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Evaluation of groundnut (*Arachis hypogaea* L.) storage methods and *Caryedon serratus* (Oliver) pest management in the Senegalese Groundnut Basin (Fatick, Kaolack and Kaffrine)

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Abstract
Senegalese farmers have often recourse to local plants in the post-harvest management. The groundnut storage methods have been assessed by surveying 180 farmers in the Groundnut Basin (Fatick, Kaolack and Kaffrine). Three plants (*Khaya senegalensis*, *Azadirachta indica*, *Eucalyptus camaldulensis*) were identified as insecticidal plants. The levels of damaged pods and seeds by *C. serratus* were respectively: 56% and 33.34% in Fatick; 65% and 26% in Kaolack; 64% and 56% in Kaffrine. The storage rooms and plastic barrels were used as follows: 81% and 37,88% in Fatick ; 97% and 6,67% in Kaolack ; 93% and 3% in Kaffrine. The proportion of pesticides and insecticidal plant utilisation was 96,67% and 30% in Kaffrine ; 80% and 37% in Kaolack ; 73,33% and 40% in Fatick. The storage rooms were mostly built with cement in all regions (90% in Kaolack and 80% in Kaffrine) but Fatick where the banco was used at 33.33%. The highest levels of infestation were recorded in March – April (60% in Kaolack, 43.33% in Kaffrine) and in April – May (47% in Fatick).

Keywords: storage, groundnut, producers, *Caryedon serratus*, Senegal

1. Introduction
Food security is among the major fields where the scientific community is expected to achieve impactful progress in Sub Saharan Africa where more than 25% of the population remains undernourished [1]. The increase of food production is an urgent endeavor to face the demographic growth. However major constraints are faced by African farmers who suffer severe postharvest losses for cereals estimated at more than 4 billion US$ annually [2]. It appears to be of the upmost importance to handle the factors influencing both the pest incidence and the insect proliferation on plants as well as on harvest [3-7]. Groundnut (*Arachis hypogea* L.) is a leguminous plant from South America probably East Bolivia. Introduced in West Africa, particularly in Senegal, at the end of the 16th century, groundnut has progressively become the main cash crop. This important oilseed crop is a major export crop with relatively low yield about 320 kg/ha in 2002 [8]. Groundnut occupies an important place in the country economic system and generates about 160 million US$ every year. Possessing high oil content (50%), interesting protein content (25%) and vitamins (E, B and K), this oleaginous plant offers important nutrient intake for local populations. Groundnut attracts more than 100 species of insects [9, 10] of which the weevil is the most damaging. The important losses caused by the weevil can rise up to 80% during the harvest and the storage for a 4-month storage time in Senegal [11]. The holes dug by the larva enable attacks of other insects and facilitate the development of a fungi (*Aspergillus flavus* Link) producing a carcinogenic toxin called aflatoxin [12]. With regard to the severity of post-harvest losses due to insects, [13] considers that African farmers are working for the insects.
To face the threat posed by insects which are the main stock pests, the strategy relies on chemical pesticides. The effectiveness of these products to control the stocks is proven in optimal conditions. However several drawbacks are noted like the insect acustoming and the selection of resistant strains [14], poisoning, pollution and ecological disorders [15]. The advent of synthetic insecticides has put the practices of local communities on hold. During many years, an excessive, unreasonable and continuous application of synthetic pesticides (insecticides, fungicides, nematicides, rodenticides) was observed in spite of the warning on pesticide adverse effects that led governments to consider environmental issues related to

pesticide overuse [16]. The pesticide usage is now declining worldwide due to their high persistence. Scientists stress the need of a concerted effort of researchers and politicians to increase the competitiveness of alternative pest control methods and give them more consideration [17]. Research programs on natural insecticides were initiated in many countries like Senegal, Togo, Benin, Burkina Faso, Niger after international colloquiums of the African Network of Research on weevils (REARB) [18]. Various insecticidal plants tested on the beetle (Bruchidae family) attacking groundnut, maize and bean showed insecticidal and ovicidal effects [19, 20]. As one of the most studied plants, the neem *Azadirachta indica* A. Juss is currently the main source of natural insecticide controlling more than 400 species of insects [21-24]. The neem regulates the growth and modifies the behavior of certain pests [25-33] also reported the repulsive effect of isolated essential oil of *Eucalyptus camaldulensis* Dehnh on mosquitoes in Japan. According to the author, the *Acorus camalamus* Var. oil was also used to control *Prostephanus truncatus* Hom on maize. The objectives of this study revolve around the review of the storage methods in the Groundnut Basin and the identification of alternative biocidal plants against *Caryedon serratus* at the infestation early stage.

2. Methodology

2.1 Study area (Fig.1): Located between 11°30 - 17°30 N and 11° - 17°30 W, Senegal's total area [34] is 196,722 km². The country is bordered by Mauritania in the North, Mali to the East, Guinea to the Southeast, Guinea-Bissau to the Southwest and an enclave country of 300 km long by 20 km wide (The Gambia). Groundnut is a cash crop occupying 70% of the Groundnut Basin population and generating 35% of agricultural incomes in rural areas [35]. It has been the first cash crop in West Africa that allowed the transition from manual to animal traction agriculture [36]. The groundnut sector is confronted with diverse challenges like the decrease of both production and acreage, soil degradation, disorganisation, producer price fixing, low competitiveness, multiplicity of intermediaries, access to funding, and issues related to storage and conservation techniques in the Groundnut Basin.

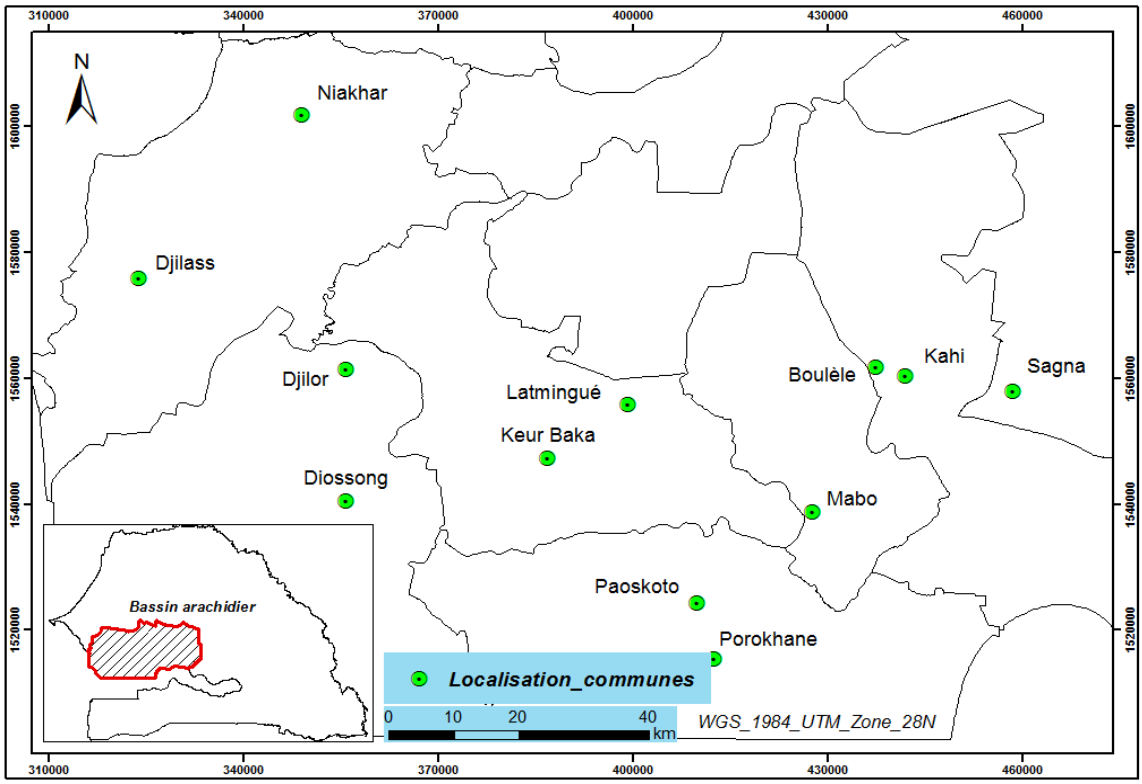

Fig 1: Map of surveyed communities in the Groundnut Basin (Bassin arachidier)

The grain storage addresses the triple concern of setting aside food supply, trading commodities and keeping seeds for the next cropping season [37]. Storage is, therefore, conducted by the farmer, the trader, the industrialist and/or the exporter. The deterioration of the stored products at these different levels will depend on storage methods falling into traditional and modern ones.

The processes and systems currently in use result from long-standing experience and tradition. Well-suited to the local conditions and providing satisfying results globally, their conception and capacity are a function of food type and harvest volume. Farmers store their harvest, either hung on a hook or on the eave, either spread on platforms, in the courtyard. To better assess the storage methods and *C. serratus* pest management, surveys were conducted according to the following method.

2.2 Identification of municipalities: A comprehensive review of the study area was carried out to appraise the natural, cultural and socio-economic conditions of the population. Exploratory visits with the staff of agriculture technical services (DRDR, SDDR), the Chamber of Crafts and the PAPIL program (Local Small-scale Irrigation Support Program) have been conducted in the municipalities of interest afterwards. As the Senegalese lowest administrative territory, the municipalities play a key role in implementing public policies especially in agricultural schemes. Municipalities were selected according to the proportion of local groundnut farmers recognised by the DRDR and SDDR officers.

2.2 Exploratory surveys: In order to collect informative data, a high precision was needed in selecting villages with an

important proportion of farmers knowledgeable with the groundnut storage issue. A pre-survey exploratory trip of three days has been arranged in the field. This trip allowed us to cooperate with the technical bodies SSDR and DRDR in the Groundnut Basin regions in order to identify the villages with the required proportion of groundnut farmers.
The visit agenda and the survey rationale have been explained to the farmers and technicians before the draw-up of a questionnaire for the regions three regions of the Groundnut Basin (Fatick, Kaolack and Kaffrine).

2.3 Village and farmer selection: The exploratory surveys has showed that farmers of the different regions expressed more interest in groundnut cultivation if they could both sell and stock. Bearing in mind the particularity of farmers' objectives and the research rationale, we developed a questionnaire on storage methods and constraints.
From the list of the villages belonging to the selected municipalities, all the accessible villages having a large number of producers were numbered. The villages to be systematically surveyed were eventually identified by a random draw based on [38]. Once the number and the names of the villages were specified, systematic surveys were conducted in each village by randomly selecting 5 producers from the total village households. The surveys covered the characteristics of both conservation techniques and biocidal plants used to control effectively the groundnut grain and seed pest *Caryedon serratus*. The questionnaire developed from the software program Sphinx investigates the beetle attack, the storage methods (warehouse, barrel), the type of pest control.
The surveys were conducted in three administrative regions of the Groundnut Basin (Fatick, Kaolack and Kaffrine) where 12 villages have been selected in each region making a total of 36 villages. As 5 producers were surveyed per village, the total number of farmers was 180 in the agro-ecological zone.

2.4 Data analysis: The raw data collected from farmers was entered and reclassified in an Excel spreadsheet. The graphical representation of data by histograms showed the trends of storage methods by farmers in the Groundnut Basin agro-ecological zone.

3. Results

The responses of Groundnut Basin farmers on weevil infestation, barrels or storage rooms, chemical or natural pesticides, banco clay or cement and the period coinciding with higher attack levels were as follows:

3.1 Evaluation of *C. serratus* attacks on groundnut pods and seeds: Attacks of *C. serratus* were more important on pods than on shelled seeds. The respective rates of damaged pods and seeds were 56% and 33.34% in Fatick, 65% and 26% in Kaolack, 64% and 56% in Kaffrine. The incidence of weevil is highest on pods in the region of Kaolack and Kaffrine (Fig.2). The attacks on seeds are more important in Kaffrine compared to the other regions. The region of Kaolack displays the singular trend of the highest damage rate for pods and the lowest for grains. This may highlight a failure of field management techniques and a more optimized grain storage process in this region.

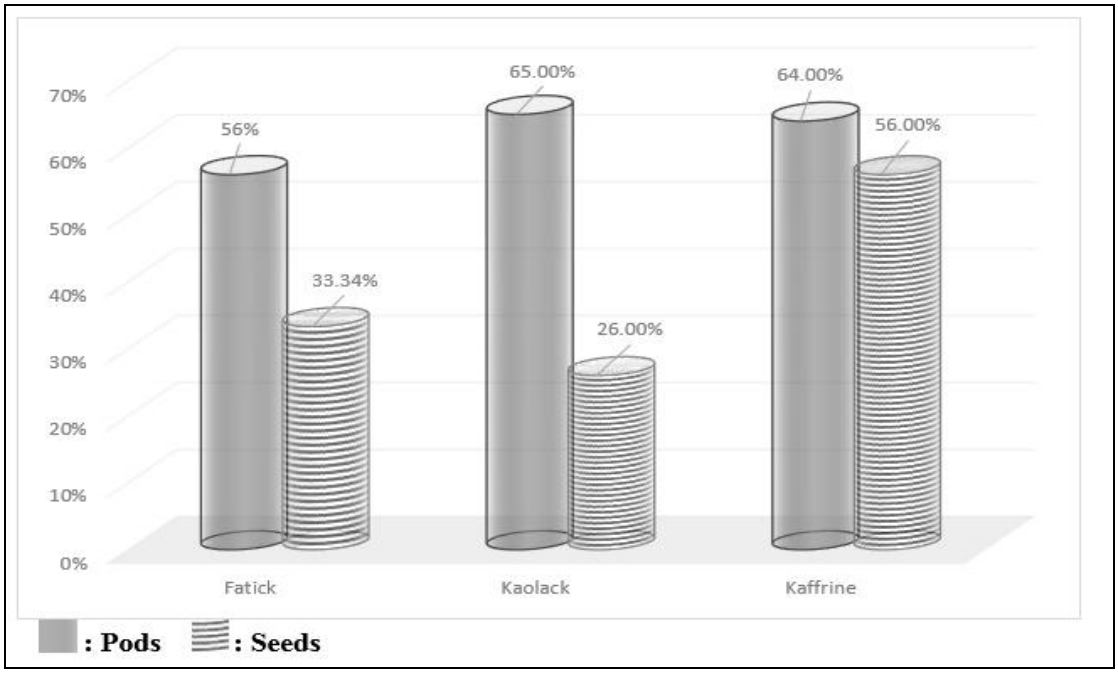

Fig 2: Proportion of respondents reporting attacks of *Caryedon serratus* on pods and grains in Fatick, Kaolack, Kaffrine

3.2 Evaluation of plastic barrel and groundnut warehouse utilisation: Storage in groundnut warehouse is more and more preferred to plastic barrels. The groundnut warehouse are used by farmers at 81%, 97% and 93% rates in Fatick, Kaolack and Kaffring. The corresponding rates for plastic barrels were 37.88%, 6.67% and 3%. Excepted in Fatick, the storage in the warehouse prevails. The plastic barrels are hardly used in Kaffrine and largely appreciated by Fatick farmers (Fig.3). Indeed, the Fatick farmers have relatively limited access to warehouse storage compared to their counterparts.

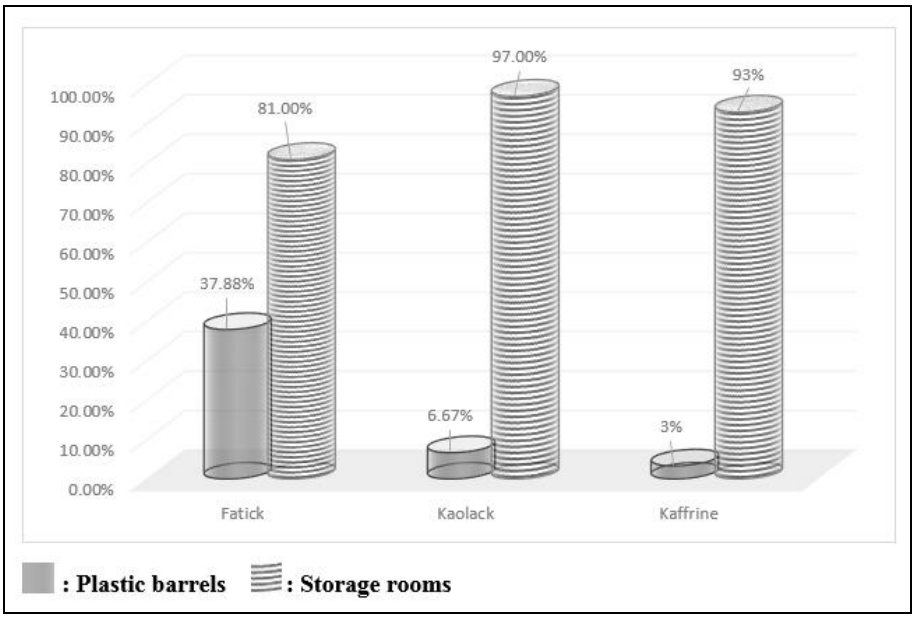

Fig 3: Proportion of respondents using plastic barrels or groundnut storage rooms in Fatick-Kaolack- Kaffrine

3.3 Evaluation of *C. serratus* pest management by chemical pesticides and insecticidal plants: The chemical pesticides predominates insecticidal plants in all regions. The following utilisation rates were recorded for chemical pesticides and insecticidal plants respectively: 96.67% and 30% in Kaffrine; 80% and 37% in Kaolack; 73.33% and 40% in Fatick. The regions of Fatick and Kaffrine have opposite pest management profiles i.e. Fatick farmers use less synthetic pesticides and are more attracted by biocidal plants compared to Kaffrine farmers (Fig.4). The Kaolack farmers are at an intermediate level between Fatick and Kaffrine for the two methods.

Even if plant insecticidal properties are well known in groundnut weevil pest management, farmers prioritize chemical pesticides they keep using in spite of health and environmental hazard. A large number of farmers is, however, using solely or in association the insecticidal plants in their storage facilities in Fatick. The presence of a wide variety of vegetal species in the Sine islands could explain this trend.

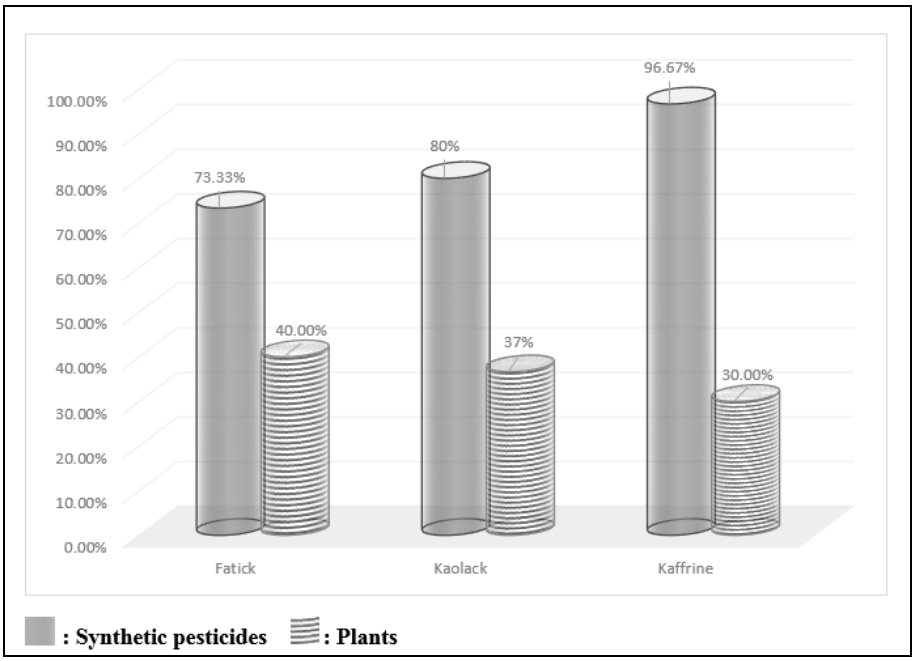

Fig 4: Proportion of respondents using chemical pesticides or plants against *C. serratus* in Fatick-Kaolack-Kaffrine

3.4 Evaluation of cement and banco clay utilisation as building materials: Cement and banco clay are key building materials we appraised in terms of affordability to farmers and grain stock security during adverse events like flooding. Cement predominates in all regions but Fatick where the utilisation was just 33.33% against 70% for the banco. The corresponding rates (cement and banco) in the other regions were as follows: 90% against 6.66% in Kaolack; 80% against 20% in Kaffrine. The utilisation of cement is very important in Kaolack unlike the banco clay (Fig.4) which is more used in Fatick. This fact may relate to the economy as the groundnut sector is more established in Kaolack where oil industry and big market sustain the investment in costly cement warehouse. The proximity of Kaffrine and Kaolack explains the relative similarity of the cement utilisation.

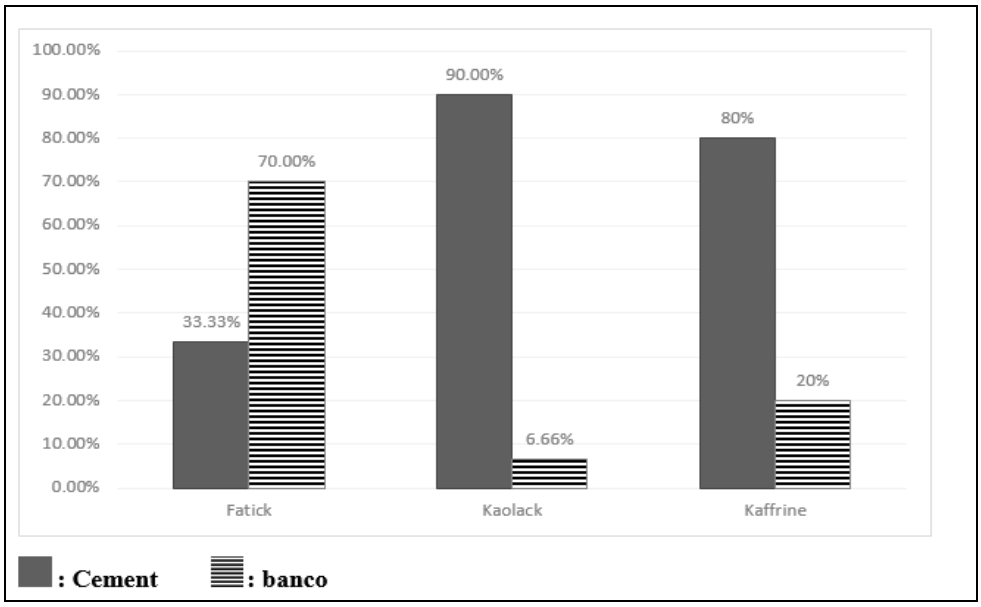

Fig 5: Proportion of respondents using cement and banco clay as building materials for the wharehouse in Fatick-Kaolack-Kaffrine

The significant presence of banco clay storage rooms in Fatick may also be justified by farmers' will to follow the traditional practices, the cultural values, a spirit of solidarity, the fear of singling out oneself and above all the modest buying power.

3.5 Periods coinciding with important damages from groundnut weevil *C. serratus*: Most farmers consider the period of March-April as coinciding with strong and frequent attacks. The respective proportions of farmers regarding January-February, March-April and April-May as critical periods are as follows : 0%, 60% and 23% in Kaolack; 33.33%, 43.33% and 33.33% in Kaffrine ; 6.97%, 33.33% and 47%. The infestation is increasing in all regions from January to March. The infestation keeps increasing in Fatick from March to May contrary to the other regions whare a sharp (Kaolack) and a slight (Kaffrine) decrease are observed from March (Fig.6). Kaolack experiences the lowest (a null infestation in January) and the highest infestation rate (60% in March). The infestation stays at the same level before and after the peak of March in Kaffrine.

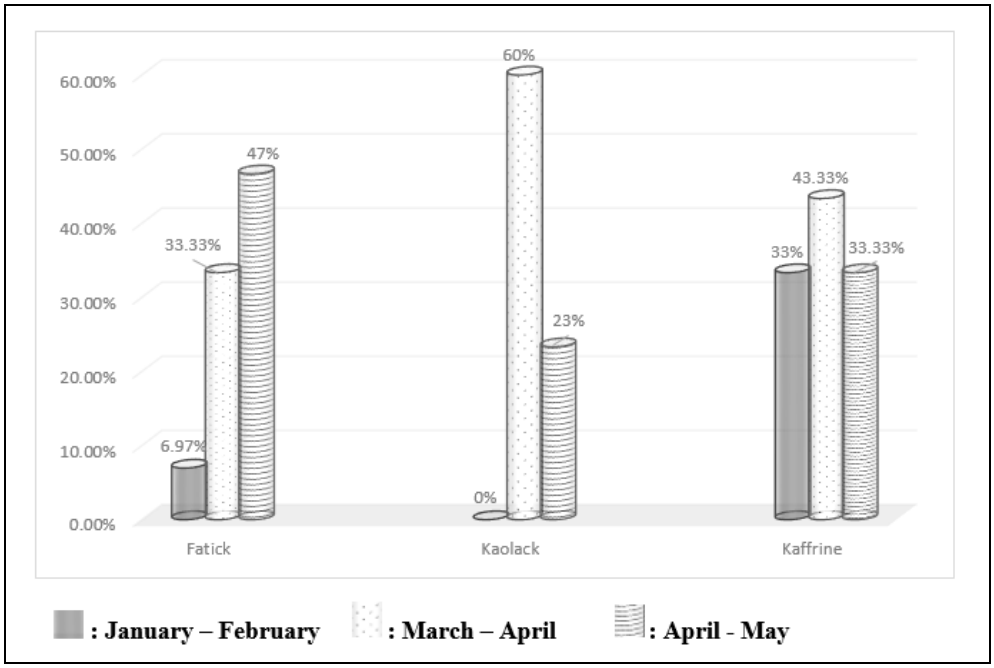

Fig 6: Months coinciding with important weevil infestation in Fatick-Kaolack-Kaffrine

4. Discussion

Weevil infestations were more severe on pods compared to seeds. Groundnut shell can be destroyed by only few insects of which a beetle of the Bruchidae family called *Caryedon serratus* Oliver or groundnut weevil causes the most severe damages. Despite offering more protective storage, the unshelled groundnut occupies one third more volume and entails higher costs [39].

Farmers have been managing the stock weevil pest by using crushed leaves of certain plants producing toxic or anti-feedant chemical substances like *Cassia spp*, *Azadirachta indica* Juss., *Hyptis spp*, *Boscia senegalensis* (Pers) [40]. However the advent of synthetic insecticides has impeded these ancient methods and the research on plant-based

pesticides. Moreover the chemical pesticides have been continuously overused at a large scale. This is confirmed in rural areas where farmers tend to sideline the biocidal plants for the chemical pesticides. With regard to the economic struggles, the Sahelian farmers have to explore all possible ways to effectively manage the food supplies at the lowest cost [41]. To that end, certain traditional methods are experiencing a renewed interest and are tested as an alternative to the chemical pesticides to manage the different pests [42, 43]. For instance, the genus Eucalyptus is characterized by a balsamic fragrance acting as bio-insecticide against the weevils [44].

Plastic barrels are effective tools for groundnut grain and seed storage but are ill-suited to the farmers' low buying power hence the low proportion of respondents using it (3%, 6% and 37% in Kaffrine, Kaolack and Fatick). However, Moussa *et al*. [45] have reported 46% of surveyed cowpea farmers using hermetic storage, and about 44% of the quantity of cowpea stored on farms in airtight containers in West and Central Africa. This shows the priority given to groundnut over the other crops in the Senegalese Groundnut Basin by storing most of the groundnut production in the available storage rooms. Several authors reported the storage effectiveness due to the hermetic feature of plastic barrels. Studies of *Boscia senegalensis* utilisation and hermetic systems have shown a drastic reduction of weevil populations by asphyxiation [46].

The utilisation of cement or banco clay as building materials of the warehouse highlights the farmers' socio-economic status. Omobowale *et al*. [47] have compared the performance of termite-mound clay, reinforced concrete and galvanized steel storage facilities. They found similar trends of temperature variation and maize quality till the fourth month of storage. The increase in relative humidity was, nevertheless, less pronounced in the galvanized steel storage facility.

Few studies have been conducted on groundnut conservation mainly because of its relative protection from pests due the storage in shell by farmers. However, infestation of groundnut weevil *C. serratus*, the principal pest of in-shell groundnut stocks, induces important losses in West African and some Central African rural areas [41]. This beetle first egg laying occurs on the pods during the drying, the first week after harvest. Lasting 16 to 22 days [48], the larvae development takes place in the grain. The cocoon is often woven inside the pod making the first and second generation almost unnoticeable. Contrarily, the following generations are readily detectable thanks to a rapid population increase that makes the infestation visible, an important production of frass, the pods gathered by the larvae weaving their cocoon and the presence of adults.

Post-harvest losses of the Sahelian zone hike about April, more or less than six months after harvest, primarily because of the fourth weevil generation. This was confirmed by the farmers Kaolack, Kaffrine and Fatick who claimed the weevil infestation peaked in the period of intense heat in March, April or May corresponding to the third generation as the life cycle of *C. serratus* is completed in about 60 days [49].

5. Conclusion

Groundnut storage in the Groundnut Basin agro-ecological zone is mainly conducted using sacks piled up in the warehouse. The ratio of farmers using plant-based extracts was higher in Fatick where a wide vegetal biodiversity allowing farmers to insecticidal plant alone or associated with other products in the storage.

The overall overuse of chemical pesticides predominates the plant-based insecticides in all three regions. The high proportion of banco clay storage rooms in Fatick stems from farmers' attachment to their traditional and cultural values as well as their relative poverty. Anticipated attacks occurs in Kaolack and Kaffrine (March, April) compared to Fatick where the infestation takes place in May. This highlight the effectiveness of insecticidal plants and traditional storage facilities mostly used in Fatick.

Competing interests

The authors declare that they have no competing interests.

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