International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 21, No. 5, p. 246-260, 2022

INNSPUB

RESEARCH PAPER OPEN ACCESS

Factors influencing the adoption of biological control technology against the pearl millet head miner in the Southern band of Niger

Issaka Hamidine*[1], Sitou Lawali[1], Moctar Rabé Mahamane[2], Ibrahim Boukary Baoua[1]

[1]*Faculty of Agronomy and Environmental Sciences, Dan Dicko Dankoulodo University of Maradi, BP 465, Maradi, Niger*

[2]*Faculty of Agronomic Sciences, University of Tahoua, Niger*

Key words: Adoption, Biological control, Pearl millet head miner, Niger

http://dx.doi.org/10.12692/ijb/21.5.246-260 Article published on November 20, 2022

Abstract

Millet, *Pennisetum glaucum* (L.) R. Br. provides the main food supply for the Sahelian populations. The pearl millet head miner (MHM) *Heliocheilus albipunctella* De Joannis is one of the main pests of this cereal crop. Biological control with augmentative releases of the ectoparasite *Habrobracon hebetor* Say is one of the methods advocated in recent years to protect crops. This study was conducted in the regions of Dosso, Maradi and Zinder to assess farmers' perception of this ecological technology and to determine the factors influencing its adoption. It covered six (6) communes including Guéchémé, Doutchi, Chadakori, Sherkin Hausa, Droum and Bandé. A questionnaire was administered to 360 producers who had benefited from the technology and were randomly selected from 24 villages. The results showed that 85% of the respondents appreciated biological control, with an adoption rate of 63%. The analyses with the Logit model revealed the socio-economic determinants of the adoption of biological control. These are mainly: a) level of education; b) incidence of millet earworm; c) yield after the release of parasitoids; d) effectiveness of parasitoids in managing millet earworm populations; e) reduction of losses; f) social peace; g) access to credit, and h) family burden.

* **Corresponding Author:** Issaka Hamidine ✉ hamidine.issaka@gmail.com

Introduction

The millet（*Pennisetum glaucum* (L.) R. Br is a major crop for livestock in traditional smallholder crop-livestock production systems in the Sahelian region of West and Central Africa and constitutes the staple food of the populations. Millet is cultivated in more than 50% of the area in the Sahel regions in Africa (MBAYE, 1993). In Niger and the Sahelian regions, 70 to 90% of agricultural production comes from food crops grown under the rains. Millet, the main cereal crop, faces biotic and abiotic constraints. These include irregular rainfall, poor soils and pest attacks. Among the pests, *Heliocheilus albipunctella* De Joannis is the major pest, causing serious economic damage in the maturity period cited by producers (Oumarou *et al.*, 2019). It is a noctuid pest of millet that lays its eggs on the apex of young millet ears. The eggs of this lepidopteran hatch into larvae and perforate the glumes and eat away the flowers, causing very significant yield losses, especially during the peak season (Gahukar, 1983; Gahukar, 1984; Guevremont, 1981, 1982; Guevermont, 1983; Bhatnagar, 1984; N'Diaye, 1984). In Niger, losses ranging from 8 to 95% have been reported (Baoua *et al.*, 2009). Several control methods based on cultural practices at the field scale as deep ploughing at the end of the crop cycle to expose the pupae to predators, late planting, cutting the apex of the ears at the beginning of the egg-laying period, early harvesting of the ears as soon as they reach physiological maturity, resistant varieties and control strategies using pesticides were recommended (Vercambre, 1978; N'Doye, 1979; Guèvremont, 1982; Maiga, 1984; Maiga, 1985; Youm et Gilstrap, 1993;). There are numerous natural enemies of *H. albipunctella*. Many predators, parasitoids and indigenous parasites have been inventoried in the Sahelian region (N'Doye *et al.*, 1984; Bhatnagar, 1987). Bal (1992) reported that the ectoparasitoid *Habrobracon hebetor* Say is the most effective in limiting the damage of this pest. Guèvremont (1982), in Maradi region, natural parasitism rates of *H. albipunctella* larvae were reported varying between 9 and 54% with *Habrobracon hebetor* predominating in 95% of parasitized larvae. Recently, the possibilities of biological control using the release of mass-reared parasitoids have been strengthened with the publication of its life and fecundity table (Youm et Gilstrap, 1993). In recent years, augmentative releases have been carried out in many regions of Niger to destroy populations of the MHM. The technology has been tested in many villages and it has been found that augmentative releases of *H. hebetor* can limit the damage of the pest and increase millet yields by up to 34% (Baoua *et al.*, 2013). Four thousand five hundred and fifteen (4515) bags of release were placed in 2015 in 301 villages and 4662 bags in 323 villages in 2016 in five regions of Niger, namely: Dosso, Maradi, Tahoua, Tillabéry and Zinder. The area of millet covered by the release was estimated at 1,417,680 ha in 2015 and 1,521,330 ha in 2016. The farmers in the five regions estimated an average yield gain of up to 50% (Amadou *et al.*, 2017). The farmers' perception of the results of these releases is the central focus of this study.

Methodology

The study was conducted around the main areas of millet production located between parallels 11°50 and 14°40 N and meridians 2°30 and 4°40 longitude; parallels 13° and 15°26 N and meridians 6°16 and 8°33 E and la (latitude: 13°48'19''N, 08°59'18''E). The climate is Sahelian and characterized by an average rainfall varying from approximately 200 to 800 mm, unevenly distributed in time and space.

The productive potential is a system consisting of lowland areas in the east and dune areas in the west. The vegetation is characterised by agroforestry parks and shrubby steppes scattered among the crop fields and open savannahs. In terms of demography, these areas have a density of 200 inhabitants/km² in some localities.

Stratified sampling was used in the seven millet-producing regions, three were selected, including Dosso, Maradi and Zinder (Fig. 1). In each region, two (2) communes were selected, namely Guéchémé and Doutchi (Dosso), Chadakori and Sherkin Hausa (Maradi), Bandé and Droum (Zinder). A total of 24 villages were selected based on the following criteria: a) accessibility of the agricultural area, b) excellent zone of millet production, c) project intervention area, d) area covered by parasitoid releases. The villages were selected by consulting the list of villages that had benefited from biological control available from the agricultural services. In each village, 15 heads of households were interviewed, for a total of 360 persons. These heads of household were randomly selected from the list of agricultural households available at the village level. The questionnaire used had three (3) main sections, namely: a) characteristics of the respondents; b) millet production; c) farmers' perception of biological control technology. The individual interviews were conducted using the KoboCollect digital system.

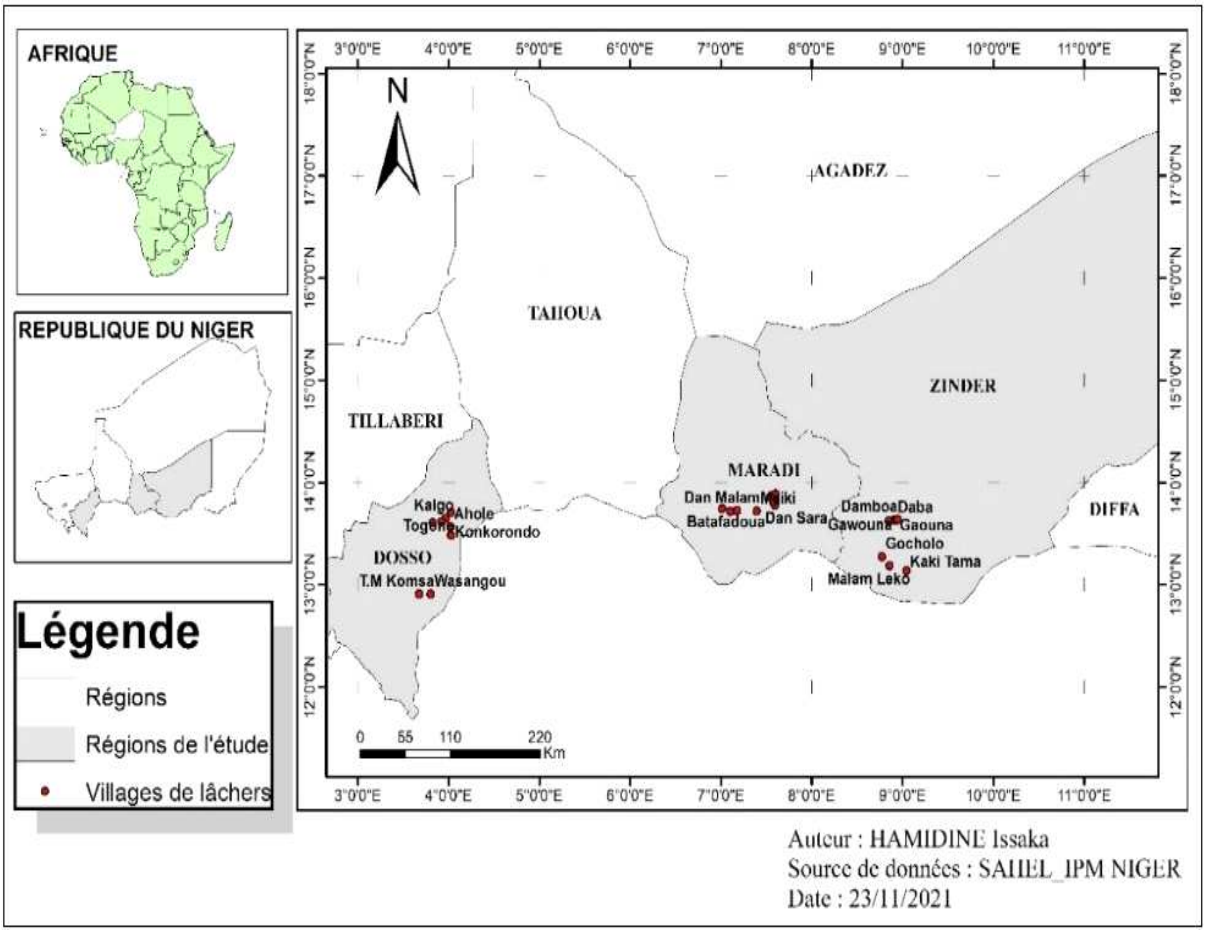

Fig. 1. Location of villages benefiting from parasitoid releases.

Method of analysis

ANOVA and Newman-Keuls tests were performed on the following variables: age of respondents, family charge, agricultural assets, average area per farm, and area occupied by millet. The percentage chi-square test followed by Cramer's Phi were performed on education status, crop systems and all other qualitative variables.

Factors determining the adoption of biological control technology

The LOGIT regression model which takes into account a dichotomous (binary) variable, was used.

The dependent variable which is the adoption of the biological control technology (ADOPTLB): takes the value 1 if the farmer adopts the technology and the value of 0 if not. The maximum likelihood method used by several authors was applied (Rabé *et al.*, 2017; Zidat, 2018, Mohamed, 2021).

Y=f (X, ε) with Y the explained variable, X the set of explanatory variables and ε the standard error (Adjobo and Yabi, 2020).

Let *Pi* be the probability that LOGIT associates with a producer adopting biological control.

$$P_i = F(S_i) = \frac{1}{1+e^{-I}}$$

I: $\alpha 0 + \alpha\ 1$ NIVINSTR + $\alpha\ 2$ INCIDMEM + $\alpha\ 3$ R_APLACHER + $\alpha\ 4$ EFFICHH + $\alpha\ 5$ REDPERT+ $\alpha\ 6$ QUIETUDLB+ $\alpha\ 7$ ACCREDIT + $\alpha\ 8$ AGE + $\alpha\ 3$ SEX

Ii = characteristics of farmers using biological control, their environment and the object of their choice;

ai = Coefficients of explanatory variables ;

Xin = Explanatory variables.

The variable "age" was introduced to see if it could influence the adoption of biological control. For the "gender" variable, the hypothesis is that men have more access to information, which could be an asset for adopting the technology. The greater the "family charge" on the farm, the more important it is to adopt the technology in order to have more subsistence to feed the family. The level of education can help in decision making in the control of the earworm on a farm in order to cope with this natural enemy hence its introduction in the model. The incidence of the pearl millet head miner causing production losses may prompt farmers to adopt biological control, one of the agro-ecological practices to control MHM. The acquisition of release bags for control of MHM requires financial resources. The effectiveness of the parasitoids released in the fields to limit the damage of millet earworm populations can positively influence the adoption of the technology.

The averages of the variables: family charge, agricultural assets (AA), area per farm (SUP_Moy) and area occupied by millet cultivation are calculated based on the following formula (Dagnelie, 1973).

$$xi = \frac{1}{N}\sum_{i=1}^{n} xi$$

Xi: observed value of the variable x at farm level i

N: total number of households surveyed.

Results

Characteristics of respondents

The average age of the respondents varied from 45 to 47 years. There were 10 to 12 persons per family, with 4 to 5 farm workers per farm. The size of the fields and the area devoted to millet cultivation are larger in Dosso than in Maradi and Zinder (Table 1).

Table 1. Socio-demographic characteristics of respondents by region.

	Age	Family expenses	AA	SUP_Moy	SUPMIL
Dosso	47,72±13,39a	10,67±5,37a	4,66±3,27a	6,68±4,64a	3,90±2,49a
Maradi	45.09 ± 12.32a	11,03±5,07a	4,61±3,22a	4,13±3,23b	2,15±1,60b
Zinder	46,02±13,28a	12,27±6,17a	4,49±2,90a	5,04±3,51b	2,76±1,92c
Average	46.14 ±13.28	11,4±5,61	4,58±3,11	5,15±3,88	2,84±2,10
ANOVA	F=1.22 ; p=0.29	F=2,93 ; p=0,05	F=0.10 ; p=0.89	F=13.78 ; p=0.00	F=23.05 ; p=0.00

Averages followed by the same letter in the column are not different

AA: Agricultural Assets; SUP_Moy: average area per farm; SUPMIL: area occupied by millet cultivation.

It was also found that 94.3% of the respondents were men, and the majority of them were Hausa (96.4%). The results showed that 24% of the respondents are members of a farmers' organization, 37.7% have access to credit and more than 50% are in contact with projects, NGOs and agricultural agents. The main mode of land acquisition in the zone is inheritance, which varies from 77 to 91% depending on the region, followed by purchase (24.5%). Purchase is more common in Maradi and Zinder regions (Table 2). Community land is more common in Sherkin Hausa in the Maradi region.

Agriculture is the main activity of the population (Fig. 2). It is followed by trade and the rural exodus. Other activities were noted, notably masonry, mechanics, the sale of wood and straw, agricultural wage labour, handicrafts, etc.

Table 2. Proportions (%) of responses in relation to land tenure patterns.

Regions	Municipalities	Land holding methods						
		Legacy	Purchase	Don	Pledge	Rental	Loan	T.C
Dosso	Doutchi	91,4	7,1	0	7,1	1,4	8,6	0
	Guechamé	87,9	9,1	0	15,2	3,0	0	0
Maradi	Chadakori	82,8	28,1	3,1	14,1	1,6	4,7	0
	Sherkin. Hausa	77,6	36,8	1,3	10,5	2,6	18,4	11,8
Zinder	Banded	89,7	32,8	0	5,2	1,7	8,6	1,7
	Droum	91,9	25,6	1,2	12,8	3,5	8,1	0
%Average		86,8	24,5	1,0	10,6	2,3	9,0	2,6
Chi-square		10,15	24,51	4,49	4,65	1,12	12,99	32,76
V of Cramer		0,16	0,25	0,10	0,11	0,05	0,18	0,29
Meaning		ns	***	ns	ns	ns	*	***

*: $p<0.05$;
***: $p<0.001$; ns: not significant; T.C: Community Land.

Millet varieties grown and production constraints

Two types of millet varieties are used by farmers in a variable climatic context. These are improved short-cycle varieties and local long-cycle varieties. The results in Table 3 show that local varieties (27.6%) are the least used compared to improved varieties. The HKP and Zatib varieties are the most used in the three regions.

The HKP variety is still the most used in the Dosso and Maradi regions compared to the Zinder region. On the other hand, CT6 is the least used in all regions.

Table 3. Millet varieties used by respondents.

Regions	Municipalities	Millet varieties used				
		HKP	Zatib	CT6	SOSAT	Local
Dosso	Doutchi	38,6	5,7	1,4	1,4	24,3
	Guéchémé	30,3	15,2	6,1	6,1	27,3
Maradi	Chadakori	39,1	9,4	3,1	15,6	32,8
	Sherkin Hausa	17,1	5,3	9,2	5,3	22,4
Zinder	Band	19,0	37,9	12,1	10,3	29,3
	Droum	23,3	11,6	5,8	11,6	30,2
%Average		27,4	13,2	6,2	8,5	27,6
Chi-square		15,77	39,73	8,42	11,25	2,67
V of Cramer		0,20	0,32	0,14	0,17	0,08
Meaning		***	***	ns	*	ns

*: $p<0.05$;
***: $p<0.001$; ns : not significant.

Table 4. Perceived constraints of millet cultivation.

Regions	Municipalities	Millet growing constraints								
		Ins. rav	Diseases	P.S.	M.H	F.E	Drying	S.S	C.M.O	V.I
Dosso	Doutchi	82,9	1,4	55,7	1,4	15,7	51,4	0	32,9	0
	Guechamé	84,8	9,1	78,8	18,2	15,2	45,5	0	33,3	9,1
Maradi	Chadakori	96,9	1,6	85,9	1,6	10,9	50,0	1,6	4,7	23,4
	S. Hausa	88,2	0	76,3	10,5	21,1	48,7	0	9,2	17,1
Zinder	Band	81,0	1,7	58,6	8,6	3,4	32,8	0	3,4	10,3
	Droum	88,4	1,2	73,3	8,1	12,8	50,0	0	16,3	9,3
%Average		87,3	1,8	71,1	7,2	13,4	47,0	0,3	15,5	11,6
Chi-square		8,93	11,53	21,44	13,97	9,53	5,93	5,06	38,58	20,88
V of Cramer		0,15	0,17	0,23	0,19	0,15	0,12	0,11	0,31	0,23
Meaning		ns	*	***	*	ns	ns	ns	***	***

*: $p<0.05$;
***: $p<0.001$; ns: not significant
Ins.rav: insect pests; P.S: poor soil; M.H: weeds; F.E: poor supervision; D.S: drought; S.S: soil salinity; C.M.O: high labour cost; V.I: unsuitable varieties.

Millet cultivation is not free of production constraints. Indeed, the study reveals three main constraints to millet production in the localities visited (Table 4). These are pest pressure, soil poverty and drought during the production period in all regions. However, the poor supervision of farmers was mentioned more by farmers in the Zinder region. The high cost of labour, the proportions of which vary from 15 to 32% across the regions, is higher in Dosso than in Maradi and Zinder. For unsuitable varieties, it was mentioned more in the Maradi region than in the other regions. The constraints of disease, weed and soil salinity were not mentioned by respondents in the study area.

Table 5. Enemies of millet cultivation according to respondents.

Regions	Municipalities	Enemies millet crop				
		F.T	Crioceran	MEM	Locusts	Bedbugs
Dosso	Doutchi	4,3	15,7	61,4	35,7	35,7
	Guechamé	0	36,4	72,7	24,2	27,3
Maradi	Chadakori	1,6	6,3	37,5	6,3	1,6
	Sherkin Hausa	0	17,1	48,7	11,8	1,3
Zinder	Band	5,2	19,0	48,3	6,9	6,9
	Droum	4,7	9,3	39,5	14,0	14,0
%Average		2,8	15,2	49,1	16,0	13,4
Chi-square		6,25	18,58	18,24	31,22	54,81
V of Cramer		0,12	0,21	0,21	0,28	0,37
Meaning		ns	***	***	***	***

***: p<0.001; ns: not significant; Stem borer; Millet earworm.

Pest pressure remains the main constraint to millet production noted. Among the range of pests, the millet head miner (MHM) was the most important pest reported by the majority of respondents, followed by locusts in all three regions (Table 5). For the stem borer, it was reported more in the Zinder region. Locust and bugs were more mentioned in Dosso region compared to Maradi and Zinder.

Table 6. Perceptions of sources of access to technology information.

Regions	Municipalities	Information sources					
		P.GIMEM	INRAN	OP	C.P	A.A	No answer
Dosso	Doutchi	14,3	0	0	5,7	71,4	28,6
	Guechamé	12,1	3,0	12,1	9,1	81,8	9,1
Maradi	Chadakori	20,3	9,4	3,1	9,4	60,9	6,3
	Sherkin Hausa	21,1	3,9	2,6	5,3	59,2	15,8
Zinder	Band	8,6	8,6	3,4	10,3	67,2	15,5
	Droum	22,1	8,1	0	9,3	54,7	12,8
%Average		17,3	5,7	2,6	8,0	63,8	15,2
Chi-square		6,64	8,60	16,31	2,11	10,74	15,01
V of Cramer		0,13	0,14	0,20	0,07	0,16	0,19
Meaning		ns	ns	***	ns	*	*

*: p<0.05 ;
***: p<0.001 ; ns : not significant
INRAN: National Institute of Agronomic Research of Niger; OP: Farmers' organisation; C.P: Peasants' Colleague; A.A: Agriculture Agent.

Farmers' perceptions of sources of access to information on biological control

Biological control (BC) has emerged as an alternative for the management of MHM in the high millet production zone. After many years of implementation, this study on farmers' perceptions of biological control analyses the views of farmers (Table 6). Indeed, the most important sources of information about this technology are agricultural agents and the Integrated Management of Millet head miner (GIMEM) project, according to the respondents. In the regions of Maradi and Zinder, farmers mentioned INRAN as a source of information about the technology. Fewer respondents did not comment on the source of information on the technology in the Maradi region.

Table 7. Farmers' perceptions of funding sources for biological control.

Regions	Municipalities	Source of funding			
		Status	Search	NGO/Project	Farmers
Dosso	Doutchi	32,9	0	32,9	11,4
	Guechamé	30,3	0	48,5	12,1
Maradi	Chadakori	31,3	6,3	39,1	0
	Sherkin Hausa	60,5	14,5	34,2	0
Zinder	Band	27,6	3,4	46,6	5,2
	Droum	9,3	3,5	65,1	3,5
%Average		31,8	5,2	44,7	4,7
Chi-square		49,55	20,04	22,95	18,52
V of Cramer		0,35	0,22	0,24	0,21
Meaning		***	***	***	***

*** : p<0,001.

Table 8. Proportion of responses on the MEM cycle description.

Regions	Municipalities	Description of the MEM cycle					
		App. Field	Egg-laying site	Laying stage	Dev.L	P.D	S.S.S
Dosso	Doutchi	35,7	10,0	24,3	21,4	52,9	1,4
	Guechamé	42,4	21,2	21,2	21,2	21,2	0
Maradi	Chadakori	43,8	6,3	3,1	6,3	28,1	6,3
	Sherkin Hausa	46,1	1,3	5,3	1,3	26,3	6,6
Zinder	Band	24,1	3,4	10,3	3,4	41,4	8,6
	Droum	37,2	5,8	4,7	1,2	36,0	8,1
%Average		38,2	6,7	10,3	7,8	35,4	5,7
Chi-square		8,14	16,92	27,61	37,99	17,37	6,40
V of Cramer		0,14	0,20	0,26	0,31	0,21	0,12
Meaning		ns	***	***	***	***	ns

***: p<0.001 ; ns : not significant.
Dev.L: Larval development; P.D: Period of Damage; S.S.S: Dry season stay.

There are two main sources of funding for this technology. These are NGOs and/or projects (44.7%) and the government (Table 7). Other sources of funding, such as research (5.2%) and self-financing, are low. In addition, more than 20% of farmers are unaware of the sources of support for financing the biological control technology for all regions.

Knowledge of the MHM cycle

Responses regarding knowledge of the MHM cycle are presented in Table 8. The majority of respondents stated that they observe the appearance of MHM in the field and especially during the damage period in all regions. The sites of oviposition and larval development were hardly mentioned by all respondents.

Indications of millet head miner (MHM) appearance

The main warning signs for the emergence of MHM are early planting and pockets of drought in all three regions (Table 9). Soil poverty (Pauv. sol) is more frequently mentioned by respondents in Dosso and Maradi regions. More than 50% of the latter are unaware of the causes of this calamity which compromises the hopes of the agricultural and non-farming population.

Table 9. Perceived warning signs of MEM.

Regions	Municipalities	Warning signs of the onset of MEM			
		Early sowing	Drought	Poor soils	No answer
Dosso	Doutchi	40,0	35,7	0	45,7
	Guechamé	36,4	27,3	12,1	30,3
Maradi	Chadakori	26,6	9,4	6,3	57,8
	Sherkin Hausa	14,5	25,0	6,6	46,1
Zinder	Band	20,7	6,9	0	67,2
	Droum	29,1	5,8	3,5	61,6
%Average		27,1	17,6	4,1	53,2
Chi-square		14,83	36,68	12,79	17,67
V of Cramer		0,19	0,30	0,18	0,21
Meaning		*	***	*	***

* : p<0.05 ;

*** : p<0.001.

The effect of *Habrobracon hebetor* on millet is shown in Fig. 3. Indeed, more than 90% of the respondents confirmed that the presence of the parasitoid did not affect the taste of the millet or the colour and structure of the millet by-products. On the other hand, almost all respondents affirmed that the parasitoid does not affect the shelf life of millet in all regions. The results also show the respondents' opinions on the taste of millet that has been damaged by MHM. However, 90% of the farmers confirm that millet attacked by MHM tastes unpleasant on the tongue. Some farmers (8%) think that the taste of millet attacked by MHM is unchanged, and others are even 'unresponsive' to the taste question.

Table 10. Factors determining the adoption of biological control.

	Exp(B)	E.S	Wald	Meaning
SEX	0,142	1,091	3,209	0,073*
AGE	1,005	0,012	0,204	0,652
NIVINSTR	2,490	0,344	7,017	0,008***
ACCREDIT	1,871	0,276	5,164	0,023**
CHARGF	1,058	0,028	4,111	0,043**
INCIDMEM	0,119	0,471	20,425	0,000***
R_APLACHER	0,998	0,001	7,211	0,007***
EFFICHH	7,521	0,581	12,067	0,001***
REDPERT	87,268	0,737	36,776	0,000***
QUIETUDLB	4,080	0,414	11,508	0,001***
Constant	0,352	1,461	0,511	0,475
Wald chi2	145,44			
Prob of chi2	0,000			
Nickname R2	0,42			

* : p<0,1 ; * * : p<0,05 ;

***: p<0,01.

Several constraints related to the use of biological control technology were identified (Fig. 4). Indeed, 17% of respondents stated that they lacked the resources to purchase release bags, compared to 12% who said that there were no constraints. On the other hand, more than 60% of respondents stated that the main constraint to using the technology was the lack of availability of release bags at the right time. In addition, other constraints such as the high cost of bags, the difficulty of guarding and using the bags, and others were not mentioned by the farmers.

Evaluation of the efficacy of H. hebetor releases for the control of the Millet head miner

The biological control technology was assessed differently by the farmers interviewed (Fig. 5). The results show that biological control was assessed as good, very good and excellent by more than 80% of the respondents. On the other hand, it was rated poorly by less than 5%.

Table 11. Suggestions for making biological control sustainable.

Regions	Municipalities	Suggestions				
		S.M.C	A.P.V	GT	S.L.B	Other
Dosso	Doutchi	37,1	74,3	54,3	40,0	5,7
	Guechamé	30,3	36,4	51,5	81,8	3,0
Maradi	Chadakori	12,5	21,9	34,4	87,5	4,7
	Sherkin Hausa	38,2	52,6	65,8	61,8	0
Zinder	Band	6,9	43,1	46,6	70,7	3,4
	Droum	8,1	30,2	30,2	81,4	3,5
%Average		21,7	43,7	46,5	69,5	3,4
Chi-square		43,34	48,54	26,33	48,77	4,20
V of Cramer		0,33	0,35	0,26	0,35	0,10
Meaning		***	***	***	***	ns

*** : p<0.001 ; ns : not significant

S.M.C: make release bags cheaper: A.P.V: increase the point of sale of the bags: S.L.B: make the technology widely known; RGT: free technology.

Analysis of the level of adoption of this technology

The adoption rate of the biological control technology by region is presented in Fig. 6. Indeed, a 63% adoption rate of the technology across all regions was recorded and the Chi-square test shows that there is no significant difference (p=0.56).

Determinants of adoption of biological control technology

Among the ten (10) parameters introduced in the binary logistic regression model, nine (9) explanatory variables (Table 10) were found to influence the adoption of the technology. The chi² test is highly significant (p=0.000) at the 1% level and the Pseudo R^2 is 42%.

Factors for the sustainability of biological control

The sustainability factors of the biological control technology are shown in Table 11. Nearly 70% of the respondents suggested that there should be widespread awareness of the technology, 46.5% opted for free bags, 43.7% thought that there should be an increase in the number of bag outlets to ensure availability. On the other hand, some operators think that for the technology to be sustainable, bags should be made cheaper at the point of sale in all communes.

Discussion

This study, conducted in villages that have benefitedfrom biological control activities, revealed several results. The majority of respondents are men and their main mode of land acquisition is inheritance. These results corroborate those of (Hamidine *et al.*, 2021) who reported that inheritance is the most common mode of acquisition. Improved varieties are the most widely used with a rate of 55.3%, which is due to the context of climate change which leads to the choice of short-cycle varieties (Tahirou *et al.*, 2020). The main constraints to millet cultivation are insect pests, poor soils and drought. These results are similar to those of (Oumarou *et al.*, 2019), which noted the same main constraints that hinder the development of the millet crop. Among the enemies of millet production, the millet earworm is indicated as the most important pest (49.1%) of the responses recorded. This explains how often this pest is a concern for millet farmers. In their study, (Oumarou *et al.*, 2020) reported that the millet ear miner stood out as the most formidable pest among the range of millet pests in Niger.

The results show that the main source of funding for this technology remains projects and the government. More than 95% of producers are unanimous that the parasitoid has no effect on the structure, quality and conservation of millet. All respondents confirm that the parasitoid has no impact on human and animal health or on the environment. The same results were reported by (Amadou *et al.*, 2017). As far as MHM is concerned, it induces an unpleasant taste in the various foods derived from millet that have been attacked.

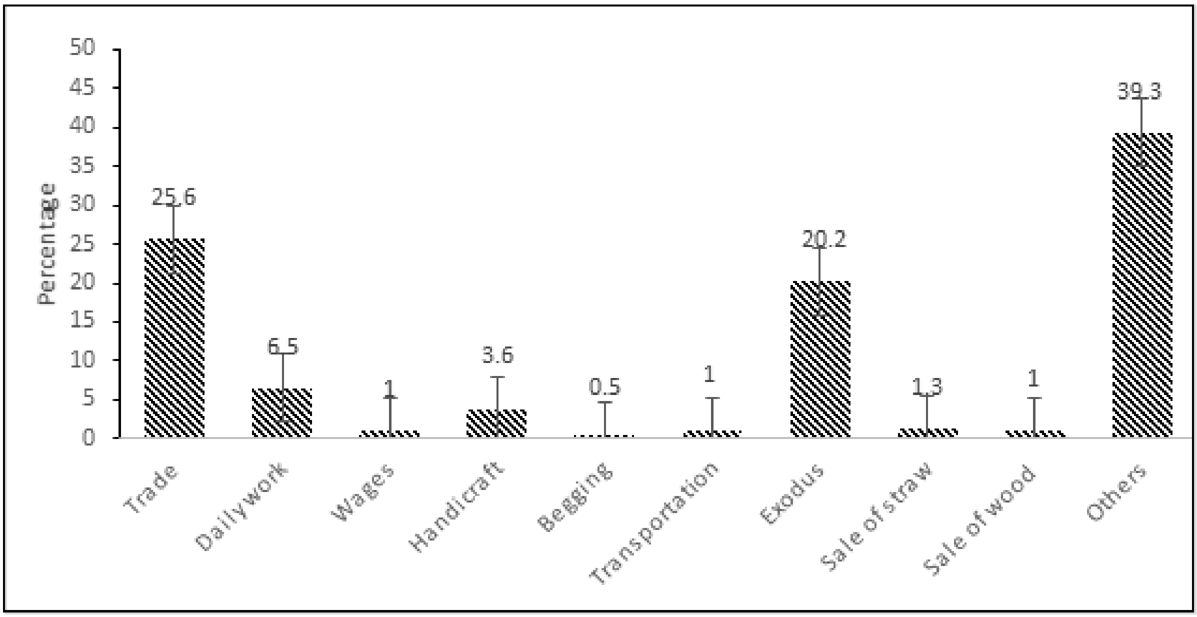

Fig. 2. Proportion of responses in relation to secondary activities.

This was reported by more than 90% of the respondents who said that the attacked millet grains were in the form of broken pieces and had an unpleasant smell. Respondents said that food from attacked millet does not keep for long, it spoils very quickly compared to unattacked millet. This may be due to the injuries to the millet grains caused by the millet head miner, which can lead to infections. For the management of MHM populations by parasitoids, opinions were collected on the effectiveness after release. However, more than 90% of the surveys rated the parasitoid as medium and very effective. This is due to the damage limitation of the MHM, which allows for crop recovery.

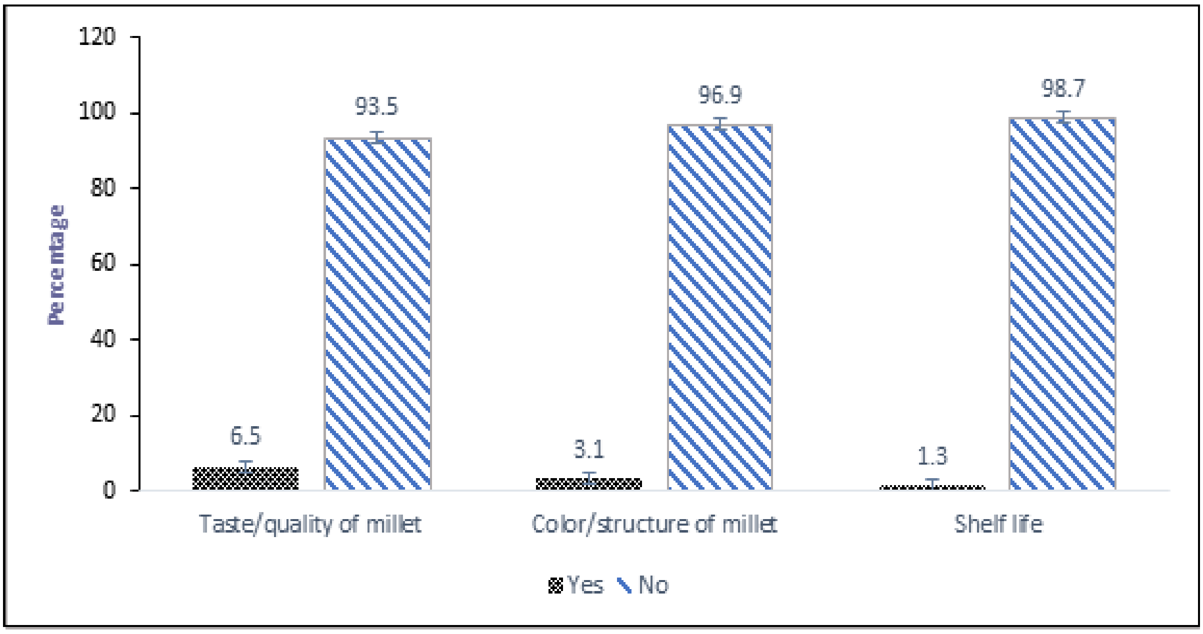

Fig. 3. Proportion (%) of responses on the negative effect of *H. Hebetor* on millet.

The results show that over 96% of the beneficiaries rated the technology as fair to excellent. These results confirm those of (Amadou *et al.*, 2017) which reported that 77% of respondents found the technology useful. Although appreciated by the respondents, the biological control technology faces two main constraints that hinder its dissemination. These are the unavailability of bags at the right time and the lack of means to purchase them. These statements may be related first to the lack of knowledge about the availability of release bags, given the presence of several private parasitoid productions and sales units. Attacks occur during the period when stocks are very limited. Farmers are looking to get out of this lean period with small savings, which can impact the means of purchasing release bags.

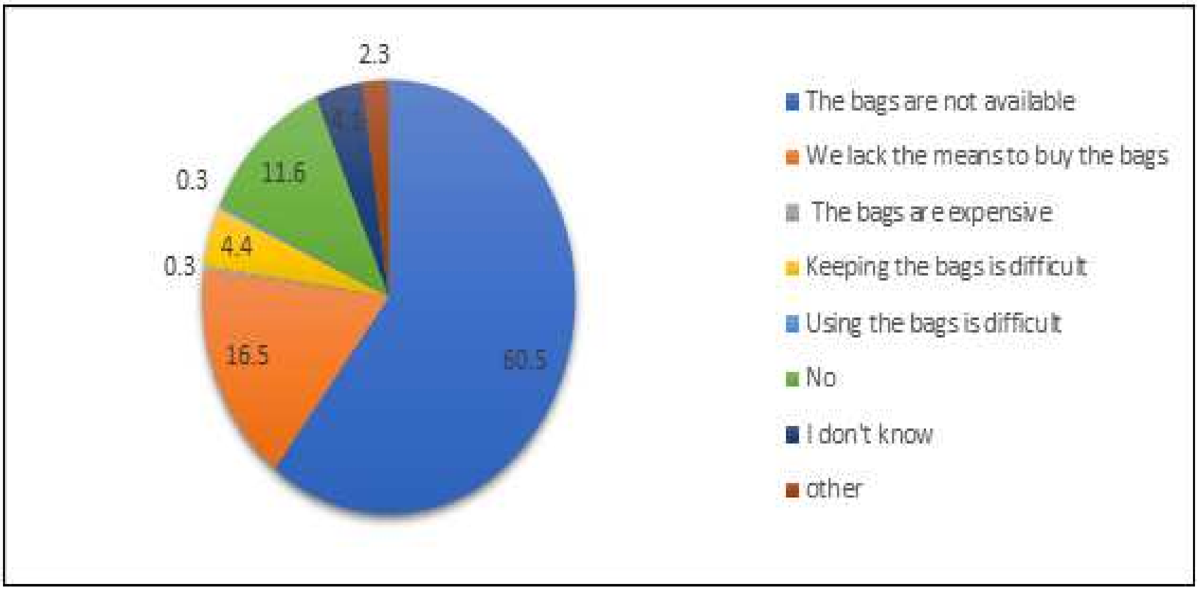

Fig. 4. Proportion of responses in relation to constraints to the use of biological control.

After the release operation, the millet head miner populations are reduced by the parasitoid so that the latter propagates its offspring to further limit the damage of the pest. A mortality rate of 78% was reported by the respondents. This rate is almost similar to those of several authors (Baoua *et al.*, 2013; Baoua *et al.*, 2014; Amadou *et al.*, 2017). As for the yield increase after release, it was estimated at 56% by all respondents. This result is higher than that obtained by (Baoua *et al.*, 2013; Amadou *et al.*, 2017) which are 34% and 50% respectively. This increase may be due to the increased release of parasitoids that is done every year to control the populations of the pest in the field.

Socio-economic factors influencing the adoption of biological control

In normality, people make their choices and preferences according to their understanding, their vision and, above all, the results they hope for (Adjobo and Yabi, 2020). The adoption of technology is conditioned by a number of easily accessible factors (Boudon, 2004). Based on this, the determinants of the adoption of biological control of the millet earworm were identified. A 63% adoption rate of the technology was recorded. This is due to the benefits that farmers derive from this technology. The age variable had no influence on the adoption of the technology. This can be explained by the resistance of some older people to new farming practices in their fields. A similar result was reported by (Issoufou *et al.*, 2017; Diaby *et al.*, 2020) who reported that age does not influence the adoption of new technologies. The level of education has a great influence on the adoption of technology. According to (Feder, 1982), reported (Yabi, 2016), educated farmers have better skills to apply and disseminate technologies from extension services. For (Dakin, 2008) education increases the level of adoption of new technologies. On the other hand, education is a factor affecting the adoption and application of technologies in rural areas (Azontondé, 2004). For (Kpadenou *et al.*, 2020), in their study on the determinants of adoption of integrated pest management, pointed out that educated farmers tend to adopt biological control more than uneducated farmers.

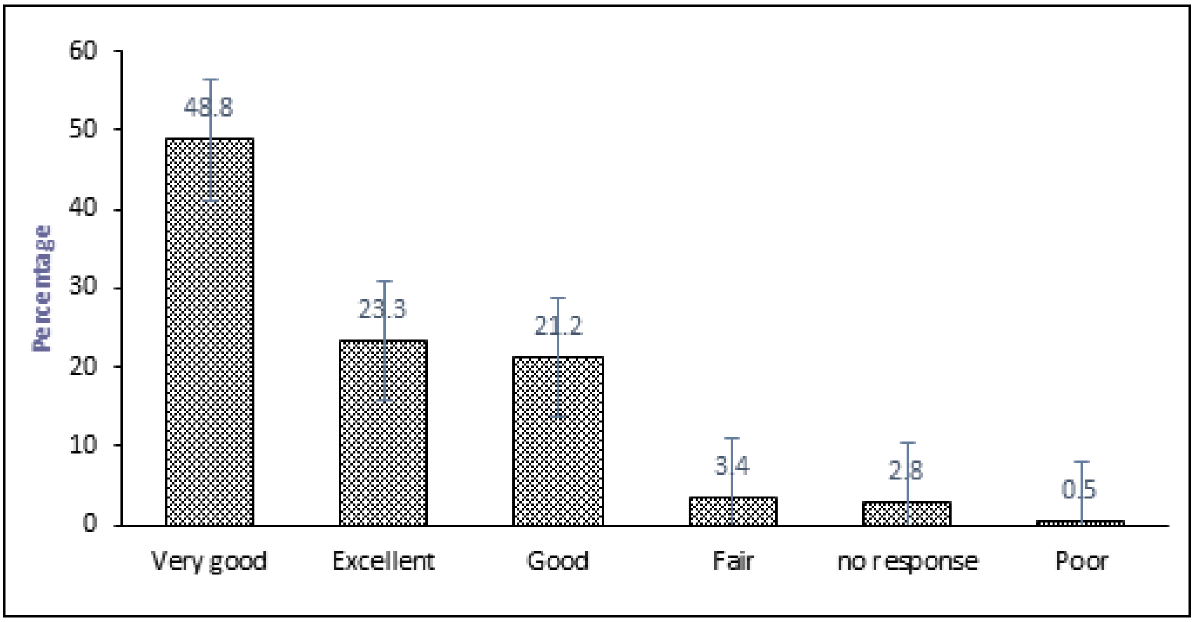

Fig. 5. Respondents' appreciation of biological control technology.

Access to credit was found to be an important determinant of the adoption of biological control technology. This was due to access to release bags through the credit received. According to (Sale *et al.*, 2014) according to the study, farmers with easy access to credit tend to adopt the new technologies better. The result is also similar to those of (Dossa and Miassi, 2018) who noted that access to credit influences the adoption of new technologies. For (Sissoko, 2019), credit is a key factor in accessing technology. Another factor that is a determinant of adoption is the family charge, which depends on agricultural production for the food security of all members.

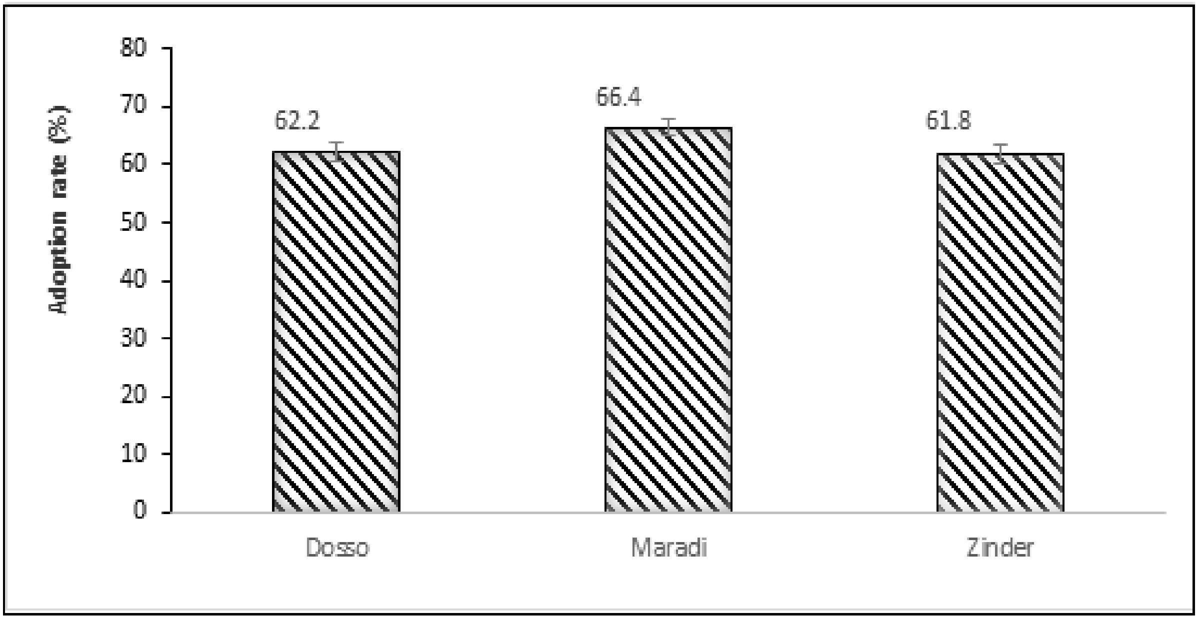

Fig. 6. Proportions of responses on the adoption rate of biological control technology by regions.

According to Yabi, 2016 farmers with a large family charge will tend to adopt a technology. On the other hand, Sissoko, 2019 indicates that in Mali, large farmers with a high number of people in charge adapt the technologies to ensure grain self-sufficiency. Overall, the incidence of millet ear miners in recent years has influenced the adoption of the technology with a significance of 1%. This technology provides an alternative for farmers to deal with this important millet pest that causes significant damage and undermines the hope of the farming community.

On the other hand, the yield observed after the release of the parasitoids influenced the adoption of the technology. This was also the case for the effectiveness of the parasitoids and the reduction of losses. Indeed, technology is only adopted by farmers when they can benefit from it (Kpadenou *et al.*, 2020) Hence its adoption in the context of this study. The factor of social tranquility, which was significant at 1%, also contributed to the adoption of biological control technology in Niger.

Conclusion

This study conducted in the regions of Dosso, Maradi and Zinder on the perception and determinants of the adoption of biological control of the millet head miner revealed a number of results. The majority of respondents are men who own less than 3 ha of land for millet cultivation with an average family size of 11.4±5.61 members per farm. Biological control is currently the only alternative to the main constraint of millet, which is the head miner. A mortality rate of more than 70% after the release operation was estimated by the respondents. This innovation is very well appreciated by more than 80% of the farmers with an adoption rate of 63%. The biological control induces a yield gain of 56% per ha after the release of the parasitoids. The factors determining the adoption of the technology are the level of education, access to credit, family charge, the incidence of the millet head miner, the yield after release, the effectiveness of the parasitoids, the reduction of losses and social tranquility. It would therefore be necessary to intensify the dissemination of this biological control technology in order to save crops throughout the millet production zone threatened by this pest.

Acknowledgements

We sincerely thank the SAHEL-IPM Niger project of the Dan Dicko Dankoulodo University of Maradi for fully funding this study.

References

Adjobo OMF, Yabi JA. 2020. Determinants Socio-Economiques de l'adoption des Modes de Vente de la Noix d'anacarde dans les Communes de Djougou, Tchaourou et Glazoue au Benin. European Scientific Journal **16(19),** 313–336. https://doi.org/10.19044/esj.2020.v16n19p313

Amadou L, Baoua IB, Ba MN, Haussmann B, Altiné M. 2017. Gestion de la chenille mineuse de l'épi du mil par des lâchers du parasitoïde Habrobracon hebetor Say au Niger. Cahiers d'Agricultures **26(5),** 55003. https://doi.org/10.1051/cagri/2017045

Azontondé R. 2004. Impact économique de l'adoption des pratiques de la gestion intégrée de la fertilité des sols (GIFS) au Sud-Bénin : Cas d'Aplahoué (commune de Klouekanme) et de Banigbé (commune d'Ifangni). (154 p).

Ba MN, Baoua IB, N'Diaye M, Dabire-Binso C, Sanon A, Tamò M. 2013. Biological control of the millet head miner Heliocheilus albipunctella in the Sahelian region by augmentative releases of the parasitoid wasp Habrobracon hebetor: effectiveness and farmers' perceptions. Phytoparasitica **41(5),** 569–576. https://doi.org/10.1007/S12600-013-0317-X

Bal AB. 1992. Les insectes du mil au Sénégal ; Importance du parasitisme et méthodes de lutte dans lutte intégrée contre les ennemis des cultures vivrières dans le Sahel. Eds. INSAH et Johon Libbey, 13–23.

Baoua BI, Ba M, N'diaye M. 2009. Rapport de synthèse du projet GIMEM. 29 p.

Baoua IB, Amadou L, Oumarou N, Payne W, Roberts JD, Stefanova K. 2014. Estimating effect of augmentative biological control on grain yields from individual pearl millet heads. Journal of Applied Entomology **138(4),** 281–288. https://doi.org/https://doi.org/10.1111/jen.12077

Bhatnagar VS. 1984. Programme de lutte biologique. Projet CILSS. Nioro du Rip, Sénégal, Rapport d'activé (78 p).

Bhatnagar VS. 1987. Conservation and encouragement of natural enemies of insect pest in dry land subsistence farming: problem, progress and prospects in the Sahelian zone. Institute Science Application **8(6),** 791–795.

Boudon R. 2004. Théorie du choix rationnel ou individualisme méthodologique (281–307 p). https://doi.org/10.3917/rdm.024.0281

Dagnelie P. 1973. Théories et méthodes statistiques. Applications agronomiques, (375 p).

Dakin L. 2008. Impact socio-économique des interventions du PDRT sur les femmes rurales du département de la Donga, (106 p).

Diaby M, Kone Y, Traore K, Maiga AS, Togo AM. 2020. Analyse des déterminants de l ' adoption de la Régénération Naturelle Assistée (RNA) dans la zone soudano-sahélienne : cas des cercles de Diéma et Kolokani au Mali. International Journal of Biological and Chemical Science **14(2),** 473–485.

Dossa FK, Miassi YES. 2018. Facteurs Socio-Economiques Influençant L ' adoption de Coton Biologique au Nord- Est du Bénin : Cas de la Commune de Kandi. International Journal of Progressive Sciences and Technologies **6(2),** 577–584.

Feder G. 1982. Adoption of interrelated agricultural innovations: complementary and the risk, scale and credit. American Journal of Agricultural Economics, **8(12),** 59–73.

Gahukar R. 1983. Programme d'entomologie du CILSS-PLI, Niorodu-RipS, Sénégal. Rapport d'activité (52 p).

Gahukar RT. 1984. Insect Pests of pearl millet in West Africa. Tropical Pest Management **2(30),** 142–147.

Guèvremont H. 1983. Recherches sur l'entomofaune du mil. Rapport annuel de recherche. Maradi, Niger : Centre National de Recherches Agronomique de Tarna (49 p).

Guèvremont H. 1981. Etudes sur l'entomofaune du mil. Rapport annuel de recherches pour l'année 1980 (deuxième partie). Centre National de Recherche Agronomique. CNRA, Tarna, Maradi, Niger (31 p).

Guèvremont H. 1982. Etude sur la mineuse de l'épi et autres du mil ; rapport annuel de recherche pour l'année 1981 CNRA de Tarna, Maradi, Niger (p 57).

Hamidine I, Lawali S, Moctar RM, Baoua IB. 2021. Caractérisation des exploitations agricoles familiales productrices du mil et leur niveau de résilience dans la bande sud du Niger. Journal of Agriculture and Veterinary Science (IOSR-JAVS), **14(7),** 5–16. https://doi.org/10.9790/2380-1407010516

Issoufou OH, Boubacar S, Adam T. 2017. Determinants de l'adoption et impact des varietes ameliorees sur la p roductivite du mil au niger. African Crop Science Journal **25(2),** 207–220.

Kpadenou CC, Tama C, Tossou BD, Afouda YJ. 2020. Facteurs D'adoption de la Gestion Intégrée des Ravageurs en Production Maraîchère Dans la Vallée du Niger au Bénin. European Scientific Journal **16(3),** 101–120. https://doi.org/10.19044/esj.2020.v16n3p101

Maiga SD. 1984. Rapport annuel 1983. Projet CILSSPLI Ouagadougou, Burkina Faso (16 p).

Mbaye DF. 1993. Contraintes phytosanitaires du mil dans le Sahel : état des connaissances et perspectives. In : HAMON SERGE (ED., 173–186.

Mohamed B. 2021. OEB Univ. Publish. Co. Journal of Financial, Accounting and Managerial Studies, **8(2),** 838–856.

Oumarou N, Baoua I, Saidou AA, Amadou L, Stern D. 2019. Perception des paysans sur la contrainte de la mineuse de l ' épi Heliocheilus albipunctella De Joannis , ravageur important du mil en zone sahélienne. Tropicultura **37(1),** 1–10. https://doi.org/10.25518/2295-8010.255

N'Diaye A. 1984. Etude de la biologie et du cycle vital de Raghuva albipunctella De Joannis (Lepidoptera, Noctuidae) ravageur du mil pénicillaire. Mémoire de maîtrise. (p 120).

N'Doye M. 1979. L'entomofaune nuisible du mil B chandelle (P. Typhoüies) au Senegal. In Proceeding Du Congr & Sur La Lutte Contre Les Insectes En Milieu Tropical, 515–530.

Oumarou MN, Baoua I, Saidou AA, Laouli A. 2020. Evaluation des génotypes de mil Pennisetum glaucum (L .) R . Br . pour la résistance ou la tolérance à la mineuse de l ' épi de mil , *Heliocheilus albipunctella* De Joannis au Niger Screening of millet genotypes *Pennisetum glaucum* (L .) R . Br . International Journal of Biological and Chemical Science, **14(2)**, 501–512.

Rabe MM, Baoua I, Adeoti R, Sitou L, Amadou L, Pittendrigh B, Mahamane S. 2017. Les déterminants socioéconomiques de l'adoption des technologies améliorées de production du niébé diffusées par les champs écoles paysans dans les régions de Maradi et Zinder au Niger. International Journal of Biological and Chemical Sciences **11(2),** 744-756. https://doi.org/10.4314/ijbcs.v11i2.17

Sale A, Folefack PD, Obwoyere GOL, Wati N, Lendzemo WV. 2014. International Journal of Biological and Chemical Science **2(8),** 680–694. https://doi.org/http://dx.doi.org/10.4314/ijbcs.v8i2.24

Sissoko P. 2019. Le microdosage d'engrais : une technique d'amélioration des moyens d'existence des producteurs pauvres au Sahel. Cas des exploitations agricoles à base de mil et de sorgho au Mali. Université de Liège, Gembloux Agro-Bio Tech (Belgique). (269 p).

Tahirou H, Lawali S, Abdou MM. 2020. Influence des facteurs socioculturels et techniques sur la performance des exploitations agricoles familiales au Niger. Afrique SCIENCE **17(4),** 93–103.

Vercambre B. 1978. Raghuva spp., Masalia spp., chenilles des chandelles du mil en zone sahélienne. Agronomie Tropicale **10(33),** 62–79.

Yabi JA. 2016. Déterminants socio-économiques de l ' adoption des pratiques culturales de gestion de la fertilité des sols utilisées dans la commune de Ouaké au Nord- Ouest du Bénin Socio-economic determinants of the adoption of agricultural practices of soil fertility. International Journal of Biological and Chemical Science **10(2),** 779. https://doi.org/10.4314/ijbcs.v10i2.27

Youm O, Gilstrap F. 1993. Population dynamics and parasitism of Coniesta(Haimbachia) ignefusalis, *Sesamia calamistis*, and *Heliocheilus albipunctella* in millet monoculture. Insect Science and its Application **14(4),** 419–426.

Zidat RMA. 2018. Le choix d'un régime de change pour l'Algérie : the choice of an exchange rate regime for algeria : an approach in binary logit. Les Cahiers Du Cread **33(123),** 43–67.