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EVALUATION OF TECHNICAL ITINERARIES FOR THE TREATMENT OF FOOD CROPS IN IVORY COAST (CÔTE D'IVOIRE)

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Abstract
The objective of this study was to evaluate the technical paths of management of the cropping of food crops in the Iffou Region in central-eastern Côte d'Ivoire. A survey was carried out in the three Departments that make up the Iffou Region (Daoukro, M'Bahiakro and Prikro). A sample of 825 food producers was surveyed in 63 localities within the region between May and August 2014. The results of the survey reveal that the majority of farmers used manual weeding. The results also show that 88.96% of farmers work with traditional tools. The cultivated fields are 97.45% family-owned. Producers generally carry out 3 weeding sessions per season in the Iffou Region. This study demonstrates that chemical weed control increases the sown area and yields of food crops. It also makes it possible to solve the expensiveness and lack of workers if the workforce. Finally, the results show that in an average of 0.39 ha of cultivated area, 2.70 t / ha of average production is obtained.
***Keywords*:** technical itineraries, weeds, weed control, food crops, Côte d'Ivoire.

Introduction
Despite its importance, the Ivorian food sector is relegated to a ranking of secondary importance in exporting crops such as coffee and cocoa. Food crops have low yields and are generally confined to subsistence crops. In response to population growth, the state has decided to give priority to the food sector in order to achieve food self-sufficiency (Koudou, 2014). To guarantee food security for the growing population, it is therefore essential to consider the factors of good food production and to include production techniques. The improvement of the latter requires taking stock of the cultural habits of the producers so as to better appreciate them and to propose solutions for the observed difficulties. It is with this in mind that this study was conducted in the Iffou Region, which is part of the former Cocoa belt. After more than thirty years of being fallow, the land has regenerated and is once again suitable for agriculture. The practice of food crops is therefore conducive to this process because of the favourable natural conditions. The diversity of both climate and vegetation is a major asset of crop variation. Despite these potentialities, food production is low because of the steady and accelerated decline in yields. One of the causes is the impact of weeds. Thus, weed control constraints play an important role in the reduction of yields and often lead to the very low productivity of certain crops. Estimates of weed harvest losses averaging around 25%, can be as high as 50% and 80% for some food crops (Cramer, 1967; Walker 1975 and Regehr, 1993). In the current context, where weed control is made difficult by unsuitable technical routes and the use of traditional non-performing tools, one can ask the question of how to achieve good crop weed control in order to improve yields. The aim of this study was to improve the weed control of food crops. On the one hand, it is necessary to identify the technical pathways of weeding that are practiced by the farmers and on the other to evaluate such pathways impact on crop yields.

Methodology
Study environment
As aforementioned, this study was conducted in the Departments of Daoukro, M'Bahiakro and Prikro within the Iffou Region in central-eastern Côte d'Ivoire (Figure 1). This region covers an area of 8955 km^2 which is 2.8% of the national territory. The population of the Iffou Region is estimated at 311,642 inhabitants (RGPH, 2014). The Iffou Region straddles the forest and savannah zones. According to Eldin (1971) and Charpentier et al. (1999), Daoukro Department has atmospheric (sub-equatorial) and Baoulean (Guinean) climates. The climate of M'Bahiakro Department is essentially of the Baoulean type (Guinean). The Prikro Department straddles the Baoulean and Sudanese climates. The relief is fairly flat, consisting largely of plateaus. There are lowlands, river basins (watersheds), ferralitic soils and ferruginous soils. The soil is floodable in places during to the rainy season (Riou, 1962; Yessoh, 1973). This climate diversity is a natural asset for agriculture, which makes it possible to vary the importance of the application of a particular culture.

Settlement and socio-economic activity

The Iffou Region is populated by the indigenous people of Baoulé, Agni, N'Gain and Andoh origin. The non-natives are the Senufo and Malinké, who come from other parts of Côte d'Ivoire. To all of these populations are added non-Ivorian nationals of the Economic Community of West African States (ECOWAS), which is mainly composed of Burkinabés and Malians. Agriculture, which is very varied is the main economic activity in the Region of Iffou. There are cash crops (coffee, cocoa, rubber, cashew nuts and oil palm), food crops (yams, cassava, bananas, plantains, rice, corn and peanuts) and vegetable crops such as eggplant, okra, tomato, cabbage, squash, zucchini, pepper, carrot, melon and onion). In addition, livestock (cattle, sheep, goats, pigs and poultry) and fisheries are still of little interest to the populations of this region.

Biological material

The biological material in this study includes major food crops and weeds.

- The main food crops grown in the Iffou Region are yam (*Dioscorea cayenensis*, *D. rotundata* et *D. alata* L. Dioscoreaceae); Cassava (*Manihot sp.*, Euphorbiceae); Plantain (*Musa sp.* L.); Maize (*Zea mays* L. Poaceae); Rice (*Oryza glaberrima* Steudel and *O. sativa* L. Poaceae) and groundnut (*Arachis sp.* (L.) Fabaceae),
- The most regular weeds of the main food crops are *Rottboellia cochinchinensis*, *Imperata cylindrica*, *Cyperus rotundus*, *Chromolaena odorata*, *Mucuna pruriens*, *Oryza longistamina*, *Croton hirtus*, *Bidens pilosa* et *Crassocephallum ruderale*.

Technical material

The technical material is of a composite nature. A Global Positioning System (GPS) was used to locate survey sites and to measure sown areas. A weighing scale was used to weigh crops. Field information was collected on survey forms. Word processing, data entry and data processing were carried out using Microsoft Word and EXCEL spreadsheets. The XLSTAT software version 2014.5.03 made it possible to carry out the chi-square tests (χ^2) and the analysis of one-factor analysis of variance (ANOVA 1).

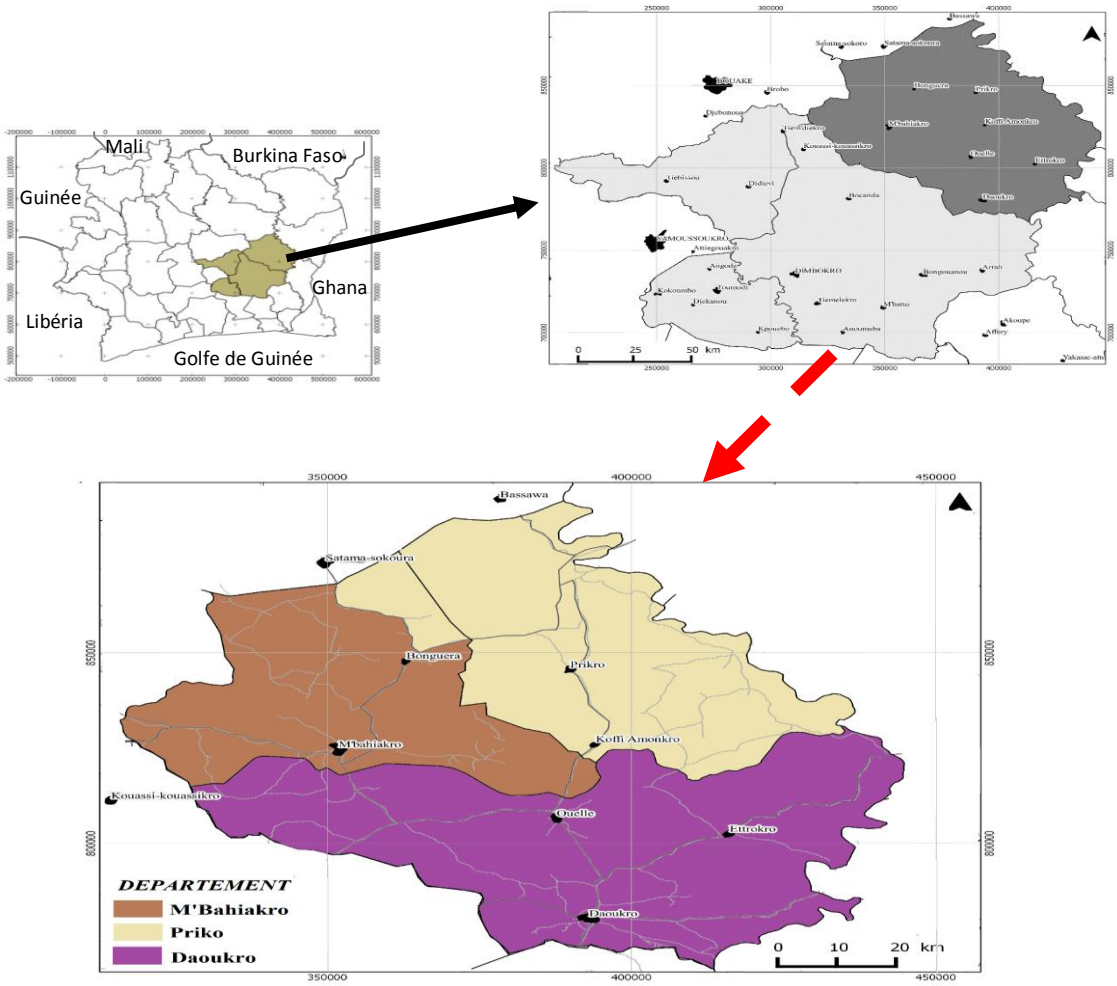

Figure 1. Localisation of the study region
(Modified from the geographical division map of the Ministry of Foreign Affairs, 2009)

Sampling method

The survey was carried out between May and August 2014 within the three Departments (Daoukro, M'Bahiakro and Prikro) which make up the Iffou Region. Within a particular department, we divided up the farmers by locality (villages and settlements). We selected 63 locations with 21 per department. The sample size is 825 (275 peasants per department), that are producing a food crop. The localities were chosen in collaboration with the advisers of the National Agency for Rural Development Support (ANADER) that is located in each department, taking into account their accessibility and especially the availability of farmers throughout the investigation process. As aforementioned, the objective of this study was to characterise the technical pathways of weeding and to evaluate their impact on the yields of food crops in order to envisage their possible improvement. The producers interviewed were randomly selected with respect to their particular field, whether they were in their place residence or in their place of work (in the fields). The only criterion that guided us in choosing the interviewees was that they had to be the producer of the food crops. The interviews were conducted in the French language. Whenever the respondent did not speak the French language, then we conducted the conversation in his / her mother tongue using a auxiliary assistance.

Data collection

The information was collected from a survey sheet containing various data on food crops that are produced by the farmer. For each sampled producer, the questionnaire consisted of the collection of information on three groups of variables: socio-professional information, agronomic information and agro-economic information. Socio-professional information includes variables such as ethnicity, gender, education, occupation, marital status, age, and household size. Agronomic information refers to variables such as sowing date, soil type, parcel age, seed used, field management, clearing, type of weed control, number of weed control, time period between sowing and first weeding, weeding time, sown areas, and yields. The agro-economic variables include the mode of work, and the types of labour and inputs.

Exploitation of collected data

The collected data were first ordered by department and then grouped into regions. To simplify and facilitate the input, the answers obtained to the questions asked were coded. We configured an input model using Epida software. From the input model we accessed an SPSS data matrix and a database of Excel data. Finally, we carried out the various statistical tests.

Statistical analysis

The statistical tests used were the chi-square test (χ^2) and the one-way analysis of variance (ANOVA 1).
The chi-square test (χ^2) was used to establish whether there is a relationship between the three departments regarding the technical weed control pathways. When a relationship exists at the threshold of 0.05%, the chi-square test (χ^2) was completed by the Marascuilo procedure, which consists of carrying out tests of comparison in a two-by-two manner for all of the proportion couples. This makes it possible to identify the proportions that are responsible for the existence of any correlation between the departments for the considered parameter. The results were analysed using XLStat software version 2014.5.03.

The one-factor analysis of variance (ANOVA 1) made it possible to compare the production obtained according to the type of weeding and the weeding time, using the XLStat software version 2014.5.03. For the realisation of the ANOVA, the normality and the equality of the variances were first checked. When a significant difference was observed between weed control patterns, the ANOVA was supplemented with multiple comparisons by performing the Duncan test, which makes it possible to classify weeding methods by homogeneous class. The smallest significant difference between these parameters was set at $P \leq 0.05$.

Results

Typology of surveyed producers

The distribution according to the origin of the growers shows that the surveyed producers are composed of 87.87% of indigenous people: Baoulé, Agni, Andoh and N'Gain, 8.84% allochthones (Malinké) and 3.27% Foreign countries (Table I).

Medium-sized and medium-sized areas

The main crops grown in the Iffou Region are yam, cassava, maize, plantain, rice, and groundnuts. Among all of these speculations, yams and cassava occupy the largest areas that are sown with better yields (Table II).

Field Management Mode

In the Iffou Region, food crops are usually cultivated in two ways: collective fields and individual fields. The majority of cultivated fields are collective (97.45%), but there are more individual fields in Daoukro than in M'Bahiakro and Prikro where the percentage of individual fields is very low (Table III).

Table I. Distribution of surveyed farmers by ethnic group

Departments	Number of Farmers investigated	Ethnicity of surveyed farmers					
		Baoulé	Agni	Andoh	N'Gain	Malinké	Foreigners
Daoukro	275	171	71	3	0	25	5
M'Bahiakro	275	198	3	0	18	48	8
Prikro	275	14	0	247	0	0	14
Iffou	825	383	74	250	18	73	27

Table II. Medium-sized areas and medium-sized productions of the departments

	Average cultivated surface (ha)			Average production (t/ha)		
Staple crops	DAOU	MBAH	PRIK	DAOU	MBAH	PRIK
Dio sp.	0.20	0.68	0.37	4.05	3.96	3.88
Man sp.	0.45	0.44	042	7.26	7.16	7.08
Zea sp.	0.37	0.37	0.41	2.08	1.95	1.82
Mus sp.	0.39	0.21	0.17	3.70	0.98	0.77
Ory sp.	0.47	0.41	0.44	1.23	1.23	0.88
Ara sp.	0.12	0.25	0.29	0.08	0.55	0.74

Table III. Comparison of field management mode according to department

	Field			**Statistical parameters of chi-square**		
	Collective	**Individual**	**N**	***ddl***	***χ²***	***P***
Daoukro	94.89	5.11	275			
M'Bahiakro	97.82	2.00	275	2	12.67	< 0.01
Prikro	99.64	0.36	275			

Typology of weeding

In the Iffou Region, the weeding of food crops is undertaken in two ways: manual weeding, and chemical weed control coupled with the manual method. The proportion of farmers who hand-weed is 88.12%. This type of weeding is carried out using the machete, the hoe and the daba (African hoe fabricated by village blacksmiths). Nevertheless, some producers carry out chemical weeding according to the proportions per department that are presented in Table IV.

Used tools

The main tools used in food production are both traditional and modern. However, the use of traditional equipment is more frequent with a proportion of 88.84%. Table V presents the situation by department.

Weed Control Frequency

The number of the most frequent weedings in the three departments (Daoukro, M'Bahiakro, and Prikro) is three (36.53%). The results of the survey on the frequency of weeding per crop cycle are given in Table VI.

Table IV. Comparison of the type of weeding according to department

Locality	**Weeding style**			**Statistical parameters of chi-square**		
	Manual	**Manual & chemical**	N	***ddl***	***χ²***	***P***
Daoukro	82.55	17.45	275			
M'Bahiakro	90.54	9.46	275	2	12.854	< 0.01
Prikro	91.27	8.73	275			

Table V. Comparison of the type of weeding tools according to department

Locality	Weeding tools			Statistical parameters of chi-square		
	Traditional	Traditional & Modern	N	*ddl*	χ^2	*P*
Daoukro	83.27	16.73	275			
M'Bahiakro	91.27	8.73	274	2	13.594	< 0.01
Prikro	92.00	8.00	275			

Table VI. Weeding frequency per crop cycle according to department

Type of work	Locality			N	Statistical parameters of chi-square		
	Daoukro	M'Bahiakro	Prikro		*ddl*	χ^2	*P*
With workforce	17.73	10.36	8.54	209	2	13.49	< 0.01
Without workforce	82.27	89.64	91.46	616			

Table VII. Comparison of the workforce type according to department

Number of weedings	Locality			N	Statistical parameters of chi-square		
	Daoukro	M'Bahiakro	Prikro		dl	χ^2	*P*
1	20.73	14.96	25.82	169	6	30.955	<0.001
2	26.18	41.97	29.82	269			
3	37.82	36.86	34.91	301			
4	15.27	6.20	9.45	85			

Type of workforce

Work in food crops is carried out in two ways: labour without wage, and labour with wage. Most of the farming fields of the surveyed peasants are grown without labour wage (87.79%). Table VII summarises the results for this factor.

Average production according to weed control

The difference in production is significant between manual and chemical weeding coupled with manual weeding at the level of the different food crops (Table VIII). Production in the case of coupled chemical and manual weeding is higher than for manual weeding. The average production following each weeding mode varies from one crop to another.

Working time and production costs

The different working times and related costs per ha are given in Table IX. Analysis of the results presented in Table IX shows that manual weeding is the mode that requires the most working time with respect to higher crop production.

Table VIII. Average production according to weed control type

Weeding type	Yam	Cassava	Maize	Plantain banana	Rice	Arachide
Chemical & manual	6.93 ± 0.04^{b}	9.91 ± 0.05^{b}	3.93 ± 0.05^{b}	2.73 ± 1.14^{a}	2.84 ± 0.010^{b}	1.61 ± 0.23^{b}
Manual	3.96 ± 0.04^{a}	7.16 ± 0.05^{a}	2.85 ± 0.05^{a}	1.81 ± 1.14^{a}	1.51 ± 0.010^{a}	$0,.45 \pm 0.23^{a}$
F	2583.32	440.18	166.60	0.32	80.38	39.07
p-value	<0.0001	<0.0001	0.0002	0.59	0.0009	0.0033
ddl	5	5	5	5	5	5

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Table IX. Comparison of working time and production costs according to weed control type

Weeding type	Number of people	Ave. time ± Stand. dev. (h/ha)	Cost (West African Francs CFA/ha)	Statistical parameters
Chemical	15	3.00 ± 0.4243^{a}	24,500	*ddl* = 2
Mulching	15	124.66 ± 0.4243^{b}	39,000	*F* =10.37
Manual	15	256.00 ± 0.4243^{b}	28,000	*p-value* = 0.01

Discussion

Technical pathways for weeding are not sufficiently diversified in the Iffou Region. The most used method (88.23%) is hand-weeding using traditional tools. Indeed, according to Camara (1984), in Côte d'Ivoire the farmers weed using the hoe, the Daba and the machete. In addition, Kouadio (2003) assessed the proportion of traditional tools at 64% for maize growing within the Gagnoa region.

In the Iffou Region, the use of herbicides is still poorly integrated into weed control programmes. This would be due either to the lack of interest of farmers or to the high cost of herbicides. The majority of food producers in this region live in rural areas and they do not have enough contact with outreach services and also they are reluctant to adopt new technologies. In other parts of the country, herbicides are increasingly being applied. The work of Kouadio (2003) shows that chemical weeding is practiced by 36% of farmers in second-cycle maize growing within Gagnoa.

With respect to cropping cycle, the weeding frequency is estimated to be an average of three times. This could be explained by the fact that the populations of Iffou share the same traditions and customs. This is due to the fact that the majority of farmers grow yams, which require at least three weedings per cropping cycle in order to expect good yields. The number (4 times) of weed controls observed in Daoukro would be linked to the cultivation of plantain banana, in addition to the yam, within this department. Daoukro is the only department that is partly located in the rainfall sector of the Guinean domain which is favourable to the cultivation of the plantain banana. The frequency of weed control is not specific to the Iffou Region. Indeed, Serpantié and Marnotte (1980) have shown that a field of yams usually has two or three weed types, but in some situations five can be observed. Other sources such as the Centre for Agronmic Research (CNRA, 2013) in Côte d'Ivoire, indicate that there are two to four weedings during cassava cultivation and three to four weedings for plantain banana. Rice requires at least two manual weedings or chemical pre-emergence weed control followed by manual weeding at 45 days after sowing (DAS) (Tehia and Marnotte, 2001). According to these authors, a pre-emergence chemical weeding followed by a manual weeding at 45 DAS would allow a good maintenance of a field of corn. Peanut requires one to two hoeing sessions to keep the plots clean (BNDA, 2014).

In terms of the area planted, the yam has the highest average cultivated area. All farmers have a field of at least 0.25 ha in size. The small average cultivated area of the plantain banana is related to the fact that the forest zone is favourable to its cultivation nd is concentrated only in the south of the Department of Daoukro. In M'Bahiakro and Prikro, fields of plantain banana are rare. The average cultivated area of peanuts is also low. Peanut cultivation is of little interest to the indigenous peoples (Baoulé, Agni, Andoh, and N'Gain) and it is generally practiced by Malinke and foreigners.

In terms of production parameters, cassava has the best yield because it is a plant that can adapt to harsh environmental conditions where others fail. It is suitable for all climates and all types of soils. In crops of yam and cassava, farmers apply herbicides only during clearing. For these, the residues of the herbicide could end up in the tubers and thus affect the organoleptic properties. The farmers think in the same way for peanuts. For plantain banana, growers use the herbicide only during the installation of the plots. This is why there is no difference in yield, depending on the type of weeding. For maize and rice, yields are best when manual weeding is coupled with chemical weed control. In this case, in addition to what they use when installing the plots, the farmers use a pre- or post-emergence herbicide, and often they associate the two. The yields obtained are all lower than those recorded by the services of CNRA (2012) for all food crops (including those for chemical and manual weed control) and also Boraud et al., 2015 for rice cultivation. On the other hand, they are essentially identical to those obtained by the agents of the 3N (2011) initiative *(write here the full name of that 3N initiative).* The observed difference may be due to the fact that farmers do not control the application conditions of herbicides. This would also be due to the fact that varieties used by CNRA are improved varieties, more resistant to grass cover, disease and more productive.

Conclusion

Farmers in the Iffou Region were interviewed in order to get a better appreciation of the technical and weed control pathways. The results of this survey are used to characterise the method of maintenance of the fields in the region and also to describe the factors of production that are related to weeding. Thus, among other results, it is noteworthy that 88.96% of growers work with traditional tools. The cultivated fields are 97.45% family-owned.

Producers generally carry out 3 weedings per crop cycle in this region. The duration of the time period dedicated to weed control is the longest of all production activities. It is also clear from this survey that yam and cassava occupy the largest areas that are sown which have better yields. Weed control is the most costly agricultural activity in the region. This study shows the substitution of manual weeding by chemical weeding. This introduction of herbicides into the technical weed control pathways increases the sown area and improves yields. From a socio-economic point of view, the use of herbicides makes it possible to address the problem of labour shortages and high prices, and it may still allow children to be released for schooling in order to improve educational enrolment rates.

For better production of food crops, managers should sensitise and train farmers in new herbicide weed control techniques. Given the importance of herbicides, it is desirable that the state subsidises these chemicals in order to facilitate their access to all farmers. This would improve farmers' returns and annual agricultural incomes.

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