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Research Article

Methods and strategies of the conservation of cereals' plant genetic resources cultivated in the Far-North Region of Cameroon

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Abstract

Cereals are an integral part of agricultural production and are the base crops essential for food security. However, recent studies conducted in the Sudano-Sahelian zone on cereal seed management strategies have revealed a real deficit of post-harvest conservation structures and strategies that promote the spoilage of seeds stored in the field and in equipment. The present study aims to evaluate farmers' conservation methods and strategies for optimizing the germination capacity of seeds preserved *in situ* and *ex situ*. The study was carried out among producers in the Sudano-Sahelian zone, more specifically in Far-North Region in the localities of Mora, Gazawa and Moutourwa. The methodological approach consisted of random sampling of farmer's organizations and a representative sample of 87 producers in the 03 localities was surveyed. Respondents for all 03 villages are subjected to a questionnaire according to the tools and techniques of a participatory research approach based on direct observations, free discussions and individual interviews. Surveys revealed that a total of 02 crops are produced in the 3 localities, namely: Maize (20.68%) and Sorghum (79.31%). The respective varieties of these crops are: CMS 9015 (14.94 %) and TZEE (5.74%) for Maize; for the Sorghum varieties they are S-35 (16.09%), Zouaye (9.19%), Sectaire (10.34%), Viri (6.89%), Dadoudou (5.74%), Adjagamari (2.29%), Dalassi (5.74%), Muskuwari (3.44%), red millet (13.79%) and white millet (5.74%). As for *in-situ* strategies and methods, it should be noted that the conservation of these seeds is done by regular control of fields (31.03 %), selection of good corn on the field (17.24 %), treatment on the fields against red insects (25.28 %), respect of isolation distances of plots (8.04 %), separate harvesting of varieties (3.44 %), purification of hors-types on the fields (10.34 %) and chemical treatment of crop plots (4.59 %). The *ex-situ* conservation of the seeds is done as follows: placing the seeds on plots in a clean and treated store (12.64 %), arranging the bags on the pallets (12.64 %), providing sunlight to the harvested products (18.39 %), packaging them in secure polyethylene bags (31.03 %), covering the seed bags with tarpaulins (18.39 %) and biologically treating the seeds with oils extracted from the plants (6.89 %). From the two crops identified by producers, sorghum is the most widely grown cereal in the Far North. Due to its agronomic requirements, this crop is the most suitable for this area because it provides the best harvest yields among all cultivated cereals. Producers prefer it because it allows for the preparation of better traditional dishes and is also known for its brewing potential. Furthermore, all of these conservation strategies both *in situ* and *ex situ* identified above, allow the maintenance of the qualitative,

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nutritional, and germination properties of the seed throughout conservation, for the preservation that can satisfy producers' expectations.

Keywords: *Methods, Strategies, Conservation, cereals, Far-North Region, Cameroon.*

Introduction

The conservation of agricultural genetic resources is only of interest if they are used effectively. This requires strong connections throughout the chain value, which ranges from resource conservation by farmers and their communities to consumption by consumers, harvesting, storage in gene banks, and research. Plant genetic resources are a key strategic resource for sustainable agricultural production (FAO, 2011). Their conservation and effective use are essential to ensure food security and nutrition, for the present and the future (FAO, 2014). Some of these resources are used today; others are tomorrow's "reservoirs" for needs that are still unknown. In the crop sector, they concern cultivated plants as well as wild species and genetic material used in breeding (Gnis, 2021). Managing genetic resources consists of inventorying, characterizing and assessing, conserving, regenerating and disseminating. The challenge of managing plant genetic resources is to guarantee the availability of cultivated biodiversity for the future. It is important to maintain the diversity of these genetic combinations, created or developed over time, in a wide variety of environments, as it is a breeding ground from which to draw to create new varieties. However, the collections containing these resources must be managed wisely. Indeed, the aim of conservation actions is to maintain and preserve production material, but also and above all to be able to meet the present and future expectations of users of plant genetic resources: geneticists, breeders, producers, etc. (Charrier *et al.,* 1984). The methods of conservation of this heritage vary both from the point of view of the general strategy and the techniques adopted. They must be appropriate to the specificities of the different types of plants. Two global resource management strategies are used: in situ and ex situ conservation, in which the collections are maintained respectively in their growing area or in specialized centers in the form of: whole plants, seeds, tissues, pollens (Charrier *et al.,* 1984).

The sub-region is a producer of several foodstuffs that are kept at the level of the peasant as well as the cooperatives and the state in structures of various sizes. Cereals are an integral part of agricultural production and constitute the base crops that are essential for food security (Sangaré *et al.,* 2009). When management is effective, cereals perform very well and when sufficient attention to detail is paid, they are one of the most profitable crops. Seed conservation helps to prevent and compensate years of low production. It also helps to avoid the loss of species and populations. Conserving is not just about growing a plant or locking its seeds in the soil. It also means perfectly controlling all the storage parameters in order to ensure the best possible conditions, mastering the cultivation techniques of the different species, in order to regenerate them regularly (Charrier *et al.,* 1984). In addition, there are major problems for plant genetic resources: the gradual loss of genetic diversity and the low valuation of existing variability, which can be explained by the disappearance of long-cycle of varieties and the gradual disappearance of wild relatives of cultivated plants (Issaka, 1995). This is due in particular to the lack of adaptive strategies adopted by producers in the face of droughts often recorded at the end of the plant cycle, to the selection objectives of research institutions which have placed more emphasis on short-cycle of varieties in response to producers' requests, to the inadequacies in the systems for the conservation of genetic diversity due to the failure to take into account local knowledge and breeding practices, the lack of strategies and program for the in situ conservation of plant genetic resources, *etc* (Issaka, 1995). The consequences of the loss of genetic variability of crop species are significant for populations. Indeed, the disappearance of certain local ecotypes of cereals will deprive researchers of international and national research institutions of genetic material whose adaptation to extreme growing conditions is no longer to be demonstrated (Issaka, 1995).

Recent studies conducted in the Sudano-Sahelian zone on cereal seed management strategies have revealed a real deficit of post-harvest conservation structures and strategies that promote the deterioration of seeds stored either in the field or in equipment. If nothing is done, the loss of local cereal cultivars will be irreversible and this could reinforce the food insecurity situation of the populations of the Sudano-Sahelian zone. To compensate for these insufficiency and inadequacies, the present study was initiated in order to help circumscribe the progressive loss of the phytogenetic diversity of the main cultivated cereals in the Sudano-Sahelian zone while promoting their sustainable use by local populations.

MATERIAL AND METHODS

Localization of the study area

The present study is part of the *in situ* and *ex situ* conservation of the main cereal crops grown in the Sudano-Sahelian zone of Cameroon. It covers the administrative region of the Far North, which is characterized by very irregular annual rainfall (400 to 1200 mm/year), periodic droughts and 65 % of which are rural people who eat mainly cereals. The study was conducted particularly in the Far North in 03 distinct localities: Mora, Gazawa and Moutourwa, which are recognized as cereal production centers because, of their pedoclimatic conditions. They are home to the seed farms of the agricultural research centers and the majority part of the populations are producers and multipliers of several local varieties and cereal seeds resulting from the work of the agricultural research institutions of the region.

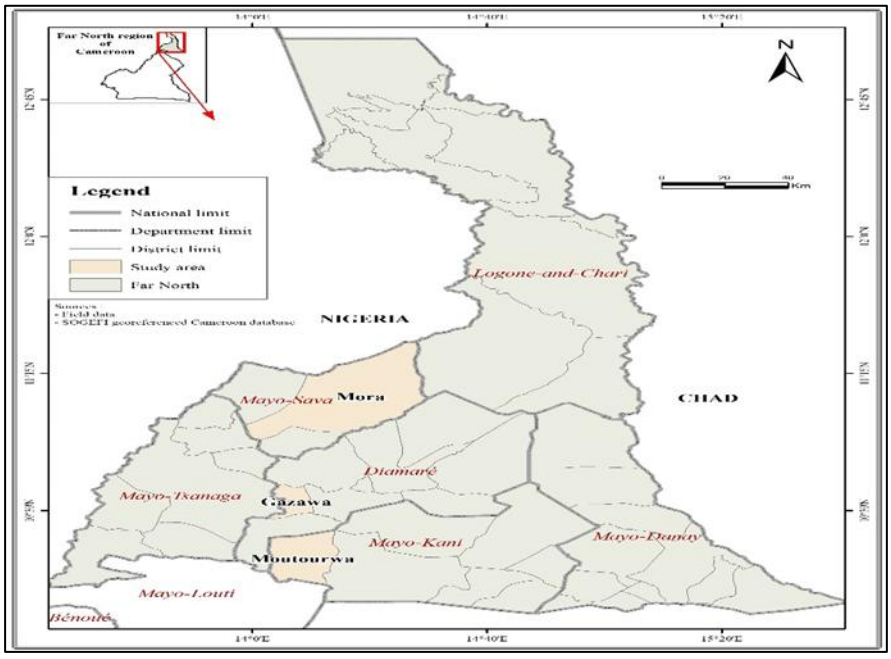

Figure 1: Localization Map of the study area.

Material used for field data collection

The material used for the field study is listed below:

- Survey sheets administered to local cereal producers grouped in the form of GICs;
- Argis and Google Earth mapping and georeferencing software;
- The EXCEL 2013 spreadsheet, used for the recoding, synthesis and representation of histograms;
- The SPSS STATISTIC 20 software, which made it possible to perform Multiple Correspondence Analyses of the variables from the survey to determine the existing correlations between them;
- A bibliographic database.

Data sampling

The agricultural situation is assumed to be generally almost homogeneous between the three localities of the Far North region considered in this study (Mora, Gazawa and Moutourwa). The methodological approach consisted of random sampling of farmers' organizations and a representative sample of 87 producers in the 03 localities was surveyed. Respondents for all 03 villages are subjected to a questionnaire according to the tools and techniques of a participatory research approach based on direct observations, free discussions and individual interviews. The information focused on (i) the inventory of the varieties grown in each study site, (ii) the methods and strategies for *in situ* and *ex situ* seed conservation and (iii) the evaluation of seed productivity by studying their germination properties.

Data processing

The data collected was processed and analyzed several times by Microsoft Excel and the SPSS software. Mean values, standard deviations and percentages were calculated considering all parameters recorded and existing

correlations were determined using the ACM analysis. The results on the inventory of the varieties grown in the three study sites, the methods and strategies for *in situ* and *ex situ* conservation of seeds and the evaluation of seed productivity by studying their germinative properties are presented in the form of histogram illustrating the respective percentages and numbers of the variables that emerged after the surveys.

Results And Discussion

Different varieties of cereals by locality

Figures 2, 3 and 4 show the different varieties of sorghum and maize grown by producers at our three study sites: Gazawa, Mora, and Moutourwa. The different cereal varieties presented in the charts are based on survey results conducted during the field study. It was carried out using a pre-established questionnaire.

Different varieties of cereals cultivated in the Mora site

Agriculture is the main economic activity practiced in the locality of Mora after livestock farming. The main crops cultivated in order of importance are: rainy season sorghum; dry-season sorghum (Muskuwari), maize. This production is partly intended for consumption and marketing. The cultural diversity, the dynamism and hard work of the populations, the presence of vast swathes of fertile land are great assets for agriculture, a lever for the local economy of this locality, climatic conditions, the poverty of the soil in places (especially in mountain areas) as well as the very limited access of producers to financing (for the acquisition of agricultural inputs). The low mechanization of production activities is a constraint to the development of agriculture in this locality. According to the survey results, the main cultivated cereals are red millet, commonly known as Muskuwari (36.7 %), and the S-35 sorghum variety (20 %). The maize varieties cultivated are CMS 9015 (10 %) and TZEE with a low percentage of 3.3 % **(Figure 2)**.

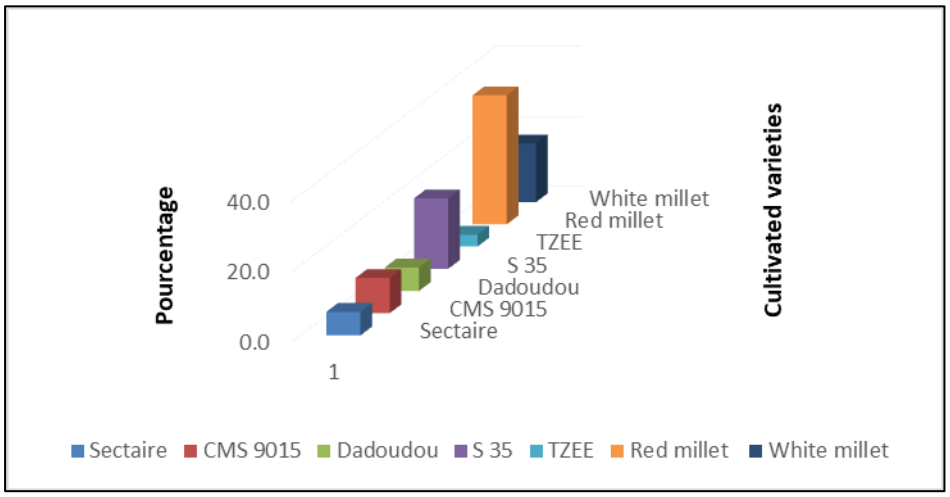

Figure 2: Distribution of cereal varieties grown in Mora.

Different varieties of cereals grown in the Gazawa site

The locality of Gazawa is essentially an agricultural area; nearly 80 % of the population derives its income from agriculture. The main crops in the rainy season are maize (*Zea mays*), rainfed sorghum (*Sorghum bicolor*), and in the dry season off-season sorghum (Muskuwari) grown on large tracts of Vertisols. Cereals are the basis of food in the Diamare plain, as is the case in the entire Sudano-Sahelian zone. Our study results show that the main cultivated cereals are the local varieties Sectaire, Viri and the certified Zouaye variety with percentages of 20 % and 17.1 % respectively for the Viri and Zouaye varieties each and the S 35 (14.3 %). For maize varieties, CMS 9015 is reported with a percentage of 20 % **(Figure 3)**.

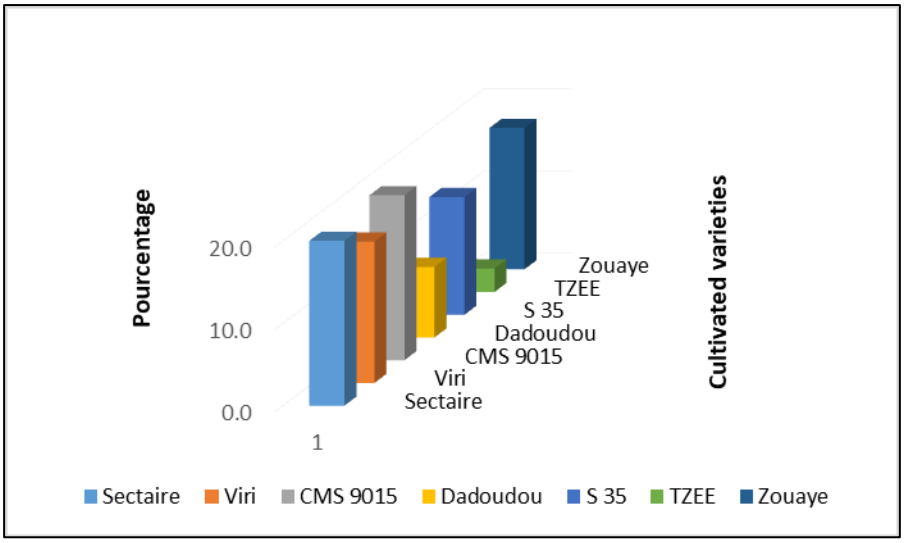

Figure 3: Distribution of cereal varieties grown in Gazawa.

Different varieties of cereals cultivated in the Moutourwa site

Agriculture is the main economic activity practiced in the commune of Moutourwa. It mobilizes several agricultural assets around two categories of crops: rainfed crops (red sorghum, maize, etc.) and off-season crops (dry season sorghum or Muskuwari). The results of the survey carried out in this area revealed that the cereal varieties widely cultivated in this locality are: CMS 9015 certified maize and TZEE with the same percentage of 13.6 % and S 35 and Dalassi sorghum varieties (13.6 % and 22.7 %). Cereal varieties which are not produce in other localities are Adjagamari and Dalassi **(Figure 4)**.

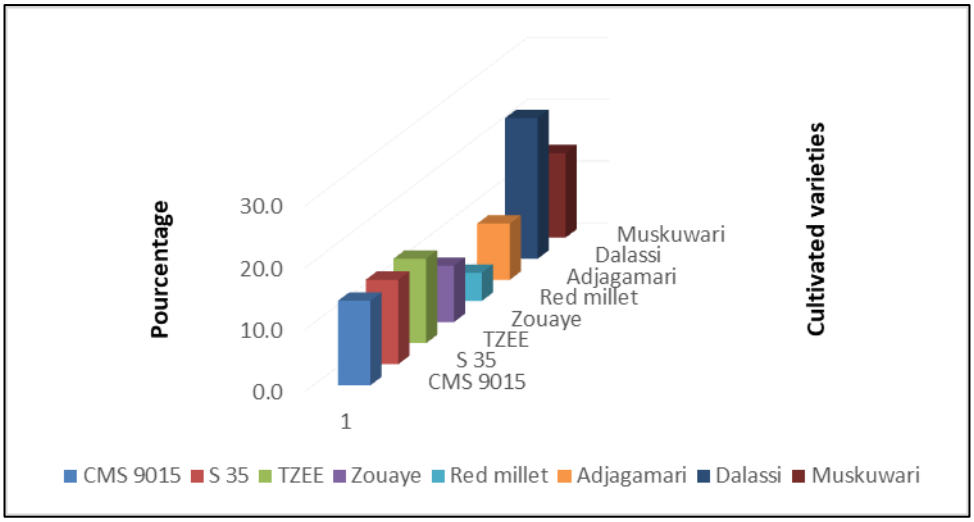

Figure 4: Distribution of cereal varieties grown in Moutourwa.

Varieties characterization by study area

Strategies for managing seed on a good condition

The figure 5 below presents the ACM carried out on the inventory data of cereal varieties and the methods of maintaining seeds in good condition. According to our different study areas (Mora, Moutourwa and Gazawa), it appears that the populations grow cereals either for subsistence, trade or sometimes both. The system of procuring cereal seeds is done either through purchases on the market, exchanges between farmers and sometimes these seeds come from conservation. The main cultivated crops are maize and sorghum. As cultivated maize varieties we have: CMS 9015 and TZEE. The local varieties of sorghum cultivated are Sectaire, Viri, Dadoudou, Adjagamari, Dalassi, Muskuwari, red millet and white millet. As certified varieties of sorghum we have S 35 and Zouaye. All these varieties are produced for several reasons: red color, seed shape, high yield, resistance to diseases and insect attacks, long-term conservation, short cycle, adaptation to the environment and economic income.

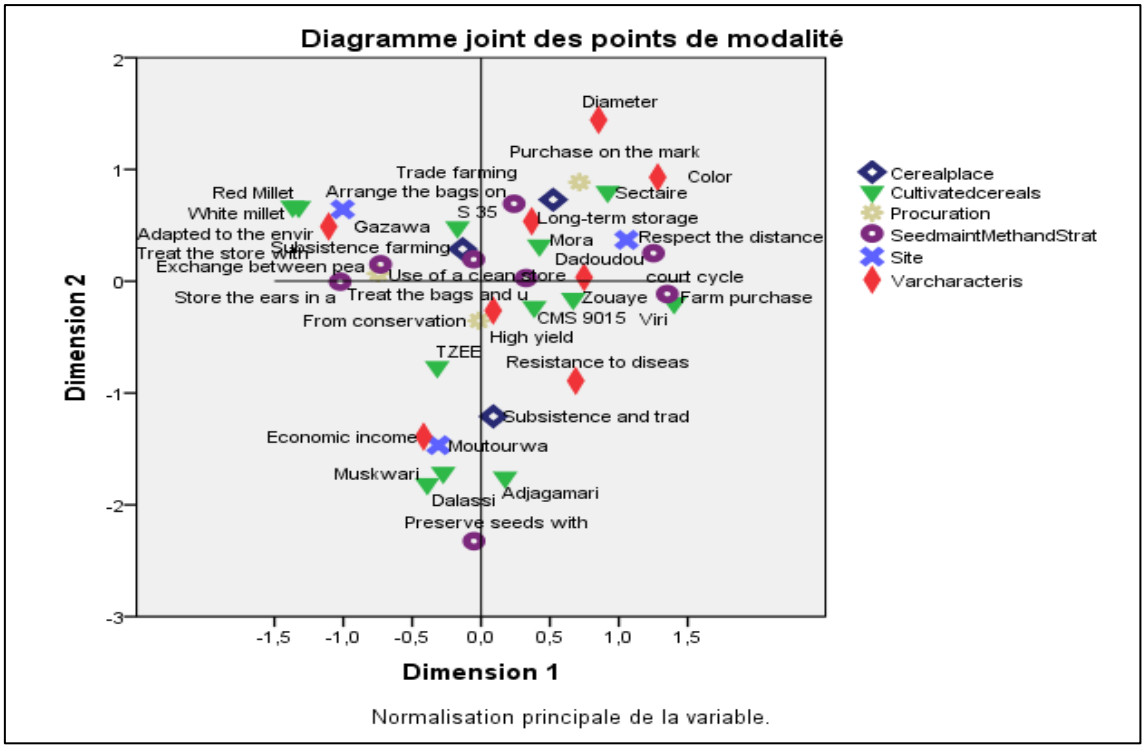

Figure 5: ACM carried out on the data of inventoried cereal varieties and maintenance methods of seeds in good condition.

Quality of seeds

Figures 6 and 7 illustrate the different characteristics of seeds, whether in good or poor condition, resulting from the storage conducted by producers in our study area using their local knowledge of preservation, which encompasses the various methods and conservation strategies identified during the survey phase.

According to the survey conducted in the three study locations, the storage time for cultivated seeds is five years for the majority of farmers. For a lower part, the time to conservation of these varieties is more than fifteen years. The main conservation structures are: the stores, the polyethylene bags, the MINADER propagation farms, the ears of corn hung in the open air and the granaries. The placement of seeds in these structures is done either in the form of piles on plots or by placing the bags in bulk. The various attacks noticed in the field are: caterpillars, termites, locusts, stem borers, Striga and water stress. In the conservation warehouses the presence of weevils, insects, rodents and the effect of humidity and temperature of the enclosure can be seen. Seeds conserved on a good condition are characterized by rapid development (14.94 %), good production with high yields (34.48 %), seeds are strong and have a good time of conservation (18.39 %), good germination and good emergence of plants (32.18 %). On the other hand, the attacked seeds are characterized by dormancy and low yield (28.73 %). The presence of the holes is noted and these seeds are crushed and mealy (32.18 %), there is an absence of germs (26.43 %) and the presence of red insects inside the holes (12.64 %). **(Figures 6 and 7)**

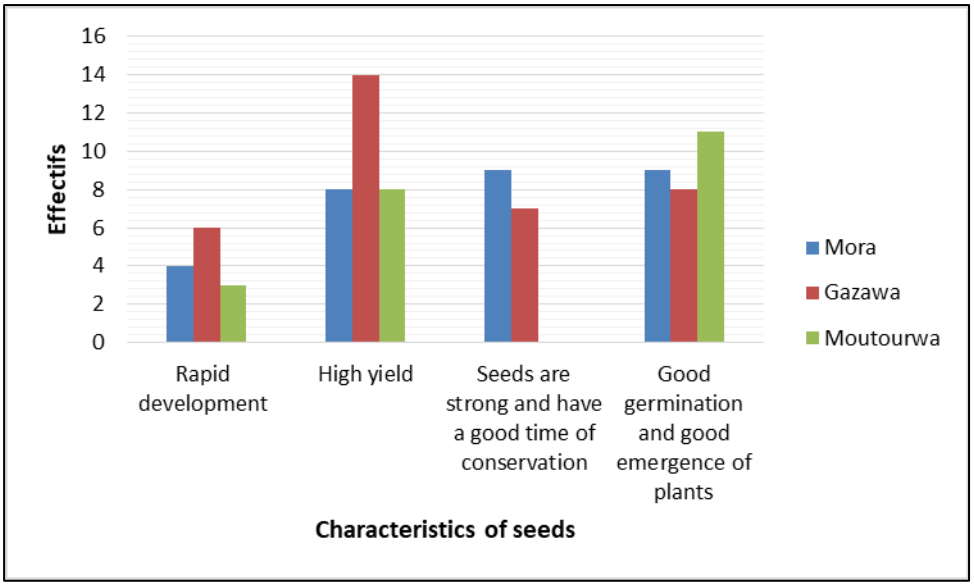

Figure 6: Characterization of seeds in good condition at the time of storage.

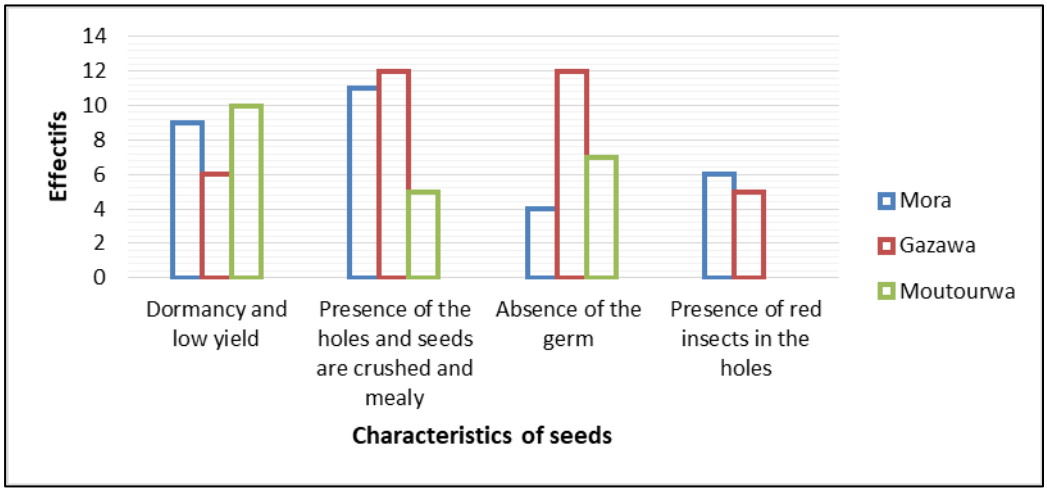

Figure 7: Characterization of seeds attacked during storage.

Cereal seed conservation strategies *in-situ* and *ex-situ* by farmers

The main strategies and methods of conservation used to maintain seeds in good condition include chemical and biological treatment, the use of clean stores treated with approved products, and the placement of bags on pallets. It is necessary to use secure polyethylene packaging, respect the spacing standards between crop plots, sun-dry the harvested products, select the good ears in the fields, and carry out plot purification.

The figure 8 illustrates the main strategies for *in situ* seed storage by study site. For seeds that are stored in crop plots, the conservation of these seeds is done by regular control of the fields (31.03 %), selection of good ears in the field (17.24 %), treatment of the fields against red insects (25.28 %), respect for the isolation distances of the plots (8.04 %), separate harvesting of varieties (3.44 %), purification of hors-types (10.34 %) in the fields and chemical treatment of crop plots (4.59 %).

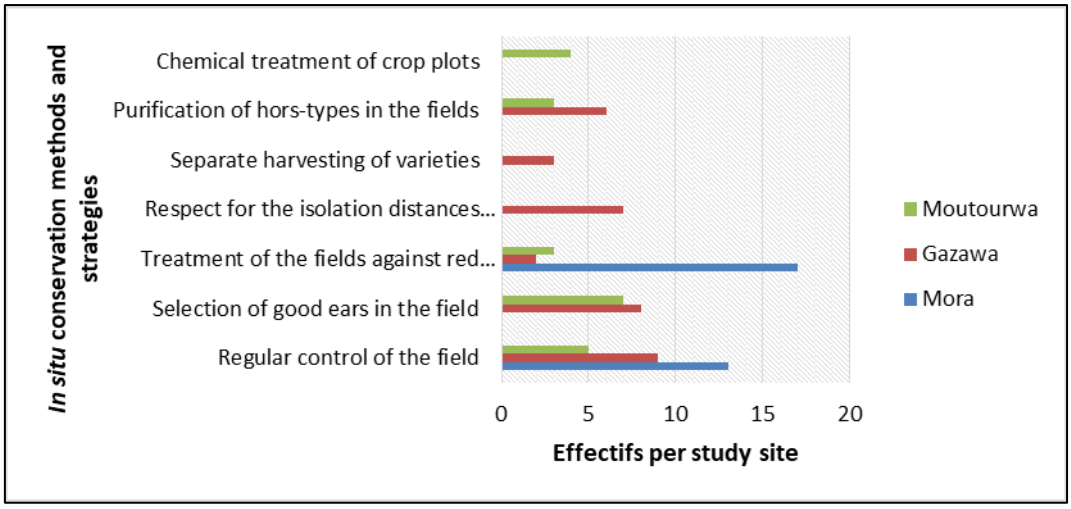

Figure 8: Characterization of *in situ* seed conservation strategies.

The graph in Figure 9 illustrates the main strategies for *ex situ* seed conservation in all three study sites. The conservation of seeds in conservation warehouses is done by placing seeds on plots in a clean and treated store (12.64 %), arranging the bags on the pallets (12.64 %), providing sunlight to the harvested products (18.39 %), packaging them in secure polyethylene bags (31.03 %), covering the seed bags with tarpaulins (18.39 %) and by biologically treating the seeds with oils extracted from the plants (6.89 %).

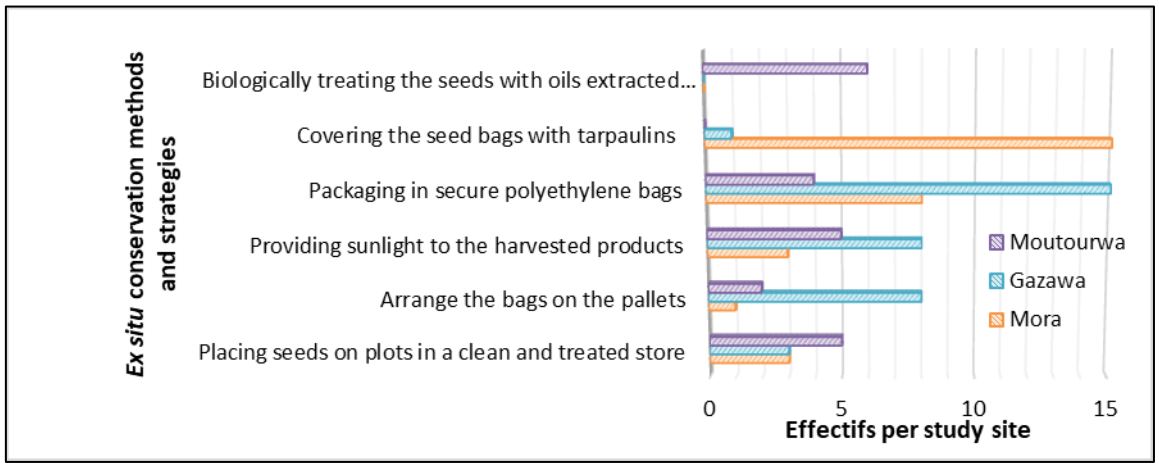

Figure 9: Characterization of *ex-situ* seed conservation strategies.

Germination of cereal seeds *in situ* and *ex situ*.

factors disrupting seed germination *in situ* and *ex situ*.

Figure 10 illustrates the different factors that disrupt the germinative capacity of seeds, which are the main causes of deterioration in their quality. In the three localities visited, the survey reveals that the climate is characterized by rainfall variability, low humidity in the air, low rainfall, and high temperature, sudden start of rainfall, heavy rainfall and good solar radiation. However, several particularities are observed, namely: the sudden rainy stop, the absence of rain, the decrease in harvest yields, climate change, and the disappearance of certain varieties and sometimes an increase in harvest yield. Regarding the evaluation of the productivity dynamics of preserved cereal seeds by studying germinative properties, the survey conducted reveals that the germination capacity of the different varieties of cereals grown in all three study sites is either increasing, decreasing, constant or at an annual variation. This germination rate of the seeds can be either effective, partial or dormant or sometimes not germination. For crop areas ranging from half a hectare to more than two hectares, bag yields vary from 10 bags to more than 40 bags. These low yields are due to several factors of germination disruption. These include: high rainfall (11.49 %), worm and insect attacks (31.03 %), low rainfall (12.04 %), poor chemical treatment of seeds (11.49 %), heat and poor conditioning (10.34 %), soil low fertility and the use of poorly dosed chemicals in the fields (9.19 %) and humidity (13.79 %).

Disruption of seed germination can be caused by red insect attacks, earthworms, mold, rodents, rising temperatures, aphids and mites. To protect their seeds during storage, farmers use several methods: chemical seed treatments and the use of insecticides and rat poisons. As other products to protect against these attacks, farmers use organic oils and firewood ash.

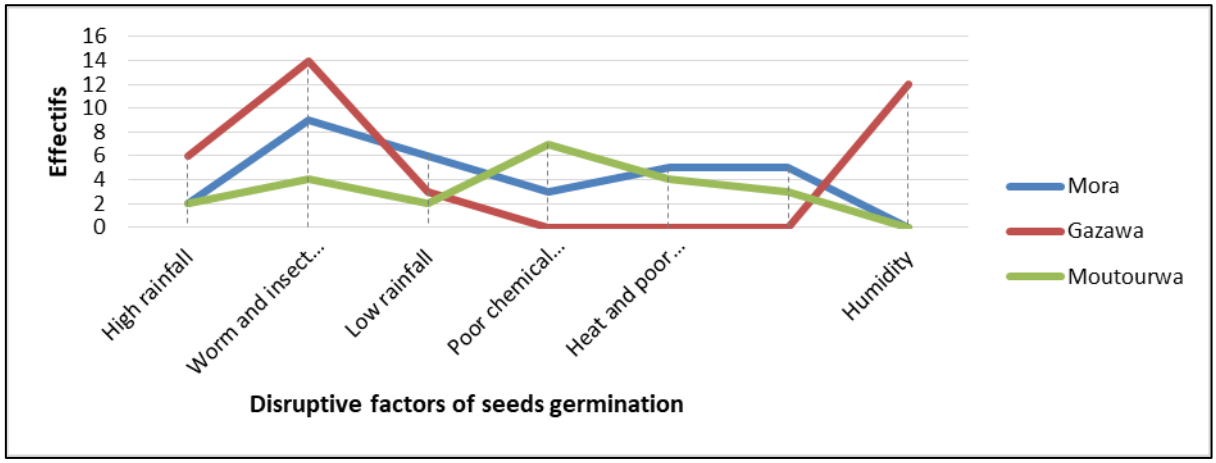

Figure 10: The different fators of disturbance of the germination of cereal seeds.

Strategies for the maintenance of the germination capacity of cereals seeds.

Figure 11 illustrates the method and strategy used by producers during the conservation for maintaining the germination capacity of cereals seeds by locality. In view of all these factors of disturbance of the germination faculty, its maintenance can be achieved through several conservation strategies: keep in an aerated and dry environment (44.82 %), regularly check the seeds stored (12.64 %), treat the seeds and store them without deseeding (29.88 %), mix with oils and keep them in stores and granary (9.19 %), use tightly sealed bottles for storage (1.23 %) and do not mix with the consumption bags (2.29 %).

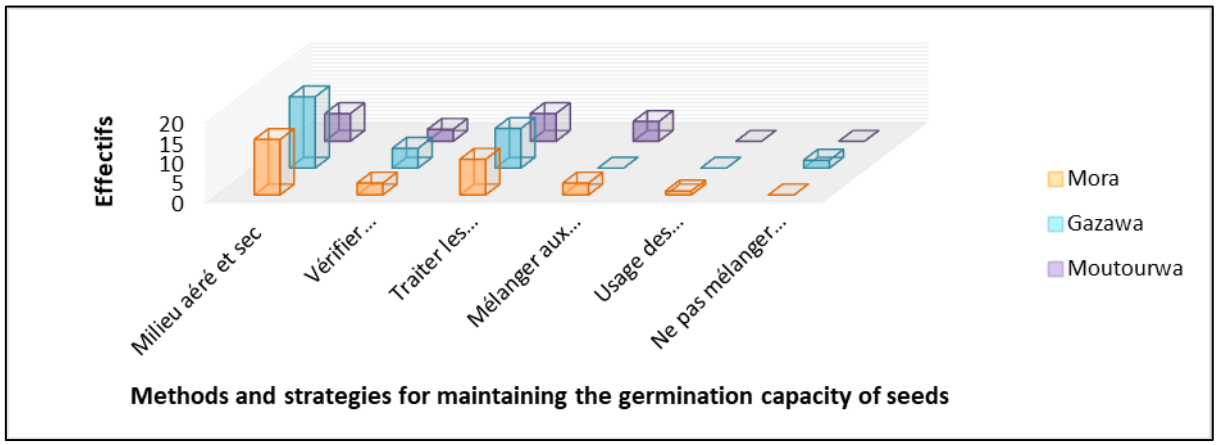

Figure 11: Methods and strategies for maintaining the germination capacity of cereal seeds.

Discussion

Our study results showed that two main types of cereals are cultivated in our covered study area. These are sorghum and maize. Sorghum is the main cereal and it has a great importance in the processing mode compared to maize whose processing range is narrower. Many studies such as the work of research institutions have shown that sorghum is the most cultivated cereal in the Sudano-Sahelian zone because of the advantages it presents such as its adaptability to photosynthesis compared to other crops. This is why some varieties complete their production cycles in less than three months which favors several harvests in a year. It perfectly withstands high heat and has an advantage in the face of global warming, which is increasing over time, because its irrigation requirements are 40% lower than those of maize. Its cultivation requires less fertilizer and work than maize, for the same harvest. Several varieties adapted to the Sudano-Sahelian zone are being developed by research

institutions. Specifically, in the Far North region these are varieties such as S 35, Zouaye, CS 54 and Damougari, which are made available to producers (Amougou and Seyfaou, 2021).

The results of these authors support our study because for all the crops combined, 12 cereal varieties were recorded, namely 10 varieties of sorghum (Sectaire, Dadoudou, S 35, Viri, Zouaye, Adjagamari, Dalassi, Muskuwari, red millet and white millet) and 2 varieties of maize (CMS 9015 and TZEE). Almost all the sorghum varieties recorded are dominant excepted Dadoudou variety which is the least cultivated. Furthermore, the two varieties Dalassi and Adjagamari are among the producers' preferred varieties which are only cultivated in Moutourwa. At Mora, the dominant varieties of sorghum are: red millet and white millet. Red millet cultivation is also practiced in Moutourwa but on a small scale. All these local varieties have been preserved by producers for several years, they are used for their seeds and fodder. They are adapted to the climatic variations of the area and allow the preparation of several local dishes and drinks to feed the populations. The results of the work carried out by (Tchuenga and Saha, 2017) on climatic constraints and pests of maize have shown that Cameroon does not meet the national demand for maize. In the agro-ecological zones where this cereal is cultivated, the most frequent climatic hazards are: heavy rains which generally affect maize at maturity, dry spells affect maize at germination, early and delayed rains influence the sowing and harvesting period. The results of the present study show a similarity of results. Although maize is cultivated in the Far North Region, this crop is practiced on a small scale. The most dominant variety in the three study sites visited is CMS 9015, a variety made available to producers by agricultural research institutions. Although it does not produce very good yields, it is the most suitable variety for the area unlike CMS 8704 which is less appreciated by producers due to its agro-morphological characteristics which do not meet the expectations of producers. It's a variety that has almost disappeared and is barely cultivated by producers. The results of this study corroborate with those of the study cited above, because they showed that pests cause damage in fields and also in stocks which can cause a significant drop in yields.

The survey conducted among producers reveals that they use several conservation methods and strategies to combat the attack of these pests in fields and in conservation storage equipment. These are *in situ* and *ex situ* conservation strategies and methods adopted in order to maintain varieties for sustainable use, to avoid pre and post-harvest losses that can lead to poor harvest yields, but also to avoid the loss of seed germination capacity caused by pests. *In situ* conservation consists of preserving varieties in their natural environment such as fields. Producers to maintain their varieties by *in situ* conservation use several methods such as: regular field monitoring, selection of good ears in the field, treatment of fields against red insects, respecting plot isolation distances, separate harvesting of varieties, purifying « hors-types » in the fields and chemical treatment of crop plots. This should make it possible to detect attacks in order to be able to act and prevent the proliferation of germs that can lead to the degradation of the germination quality of the seed. The selection of the best ears in the field, which constitutes one of the strategies, makes it possible to choose seeds that have reached their physiological maturity and can thus maintain all the properties and qualities of a good seed that can be used for sustainable agriculture. *Ex situ* conservation consists of storing grains in controlled conditions such as cold rooms, gene banks and storage warehouses, in other words outside of their natural habitat. The most appropriate *ex situ* conservation strategies adopted in storage warehouses for good conservation include the use of secure polyethylene packaging for its resistance to shocks and chemicals products, but also for its low moisture absorption and its non-bacterial retention. Other methods such as sunning harvested products, the use of clean and treated stores and the use of oils extracted from plants for the conservation of seeds help to combat enemies of stocks, thus maintaining their germination capacity because rodents, when they attack, consume the germ of the seed. They also play an important role because they help to combat the proliferation of mold by reducing the humidity of the seed through sunburn.

The germination capacity of the seed when it is not effective could lead to dormancy of the seed after sowing, that can cause an absence of emergence. Consequently, the plant will not be able to grow, which will lead to an absence of yield. Moreover, when it is effective, it can be disturbed by several factors: humidity, high rainfall, attacks by worms and insects, low rainfall, poor chemical treatment of seeds, heat and poor conditioning, infertility of the soil and the use of poorly dosed chemicals in the fields. Indeed, physical factors such as: the water content of the seed, ambient temperature and humidity of the seed can promote the development of mold, thus leading to the alteration of the quality of the seed, thus affecting the germination capacity. Humidification of the environment by evapotranspiration of the seeds will promote the growth of mold on the stored seeds. When in a warehouse, the humidity of the enclosure and the ambient temperature are modified, this could impact

the quality of the seed also favoring the development of certain pests such as insects that are tolerant to heat. These results support those of the study conducted by (Fatoumata et *al*., 2020) on the post-harvest management of cereal seeds produced in the Far North of Cameroon.

Conclusion

The study carried out in the Sudano-Sahelian zone in the localities of Mora, Gazawa and Moutourwa aimed to evaluate farmers' conservation methods and strategies for optimizing the germination capacity of seeds stored *in situ* and *ex situ*. The most cultivated cereal is sorghum with the producers' preferred local varieties being: S 35, Sectaire, Viri, Zouaye, Adjagamari, Dalassi and Muskuwari. The *in situ* conservation strategies most used by producers are: regular control of fields, selection of good ears in the field and treatment against pest attacks. *Ex situ* conservation consists of keeping harvested products outside their natural habitat either in cold rooms or in gene banks for agricultural research institutes. *In situ* and *ex situ* conservation through the strategies and methods adopted by producers are the two measure used to preserve the genetic diversity of maintained varieties, combat pre- and post-harvest losses and promote sustainable agriculture.

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