African Crop Science Journal, Vol. 27, No. 2, pp. 165 - 182
Printed in Uganda.
ISSN 1021-9730/2019 $4.00

DOI: https://dx.doi.org/10.4314/acsj.v27i2.4

FARMERS' KNOWLEDGE AND MANAGEMENT PRACTICES OF WEEDS IN RICE FIELDS IN COTE D'IVOIRE

A.C. YAO [1, 2], E.L. BOMISSO [3], D.M. ANGAMAN [4], I.J. IPOU [3] and M.W. KONE [1,2]

[1] UFR Sciences de la Nature, Université Nangui Abrogoua, Abidjan, BP 801 Abidjan 02, Côte d'Ivoire
[2] Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), BP 1303 Abidjan 01, Côte d'Ivoire
[3] UFR Biosciences, Université Félix Houphouët Boigny, Abidjan, BP 582 Abidjan 22, Côte d'Ivoire
[4] UFR Agroforesterie, Université Jean Lorougnon Guédé, BP 150 Daloa, Côte d'Ivoire
Corresponding author: clementine.yao@csrs.ci

(*Received 11 February 2019; accepted 23 April 2019*)

ABSTRACT

Rice (*Oryza sativa* L.) is one of the most consumed cereal food crops in the world, in particular in sub-Saharan Africa. However, in Cote d'Ivoire its production faces severe competition from weed infestation. This study was carried out to identify practices and traditional management methods of weeds in rice fields from Cote d'Ivoire that can be used in an integrated weed managment package with less pesticide usage. A survey was conducted among 396 farmers in three locations (six villages per area) of rice production in Cote d'Ivoire, using semi-structured interviews and field observations. The results revealed that upland, irrigated and lowland rice were cultivated in the study areas. In rice fields, the main weeds difficult to control were *Cyperus rotundus, Eleusine indica*, *Oryza longistaminata*, *Porophyllum ruderale* and *Rottboellia cochinchinensis*. Biological control and a combination of chemical and manual methods were used to manage the weeds due to their resistance to most of the herbicides. The farmers cited 23 plant species (seven herbicidal and 16 allelopathics) used for the control of weeds. Studies of these plants in the effective control of weeds would be worthwhile to explore the development of alternative to chemical controls, less harmful to humans, crops and environment.

Key Words: Cote d'Ivoire, knowledge, management, rice, rice farmers, weeds

RÉSUMÉ

Le riz est l'aliment céréalier le plus consommé dans le monde et plus particulièrement en Afrique subsaharienne. Cependant, en Côte d'Ivoire, sa production doit faire face à une forte concurrence de l'infestation de mauvaises herbes. Cette étude a été menée en vue d'identifier les pratiques et les méthodes de gestion traditionnelles des mauvaises herbes dans les rizières de la Côte d'Ivoire qui peuvent être utilisées dans un ensemble de gestion intégré des mauvaises herbes avec une utilisation

moindre de pesticides. Des enquêtes ethnobotaniques et de connaissance ont été menées auprès de 396 riziculteurs dans rois zones de production du riz (six villages par zone). Les résultats révèlent que la riziculture de plateau, de bas-fond et irriguée sont pratiquées dans les trois zones. Dans les rizières de ces trois zones, les adventices majeures difficiles à contrôler sont *Cyperus rotundus*, *Eleusine indica*, *Oryza longistaminata*, *Porophyllum ruderale* et *Rottboellia cochinchinensis*. La lutte biologique et la combinaison des méthodes chimiques-manuelles sont utilisées pour contrôler les mauvaises herbes résistantes aux herbicides chimiques. Les paysans ont cité 23 espèces végétales (sept herbicides et 16 allélopathiques) utilisées pour contrôler les adventices. Des études sur ces plantes mériteraient d'être explorées pour développer une alternative au contrôle chimique moins nocive pour l'homme, les cultures et l'environnement.

Mots Clés : Adventices, connaissance, Côte d'Ivoire, gestion, riz, riziculteurs

INTRODUCTION

Rice (O*ryza sativa* L.) is one of the most consumed cereal worldwide (Ahmadi and Bouman, 2013; Timothy *et al.*, 2016); and is one of the most important staples in sub-Saharan Africa (Bouadou, 2010), where it serves as the main daily food for many people. Although efforts have been made to increase the production by the improvement of the varieties and farming systems, the average yield is still insufficient to cover community needs. For example, Cote d'Ivoire produces 395,000 metric tonnes, against its demand thus requiring importation of more than 1,190,074 metric tonnes of rice (Mendez *et al.*, 2011; CORAF, 2014). In order to reduce importation of rice, the Government of Cote d'Ivoire launched in 2012 a national rice development strategy to increase the production by 2020 (ONDR, 2012).

However, rice production still faces several constraints such as smothering by weeds (Kouamé *et al.*, 2011; Konan *et al.*, 2014). Weeds cause high rice yield losses that range from 8 to 15% for irrigated rice, and 25 to 30% for the low and upland rice (Johnson, 1997). Most of the weeds in rice field in many West African countries, including Côte d'Ivoire, are known and some of these are *Cyperus difformis*, *Echinochloa crus-galli*, *Echinochloa colona*, *Euphorbia heterophylla, Rottboellia cochinchinensis, Digitaria horizontalis, Fimbristylis littoralis*, *Ageratum conizoides* and *Striga hermonthica* (Ipou Ipou *et al.*, 2004; Mangara *et al.*, 2010; Kouamé *et al.*, 2011; Konan *et al.*, 2014; Touré, 2014). Poor management practices of weeds affects the quality and quantity of rice (Johnson *et al.*, 2004). Weed control remains a major challenge for Cote d'Ivoire, where rice is grown predominantly by small-scale farmers.

Worldwide the best method for controlling weeds currently relies on the use of herbicides (DEAT, 1973). However, in recent years, these products are increasingly ineffective due to resistance development of many weeds (Powles and Yu, 2010). In addition, herbicides have negative impacts on environment due to their ecotoxicity (Bedding *et al.*, 1983; Traoré *et al.*, 2006). In such conditions, it becomes necessary to develop alternative control mechanisms that are less harmful. Traditional knowledge of control can be an important and crucial basis for development of integrated weeds control method.

The objective of this study was to inventory the farmers' knowledge and current management practices of rice weeds in Cote d'Ivoire as a basis for designing effective and environmentally safe control methods in rice production systems.

METHODOLOGY

Study areas. This study was carried out in three rice growing regions of Cote d'Ivoire in West Africa during 2014-2015. Danane and

Guiberoua are high rice production areas, with 57 % of total national production; and Ferkessedougou, a medium production zone, with 37 % of total national production (ONDR, 2012). Danane (7°15'46" N, 8°9'35" W) is located in Western Cote d'Ivoire and characterised by evergreen rainforest (Guillaumet and Adjanohoun, 1971). However, the current vegetation appears very degraded. The soils are of highly to moderately desaturated ferralitic types, coming from granite (Avenard *et al.*, 1971).

According to climate data from 1987 to 2015, climate of Danane (Fig. 1) is marked by two seasons; a long rainy season from March to November and a dry season from December to February (SODEXAM, 2016).

Guiberoua (6°14'12" N, 6°10'39" W) is located in Western-central Cote d'Ivoire in a rainforest. The climate is characterised by two seasons; a long rainy season going from February to November and a short dry season extending from December to January (Fig. 1). Gravelly soils are from granites or shales (Avenard *et al.*, 1971).

Ferkessedougou (9 ° 35 '37 ", N 5 ° 11' 50" W) is in the savannah of Northern Cote d'Ivoire. The sudanian climate of this locality is marked by two seasons (Fig. 1). A rainy season that extends from April to October and a dry season from November to March during which there is harmattan (SODEXAM, 2016). Due to these adverse weather conditions, several hydro-agricultural dams have been built in this area to promote rice cultivation (Bezançon, 1995). The relief of the region of Ferkessedougou is slightly rugged with plains and uplands. Granites occupy most of the northern region.

Sampling. Sample size was calculated using the formula described by Vessereau (1992):

$$n = t^2 x\, p \frac{1-p}{m^2}$$

Where:

t = 1.96 at a trust level of 95 %, m = standard error at à 0.037 %, p = average percentage of farmers (0,83) in the three zones. The sample in each area was determined using the quota method taking into account the size of the rural population following the general population census (RGPH, 2014). For Danane, 114 rice farmers interviewed (19 per village). In Ferkessedougou, there are 120 (20 per village). In Guiberoua, 162 rice farmers were interviewed (27 per village). In total, a sample of 396 rice farmers was obtained (Table 1).

Data collection. The survey was carried out directly in the rice fields. A semi-structured interview facilitated the survey among 396 rice farmers. In each area, six villages were randomly selected (Table 1). The questionnaire comprised different sections on sociodemographic characteristics, farm characteristics, weed species in the field rice, farmers'knowledge and perception of weeds and their control methods.

Botanical identification of plant species. Voucher specimens of recorded plants were collected in the presence of rice farmers. Plants were identified using literature by Hutchinson and Dalziel (1954); Aubreville (1959); Lebrun and Stork (1997); and Arbonnier (2000), stored at the herbarium of Centre Suisse de Recherches Scientifiques en Côte d'Ivoire.

Data analysis

Type of rice field or multiple cropping practice. To show the dominant type of rice field or multiple cropping practice in the three localities visited, the rates of type rice fields (upland, lowland and irrigated) and intercropping were calculated using the following formula:

$$TR \text{ or } I = \frac{Pi}{NTR} x\, 100$$

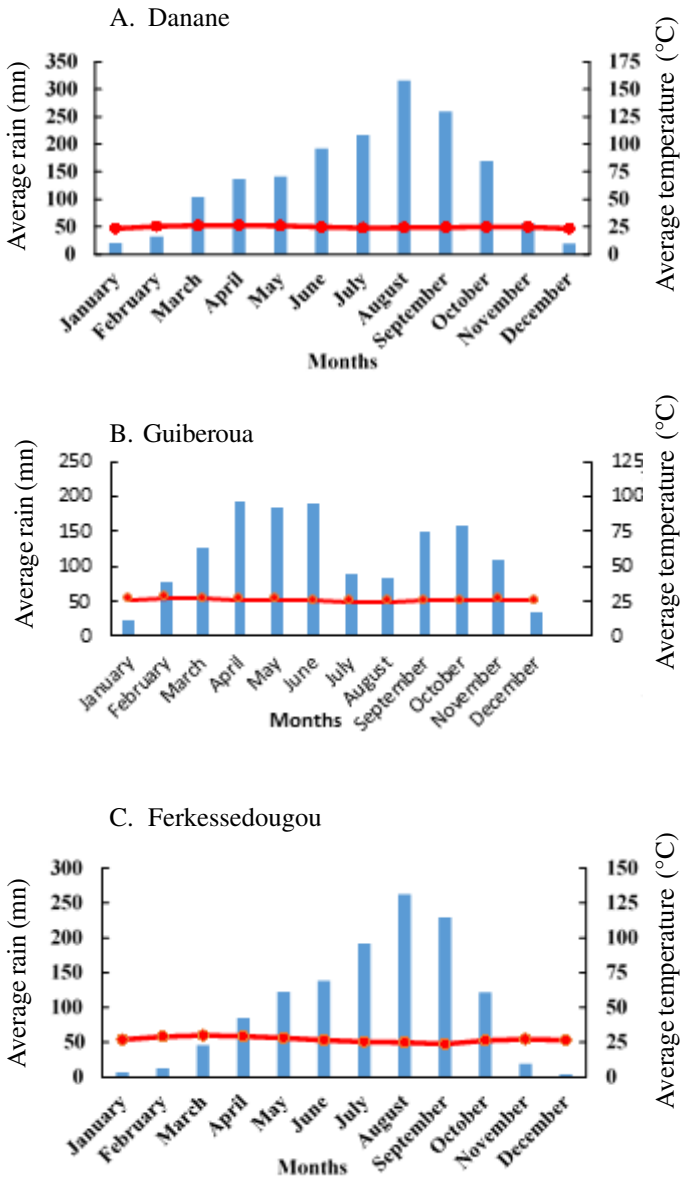


Figure 1. Rainfall and temperature of study areas in Cote d'Ivoire.

Where:

TR (%) = rate of rice fields

I (%) = intercropping

Pi = number of farmers practicing a type of rice field, and

NT = Total rice farmers

Importance of each plant species. Weeds and plants (herbicidal and/or allelopathic properties) have been reported by farmers. The importance of each plant was expressed by the plant value (PV). This value was calculated using the following formula (Hoffman and Gallaher, 2007)

TABLE 1. Number of rice farmers by study area and villages visited in Cote d'Ivoire

Study area	Visited villages	Rice farmers interviewed	Total
Danane	Kanapleu	19	114
	Dongouiné	19	
	Gniempleu	19	
	Deahouepleu	19	
	Goleu	19	
	Yieupleu	19	
Ferkessedougou	Tchassanakaha	20	120
	Dekokaha	20	
	Parawalakaha	20	
	Tchologokaha	20	
	Nambirguekaha	20	
	Tchiebinguékaha	20	
Guiberoua	Zohoa	27	162
	Djetohoa	27	
	Otéhoa	27	
	Djekro	27	
	Ondjahio	27	
	Bilahio	27	
Total			396

$$PV = \frac{\Sigma RUp}{RU} \times 100$$

Where:

PV = plant value of each plant species

RUp = number of times the plant species (weeds or herbicidal /allelopathic plant) is cited

RU = total number of citations for each category of plant species.

Rate of use of control methods. Methods used to control weeds were indicated by farmers. For each method, the rate of use was calculated according to the following formula:

$$ML = \frac{Pm}{NTR} \times 100$$

Where:

ML (%) = rate of use of each control method,

Pm = type of control method used by a farmer

NTR = total of rice farmers

Degree of agreement. To assess the degree of agreement around each herbicide-dominated plant species, the informant consensus (IC) that translates the agreement of rice farmers who use a plant species in each locality was calculated according to the following formula (Byg and Balslev, 2001):

$$IC = \frac{n_{is}}{n}$$

Where:

IC = important value

n_{is} = number of rice farmers who used a species

n = total number of respondents

The IC is between 0-1. A low value close to 0 indicates that the informants disagree on the use of a plant. A value close to 1 shows high agreement of respondents on the usage of a plant.

Statistical analysis. Data were statistically analysed using Correspondence Factor Analysis (CFA) with the software Xlstat (2014) and a Chi-square test with Statistical Package for the Social Sciences (SPSS 20.0 software). The CFA allowed to link uses and perception of farmers on the negative effect of herbicides. For the CFA purpose, each species was abbreviated using the three first letters of a genus, with two first of a species (Bayer, 1986). For herbicide, the three first letters were used.

Statistical tools such as Chi-square were used to establish relationships between cultural practices, control methods used, and areas, age of farmers and use of control methods. Chi-square was also used to verify whether knowledge of biological control of weeds is linked to the areas. A pairwise comparison was performed after the Chi-square test, when there were more than two categories, using the procedure of Marascuilo and Serlin (1988) to the threshold $\alpha = 5\%$.

RESULTS

Socio-demographic characteristics of farmers. Results showed that in each production area, women managed most of the rice farms (Table 2); and the situation was similar in the 3 sites. Rice farmers' age varied significantly ($P < 0.05$) between areas, ranging from 52-80 for Danane, and 30-40 for Ferkessedougou and Guiberoua.

Education level of farmer varied widely, with the majority at Ferkessedougou (92.5%) and Danane (78.07) having no formal education, although some were able to speak French. In Ferkessedougou, only 5% had secondary school level. Similarly, secondary school level was 7.02 % and 18.52% in Danane and Guiberoua, respectively (Table 2).

In each locality, farming experience in rice cultivation was from 1 year to more than 30 years. However, there was no significant ($P > 0.05$) difference between the three localities. Land size among farmers ranged from (0.5-1 ha), medium (1.5-3 ha) and large (3.5-9 ha). There was a significant difference ($P < 0.01$) between the size of rice fields in the studied areas; whereby most farmers had small and medium-scale fields. The proportion of rice farmers possessing large-scale farm was 6.67, 3.70 and 3.51% in Ferkessedougou, Guiberoua and Danane, respectively (Table 2). Most of the farmers interviewed considered rice cultivation as their main activity.

Cropping practices. The rate of rice field types was statistically different between the production areas ($P < 0.001$). Upland rice fields were predominant in Danane (92.11%), and lowland rice fields in Guiberoua (95%); while wet rice was the most cultivated in Danane (33.33%) and Ferkessedougou (30.17%).

Intercropping was more common in Danane, where 75% of rice farmers associated rice with other food crops such as eggplant, cassava and beans (Table 3). The results also showed a significant difference ($P < 0.001$) in this practice between the three areas.

Weeds inventoried in rice fields. A total of 108 weeds was inventoried in rice field; and these were classified in 31 families and 87 genera (Fig. 2). The most predominant families were Poaceae (25 species), Asteraceae

TABLE 2. Socio-demographic and economic characteristics of rice farmers in Cote d'Ivoire

	D		F		G		Chi-square	
	n	%	n	%	n	%	df	χ^2 value
Gender								
Male	29	25.44	43	35.83	56	34.57		
Female	85	74.56	77	64.17	106	65.43	2	3.474^{ns}
Age								
[19-29]	15	13.16	14	11.67	20	12.35		
[30-40]	25	21.93	43	35.83	67	41.36		
[41-51]	32	28.07	32	26.67	35	21.6		
[52-80]	42	36.84	31	25.83	40	24.69	6	12.793*
Education level								
No formal	89	78.07	111	92.5	104	64.2		
Primary	17	14.91	3	2.5	28	17.28		
Secondary	8	7.02	6	5	30	18.52	4	38.190***
Farm experience (year)								
[1-2]	4	3.51	2	1.67	7	4.32		
[3-5]	10	8.77	16	13.33	34	20.99		
[6-15]	21	18.42	32	26.67	47	29.01		
[16-30]	37	32.46	38	31.67	50	30.86		
>30	42	36.84	32	26.67	24	14.81	3	7.705^{ns}

TABLE 2. Contd.

	D		F		G		Chi-square	
	n	%	n	%	n	%	df	χ^2 value
Field area (ha)								
[0.5-1]	59	51.75	68	56.67	120	74.07		
[1.5-3]	51	44.74	44	36.67	36	22.22		
[3.5-9]	4	3.51	8	6.67	6	3.7	4	18.874**
Main activities								
Trader	21	18.42	6	5	26	16.05		
Official	5	4.39	4	3.33	5	3.09		
Small Business	7	6.14	36	30	15	9.26		
Rice farmers	81	71.05	74	61.67	116	71.6	6	39.153***

Statistically significant at **P<0.01; ***P<0.001; ns = not significant, D = Danane, F = Ferkessedougou, G = Guiberoua

TABLE 3. Types of rice in the three study areas in Cote d'Ivoire

Practices	%				Chi-square	
	Danane	Ferkessedougou	Guiberoua	Mean	df	χ^2value
Upland rice	92.11	12.93	17.47	40.84	2	203.05***
Wet rice	33.33	30.17	0.60	21.37	2	126.47***
Lowland rice	40	69	95	68	2	134.30***
Intercropping	75	3	19	32.33	2	155.97***

Statistically significant at ***P<0.001

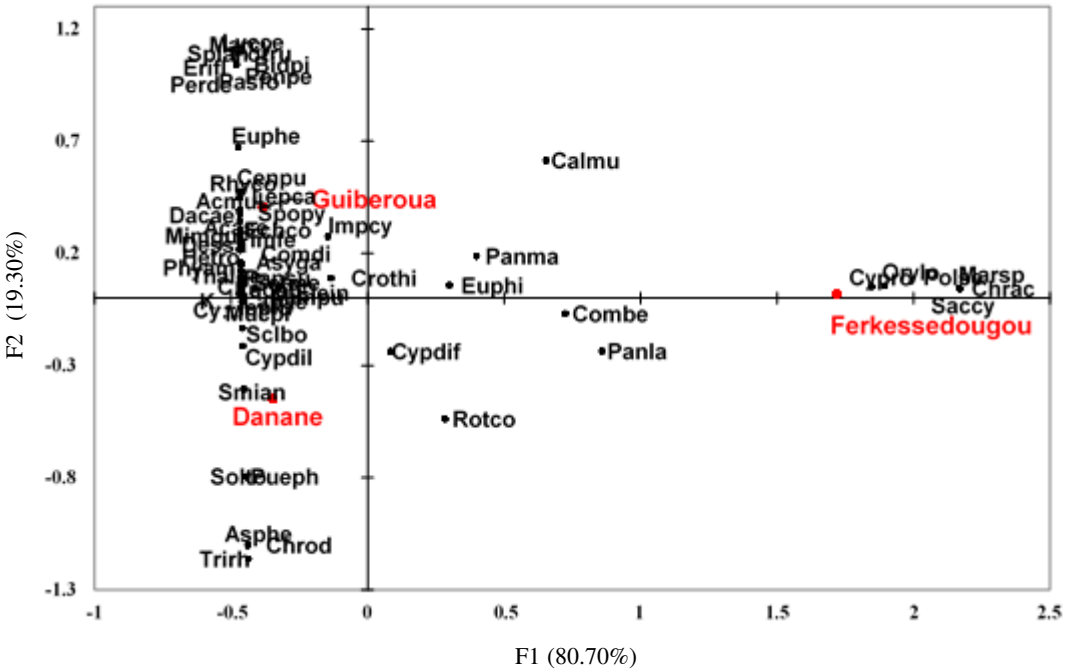


Figure 2. Groups of weeds linked to each study area (AFC).

Danane: Chrod: *Chromolaena odorata*, Pueph: *Pueraria phaseoloides*, Smian: *Smilax anceps,* Trirh: *Triumfetta rhomboidea,* Asphe*: Aspilia helianthoides*, Solto: *Solanum torvum*;

Guiberoua: Porru: *Porophyllum ruderale*, Erifl: *Erigeron floribundus*, Lycce: *Lycopodiella cernua,* Bidpi: *Bidens pilosa,* Penpe: *Pentodon pentandrus,* Spian*: Spigelia anthelmia;*Pasfo *: Passiflora foetida.* ; Bidpi : *Bidens pilosa*; Marcy : *Mariscus cylindristachyus* ; Perde : *Persicaria decipiens*

Ferkessedougou: Cypro: *Cyperus rotundus,* Orylo*: Oryza longistaminata,* Polse*: Polydora serratuloides,* Saccy*:Sacciolepis cymbiandra,* Chrac *:Chrysopogon aciculatus,* Marsp: *Mariscus sphacelatus*

Species common to the three localities: Croth: *Croton hirtus*; Euphi: *Euphorbia hirta*; Panma: *Panicum maximum*; Impcy: *Imperata cylindrica,* Cypdif: *Cyperus difformis*; Rotco: *Rottboellia cochinchinensis*; Panla: *Panicum laxum*

(14 species), Fabaceae (14 species), and Cyperaceae (10 species).

Correspondence Factor Analysis (CFA) allowed to gather weeds by study area. Six weeds were specific at Danane. Nine plant species were linked to Guiberoua and six weeds are specific to Ferkessedougou. Several weeds were common to Danane and Guiberoua. These plant species were *Croton hirtus*, *Euphorbia hirta*, *Panicum maximum*, *Imperata cylindrica*, *Cyperus difformis*, *Rottboellia cochinchinensis* and *Panicum laxum* (Fig. 2). The 13 most farmers cited weeds are indicated in Table 4.

Farmer weed control methods. Rice farmers had knowledge about four weed control methods, namely manual, chemical, manual-chemical and biological control methods (Fig. 3). However, manual, chemical and manual-chemical methods were the most used in the three study areas.

The use of manual control, based on hand weeding (75.25%), and machetes and hand hoes (24.75), varied from locality to another (χ^2 (2) = 75.96; P<0.001). In the Danane region, farmers (72 %) used manual control against 40 and 20%, respectively in Guiberoua and Ferkessedougou (Fig. 3).

Generally, across localities, farmers used sole chemicals for weeds control, with the exception of Ferkessedougou region where 16.3% of farmers used the chemical method alone (χ^2 (2) = 27.21; P<0.001). Due to the high cost, and negative effects, especially inefficient chemical tools, several farmers preferred manual control. However, they stated this method was labourious to use. So, they often combined chemical and manual methods (χ^2 (2) = 36.13; P<0.001).

Farmer perception of impact of herbicides. Overall, 2.4 D amine salt and Glyphosate were the active compounds used by the rice farmers in the study region. Farmers were aware of the negative effects of herbicides on humans, crops and environment (Fig. 4). The farmers also felt that herbicides may bring health conditions such as dizziness, nauseas and headaches. According to 67.68% of farmers, the use of herbicides resulted in the disappearance of microfauna, especially worms and certain insects around fields. Some of the farmers (63.89%) also attributed the loss taste and flavour of rice to the use of herbicides.

Farmer knowledge of herbicidal plants. Among the respondents, those aged 51-80 had good knowledge about the use of plants in weed control (Fig. 5) and allelpathic properties (Fig. 6). Up to 21.05% of respondents from Danane had knowledge about herbicide use, while up to 2.41 % from Guiberoua were herbicide knowledgeable. In the Ferkessedougou region, farmers revealed having no knowledge about herbicidal plants (Table 5).

Seven plant species were recorded for use in weeds control (Table 6). The respondents knowledge ranged from 0.2 to 0.44, which were low for all the cited plants. Farmers also indicated having observed allelopathy and 16 plants were cited in this case (Table 7).

DISCUSSION

Results showed that farmers had knowledge of management practices for controlling weeds such as *Cyperus rotundus, Eleusine indica*, *Oryza longistaminata*, *Porophyllum ruderale* and *Rottboellia cochinchinensis.* Study farmers mainly used three weed control methods namely manual, chemical and manual-chemical. The quality of the rice is unquestionable after using of manual method and is considered 100% natural. Agronomically, this traditional technique is also of interest because it allows a restructuring of the soil surface, better infiltration of water and therefore less runoff (Fontaine *et al.*, 2013). However, it is tiresome and expensive. This study has revealed that in the three localities visited, manual method is mainly carried out by women. This finding is also made in many

TABLE 4. List of the most cited weeds by rice farmers in Cote d'Ivoire

Plant species	Family	Rice fields	Plant value (%)			Total
			Danane	Ferkesse-dougou	Guiberoua	
Christella dentata (Forssk.) Brownsey & Jermy	Thelypteridaceae	Lowland rice	6.14	0	10.9	17.04
Chromolaena odorata (L.) R.M. King & H. Rob.	Asteraceae	Upland rice	0.33	0.07	0.4	0.8
Cyperus dilatatus Schumach. & Thonn.	Cyperaceae	Lowland rice, upland rice, wet rice	10.32	0	8.88	19.2
Cyperus rotundus L	Cyperaceae	Lowland rice, upland rice, wet rice	14.85	12.8	15.33	42.98
Eleusine indica (L.) Gaertn.	Poaceae	Upland rice	8.1	21.82	7.23	37.15
Imperata cylindrica (L.) Raeuschel	Poaceae	Upland rice	5.51	4.89	6.05	16.45
Mimosa pudica L.	Fabaceae	Upland rice, wet rice	6.93	1.69	9.49	18.11
Oryza longistaminata A.Chev. & Roehr.	Poaceae	Wet rice, lowland rice	7.4	9.6	18.2	35.2
Panicum maximum Jacq.	Poaceae	Upland rice,wet rice	4.72	17.05	0.41	22.18
Panicum subalbidum Kunth	Poaceae	Upland rice, wet rice	9.45	0	9.22	18.67
Porophyllum ruderale (Jacq.) Cass.	Asteraceae	Upland rice	9.81	18.4	0.96	29.17
Pueraria phaseoloides (Roxb.) Benth.	Fabaceae	Upland rice	10.77	0	4.81	15.58
Rottboellia cochinchinensis (Lour.) Clayt	Poaceae	Upland rice, lowland rice	5.67	13.68	8.12	27.47

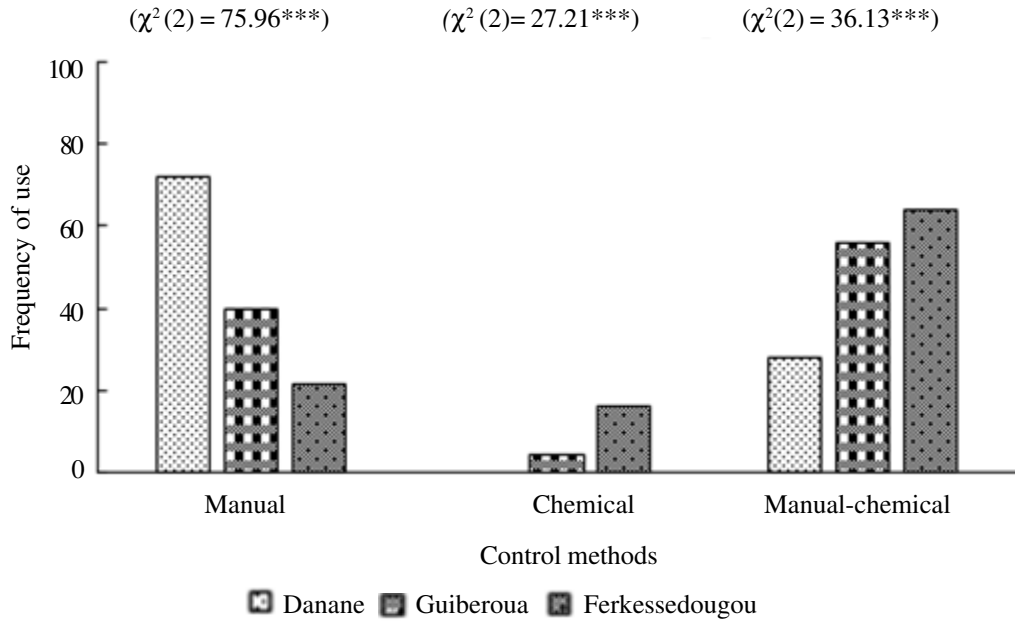


Figure 3. Frequency of weed control methods in rice field in Cote d'Ivoire.

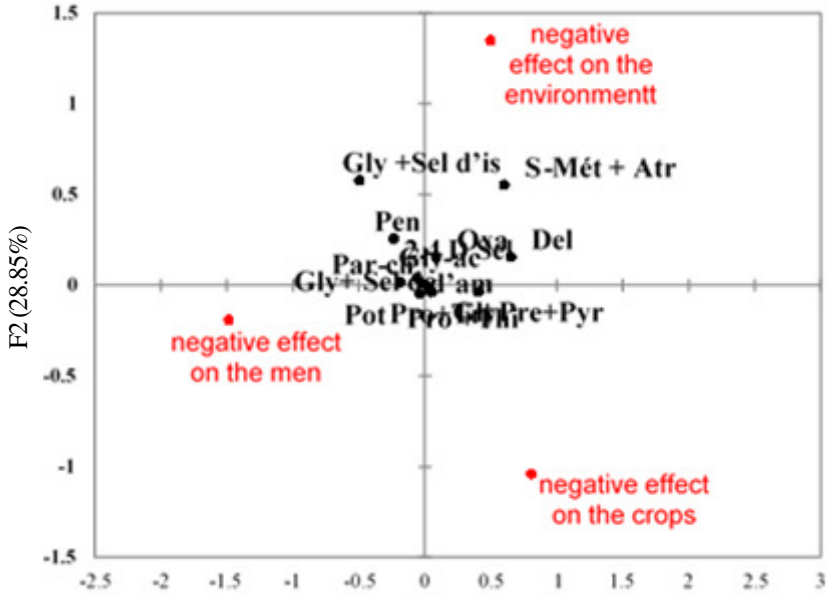
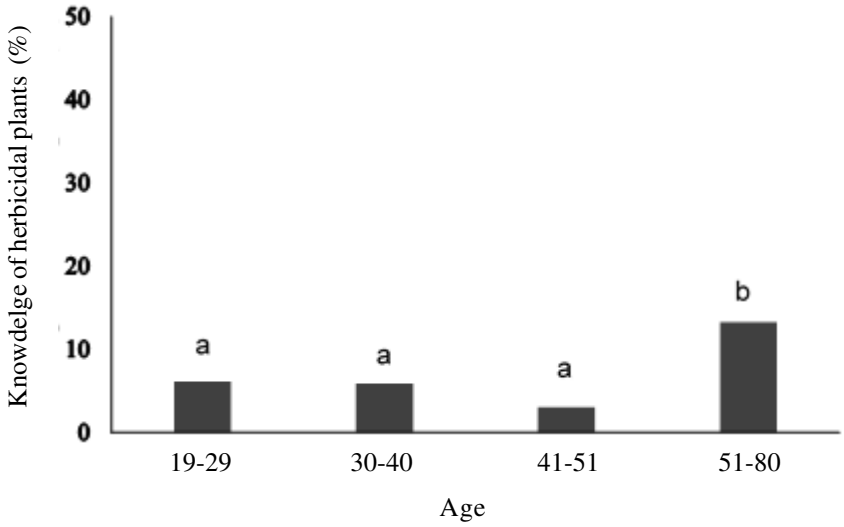


Figure 4. Farmers' perceptions of negative effects of herbicides in humans, crops and environment (AFC) in rice producing areas in Cote d'Ivoire.



Sticks followed by the same letter are not significantly different ($\alpha = 0.05$)

Figure 5. Rice farmer knowledge of herbicidal plants by age in Cote d'Ivoire.

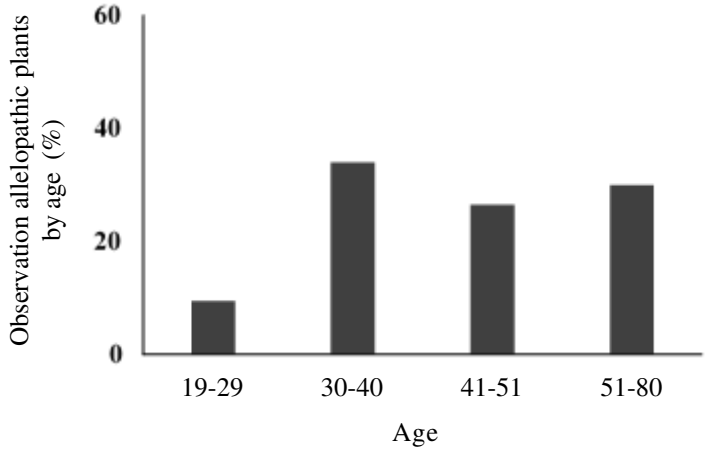


Figure 6. Rice farmer observation of allelopathic plants by age in Cote d'Ivoire.

TABLE 5. Farmers' knowledge of traditional control of weeds in three study rice areas in Cote d'Ivoire

Rice production areas	% of knowdelge		Chi-square	
	Yes	No	df	χ^2
Danane	21.05	78.95	2	206.95**
Guiberoua	2.41	97.59		
Ferkessedougou	0	100		

Statistically significant ***P<0.001

TABLE 6. Plant species with herbicidal effect according to rice farmers in rice growing areas of Cote d'Ivoire

Plant species	Family	Local language	Life forms	Plant parts	Preparation	Target weeds	Informant consensus		
							D	G	F
Alchornea cordifolia (Schumach & . Thonn.) Müll. Arg.	Euphorbiaceae	Fond (Yacouba)	mP	Leaves	Infusion	All weeds	0.35	nd	nd
Cyperus dilatatus Schumach	Cyperaceae	Serikian (Yacouba)	H	Whole plant	Decoction	*Cyperus dilatatus*	0.44	nd	nd
Hura crepitans L.	Euphorbiaceae	Casia (Yacouba)	mP	Leaves	Infusion	All weeds	0.24	nd	nd
Imperata cylindrica (L.) Raeusch.	Poaceae	Savane	G	Whole plant	Decoction	All weeds	nd	0.23	nd
Leptochloa fusca (L.) Kunth	Poaceae	Kaman (Baoule)	G	Whole plant	Decoction	*Leptochloa fusca*	nd	0.27	nd
Musanga cecropioides R.Br. ex Tedlie	Urticaceae	Loh (Yacouba)	MP	Leaves	Infusion	All weeds	0.20	nd	nd
Solanum scabrum Mill.	Solanaceae	Negbokoua (Bete)	np	Leaves	Infusion	All weeds	nd	0.26	nd

D = Danane, G = Guiberoua, F = Ferkessedougou, nd = not determined .Lifeform: H = Hemicryptophytis; mp = Microphanerophytis; MP = Megaphanerophytis; mP = Mesophanerophytis; np = Nanophanerophytis; G = Grass

parts of Cote d'Ivoire (Binaté-Fofana, 1996; Doumbia and Tahouo, 2011).

Concerning chemicals, it was noted that farmers generally used herbicides containing glyphosate as the active ingredient. However, they often complained that these products did not kill weeds properly. Many cases of herbicide resistance have been described worldwide (Pratley *et al.*, 1999; Tran *et al.*, 1999; Simarmata *et al.*, 2003; Heap, 2014). This phenomenon is growing and is a serious problem for farmers.

Farmers in the study reported health problems due to herbicides such as dizziness, nauseas and headaches. To reduce the use of herbicides, some farmers based their strategy of weed control on the cultivation practices or a combination of two control methods. For example, in the Danane region, farmers practiced upland rice in combination with crops such as eggplant, cassava and beans. This multiple cropping practice is suitable for an effective fight against weeds (Diagne, 1995).

In light of the many constraints such as high cost of herbicides, weeds resistance to herbicides, and intensive labour requirement with manual methods, it is imperative that alternative control methods are explored. Interestingly, the surveyed farmers had knowledge about plants with herbicidal properties. This information was common mostly among 51-80 year age groups. This may be attributable to the fact that old people usually have knowledge because of experience gained over time. In Danane, farmers of this age practiced more rice production and knew by 21% the biological control. For Guiberoua, more young people of 30-40 years devoted to this activity and knew by 2% the biological control.

In view these results, knowledge of biological control is linked to age in the study area. But, in Ferkessedougou, farmers are of similar age (30-40 years) and stated having no knowledge about herbicidal plants. This situation is understandable because the cultivation of rice is part of tradition of Danane

TABLE 7. Weed species with allelopathic property according to rice farmers in Cote d'Ivoire

Plant species	Family	Local language	Life forms	Plant value (%)		
				Danane	Ferkessedougou	Guiberoua
Ageratum conyzoides L.	Asteraceae	Aboklo (Agni)	np	nd	nd	13.56
Albizia zygia (DC.) J. F. Macbr.	Fabaceae	Zaha (Yacouba)	mP	nd	nd	13.56
Anacardium occidentale L.	Anacardiaceae	Anacarde	mP	nd	15.85	nd
Azadirachta indica A. Juss.	Meliaceae	Neem	mP	9.55	nd	nd
Bambusa vulgaris Schrad. ex J.C. Wendl.	Poaceae	Yeli (Yacouba)	Gr	5.88	0	0
Carica papaya L.	Caricaceae	Papayer	mP	nd	10.38	nd
Cola cordifolia (Cav.) R. Br.	Malvaceae	Watigue (Niarafolo)	mP	nd	19.13	nd
Mangifera indica L.	Anacardiaceae	Manguier	mP	nd	13.66	nd
Mansonia altissima (A. Chev.) A. Chev.	Malvaceae	Doh (Yacouba)	MP	11.14	nd	nd
Pentaclethra macrophylla Benth.	Fabaceae	Gbiao (Yacouba)	mP	12.27	nd	nd
Scaphopetalum amoenum A. Chev.	Malvaceae	Cacaoyer F	mP	nd	nd	10.17
Scleria depressa (C.B.Clarke) Nelmes	Cyperaceae	Glor (Yacouba)	Gr (np)	9.32	nd	nd
Tamarindus indica L.	Fabaceae	Tomi (Malinke)	mP	nd	nd	12.57
Tectona grandis L.f.	Lamiaceae	Theque	mP	0	12.28	0
Tithonia diversifolia (Hemsl.) A. Gray	Asteraceae	Fleur marguerite	mP	nd	nd	16.95
Trichilia monadelpha (Thonn.) J. J. de Wilde	Meliaceae	Wa (Yacouba)	mP	8.86	nd	nd

nd: not determined. Life form: Gr = Rhizomatous Geophytis; mp = Microphanerophytis; np = Nanophanerophytis; MP = Megaphanerophytis; mP = Mesophanerophytis

and Guiberoua people, both of which are high rice production areas located in the forest and are very suitable for growing rice.

Rice farmers indicated several plants useful for biological control. *Cyperus dilatatus* and *Alchornea cordifolia* were the most commonly used, with consensus indices of 0.44 and 0. 37. Some plants such as *Imperata cylindrica* and *Chromolaena odorata* that were indicated viewed in the present study as weeds, were reported in a previous study to have inhibitory effects on the growth of *Centrosema pubescens* (Rusdy *et al.*, 2015). In the present study, some farmers aged from 30-40 and 51-80 observed allelopathic effects of some plant species. This may be attributable to the fact that more people of this age practiced cultivation of rice and spent more time in the field, than the other age groups.

ACKNOWLEDGEMENT

This work was supported by "Programme d'Appui Stratégique à la Recherche Scientifique (PASRES)", grant PASRES/ N°128. The authors thank Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS) for technical assistance. We are also grateful to Mr. Yao Konan for assistance with statistical analysis

REFERENCES

Ahmadi, N. et Bouman, B. 2013. Riz et rizicultures, enjeux économiques, écologiques et scientifiques: [Editorial]. *Cahiers Agricultures* 22 (5): 333-335.

Aleem, M., Alamu, L. and Olabode, O. 2014. Allelopathic effects of some selected tree Species on the germination and growth of cowpea (*Vigna unguiculata* L. Walp.). *Open Journal of Forestry* 4: 310-315. http://dx.doi.org/10.4236/ojf.2014.44037

Arbonnier, M. 2000. Arbres, arbustes et lianes des zones sèches d'Afrique de l'Ouest, CIRAD/MNHN/UICN. Montpellier, France. 541pp.

Aubreville, A. 1959. La flore forestière de la Côte d'Ivoire. Centre technique forestier tropical, Nogent-sur -Marne, 3 tomes. 286pp.

Avenard, J.M., Eldin, M., Girard, G., Sircoulon, J., Touchebeuf, P., Guillaumet, J.L., Adjanohoun, E. et Perraud, A. 1971. Le milieu naturel de la Côte d'Ivoire, Mémoires Orstom, Paris, France. 392pp.

Bayer, A. 1986. Important crops of the world and their weeds (Scientific and common names, synonyms, and WSSA/WSSSJ approved computer codes), Leverkussen, Federal Republic of Germany. 1465pp.

Bedding, N.D., Mcintyre, A.E., Perry, R. and Lester, J.N. 1983. Organic contaminants in the aquatic environment II. Behaviour and fate in the hydrological cycle. *Science of The Total Environment* 26:255-312.

Bezançon, G. 1995. Riziculture traditionnelle en Afrique de l'Ouest : Valorisation et conservation des ressources génétiques. *Journal d'agriculture Traditionnelle et de Botanique Appliquée* 2: 3-24.

Binaté-Fofana, N. 1996. Les femmes et l'intensification rizicole: Etude des systèmes de production à Korhogo au Nord et à Gagnoa au Centre-ouest de la Côte d'Ivoire. Doctorat Thèse de 3e cycle, CIRES, Abidjan (Côte d'Ivoire).145pp.

Bouadou, B. 2010. Aperçu du développement rizicole en Côte d'Ivoire. Rapport « Etat des lieux de la filière rizicole ». FAO, Rome9

Byg, A. and Balslev, H. 2001. Diversity and use of palms in Zahamena, eastern Madagascar. *Biodiversity and Conservation* 10: 951–970.

CORAF. 2014. Etude régionale de la Chaîne de Valeur du Riz en Afrique de l'Ouest (Côte d'Ivoire, Libéria, Mali, République de Guinée et Sera Léone). *Rapport du projet* CORAF/WECARD, Côte d'Ivoire: 72pp.

Deat, M. 1973. Etude économique de deux herbicides en culture cotonnière en Côte d'Ivoire. *Coton et Fibres Tropicales* 28(2): 293-295.

Diagne, M. 1995. L'enherbement des rizières irriguées de la moyenne vallée du fleuve Sénégal: situation actuelle et perspectives de recherche. *Mémoire de Confirmation jhnatiorl ISRA (Saint-Louis)*.

Doumbia, S. et Tahouo, O. 2011. La perception paysanne du changement climatique en riziculture pluviale et les stratégies d'adaptation au centre-ouest de la Côte d'Ivoire. pp. 8-10.

Fontaine, L., Bonin, L., Lieven, J., Garnier, J-F., Zaganiacz, V., Rodriguez, A. et Lemarié, P. 2013. Optimiser et promouvoir le désherbage mécanique en grandes cultures. *Innovations Agronomiques* 28: 113-125.

Guillaumet, J.L. et Adjanohoun, E. 1971. Le milieu naturel de la Côte d'Ivoire, Paris, France. 391pp.

Haefele, S.M., Wopereis, M.C.S. and Donovan, C. 2002. Farmers'perceptions, practices and performance in a Sahelian irrigated rice scheme. *Experimental Agriculture* 38: 197-210.

Heap, I. 2014. Global perspective of herbicide-resistant weeds. *Pest Management Science* 70:1306-1315.

Hutchinson, J. and Dalziel, J.M. 1954. Flora of West Tropical Africa, London. 276pp.

Ipou Ipou, J., Marmotte, P., Kadio, G.A., Aké, S. and Touré, Y. 2004. Influence de quelques facteurs environnementaux sur la germination d'*Euphorbia heterophylla* L. (Euphorbiaceae). *Tropicultura* 22:176-179.

Johnson, D.E. 1997. Les adventices en riziculture en Afrique de l'Ouest, Imprit design, United Kindom. 312pp.

Johnson, D.E., Wopereis, M.C.S., Mbodj, D., Diallo, S., Powers, S. and Haefele, S.M. 2004. Timing of weed management and yield losses due to weeds in integrated rice in the Sahel. *Field Crop Research* 85:31-42.

Konan, Y., Akanvou, L., Ncho, S., Arouna, A., Eddy, B. et Kouakou, C.K. 2014. Analyse de l'éfficacité technique des riziculteurs face à l'infestation des cultures par les espèces parasites *Striga* en Côte d'Ivoire. *Revue Ivoirienne des Sciences et Technologie* 23:212-223.

Kouamé, K.F., Ipou, I.J., Toure, A. and N'guessan, K.E. 2011. Major weeds of rice agro-ecosystems in Côte d'Ivoire. *Agriculture and Biology Journal of North America* 2:1317-1325. doi:10.5251/abjna.2011.2.9.1317.1325.

Lebrun, J.P. et Stork, A.L. 1997. Enumération des plantes à fleurs d'Afrique tropicale. Gamopétale: Clethraceae à Lamiaceae, Conservatoire et Jardin Botanique de la ville de Genève, Suisse. 712pp.

Mangara, A., N'daadopo, A., Traore, K., Kehe, M., Soro, K. et Toure, M. 2010. Etude phytoécologique des adventices en cultures d'ananas. *Journal of Applied Biosciences* 36:2367-2382.

Marascuilo, I.A. and Serlin, K.C. 1988. Statistical methods for the social and behavioral sciences WH Freeman/time Books/Henry holt & co. 804pp.

Mendez, D.V.P., Bauer, J.M., Soumaré, P. et Laouali, I.M.C. 2011. Crise rizicole, évolution des marchés et sécurité alimentaire en Afrique de l'Ouest. http://www.wfp.org/content/afrique-de-l-ouest-crise-rizicole-evolution-des-marches-et-securite-alimentaire-avril-2011.

ONDR. 2012. Stratégie Nationale révisée de Développement de la Filière riz en Côte d'Ivoire (SNDR) 2012–2020. *Ministère de l'Agriculture,* République de Côte d'Ivoire. 40pp.

Powles, S.B. and Yu, Q. 2010. Evolution in action: Plants resistant to herbicides. *Annual Review of Plant Biology* 61:317-347.

Pratley, J.E., Urwin, NaR, Stanton, R.A., Baines, P.R., Broster, J.C., Cullis, D.E., Schafer, D.E., Bohn, J.A. and Krueger, R.W. 1999. Resistance to glyphosate in *Lolium rigidum*. *Weed Science Society Conference, Bangkok* 47:405-411.

Rusdy, M., Riadi, M., Sari, A.M. and Normal, A. 2015. Comparative allelopathic effect of *Imperata cylindrica* and *Chromolaena*

odorata on germination and seedling growth of *Centrosema pubescens*. *International Journal of Scientific and Research Publication* 5(4):5.

Simarmata, M., Kaufmann, J.E. and Penner, D. 2003. Potential basis of glyphosate resistance in California rigid ryegrass (*Lolium rigidum*). *Weed Science* 51:678-682.

Sodexam. 2016. Données météorologiques de 1987-2015 de Danané, Guibéreoua, Ferkéssédougou et Abidjan. Société d´exploitatation et de développement Aéroportuaire, aéronautique et Météorologiques : Direction de la Météorologie Nationale, Port-Bouët-Abidjan (Côte d´Ivoire).

Timothy, G.R., Graeme, T. et Gordon, R. 2016. Produire plus avec moins en pratique: Le maïs, le riz, le blé. FAO, http://www.fao.org/3/a-i4009f.pdf, consulté le 19 juin 2017: 124.

Touré, A. 2014. Gestion agronomique et dynamique des mauvaises herbes dans les systèmes de riz de bas fond en Afrique de l'Ouest. Thèse en Sciences Agronomiques, Université d'Abomey-Calavi. 250pp.

Tran, M., Bearson, S. and Brinker, R. 1999. Characterisation of glyphosate resistant *Eleusine indica* biotypes from Malaysia. In: Proceedings 1(B) 17th Asian-Pacific Weed Science Society Conference, Bangkok. pp. 527-736.

Traoré, S.K., Mamadou, K., Dembele, A, Lafrance, P., Mazellier, P. et Houenou, P. 2006. Contamination de l'eau souterraine par les pesticides en régions agricoles en Côte d'Ivoire (centre, sud et sud ouest). *Journal Africain des Sciences de l'Environnement* 1:1-9.

Vessereau, A. 1992. Méthodes statistiques en biologie et en agronomie. 538pp.