i. ha^{-1}. As checks, 2.5 kg a.i. ha^{-1} atrazine soluble concentrate (SC), 2.0 kg a.i. ha^{-1} atrazine wettable powder (WP), 2.5 kg a.i. ha^{-1} Primextra, and 1.25+0.83 kg a.i. ha^{-1} atrazine plus Stomp mixture were included. There were 11 treatments, including handweeding and weedy controls. Treatments were replicated four times in a randomized complete block design.

Maize, the downy mildew resistant-early streak resistant-yellow (DMR-ESR-Y) variety, was sown in all locations at the spacing of 90 cm × 40 cm. Plot sizes were 6 m × 5 m. Seeds were sown on 10 August at Ilorin, 25 September at Ibadan, 15 August at Orin-Ekiti in 2000; and 12 June at Ilorin, 16 July at Ibadan, 31 May at Orin-Ekiti in 2001. Herbicides were applied with a CP 15 knap-sack sprayer calibrated to deliver 200 l ha^{-1} spray solution the same day seeds were sown. Treatment effects were assessed by phytotoxic rating [2 weeks after treatment (WAT)], visual weed rating [6 weeks after sowing (WAS)], plant height (9 WAS), and by grain yield at harvest. Visual weed rating was determined on a scale of 0-10, where '0' indicated no weed control and '10' indicated complete weed control. Weeds were collected from two randomly selected 50 cm × 50 cm quadrat in each plot. The data were analyzed using the Analysis of Variance (ANOVA). Probabilities equal to or less than 0.05 were considered significant for main effects and interactions.

Results and discussion

Significant effects on crop injury, weed control rating, plant height and maize grain yield due to herbicide treatments were observed. The Duncan Multiple Range Test was used to separate differences between treatment means when ANOVA indicated such differences (Gomez & Gomez, 1984). No difference was found between the years for any of the measured variables; therefore, data from individual years were combined for each location.

Predominant weeds found in association with maize on the experimental site in Ilorin were *Rottboellia cochinchinensis*, *Cyperus rotundus*, and *Cleome viscosa*. In Ibadan, *Panicum maximum*, *Oldenlandia corymbosa*, and *Ageratum conyzoides* were found; and in Orin-Ekiti, *Pennisetum purpureum*, *Euphorbia heterophylla* and *Cyperus esculentus* were found. Table 1 shows the monthly rainfall at the experiment sites for both years; and Table 2, the physico-chemical properties of soils in each location.

Phytotoxic rating determined 2 weeks after treatment showed pronounced crop injury effect from 1.34 to 1.61 kg a.i. ha^{-1} Atoll treatments in all locations (Table 3). Crop injury increases as the herbicide concentration increases in all locations. The crop injury was more pronounced in Ibadan, leading to loss of maize stands.

Akobundu (1987) reported that soil texture and organic matter were the most important factors which influenced herbicide activity in soils. Similarly, it was also reported that high clay and organic matter levels of the soil absorbed some fraction of applied herbicide and rendered it unavailable for plant uptake and herbicidal activity (Ayeni & Yakubu, 1995). The results of this study corroborate these findings. The low organic carbon in the soil at the Ibadan station makes the applied herbicide available for optimum uptake.

TABLE 1

Monthly Rainfall at the Experimental Sites During 2000 and 2001 Cropping Seasons

Month	*Ilorin*		*Ibadan*		*Orin-Ekiti*	
	2000	*2001*	*2000*	*2001*	*2000*	*2001*
January	71.0	0.0	8.8	0.0	2.1	0.0
February	0.0	5.4	0.8	7.5	0.0	0.0
March	3.8	46.2	49.7	15.1	19.1	49.4
April	93.2	61.7	77.2	101.6	158.5	145.1
May	230.0	133.5	188.1	206.3	113.1	123.3
June	178.6	108.0	194.6	159.3	229.3	235.1
July	94.3	65.9	221.1	219.6	168.0	112.0
August	183.9	42.0	278.9	42.5	122.3	51.0
September	262.8	172.8	172.5	311.2	220.8	322.3
October	66.3	44.8	215.6	137.3	224.5	81.7
November	0.0	3.7	0.0	46.3	0.0	0.0
December	0.0	0.0	0.0	0.0	0.0	0.0
Annual total	1183.9	684.0	1406.5	1246.7	1257.7	1119.9

TABLE 2

Physico-chemical Properties of Soils at the Experimental Sites

Properties	*Ilorin*	*Ibadan*	*Orin-Ekiti*
*p*H	6.1	6.3	5.8
Organic C (%)	1.61	0.67	1.93
Total N (%)	0.16	0.06	0.18
Avail. P (mg kg^{-1})	11.54	3.06	2.36
Ca (cmol kg^{-1})	4.03	2.75	4.03
Mg (cmol kg^{-1})	2.68	1.85	2.68
K (cmol kg^{-1})	0.58	0.65	1.17
Na (cmol kg^{-1})	0.95	0.91	1.16
CEC	8.34	6.25	9.15

TABLE 3

*Effect of Atoll Applications on Crop Injury at 2 Weeks After Treatment**

Treatment (kg a.i. ha^{-1})[a]	*Ilorin*	*Ibadan*	*Orin-Ekiti*
0.54 Atoll	1.00 c	1.25 c	0.00 c
0.81 Atoll	2.25 bc	2.12 c	1.37 b
1.08 Atoll	2.50 bc	3.75 b	1.87 b
1.34 Atoll	4.25 ab	6.25 a	3.00 a
1.61 Atoll	5.25 a	7.50 a	3.75 a

Means followed by the same letter within a column are not significantly different at 5% level using DMRT.

*Crop injury rating – '10' = complete destruction, '0' = no crop injury.

a – Atoll is a proprietary formulation of Rhône-Poulenc containing 37.5 g l^{-1} isoxaflutole and 500 g l^{-1} atrazine.

Therefore, it explains why the crop injury was more at this location. However, in Ilorin and Orin-Ekiti, the phytotoxic effect of the herbicide was non-lasting because most crops recovered from the initial injury by 4 weeks after sowing.

Weed control increased with increase in Atoll concentration (Table 4). Weed control rating value of 7 indicates a satisfactory level of weed control. At this level, weed control is as good as the handweeded check. In Ilorin station, an acceptable weed control was recorded in 1.6 kg a.i. ha^{-1} Atoll treatment, but this was not significantly different from values recorded from 0.81 to 1.34 kg a.i. ha^{-1} Atoll treatments. A high rate of Atoll will be required to effectively control the grassy weeds

TABLE 4

Effect of Herbicides on Weed Control Rating at 6 Weeks After Sowing

Treatment (kg a.i. ha^{-1})[a]	*Ilorin*	*Ibadan*	*Orin-Ekiti*
0.54 Atoll	5.5 def	9.5 a	5.2 d
0.81 Atoll	6.1 cd	9.5 a	6.9 bcd
1.08 Atoll	6.1 cd	10.0 a	7.7 abc
1.34 Atoll	6.4 bc	9.7 a	8.6 ab
1.61 Atoll	7.1 abc	10.0 a	8.1 ab
2.5 Atrazine SC	3.7 ef	8.7 a	5.0 d
2.0 Atrazine WP	3.2 f	8.5 a	5.7 cd
1.25 + 0.83 Atrazine + Stomp	8.2 ab	9.2 a	5.1 d
2.5 Primextra	4.2 def	9.5 a	6.0 cd
Handweeded check	8.5 a	10.0 a	9.2 a
Weedy check	0.0 g	0.0 b	0.0 e

Means followed by the same letter within a column are not significantly different at 5% level using DMRT.
Weed control rating – '10' = complete weed control, '0' = no weed control.
a – Atoll is a proprietary formulation of Rhône-Poulenc containing 37.5 g l^{-1} isoxaflutole and 500 g l^{-1} atrazine.
SC – soluble concentrate, WP – wettable powder.

that are predominant in Ilorin. Also, in Orin-Ekiti, satisfactory weed control recorded in 1.08 kg a.i. ha^{-1} Atoll treatment was not different from 6.9 in 0.81 kg a.i. ha^{-1} Atoll plots. The excellent weed control observed in Ibadan station was similar in all Atoll treatments as well as in other herbicide treatments (Table 4). Atoll treatments applied at 1.34 and 1.61 kg a.i. ha^{-1} controlled weeds more effectively than 2.5 kg a.i. ha^{-1} Primextra and the atrazine formulations at 6 WAS in Ilorin and Orin-Ekiti.

In Ilorin station, taller plants measuring 169.2 and 163.0 cm were produced by 1.61 kg a.i. ha^{-1} Atoll and atrazine + Stomp mixture, respectively. Plants from these treatments were significantly taller than plants from 2.5 kg a.i. ha^{-1} Primextra (Table 5). Plants from Ibadan were as high as 165.0 cm in 2.0 kg a.i. ha^{-1} atrazine wettable powder (WP); and these were taller than plants produced in 1.25 + 0.83 kg a.i. ha^{-1} atrazine + Stomp and 1.34 kg a.i. ha^{-1} Atoll treatments. In Orin-Ekiti, plants with an average height of 179.0 cm from 1.61 Atoll treatment were significantly different from the shortest plants averaged 161.8 cm in 2.5 kg a.i. ha^{-1} atrazine soluble concentrate (SC).

Table 6 shows the effect of herbicide treatments on maize grain yield. In Ilorin, maize yield from 1.25 + 0.83 kg a.i. ha^{-1} atrazine + Stomp was comparable to 1.34 and 1.61 kg a.i. ha^{-1} Atoll treatments. Formulations of atrazine alone did not give good yields. Primextra treatment at 2.5 kg a.i. ha^{-1} was not as good as atrazine + Stomp and Atoll rates in grain yield. But handweeded check was not different from the higher rates of Atoll and atrazine + Stomp.

The highest concentration of Atoll, 1.61 kg a.i. ha^{-1}, had the greatest crop injury in Ibadan. This explains why it produced the lowest yield that was only significantly different from 1.25 + 0.83 kg a.i. ha^{-1} atrazine + Stomp. Even the weedy check was not different from other weed control treatments as expected. Orin-Ekiti had the highest yield produced from 0.81 kg a.i. ha^{-1} Atoll plots; and this was significantly different from other treatments, except for 1.34 kg a.i. ha^{-1} Atoll. The two atrazine formulations (SC and WP) produced yields that were similar to the yield from weedy check in Orin-Ekiti. When compared with yield produced from 0.81 kg a.i. ha^{-1} Atoll treatments, yield losses in weedy checks were 67.32 per cent in Ilorin, 18.81 per cent in Ibadan, and 46.67 per cent in Orin-Ekiti.

TABLE 5

Effect of Pre-emergence Herbicides on Plant Height (cm) at 9 Weeks After Sowing

Treatment (kg a.i. ha^{-1})[a]	*Ilorin*	*Ibadan*	*Orin-Ekiti*
0.54 Atoll	149.2 bc	153.1 ab	170.6 ab
0.81 Atoll	169.0 a	150.0 ab	174.7 ab
1.08 Atoll	156.0 ab	151.7 ab	168.4 ab
1.34 Atoll	160.2 ab	144.0 b	171.9 ab
1.61 Atoll	169.2 a	152.1 ab	179.0 a
2.5 Atrazine SC	NA	160.8 ab	161.8 b
2.0 Atrazine WP	NA	165.0 a	177.5 ab
1.25 + 0.83 Atrazine + Stomp	163.0 a	147.6 b	170.1 ab
2.5 Primextra	146.7 bc	159.0 ab	168.7 ab
Handweeded check	155.7 ab	158.5 ab	164.7 ab
Weedy check	141.5 c	152.1 ab	164.2 ab

Means followed by the same letter within a column are not significantly different at 5% level using DMRT.
a – Atoll is a proprietary formulation of Rhône-Poulenc containing 37.5 g l^{-1} isoxaflutole and 500 g l^{-1} atrazine.
SC – soluble concentrate, WP – wettable powder, NA – not available.

TABLE 6

Effect of Herbicide Treatments on Maize Grain Yield (t ha^{-1})

Treatment (kg a.i. ha^{-1})[a]	*Ilorin*	*Ibadan*	*Orin-Ekiti*
0.54 Atoll	1.45 cde	0.95 ab	2.77 b
0.81 Atoll	2.05 ab	1.17 ab	3.15 a
1.08 Atoll	1.79 bcd	1.13 ab	2.44 b
1.34 Atoll	2.12 ab	1.02 ab	2.89 ab
1.61 Atoll	1.88 abc	0.78 b	2.61 b
2.5 Atrazine SC	0.68 f	1.11 ab	1.77 c
2.0 Atrazine WP	0.43 f	1.16 ab	1.54 c
1.25 + 0.83 Atrazine + Stomp	2.49 a	1.27 a	2.49 b
2.5 Primextra	1.49 cd	1.02 ab	2.60 b
Handweeded check	2.33 ab	1.11 ab	2.40 b
Weedy check	0.67 f	0.95 ab	1.68 c

Means followed by the same letter within a column are not significantly different at 5% level using DMRT.
a – Atoll is a proprietary formulation of Rhône-Poulenc containing 37.5 g l^{-1} isoxaflutole and 500 g l^{-1} atrazine.
SC – soluble concentrate, WP – wettable powder.

Table 7 shows the effect of herbicide treatments on 1000-seed weight of maize. Herbicide treatments did not show much influence on the weight of maize seeds. Atrazine SC applied at 2.5 kg a.i. ha^{-1} had the lowest seed weight in Ilorin, but no significance was observed in Ibadan. Primextra and atrazine + Stomp produced significant seed weights in Orin-Ekiti.

Conclusion

For a safe environment, herbicides such as the isoxazole family with low rates of application are desirable. Results showed that atrazine + isoxaflutole (Atoll) can be used to control annual weeds in the three agro-ecological zones of south-western Nigeria. In the Ilorin (southern Guinea savanna) and Orin-Ekiti (forest) zones, Atoll could be applied at 0.81 - 1.34 kg a.i. ha^{-1}, depending on

TABLE 7

Effect of Herbicide Treatments on 1000-seed Weight of Maize

Treatment (kg a.i. ha^{-1})[a]	*Ilorin*	*Ibadan*	*Orin-Ekiti*
0.54 Atoll	191.6 ab	190.7	184.6 ab
0.81 Atoll	189.4 b	187.2	184.7 ab
1.08 Atoll	191.9 ab	189.4	182.0 ab
1.34 Atoll	192.8 a	187.6	183.8 ab
1.61 Atoll	191.0 ab	189.1	185.8 ab
2.5 Atrazine SC	185.7 c	190.8	184.5 ab
2.0 Atrazine WP	191.8 ab	187.8	184.3 ab
1.25 + 0.83 Atrazine + Stomp	189.3 b	190.1	187.9 a
2.5 Primextra	191.5 ab	188.6	181.3 b
Handweeded check	189.6 ab	188.6	183.3 ab
Weedy check	191.1 ab	190.2	182.4 ab
		NS	

Means followed by the same letter within a column are not significantly different at 5% level using DMRT.
a – Atoll is a proprietary formulation of Rhône-Poulenc containing 37.5 g l^{-1} isoxaflutole and 500 g l^{-1} atrazine.
SC – soluble concentrate, WP – wettable powder, NS = not significant.

the weed intensity. Ibadan (forest/savanna transition) zone could receive 0.54 - 1.08 kg a.i. ha^{-1} Atoll to minimize crop injury.

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