Agricultural Sciences, 2024, 15, 1-14
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Study of the Constraints of Millet Production (*Pennisetum glaucum* (L.) R. Br.) and the Peasant Perception of Biological Control in the Tahoua Region

Rabé Mahamane Moctar[1*], Hama Oumarou[1], Issaka Rabo Salissou[2], Abdoulaye Amoustapha Soumaila[1*], Bakoye Nouhou Ousmane[1], Baoua Ibrahim[3]

[1]Faculty of Agricultural Sciences, Djibo Hamani University of Tahoua, Tahoua, Niger
[2]NGO Sahel Bio of Maradi, Maradi, Niger
[3]Faculty of Agronomy and Environnemental Science, DanDicko DanKoulodo University of Maradi, Maradi, Niger
Email: *mocnad1@gmail.com

How to cite this paper: Moctar, R.M., Oumarou, H., Salissou, I.R., Soumaila, A.A., Ousmane, B.N. and Ibrahim, B. (2024) Study of the Constraints of Millet Production (*Pennisetum glaucum* (L.) R. Br.) and the Peasant Perception of Biological Control in the Tahoua Region. *Agricultural Sciences*, **15**, 1-14.
https://doi.org/10.4236/as.2024.151001

Received: November 15, 2023
Accepted: January 6, 2024
Published: January 9, 2024

Abstract

Millet (*Pennisetum glaucum* (L.) R. Br.) is the Sahelian crop par excellence due to its adaptation to the particular production conditions in this region. Unfortunately, in recent years this crop has been threatened by very strong parasitic pressure and drought during the production period. The objective of this study is to analyze the main constraints of millet production and the solutions known to producers. A survey was carried out in November 2022 with a sample of 298 producers in five municipalities in the Tahoua region. The main constraints are drought and pressure from crop pests (locust, millet ear miner, floricultural insects) according to 57.9% of respondents. The millet ear miner is the most formidable pest according to 55% of respondents. Thus, the average yield obtained in a year of good production without the leafminer is 194 kg/ha and that obtained in a year of millet ear leafminer is around 27 kg to 43 kg/ha depending on the municipality. The yield obtained this last campaign after the attack of this leafminer varies from 64 to 77 kg/ha depending on the municipalities compared to a potential yield of over 1000 kg/ha. More than half of producers (58.1%) are unaware of the existence of biological control compared to only 12.5% who are aware of this alternative method. Work to popularize this technology is necessary in the five municipalities and the entire region in general.

Keywords

Biological Control, Ear Miner, Millet

1. Introduction

The 2022 Global Report on Food Crises (GRFC 2022) highlights the alarming deterioration of acute food insecurity in 2021 in numerous food-crisis countries/territories. Nearly 193 million people were in Crisis or worse (IPC/CH Phase 3 or above) or equivalent in 53 countries/territories where comparable data were available in 2021—as a result of intensified conflict, significant economic shocks and some of the most severe weather extremes in recent years, or a combination of these drivers. Several factors are at the origin of the increase in acute food insecurity from 2021 to 2023. These include, among others: Conflicts (main factor, having pushed 139 million people from 24 countries or territories into acute food insecurity, when there were only 99 million in 23 countries or territories in 2020); Extreme weather events (more than 23 million people in eight countries or territories, compared to 15.7 million people in the 15 countries or territories recorded the previous year); Economic shocks (more than 30 million people in 21 countries or territories, a decrease compared to the more than 40 million people in the 17 countries or territories recorded in 2020, the latter figure mainly explained as an impact of the pandemic of COVID-19); Russia's invasion of Ukraine threatens global food security. The international community must act to avoid the largest food crisis in history and the social, economic and political upheaval that could ensue (FAO, 2023) [1].

Agriculture is seen as the most important sector of the national economy. This constitutes the main source of income for more than 80% of the Nigerien population. It is a country that faces structural food insecurity and recurring crises reflecting the extreme fragility of the economy and the precarious lifestyle of a significant segment of the population, particularly rural ones [2]. It is one of the most cultivated cereals in arid and semi-arid regions [3]. In Niger, it is used by 97% of households and represents 23% of food consumption [4]. Millet (*Pennisetum glaucum* (L.) R. Br.) occupies 7th place among the most important cereals in the world [5]. It is a cereal originating from Africa and domesticated more than 4000 years ago [6] [7] and is cultivated in the arid and semi-arid regions of Africa and of India mainly for human food and incidentally as fodder and construction materials [8]. According to [9] and [10], in addition to their use in making huts, sheds, attics, fences and fodder, they are used for the preparation of many dishes: pancakes, couscous, semolina, porridge, breads or donuts. For many Sahel countries, millet represents more than 75% of cultivated cereals [11]. Indeed, millet is the Sahelian crop par excellence due to its adaptation to particular production conditions and its tolerance to poor soils and droughts [12]. It is a valuable food crop due to its very high energy value (4090 to 4560 Kcal/Kg) its high starch content (60.2% - 67.1%) and proteins (11.2% - 12.5%), and which provides vitamins and minerals to millions of households. In addition, after ginning the crop residue is transformed into animal feed.

Millet is cultivated on more than 12 million hectares in West Africa and occupies more than 65% of the area sown in Niger [13] [14]. Millet production in

Niger in 2016 was 3.8 million tonnes and ranks first among cereals produced and consumed in the country [15]. In recent years, the production of this cereal has been compromised by certain biotic and abiotic factors, notably the poor distribution of rainfall in time and space, the decline in the level of soil fertility and parasitic pressure which contribute enormously to the drop in production [16]. However, since the great droughts of 1974, millet cultivation in the West African Sahel has been confronted with the devastation caused by the millet ear miner (MEM) caterpillar *Heliocheilus albipunctella* De Joannis (Lepidoptera, Noctuidae) [17]. This lepidopteran which develops on the fruiting body of millet [18] can cause grain yield losses of 40% to 85% [19] [20] [21] [22]. Among the pests, *Heliocheilus albipunctella* De Joannis is cited by producers as the most dangerous in terms of the damage it causes [23].

In Niger, losses ranging from 8% to 95% were estimated [24]. All these constraints expose the population to food insecurity, an increasing reduction in the level of food coverage from one year to another. Control methods have been developed to resist this pest which continually decreases production from one year to the next. These last years, technology augmentative releases was tested in several villages of regions of Niger in order to destroy the populations of the MEM and it has been established that increased releases of *H. hebetor* can limit MEM damage and increase millet yields by 34% [25]. Producers in regions benefiting from the technology estimated a gain in millet yield of 50% on average [26]. The main objective of this study is to characterize agricultural operations, the perception of biological control, the main constraints and means of control of millet cultivation in the Tahoua region. The specific objectives assigned to this study are to identify the main constraints and methods of combating millet cultivation in the Tahoua region.

2. Materials and Methods

2.1. Study Area and Sampling

Stratified sampling was applied in the five communes of the Tahoua region, namely Malbaza, Illela, Keita, Karofane and Tahoua, selected on the basis of the following criteria: the accessibility of the area and the production of millet par excellence. The sampling base of the municipalities taken was based on the fact that the area suffered attacks from the millet ear miner caterpillar. Random sampling was done to obtain the observation units, that is to say the farm managers (CE).

2.2. Collection of Data

A total of 298 millet producers were surveyed. The individual interviews were carried out using a digital KoboCollect system installed to facilitate data collection. The collection sheet is structured into five parts:

✓ Socioeconomic and demographic characteristics of respondents: gender, age of respondents, marital status, level of education, membership of a PO, mode of land acquisition, access to credit, contact with NGOs, household size, active person, number of fields, average surface area operated per family;

- ✓ Cultivation system and type of millet variety cultivated;
- ✓ The yield and income generated by the crop;
- ✓ Constraints on millet production, notably parasitic pressure;
- ✓ Control methods used by producers.

2.3. Analysis Method

The chi-square test analysis was carried out on the level of education, marital status, different cropping systems and on all other qualitative variables. Analysis of variance (ANOVA) and the Newman-Keuls test are applied to the following variables: age, family responsibilities, agricultural assets, number of fields laid out, total area, area occupied by millet, the yield of millet.

3. Results and Discussion

3.1. Socioeconomic and Demographic Characteristics of Respondents

The analysis of the Producer Profile indicates that 91.2% of respondents are men compared to 8.8% of women. In the commune of Karofane and Malbaza all the respondents are men (100%) compared to that of Keita, Illela and Tahoua where there are female respondents. The majority of producers (88.2%) in the five communes are indigenous and 97.5% are married compared to respectively 1.5%, 0.5% and 0.5% who are single, divorced and widowed. The producers surveyed are mainly Hausa and present 98.0% of the sample surveyed with 51.9% of respondents who received no training, 24.6% literate, 14.5% Primary and 7.7% of producers who received secondary training. The proportion of producers who belong to a peasant organization is 29.9% of the surveyed sample.

Inheritance constitutes the main mode of acquisition of the plot and the last ones are the loan and donation with respectively 0.7% and 0.3% of producers. The results indicate that 91.6% of producers in the surveyed sample do not have access to agricultural credits and 69.6% of producers are in contact with projects/NGOs compared to 30.4% of respondents who are not. The chi-square test analysis presents a significance at the only significant level of 5% between the five municipalities (**Table 1**).

The age distribution of producers varies from 41 to 53 years with an average family burden of nine (09) people (±4.54) including four (04) active children (±3.15) on average per household. The number of fields cultivated by the farm manager varies from 2 to 4 fields per household with a total area of 04hectares (±4.03). It also emerges from this analysis that the distribution of the area sown for millet production by producers varies from 2 to 3 ha depending on the municipalities (**Table 2**).

Table 1. Proportions of respondents' responses on socio-economic characteristics.

Variables	Terms	Illela	Karofane	Keita	Malbaza	Tahoua	Mean (%)	χ^2	Significance
Sex	Man	87.2	100.0	80.0	100.0	89.7	91.2	11.54	**
	Women	12.8		20.0		10.3	8.8		
Aboriginal	Yes	100.0	100.0	100.0	77.3	65.5	88.2	48.31	***
Situation matrimonial	Married	97.7	100.0	100.0	100.0	89.7	97.5	9.80	*
	Bachelor	2.3	0	0	0	3.4	1.5	2.54	ns
	Divorce	0	0	0	0	3.4	0.5	6.06	ns
	Widower	0	0	0	0	3.4	0.5	6.06	ns
Educational level	None	58.4	20.4	73.6	68.8	40.0	51.9	8.31	ns
	Literated	20.8	79.6	1.9	0	16.0	24.6	80.60	***
	Primary	11.9	0	15.1	18.8	30.0	14.5	27.64	***
	Secondary	7.9	0	9.4	9.4	14.0	7.7	13.06	**
Membership to an OP	Yes	36.5	39.5	22.1	9.1	19.8	29.9	10.73	***
Method of maintaining the plot	Legacy	80.0	73.5	80.0	72.8	48.6	70.01	27.5	***
	Purchase	10.2	24.4	10.0	27.2	38.3	22.8	29.6	***
	Rental	6.8	2.1	10.0	0	9.8	6.2	5.9	**
	Ready	1.5	0	0	0	3.3	0.7	2.7	ns
	Don	1.5	0	0	0	0	0.3	1.3	ns
Access to credits	Yes	5.7	15.6	5.3	13.6	3.6	8.4	5.7	ns
Contact with researchers/NGO	Yes	62.6	60.0	70.0	95.5	82.8	69.6	19.28	**

*p < 0.1, **p < 0.05, ***p < 0.01; ns: non-significant differences.

Table 2. Sociodemographic characteristics of respondents by municipality.

Municipalities	Age	Household size	People Active	Number of Chp	SupT	SupMil
Karofane	48.38 ± 13.53b	12.33 ± 4.84b	5.73 ± 3.60 ab	3.60 ± 4.73a	4.43 ± 4.32a	3.30 ± 2.11a
Illela	48.38 ± 13.77ab	8.93 ± 4.07 ab	4.37 ± 3.31a	4.51 ± 1.76ab	4.07 ± 2.83a	2.92 ± 3.25a
Keita	47.10 ± 9.96a	11.20 ± 3.80 b	4.20 ± 2.01a	2.47 ± 1.50ab	4.44 ± 5.22a	2.88 ± 1.73a
Malbaza	53.68 ± 17.92a	7.18 ± 4.61a	3.68 ± 2.28a	2.09 ± 0.97a	4.04 ± 4.26a	3.34 ± 2.23a
Tahoua	41.91 ± 10.91ab	6.96 ± 2.87 ab	3.08 ± 1.28a	2.86 ± 1.66ab	3.91 ± 2.57a	2.48 ± 1.32a
Average	48.01 ± 13.74	9.43 ± 4.54	4.38 ± 3.15	3.02 ± 2.89	4.00 ± 4.03	2.98 ± 2.55
Anova	F = 3.75; ddl = 4/200; p ≤ 0.008	F = 10.76; ddl = 4/200; p ≤ 0.000	F = 3.45; ddl = 4/186; p ≤ 0.010	F = 2.79; ddl = 4/195; p ≤ 0.027	F = 0.14; ddl = 4/195; p ≤ 0.963	F = 0.58; ddl = 4/198; p ≤ 0.68

3.2. Cultivation System and Varieties of Millet Cultivated

The results of the analysis in Table 3 show the locations of the millet varieties used and the cultivation system preferred by the producers of the surveyed sample. The local variety is the main variety used by 68.7% of producers. On the

Table 3. Proportions of respondents of some operating practices.

Variables	Terms	Illela	Karofane	Keita	Malbaza	Tahoua	Mean (%)	χ^2	Significance
Varieties used	Local	85.1	83.3	37.7	68.8	58.0	68.7	46.36	***
	Local/HKP	10.9	16.7	60.4	9.4	16.0	21.9	56.97	***
	HKP	4.0	0	1.9	0	17.0	9.7	19.49	***
	Sosat	0	0	0	21.9	9.0	2.7	48.92	***
Cultivation system	Partner	74.1	48.9	40.0	81.8	75.9	66.2	18.75	***
	Pure	25.9	53.3	60.0	18.2	24.1	34.9	20.23	***
Cultivation system partner	Sorghum0 Cowpea	66.1	41.7	50.0	88.9	63.6	64.0	11.96	**
	Sorghum	6.5	54.2	25.0	11.1	9.1	16.9	30.70	***
	Cowpea	19.4	4.2	25.0	0	27.3	15.4	9.63	*
	Sorghum0 Cowpea0 Peanut	8.1	0	0	0	0	3.7	6.19	ns

*p < 0.1, **p < 0.05, ***p < 0.01; ns: non-significant differences.

other hand, 21.9% of respondents combine the local variety with the improved variety. Only 9.7% and 2.7% of producers use only the improved HKP and Sosat varieties. More than 3/4 of respondents associate millet with other crops. This is the Mil-sorghum-Cowpea association for 64% of respondents, Mil-Sorghum and Millet-Cowpea for respectively 16.9% and 15.4% of respondents. It was observed in the commune of Illela the association Mil-Sorghum-Cowpea-Peanut by 8.1% of producers (Table 3).

Many producers in the commune of Malbaza, Keita and Karofane point out that local varieties like Gergera and Zango are slightly resistant to the attack of the millet ear miner. In fact, 46.3% of producers in all five communes think that the local variety "Gergera" is more resistant to the millet ear miner and 17.9% think more of the local variety "Zongo". For the improved HKP variety, there are 4.9% of respondents who consider it a little more resistant to the leafminer than the local one. Only less than 1/3 of respondents are convinced that no variety can resist the attack of the millet ear miner caterpillar, because in the event of an attack losses are around 100% regardless of variety (Table 4).

3.3. Analysis of Millet Yield at the Commune Level

The yield obtained in the year from the miner without releasing it varies from 82.46 to 121.56 kg per hectare depending on the municipalities, *i.e.* an average for the five municipalities of 96.62 ± 99.08 kg per hectare. The yield obtained in a year of good production without the leaf miner still remains low with an average of 194.17 ± 25.91 kg per hectare in all municipalities combined but twice as high as that in a year with the leaf miner. It also emerges from analysis of Table 5 that the yield obtained following a very large infestation of the leafminer is very

Table 4. Proportion of respondents on some varieties resistant to MEM attack.

Terms		Illela	Karofane	Keita	Malbaza	Tahoua	Mean (%)	χ^2	Significance
None		45.5	27.3	0	0	60.0	30.9	24.38	***
HKP		9.1	0	0	0	13.3	4.9	7.27	ns
Local	Gergera	25.0	54.5	62.5	95.5	6.7	46.3	41.78	***
	Zango	20.5	18.2	37.5	4.5	20.0	17.9	5.22	ns

***$p < 0.01$; ns: non-significant difference.

Table 5. Analysis of yields obtained by municipality with and without releasing *H. hebetor*.

Municipalities	Average yield of millet in MEM year without release of *H. hebetor* (kg)	Millet production in a year of good production without the MEM (kg)	Millet yield in year of high MEM infestation (kg)	Rd obtained/ha after the MEM attack last year (kg)
Illela	91.47 ± 58.03a	188.50 ± 30.25a	28.27 ± 8.96a	66.56 ± 84.94a
Karofane	100.78 ± 65.62a	191.51 ± 26.93a	26.74 ± 11.63a	64.44 ± 84.63a
Keita	102.54 ± 61.49a	197.36 ± 18.29 b	31.03 ± 8.84a	76.86 ± 95.32ab
Malbaza	82.46 ± 63.18a	199.72 ± 20.85b	42.61 ± 5.67b	73.97 ± 77.27b
Tahoua	121.53 ± 51.80b	193.57 ± 19.84a	35.41 ± 9.65a	94.10 ± 96.77b
Average	96.62 ± 99.08	194.17 ± 25.91	30.65 ± 10.58	81.63 ± 89.33
Anova	F = 0.80; df = 4/143 p ≤ 0.523	F = 1.06; ddl = 4/193; p ≤ 0.376	F = 0.63; ddl = 4/192; p ≤ 0.640	F = 8.06; ddl = 4/165 p ≤ 0.000

low and is around 28.27 ± 8.96 to 42.61 ± 5.67 kg per hectare depending on the communities. Following the attack of the leafminer in the last campaign of 2022, the yield obtained varied from around 64.44 ± 84.63 kg to 94.10 ± 96.77 kg per hectare depending on the municipalities, an average of 81.63 ± 89.33 kg per hectare. Therefore, the yield can be reduced by 4 times in a year of heavy infestation compared to the year of good production without leafminer (Table 5).

3.4. Main Constraints of Millet Production and Solution in the Study Area

The main constraints of millet production are biotic and abiotic (Table 6). Thus, more than half of the producers surveyed (55%) mentioned the millet ear miner as their main problem. The commune of Malbaza is more affected with a proportion of 71.4% of producers and that of Keita and Karofane with 64.7 and 64.7% of respondents respectively. Compared to other pests, such as caterpillars, locusts and small floricultural insects, producers are not greatly affected by these parasites. The chi-square test analysis at the 5% threshold shows us that there is a significant difference between the municipalities (Table 7).

The results in Table 7 illustrate that more than half (58.1%) of producers in the study area do nothing about the threat of insect pests of millet cultivation. 21.6% of producers in the surveyed sample only pray following the attack of this

Table 6. Proportions of producers on the main enemies of millet cultivation.

	Illela	Karofane	Keita	Malbaza	Tahoua	Mean (%)	χ^2	Significance
Miner	48.7	64.4	64.7	71.4	38.5	55.0	8.69	ns
Caterpillar	28.2	26.7	5.9	0	19.2	21.2	11.74	**
Cricket	19.2	8.9	0	0	30.8	14.8	16.27	***
Black insects	3.8	0	0	28.6	0	4.8	30.89	***
Drought	0	0	29.4	0	11.5	4.2	36.46	***

**p < 0.05 ***p < 0.01; ns: non-significant difference.

Table 7. Proportions of respondents on means of combating enemies of millet cultivation.

Terms	Illela	Karofane	Keita	Malbaza	Tahoua	Mean (%)	χ^2	Significance
Nothing to do	80.0	32.0	15.0	0	80.1	58.1	71.50	***
Prayers	4.7	0	55.0	100.0	15.0	21.6	86.11	***
Biological control	2.0	50.0	0	0	3.0	12.5	69.25	***
Chemical control	5.3	0	30.0	0	0	8.8	18.13	***

***p < 0.01.

pest. The chi-square test analysis at the 5% threshold shows us a significant difference at the level of the different municipalities. On the other hand, other producers use biological control (12.5%) and some use chemical control (8.8%).

Biological control, which is the only effective alternative for the fight against millet ear miner, is unknown to most producers in the five communes. As for those who know the technology, the information came to them from agricultural agents according to 23.8% of producers, INRAN agents for 33.3% and the GIMEM project team (38.1%). For the perception of the technology, 35.7% of producers attest to knowing the technology well and 64.3% declared having observed the effects of it in their fields after application. The effectiveness of the technology was appreciated at different levels by farmers from four municipalities. In the commune of Illela 80.0% of producers stated that the technology is poor in the field compared to 14.3% of producers in Karofane. But on the other hand, 42.9% of producers declared that the technology is very good in the field compared to 20.0% in Illela, fair in Tahoua and finally good in Malbaza (Table 8).

4. Discussion

The results obtained during this study show that millet cultivation is an activity dominated by men representing more than 90% of the surveyed sample. This situation could be explained on the one hand by the fact that cultivable land is not accessible to women and on the other hand millet cultivation occupies large areas. These results corroborate the study by [27], finding similar results, where men represent more than 83% of respondents.

Table 8. Proportion of producers according to the source of information, perception and effectiveness of technology.

Variables	Terms	Illela	Karofane	Malbaza	Tahoua	Mean (%)	χ^2	Significance
Information source	GIMEM project team	0	87.5	0	0	38.1	15.16	***
	INRAN	100.0	0	0	0	33.3	21.00	***
	Agricultural agents	0	25.0	50.0	100.0	23.8	8.59	**
	Peasant organization	0	0	50.0	0	19.0	9.39	**
Perception about technology	Knowledge of biological control	32.5	71.4	0	0	35.7	7.77	*
	Observation of effects in the fields	67.5	28.6	100.0	100.0	64.3	7.77	*
Effectiveness of technology	Poor	80.0	14.3	0	0	35.7	6.78	*
	Very good	20.0	42.9	0	0	28.6		
	Fair	20.0	14.3	0	100.0	21.4	4.15	ns
	Good	0	14.3	100.0	0	14.3	7.00	*
	Excellent	0	14.3	0	0	7.1	1.07	ns

*p < 0.1, **p < 0.05, ***p < 0.01; ns: non-significant differences.

The main mode of land acquisition remains inheritance by the majority of producers. These results corroborate those of [28] who reported that inheritance is the most common mode of acquisition in rural areas. The local variety is the main variety used by 68.7% of the producers surveyed. These results are different from those of [29]. Which show the use of improved varieties by more than 55.3% of producers. The farming system is essentially based on the combination of cereal/legume and cereal/cereal crops, used by more than 65.0% producers in the surveyed sample. The associated millet-cowpea-sorghum system is more used by 64.0% of producers, which brings us closer to the results of [30]. [28] reports that the associated Mil-Niébé system is more used by more than 87% of the sample surveyed in the Maradi region.

Pest pressure is one of the main constraints on millet production. Indeed, millet is attacked by the millet ear miner, insect pests and locusts highlighted by 57.9% of producers in the sample surveyed, but the most important of these constraints remains the millet ear miner. These results are close to those of several authors who have conducted studies on MEM [27] [31] [32] [33]. Producers do not have any effective method of combating MEM, more than 55.0% of producers in the surveyed sample declared that they do nothing to fight against this pest [27] [34].

Thus, some producers in the surveyed sample mentioned biological control (12.5% of producers in the surveyed sample) and chemical control by 8.8% producers in the fight against MEM. These results bring us closer to the study of [35], and similar results from [27], mentioning that some producers use biological control to fight against MEM.

The yield obtained in a year of very good production without the leaf miner for the five municipalities is on average 194.17 ± 25.91 kg per hectare. It also appears that the yield obtained following a very large leafminer infestation is very low and is around 28.27 ± 8.96 to 42.61 ± 5.67 kg per hectare depending on the municipality. These results for the MEM attack are close to those found by [23]. This low yield is not only due to the attack of insect pests, but also to biotic constraints such as millet downy mildew disease, the pathogen of which is *S. graminicola* which constitutes an important factor limiting full exploitation. The yield potential of cultivated millet varies. Millet downy mildew has been recognized as a disease of great importance since the beginning of the 20th century; however, it attracted relatively little world attention until the 1960s [36].

The biological control carried out against the millet head miner is unknown by most of the producers in the sample surveyed in the five communes. As for those who know the technology, most of them, the information came to them through an agricultural agent, INRAN and the GIMEM Project Team are the source of information for agricultural producers. Illela and Karofane then in the commune of Malbaza, by a peasant organization. The effectiveness of the technology was assessed at different levels by farmers from four municipalities from the entire sample surveyed.

In the commune of Illela 80.0% of producers declared that the technology is poor in the field against 14.3% of producers in Karofane, 42.9% of producers declared that the technology is very good in the field against 20.0% in Illela, fair in Tahoua and finally good in Malbaza. This situation could be explained on the one hand by the fact that the producers did not use a good number of release bags which could cover the area or on the other hand the neighboring producers did not apply the release technology. These results are different from those of several authors where they demonstrated the effectiveness of biological control [25] [37] [38]. Currently, the technology is being intensively transferred to producer organizations through private community units in the regions of Maradi, Zinder, Dosso and Tillaberi. However, this transfer is less significant in the Tahoua region, which explains the lack of knowledge of this technology by producers in the study area. Therefore, to improve the use of biological control in the area, large-scale popularization is necessary with the involvement of all partners, particularly farmer organizations.

5. Conclusion

It appears from this study that millet is one of the most important cereals in Nigerien family farming. Its yield is low due to biotic pressures and edaphic constraints. The management of millet insect pests such as the millet ear miner must first begin with raising awareness among producers in this region on the early diagnosis of infestations in order to take measures. The rate of use of biological control technology is too low (12%) and will need to be improved. More than half of those surveyed do nothing (58%) do nothing to deal with the millet head miner. Promoting the use of biological control could help producers in the region reduce losses from this pest and increase yields and household agricultural income. Efforts should also be made through programs to popularize agroecological technologies.

Acknowledgements

We thank Djibo Hamani University of Tahoua which financed this study as part of the activities of Study of the constraints of millet production (*Pennisetum glaucum* (L.) R. Br.).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] FAO: Food and Agriculture Organization (2022) Rapport mondial sur les crises alimentaires: L'insécurité alimentaire aiguë atteint de nouveaux sommets https://fr.wfp.org/communiques-de-presse/rapport-mondial-sur-les-crises-alimentaires-le-nombre-de%20personnes-victimes-insecurite-alimentaire-a-augmente-de-258-millions

[2] Abdou, R. (2014) Caractérisation de la diversité génétique de cultivars d'oignon du Niger en vue de leur conservation in situ et de leur amélioration. Master's Thesis, Université de Liège-Gembloux Agro-Bio Tech, Gembloux.

[3] Sehgal, D., Rajaram, V., Armstead, I.P., Vadez, V., Yadav, Y.P., Hash, C.T., *et al.* (2012) Integration of Gene-Based Markers in a Pearl Millet Genetic Map for Identification of Candidate Genes Underlying Drought Tolerance Quantitative Trait Loci. *BMC Plant Biology*, **12**, Article No. 9. https://doi.org/10.1186/1471-2229-12-9

[4] Karimou, I., Haougui, A., Basso, A., Ali, M., Halilou, H., *et al.* (2021) Le mildiou du mil [*Sclerospora graminicola* (Sacc.) Schroet.]: Incidence de la maladie en milieu paysan et caractérisation morphologique des isolats au Niger. *Journal of Environmental Science*, *Toxicology and Food Technology* (*IOSR-JESTFT*), **15**, 14-21.

[5] Moumouni, K.H. (2014) Construction d'une carte génétique pour le mil, *Pennisetum glaucum* (L.) R. Br, par une approche de génotypage par séquençage (GBS). Master's Thesis, Université de Laval de Québec, Québec.

[6] Manning, K., Pelling, R., Higham, T., Schwenniger, J.L. and Fuller, D.Q. (2011) 4500-Year-Old Domesticated Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) from the Tilemsi Valley, Mali. New Insights into an Alternative Cereal Domestication Pathway. *Journal of Archaeological Science*, **38**, 312-322. https://doi.org/10.1016/j.jas.2010.09.007

[7] Clotault, J., Thuiller, A.C., Buiron, M., Mita, S.D., Couderc, M., Haussman, B.I.G., Mariac, C. and Vigouroux, Y. (2012) Evolutionary History of Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) and Selection on Flowering Genes Since Its Domestication. *Molecular Biology and Evolution*, **29**, 1199-1212. https://doi.org/10.1093/molbev/msr287

[8] Bashir, E.M., Ali, A.M., Melchinger, A.E., Parzies, H.K. and Haussman, B.I.G. (2014) Characterization of Sudanese Pearl Millet Germplasm for Agro-Morphological Traits and Grain Nutritional Values. *Plant Genetic Resources*, **12**, 35-47. https://doi.org/10.1017/S1479262113000233

[9] Saidou, A.A. (2011) Etude moléculaire, évolution et caractérisation de gènes impliqués dans l'adaptation du mil (*Pennisetum glaucum* [L.] R. Br.) aux changements climatiques. Master's Thesis, Montpellier Sup Agro, Montpellier.

[10] Hamadou, M., Idrissa, S., Mahamadou, C., Souleymane, O. and Valentin, K. (2017) Potentialités fourragères du mil (*Pennisetum glaucum* (L.) R. Br): Revue de littérature. *Journal of Animal et Plant Science*, **34**, 5424-5447. https://m.elewa.org/Journals/wp-content/uploads/2017/10/2.Moussa-1.pdf

[11] Goudia, D.B., Issa, K. and Tom, H.C. (2016) Grain Iron Density Variability among New Farmer-Preferred Experimental Millet Varieties from Niger. *International Journal of Biological and Chemical Science*, **10**, 1865-1868.

[12] Kadri, B.K., Halilou, H. and Karimou, I. (2019) Culture du mil [*Pennisetum glaucum* (L) R. Br] et ses contraintes à la production: Une revue. *International Journal of Biological and Chemical Sciences*, **13**, 503-524. https://doi.org/10.4314/ijbcs.v13i1.40

[13] Abasse, T., Yayé, A., Aboul Habou, Z., Adamou, A.I. and Adam, T. (2013) Influence des Parcs agro-forestiers à Piliostigma reticulatum sur l'infestation des plants de mil par les insectes floricoles et Coniesta ignefusalis (Hmps) (Lépidoptère: Pyralidae) dans la zone d'Aguié au Niger. *Journal of Applied Biosciences*, **66**, 5140-5146. https://doi.org/10.4314/jab.v66i0.95011

[14] IRD (Institut de Recherche pour le Développement) (2009) Le mil, aliment du futur au Sahel. Fiche N°325.

[15] (2018) FAOSTAT. https://www.fao.org/faostat/fr/

[16] Garba, M. and Gaoh, N.B. (2008) Utilisation de Habrobracon hebetor (say) dans la lutte biologique contre *heliocheilus albipunctella* (de joannis) mineuse de l'épi du mil. AFPP—8ème conférence internationale sur les ravageurs en agriculture.

[17] Vercambre, B. (1978) Raghuva spp. Masalia spp., chenilles des chandelles du mil en zone sahelienne. *Agron Trop*, **10**, 62-79.

[18] Gahukar, R.T. (1984) Insect Pests of Pearl Millet in West Africa: A Review. *Tropical Pest Management*, **30**, 142-147. https://doi.org/10.1080/09670878409370867

[19] Gahukar, R.T., Guèvremont, T.H., Bhatnagar, V.S., Doumbia, Y.O., Ndoye, M. and Pierrard, G. (1986) A Review of the Pest Status of the Millet Spike Worm, *Rhaguva albipunctella* (De Joannis) (Noctuidae: Lepidoptera) and Its Management in the Sahel. *International Journal of Tropical Insect Science*, **7**, 457-463. https://doi.org/10.1017/S1742758400009668

[20] Nwanze, K.F. and Sivakumar, M.V.K. (1990) Insect Pests of Pearl Millet in Sahelian West Africa, *Raghuva albipunctella* De Joannis (Noctuidae, Lepidoptera): Distribution, Population Dynamics and Assessment of Crop Damage. *Tropical Pest Management*, **36**, 59-65. https://doi.org/10.1080/09670879009371433

[21] Krall, S., Youm, O. and Kogo, S.A. (1995) Panicle Insect Pest Damage and Yield Loss In Pearl Millet. In: Nwanze, K.F. and Youm, O., Eds., *Proceeding of an International Consultative Workshop on Panicle Insect Pest of Sorghum and Millet*, ICRISAT Sahelian Centre, Niamey, 135-145.

[22] Youm, O. and Owusu, E.O. (1998) Assessment of Yield Loss Due to the Millet Head Miner, *Heliocheilus albipunctella* (Lepidoptera: Noctuidae) Using a Damage Rating Scale and Regression Analysis in Niger. *International Journal of Pest Management*, **44**, 119-121. https://doi.org/10.1080/096708798228428

[23] Oumarou, N., Baoua, I., Saidou, A.A., Amadou, L. and 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.

https://popups.uliege.be/2295-8010/index.php?id=255

[24] Baoua, B.I., Ba, M.N., N'diaye, M., Dabire Binso, C., Tamo, M. and Aminou, A.M. (2009) Rapport d'activités du projet de gestion intégrée de la mineuse de l'épi du mil au sahel. Bilan 2006/2008. IER/INERA/INRAN/ITA, Mali.

[25] Baoua, I.B., Amadou, L., Oumarou, N., Payne, W., Roberts, J.D., Stefanova, K. and Nansen, C. (2014) Estimating Effect of Augmentative Biological Control on Grain Yields from Individual Pearl Millet Heads. *Journal of Applied Entomology*, **138**, 281-288. https://doi.org/10.1111/jen.12077

[26] Amadou, L., Baoua, I.B., Ba, M.N., Haussmann, B. and Altiné, M. (2017) Gestion de la chenille mineuse de l'épi du mil par des lâchers du parasitoïde *Habrobracon hebetor* Say au Niger. *Cahiers Agricultures*, **26**, Article No. 55003. https://doi.org/10.1051/cagri/2017045

[27] Boly, A., Waongo, A., Kaboré, A., Traore, F., Ba, M.N. and Sanon, A. (2022) Perception des producteurs sur les insectes ravageurs du mil au Burkina Faso: Place de la mineuse de l' épi de mil, *Heliocheilus albipunctella* De Joannis (Lepidoptera: Noctuidae). *Journal of Applied Biosciences*, **176**, 18322-18341.

[28] Hamidine, I., Lawali, S., Moctar, R.M. and Baoua, B. (2021) Caractérisation des exploitations agricoles familiales productrices du mil et leur niveau de résilience dans la bande sud du Niger. *IOSR Journal of Agriculture and Veterinary Science* (*IOSR-JAVS*), **14**, 5-16.

[29] Tahirou, H., Lawali, S. and Abdou, M.M. (2020) Influence des facteurs socioculturels et techniques sur la performance des exploitations agricoles familiales au Niger. *Afrique Science*, **17**, 93-103.

[30] Zongo, K.F., Hien, E., Mare, B.T. and Guebre, D. (2021) Performance de l'association mixte sorgho-niébé sur les productivités du sorgho et des sols en zone Soudano-Sahélienne du Burkina Faso. *International Journal of Biological and Chemical Science*, **15**, 987-1005. https://doi.org/10.4314/ijbcs.v15i3.12

[31] Ba, M.N., Baoua, I.B., N'Diaye, M., Dabire-Binso, C., Sanon, A. and 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**, 569-576. https://doi.org/10.1007/s12600-013-0317-x

[32] Thiaw, C., Brevault, T., Diallo, N.F., Sow, A., Ngom, D., Soti, V., Sarr, I., Dorego, G.S., Diop, M., Cisse, N. and Sembene, M. (2017) Incidence et régulation naturelle de la chenille mineuse de l'épi de mil, *heliocheilus albipunctella* de joannis (lepidoptera, noctuidae) a Bambey dans le bassin arachidier au Sénégal. *Agronomie Africaine*, **29**, 83-95.

[33] Oumarou, M.N., Baoua, I., Aziz, A.A. and Laouali, A.L. (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. *International Journal of Biological and Chemical Science*, **14**, 501-512. https://doi.org/10.4314/ijbcs.v14i2.16

[34] Oumarou, S., Madougou, G. and Bagué, G. (2019) Support de formation des membres des Organisations Paysannes (OP) des régions de Tahoua, Zinder et Dosso, productrices de parasitoïdes dans la lutte biologique contre la chenille mineuse de l' épi. https://reca-niger.org/IMG/pdf/module_elevage_habrobrcon_2019_gpv_cra.pdf

[35] Gahukar, R.T. and Gadi, V.P. (2019) Management of Economically Important Insect Pests of Millet. *Journal of Integrated Pest Management*, **10**, 1-10. https://doi.org/10.1093/jipm/pmz026

[36] Institut National de la Statistique (INS) and Direction Générale de la statistique (2014) Rue de la Sirba B.P 13416 Niamey—Niger.

[37] Ba, M.N., Baoua, I.B., Kaboré, A., Amadou, L., Oumarou, N., Dabire-Binso, C. and Sanon, A. (2014) Augmentative On-Farm Delivery Methods for the Parasitoid *Habrobracon hebetor* Say (Hymenoptera: Braconidae) to Control the Millet Head Miner *Heliocheilus albipunctella* (de Joannis) (Lepidoptera: Noctuidae) in Burkina Faso and Niger. *BioControl*, **59**, 689–696. https://doi.org/10.1007/s10526-014-9613-8

[38] Kabore, A., Ba, N.M., Dabire-Binso, C.L. and Sanon, A. (2017) Field Persistence of *Habrobracon hebetor* (Say) (Hymenoptera: Braconidae) Following Augmentative Releases against the Millet Head Miner, *Heliocheilus albipunctella* (de Joannis) (Lepidoptera: Noctuidae), in the Sahel. *Biological Control*, **108**, 64-69. https://doi.org/10.1016/j.biocontrol.2017.03.001