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Post-harvest management and phytosanitary practices used to preserve sorrel seeds, *Hibiscus sabdariffa* L. in Burkina Faso

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ABSTRACT: In the lack of a suitable control strategy, sorrel seeds are heavily damaged by *S. niger* during the storage. Better post-harvest management will make it possible to add value to this legume and make it available throughout the year. The aim of this study was to gain a better understanding of the various post-harvest practices applied to sorrel seeds, from harvesting to storage, with a view to implementing an effective control strategy against *S. niger*. A survey was conducted among 600 producers in 12 regions, one hundred (100) sorrel seeds traders and one hundred (100) pesticide sellers in the cities of Ouagadougou, Bobo-Dioulasso, and Pouytenga of Burkina Faso.

The results showed that eight percent (8%) of farmers and 56% of traders used chemical insecticides to preserve sorrel seeds. Phostoxin, an organophosphate insecticide, and Protect DP, an insecticide of the pyrethroid family, were respectively used by 87% and 13% of seed traders. Eighty-three percent (83%) of farmers and 76% of traders did not follow the prescribed doses.

The incorrect use of insecticides before and after use is a factor in environmental pollution and often results in their ineffectiveness against pests. This information is very useful for developing an integrated protection strategy for sorrel seeds.

KEYWORDS: post-harvest management, sorrel seeds, conservation, insecticide, *S. niger,* Burkina Faso.

1 INTRODUCTION

In West Africa, *Hibiscus sabdariffa* L. is grown as a cash crop, providing producers with financial income and populations with a critical food source [1]. It is grown mainly for food, therapeutic, and industrial purposes [1]. The seeds of *H. sabdariffa* are particularly well known for their richness in nutrients and the plant itself for its medicinal properties [2]. On average, the seed contains 26% protein, 20% fat, and 40% total sugars [3]. Despite efforts to increase production, the context of food insecurity is still marked by significant post-harvest losses [4]. Some authors consider that the losses recorded are increasing because the traditional storage and processing technologies used are generally inadequate, with the risk of infestation of stored products [5]. However, one of the major problems with this crop remains the difficulty of preserving it over the medium and long term.

In Burkina Faso, sorrel seeds undergo heavy infestation by insect pests during storage, the main one being *Spermophagus niger* Motschulsky [6]. These post-harvest losses have a negative impact on food availability, resulting in reduced feed use [7]. Despite the harmful effects of pests, sorrel seeds are available from producers and traders throughout the year for various uses. This suggests the existence of endogenous methods used by the rural population to combat insect pests. Unfortunately, little is known about these control strategies and various post-harvest practices. However, some control methods could present health risks for consumers [8]. This is undoubtedly the case with the untimely and continuous use of synthetic insecticides,

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which can have negative repercussions on non-target organisms in the environment [9]. Because of the potentially harmful effects of these products, agriculture must take greater account of environmental requirements.

The main goal of this study aimed to contribute to a better understanding of the post-harvest management of sorrel seeds in Burkina Faso. The study specifically involved: (i) identifying constraints related to post-harvest storage and stock protection methods through a survey in rural areas, (ii) and analyzing insecticide use patterns and the risks involved.

2 MATERIAL AND METHODS

2.1 CONDUCT OF THE STUDY

The study was conducted in three different agro-ecological zones of Burkina Faso. It first concerned sorrel seeds producers. A survey was conducted among 600 sorrel producers in twelve localities in the twelve regions of Burkina Faso, excluding the Sahel (figure 1). Next, one hundred (100) sorrel seed traders (wholesalers and retailers) from the major cereal markets were surveyed: 30 from Pouytenga, 40 from Ouagadougou, and 30 from Bobo-Dioulasso (figure 1). A further one hundred (100) insecticide traders, distributed above, were also interviewed. Interviewees were randomly selected from the major grain markets in the three provinces. For the survey of pesticide and sorrel seeds traders, the choice of these areas was justified by the high density of cereals, sorrel seeds, and pesticide traders in these three towns. The survey ran from the beginning of November 2021 to the end of February 2022.

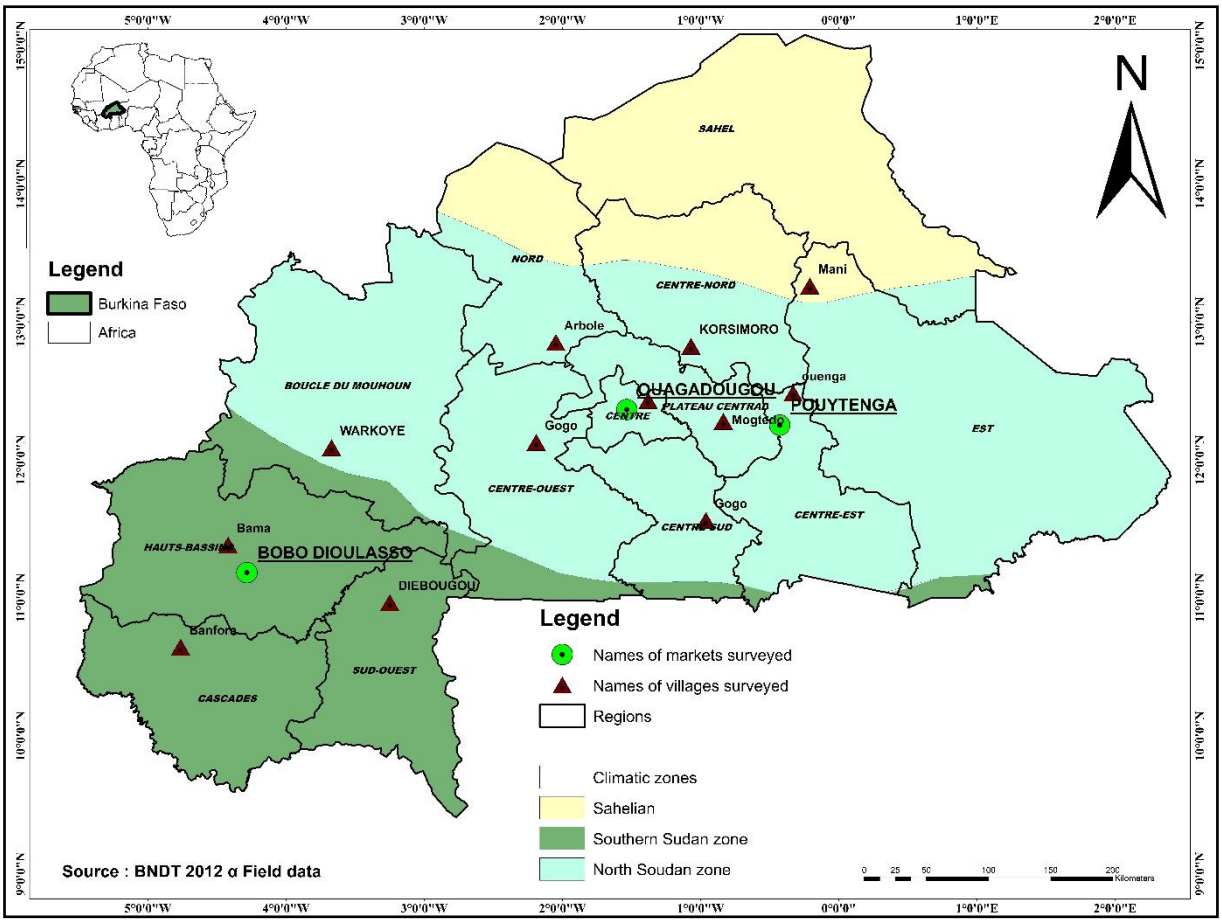

Fig. 1. Location of study areas

2.2 SURVEY OF SORREL PRODUCERS

The six hundred (600) sorrel producers surveyed were spread over twelve regions, with fifty (50) producers per region. The questionnaire was administered to each respondent individually to avoid any influence from one to the other. The survey form included information on the following:

- Integrity of sorrel seeds after harvest;
- Knowledge of the insecticides used and how they are used to protect stocks;
- Storage structures;
- Risks of poisoning;
- Phytosanitary practices and conditions for the use of insecticides;
- Average price of a Yoruba plate by region.

2.3 SURVEY OF INSECTICIDE TRADERS

- The survey of one hundred (100) insecticide traders (retailers and wholesalers) mainly concerned:
- The origin of the insecticides sold;
- Knowledge of how to use insecticides;
- Storage of insecticides.

2.4 SURVEY OF SORREL SEED TRADERS

The survey was conducted among one hundred (100) sorrel seed traders. The questions focused on:

- Duration of the stock and the market value of the seeds
- Storage facilities;
- Knowledge of the insecticides used;
- Risks of poisoning
- The origin of insecticides, their conditions, and their methods of use;
- Personal protective equipment used and the place where empty bottles or packaging are stored.

2.5 DATA ANALYSIS

The collected data were coded and entered using Sphinx software, and the Excel 2016 spreadsheet was used for descriptive statistical analysis in terms of percentages and averages. A check of the distribution of the data with the Shapiro – Wilk test using the Shapiro-test function was performed on the price of one Yoruba plate (equivalent to approximately 2.45kg) of sorrel seeds. When normality and homogeneity were not verified, the Kruskal– Wallis alternative test was used. All tests were performed at the 5% probability level when the test of variance was significant.

3 RESULTS

3.1 SOCIODEMOGRAPHIC CHARACTERISTICS OF SORREL SEEDS PRODUCERS

The majority of sorrel seeds producers surveyed were women (65.16%). The majority of farmers were between 30 and 45 years old (Table 1). 60% of famers surveyed had a primary or secondary education level. Regarding sorrel seeds traders, 57% of those surveyed were women, most of whom were 45 years old. Most of these women were literate, and 31% had primary education level (Table 1). The pesticide sellers were all men, most of whom had a primary education level and were between 25 and 35 years old (table 1).

Table 1. Sociodemographic characteristics of producers, sorrel seed traders, and pesticide traders

Characteristics of the surveyed population		Producers (%)	Sorrel seed traders (%)	Pesticide traders (%)
Gender	Man	34.8	43	100
	Woman	65.16	57	0
Education level	Not literate	11.83	0	0
	Literate	18.33	53	13
	Primary level	29.5	31	(55)
	Secondary level	30.5	(16)	17
	Superior	9.83	0	15
Age range	[25 - 30]	16.83	0	40
	[30 - 35]	26.83	29	41
	[35 - 40]	31.16	14	15
	[40 - 45]	17.33	17	4
	≥45	7.83	(40)	0

3.2 Conditions Of Seeds At Harvest Time For Different Hibiscus Sabdariffa Morphotypes

For the different morphotypes grown by the surveyed farmers, 18% said that they noticed insect emergence holes in the sorrel seeds at harvest. All morphotypes were grown, with a preference for the long red morphotype known as *Bissap* (54%) (Figure 2). The survey showed that 60% of farmers harvested the capsules when they were opened and 40% harvested when the seeds were mature and the capsules were opening or not.

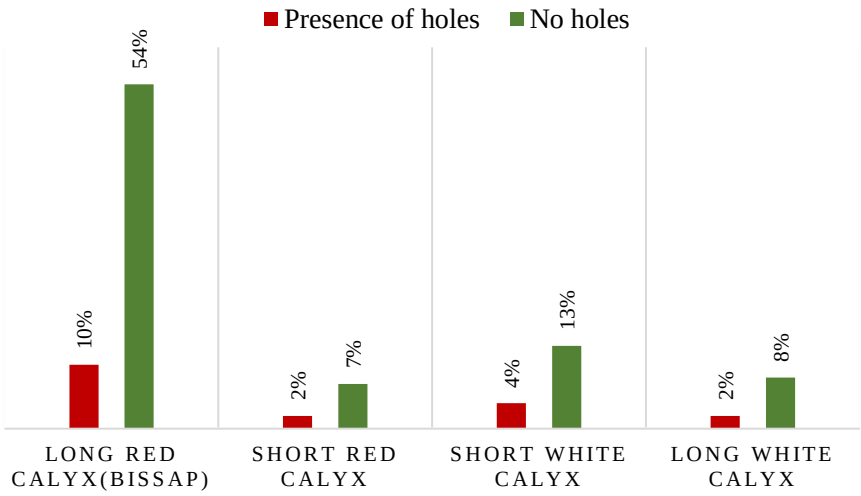

Fig. 2. Seeds conditions of the four different varieties at harvest

3.3 Storage Structure And Stock Protection Methods

3.3.1 Storage Structure

The results showed that the traders surveyed (100%) stored sorrel seeds in polypropylene bags. Various storage structures were used by farmers. These were PICS bags (5.83%), polypropylene bags (6.16%), jars (16.66%), and cans (71.33%) (Figure 3).

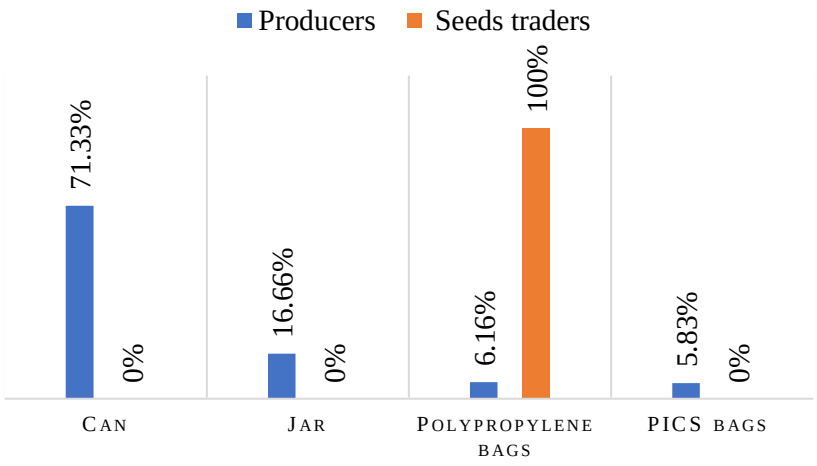

Fig. 3. Proportions of responses on preservation methods used by sorrel seeds producers and traders

3.3.2 METHODS OF STOCKS PROTECTION

3.3.2.1 USE OF INSECTICIDES

The results of the survey showed that 56% of traders used insecticides, compared with 8% of producers (Figure 4).

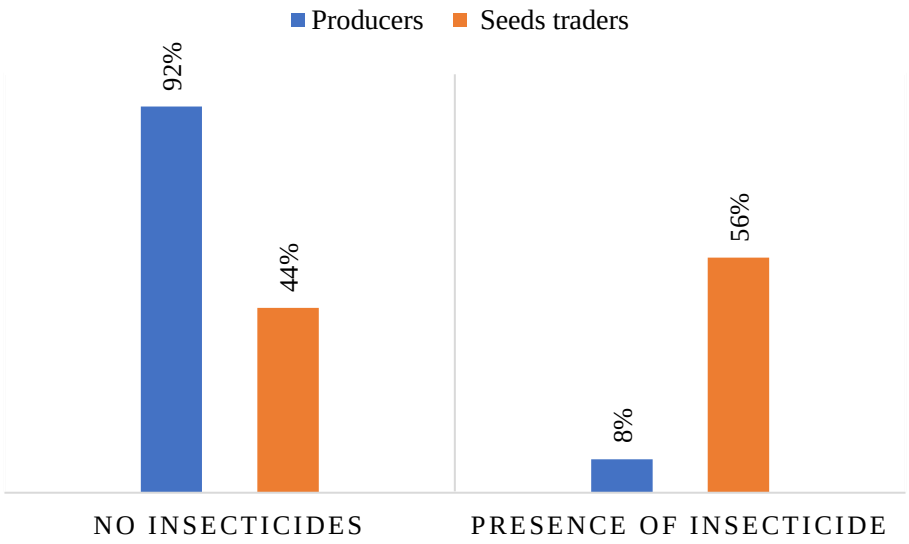

Fig. 4. Response of seeds farmers and traders on the use of insecticides

Figure 5 shows the pesticides used by growers and traders. 87% use Phostoxin (aluminum phosphide) from the organophosphate family, which acts by fumigation, and 13% use Protect DP (permethrin/deltamethrin) from the pyrethroid family.

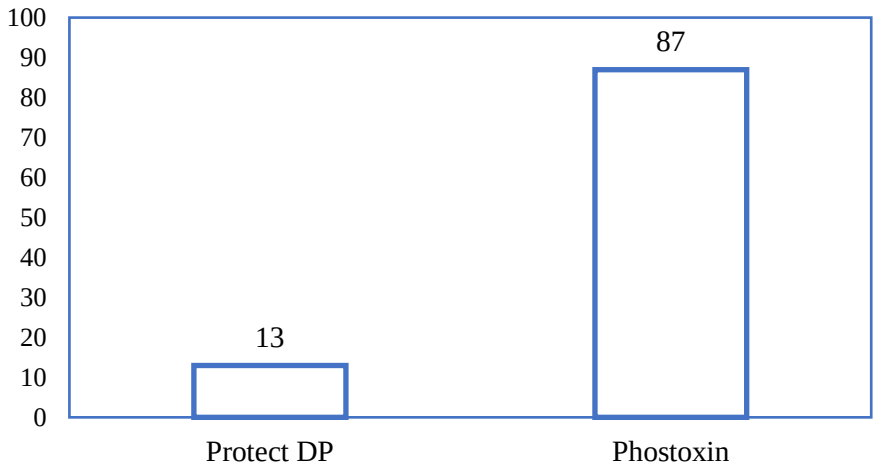

Fig. 5. Different insecticides used by sorrel seed producers and traders

3.3.2.2 METHOD OF USE OF INSECTICIDES

3.3.2.2.1 COMPLETION OF PRESCRIBED INFORMATIONS

The survey revealed that 9% of producers and 17% of traders read the information on insecticide labels before using them (Figure 6).

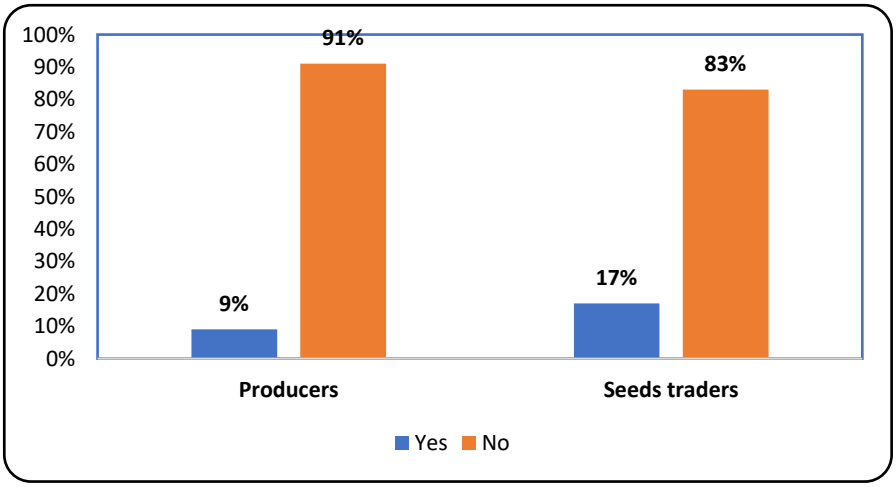

Fig. 6. Completing the prescribed information

3.3.2.2.2 APPLICATION OF RECOMMENDED PRESCRIPTIONS

The results of the survey showed that none of the users used protective equipment when applying treatments to preserve the seeds. The majority did not comply with the prescribed doses. Furthermore, according to the results obtained, only 24% of traders and 17% of farmers knew that there was a risk of insecticide poisoning if the prescribed dose was not observed (Figure 7).

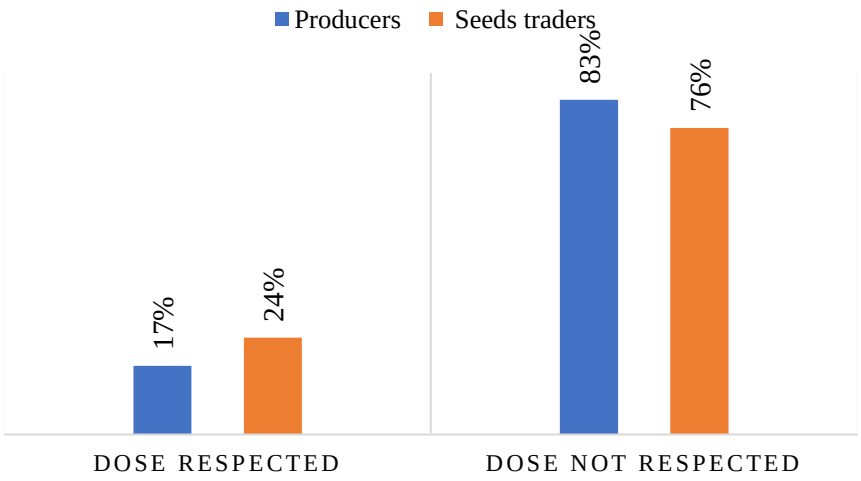

Fig. 7. Proportion of sorrel seeds producers and traders complying with prescribed doses

3.3.2.2.3 USE OF PROTECTIVE EQUIPMENT

The results of the survey showed that none of the actors used protective equipment during seed conservation treatments (Figure 8).

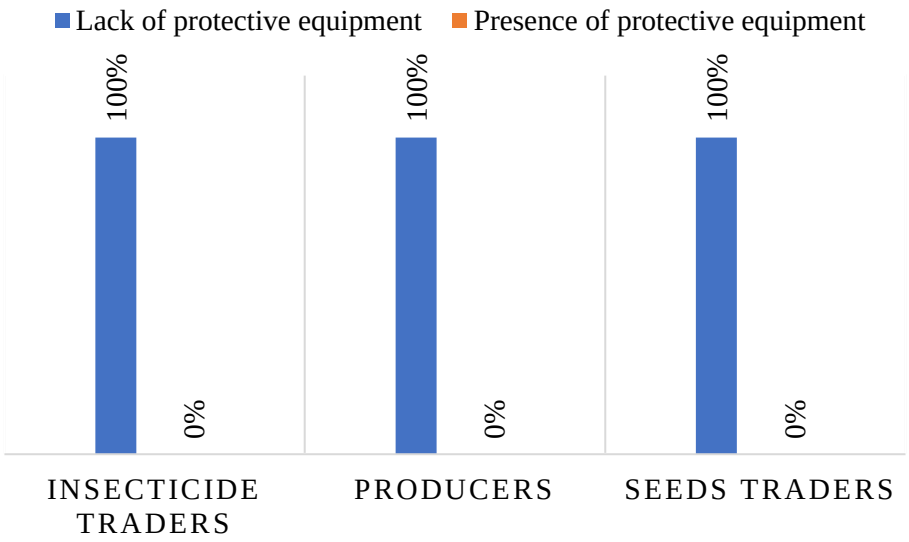

Fig. 8. Use of protective equipment

3.3.3 STORAGE FACILITIES FOR SEEDS TREATED WITH INSECTICIDES BY TRADERS AND PRODUCERS AND FATE OF EXPIRED INSECTICIDES

Two types of storage structure for insecticide-treated seeds are used by traders and growers. These are warehouses, which are used mainly by sorrel seed traders (71%), followed by dwellings, which are used mainly by growers (100) (Figure 9).

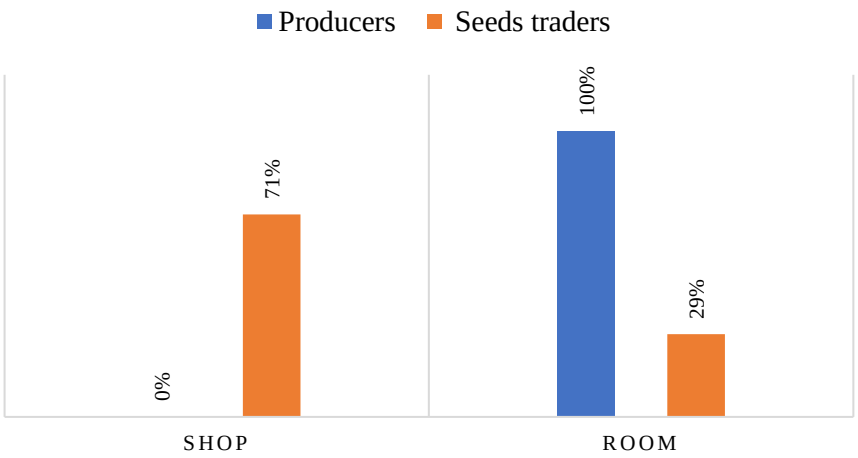

Fig. 9. Storage structures for seeds treated with insecticides by traders and producers

Eighty-five percent (85%) of traders continue to sell their insecticides even after their expiry date, compared with 11% who incinerate them and 4% who throw them away. All respondents said that they had not received training in the various practices involved in selling insecticides (figure 10).

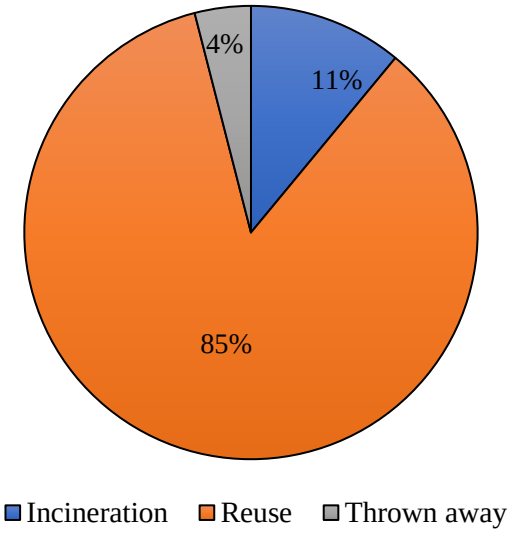

Fig. 10. Traders' response to the fate of obsolete insecticides

3.4 The Impact Of Insecticides On Health

All the respondents who used pesticides to preserve sorrel seeds said that they experienced temporary discomfort such as colds, coughs and itching.

3.5 Average Selling Price And Place Of Sale Of Sorrel Seeds

The average price of a Yoruba plate (equivalent to about 2.45kg) varies significantly at harvest time from one region to another at the same time and increases significantly with each quarter. Note that the average price six months after harvest is 1500 FCFA per Yoruba plate in several regions of the country (table 2).

Table 2. Average price of a Yoruba plate by region, depending on the selling period

Region	Harvest prices	Prices after three months	Prices after six months
Centre	556 a	1026 ab	1504 a
IC 95%	[541,38- 570,61]	[1005,63 -1046,36]	[1484,4- 1523,5]
Southwest	542 ab	1060 a	1500 a
IC 95%	[527,38- 556,61]	[872,63 - 91336]	[1480,42- 1519,57]
Centre-east	531 ab	1000 b	1474 ab
IC 95%	[541,38- 570,61]	[979,63- 1020,36]	[1454,42- 1493,57]
East	532 ab	1006 b	1496 a
IC 95%	[517,38- 546,61]	[985,63- 1026,36]	[1476,42- 1515,57]
Centre-west	531 ab	1004 b	1496 a
IC 95%	[516,38- 545,61]	[958,63- 999,36]	[1476,42-1515,57]
North	524 ab	1008 b	1496 a
IC 95%	[509,38- 538,61]	[987,63 -1028,36]	[1476,42- 1515,57]
Mouhoun Boucle	517 bc	763 e	1028 e
IC 95%	[502,38- 531,6199]	[742,63- 783,36]	[1008,42- 1047,57]
Centre-North	488 cd	979 b	1444 b
IC 95%	[541,38- 570,61]	[958,63- 999,36]	[1424,42- 1463,57]
Centre-south	482 cde	835 d	1462 ab
IC 95%	[467,38- 496,61]	[814 ,63- 855,36]	[1442,42- 1481,57]
Plateau-central	474 de	893 c	1466 ab
IC 95%	[459,38- 488,61]	[872,63- 913,36]	[1446,42- 1485,57]
Cascade	450 ef	904 c	1390 c
IC 95%	[435,38- 464,6199]	[883,63- 924,3]	[1370,42- 1409,57]
Hauts-bassins	432 f	750 e	1028 e
IC 95%	[417,38- 446,61]	[729,63- 770,36]	[1192,42- 1231,57]
Probabilité	χ^2= 191.94, df = 11, p-value < $2.2e^{-16}$	χ^2= 365.69, df = 11, p-value < $2.2e^{-16}$	χ^2= 361.14, df = 11, p-value < $2.2e^{-16}$

4 DISCUSSION

This study has shown that all sorrel morphotypes are grown by women, with a preference for the long red morphotype known as *Bissap* for its many uses. Most farmers said that they harvest the capsules when they opened them. At this time, the seeds are already infested, and the puncture holes become visible a few days after harvesting. Previous studies have shown that the harvest date has a certain effect on overall infestation rates [10,11], and it is from this small number of insects that large-scale contamination of stocks will occur [12].

To reduce the infestation of sorrel seeds, several storage structures are used, of which cans are the most popular. Very few farmers used PICS bags, which are recommended for storing dry seeds. Indeed, storing sorrel seeds in PICS bags limits the development and damage of *S. niger* [13]. Cans and jars, which are traditional storage structures, are limited to small-scale stocks.

The survey also revealed that 56% of traders and 8% of producers use synthetic insecticides to protect their stock when they notice a massive emergence of insects. Two insecticides are used for this purpose. These are phostoxin from the organophosphate family, which is used more by traders (87%), and PROTECT DP from the pyrethroid family. This finding is similar to previous studies that have shown that chemical control has often been considered despite stock pests [14,15]. After the expiry date, pesticides are still sold and used by sorrel seed traders. Added to this is the failure to comply with the recommended doses and conditions of use and inadequate storage structures for chemicals or treated seeds.

The absence of protective equipment during the application of chemicals constitutes a violation of article 2 of the FAO code of conduct (2013) [16], which recommends that all pesticide handlers be equipped with personal protective equipment. All these poor practices are sources of health problems and environmental pollution [17,18,19,20,21]. However, the high level of education of pesticide and sorrel seeds traders should make it possible to ensure that the seeds are well preserved while

respecting the recommended doses to reduce health risks and, above all, protect the environment. However, this is far from the case. According to [22], improper use of chemicals has effects such as itching and respiratory and vision problems that are felt by various handlers.

The survey revealed that all those who had used pesticides without protective equipment were experiencing discomfort. We think that the discomfort observed by the handlers of synthetic insecticides correlates not only with the level of literacy but also with the lack of use of appropriate protective equipment. These results are in agreement with the work of [22], who had shown that the use of pesticides without adequate equipment was responsible for intoxication among cowpea producers and traders.

Insect infestation of sorrel seeds can compromise their economic value. The difficulty of preserving healthy seeds means that some farmers sold them for around 500 CFA francs, whereas the average price of a Yoruba plate (equivalent to around 2.45kg) six months after harvest is 1,500 CFA francs. This gradual increase in the selling price of sorrel seeds is similar to that of other legumes such as cowpea [22], and zamné seeds [23]. This could be explained by their annual production, the non-availability of these commodities throughout the year, and their increasingly growing demand.

5 CONCLUSION

This study has enabled us, for the first time, to take stock of the post-harvest management of sorrel seeds. Seeds are stored in various structures, of which nylon bags were the most common. Traders used only polypropylene bags for storage. The sale of sorrel seeds provided a significant source of income. Indeed, the average price of a Yoruba plate of sorrel seed triples within six (6) days of harvest. When insects emerge in stocks, sorrel producers and traders' resort to insecticides rather than other conservation methods. Some insecticides used were found to be unfit, unregistered, and/or obsolete. It also emerged that not only do users not respect the doses recommended by manufacturers, but chemicals were still being used despite their expiry date.

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