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Post-harvest storage systems and insect pests occurring on Bambara groundnuts (*Vigna subterranea* (L.)Verdc) in the Sudano-Guinean savannah of Cameroon

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Abstract
In Sub Saharan Africa, one of high potential nutritional crop is the Bambara groundnut. Popular and neglected legume, it is available in very low amount despite of being the richest seeds in lysine and methionine. To enhance the production of this crop and raise it as a strategic crop to fight hunger, the present work investigate in smallholders farms, the typology of systems of production of Bambara groundnuts in Adamawa Region of Cameroon. After 2 agricultural campaigns, storage facilities, morphotypes cultivated, storing method and protective tools to secure stored seeds were censed. Two bruchids (Coleoptera: Chrysomelidae): *Callosobruchus subinnotatus* (Bridwell) and *Callobruchus maculatus* (Fabricius), are major pests present on 10 of the 14 morphotypes of Bambara groundnuts sampled. To alleviate their damages, hazardous pesticides are currently used by producers, the possibility for developing some alternatives from local tools is discussed.

Keywords: Adamawa region, Bambara groundnuts, stored products, pests.

1. Introduction
Peanuts (*Arachis hypogea* L.), common beans (*Phaseolus vulgaris* L.), cowpeas (*Vigna unguiculata* L.), Bambara groundnuts (*Vigna subterranea* L.) and soy bean (*Glycine max* L.) [Fabaceae] are the main leguminous crops consumed and cultivated in the Sudano Guinean zones of Cameroon because of their importance in the populations feeding habits [1]. Bambara groundnuts also known as ground peas, is a minor leguminous crop in sub-Saharan Africa adapted to various climatic and ecological conditions. It is a highly caloric plant with 387 kcal/100 g, rich in vitamins, minerals and very balanced protein components [2, 3, 4]. Proteins in Bambara groundnuts seeds have a high content of lysine and their association with cereals in alimentation constitutes a nutritional complement for local population who facing cheap animal protein supplies [5]. Bambara groundnuts cultivation contributes to soil fertilization through the fixation of symbiotic nitrogen associated with rhizobium bacteria [6]. Despite of these numerous advantages, Bambara groundnuts is still part of neglected species and rarely used in plant breeding programs [7]. These leguminous crops are cultivated for a long time but have more cultural importance than utilization in alimentation by population in Sudano Guinean zone of Cameroon. Improvement in the production and conservation of these crops may achieve food self-sufficiency and overcome chronic proteomic deficiency occurring in the region. Unfortunately, during storage, these crops are attacked and destroyed by diverse pests [8] and mainly synthetic insecticides are used to reduce post-harvest losses [9]. Moreover, some morphotypes resist well to insects attacks, diseases and drought conditions [10]. This leguminous crop gathers a wide diversity of ecotypes and it is vulnerable to bruchid's attack during storage. To fight against these bruchids (Bruchidae), peasants and traders of Adamawa region uses less recommended methods like utilization of chemicals pesticides. These chemicals contaminate both food and environment. This work aims at check census of local diversity of Bambara groundnuts and all endogenous knowledge associate to their efficient postharvest protection. In this context, storage facilities, methods of seed protection against pests and susceptibility of some ecotypes are assessed, in the Adamawa Region, high lands of the Sudano Guinean zone of Cameroon.

2. Materials and methods

2.1 Sampling localities

The Sudano Guinean area in Cameroon coverts the highland of the Adamawa Region stretches for about 400 km between Nigeria and the Central African Republic. The climate is characterizes by two seasons split in seven-month of rainy season from April to October and five months of dry season from November to March. The annual rainfall is about 1400 mm [11]. The population is constituted by breeders commonly call (Bororo and Foulbés) and farmers constitute by the community (Mboum, Dii, Gbaya, Tikar and Mambila) [12]. In at least 4 localities in the 5 Divisions of the Region (Mayo-Banyo, Djérem, Mbéré, Vina, Faro et Déo) collection of different Bambara groundnuts ecotypes cultivated and sold was made. Moreover, at least 20 producers were interviewed per Division. The recapitulation of the Divisions visited and the localities sampled is made in table 1.

Table 1: Distribution of areas sampled by Divisions in Adamawa Region during 2014

Divisions	Localities sampled	GPS coordinates
Mayo-banyo	Banyo, Mayo-darlé, Nyamboya, Bankim, Mbamti-katarko	6.7500°N, 11.8333°E
Djérem	Ngaoundal, Tibati, Meng, Tela, Danfili, Gala-gala	6.4833°N, 12.6500°E
Mbéré	Meiganga, Dir, Badjere, Garga-limbona, Mbagodo	6.5167°N, 14.3000°E
Vina	Ngaoundéré II, Dang, Mbé, Ngaoundéré I	7.3167° N, 13.5667° E
Faro et Déo	Tignère, Sadec, Mayo-tignère, Galim-tignère	7.3667°N, 12.6500°E

2.2. Collection of information about the storage seeds of Bambara groundnuts

Producers of the sampling areas were interviewed to access the amount of Bambara groundnuts harvested, in which form these seeds are stored, the type of storage module, the storage time, most noxious pests and the most efficient protective method to avoid losses. Interviews consisted in direct discussion with farmers and traders in the villages [13]. These investigations were carried out firstly in households with Bambara groundnuts producers and secondly with dealers during the market days in some localities. During the same time, at least 5kg per morphotype of seeds were collected from the dealers and taken back to the laboratory.

2.3. Sampling and characterization of Bambara groundnuts' seeds

During prospection in the study area, all Bambara groundnuts seeds found in peasant granaries or on local markets were collected and taken to the laboratory under controlled conditions of temperature and humidity with Thermo-hydrometer (T:27°C; RH: 53%). Their description was carried out on the basis of the variability of the seed coat, color, shape of seed and hilum outline as published by International Plant Genetic Resources Institute [14] and [15]. A binocular lens Nikon SMZ 800 supplied with a cold light production device for microphotography Nikon Coolpix 5400 camera was used to observe the specificity of each seeds and to snap each morphotype.

2.4. Diversity of insect pests associated with stocks of Bambara groundnut seeds

Bambara groundnut seeds collected from the producers were grouped by morphotype and put in 1200ml glass jars for 100 days observation. Each jar was filled with 300g of seeds sealed with perfored cover. Four replications were done for each morphotype. A codification of samples was made taking into account the country (CM: Cameroon), region (AD: Adamawa or EN: Far North), the initials of the collector (MC: Madou Chantal), the sequential number of the sample (01) e.g. CM/AD/MC/01 and the morphotypes with EN indication are those identified from Far North samples. The survey was made by sieving the jar content every 20 days to remove emerging insects.

Emerging insect extracted from seeds were identified and counted. Identification of these insects was done with the guide of the key identification of insects of stored products in hot tropical regions [16]. Finally the weight loss due to insect attack at the end of the storage was estimated.

3. Results and discussion

3.1. Diversities of Bambara groundnut morphotypes sampled

Bambara groundnut is a native African leguminous crop. In the Sudano-Sahelian agroecologica area in Cameroon, 90% (72/80) of its culture are owned by women. A similar situation has been reported in Tanzania [17] and Ghana [18]. Gbaya, Nyamba, Tupuri and Duru communities refer to this leguminous plant during some traditional rituals and cultural ceremonies. The most productive localities of Bambara groundnuts in the Adamawa Region are: Tibati, Meiganga, Ngaoundal and Ngaoundéré.

In the overall sampling zone, 14 Bambara groundnuts morphotypes were collected (Plate 1) among which five were identified in the collection of Ndiang *et al.* [15] obtained in the Regions North and Central Cameroon and two in the savannah zone of the Ivory Coast [13]. A sampling carry out in Benin by Gbaguidi [19], pointed out 52 Bambara groundnuts morphotypes. Recent work pointed out a significant variability among varieties of Bambara groundnuts both at the morphological and molecular level [20-22]. The 2 most common morphotypes are CM/AD/MC/09 (brown) and CM/AD/MC/10 (dark brown). They are most preferred by farmers because of their yield of 2 to 3 seeds per pod. Other observations pointed out the fact that many countries in Africa where the Bambara groundnuts are cultivated, the cream-colored seeds are the most consumed [23, 13].

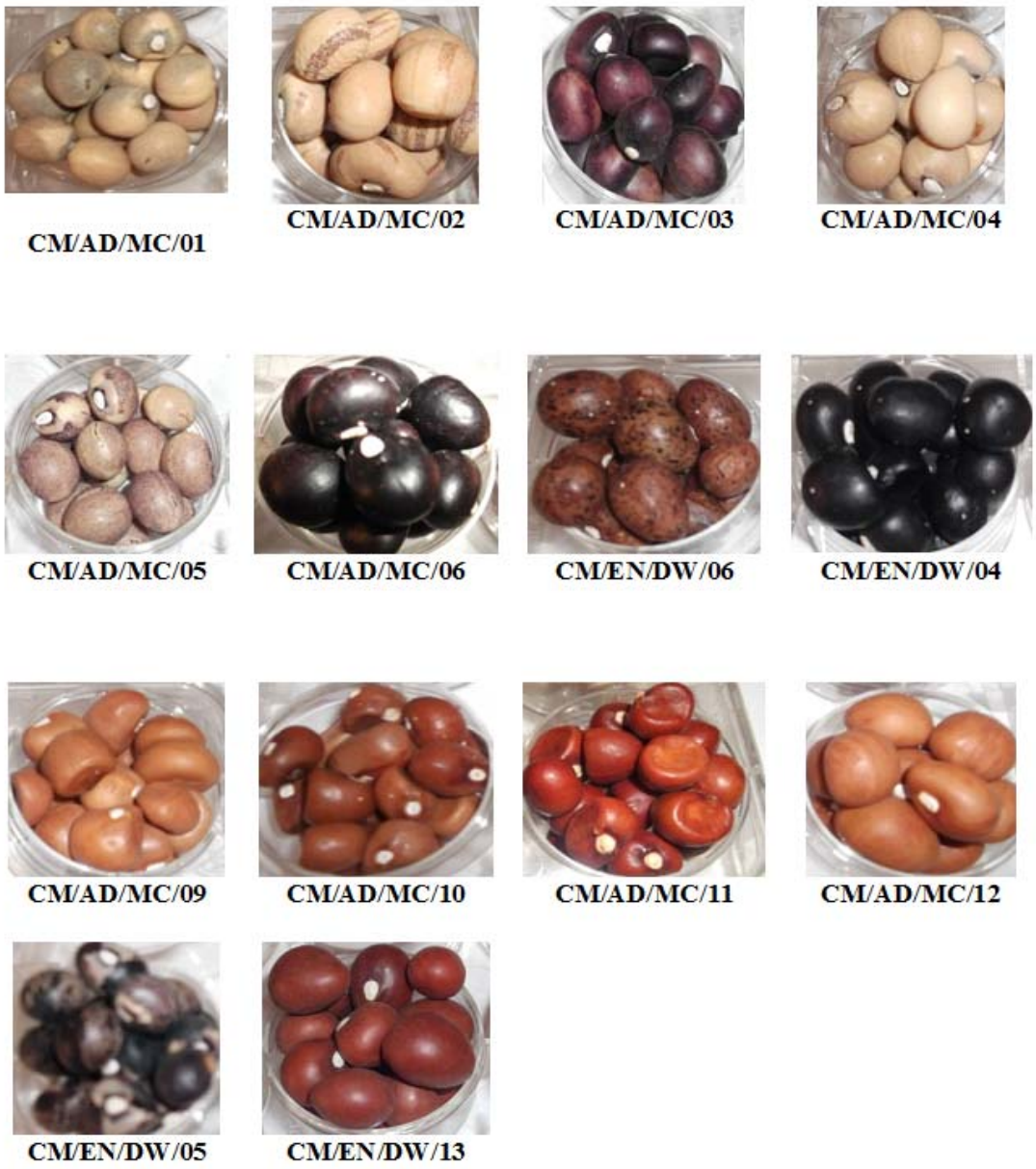


Plate 1: Bambara groundnuts harvested sampled in the Sudano Guinean savannah in the Adamawa Plateau in Cameroon during 2014.

3.2. Storage of Bambara groundnuts in Adamawa Region

In general, an important part of harvested Bambara groundnuts is sold and the rest kept for familial needs [24]. Moreover, another part of the harvested seeds is stored as propagule for next cultivation campaign. Seeds are stored with or without pod. All producers in the Faro et Déo Division stored Bambara groundnut with pod, 88.23% did that in the Mbéré Division (Table 2). Thus during in the field in 2015, over 80% of harvested Bambara groundnut is sold and ate as fresh pods. In Benin, Bambara groundnut is stored only with pod [25].

Table 2: Relative importance (%) of storing forms of Bambara groundnuts by producers in the 5 Divisions of the Adamawa Region of Cameroon during 2014.

Form	Vina	Mayo-Banyo	Djérem	Faro et Déo	Mbére
With Pod (%)	60	37.5	76.92	100	88.23
Without Pod (%)	40	62.5	23.07	0	11.76

Stored both as naked seeds and with pod, Bambara groundnuts is stored in 2 main storage facilities: bags or in jars (Table 3). Bags are kept in loft, bedroom or in kitchen roof. In rural areas jars are used only in 2 Divisions of the Adamawa region.

Table 3: Diversities of containers used for storage (%) of Bambara groundnut in the 5 Divisions of the Adamawa Region of Cameroon in 2014.

Containers (%)	Vina	Mayo-Banyo	Djérem	Faro et Déo	Mbére
Jars	0	18.75	0	75	0
Bags	100	81.25	100	25.00	100

The regular storage of their products within rooms indicates the desire of producers to secure their seeds and avoid any form of losses [25].

3.3. Entomofauna of Bambara groundnuts in stock in the Adamawa Region

Four insect species emerged from the seeds collected: *Callosobruchus maculatus*, *Callosobruchus subinnotatus*, *Tribolium castaneum* (Coleoptera: Tenebrionidae)

Anisopteromalus calandrae (Hymenoptera: Pteromalidae). It appears that, *C. maculatus* and *C. subinnotatus* are the two main pests of Bambara groundnutsand widespread in all five division of the Adamawa Region. Ajayi and Lale [26] mentioned that bruchids are major pests of Bambara groundnuts. Table 4 shows that the *C. subinnotatus*is the most abundant bruchid in the Sudano Guinean may because of favorable environment for its development but not for *C. maculatus*. In Cameroon, *C. maculatus* is known to be an important stored seeds pest in sudano sahelian dried areas [27]. A total of 20358 insect pests on 12000g Bambara groundnuts, demonstrates the vulnerability of this leguminous during storage and requires special attention to prevent the total loss of stock. These insects infest the field seeds and continue to multiply during storage [28].

Table 4: Numerical importance of insects identified in Bambara groundnuts brought from different localities of Adamawa during 2014.

Oder	Family	Genus	Species	Number	Percentage
Coleoptera	Bruchidea	*Callosobruchus*	*subinnotatus*	18768	92.20
			maculatus	1542	7.57
	Tenebrionidae	*Tribolium*	*castananeum*	15	0.00
Hymenoptera	Pteromalidae	*Anisopteromalus*	*calandrae*	33	0.02

3.4. Assessment of damage caused by *Callosobruchus maculatus* and *Callosobruchus subinnotatus* in 10 ecotypes after 100 days of observation

During investigations, 14 morphotypes of Bambara groundnuts were identified, and 10 were observed in laboratory conditions for their susceptibility of bruchid attacks. Damaging activities of bruchids on these seeds were characterized by the number of hole per seed and the number of holes per seed on 25 seeds were taken randomly from a sample of 300g. Morphotypes CM/AD/MC/09 (9.90±6.36%) and CM/AD/MC/04 (9.17±5.89%) exhibited the most important mass compared to morphotypes CM/AD/MC/12 (0.42±0.83%) and CM/EN/DW/05 (0.00%), which have reduce losses (Table 5). The largest number of perfored seeds was observed on the ecotype CM/AD/MC/09 (14.00±7.80), while morphotype CM/EN/DW/05 presented no breakthrough seed, it may be the most resistant morphotype because it does not facilitate the larval development. The number of holes per seed morphotypes CM /AD/MC/04, CM/EN/DW/06, CM/AD/MC/06 and CM/AD/MC/09 is between 1 to 2 holes and the remainder morphotypes below.

Table 5: Characterization of bruchids damages through % loss, seeds with hole, holes per seeds from 25 seeds and the number of each bruchids emerging from 300g of seeds of each of morphotype collected and observed for 100 days.

Morphotype	% loss	Seeds with holes	Hole /seed	Bruchids emerging from 300g	
				C. subinnotatus	*C. maculatus*
CM/AD/MC/04	9.17±5.89	13.50±3.54	1.46±0.550	387	8
CM/AD/MC/06	5.94±6.22	12.00±7.80	1.13±0.60	217	0
CM/AD/MC/09	9.90±6.22	14.95±7.64	1.35±0.35	517	33
CM/AD/MC/10	5.80±6.69	7.20±6.30	0.66±0.91	146	0
CM/AD/MC/11	7.33±10.37	7.50±10.61	0.62±1.26	28	176
CM/AD/MC/12	0.42±0.83	8.25±10.21	0.98±1.12	68	58
CM/EN/DW/04	7.03±8.02	11.08±9.81	0.43±0.87	414	0
CM/EN/DW/05	0.00	0.00	0.00	0	0
CM/EN/DW/06	5.00±3.06	10.33±3.06	1.14±1.02	225	0
CM/EN/DW/13	3.33±4.71	4.00±5.66	0.66±0.15	134	13

Considering loss of mass, closed inventories tests [29] show in the case of pre-infestation of peanuts by *Caryedon serrates* (Coleoptera: Bruchidae), even though small, can be enough to completely destroy stocks in four months of storage, observation also made in the case of Bambara groundnuts in the presence of *C. Subinnotatus*.

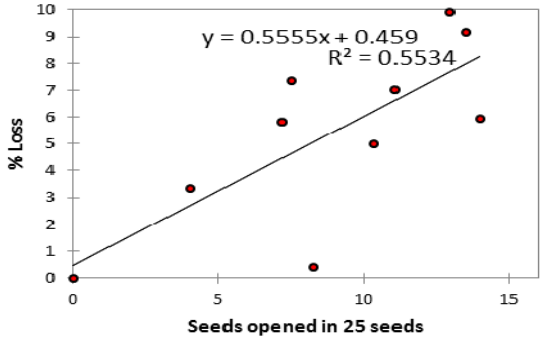
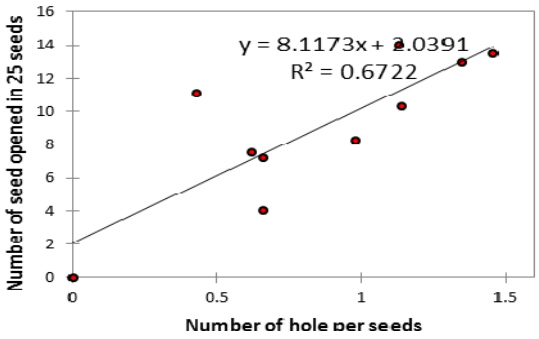


Fig 1: Linear Regression of drilled seeds on weight loss



*Significant *** highly significant

Fig 2: Linear Regression of number of hole per drilled seeds

To evaluate the relationship between these 3 factors a Pearson correlation test was done. Weight loss increases significantly with the number of drilled seeds (P=0.014; r=0.744*; df=8). There is a positive and significant correlation between the average number of seeds per hole and the number of performed seeds (P=0.004; r=0.820***; df=8) (Figure 1 and 2). This can be explained by the fact that this bruchids had filled a large number of eggs on the seeds. These resources containing the substances were allowed appetizing good larval development of pests which this aggressive character pronounced.

3.5. Susceptibility of 10 ecotypes of Bambara groundnuts to bruchids for 100 days

Figure 3 presents the susceptibility of 10 ecotypes of Bambara groundnuts in the presence of pests 100 days later. Generally, we note two ecotypes curves which are highlight through the important attack. Gradually, emergence decrease till a null threshold where no bruchid is registered.

The shape of the curves ecotypes CM/AD/MC/09 and CM/EN/DW/04 is increasing (Figure 3). It shows the gradual development of insects, which can be explained by the availability of resources and the quality of the potentially significant nutrient appreciable by bruchids. Moreover the presence of an unpleasant substance could be contained in the seeds of ecotype CM/AD/MC/09 and CM/EN/DW/04 which is toxic to *C. maculatus* but not for *C. subinnotatus*, explained by the reduced emergence. In contrast, the ecotype CM/EN/DW/05 did not develop any bruchids after 100 days, this is justified by its monotonous curve which can be explained by the fact that this ecotype is resistant to bruchids or the seeds to storage were treated with synthetic insecticides with high persistence. Storage is successful if at the end the stored products have no depreciation form, neither its quality nor its quantity [27]. A part from the preferred quality of nutrients by bruchids, level of initial infestation is not the same for all ecotypes in all localities. After 100 days of storage the attacked seeds became unfit for consumption and lose their germination capacity. Between harvest and consumption, over 30% of production is loss, highest proportion in the Sahel region due to the long storage period [27].

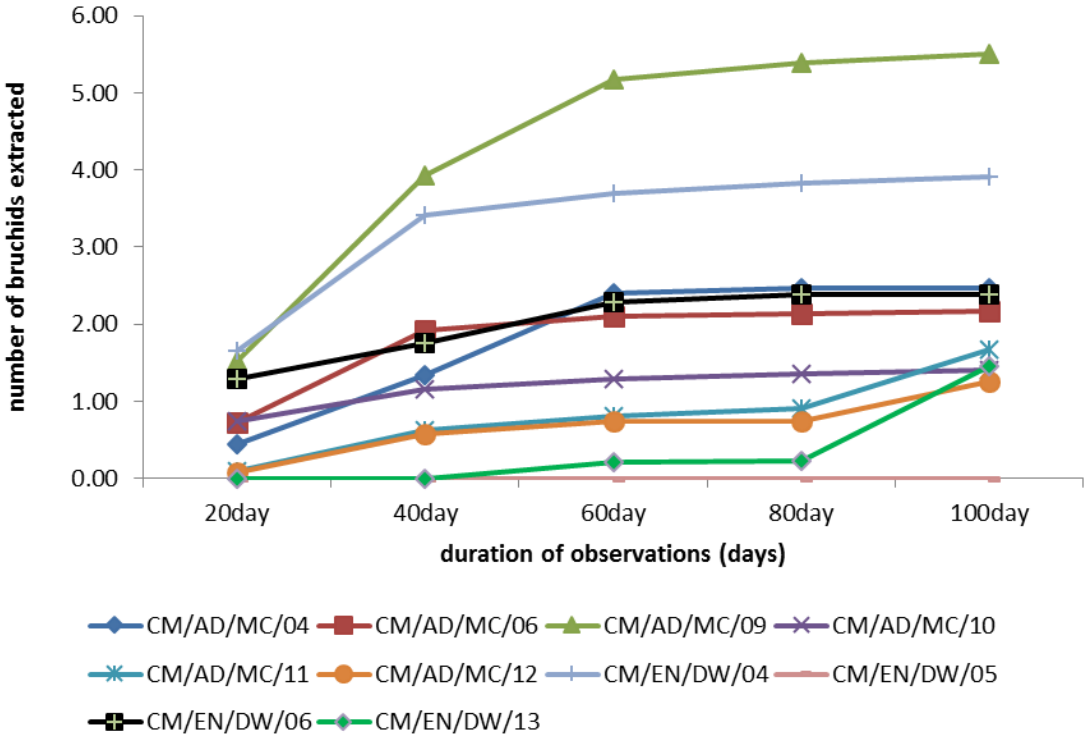


Fig 3: Fluctuation of cumulative number of bruchid emerging from 10 morphotypes of Bambara groundnuts observed for 100 days in glass flask under laboratory condition.

3.6. Local protective tools to prevent losses in Bambara groundnuts stocks

Local producers frequently use ash, honey and chemical pesticides to treat their stored seeds. These chemicals insecticides include in their active ingredients: deltamethrin, pirimiphos-methyl, chlorpyrifos-ethyl and malathion. The dependence of peasant to these chemical is high: 100% in Mayo-Banyo; Faro et Déo and 71.43% in Vina.

The use of ash applied on seeds was also mentioned in the conservation of Bambara groundnut seeds in the savannah zone in Côte d'Ivoire [13].

Table 6: Protective methods frequently used by producers in the Adamawa Region to prevent stored Bambara groundnuts from pest attacks

Methods (%)	Vina	Mayo-Banyo	Djérem	Faro et Déo	Mbére
Chemical product	71.43	100	22.22	100	42.86
Ash	28.57	0	44.44	0	0
Honey	0	0	33.33	0	57.14

Producers applying these chemical pesticides are not aware of hazards associated to their use but their effectiveness in pest

stocks control is obvious [30]. According to surveys, conservation average duration is five months. Search for alternative products less or not dangerous for the consumer and the environment is a priority [31]. However, 18.18% of peasants use exclusively ash for the conservation of seeds. This preservative method is most popular in Burkina Faso [32]. The use of repellent aromatic plant in granaries and other storage facilities is not widely practice in the Adamawa Region, as it is the case in the North and Far North Regions of the country [3].

4. Conclusion

In the Sudano Guinean region of Cameroon, 14 morphotypes of Bambara groundnuts are grown. Ecotypes CM/AD/MC/09 and CM/AD/MC/10 are the most common and also the most susceptible to both *C. maculatus* and *C. subinnotatus*, which are their major pests in the study area. To reduce the noxious activities of these pests, hazardous pesticides are mostly used (65% of producers). To achieve the production of safe and clean seeds, there is the need to develop and popularize alternative tools that are user and ecological friendly.

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