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Effects on Plant Species Composition of Glyphosate Application in a Plantain System after Secondary Forest Clearing

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Abstract

Weed control is a major challenge in African smallholder agriculture. In long-term crops, particularly those planted at low densities, such as plantain (*Musa* spp. group ABB) weed control is virtually absent and has received little research attention. Plantain is dominantly grown after slash and burn of old secondary forest, where little weed growth occurs in the first year. Declining availability of such land and increasing pressure of invasive weeds requires changing plantain management. Plantain is the most important food cash crop in Cameroon and large parts of the Congo basin. This study evaluates how herbicide use affects the species composition in a plantain field established in young secondary forest.
Plant species were determined in plantain plots and sub-plots were either slashed or treated once or twice with 6 l ha-1 Roundup. Species' survival was determined at 10, 20, and 30 days after treatment (DAT). The forest around the site, sampled as a control had 154 species. At 14 months after planting 171 species were identified in plots to be slashed and 182 species in plots to be treated with herbicide. Survival at 30 DAT, following single herbicide application ranged from 13 to 25 %. When treated twice, survival was 32% ($p < 0.001$ compared to single treatment). Slashing caused the disappearance of 12 species (equivalent to 97% survival). About 100 DAT, 159 and 139 species were identified in slashed and sprayed plots, respectively, representing 97 and 76% of the initial number of species. When herbicide was used at 17 months after planting, species numbers increased by about 20% over the following 5 months, when treated once and when treated twice. Weeds were classified by their response to herbicide into highly susceptible: died within 10 DAT, 40 spp., 25–28%; susceptible: died within 10–30 DAT, 53 spp., 34–36%; tolerant: showed symptoms but recovered, 54 spp., 32–35%; resistant: showed no symptoms, 8 spp., 4–5 %. All tolerant and resistant species were members of the forest plant community. No typical cropping phase weed was tolerant or resistant. Glyphosate use may retain species communities similar to those found in forests.

Keywords: Glyphosate, plantain, Round-up, secondary forest, species community, survival, weeds

Introduction

Banana and plantain are important staple foods in the East African Great Lakes zone and the West African humid lowlands; they provide more than 25 % of carbohydrates and 10 % of the calories requirements for more than 70 million people (Robinson, 2000). Weed control is a major challenge in African small-holder agriculture. Weeds can cause up to 60-70 % yield loss in banana production through competition with the food crops, as hosts of and provision of niches

for pests and diseases. Weed management is thus an important component in banana production (Akobundu, 1987). Plantain is a long-term crop, it is planted at low densities and weed control is virtually absent and has received little research attention. Plantain, the most important food cash crop in Cameroon, is mainly grown after slash and burn of old secondary forest, where little weed growth occurs in the first year. It thus promotes the conversion of forest to bush and grass land, due to the long phase in which re-growth is slashed and invasive weeds can establish, replacing forest species. Declining availability of such land and increasing pressure of invasive weeds requires changing plantain management. Glyphosate, next to paraquat, is a commonly used herbicide in Cameroon, however, there are no concrete recommendations on its use in plantain and there is no information on how it affects the flora after secondary forest clearing. The invasion of cropped land, specifically by *Chromolaena odorata* and a number of other Asteraceae has lead to delayed or arrested recovery of forest re-growth after cropping. This will in the long term affect plant biodiversity and may compromise future land use options. Although herbicides may have strong negative effects on biodiversity the importance of weed control requires testing the traditional slashing versus herbicide use.
This study evaluates how herbicide use affects the species composition in a plantain field established in young secondary forest.

Materials and methods

The study was conducted at Eloumden, a village situated 4 km South-west of Yaoundé, Cameroon. Eloumden is at 700 m altitude, 3°50.5' N and 11°26.3' E. Secondary forest, fallows and cocoa plantations dominate the landscape. The climate is characterised by bimodal rainfall, with two rainy seasons, the first one from March to July and the second from September to November.
The experimental design was initially a 3 factorial randomised complete block design with five replications. First factor was planting density at 1600 versus 2500 plants ha^{-1}, second factor was fertilizer application at nil versus 120 – 40 – 180 kg ha^{-1} of N, P and K, third factor was weeding method: glyphosate (Roundup®) applied at the rate of 6 l ha^{-1} versus slashing by cutlass. The first glyphosate application in May 2004, as a factor caused severe damage to the plantains because too many plants were small and had leaves close to the floor. The treatment was discontinued and weeding was conducted in all plots with cutlasses until 14 months after planting (MAP). In July 2005 (14 MAP) glyphosate was applied in every plot on an area of 2 times 12 m^2 versus a mechanical slashing on the same area. This treatment was repeated at 17 MAP on one of the areas previously treated and one area where no glyphosate was applied previously.

The response of each weed species to glyphosate was assessed through recording presence or absence of the species before and at 10, 20 or 30 days after herbicide treatment (DAT). The level of damage caused by glyphosate on each species was assessed using a scale ranging from 0 (no damage) to 4 (death of the species).

Species inventories were carried out in the secondary forest around the experimental field and were used as a control. Before and about 100 days after each weeding, a species inventory was also carried out both in the slashed and the sprayed sub-plots in each experimental plot. The aim of these in-farm inventories was to compare the evolution of the species richness following the two weeding methods.

Plantain suckers of the local variety Ebang (Musa spp. Group AAB false horn) were planted in April 2004 after treatment with boiling water against nematodes (30 seconds in water at 100 ºC) (Hauser, this issue).

The data collected were analysed using the GLM procedure in SAS version 8.1. Means were compared by calculating ls means and p diff procedures.

Results

Species richness and composition

154 species grouped into 58 plant families were recorded in the secondary forest surrounding the experimental field. The most frequent families were Euphorbiaceae (11 genera and 11 species), Fabaceae (8 genera and 10 species), and Rubiaceae (9 genera and 9 species). In the experimental field, inventories at 17 MAP showed a decrease in species richness with both weeding methods. Slashing reduced species richness by 7% from 171 to 159 species, whereas the reduction was 24% after glyphosate application, from 182 to 139 species (Figure 1). Five months after the October herbicide application (17 MAP), species numbers had increased by 24 and 20 % in the re-growing communities after one and after two treatments, respectively (Figure 2).

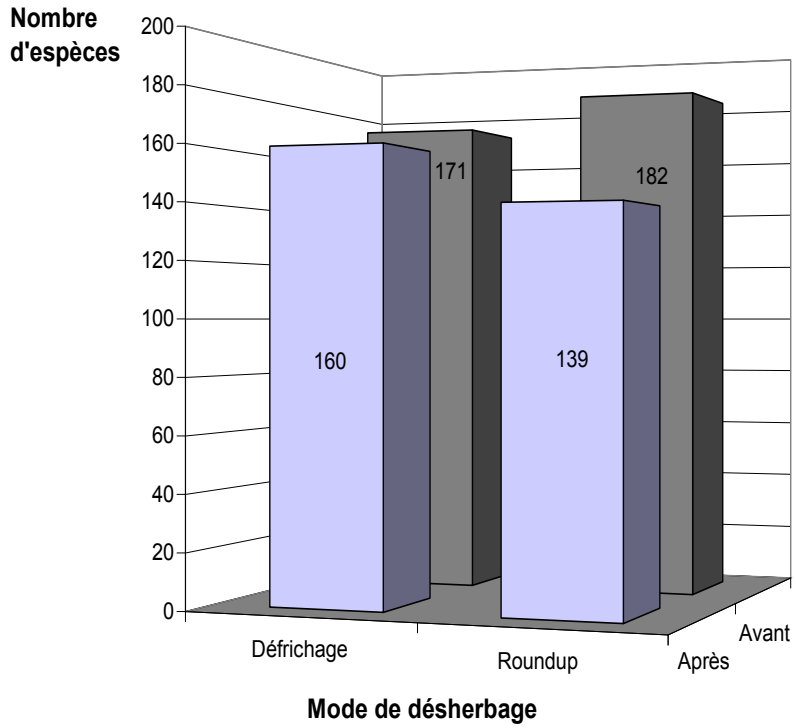

Figure 1. Species richness before and 14 months after weeding in July 2005

Sensitivity of weeds to glyphosate

Mean species survival was higher within the communities treated twice than in those treated once (Table 1). For the communities treated once, mean survival was higher after the treatment in July than after that of October 2005. 30 DAT survivals ranged from 13 to 25 % following single herbicide application, and were 32 % after two treatments ($p < 0.001$ compared to single treatment).

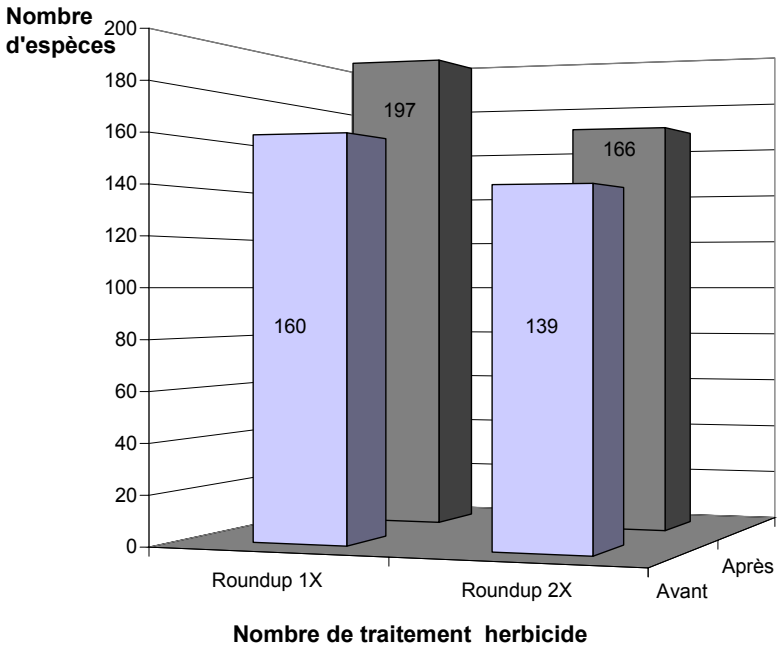

Fig. 2. Species richness before and 5 months after herbicide treatment, in October 2005.

Table 1. Mean weed survival rate (%) following one and two glyphosate treatments.

Glyphosate treatment	Survival (%)		
	10 DAT	20 DAT	30 DAT
Twice (in July and Oct.)	48,61 a	38,43 a	32,01 a
Once (in July)	35,67 b	28,98 b	24,69 b
Once (in October)	22,20 c	16,35 c	13,01 c

Within columns, means labelled with different letters are significantly different at $p < 0.0001$

Weed species, were grouped into four categories of sensitivity to glyphosate: The highly susceptible species which were killed within 10 DAT (e.g. *Ageratum conyzoides, Fleurya ovalifolia, Oxalis barrelieri, Emilia coccinea, Trema orientalis, Momordica cissoides, Physalis angulata, Chromolaena adorata,* etc.) representing 25 to 28 % of the total; the susceptible species, which died within 10 to 30 DAT (e.g. *Paspalum orbiculare, Commelina benghalensis, Pityrogramma calomelanos, Eleusine indica, Setaria barbata, Diodia scandens, Elephantopus mollis,* etc.), representing about 34 to 36 % of the total ; the tolerant species, which were partially damaged but recovered after some time (e.g. *Haumania danckelmaniana, Gnetum africanum, Mallotus oppositifolius, Alchornea cordifolia, Hypselodelphis zenkeriana, Talinum triangulare,* etc.), representing about 32 to 35 % of the total; and the resistant species which showed no symptoms of damage (e.g. *Hippocratea indica, Megaphrynium macrostachyum, Leptonychia multiflora, Baphia* spp., *Claoxylon* sp., etc.) representing about 4 to 5 % of the total (Table 2).

Table 2: Weeds species categories following their sensitivity to glyphosate after the treatment of july and october 2005

	Treatment for the 1st time		Treatment for the 2nd time	
Categories	Total	%	Total	%
Highly susceptible	40	25,48	41	27,7
Susceptible	54	34,39	53	35,81
Tolerant	56	35,67	47	31,76
Resistant	07	4,46	07	4,73
Total	**157**	**100 %**	**148**	**100 %**

Discussion

Evolution of the species richness of the experimental site

A reduction of 73 % in species richness occurred through conversion of forest to a plantain field. The reduction of the number of weed species due to reduced shading has already been reported by Perfecto *et al*. (1996, cited by Gillison, 2004), which is the consequence of increasing competition from aggressive helliophyllic species. In the plantain field, the two weeding methods lead to a reduction of the species richness in the 14 weeks-old succeeding communities, but that reduction was about four times higher after glyphosate action than after slashing. This is probably because unlike slashing, glyphosate being a systemic herbicide totally eliminates some species which rely on vegetative regeneration. The increase in the species richness over 5 months after the October treatment is due to the appearance of new species in the site.

Weed response to glyphosate

After the early treatment with glyphosate in July more resistant weed species were found than after the late treatment in October 2005. This could be due to a greater dominance of typical cropping phase weeds which were all not resistant to glyphosate. The higher dominance of such species should be expected because there was no previous removal of these species as compared to the early treatment. Similarly the higher proportion of resistant species after two treatments (July and October) might be the result of the selection exerted by the herbicide (Darency 1996, cited by Kropff *et al*., 1999).

There was a general tendency in the response type of weeds to the herbicide: the most susceptible weeds were among the invasive species, whereas species that were tolerant or resistant to glyphosate were mostly species found in the forest around the plantain field. Globally, only about 60 to 64 % of species treated with glyphosate were effectively killed at the rate of 6 l ha^{-1} glyphosate applied in this experiment, the rest being not or slightly damaged (table 2). Generally, glyphosate reduced the number of aggressive invasive species more severely than species typically found in forest communities.

Conclusion

Glyphosate was very effective in controlling the species that can be considered invasive and could change the weed flora of forest ecosystems. Thus herbicide use has the potential to increase the probability that the initial vegetation will dominate through and after the cropping phase and ultimately return to secondary forest vegetation. The results of this study demonstrated the complementary effect of chemical and cultural methods, for an efficient, economic and sustainable management of weeds in forest agro-ecosystems.

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