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Socio-economic reasons for high weed infestations in Northwestern Benin maize (*Zea maize* L.) production systems

Geoffroy Gantoli[2]*, Horst Oebel[2], Desire S. M. Agossou[3] and Roland Gerhards[1]

[1]Department of Weed Science, Institute of Phytomedicine, University of Hohenheim, Otto-Sander Straße 5, 70599 Stuttgart, Germany.
[2]Gesellschaft für Internationale Zusammenarbeit (GIZ), Germany.
[3]Department of Economics, Socio-Anthropology and rural Communication, Faculty of Agricultural Sciences, University of Abomey-Calavi, Benin.

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Right timing of weed control is one of the most important challenges farmers in North Benin are facing. Weed infestation rates in maize production in the dry savanna zone in Northwestern Benin are often very high causing significant yield losses. The aim of the study was to determine reasons for late weed control in maize, which is the dominating crop in this area. A survey was conducted among 100 representative farmers in Northwestern Benin. Descriptive statistical methods were used to calculate proportion, frequency or mean of socio-economic data assessed. The descriptive analysis aimed to select relevant variables for regression analysis. Regression models were applied to identify reasons for low weed control efficacy in maize. The results revealed that poor weed control in maize often occurred in small family farms with diverse cropping systems. These famers are often in conflict to control weeds in several crops simultaneously. Weeds are mostly removed by hand-hoeing. Due to their economic situation, they have usually no access to hired labor. Maize yields in the surveyed area could be increased if farmers had access to credit services (1), if farmers would get better recommendations of critical periods of weed control (2) and if more efficient weed control methods would be available to suppress weed populations (3).

Key words: Manual weeding, critical period of weed control, small producer, crop diversification, credit access facilities.

INTRODUCTION

Maize is the most dominant arable crop in Benin. It is mostly grown and consumed by farmers as food crop.

*Corresponding author. E-mail: geoffroy.gantoli@giz.de.

Some farmers sell maize to increase their income. One of the main constraints faced by farmers in the production of arable crops is effective weed control (Vissoh et al., 2004). Yield losses due to weed competition in Africa ranged between 55 and 90% for maize, 50% for common bean, 40-80% for sorghum, 40-60% for cowpea, 50-100% for rice, 80% for cotton, 50-80% for wheat and groundnut, and 90% for cassava (Ambe et al., 1992; Akobundu and Okezie, 1987; Olowe et al., 1987; Ngouajio et al., 1997, Ishaya et al., 2007; Chikoye et al., 2004; Dadari and Mani, 2005).

Most farmers are aware of different methods of weed control, including inversion tillage, pre-planting burning, mechanical seed-bed preparation, harrowing, post-emergent hand-weeding, hoeing and chemical weed control. Farmers partly receive recommendations on integrated weed management by local extension services. Often, chemical weed control is recommended by crop consultants (Bakare, 2007). However, not all farmers have access to all these methods of weed control. Especially poor farmers cannot afford these technologies. The majority of farmers are not able to pay for herbicides and application technologies. It is also reported that chemical weed control in developing countries causes environmental pollution and contamination of users and food (Udoh, 2003). Therefore, hand-weeding and cultural weed management methods including crop rotations are the most dominant means of weed control (Akobundu and Okezie, 1987). Since farming systems in developing countries are mostly diversified in terms of the number of different crops grown on a farm, farmers often spend less time for each individual crop to keep it weed-free. Weeding requires a high amount of resources in Benin including both labor and financial means. For small producers, the family labor composes the most part of labor available for crop management including weed control because they cannot afford hired labor. Udoh (2003) reported that 30-42% of the total farm labor capacities are spent in controlling weeds in the humid regions of tropical Africa. In maize, hand-hoeing requires more than 100 h of labor ha^{-1} in Benin (Harsch, 2004). The challenge for farmers is to allocate labor within the critical time period for weed control. This critical period for weed control is known as the time period when it is crucial to maintain the field weed-free to prevent yield losses (Swanton and Weise, 1991). Although some farmers are aware of critical time periods for weed control, they sometimes coincide with other crops. The critical time period for weed control in maize ranges between 14 and 42 days after sowing or between the four to eight-leaf stage of maize under European and North American growing conditions (Zimdahl, 1981). In Benin, Gantoli et al. (2013) found that the critical period for weed control started at the four-leaf stage of maize and extended to the ten-leaf stage or flowering. In humid regions of tropical Africa, maize needs only four weeks from the four-leaf stage until flowering (Gleason, 1956; Bunting and Ludwig, 1964 quoted by Uremis et al., 2009).

The aim of this study was to investigate socio-economic reasons for late weed control in Northwestern Benin maize cropping systems and the potential for increasing weed control efficacies.

MATERIALS AND METHODS

Study area

This study was conducted in four communities of the western Atacora agro-ecological zone in Northwestern Benin. Djougou and Natitingou are geographically extent communities having many dispersed localities. Both are department capitals. Ouaké and Copargo are small communities with border localities to the Republic of Togo.

The climate in western Atacora is tropical with one rainy season from May to October, which corresponds to the growing season of annual crops including maize. Average annual rainfall in the region usually varies between 1200 and 1400 mm with an average temperature of 27°C varying from 17 to 35°C. The soil type is ferruginous tropical loamy sand.

Composition of the survey

The survey was carried out among 100 representative farmers producing maize as the main crop in the four districts of Northwestern Benin. The producers were selected randomly with the help of farm leaders of each district. We hypothesized that small family farmers had less access to hired labor for weed control than large farms. Therefore, representative groups of small and large producers were included in the survey. Small producers were defined as farms with less than one hectare in Ouaké, less than two hectares in Djougou and Copargo and less than 1.5 ha in Natitingou. The average size of all farms surveyed was 4.5 ha.

We assumed that weed control intensity would differ between farmers using maize only for consumption and for consumption and certified seed production. Therefore, both groups were represented in the survey.

Finally, 34% seed producers and 66% corn producers, only consuming corn and 62% small farmers and 38% large farmers were selected for the survey (Table 1). This corresponds to the distribution of farms in the four districts according to local statistics.

Data assessment

Before farmers were interviewed and assessments were made in their fields, a questionnaire was prepared to collect equal agronomic and socio-economic data from all farms. Data included densities of weed species in maize prior to the first hand-weeding, weed control methods applied in the farm and the farmer's personal conception of efficacy of weed control in corn. Weed infestations levels were correlated to yield potential of crops. Age, education level of farmers and membership in farmers' organizations were assessed as we assumed that this was correlated to their knowledge of integrated weed management strategies and ability to cooperate with extension services. Family size and number of active members in farm operations were recorded to calculate available family labor for weed control. Farmers were asked if they had access to credit or capital to hire labor for weed control. Crop diversity and acreage of all crops produced in the farm were recorded to determine if weed control in maize coincided with management practices in other crops.

Table 1. Geographical distribution of farms in the survey, farm size and use of maize.

Community	Seed maize producer		Only consumption maize producer		Small maize producer		Large maize producer	
	No.	%	No.	%	No.	%	No.	%
Ouaké	14	56	11	44	18	72	7	28
Djougou	12	48	13	52	15	60	10	40
Copargo	6	24	19	76	14	56	11	44
Natitingou	2	8	23	92	15	60	10	40
Total	34	34	66	66	62	62	38	38

Table 2. Farmers' perception of late weed control in maize and their classification in "late weed control" and "not late weed control".

Farmers' perception of late weed control	%
Always	1
Sometimes/often	53
Rarely	41
Never	5
Dependent variable:	
Not late weed free (0)	46
late weed free (1)	54

Data analysis

Simple descriptive statistical methods were used to calculate proportion, frequency, median or mean of socio-economic data assessed. The descriptive analysis aimed to select relevant variables for regression analysis. Regression models were applied to identify reasons for late weed control in the maize production. Producers responding that they "always", "sometimes" or "often", succeeded to keep their maize fields weed-free in the critical period of weed control were categorized as "late weed free" and given the discrete variable modality "1". Farmers "rarely" or "never" keeping their maize fields weed free in the critical period were categorized as "not late weed free" with the variable modality "0" (Table 2). A Logit model was used for this transformation (Wooldridge, 1999 and 2002). The logit model is presented as:

$$y^* = \beta' x + e$$

where β is a K-vector of parameters, x is a vector of explanatory variables and e $\sim$N(0; 1) is a random shock. We observed y = 1 if y* > 0 and y = 0 otherwise. If e $\sim$N (0; σ^2), σ is not identified. To see this, divide both left and right hand sides by σ.

Logit model estimation is based on independent variables collected in the surveys. According to our hypothesis, lack of credit access and hired labor, competing crops produced simultaneously from June to October), low education level and the lack of extension agents are the main causes for late weed control in maize. For variables related to the effects of weeds infestation and its consequences on maize, scores between "-2" (very negative effect), "-1" (negative effect), "0" (no effect), "1" (positive effect) and "2" (very positive effect) were given by producers. Then, average scores of each variable were calculated. A student T-test was used to check whether the average scores were statistically different from "0" meaning that the variables had a significant effect on weed control in maize. Descriptive statistics and econometrics analysis were performed using R 2.8.1 software.

RESULTS

Structure and education of farm household

The median age of the farmers in the survey was 37 years. Farm households, in average consisted of 7 members with four members actively being involved in crop production (Table 3). These data support the importance of family labor for small family farms in developing countries.

About half of the farmers did not receive any education in school, 34% visited primary school and only 17% have a secondary education level (Table 4). Farmers in the districts of Natitingou and Copargo had a significantly higher education level than farmers in Djougou and Ouaké. Besides their activity in crop production, 70% of the producers additionally worked in the agricultural sectors of trading or animal breeding.

Membership in farm organizations, access to credit and extension services

The survey revealed that about half of the producers were members in farmers' organizations and even three third had access to extension services and re-commendations of critical periods for weed control (Table 5). However, only 23% of the farmers could get credits and if this was the case they mostly used it to purchase seeds and fertilizer. Only one farmer in the survey was able to get credit to hire labor for weed control.

Cropping systems

The majority of farmers (66%) responded that maize was

Table 3. Structure of the farm household.

Parameter	Minimum	Maximum	Median	Mean
Age	20	65	37	39
Household size	1	10	7	7
Number of active members	1	9	4	4

Table 4. Education level for all communes surveyed.

District	No education		Primary education		Secondary education	
	No.	%	No.	%	No.	%
Djougou	17	68	4	16	4	16
Ouaké	13	52	10	40	2	8
Natitingou	7	28	14	56	4	16
Copargo	12	48	6	24	7	28
Total	49	49	34	34	17	17

Table 5. Proportion of farmers being members in farm organizations and having access to credit and extension services.

Parameter	Member in farm organization (%)	Access to credit (%)	Contact to extension service (%)	Recommendations of critical periods for weed control (%)
Yes	53	23	76	72
No	47	77	24	28
Use of credits				
If credit is available, it was used for	**N**	**%**		
Purchase ofseeds/fertilizer	20	87.1		
Tillage	1	4.3		
Weed control	1	4.3		
Others	1	4.3		

their dominant crop in the rotation followed by yam (14%), cotton (7%) and millet/sorghum (7%) (Table 6). Maize was produced by all farmers in every year mostly in rotations with yam, millet/sorghum, rice, groundnut and cassava. Cotton and vegetables were less frequently grown (Table 6). However, if farmers decided to grow cotton, average cotton acreage was relatively high with 2.4 ha. About one third of the arable land in Northwestern Benin was cropped with maize. Still, crop diversity was rather high. It ranged from two to eight crops. The majority of producers (75%) simultaneously grew three to five crops. This confirms that crop diversification is a main characteristic of small-scale family farms in northwestern Benin.

Yield potentials and weed infestations

Arable land was classified into the most fertile “bottom land” with highest soil moisture content, the less fertile and dry “high land” and the very unfavorable “shallow land” (Table 7). Only irrigated crops, mostly rice is grown on the “shallow land”. Maize requires fertile and moist soils and therefore, is preferred in the “bottom land”. Also, yield potential is highest for “bottom land”. However, weed infestation levels were also highest in the “bottom land” with the dominating and difficult-to-control species *Cyperus distans* L. (6.5 m^{-2}), *Digitaria horizontalis* (Willd) (6.1 m^{-2}), *Mitracarpus villosus* (Sw.) DC (2.6 m^{-2}), *Tridax procumbens* Oliv. & Hiern (2.0 m^{-2}), *Commelina benghalensis* L. (1.1 m^{-2}), *Rottboellia cochinchinensis* (Lour.) Claiton (1.0 m^{-2}).Thus, it was very challenging for farmers to keep maize weed free in the critical period of weed control in the “bottom land”.

Reasons for late weed control

Table 8 shows that family labor was more important for

Table 6. Dominance, Frequency and average acreage of crops in northwestern Benin family farms; the average acreage of all farms surveyed was 4.5 ha.

Crop	Dominance (%)	Frequency (%)	Average acreage (ha)
Corn	66	100	1.5
Yam	14	92	0.8
Cotton	7	26	2.4
Millet/Sorghum	7	77	0.9
Rice	4	52	0.6
Groundnut	4	49	0.6
Cassava	1	43	0.4
Vegetables	1	11	0.6

Table 7. Proportion of different soil classes and weed infestations levels in the farm fields.

Parameter	Corn	Cotton	Rice	Yam
Soil classes				
High land	45.0	14.3	0.0	30.2
Bottom land	53.0	85.7	16.7	64.2
shallow	2.0	0.0	83.3	5.6
Weed infestation levels				
Very high	33.0	60.7	37.0	26.7
High	43.0	32.1	61.1	44.4
low	24.0	7.1	1.9	28.9
Difficulty to control weeds				
Very difficult	30.0	53.6	74.1	30.0
Difficult	40.0	32.1	18.5	31.1
Not very difficult	30.0	14.3	7.4	38.9

small farms and for the non-seed producers than for large producers and seed producers. This can be explained bythe fact, that small farmers have no financial means to pay for hired labor. Seed producers however, receive income for maize seed that they can invest for hired labor. Seed producers are also obliged to keep their maize fields weed free in the critical period of weed control.

Weed control in maize often coincided with weeding in other crops. Overlaps in timing of hand weeding were highest for yam (65%), followed by cotton and rice with 12% for each crop. However, 77% of the farmers gave priority to weeding in maize, when they had to decide which crop was weeded first. Only 13% of the farmers decided to begin weeding in yam, 7% started weeding in cotton, 2% in groundnut and 1% in rice (Table 9). In conclusion, maize was the seen as the most valuable crop for the farmers.

Surprisingly, 80% of the farmers reported that the difficult socioeconomic situation was responsible for weed problems (Table 10). Only 17% of the farmers answered that large persistent weed seed banks and vegetative propagules of perennial weed species caused weed problems indicating that farmers seem to have little awareness for preventive weed control strategies to avoid and reduce weed infestation.

The statistical analysis revealed that three variables significantly correlated with late weed control in maize: small farms, maize not being the dominant crop in the farm and high diversity of crops in the rotation (Table 11). Farmers realized that late weed control in maize resulted in reduced growth, quality and yield of maize (Table 12). Maize leafs in weedy fields turned yellow probably due to nutrient and water shortage (Baco et al., 2011). More than half of the farmers reported that weed competition was associated with higher pest infestations. Unfortunately, although producers were aware of significant negative impacts of weed competition on maize growth, they still failed to control weed in the critical periods.

Table 8. Number and proportion of family labor for crop production.

Parameter	100%		75%		50%		25%	
	N	%	N	%	N	%	N	%
Large producers	7	18.4	12	31.6	10	26.3	9	23.7
Small producers	22	35.5	18	29.0	7	11.3	15	24.2
Seed producers	5	14.7	12	35.3	5	14.7	12	35.3
Non seed producers	24	36.4	18	27.3	12	18.2	12	18.2
Overall producers	29	29.0	30	30.0	17	17.0	24	24.0

Table 9. Priority for weed control in different crops.

Crop	Percentage
Maize	77
Yam	13
Cotton	7
Groundnut	2
Rice	1

Table 10. Farmers' perception of reasons for late weed control.

Reasons	Percentage
Difficult socio-economic situation	80
Landscape/invading weeds	17
No idea	3

DISCUSSION

Crop diversification and weed control challenges in corn production system

Family farms in Northwestern Benin need to produce food for the family members and sell crops to receive income for seeds, fertilizer, housing, education, clothes and medical services. Therefore, they have to grow several crops on their farm land. High crop diversity also compensates for risk of crop failure in individual years due to drought, pests or weed competition. In fact, the small scale production systems in developing countries are characterized by high diversification of the crops produced at farm level (Akobundu and Okezie, 1987). Despite several advantages associated with a high crop diversity, farmers are facing severe problems with allocating sufficient labor for weeding in the critical period of weed control in each crop. For maize, critical period of weed control lasts only three to six weeks from the 8-leaf stage until flowering under Northern Benin cropping conditions (Gantoli et al., 2013). Often, only producers who can afford to employ hired labor manage to keep maize and other crops weed-free in the critical period of weed control. On average 46% of small producers in Northwestern Benin depending on labor failed to remove weeds in the critical period of weed control. This increases pest infestations which can be due to lower stress tolerance or weed species attract pests (Mahadi et al., 2013). Consequently, grain yields were reduced by approximately 50% (Gantoli et al. 2013) causing a tremendous loss of farm income and food supply.

Socio-economic problems caused by weed competition

Small farmers are currently lacking many resources needed to improve weed control efficacy in their crops including machinery for weed hoeing and capital for hired labor and other farm inputs. Farmers often take their children in the fields for weeding, which consequently stops them from visiting school and getting better education. Due to several successful projects to promote children's education, the family labor is continuously decreasing in many African countries (Baco et al., 2011). Education also requires financial resources of the farm families, which again reduce their potential to invest in hired labor or farm inputs. Although farmers are often aware of critical periods of weed control, about half of the fields remain weedy due to these socio-economic problems. Possible solutions of this problem would be co-operations between farmers, which could increase labor productivity in critical periods of weed control and decrease costs for farm inputs such as seeds and fertilizer (Doggett, 1991). Mixing maize with more competitive crops such as cassava and reducing acreage of very problematic crops including cotton might reduce weed competition and total labor for manual weeding in the farm (Zinzindohoue, 2012). Finally, the investment in efficient technologies for weed control such as machine hoeing would increase weed control efficacy, crop yield and farm incomes (Kamara and Sanginga, 2001; Rasheed et al., 2003). In conclusion, the results proof that weeding is very time-consuming and labor use efficiency for weed control in northern Benin needs to be

Table 11. Estimation of the determinants for late weed control using the logit model.

Parameter	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-5.15805	1.59419	-3.236	0.00121***
Size of farm	1.17733	0.56766	2.074	0.03808**
Seed producer	-0.13853	0.50997	-0.272	0.78589
Number of year of education	0.09986	0.06747	1.480	0.13884
Practice of a second activity	0.87511	0.53802	1.627	0.10384
Number of crops cultivated	0.53430	0.20607	2.593	0.00952***
Type of main crops cultivated	0.41094	0.17013	2.415	0.01572**
Type of competing crop	0.18971	0.11570	1.640	0.10107

'***'significance at 1% level, '**'significance at 5% level.

Table 12. Trends of late weed control effects perceived among farmers surveyed.

Parameter	Mean	Std. Deviation	Significance	95% Confidence Interval
Modeled effects				
Reduction of maize growth	0.99	0.10	***	[0.97; 1.01]
Yellow maize leaves	1.00	0.00	***	-
Losses of yield	1.00	0.00	***	-
Reduction of grain quality	0.98	0.14	***	[0.95; 1.01]
Increase of pests	0.80	0.40	***	[0.72; 0.88]
High weed infestation of crops in neighboring fields	0.66	0.47	***	[0.57; 0.75]
Farmer's perception				
Reduction of maize growth	-1.43	0.51	***	[-1.53; -1.33]
Yellow maize leaves	-1.71	0.57	***	[-1.8 ; -1.60]
Losses of yield	-1.42	0.49	***	[-1.52; -1.32]
Reduction of grain quality	-1.23	0.58	***	[-1.35; -1.11]
Increase of pests	-1.08	0.69	***	[-1.22; -0.94]
High weed infestation of crops in neighboring fields	-0.67	0.49	***	[-0.77; -0.57]

*** Significance at 1%; modeled effects (0=No 1=Yes); farmer's perception (-2=Very negative -1=Negative 0=No effect +1=Positive +2=Very positive).

increased to improve social and financial situation of family farms.

Conflict of Interests

The authors have not declared any conflict of interests.

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