Control of Weed in the Cotton Crop by the Association Flufenacet + Diflufenican in Cote D'ivoire

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Abstract: *The herbicide efficacy and selectivity of the flufenacet + diflufenican combination were studied in cotton at three different sites over two years in Côte d'Ivoire. The Fisher block design adopted for both types of trials included adjacent controls for the efficacy trials. The three rates of this combination (160 + 40 g a. s. /ha, 200 + 50 g a. s. /ha and 300 + 75 g a. s. /ha) controlled weediness well when it was not dominated by Acanthospermum hispidum DC. and Mesosphaerum suaveolens (L.) Kuntze. From 200 + 50 g a. i. /ha, the correct effectiveness of these herbicides is maintained until at least 50 days after sowing. This herbicide combination is selective for the cotton crop despite the appearance of some signs of phytotoxicity which disappear before 80 days after sowing. The three tested doses of flufenacet + diflufenican had no significant effect on the number of plants at harvest, the number of open bolls and the yield. It is therefore selective on cotton.*

Keywords: Cotton, flufenacet + diflufenican, weeds, efficacy, selectivity.

1. Introduction

In Côte d'Ivoire, the chemical weed control of cotton crops has been carried out successively with the combinations fluometuron + diuron, metolachlor + terbutryn, metolachlor + prometryn and S - metolachlor + prometryn. Their withdrawal or ban has created a legal vacuum. This gives rise to the following recurring question: "Which herbicide should be used for weeding cotton crops from now? Manual weeding, preceded by pre - emergence contact weeding and possibly supplemented by directed cache treatments, remains the appropriate control method. Faced with this situation, the search for new herbicides or the repositioning of old herbicides that are still authorised appears necessary. Following this path, Bayer Crop Science proposed in 2013 the study of the biological behaviour of the combination flufenacet + diflufenican in cotton crops. This study on the efficacy and selectivity of this herbicide in cotton crops provides the information needed to make decisions in the face of new problems such as the proliferation of certain weeds or cases of resistance to herbicide, etc.

2. Materials and Methods

Location
The study was carried out in Côte d'Ivoire in 2013 and 2014 at the CNRA cotton research station in Bouaké and at two observation posts (OPs) in Nambingué and Boundiali, in the north of the country. These OP belong to two cotton companies, Ivoire Coton and SECO (Société d'exploitation du Coton). The soil characteristics of these sites are presented in Table I.

Table I: Soil characteristics of the trial sites

Locality	Soil types
Bouaké	clayey
Boundiali	clayey
Nambingué	sandy

Plant material
Four varieties are used: W766 C, Y616 B in the 2013 and 2014 trials in Bouaké respectively, X442 C in the two trials in Boundiali and in the 2013 trial in Nambingué. In 2014, the variety Y764 A was used in Nambingué.

Herbicide
The herbicide tested was the combination flufenacet + diflufenican (LIBERATOR 500 EC, Bayer CropScience; 400 + 100 g a. s. /L). This combination, effective against grasses and broadleaf weeds, acts from the germination to the 2 - leaf stage of the weeds. Both active ingredients are absorbed by the roots and the hypoctyl. Diflufenican also has a foliar action (Bayer CropScience). Henriet (2009) noted that flufenacet is mainly active against grasses and that to obtain a full spectrum of action it must be combined with diflufenican.

Experimental set - up and objects studied

Efficiency tests
The Fisher block design with adjacent control and three replications was adopted. The herbicide combination (flufenacet + diflufenican) is studied at three rates 160 + 40 g a. s. /ha, 200 + 50 g a. s. /ha and 300 + 75 g a. s. /ha. These rates are compared to the reference product, the combination S - metolachlor + prometryn (CODAL GOLD 412.5 SC, Ciba Geigy; 162.5 + 250 g a. s. /L) applied at 650 + 1000 g a. s. /ha.

Selectivity tests
The Fisher block design with five replicates in Bouaké and four in the P. O. was chosen. The combination of flufenacet + diflufenican was tested at three doses 200 + 50 g a. s. /ha, 400 + 100 g a. s. /ha and 600 + 150 g a. s. /ha. The first dose is the one considered effective. The estimation of the aggressiveness of the herbicide required taking into account the double and triple doses of the first one. The behaviour of the cotton plants that received the herbicide doses was

compared to that of cotton plants grown on a control plot without herbicide.

Crop management
The sowing, carried out manually between 25 June and 27 July, is preceded by mechanical preparation of the plots (ploughing and spraying). The spacing adopted is: 80 cm x 30 cm.

A bottom dressing of 200 kg/ha of NPK (15 - 15 - 15) is applied at the time of tillage.

During the crop cycle, no weeding is done and the crop is not harvested at the end of the cycle for the efficacy trials. In contrast, the selectivity trials, which are kept clean by hand weeding throughout the crop cycle, receive 50 kg/ha of urea; all recommended insecticide treatments are carried out and the trials are harvested at the end of the cycle.

Herbicides are applied pre - emergence to the crop and weeds with a pressure - maintained knapsack sprayer, fitted with a mirror nozzle to treat a 1.6m wide band. The spray rate per hectare is 150 litres.

Herbicide efficacy rating
Herbicide efficacy is assessed at approximately 20, 40, 60 and 80 days after sowing (DAS) using the BTC (Bioassay Commission) scale modified by Marnotte & *al*., (2004) The scores, ranging from 1 to 9, are defined in percentage of biomass destroyed as follows.1: 1% (no efficacy); 2: 7% (very low efficacy); 3: 15% (low efficacy); 4: 30% (poor efficacy); 5: 50% (medium efficacy); 6: 70% (moderate efficacy); 7: 85% (acceptable efficacy); 8: 93% (proper efficacy); 9: 100% (perfect efficacy). During the effectiveness ratings, plot surveys are carried out. Following the same scale, an efficacy rating is given to the first three dominant weeds on each plot.

Herbicide selectivity rating
Like efficiency, selectivity is scored according to the CEB scale modified by Marnotte&*al*, (2004). The scores vary from 1 to 9 and their meanings are described below.1: no sign of phytotoxicity; 2: some spotting and discolouration; 3: numerous spotting and heavy discolouration; 4: 30% loss of biomass compared to the control; 5: 50% loss of biomass compared to the control; 6: 70% biomass loss compared to the control (high phytotoxicity); 7: 85% biomass loss compared to the control (very high phytotoxicity); 8: more than 90% biomass loss compared to the control (only a few plants survive); 9: 100% biomass loss compared to the control.

Data processing
The efficacy or selectivity of a herbicide rate is characterised by the median of the plot scores which represents, better than the mean, the central value of a distribution (Snedecor& Cochran, 1971). A herbicide is considered to be effective if its score is$\geq$ 7 at 50 JAS and it is selective if it is not very aggressive towards the crop (score $<$ 4) and if the yield obtained with each of the first two doses does not differ significantly from that of the control.

The data collected at harvest (number of plants/ha, number of open bolls/ha and seed cotton weights) are subjected to an analysis of variance with Genstat software in order to compare the means of these variables.

3. Results and Discussion

Efficiency tests
Flora of the trials
The flora of the trials comprises 13 families, 30 genera and 35 species. The most represented families are Poaceae with 9 species, Cyperaceae with 5 species and Euphorbiaceae with 4 species. Weeds with a relative frequency of at least 80% in one of the trials were *Acanthospermum hispidum*DC. (8 to 100%), *Urochloa lata (*Schumach.) C. E. Hubbard (16 to 100%), *Commelina benghalensis* L. (16 to 100%), *Cyperus rotundus* L. (100%), *Dactyloctenium aegyptium (*L.) P. Beauv. (100%), *Digitaria horizontalis* Wild. (8 to 100%) and *Euphorbia heterophylla* L. (9 to 91%)

Effectiveness of treatments
Following early post - emergence weed control with glyphosate in 2014, all plots in the Nambingué trial (treated and control) remained very clean until 20 days after sowing, which explains the absence of scores at this date (Table II).
S - metolachlor + prometryn at 162.5 + 250 g/ L
S - metolachlor + prometryn, the reference product tested at 650 + 1000 g/ha, had perfect to acceptable efficacy (scores 9 to 7) for at least 50 days after sowing in all three trials in 2013 and in two out of three trials in 2014 (Table II).
Its effectiveness is good to perfect (note 8 and 9) on *A. hispidum*, *U. lata*, *Celosia trigyna* L. *Cleome viscosa* L. *C. benghalensis, Croton hirtus* L'Hér. *D. aegyptium*, *D. horizontalis*, *Mesosphaerum suaveolens (*L.) Kuntze and *Leucas martinicensis*R. Br. at 50 days after sowing.
flufenacet + diflufenican: 400 + 100 g/L

From the first dose, 160 + 40 g/ha, the flufenacet + diflufenicancombination provides acceptable to perfect weed control (scores 7 and 9) but the residual is low, 20 days after sowing in five trials out of six. However, in one of the trials, at Nambingué, where the flora is mainly composed of grasses and Commelinaceae, its effectiveness remained acceptable up to 50 days.

The dose of 200 + 50 g/ha of flufenacet + diflufenican, assumed a priori to be effective, allows each year perfect to acceptable weed control (score 9 to 7) for at least 50 days in the Boundiali and Nambingué trials (Table II).

In the same localities, the highest dose, 300 + 75 g/ha flufenacet + diflufenican, provides acceptable (score 7) to perfect (score 9) weed control with a residual of at least 50 days (Table II).

The last two doses, 200 + 50 g/ha and 300 + 75 g/ha of flufenacet + diflufenican, are effective at 20 days on average in the Bouaké trial (ratings 7 or 8) but their residuals do not reach 30 days because of their inability to control *A. hispidum* and *M. suaveolens*.

Each of the tested doses (160 + 40 g/ha; 200 + 50 g/ha and 300 + 75 g/ha of flufenacet + diflufenican) controlled *D.*

*horizontalis, D. aegyptium, C. trigyna, L. martinicensis*and *Ocimum canum*Sims very well up to 50 days.

On *Ageratum conyzoides*L. and *C. benghalensis*, their good efficacy (rating 7 and 8) lasted only 20 days after sowing. *Amaranthus graecizans* L. and *Amaranthus viridis*L. were very well controlled by the three doses at 20 days, but were no longer observed in the plots at 50 days.

U. lata, C. viscosa and *C. hirtus* are only controlled by the two high doses (200 + 50 g/ha and 300 + 75 g/ha of flufenacet + diflufenican).

All three doses of this herbicide combination are insufficiently effective against *A. hispidum*. Also, the first two doses (160 + 40 g/ha and 200 + 50 g/ha) are ineffective against *M. suaveolens*.

Table II: Median herbicide efficacy scores in the differenttrials

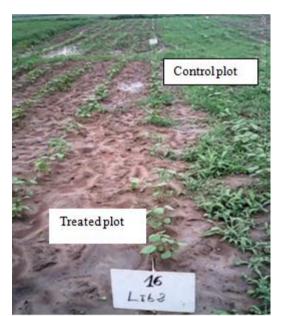| Herbicides studied		Test site	Herbicide rate effectiveness by year and observation date							
			2013				2014			
Active substances	Dose (g/ha)		20 JAS	40 JAS	50 JAS	80 JAS	20 JAS	30 JAS	50 JAS	80 JAS
flufenacet + diflufenican	160 + 40	Bouaké	7	4	3		5	5	4	1
		Boundiali	8		4	4	9		6	1
		Nambingué	7		5	4	*		7	1
	200 + 50	Bouaké	7	5	3		4	4	4	1
		Boundiali	8		7	5	9		7	7
		Nambingué	8		7	4	*		8	6
	300 + 75	Bouaké	8	5	3		7	6	5	1
		Boundiali	9		7	6	9		8	7
		Nambingué	8		7	4	*		8	6
S - metolachlor + prometryn	650 + 1 000	Bouaké	8	8	7		7	6	5	4
		Boundiali	9		7	4	9		8	8
		Nambingué	9		7	6	*		7	5

Figure 1: Real weed control with flufenacet + diflufenican at 200 + 50 g/ha

Selectivity tests
Effect on the physical aspect of the crop
The first dose of the herbicide (200 + 50 g/ha flufenacet + diflufenican) is perfectly selective to cotton with a phytotoxicity score of 1 in five trials and a score of 3 in the sixth trial. This phytotoxicity of intensity 3 disappears before 50 days.

The second dose (400 + 100 g/ha flufenacet + diflufenican) did not cause any signs of phytotoxicity at the different observation dates in three trials out of six. In the three other

trials where phytotoxicity was observed, it was marked by necrosis on cotyledons and first leaves and by a reduction in the size of the cotton plants. This phytotoxicity rated 3 or 4 disappears before 50 or 80 days after sowing depending on the locality.

The third dose (600 + 150 g/ha) caused more severe symptoms in two of the six trials in Boundiali and Nambingué in 2013: necrosis on cotyledons and first leaves and especially empty pits. The phytotoxicity score is evaluated at 5 (50% biomass reduction) in these two trials. These symptoms disappeared at 50 days after sowing in one trial and at 80 days in the other. In the other four trials the phytotoxicity observed was very low with scores less than or equal to 3.

Effect on yields and its components
The three doses of the herbicide combination flufenacet + diflufenican (200 + 50 g/ha; 400 + 100 g/ha and 600 + 150 g/ha) did not have a significant effect on yields and their components, notably the number of plants at harvest and the number of bolls harvested in each of the trials (Tables III, IV and V).

The yields obtained vary from:
- 1, 510 to 1, 749 kg/ha in 2013 and 1, 330 to 1, 441 kg/ha in 2014 in Bouaké (Table III);
- 755 to 911 kg/ha in 2013 and 1, 316 to 1, 395 kg/ha in 2014 in Boundiali (Table IV);
- 234 to 418 kg/ha in 2013 and 609 to 777 kg/ha in 2014 in Nambingué (Table V).

Table III: Yield and its components in the Bouaké trials

Objects studied		2013			2014		
		PAR/ha	CO/ha	RTD (kg/ha)	PAR/ha	CO/ha	RTD (kg/ha)
Herbicides	Doses (g/ha)						
flufenacet + diflufenican	200 + 50	41 146	313 887	1 749	64 875	289 000	1 330
	400 + 100	42 361	319 963	1 567	66 188	325 312	1 441
	600 + 150	41 580	315 536	1 510	63 938	317 688	1 410
Witness	0	43 316	314 234	1 493	63 375	315 188	1 380
Overallaverage		42 286	315 933	1 549	62 375	304 045	1 370
CV (%)		11, 4	7	10, 2	9	13, 7	13
Bonferroni test at significance level α = 5		NS	NS	NS	NS	NS	NS

Legend: PAR: number of plants at harvest; CO: number of open bolls; RDT: yield

Table IV: Yield and its components in the Boundiali trials

Objects studied		2013			2014		
		PAR/ha	CO/ha	RTD (kg/ha)	PAR/ha	CO/ha	RTD (kg/ha)
Herbicides	Doses (g/ha)						
flufenacet + diflufenican	200 + 50	62 413	224 651	911	58 438	292 734	1 395
	400 + 100	49 652	199 738	755	60 312	277 969	1 316
	600 + 150	55 208	208 158	842	58 516	283 203	1 371
Witness	0 L/ha	58 073	205 120	694	52 891	261 719	1 391
Overallaverage		51 587	201 400	791	53 873	276 172	1 308
CV (%)		13, 2	11, 2	26, 3	12	18, 5	19, 5
Bonferroni test at significance level α = 5		NS	NS	NS	NS	NS	NS

Legend: PAR: number of plants at harvest; CO: number of open bolls; RDT: yield

Table V: Yield and its components in the Nambingué trials

Objects studied		2013			2014		
		PAR/ha	CO/ha	RTD (kg/ha)	PAR/ha	CO/ha	RTD (kg/ha)
Herbicides	Doses (g/ha)						
flufenacet + diflufenican	200 + 50	38 047	104 375	418	50 859	114 062	676
	400 + 100	33 359	95 469	344	52 266	98 438	609
	600 + 150	28 516	80 469	234	47 891	138 750	777
Witness	0	33 750	92 500	258	52 109	100 781	609
Overallaverage		32 812	110 234	359	42 511	98 348	578
CV (%)		12, 9	36, 9	43, 4	18, 7	27, 7	25, 3
Bonferroni test at significance level α = 5		NS	NS	NS	NS	NS	NS

Legend: PAR: number of plants at harvest; CO: number of open bolls; RDT: yield

4. Conclusion

The weediness of the plots is dominated by *A. hispidum*, *M. suaveolens* and *D. horizontalis* in Bouaké, by *U. lata*, *D. aegyptium* and *D. horizontalis* in Boundiali and by *M. suaveolens* and *D. horizontalis* in Nambingué.

S - metolachlor + prometryn, the reference product tested at 650 + 1000 g/ha, kept plots clean with a residual of up to 80 days in some trials. Its efficacy was very good on *D. horizontalis*, *U. lata*, *D. aegyptium* and *M. suaveolens*.

The combination flufenacet + diflufenican allows an acceptable to perfect weed control from 200 + 50 g/ha with a remanence of at least 50 days after sowing. However, when the weed is dominated by *A. hispidum* and *M. suaveolens*, its efficiency becomes insufficient at 160 + 40 g/ha and 200 + 50 g/ha. The three tested doses of flufenacet + diflufenican (160 + 40 g/ha; 200 + 50 g/ha and 300 + 75 g/ha) controlled *D. horizontalis, D. aegyptium, C. trigyna, L. martinicensis* and *O. canum* very well up to 50 days after sowing.

The single and double doses of flufenacet + diflufenican (200 + 50 g/ha and 400 + 100 g/ha) caused a slight phytotoxicity (notes 3 or 4) which disappeared before 80 days. This phytotoxicity, which increases with the third dose (note 5), also disappears before 80 days. Phytotoxicity, characterised by necrosis on cotyledons and first leaves, reduction in cotton plant size and empty bolls, had no significant effect on yield, number of cotton plants at harvest and number of open bolls.

In 2013, the dose of 200 + 50 g/ha of flufenacet + diflufenican, proposed by Bayer CropSciences, had an acceptable to correct efficacy with a residual of up to 50 days after sowing. It still had good efficacy in 2014 with a persistence that varied from 30 to 80 JAS. As this effective dose and its multiples (double and triple) are selective for cotton crops, the flufenacet + diflufenicancombination can be tested in a farming environment, in order to specify the constraints of using this formulation under real conditions.

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