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Research Article

Efficacy of Post-Emergence Herbicides against Weeds of Sugarcane in South West Burkina Faso

Adama Sanou[1], Boureima Yogo[1], Djibril Yonli[1], Parfait Loci Traoré[2], Bintou Sanou[1], Drissa Coulibaly[1] et Hamidou Traoré[1]

[1]*Institut de l'Environnement et de Recherches Agricoles (INERA), Direction Régionales de recherches environnementales et agricoles de l'Ouest, Station de Farako-Bâ, BP 910 Bobo Dioulasso, Burkina Faso*

[2]*Nouvelle société sucrière de la Comoé (SN-SOSUCO), Bérégadougou*

Abstract

Sugar cane (*Saccharum officinarum* L.) is one of the world's leading industrial crops. In Burkina Faso, it faces a number of agronomic constraints, notably weed infestation. In the short term, chemical control remains an alternative for reducing weeds damage on crops and mitigating low sugarcane yields. With a view to improving sugarcane productivity, the aim of this study was to evaluate the efficacy of Triclopyr 480 g/L EC, a post-emergence herbicide in sugarcane cultivation on Bérégadougou perimeter in South-west Burkina Faso. Two trials were carried out in a completely randomized block design, with six (06) treatments and three (03) replicates. Three doses of Triclopyr 480 g/L EC were compared with a reference control and two untreated controls. The floristic inventory before and after herbicide treatment revealed a total of 40 species in 18 families, dominated by the dicotyledonous class (72.5%). Triclopyr 480 g/L EC at the intermediate dose of 2 l/ha reduced weed infestation by 53.2% compared with the non-weeded control and leading to efficacy of 85.6%. Triclopyr 480 g/L EC thus allowed an average yield gain of 14.9 t/ha compared to the non-weeded control.

Keywords: *Herbicide, efficacy, Triclopyr, 2,4-D amine, Sugar cane, weeds.*

Introduction

Sugar cane (*Saccharum officinarum* L.) is a grass cultivated mainly for its sugar-rich stalks. This crop occupies an area of 25 billion hectares worldwide, with an annual production of sugarcane stalks of over 1.5 billion tonnes (Tialou, *et al.*, 2021). More than 50% of this production comes from Brazil, India and the European Union (Courteau, 2005).

Within the West African Economic and Monetary Union (UEMOA), sugar production is estimated at nearly 400,000 tonnes of stalks per year. In Burkina Faso, the Nouvelle société sucrière de la Comoé (SN-SOSUCO) has been in charge of sugar production since 1974. It produces sugar cane on 4,000 ha with an average yield varying between 75 and 80 t of stalks/ha, depending on the variety grown. National production is estimated at an average of 300,000 tonnes of cane and employs nearly 3,000 people every year (SN-SOSUCO, 2020).

However, sugarcane production has to face up to the damage caused by bio-aggressors, of which weeds are a major and constant threat (Lebreton, 2010). Losses due to weeds are estimated at an average of 400 kg/ha in the event of heavy infestation (Marion and Marnotte, 1991). For this reason, weed control in sugarcane plots is necessary for good yields. Various control methods are used to reduce the damaging effect of weeds on

***Corresponding Author:**
Adama Sanou;

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sugarcane, of which manual weeding, mechanical weeding and chemical weeding are the most common. The various cycles of sugarcane cultivation result in degrees of weed severity in which each species requires a different weed control method (Aekrathok, *et al.*, 2021).

In industrial crops such as sugarcane, chemical control is the alternative for reducing weed pressure on sugarcane plants (Marnotte, 2010). In the various practical means of chemical control, the high infestation of certain weeds on sugarcane yields is thought to be linked to the effect of certain herbicides that have become very ineffective. According to Dianda (2016), the development of weed resistance is due to the continuous use of the same active ingredients. It is therefore necessary to have several ranges of active compounds in order to rotate herbicide applications and thus prevent the development of resistance in weeds.

Materials and Methods

Study site

Two series of trials were planted on LMO5C and ASPN4D irrigated plots on the SN-SOSUCO sugar perimeter during the 2022 wet season (figure 1). The perimeter is located in Bérégadougou in the Cascades region, Comoé province. It is located between 10°41' and 10°47' north latitude and 4°38' and 4°39' west longitude, with an average altitude of 270 m. The SN-SOSUCO irrigated perimeter covers a fully irrigated area of 4,000 ha, stretching from east to west over a length of more than 20 km, and from north to south over a width of more than 6 km (Ouattara, 2007). Average annual rainfall is between 1,180 and 1,200 mm. During the trials, the highest number of days (16 days) and rainfall amounts (333.1 mm) were recorded during the month of August (figure 2). A soil analysis was carried out prior to planting the trials, using samples taken from the 0-30 cm and 30-60 cm horizons. The average organic matter content was low (1.47%), with a fairly acid soil (pHwater = 5) (Table 1).

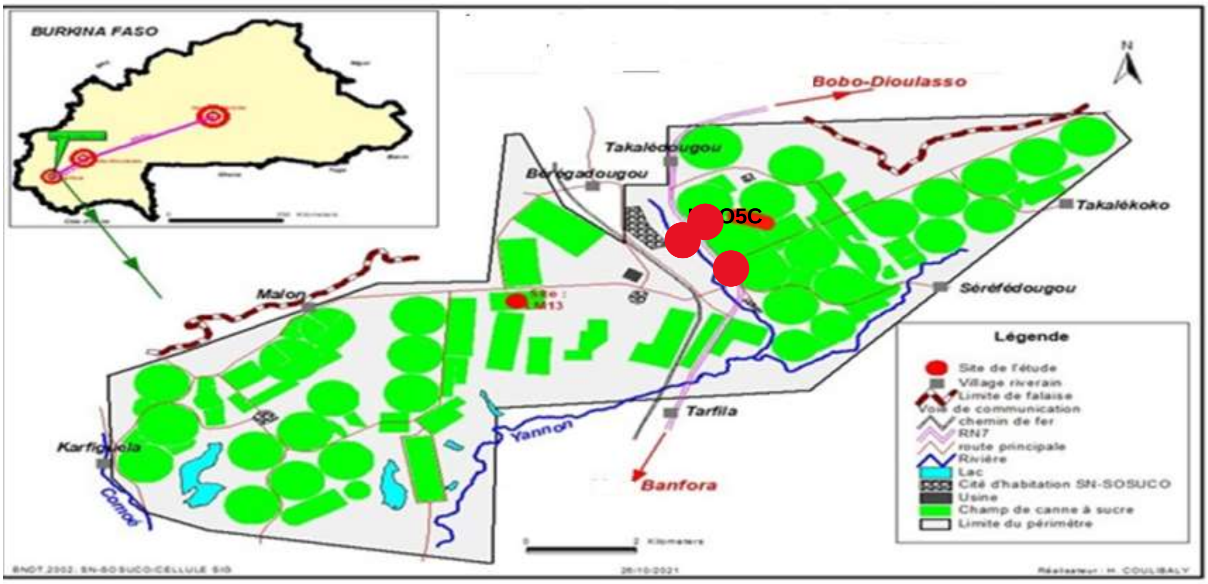

Figure 1: Plot plan of sugarcane fields Source: SN-SOSUCO, 2021.

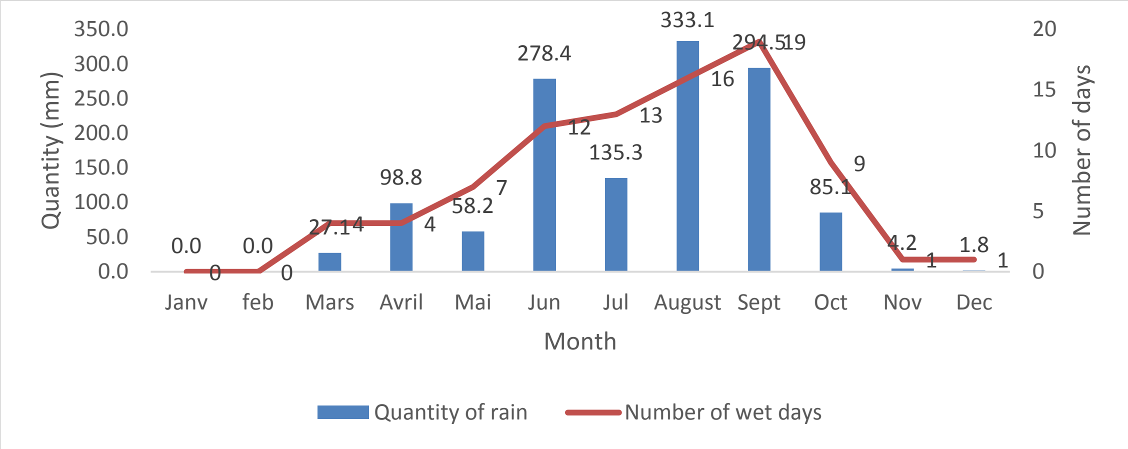

Figure 2: Pluviosity on SN-SOSUCO sugarcane plots during the 2022 wet season. Source: SN-SOSUCO, 2022

Table 1: Physico-chemical soil properties of experimental plots

Physico-chemical properties	content	Horizon	
		0-30 cm	**30-60 cm**
pH	pH_water	5	5
	pH_KCl	4,2	4,15
Organic matter (M.O)	Total nitrogen ‰	1,105	0,595
	Carbon	1,27	0,435
	M.O%	2,19	0,75
	C/N	11,5	7,5
Phosphore	P_2O_5ASS ‰	0,06	0,025
AL-ECH (MEQ/100g)	AL-ECH (MEQ/100g)	0,075	0,305
absorbent complex	Ca meq/100g	1,55	1,925
	Mg meq/100g	0,375	0,65
	K. meq/100g	0,16	0,21
	Na meq/100g	0,055	0,04
	Sum of bases. Sm/100g	2,14	2,825
	1.	4,9	5,825
	Saturation V = S/T 100V%	43,805	50,4

Source: SN-SOSUCO, *2022.*

Materials

Seven (07)-month-old cuttings of the R579 sugarcane variety were used. The cuttings had two eyes each. The cuttings were planted manually in each furrow.

The herbicides used were Triclopyr 480 g/l (3,5,6-trichloro-2-pyridinyloxyacetic acid), a systemic foliar herbicide, and 2,4-D amine 720 SL (TR: reference herbicide), commonly used in SN-SOSUCO sugarcane plots.

Experimental Design

Planting was carried out in rows spaced 1.3 m apart. Each elementary plot has a surface area of 100 m² (7.8 m x 12.82 m). The two (02) central lines of the elementary plot represent the useful plot. Spacing was 1.5 m between replicates and 2.5 m between treatments in the same replicate. The experimental design a completely randomized block with six (6) treatments and three (03) replicates, i.e. 18 elementary plots. The different treatments in comparison were composed of two chemical treatments (Triclopyr 480 g/L SL, 2,4-D amine 720 SL) and two controls:

T1: 1.5 L/ha Triclopyr 480 g/L, i.e. 720 g/ha active ingredient (a.i.), applied 40 days after planting (JAP);
T2: 2 L/ha Triclopyr 480 g/L, i.e. 960 g/ha of active ingredient 40 DPA;

T3: 2.66 L/ha Triclopyr 480 g/L, i.e. 1276.8 g a.i./ha, 40 JAP ;
T4: 4 L/ha 2,4-D amine 720 g/L, i.e. 2880 g/ha of a.i./ha, 40 JAP;
T5: Three manual weedings at 15, 30 and 45 days after treatment;
T6: Untreated control, weeding for 45 days after treatment (95 DPA).

Crop Management

Plot preparation consisted of cross-ploughing to a depth of 25 cm, followed by sol pulverization and furrowing to a depth of 20 cm. Healthy cuttings with 2 to 3 "eyes" of the R579 variety were planted. These cuttings came from a 7-month-old nursery plot. After cutting the stems into 20 cm cuttings, they were manually planted in the bottom of the furrow in double rows, then covered with 2 to 5 cm of fine soil. The average quantity of cuttings planted was 6 tonnes/ha.

Mineral fertilizers consisting of NPK (14-23-14) and Di-Ammonium Phosphate (DAP) were applied at doses of 350 kg/ha and 130 kg/ha respectively, in the furrows before planting. Urea (46% N) was applied in two fractions at a rate of 300 kg/ha, i.e. 150 kg/ha at 30 days after planting (DAP) and 60 DAP respectively.

Herbicide treatments were applied with a pressure-maintained sprayer in post-emergence at the 2-3 leaf stage of most emerged weeds. The various herbicide treatments were applied on the same date, at different application rates.

Data Collection and Analysis

Data were collected on weeds and sugarcane:
A taxonomic inventory of weeds was carried out before and after herbicide treatment using the identification keys of Johnson (1997), Le Bourgeois, and Merlier (1995) at 0, 15 and 30 JAT (Table 2);

An abundance rating of emerged weeds based on the Barralis (1976) scale, which determined the abundance of individuals of each species at 0, 15 and 30 DAT;

Rate of weed cover in each elementary plot was determined using the Marnotte (1984) scale at 0, 15 and 30 days' work (Table 2);

The Coefficient of Similarity (Cs) was determined by comparing the lists of floristic inventories from the different repetitions according to Sorensen's (1948) formula. When the coefficient of similarity is greater than or equal to 50%, the floristic composition of the two lists compared is close. In the opposite case (Cs is less than 50%), the two lists compared have different floristic compositions (Aman, *et al*., 2004).

$$Cs = 2c/ (a+b) \times 100 \quad \text{(Formula 1)}$$

"a" and "b" represent the number of species belonging to the two different replicates; "c" is the number of species common to both floristic lists.

Generic (Ig) and specific (Is) diversity indices were calculated with Excel 2016 software using the formulas:

$$\mathbf{Ig} = \frac{\text{Nombre de genres}}{\text{Nombre d'espèces}} \text{ et } \mathbf{Is} = \frac{\text{Nombre d'espèces}}{\text{Nombre de genres}}$$

Table 2: Weed cover rating scale (Marnotte, 1984) and weed abundance rating scale (Barralis, 1976)

Note	Coverage rate	Abundance rate
1	< 1 %	< 1 individu/m²
2	1 à 7 %	1 à 2 individus/m²
3	7 à 15 %	3 à 20 individus/m²
4	15 à 30 %	21 à 50 individus/m²
5	30 à 50 %	> 50 individus/m
6	50 à 70 %	
7	70 à 85 %	
8	85 à 93 %	
9	93 à 100 %	

- - Calculation of percentage efficacy: the percentage efficacy of the herbicides was determined from the coverage rate using the Henderson-Tilton percentage efficacy formula and interpreted according to the efficacy rating scale (table 3).

$$\% \text{ efficacy} = (1 - \frac{Ta*cb}{Tb*ca}) *100$$

- Ta = Coverage rate of the treated plot on the day of observation;
- -Tb= Coverage rate of treated plot before product application;
- - Ca = Coverage rate of the absolute control plot before product application;
- - Cb = Coverage rate of the absolute control plot on the day of observation.
- plant coverage rateLa hauteur (cm) des tiges de canne à sucre a été mesurée à l'aide d'un mètre ruban sur dix (10) plants choisis de façon aléatoire dans chaque parcelle élémentaire 30 et 45 JAT ;
- the number of tillers per stem was also counted on the same ten (10) plants in each elementary plot at 30 and 45 JAT.

Analyses of variance and comparisons of means at the 5% probability level were performed using R software version 4.2.

Table 3: Herbicide treatment efficacy rating scale based on the Henderson-Tilton formula (1995)

Efficacy assessment	**Efficacy (%)**
very good	100
very good	99,9-98
Good to very good	97,9-95
Good	94,4-90
May be acceptable	**89,9-82**
Moderate	81,9-70
Weak	69,9-55
Very weak	54,9-30
Very low to zero	29,9-0

Results

Effect of Triclopyr 480 g/L on weed dynamics

Floristic inventory at 15, 30 and 45 days after treatment (JAT) revealed the 17 most abundant species (figure 3). The three most frequent species were *Dactyloctenium aegyptium* L. (26.5 %), *Commelina benghalensis* L. (13 %) and *Digitaria horizontalis* W. (11%). The distribution of weed families at 0, 15 and 30 JAT shows that the three main families are *Poaceae* (26%), *Euphorbiaceae* (14 %) and *Fabaceae* (10 %) (figure 4). In terms of weed classes inventoried, dicotyledons are the most abundant: 70 % at 0 JAT, 67.8 % at 15 JAT and 70.2 % at 30 JAT (figure 5).

The first two axes of the ordination diagram explain 22.71 % of the relationship between weeds and treatments. According to the indicator species analysis, treatments had a significant effect ($p < 0.05$) on the distribution of 5.97% of species (figure 6). These species are found in weed groups 1 and 2 (Table 4). Groups 1 and 2 recorded *Echinochloa colona* (L.) and *Sida rhombifolia* L. as indicator species, with indicator values of 40.9% and 61.5% respectively. Group 1 with *Digitaria horizontalis* recorded the highest diversity indices, with a Shannon index of 3.068, Simpson's index of 0.9175 and Pielou's equitability index of 0.746.

Table 4: Plant group characteristics of weed species inventoried on plots at 60 JAT

Groupe	Name of group	RS	Characteristic species	IV (%)	P value (Monté Carlo)	Dominant family	Ish	IS	IE
1	Group of *Digitaria horizontalis* Willd.	41	*Digitaria horizontalis* Willd.	77,50	0,0028	*Poaceae* : 17,07% *Asteraceae* : 9,57% *Fabaceae* : 7,32% *Euphorbiaceae* : 7,32%	2,901	0,9063	0,706
			Dactyloctenium aegyptium (L.)	68,00	0,0150				
2	Group of *Echinochloa colona* (L.)	26	*Echinochloa colona* (L.)	40,90	0,0220	*Fabaceae* : 11,54% *Asteraceae* : 7,69 *Poaceae* : 7,69% *Euphorbiaceae* : 7,69	3,068	0,9175	0,746
			Sida rhombifolia L.	61,50	0,0452				
Average							**2,9845**	**0,9119**	**0,726**

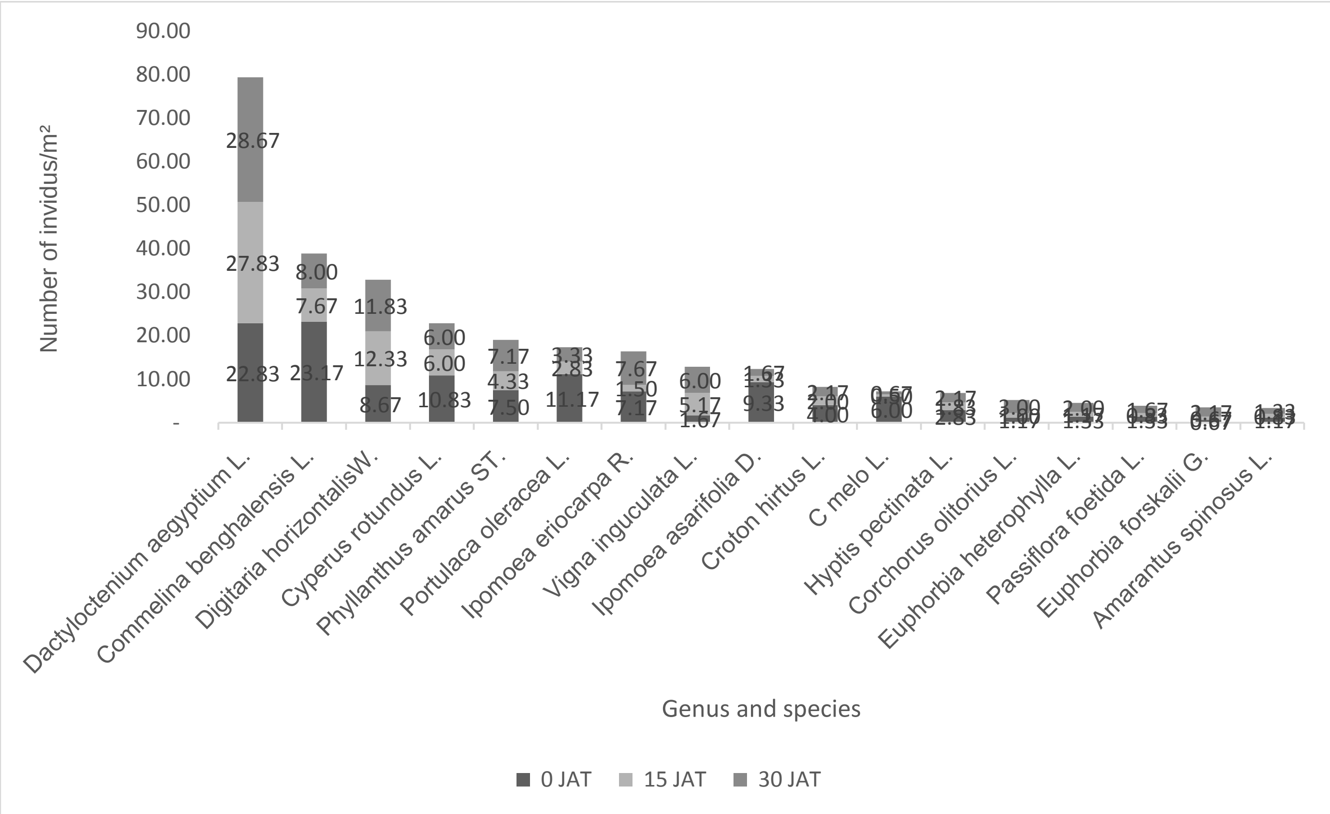

Figure 1*:* Frequency (%) of major weeds inventoried at 0, 15 and 30 days.

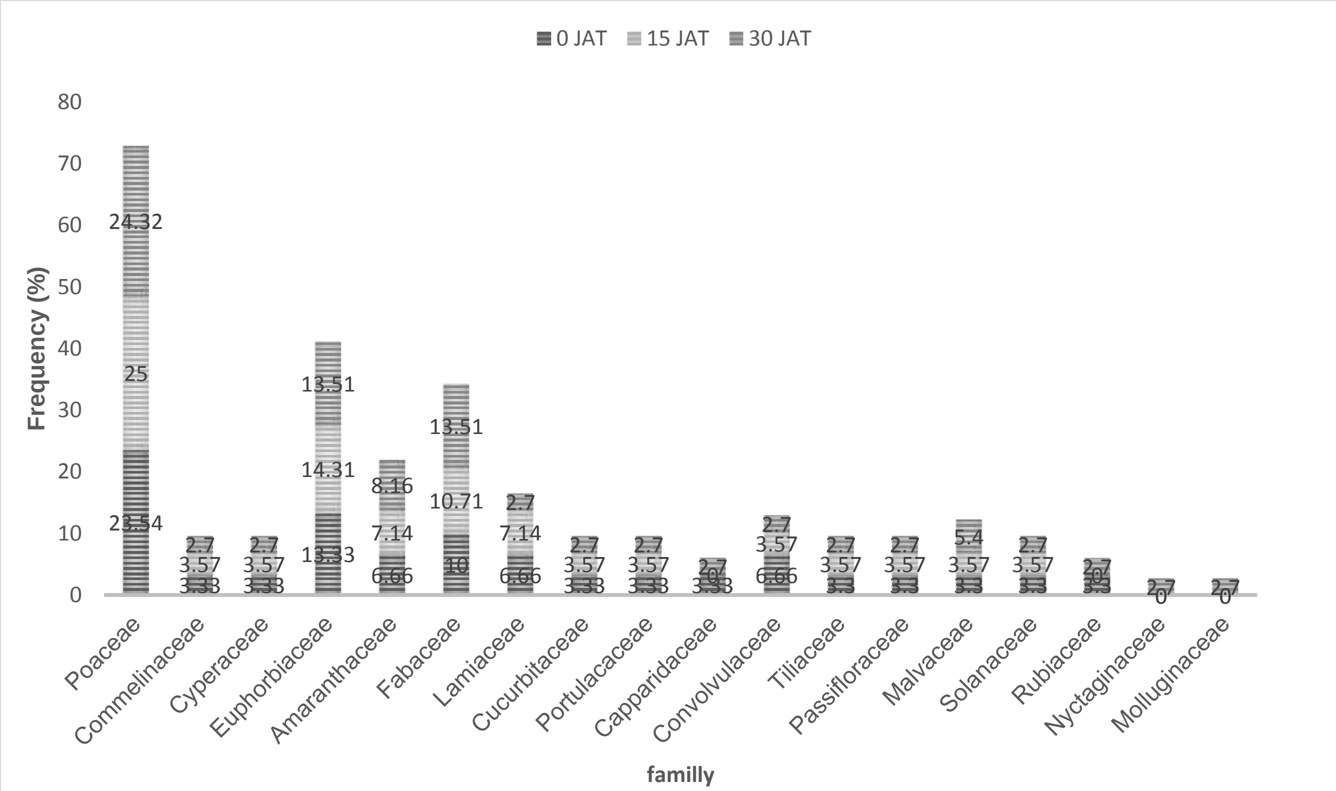

Figure 2: Frequency (%) of weed families inventoried at 0, 15 and 30 JAT

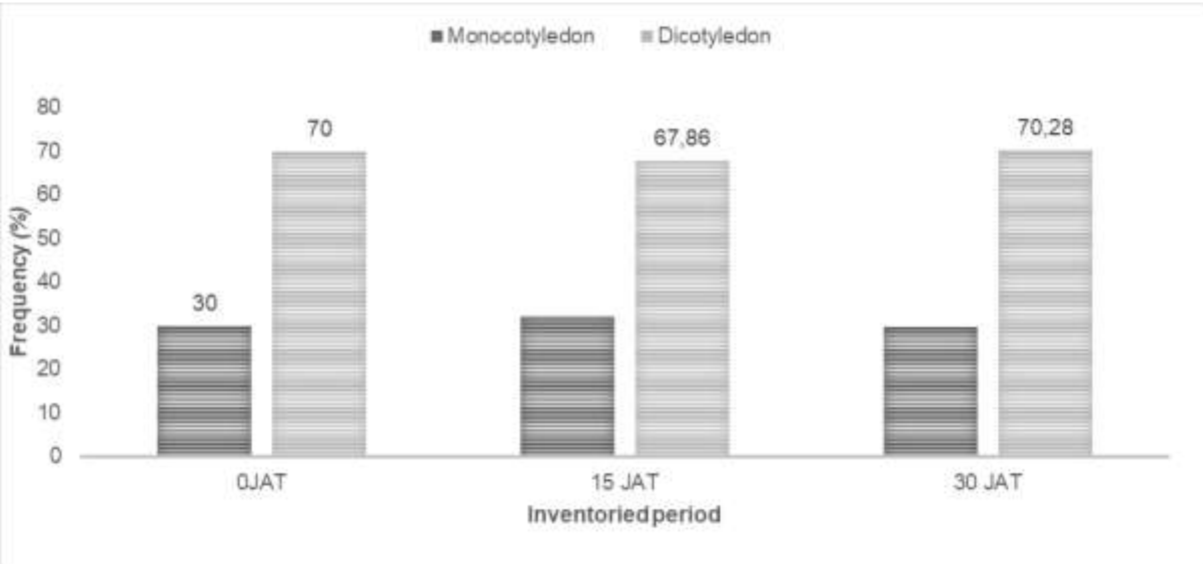

Figure 3: Frequency (%) of weed classes inventoried at 0, 15 and 30 JAT

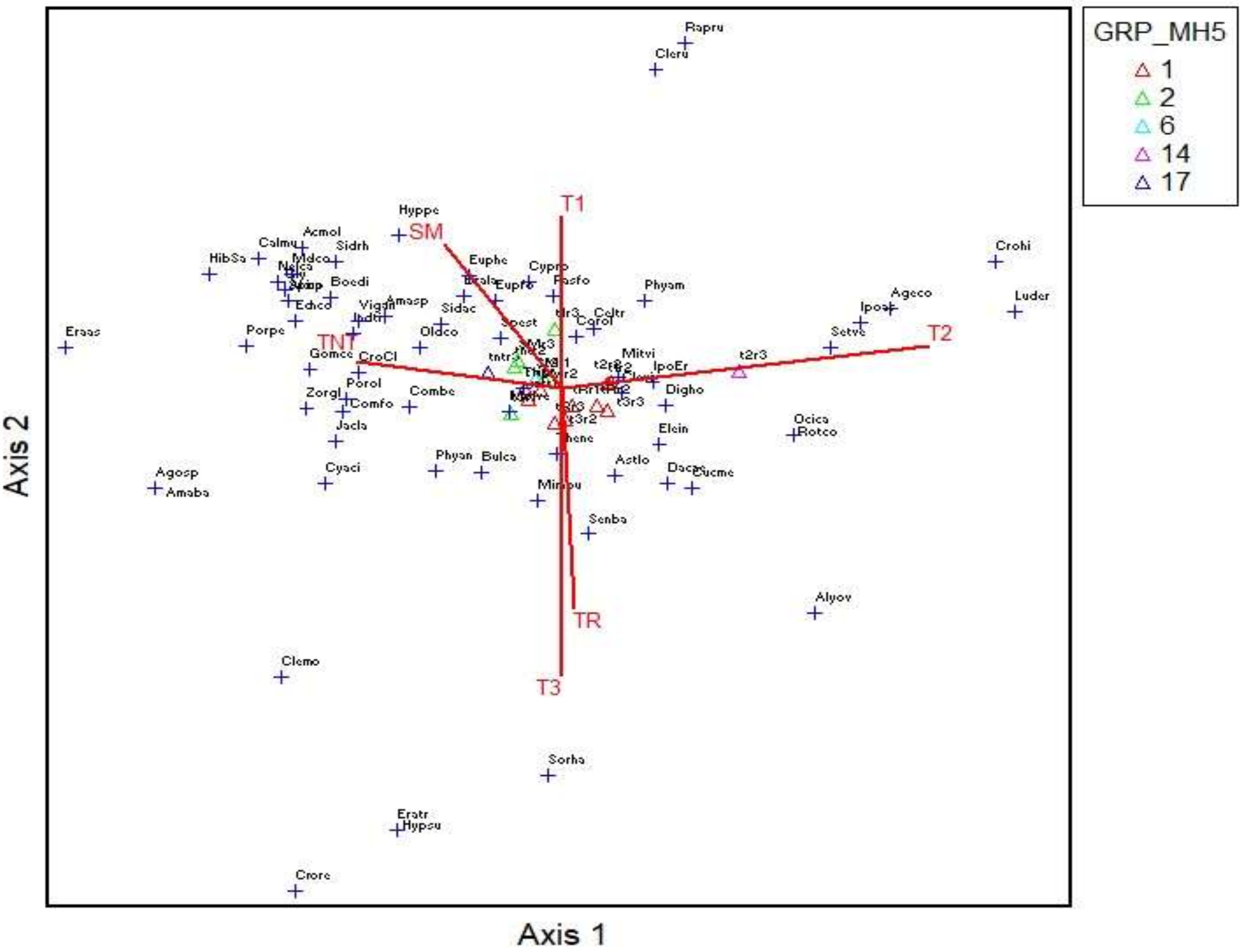

Figure 4: Distribution of weed species inventoried according to treatments

Efficacy of Triclopyr 480 g/L on weeds

Weed coverage on the ground after Triclopyr 480 g/L application was determined according to treatments at 0, 15 and 30 days after treatment (JAT) (table 5). Analysis of variance revealed that there was no significant difference (P>0.05) between treatment means at 0 DAT. The average recovery rate at this date was 70.8%. However, at 15 DAT, there was a significant difference (P<0.05) between treatments. Indeed, the lowest recovery rate (5%) was observed with the hand weeding treatment (SAR- M) and the highest (78.3%) was observed with the non-weeding treatment (TNT) (table 6). Treatments based on Triclopyr 480 g/l (1.5, 2 and 2.66 l/ha) formed a statistically homogeneous group at 15 JAT with the reference control 2,4-D amine 720 SL (4 l/ha), with a coverage rate significantly lower than that of TNT (78.3%). At 30 JAT, the same trends are observed, but the herbicide treatments and the SAR-M control are statistically similar.

The efficacy of Triclopyr 480 g/l was determined at 15 and 30 Days After Treatment (DAT) (table 7). The results show a significant difference (P<0.05) between treatments at 15 DAT. Triclopyr 480 g/l (1.5 l/ha) had the lowest efficacy (64.8%) and Triclopyr 480 g/l (2.66 l/ha) the highest (89.1%). At 30 JAT, there was no significant difference between herbicide treatments, but there was a reduction in the percentage of average efficacy (58.24%).

Table 5: Average weed cover at 0 and 15 days according to weeding method, Bérégadougou, 2022 wet season

Treatments	Active compound (g/l)	Doses (l/ha)	Coverage rate (%)		
			0 JAT	15 JAT	30 JAT
T1	Triclopyr 480 g/l	1,5	68,33 ± 7,63	43,33[b] ±15,27	50,00[a] ±13,22
T2	Triclopyr 480 g/l	2	71,66±2,88	36,66[b] ± 5,77	41,66[a] ± 7,63
T3	Triclopyr 480 g/l	2,66	73,33 ± 5,77	40,00[b] ± 0,00	41,66[a] ±10,40
TR	2,4 D Amine 720 g/l	4	71,66 ± 7,63	40,00[b] ±0,00	48,33[a] ±2,88
TNT		-	66,66 ±5,77	78,33[c] ± 7,63	100,00[b] ± 0,0
S-M		-	73,33 ±12,58	5,00[a] ± 0,00	35,00[a] ±13,22
Average			70,83	40,56	52,78
Pr > F			0,849	0,00000217	0,0000229
Significance			*NS*	*THS*	*THS*

Legend: NS: not significant; THS: very highly significant

Table 6: Efficacy of weed control methods at 15 and 30 JAT in Bérégadougou, 2022 dry season

Treatments	Active compound (g/l)	Doses (l/ha)	Efficacy (%)	
			15 JAT	30 JAT
T1	Triclopyr 480	1,5	64,83[a] ±15,98	51,78[ab] ± 20,015
T2	Triclopyr 480	2	85,58[a] ±1,98	53,45[ab] ± 14,51
T3	Triclopyr 480	2,66	89,07[a] ± 5,56	55,19[ab] ± 7,60
TR	2,4 D Amine 720	1	82,39[a] ± 2,62	47,93[ab] ± 5,97
SAR-M	-	-	97,93[b] ± 0,48	82,858[b] ± 5,61
Average			84,76	58,24
Pr > F			0,00154	0,0343
Significance			*HS*	*HS*

Legende: HS : hautement significative

Effect of weed Management Treatments on Sugarcane Yields

The average yields obtained were 83.17 t/ha for the manual weeding treatment and 60.38 t/ha for Triclopyr 480 g/l at 1.5 l/ha, i.e. a difference of 22.8 t/ha (figure 7). Increasing the Triclopyr 480 dose to 2 and 2.66 l/ha per hectare reduced this difference by 18 and 13 t/ha respectively.

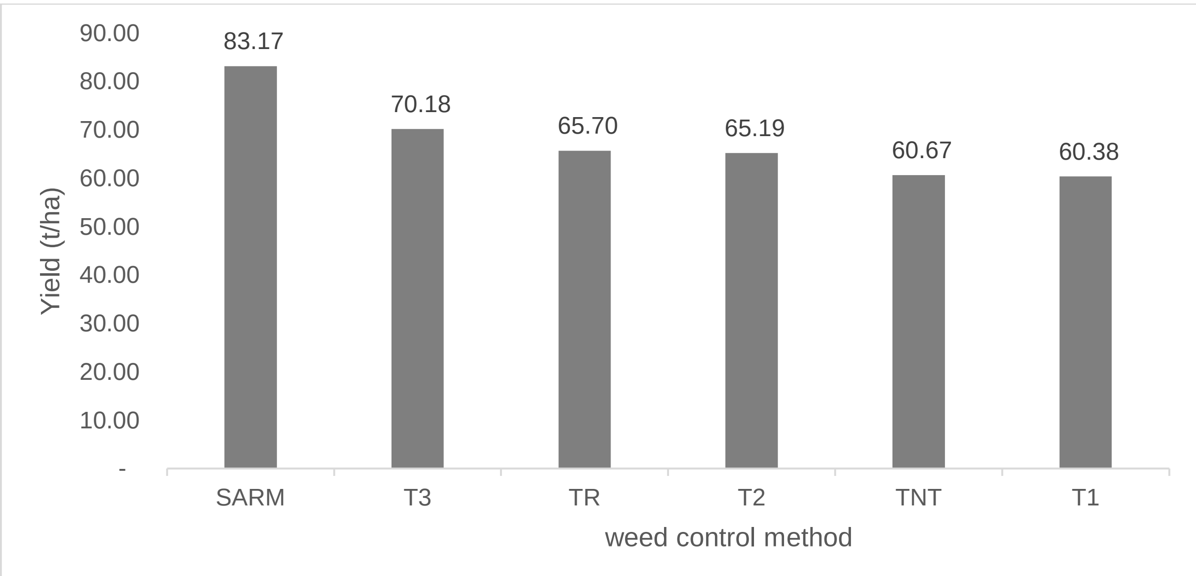

Figure 7: Average sugarcane yield (t/ha) according to weed control method

Discussion

The floristic inventory carried out before and after herbicide treatment identified 40 species, 17 of which had a species richness of at least 1 individual per m². All the species inventoried belonged to 18 botanical families. Lebreton (2010) and Boraud (2000) counted 155 and 234 species in sugarcane plots in Réunion and Sudan respectively. This difference in diversity and species richness could be explained by SN SOSUCO's cultivation system, based on water control and intensive use of herbicides. Indeed, cropping systems influence the diversity and dynamics of weed communities (Sanou*, et al.*, 2019). In terms of botanical families, Poaceae, Fabaceae, Euphorbiaceae, Amarantaceae, Malvaceae and Convolvulaceae are the most dominant. These results are similar to those of Lebreton (2010) and Boraud (2000), who ranked these families among the most representative of sugarcane plots and several other agrosystems (Melakhessou*, et al*., 2020). These three families have also been identified among the top three in other agrosystems such as cassava production (Mango*, et al*., 2022).

The dicotyledon class is the most dominant, in proportions similar to those obtained by Tialou*, et al*., (2021), who showed the dominance of dicotyledons (69%) over all the species inventoried on sugarcane crops in Côte d'Ivoire. This dominance of dicotyledons is probably linked to the effect of tillage, which is much less favourable to the development of monocotyledons (Traoré*, et al*., 2010).

The specific diversity index showed a decrease in species at 15 days after treatment (DAT). After 15 DAT, an increase in the number of species was observed. The persistence of 2,4 D-amine would therefore be between 0 and 15 JAT. The similarity coefficients were all above 50 %, which means that the weed species in the different sugarcane crop cycles are mainly the same. These results corroborate those of Guinochet (1973), Boraud (2000) and Aman (1978), who suggest that sugarcane plots probably have a relatively large common core of weed species. In addition, more than 60% of species at different sugarcane production cycles are identical (Boraud, 2000; Traoré*, et al*., 2014). The similarity of weeds emerging in the plots of the different treatments could be explained by the intensive and regular use of herbicides, which have probably reduced the floristic contingents through the phenomenon of weed selection, to such an extent that the flora is little diversified (Mangara*, et al*., 2010). The floristic homogeneity between the different replicates could also be explained by the monoculture of the sugarcane cultivation system (Tialou*, et al*., 2021).

Results obtained on the effect of herbicide doses on weed infestation showed that Triclopyr 480 g/L EC (2 l/ha and 2.66 l/ha) and 2,4-D amine 720 SL efficiently reduced the density of 12 species 15 JAT. These species include *Commelina benghalensis* L, *Cucumis melo* L, *Croton hirtus* L., *Portulaca oleracea* L., *Hyptis suaveolens* Poit, *Physalis angulata* L., *Vigna unguiculata* L., *Ipomoea eriocarpa* R., *Ipomoea asarifolia* D., *Cleome rutidosperma* DC, *Euphorbia heterophylla* L. Martin*, et al*. (2012) have also demonstrated the efficacy of these herbicide doses on lianescent species. Indeed, they noted that restricting the use of Triclopyr-based herbicides in sugarcane plantations once again favored the development of *Ipomea* spp. and *Passiflora foetida* L. Triclopyr 480 g/L EC is reported to be persistently effective on Physalis angulata L and Croton hirtus L for up to 30 days. Some monocotyledons (*Commelina benghalensis* L.) were particularly sensitive to 2,4-D amine 720 SL. However, triclopyr 480 g/L EC acted preferentially on broadleaf weeds at 2 l/ha and 2.66 l/ha.

These results are similar to those of Terry (1983), who reported that certain Monocotyledon weeds such as *Commelina benghalensis* L, *Cyperus rotondus* L, were resistant to Triclopyr at doses of 300 g/ha and 480 g/ha.

Herbicide doses based on triclopyr 480 g/L EC had a low efficacy on certain species whose numbers increased during the different floristic inventories. These were mainly *Dactyloctenium aegyptium* L., *Digitaria horizontalis* W., *Eleusine indica* G., *Brachiaria lata* L. These species represent 75% of the species tolerant to the doses of Triclopyr 480g/L EC herbicides applied. Nevertheless, we note that the Triclopyr 480 g/L EC herbicide at doses of 2 L/ha and 2.66 L/ha considerably reduced weed cover compared with the grassed control.

This reduction in weed coverage is explained by the reduced density of weeds affected by the chemicals used, i.e. Triclopyr 480g/L EC and 2,4-D amine 720 SL. However, there was an increase in coverage between 15 and 30 JAT for Triclopyr 480g/L EC and 2,4-D amine 720 SL. Due to the herbicides' limited spectrum of efficacy, an increase in recovery rate can be observed (Mangara, *et al*., 2014). This increase in weed coverage from 30 JAT suggests that the herbicides would be persistent for at least 15 days. Indeed, the percentage efficacy of Triclopyr 480 g/L EC at the different doses tested is acceptable up to 15 JAT and very low from 30 JAT.

The efficacy of these herbicides, although not taking into account the phytotoxicity data of the active compounds evaluated, allowed a significant improvement in sugarcane productivity. Manual weeding with the hoe was more effective than herbicide treatments. This could be explained by the elimination of species resistant to chemical treatments by manual weeding (Terry, 1983). The two doses of 2 l/ha and 2.66 l/ha of Triclopyr 480 g/L EC respectively gave an average yield gain of 4.5 and 9.5 t/ha compared with the non-weeded control.

Conclusion

Sugarcane production is severely limited by several constraints, the most important of which is weed infestation. The floristic inventory carried out before and after herbicide treatment revealed a total of 40 species in 18 botanical families. The two botanical families with the highest number of species were *Poaceae* and *Euphorbiaceae*. The dicotyledon class was the most dominant. The results show that different doses of Triclopyr 480 g/L EC and 2,4-D amine 720 SL significantly reduced weed coverage. Triclopyr 480 g/L EC was more effective on 72% of dicotyledons and 28% of monocotyledons. However, due to its limited spectrum of efficacy and the limited duration of its persistence, it would be useful to develop cultural practices that improve the chemical's efficacy, in particular the use of organic matter and the reduction of drift during chemical application.

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