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An Assessment of the Impact of Glyphosate and 2,4-D Amine Salt on Weeds in Niger

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Abstract: An experiment was carried out to investigate the efficacy of two herbicides, viz., glyphosate and 2,4-D amine salt at varying doses for the control of the main noxious weeds. The lowest application rate (0.5l per ha of 2,4-D and 2l per ha of glyphosate) of both herbicides gave a control of shoot growth and drastically reduced the green biomass compared to unweeded plots at different time intervals after the application. There was no re-growth up to nine days after spraying in all treated plots. The highest control of the density of noxious weeds has been obtained with 2,4-D amine salt at the dose of 1.5 l per ha and glyphosate at the dose of 4l per ha in six days after treatment; the reduction rate was more than 85%. Data on green biomass also showed drastic reduction following herbicide application.

Key words: Assessment, glyphosate, impact, Niger, weeds, 2,4-D amine salt

INTRODUCTION

Agriculture is the major occupation for most of the countries in the Sahel, especially in Niger. It contributes for 41% of the GDP and occupies 85% of the rural population (SRD, 2003). Farming occupies nearly 27% of this rural GDP (SRD, 2003). Main subsistence crops are millet, sorghum, bean, corn and rice cultivated mainly along the river and in certain valleys. The main part of this agricultural production is intended for the autoconsumption. Despite, the agronomic, technical, and climatic constraints, these crops are subject to diverse parasitic pressures. These factors seriously affect the harvest and decrease the yield. Chemicals are used to address these bioagressors.

Noxious weeds are among the major problem for crops in the Sahel, and they contribute to depreciate the harvest quantitatively and qualitatively. The weed should be considered as the worst enemy of farmers in Sahel. Weeds species have the potential to negatively impact crop plant species, including biodiversity reduction (Lodge, 1993; Woods, 1997), alteration of community structure, function, and composition (Woods, 1997), and changes in dynamic community properties (Huenneke and Mooney, 1989).

In addition, heavy infestations not only limit human use of water resources (fishing, boating, irrigation) but can also negatively impact the ecology of water bodies by restricting light penetration, degrading water quality (increased of BOD, COD and pH), and reducing valuable native plant and animal habitat and biodiversity (Thomas and Room, 1986; Oliver 1993; McFarland *et al.*, 2004) . Weeds are one of the leading problems in Niger Agriculture; they are responsible of substantial losses of farm production and extensive damage tm the environment. According to the Australia Cooperative Center of Research for Weed Management Systems has estimated the economic costs of weeds to exceed 3 billion annually dollars in terms of reduced productivity and the cost of weed control (Townsend and Sinden, 1999). The economic losses can be even more colossal if we consider that more than half of the time spend by farmers in fields is dedicated to the control. It follows that if the farmers want to increase their productivity, one of the first things to do is to improve the weed control. And nowhere is it truer than in Africa, where the weeds are a main cause of productions stagnation. The effects farming on the weeds are particularly difficult to analyze because the processes to be taken into account are complex, the range of possible variability and their interactions. Furthermore, those seeds of weeds, with high life expectancy in the ground, constitute an initial seed stock. The dynamic of those seeds depends on the history of the practices of the previous years (Rasmussen *et al.*, 2002). There are several methods toward weeds; for example numerous mechanical and cultural control options have been developed in order to manage noxious rangeland weeds, including mowing, prescribed burning and timely grazing. In addition, many herbicides are registered for weeding. This study aims to evaluate the biocide effect of glyphosate and 2,4-D amine salt on the density and green biomass of weeds. The theme was chosen, because the data of impact of these herbicides on *Cynodon dactylon* and *Cyperus rotundus* and on this agricultural ecosystem are rather rare even non-existent in Niger.

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MATERIALS AND METHODS

Experimental site and design: The field trial was carried out in the suburban district of Tillabéri (14º25′71 N, 01º42′27 W), in the Northwest of Niamey, in the "canton" of Sakoira. The suburban district of Tillabéri is 104 245 km² (Larwanou *et al*., 2005). This area is choosen because the noxious weeds were a main problem to agriculture. The region of Tillabéri belongs to the Sahelian savannah. The annual rainfall recorded in 2009 by the synoptic station of Tillabéri is 259.8 mm. The main part of the rainfall was recorded between July and August; these two months represent 52% of the total rainfall. During the field monitoring from 12 to 25 July, no rain was recorded. The temperature ranged from 32 to 38ºC. The experimental design used is a complete random block (CRB). The distance between blocks is 10 m and 10 m between the experimental units which are squares of 25 m². Nine treatments were carried: 1) Glyphosate 41 % at the amount of 2 l per ha (Glyph1); 2) Glyphosate 41 % at the dose of 3 l per ha (Glyph2); 3) Glyphosate 41 % at the dose of 4l per ha (Glyph3); 4) 2,4-D amine 720 g/L SL at the dose of 0.5l per ha (2,4-D1); 5) 2,4-D amine 720 g/L SL at the dose of 1l per ha (2,4-D2); 6) 2,4-D amine 720 g/L SL at the dose of 1.5l per ha (2,4-D3); 7) Londax (Bensulfuron methyl) at 80 g/ha ; 8) Kalach 360 SL (Glyphosate 360 g/L) at the dose of kg/ha and 9) the control. The Londax (selective) and Kalach (nondiscriminatory herbicide) are the references.

Treatment: The Glyphosate and 2,4-D amine salt (aqueous herbicidal solution) were applied in total coverage using standard equipment EC application. For this, the spray volume was worked out after calibration and the herbicide quantities were calculated as per the experiment protocol. The emission height is 50 cm. Treatments are made on weeds at the advanced stage. All the treatments were made between 8-10 am while temperature is lower than 35ºC, and the wind speed ranged between 1.5-2 m/s.

The nominal doses recommended by the firm were really applied (nominal doses = real doses). This experimental protocol was developed according to the specific protocol for the biological evaluation of weed of the Sahelian Committee of Pesticides.

Effect of Glyphosate and 2,4-D amine salt effect on weeds: The follow-up of the weed density is made before (these observations are essentially intended to be able to arrange numbers of information related to the different experimental plots pre-spray) (Day 0) and after the treatments: 3 DAT (three days after treatment), 6 DAT (six days after treatment) and 9 DAT (nine days after treatment). In each interval of time, we assess in all experimental plots the density of weed (plants per m^2). The evaluation of the density is made along diagonals on 3 sampling points (1m²); the distance of sampling points is 1 m (Fried, 2007, modified). The assessment is made in 1m borders of the plot of land to avoid interferences, and for 1 m of the center to avoid its effect. It is worth noting that any weed presenting necrosis or other symptoms due to the herbicide, is not taken into account in the density assessment. With the aim of strengthening the method of weed estimation, we coupled with the first method; a second sampling method which consisted in launching three times at random in every elementary plot of 1 m² quadrat placed on the ground and counting the number of plants (Gleason, 1920; Mosley *et al*., 1989; Sorrells and Glenn, 1991). Before spraying, we first verified the density of weeds in all experimental plots, to see if our elementary plots are homogeneous or not before the trial.

Assessment of the weeds green biomass: The weeds green biomass (g/m^2) is calculated before (Day 0) and after treatment (6 DAT). In each plot, 3 quadrats were randomly chosen for sampling. In every quadrat (1 m²), all the weed is noted, washed there delicately abundantly in the tap water to clear the ground, and weighed. We only sampled the most widely distributed species.

Data analysis: The analysis of the variance (ANOVA) was applied followed by Student-Newman-Keuls multiple comparison of means if the null hypothesis is rejected at $\alpha \leq 0.05$. The statistical comparison is based on the BACI method (Before- After- Control- Impact) (Stewart-Oaten *et al*., 1992, 2002; Underwood *et al.* 1991, 1992, 1994; Bence *et al*., 1996). The values expressed in absolute numbers were transformed by the relation y = $\sqrt{x + 3/8}$ to homogenize the variances and insure a normality of the distributions unbalanced towards the right (Sokal and Rholf, 1981, 1995). We use Minitab 14.0 software for data analysis.

RESULTS AND DISCUSSION

Weed density pre-spray: Before spraying, we estimated the level of infestation in all experimental plots, in order to verify the homogeneity of our sites. The statistical analysis of the results reveals that there is no significant difference between the experimental plots composing the site which received 2,4-D amine salt (p>0.05); this is the same for the site treated with the glyphosate; all the sites are homogenous before the spraying.

Effect of Glyphosate on the weeds density: Figure 1 indicates the structure and composition of noxious weeds in the Site 1, which received the Glyphosate treatment. The Fig. 2 demonstrates that the Glyphosate had a harmful effect on the main weed. Three days after treatment, high density reduction is observed in all herbicide treated experimental plots compared to the unweeded plots. All glyphosate and 2,4-D-treated plants

Table 1: Mean of rate reduction (±SE) of weeds density after the spraying of the glyphosate

	Treatments				
Day after spraying	2l per ha	3l per ha	4l per ha	Kalach*	Control
3 DAT	49.96^{b}±3.09	59.32^{b}±6.42	72.50^{a}±2.87	53.94^{b}±2.52	5.77^{c}±3.02
6 DAT	81.28^{b}±3.76	87.42^{b}±3.57	91.73^{a}±2.87	84.70^{b}±2.57	19.07^{c}±2.99

Values (mean±SD; N = 24) not sharing the same letter is significantly different (p <0.05), *: reference herbicide

Table 2: Mean of reduction rate (±SE) of weeds density after the 2,4-D spray

	Treatment				
Day after spraying	0.5l per ha	1l per ha	1.5 per ha	Londax*	Control
3 DAT	34.47^{a}±1.98	36.76^{a}±10.56	60.34^{b}±5.87	9.93^{c}±11.32	10.95^{c}±3.88
6 DAT	66.16^{b}±2.82	91.11^{a}±0.28	95.33^{a}±0.20	25.16^{c}±8.23	3.85^{d}±8.65

Values (mean±SD; N = 24) not sharing the same letter is significantly different (p<0.05), *: reference herbicide

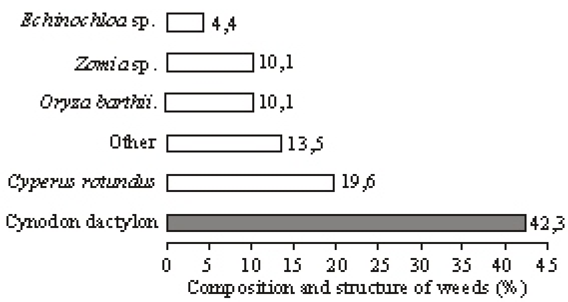

Fig. 1: Composition and structure of noxious weeds in the site treated by Glyphosate

displayed herbicide injury symptoms following chemical application. Yellowing and burning, were noted on 18 to 40% of plant tissues as early as 3 DAT. Symptoms progressed over time for all glyphosate and 2,4-D treatments. At 3 DAT, the weed reduction rate obtained accordingly to the control are respectively 49.96±3.09% for Glyphosate at the dose of 2l per ha; 59.32±6.42% for the glyphosate at the dose of 3l per ha; 72.50±2.87% for the glyphosate at the 4l per ha and 53.94±2.52% for the kalach (reference) (Fig. 2; Table 1). This density continued to increase and reach more than 80% at 6 DAT (Fig. 2; Table 1). At 9 DAT, the experiment was stopped especially because there were no weeds in the glyphosate-treated plots compared to the control. Regarding the impact of glyphosate on noxious weeds, our results agree with findings by Ssegawa (2007); he obtained 55% of reduction on weeds density after spraying of glyphosate. The negative impact of glyphosate was also recorded by Nelson *et al.* (2001), their results of outdoor herbicide trials showed that 8.97 kg/ha glyphosate mixed with a nonionic surfactant, controlled 99% of giant salvinia 42 days after treatment. In the USA, Nelson *et al.* (2007) demonstrated that 14 DAT, treatment with either 4.48 or 8.96 kg/ha glyphosate controlled 82.5 to 94% of giant salvinia whereas 2.24 kg/ha glyphosate controlled only 65 to 68% of sprayed plants. In laboratory studies, Fairchild *et al.* (2002) reported significant control of giant salvinia following glyphosate application over a broad range of rates (0.45 to 3.60% solution mixed). Thakur *et al.* (1993) also observed that glyphosate and 2,4-D (1.0 and 1.5 kg/ha) killed purple nutsedge and checked regeneration up to 360 days after spraying.

The statistical analysis at 3 DAT showed that treatments are significant $F(4/10) = 25.21$ $p = 0.001$. According to the Test of Sudent-Newman-Keuls, the glyphosate applied to the dose of 4l per ha was classified in a homogeneous group, treatments glyphosate in the dose of 3l per ha, glyphosate at the dose of 2l per ha and the kalach (reference herbicide) were grouped in the same homogeneous class, thus they have a rather similar behavior towards noxious weeds according to our results; the control is in another different class. With regard to efficiency, we note that the glyphosate at the dose of 4l per ha reduced drastically the weeds density compared to the other doses. At 6 DAT, they are the same observations as previously.

Effect of 2,4-D on the weeds density: The main noxious weeds of site 2 are illustrated in the Fig. 3. The Fig. 4 shows that different application rate of 2,4-D can be used as chemical weed killer specially for *Cyperus rotundus* in particular according to the control. At 3 DAT, we note a high density reduction in any treated experimental plots, compared to the unweeded check where this density increased. The density reduction at 3 DAT, was 34.47±1.98% for 2,4-D applied at 0.5l per ha; 36.76±10.52% at 1l per ha and 60.34±5.87% at 1.5l per ha, while we noted with the londax a rate of 10.95±3.88% reduction (Table 2). At 6 DAT, the rates were respectively 66.16±2.82% with 2,4 D1 (2,4-D at the dose of 0.5l per ha); 91.11±0.28% for 2,4 D2 (2,4-D at the dose of 1l per ha), and 95.33±0.20% for 2,4 D3 (2,4-D at the dose of 1.5l per ha) (Table 2). These results conform well with previous studies conducted by Sheley *et al.* (2004) in the USA, about a significant effect of 2,4-D on the noxious weeds. Jonathan *et al.* (2004) noted a significant density reduction of the weeds after application of 2,4-D at 1.6 kg/ha and the sugarcane yields were greater compared to the unweeded check. Our study confirms several studies (Hammerton, 1974; Hawton *et al.*, 1992; Ameena and

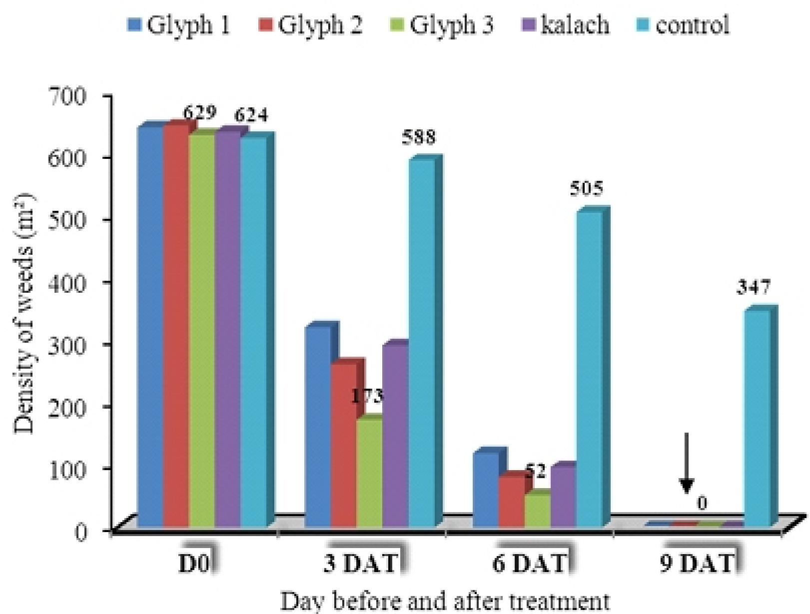

Fig. 2: Effect of glyphosate on the density of weeds before and after treatment. The arrow indicates the day after treatment where the density is null. The Fig. 1 denotes the density of noxious weeds in the treated plots with 4l per ha of glyphosate and the untreated plots

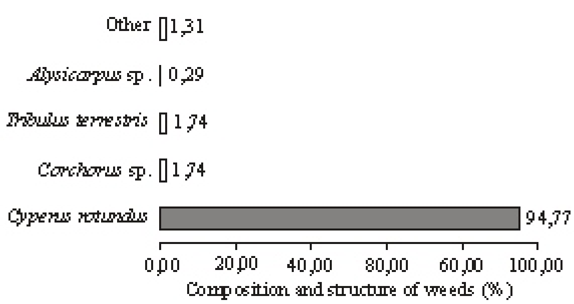

Fig. 3: Composition and structure of noxious weeds in the site treated by 2,4-D amine salt

Sansamma, 2004) on the negative impact of 2,4-D on Nutgrass (*Cyperus rotundus*).

Three days after spraying, there was significant treatment effect on the density $F(4/10) = 40.85$ p = 0,001. According to the Test of Sudent-Newman-Keuls (SNK), 2,4-D applied at the dose of 0.5l and 1 L/ha were classified in a homogeneous group, so no significant difference between these two doses; treatments 2,4 D at the dose of 1.5l per ha belongs to a different class; the londax (reference product) and the control were grouped in the same homogeneous class, thus they have a rather similar behavior towards weed. In terms of efficiency, we note the dominance of 2,4-D at the dose of 1.5l per ha compared to the other application rate. At 6 DAT, the data analysis shows a significant difference of treatments on weed density $F(4/10) = 429.80$ p = 0.001. The SNK test grouped 2,4-D at the dose of 1l per ha and 2,4-D at the dose of 1.5l per ha in the same homogeneous class; the control, the londax and the 2,4 D at application rate of 0.5 l per ha belong to three different groups.

Table 3: Impact of 2,4-D on green biomass of *Cyperus rotundus* after spraying

Treatments	3 DAT	6 DAT
Control	$0.48^{a}\pm1.11$	$12.04^{a}\pm0.19$
2,4-D at 0.5l per ha	$1.37^{b}\pm3.41$	$40.43^{b}\pm1.24$
2,4-D at 1l per ha	$16.91^{c}\pm0.23$	$77.83^{c}\pm4.15$
2,4-D at 1.5l per ha	$35.21^{d}\pm2.15$	$90.94^{d}\pm3.32$
Londax	$4.13^{e}\pm3.17$	$7.28^{e}\pm0.18$

Values (mean±SD; N = 36) not sharing the same letter are significantly different (p<0.05)

According to our results, the highest reduction is observed with the application rate of 1 L/ha as well as 1.5l per ha. The londax had no considerable effect on *Cyperus rotundus,* the most dominant noxious weed. Also the experiment was stopped at 9 DAT, because the density of weeds in the 2,4-D-treated plots is very low compared to control plots.

Effect of 2,4-D on the green biomass of weeds: Figure 5 indicates the effect of the various doses of 2,4-D amine salt on the green biomass at different time intervals. From 3 DAT to 6 DAT, we observed a decay of the green biomass in the treated plots compared to the control where this biomass increased. The strongest reductions were noted at 6 DAT, but the 2,4-D at the dose of 1,5l per ha gave strongest reduction. The londax had no effect on the green biomass compared to the various application rate of 2,4-D. With regard to day 0 values and by making a correction, we observe in Table 3 that the strong reduction

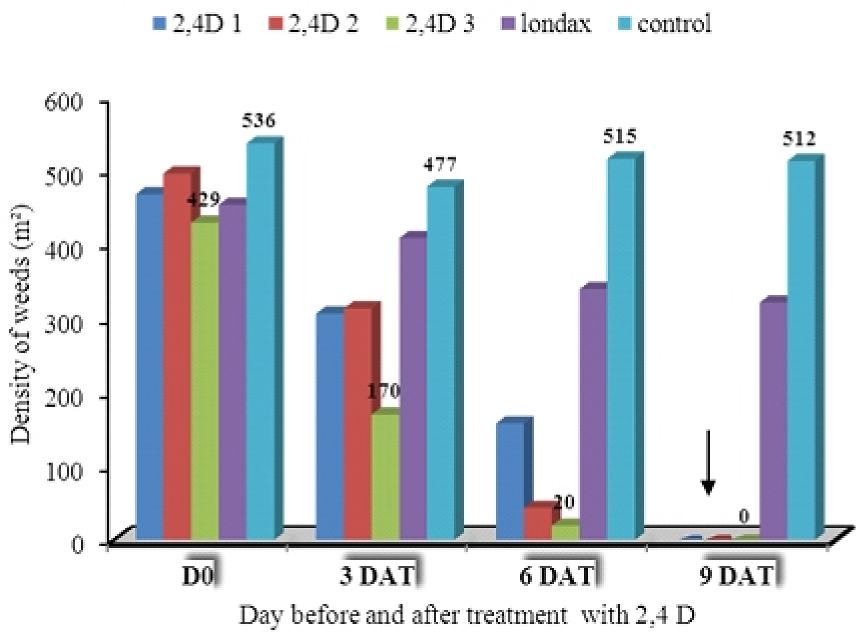

Fig. 4: Effect of 2,4-D on the weeds density before and after treatment. The arrow indicates the day after treatment where the density is null. The Fig. 3 denotes the density of noxious weeds in the treated plots with 2,4-D at 1.5l per ha and in the untreated plots

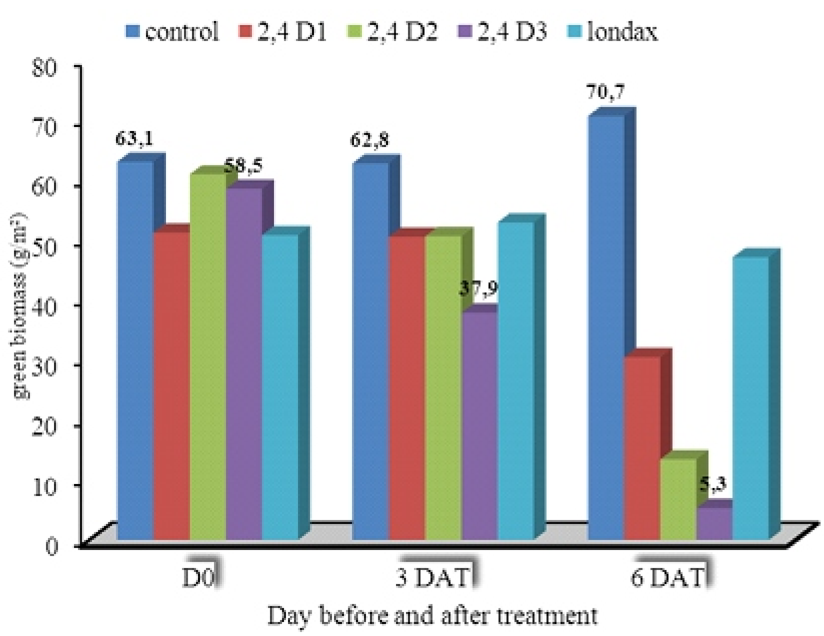

Fig. 5: Effect of 2,4-D on green biomass of *Cyperus rotundus* before and after treatment. The number above the figure denotes the density of noxious weeds in the treated plots with 2,4-D at 1.5l per ha (2,4 D3) and in the untreated plots

rate of the biomass was noted in 6 DAT. And so we obtained a reduction of 90.94±3.32% of the green biomass with the 2,4-D at the dose of 1.5l per ha; 77.83±4.15% with the dose of 1 L/ha and 40.43±1.24% with the dose of 0.5l per ha. This conclusion supports the results of Beerlin (1990), he noted that two weeks after treatments with Gylphosate and 2,4-D amine salt, the biomass and leaf area ratio of shoots in all treated

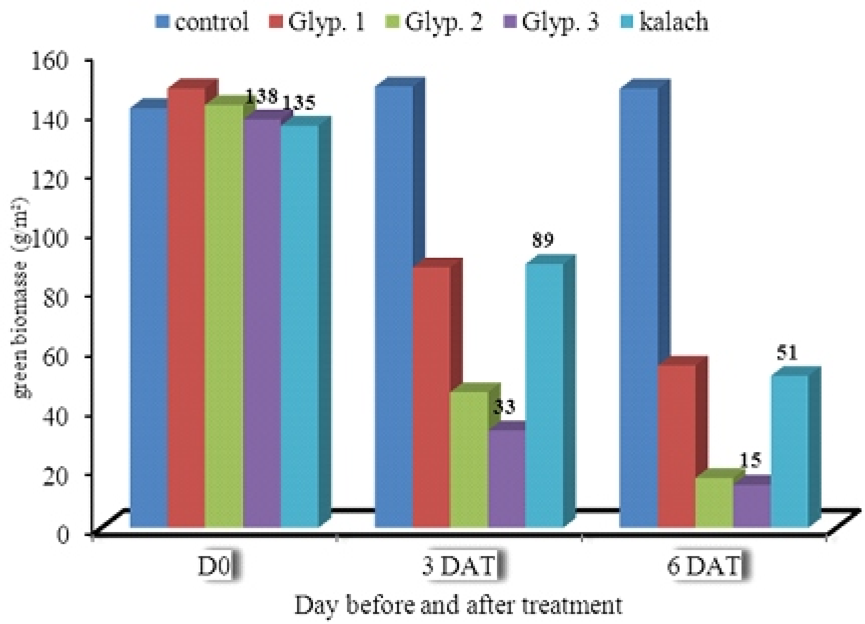

Fig. 6: Effect of glyphosate on green biomass of *Cynodon dactylon* before and after treatment. The number above the figure denotes the density of noxious weeds in the treated plots with glyphosate at 4l per ha (Glyp. 3) and in the untreated plots

Table 4: Impact of 2,4-D on green biomass of *Cynodon dactylon* after spraying

Treatments	3 DAT	6 DAT
Control	$5.17^{a}\pm0.74$	$4.67^{a}\pm1.41$
Glyphosate at 2l per ha	$40.77^{b}\pm2.17$	$63.02^{b}\pm3.14$
Glyphosate at 3l per ha	$67.82^{c}\pm4.14$	$88.19^{c}\pm0.87$
Glyphosate at 4l per ha	$76.13^{d}\pm0.75$	$89.45^{c}\pm5.11$
Kalach	$34.21^{b}\pm3.33$	$62.12^{b}\pm0.27$

Values (mean± SD; N = 36) not sharing the same letter are significantly different ($p<0.05$)

plots was depressed. Stephen *et al.* (2005) demonstrated that 2,4-D amine salt had a drastic effect on *Acroptilon repens* bioamss.

Effect Glyphosate on the green biomass of weeds: Figure 6 shows the effect of the various doses of the glyphosate on the green biomass at different intervals. From 3 DAT to 6 DAT, we observed a considerable decrease of the green biomass in the treated plots compared to control where this biomass rather increased. The decreases were noted also at 6 DAT. Table 4 indicates that the strong biomass reduction rates were noted at 6 DAT. A reduction of 89.45±5.11% of the green biomass with the treatment glyphosate at the dose of 4l per ha, 88.19±0.87% with the dose of 3l per ha and 63.02±3.14 % with the dose of 02l per ha. In the same interval, we noted an increase of the green biomass in the control.

CONCLUSION

We asserted in the introduction to the present view that several herbicides were registered to control the weeds. Hopefully, we have now justified this assertion. Towards these results, it emerges first of all that the various experimental units are homogeneous (density of weed) according to infestation by weed before treatments. The most dominant weeds are *Cyperus rotundus* and *Cynodon dactylon*. After the application of herbicides, we note that these increase the density of weeds and their green biomass. In regard of the foregoing, we can say that in our trial conditions, Glyphosate (nondiscriminatory herbicide) and 2,4-D amine salt (selective herbicide) proved to be interesting because they had an undeniable deleteriously effect on the main noxious weeds. Although all rates of glyphosate and 2,4-D provided significant control of weeds compared to untreated plants, the high rate was the most effective treatment. The use of lower chemical rates would be more economical, increase treatment efficiency, and minimize chemical inputs into the environment. We can conclude from these finding that *Cyperus rotundus* and *Cynodon dactylon* were very sensitive to glyphosate and 2,4-D amine salt.

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