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Entomotoxic Effect of Five Varieties of Bambara Groundnut (*Vigna subterranea*) and a Variety of Red Bean (*Phaseolus vulgaris*) against Old Larvae and Adults of *Tribolium castaneum* Herbst (*Coleoptera, Tenebrionidae*)

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Authors' contributions

This work was carried out in collaboration between both authors. Authors SM and KH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The entomotoxic effect of five varieties of Bambara groundnut (McFoSc, BlRSc, BlRAcV, MnRSc, and BnRaSc) and one variety of common bean flours (GGR) is evaluated on old larvae and adults of *Tribolium castaneum* (*Coleoptera, Tenebrionidae*) under laboratory conditions with ambient

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temperatures ranging from 32°C to 36°C. This study aims to mitigate the damage caused by *Tribolium castaneum* to stored grains and legumes. The flour from each variety was obtained by grinding and sieving. A total of 150g of each flour sample was infested with either 20 old larvae or 20 newly emerged *Tribolium castaneum*. The variables observed included mortality rates of old larvae and adults, the number of F1 progeny, and the number of larvae, nymphs, and adults in the first generation. The flour of red millet (MR) which is a cereal was considered as control. After introducing the adults into the flours of different varieties, no mortality was observed for the ML, MCFOSC, MNRSC, BNRASC, and GGR varieties within 24 hours. The mortality rates were 1.25 ± 0.96 and 5 ± 0.72 for the BIRSC and BIRACV varieties, respectively. After four weeks of treatment, the cumulative mortality rates for the larvae were 93.75% for the GGR variety, 66.25% for the BIRACV variety, 56.25% for the MCFOSC variety, 55% for the BIRSC variety, 37.5% for the MNRSC variety, 31.25% for the BNRASC variety, and only 5% for the control (MR). The flours of these leguminous crops have a negative impact on the development of *Tribolium castaneum* by prolonging the duration of larval development. It suggests that these different leguminous seed varieties can be effective in controlling insects during storage.

Keywords: Entomtoxic effect; Vigna subterranean; Phaseolus vulgaris; Tribolium castaneum.

1. INTRODUCTION

The world population is expected to reach 10.5 billion by 2050 [1,2], representing a 33% increase in world population. Almost all of this demographic explosion should concern sub-Saharan Africa, which would mark the most significant progress (+ 114%) [3,4]. According to Alexandratos and Bruinsma [5], food production should increase by 60% in order to attempt food demand in 2050. In the Sahel, populations mainly eat cereals and legumes [6,7]. Nevertheless this satisfactory agricultural production, in some regions, particularly in the Northern Region Cameroon, suffer from chronic food deficits [8-10]. Post-harvest losses are one of the major causes of that food insecurity [7]. On a global scale, post-harvest losses, all crops combined, are estimated at around 10% [11,12]. A joint report by the World Bank, the United Kingdom Natural Resources Institute and the Food and Agriculture Organization of the United Nations (FAO) indicates that the value of post-harvest losses of cereals in sub-Saharan Africa, could reach almost 4 billion dollars per year, out of an estimated 27 billion of annual cereal production [13].

In developing countries, like Cameroon, the greatest losses are observed during storage [1]. A significant part of these losses is attributable to insect pests, which are estimated to cause damage ranging from 25% to 40% of stored stocks after 6 months [11]. In the Northern Cameroon, *Tribolium castaneum* and *Sitophilus oryzae* are recognized as major pests of cereals during storage [14-16]. Reducing post-harvest losses is a crucial factor in achieving global food security [17]. The importance of pulses in the global economy is well established. Worldwide, pulses are among the most cultivated food crops by humans [18]. Pulses are an important source of plant protein and are considered as a substitute for animal protein. These vegetable proteins are derived from legumes and cereals. The proportion in protein varies from 8% to 17% for cereals and between 20% and 25% for legumes. For legumes, for example such as soy bean, the rate can reach up to 40% and 50% [19,20]. In addition to their nutritional value, legumes also contain other very important biochemical compounds called phytochemicals, which help protect plants against insects during cultivation [21].

Several methods are employed to control insect pests during storage, including the use of synthetic chemical pesticides. Despite their beneficial effects in crop protection, these synthetic chemical pesticides have adverse effects on human and environmental health [22-25]. In addition to their intrinsic toxicity, most of these pesticides are persistent, meaning they resist chemical, photochemical, and biological degradation. As a result, they accumulate in the environment and in humans through the food chain, giving rise to various pathologies and often severe physiological disorders [26-28]. Furthermore, these synthetic chemical pesticides have contributed to the emergence of resistance in certain pests [29,30]. As a result, alternative methods that are both less expensive and effective are being explored to mitigate the detrimental effects of these chemical insecticide products. One such approach involves utilizing natural products derived from plants or using the plants themselves. Research has shown the effectiveness of plant-derived products in controlling storage pests. For example, certain local plants, minerals, and oils have demonstrated efficacy in fighting against insects during storage [31,32]. Karbache [33], in their study on the entomotoxic effect of certain bean varieties (*Phaseolus vulgaris*) on the chickpea weevil *Callosobruchus maculatus* (F.) (Coleoptera, Bruchidae), found that beans possess general defensive compounds, such as lectins, which enable them to develop a certain resistance against *Callosobruchus maculatus*. Similarly, Guidaidi and Koumey [34] demonstrated that flours from three varieties of *Phaseolus vulgaris* (white, black, and red varieties) possess significant insecticidal properties against *Tribolium castaneum*.

Information regarding *Tribolium castaneum*, which attacks leguminous flours, is limited. Leguminous crops can have varying nutrient content, which could affect the entomotoxic effect on individuals of *Tribolium castaneum* [35,36]. Previous studies have investigated the entomotoxic effect of certain varieties of red beans (*Phaseolus vulgaris*) on the larvae and adults of *Tribolium castaneum* Herbst [37]. These studies have shown that the powder derived from the common red bean *Phaseolus vulgaris* exhibited higher toxicity towards adults of *Tribolium castaneum* compared to other tested varieties of the same species [37]. Our approach aims to evaluate the entomotoxic effect of flour from five varieties of Bambara groundnut and one variety of common red bean *(Phaseolus vulgaris)* on the mortality of mature larvae and adults of *Tribolium castaneum*, as well as larval development and reproduction. Additionally, we will assess the impact of the different leguminous flours used on the number of individuals emerging from the first generation of *Tribolium castaneum*. Furthermore, we will evaluate the entomotoxic effect of the different powders on the larvae, nymphs, and adults of *Tribolium castaneum* obtained from the first generation.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material consists of five varieties of Bambara groundnut (*Vigna subterranea*) and one variety of red common bean. (Table1): the characteristic of the legume seeds used are shown on Table 1.

2.2 Animal Material

The animal material consists of old larvae measuring 4 to 6mm in length and adults of *Tribolium castaneum* obtained through mass rearing in the laboratory at room temperature.

2.3 Methods

2.3.1 Mass rearing of larvae and adults of *Tribolium castaneum*

The *Tribolium castaneum* were reared on red millet flour, which provides a favorable environment for the extensive growth of larvae and adults [38]. The larvae and adults obtained from this rearing were used for the experiment.

2.3.2 Obtention of flour from the seeds of the different varieties of leguminous and millet

To obtain the different flours, the seeds of the various Bambara groundnut, common bean, and red millet varieties were washed, dried, and then ground using a culinary Mixer. The powder obtained was sieved using a 0.5 mm mesh sieve.

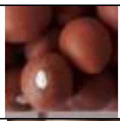
2.3.3 Experimental test

150 g of each flour was introduced into a 500 mL glass jar, covered with muslin cloth, and secured in place with a circular rubber band. Each sample was replicated four times for all the experimental tests conducted.

2.3.3.1 Entomotoxic effect of different flours (Vigna subterranea and Phaseolus vulgaris) on the mortality of olds larvae of Tribolium castaneum

Twenty olds larvae measuring between 4 mm to 6 mm in size were added to each jar containing 150 g of each flour. The jars were sealed with muslin cloth and secured with elastic bands to prevent the escape of larvae and external contamination. Deceased larvae were counted after 48 hours, one week, two weeks, three weeks, and four weeks of infestation. Each treatment was replicated four times. The control consisted of millet flour and larvae.

Table 1. Characteristics of the seeds of the different varieties

Legumes	**Varieties**	**Illustration**	**Color of tegument**	**Seed shape**	**Number of seeds / 50g**	**Aspect of the hilum**	**Collection place**
Bambara grounnut	McFoSc		Light brown	oval	54 ± 2	without outline	Méri
	BlRSc		Milky white	round	58 ± 3	without outline	Meskine
	BlRAcV		Milky white	round	62 ± 4	purple outline in the shape of a butterfly	Meskine
	MnRSc		Brown spotted with black	round	52 ± 3	without outline	Mora
	BnRaSc		Brown spotted with black	round and flattened	51 ± 2	without outline	Mora
Bean	GGR		Uniform Reds	oval	129 ± 6	without outline	Abatoir Market

2.3.3.2 Entomotoxic effect of different flours (Vigna subterranea and Phaseolus vulgaris) on the adults' mortality of Tribolium castaneum

Twenty newly emerged adults were introduced into jars containing different flours made from leguminous seeds. The number of deceased adults was recorded every 24 hours for seven days, and then after two weeks of infestation. Each treatment was replicated four times. The control consisted of the millet flour and old larvae only.

2.3.3.3 Entomotoxic Susceptibility of larvae and adults of Tribolium castaneum towards the flours used

Twenty olds larvae or newly emerged adults of *Tribolium castaneum* were introduced into jars containing different flours made from leguminous seeds. The number of deceased adults or olds larvae was recorded after 48 hours, as well as after one and two weeks. Each treatment was replicated four times. The control consisted of the red millet flour and larvae.

2.3.3.4 Entomotoxic effect of different powders (Vigna subterranea and Phaseolus vulgaris) on the emergence of first generation of Tribolium castaneum

Twenty newly emerged adults were introduced into jars containing different flours made from leguminous seeds. After 15 days, all the introduced adults were removed. 45 days after infestation with the different treatments, the number of *Tribolium castaneum* individuals that emerged in each sample was counted and classified as larvae, nymphs, and adults. Throughout the experiment, the flour used as control consisted of red millet flour, and each treatment performed was replicated four times.

2.3.4 Statistical analysis of data

The data obtained were subjected to the analysis of variances with a single classification criterion (ANOVA 1) using the STAT graphic software and is supplemented by the Kruskal Wallis test in order to determine if there are significant differences between the different powders. Calculations of means, standard deviations and graphical representations between parameters were performed using Microsoft Excel 2007 software. The mortalities were recorded as percentages, calculated by dividing the number of deceased larvae or adults of *Tribolium castaneum* by the total of 20 introduced individuals, and then multiplying the result by 100.

3. RESULTS

3.1 Evaluation of the Entomotoxic Effect of Different Flours on the Mortality of Old Larvae of *Tribolium castaneum*

Fig. 1 depicts the entomotoxic effect of the five varieties of Bambara groundnut and one variety of common bean on the survival and larval development of *Tribolium castaneum* over time.

The analysis reveals that the cumulative mortality rates of larvae vary according to the different varieties and according to time. These rates increase according to the variety and the number of exposure days. The minimum mortality rates are obtained from the first week, i.e. 36.25 ± 12.35 for the GGR variety of common bean, 25 ± 7.24 for the BIRSC variety, 20 ± 9.07 for the MCFOSC variety, 26, 25 ± 7.79 for the BIRACV variety, 13.75 ± 2.77 for the MNRSC variety, 12.5 ± 2.77 for the BNRASC variety and 0 ± 0.62 for the MR variety. The maximum cumulative mortality rates are observed at the fourth week, i.e. 93.75± 2.13 for the GGR variety of common bean, 55 ± 4.16 for the BIRSC variety, 56.25 ± 1.3 for the MCFOSC variety, 66.25 ± 5.86 for the BIRACV variety, 37.5 ± 9.4 for the MNRSC variety, 31.25 ± 5.03 for the BNRASC variety and only 5 ± 0 for the control (MR). There is a significant difference for the different powders towards old larvae at the 5% level ($P < 0.05$) over a four-week period.

3.2 Evaluation of the Entomotoxic Effect of Different Powders on the Mortality of *Tribolium castaneum's* Adults

The entomotoxic effect of five varieties of *Voandzou* and one variety of common bean on the reproduction of adult *Tribolium castaneum* over time is illustrated in Fig. 2.

The mortality of *Tribolium castaneum* adults does not exceed 20%. However, with the MR flour variety, the percentage of mortality is almost zero. With the GGR variety (common red bean), the percentage of mortality increases with the time of introduction. By the fifteenth day, the mortality rate reaches 100%. The adult cumulative mortality rates vary over time and according to the nature of the flours used. After 24 hours of introducing the adults into the flours of the different varieties, no mortality is observed with the MR, MCFOSC, MNRSC, BNRASC, and GGR varieties. The mortality rates for the BIRSC and BIRACV varieties are 1.25 ± 1.96 and 5 ± 0.72, respectively. After 48 hours, mortality is recorded for the first individuals with the MCFOSC, MNRSC, and BNRASC varieties, with rates of 3.73 ± 0.62, 1.25 ± 0, and 1.25 ± 5.10, respectively. From the fourth to the seventh day, a slight increase in individual mortality was recorded for the BIRSC, MCFOSC, BIRACV, MNRSC, BNRASC of Bambara groundnut varieties. The maximum mortality rates of individuals for the different varieties of Bambara groundnut are observed on the fifteenth day, i.e. 6.25 ± 1.67 for BIRSC; 6.25 ± 1.67 for MCFOSC; 11.25 ± 1.57 for BIRACV; 6.25 ± 2.13 for MNRSC and 17.5 ± 6.25 for BNRASC. For the GGR variety, the death of the first individuals is only observed after 72 hours of exposure. From the fifth day, there is a rapid increase in mortality of individuals for the GGR variety, reaching 18.75 ± 8.72 to 95 ± 5.33 on the fifteenth day. There is a significant difference for the various flours of Bambara groundnut and common red bean towards to adults at the level of 5% ($P < 0.05$) during the two weeks. For the control (MR), no mortality was recorded during the fifteen days. There is no significant difference for MR powder compared to adults at the 5% level ($P > 0.05$) after the two weeks.

3.3 Comparison of the Entomotoxic Effect of Flours on Old and Adult Larvae of *Tribolium castaneum*

The entomotoxic effect of five varieties of Bambara groundnut and a variety of common bean was compared to assess their effectiveness in impacting larval development and adult reproduction of *Tribolium castaneum*. Fig. 3 illustrates the mortality resulting from the comparative entomotoxic effect of the different flours derived from Bambara groundnuts and common bean on the larvae and adults of *Tribolium castaneum* after 48 hours, 7 days, and 15 days of exposure.

From Fig. 3, it can be observed that the toxicity of the different powders varies depending on the developmental stage and duration of exposure. The flours from different varieties exhibit higher toxicity towards the larvae of *Tribolium castaneum* compared to the adults. The mortality rates recorded after 48 hours of introducing the larvae into the different flours are as follows: 0% for the control (MR) and for the GGR, BIRSC, and MCFOSC varieties of red bean and Bambara groundnut, respectively; 10% for the BIRACV and MNRSC varieties; and 3.75% for the BNRASC variety. For adults, the mortality rates are 0% for the control (MR), the GGR variety of red bean, and the BNRASC variety of Bambara groundnut; 5%, 3.75%, 6.25%, and 1.25% for the BIRSC, MCFOSC, BIRACV, and MNRSC varieties, respectively.

One week after introducing the larvae into the flours of the different varieties, the recorded mortality rates are as follows: 0%, 36.25%, 25%, 20%, 26.25%, 13.75% and 12.5% respectively for the control (MR), the GGR varieties of red bean, BIRSC, MCFOSC, BIRACV, MNRSC and BNRASC of Bambara groundnut, while, in term of adults mortality rate we have 0%, 46.25%, 6.25%, 6, 25%, 10%, 3.75% and 7.5% respectively for the control (MR), the GGR varieties of red bean, BIRSC, MCFOSC, BIRACV, MNRSC and BNRASC of Bambara groundnut. Fifteen days after introducing the larvae into the flours of the different varieties, the recorded mortality rates are as follows: 0%, 78.75%, 47.5%, 42.5%, 46.25%, 25% and 23.75% for MR, GGR, BIRSC, MCFOSC, BIRACV, MNRSC and BNRASC varieties respectively, while these rates for adults are 0%, 68.75%, 6.25%, 6.25%, 10%, 3.75 % and 8.75% for MR, GGR, BIRSC, MCFOSC, BIRACV, MNRSC and BNRASC varieties respectively. From these mortality rates, it appears that the larvae are more sensitive to different powders compared to the adults of *Tribolium castaneum*. Additionally, a notably high toxicity is observed with the red bean powder, while the flours of the different varieties of Bambara groundnut present a moderate toxicity. There is a significant difference for the various flours used towards larvae and adults of *Tribolium castaneum* at the level of 5% ($P < 0.05$) during the period of two weeks of observation.

3.4 Evaluation of the Impact of Different Flours on the First Generation of *Tribolium castaneum*

The infestation of the different flours allows for an assessment of their impact on the number of individuals emerging from the first generation of *Tribolium castaneum*, as represented in Fig. 4. Specifically, the highest infestation rate is observed in the MR variety (48%), while the minimum rates are observed in the MNRSC, BIRSC, BIRACV, BNRASC, and MCFOSC varieties, with densities of 16%, 14%, 10%, 7%, and 5% respectively. The GGR variety exhibits a density of zero (0%). These leguminous flours, therefore, have varying degrees of negative effects on the reproductive rate of *Tribolium castaneum* adults. There is a significant difference among the different flours in terms of the number of individuals emerging from the first generation of *Tribolium castaneum* at a significance level of 5% ($P < 0.05$).

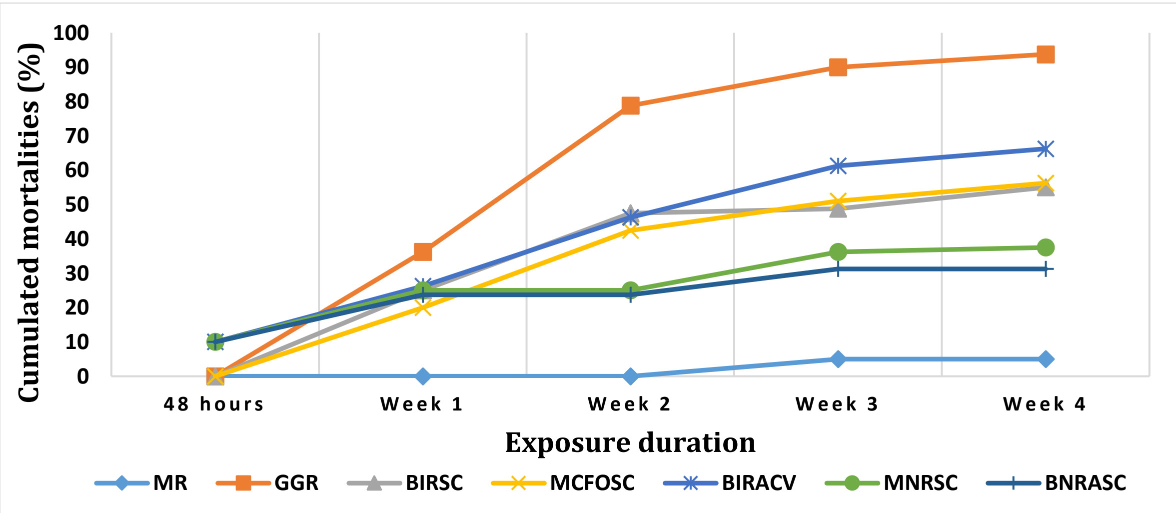


Fig. 1. Entomotoxic effect of the different flours of leguminous on old larvae of *Tribolium castaneum* by the time

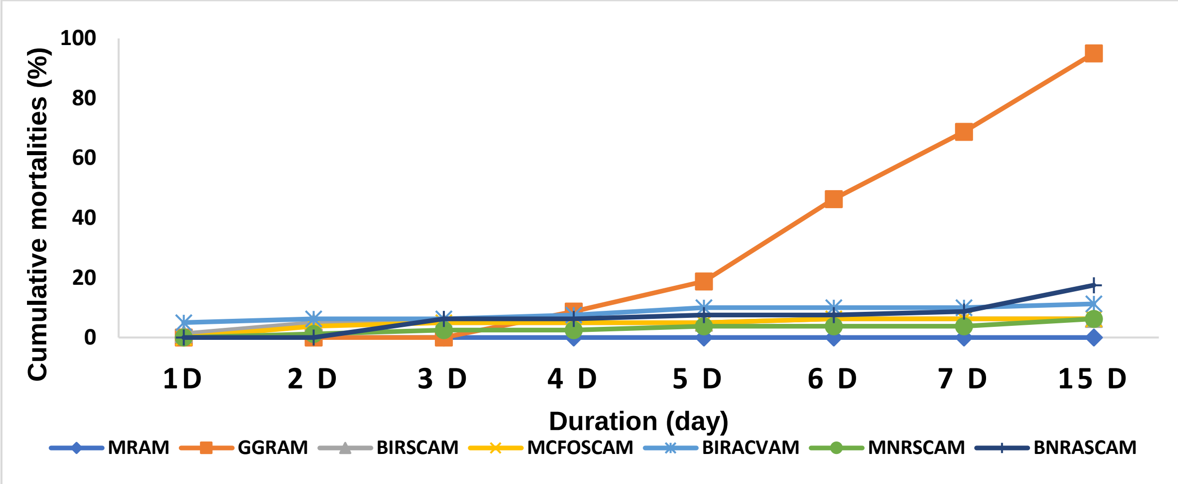


Fig. 2. Entomotoxic effect of the leguminosis flour on the mortality of *Tribolium castaneum* adults

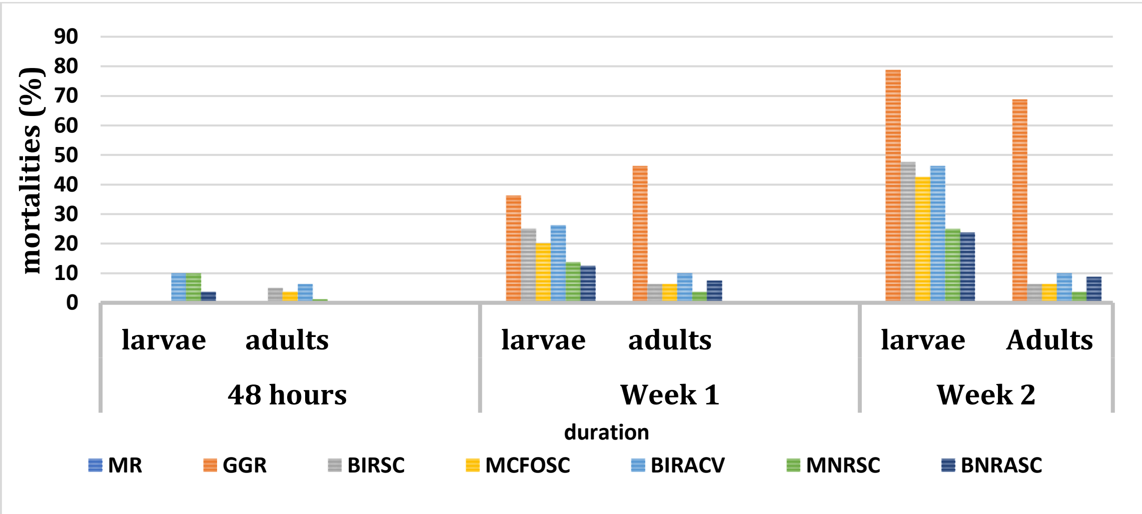


Fig. 3. Comparative effect of different powders on old and adult larvae of *Tribolium castaneum*

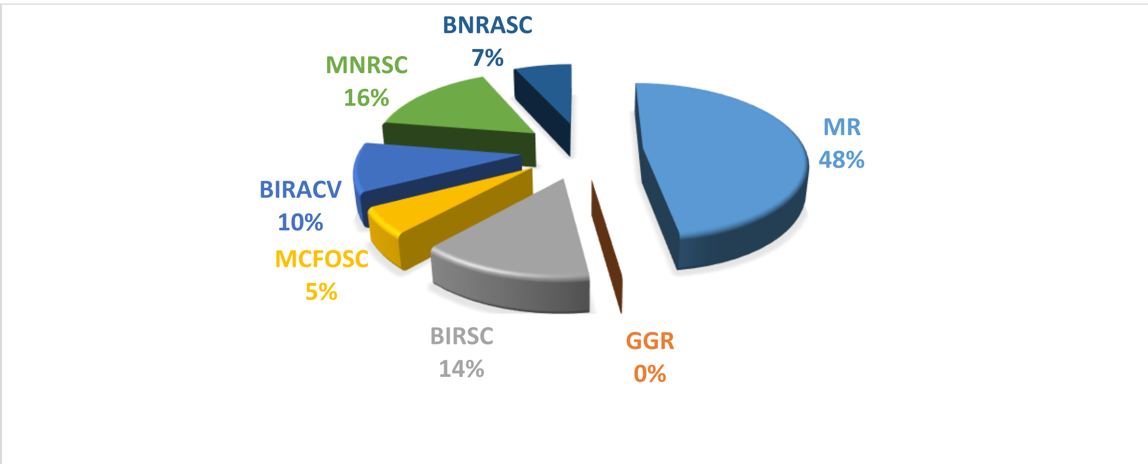


Fig. 4. Impact of different flours on the first generation of *Tribolium castaneum*

3.5 Evaluation of the Effect of Different Flours on Larvae, Nymphs and Adults of *Tribolium castaneum* Obtained from the First Generation

The qualitative and quantitative analysis of individuals from the first generation in the various powders is depicted in Fig. 5. Analysis reveals that the different flours used have an impact on the development of *Tribolium castaneum*. Specifically, the nature of the developmental stages and the relative proportion of individuals per stage vary among the different flours. Thus, the MR (control) is more favorable to the development of *Tribolium castaneum* with 100% of adult individuals, compared to the GGR flours which renders the eggs sterile because they lack post-embryonic stages. Compared to the flour of the MR variety, the flour of the MNRSC, BIRSC and BIRACV varieties are hostile with a predominance of the larval stage (96%, 95% and 95% respectively) compared to the pupal and adult stages. The flour of the MCFOSC and BNRASC varieties are very hostile to development with 0% of adults and a large predominance of the larval stage (98% and 99% respectively) compared to the pupal stage (2% and 1% respectively). Thus the flours of the different varieties inhibit more or less the development of *Tribolium castaneum*. There is a significant difference for the different flours towards the larvae, nymphs and adults of *Tribolium castaneum* obtained from the first generation at the 5% level ($P < 0.05$).

4. DISCUSSION

This study demonstrates that the feeding preference of the red flour beetle, *Tribolium castaneum*, varied depending on the leguminous flours used. The results indicated that the powders of *Vigna subterranea* and *Phaseolus* vulgaris exhibited higher toxicity towards both the larvae and adults of *Tribolium castaneum*. The toxicity levels varied depending on the developmental stage of *Tribolium castaneum* that was tested. The evaluation of the entomotoxic effect of the flours of five varieties of Bambara groundnut and one variety of common bean (*Phaseolus vulgaris*) flours on the old larvae revealed that the maximum mortality rates were observed after four weeks, whereas for the adults, these rates were recorded after only two weeks of infestation. There was a significant difference observed between the various Bambara groundnut flours and the common bean flour in terms of their impact on both the old larvae and adults. This significant difference may be attributed to the presence of identical entomotoxic molecules contained in the different flours at varying concentrations. Thus Gueye et al. [39], in their work, explain that the difference in sensitivity of insects to plants with insecticidal properties is probably linked to the active molecules they contain. These molecules can differ from one plant family to another and even within the same family, from one species to another. Similarly, Mordue and Blackwelle [40] in their studies explain that the insecticidal efficacy of synthetic molecules can vary from one species to another, with an effectiveness that depends on the concentration of active ingredient.

Similar observations were demonstrated regarding the insecticidal activity of *Lawsonia inermis* flours on *Sitophilus oryzae, Sitophilus zeamais,* and *Trogoderma granarium*. The results indicated that highly significant mortalities could be achieved with exposure periods ranging from one week to one month [41-43]. In a similar vein, Muhammad Nadeem [44], demonstrated that the maximum mortality of *Tribolium castaneum* was recorded after 72 hours of exposure to *neem* seed extracts at different concentrations. However, Gueye et al [45], in their studies showed that the type of food (whole grain and flour) has an effect on the duration of the development cycle of *Tribolium castaneum*. These factors would not only determine the duration of development, but also increase the number of larval stages. Our studies conducted at temperatures ranging from 32°C to 36°C, resulted in a maximum mortality rate towards adults after two weeks, whereas according to the work of Guidaidi and Koumey [34], this same rate was observed only after one week of introducing adults to the various *Phaseolus vulgaris* flours at temperatures ranging from 28 to 30°C. The decrease or slowdown in individual mortality could therefore be attributed to the rise in temperature.

The comparative entomotoxic effect of the various flours of Bambara groundnut and common red bean on the development of old larvae and adult *of Tribolium castaneum* after 48 hours, 7 and 15 days of exposure revealed that the flours of common bean had a greater impact on the larvae compared to the adults, on the other hand the control (MR) showed no effect on this pest. Furthermore, significant differences were observed among the different flours concerning their effects on *Tribolium castaneum* larvae and adults. This difference in effect could

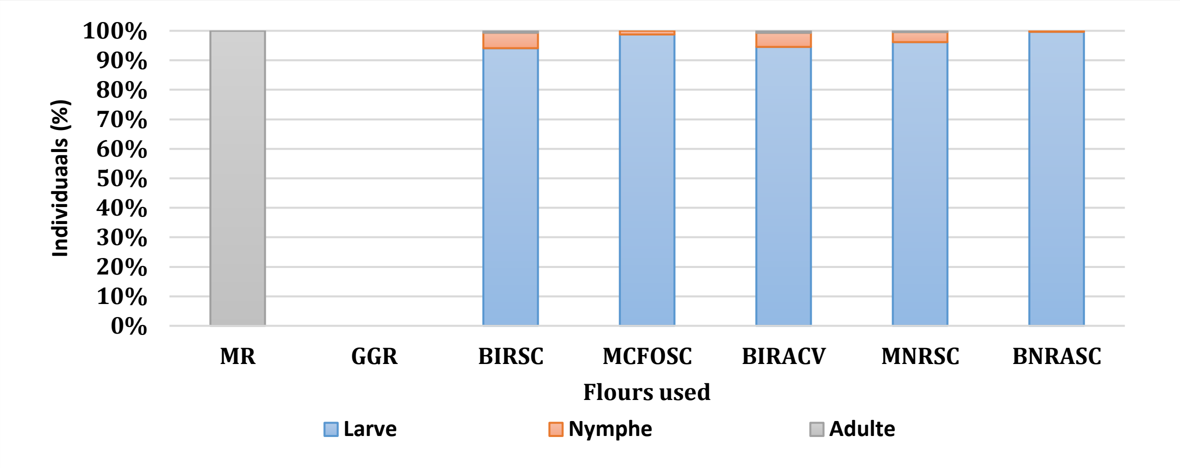


Fig. 5. Effect of the different flours on larvae, nymphs and adults obtained from the first generation of *Tribolium castaneum*

be attributed to the presence of active compounds in the different flours of Bambara groundnut and common red bean that are more toxic to mature larvae than to adults. Additionally, the flour of the control group (MR) contains favorable nutrients for the development of *Tribolium castaneum*.

Although the flours of the red common bean and the Bambara groundnut present a higher toxicity for the old larvae than for the adults, however the flour of red common bean (*Phaseolus vulgaris*) demonstrates a higher toxicity (with mortality rates of 78.75% for the old larvae and 68.75% for adults on the fifteenth day) than the powders of the different varieties of Bambara groundnut (which larval mortality rates are 47.5%, 42.5%, 46.25%, 25% and 23.75% for the BIRSC, MCFOSC, BIRACV, MNRSC and BNRASC varieties respectively against 6.25%, 6.25%, 10%, 3.75% and 7.5% adult mortality in the same varieties at fifteen days). These results agree with those of Mebarkia et al [35] who show that certain species of legumes cause a total mortality of the insect as well at 60% as at 80% such as lentil, bean and broad bean, others are less toxic such as chickpea which causes lower mortality between 3 and 23% respectively. The toxicity of legumes differs greatly from one plant species to another and at different concentrations [46-48].

The impact of the different flours of Bambara groundnut and red common bean on the number of individuals emerging from the first generation of *Tribolium castaneum* showed that the different flours have a more or less negative effects on the reproduction of adults of *Tribolium castaneum*. On the other hand the control (MR) has a rather positive effect on the reproduction of this pest. These results can be explained by the presence in the various flours of Bambara groundnut and red common bean of a toxic substance which could slow down or inhibit either the reproductive activity, or the hatching of the eggs of *Tribolium castaneum*, contrary to the control (MR) which could have compounds that stimulate the reproduction of these individuals. These results are similar to those of Kassemi [49] who showed in his studies that the flour of the leaves of *Pseudocytisus integrifolius* and *Nepeta nepetela* affects the fertility of *Tribolium castaneum*, according to him these powders have a great biological activity on the adults of *Tribolium castaneum* and other insect pests with a reduction in emerging individuals. Similar findings were obtained by Younoussa [50], who showed that *neem* powders and diatomaceous earth contain compounds with inhibitory effects on the oviposition, fecundity and fertility of *Callosobruchus maculatus*. Similarly Girma et al. [51] and Nukenine [52] explained in their studies that no emergence of *Sitophilus zeamays* was observed with diatomaceous earth powders (*FossilShield and SilicoSec*) at doses of 1 and 2g/kg; the inhibitory capacity observed is due to the physico-chemical properties of the products used. In the same way, Kellouche and Soltani [53] showed that leaf powders of four plants rich in essential oils (the fig tree, the olive tree, the lemon tree and the eucalyptus) reduced the fertility of females of *Callosobruchus maculatus* on chickpea seeds.

Although the flours of the different varieties of Bambara groundnut and the GGR variety of red common bean exhibit toxicity towards *Tribolium castaneum*. However, the flours of red bean presents a greater toxicity with 0% of individuals emerging than the flours of the different varieties of Bambara groundnut with 5%, 7%, 10%, 14%, and 16%, of emerging individuals for the varieties MCFOSC, BNRASC, BIRACV, BIRSC and MNRSC respectively. The higher toxicity of the GGR flour, which shows complete inhibition of emergence after one generation compared to the other flours of the different Bambara groundnut varieties, can be attributed to the presence of active compounds in the red bean powder that are more toxic than those present in the powders of the different Bambara groundnut varieties. *Phaseolus vulgaris* may contain phenolic compounds such as tannins (both condensed and hydrolysable) and flavonoids, which are known to have harmful effects on insect pests [54]. Tannins have been shown to influence the growth, development, and fecundity of several insect pests [55,56]. For instance, Meric [57] demonstrated in their studies that tannins inhibit the development of these insects, resulting in a lower number of eggs and smaller egg size, which can impact the survival and overall health of the first-generation individuals. According to Salunke et al. [58], flavonoids lead to a significant reduction in egg laying by *Callosobruchus chinensis*. They can also affect egg fertility, the number and weight of emerging adults from bruchids, and may exhibit toxicity towards adults, depending on the concentration used. The effect of the different flours on the larvae, nymphs and adults of *Tribolium castaneum* derived from the first generation revealed that, unlike the MR control, the different flours of Bambara groundnut and red common bean present a more or less toxic effect on the different stages of development of *Tribolium. castaneum*. There is a significant difference among the different flours in their effects on the larvae, nymphs, and adults of *Tribolium castaneum* from the first generation. This observed difference can be attributed to the presence of entomotoxic substances in the different legume flours used, which can disrupt embryo development within the eggs and slow down the overall development of *Tribolium castaneum*. The obtained result is similar to those of Ivbijaro [59] and Seck et al. [60], who demonstrated in their studies that the powder of *Azadirachta indica* seeds has insecticidal properties which are manifested by the reduction in female fertility, the extension of the development period (larvae and pupa) and reduction of emergence. From our results, it is evident that the flours derived from the seeds of different Bambara groundnut varieties and a variety of common red bean (*Phaseolus vulgaris*) are all toxic to the larvae and adults of *Tribolium* castaneum. However, the level of toxicity varies according to the type of legume and the duration of treatment.

The highest mortality rate among the mature larvae is observed during the fourth week, while for the adults, this rate is achieved after two weeks, across all varieties. This indicates that both the common red bean flour and the various Bambara groundnut flours used display significant toxicity towards both the adult and larval stages of *Tribolium castaneum*. A comparative study reveals that the larvae are more susceptible to the different flours compared to the adults of *Tribolium castaneum*. The flours of the different Bambara groundnut varieties exhibit varying levels of toxicity on adult mortality, resulting in a reduction in the number of emerging individuals in the first generation. Our results indicate that the red bean flours is the most toxic compared to the flours of the different varieties of Bambara groundnut. This toxicity results in significant mortality (95 ± 5.33) in adults and total inhibition (0%) of emerging individuals of the first generation. Bambara groundnut and common red bean flours therefore have entomotoxic properties and could constitute an alternative for the protection of stored foodstuffs against the attack of *Tribolium castaneum*. It would be advisable to further investigate this study by conducting parallel fractionation experiments alongside biological tests to determine the nature of the compounds responsible for the entomotoxic activity. Additionally, evaluating the effect of these flour varieties on other insect pests would be beneficial.

5. CONCLUSION

From our results, it appears that the powders of the seeds of the different varieties of *Voandzou* and of a variety of red bean exhibit toxicity towards both the larvae and adults of *Tribolium castaneum*, the main pest of stored foodstuffs. However, it is important to note that the level of toxicity varies depending on the specific legume varieties used and the duration of treatment. The maximum mortality rate in larvae was observed in the fourth week, while in adults, this rate is reached after two weeks for all varieties. Therefore, both the common bean powder and the various *Voandzou* powders exert significant toxicity on both adults and larvae. A comparative study shows that the larvae are more sensitive to different powders than the adults of *Tribolium castaneum*.

The powders of the different varieties of *Voandzou* have a more or less significant toxicity on adult mortality, thus leading to a reduction in individuals emerging from the first generation. Our results indicate that the powder of the red bean turns out to be the most toxic compared to the powders of the different varieties of *Voandzou*. This toxicity results in significant mortality (95 ± 5.33) in adults and total inhibition (0%) of individuals emerging from the first generation. *Voandzou* and common bean powders therefore have entomotoxic properties and could constitute an alternative for the protection of stored foodstuffs against the attack of *Tribolium castaneum*.

At the end of this work, we issue some thoughts and recommendations in the form of perspectives for the use of legumes in the protection of foodstuffs against the attack of *Tribolium castaneum* and other insect pests of stocks. This involves, among other things, identifying and extracting the compounds responsible for the entomotoxic activity by fractionation carried out in parallel with the biological tests and evaluating the effect of the powder of these varieties on other insect pests.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Aulakh J, Regmi A. Post-harvest food losses estimation: Development of consistent methodology: Food and Agriculture Organization of the United Nations. Rome Italy; 2013.
2. Tamgno BR, Tinkeu LSN. Insecticidal potential of powdery formulations based on Pisum sativum and Phaseolus vulgaris seed flours with millet stem ash against *Sitophilus oryzae* L. (*Coleoptera: Curculionidae*). Int J Biol Chem Sci. 2018;12(1):90-100.
3. FAO. Global agriculture to 2050, High Level Expert Forum - How to feed the world in 2050. Rome Italy; 2009.
4. Leridon H, De Marsily G. Demography, climate, and global food supply. EDP Sciences; 2011.
5. Alexandratos N, Bruinsma J. World agriculture towards 2030/2050: The revision. FAO; 2012.
6. Gueye MT, Diallo A, Diallo Y, Seck D, Vercammen J, Lognay G. Effects of MITC released from boscia senegalensis as biopesticide in senegalese seeds with special attention to cowpea: Detection of residues. J Environ Ecol. 2013;4(29):10-5296.
7. Nanfack FM, Dongmo Y Z, Fogang MAR. Insects involved in post-harvest losses of cereals in Cameroon: Current control methods and perspectives offered by transgenesis. Int J Biol Chem Sci. 2015;9(3):1630-1643.
8. Kongne LM, Habiba K, Sidonie FT, Tchuenguem Fohouo FN. Management of Callosobruchus maculatus F. (*Coleoptera: Bruchidae*) using methanol extracts of Carica papaya, Carissa edulis, Securidaca longepedonculata and Vinca rosea and impact of insect pollinators on cowpea types in the Far-North region of Cameroon. J Ent Zoology Stud. 2018;6(2):1017-1027.
9. Matseu NSG, IlliassaN, Habiba K, Elias NN. Insecticidal activity of powder and essential oils of vepris heterophylla (*Rutaceae*) and Syzygium aromaticum (Mytaceae) Towards Callosobruchus maculatus F. walp (*Coleoptera: Bruchidae*) on Post-Harvest Vigna unguiculata (Fabaceae) in the Far-North Region of Cameroon. J Exp Agric Int. 2021;43(3):98-112.
10. Mbouga N, Goletti M. Formulation of powder insecticides by adsorption of essential oils from Xylopia aethiopica and Ocimum gratissimum on modified Cameroonian clays (Doctoral dissertation, Montpellier, Ecole nationale supérieure de chimie); 2012.
11. Aidoo KE. Post-harvest storage and preservation of tropical crops. Int Biodeterior Biodegradation. 1993;32(1-3):161-173.
12. Harein P, Meronuck R. Stored grain losses due to insects and molds and the

importance of proper grain management. Stored Prod Manag. 1995;29-31.
13. WorldBank. Missing food: The case of postharvest grain losses in Sub-Saharan Africa. Washington DC; 2011.
14. Ngamo LST, Hance TH. Diversity of food pests and alternative control methods in tropical environments. Tropicultura. 2007; 25(4):215-220.
15. Tamgno RB, Leonard NTS. Diversity of stored grain insect pests in the Logone valley, from northern Cameroon to western Chad Republic in Central Africa. J Agricultural Sci. technol. A. 2013;3(9A): 724.
16. Koubala BB, Laya A, Massai H, Kouninki H, Nukenine EN. Physico-chemical characterization leaves from five genotypes of cassava (*Manihot esculenta* Crantz) consumed in the far north region (Cameroon). Am J Food Technol. 2015;3 (2):40-47.
17. Waongo A. Insect pests of sorghum stocks (*Sorghum bicolor* [L.] Moench) in the North Sudanian zone of Burkina Faso: Bioecology and control strategies against Rhyzopertha dominica F. (*Coleoptera: Bostrichidae*). University of Ouagadougou. English; 2016.
18. Hamadache B, Aknine M. Demonstration of the period of maximum sensitivity of winter chickpea to annual weeds in the coastal zone. Cereal farming. French; 1997.
19. Guéguen J, Walrand S, Bourgeois O. Plant proteins: Context and potential in human nutrition. Cah of Nutr and Diet. 2016; 51(4):177-185.
20. Wassouo FA, Madi A, Sobda G, Koubala BB, Mvondoawono JP. Agro-morphological diversity of thirty-six accessions of Bambara groundnut [*Vigna subterranea* (L.) Verdcourt] cultivated in the Far North Region of Cameroon. J Appl Biosci. 2019; 140:14227-14234.
21. Misgana B, Bajo W. Review on nutritional importance and anti-nutritional factors of vegetables. Int J Food Sci Nutr. 2020;9: 138-149.
22. Hickey JJ, Anderson DW. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science. 1968;162(3850):271-273.
23. Saiyed H, Dewan A, Bhatnagar V, Shenoy U, Shenoy R, Rajmohan H, Lakkad B. Effect of endosulfan on male reproductive development. About Health Perspective. 2003;111(16):1958-1962.
24. Lemaire G, Terouanne B, Mauvais P, Michel S, Rahmani R. Effect of organochlorine pesticides on human androgen receptor activation in vitro. Toxicol Appl Pharmacol. 2004;196(2):235-246.
25. Fianko JR, Donkor A, Lowor ST, Yeboah PO, Glover ET, Adom T, Faanu A. Health risk associated with pesticide contamination of fish from the Densu River Basin in Ghana. J Environ Prot. 2011; 2(02):115.
26. Fisk AT, Hobson KA, Norstrom RJ. Influence of chemical and biological factors on trophic transfer of persistent organic pollutants in the Northwater Polynya marine food web. About Sci Technol. 2001; 35(4):732-738.
27. Oliva A, Spira A, Multigner L. Contribution of environmental factors to the risk of male infertility. Hum Reprod. 2001:16(8):1768-1776.
28. Baldi I, Lebailly P, Mohammed-Brahim B, Letenneur L, Dartigues JF, Brochard P. Neurodegenerative diseases and exposure to pesticides in the elderly Am. J Epidemiol. 2003;157(5):409-414.
29. Schuster CL, Smeda RJ. Management of Amaranthus rudis S. in glyphosate-resistant corn (Zea mays L.) and soybean (*Glycine ma*x L. Merr.). Crop Prot. 2007; 26(9):1436-1443.
30. Sayyed AH, Ahmad M, Crickmore N. Fitness costs limit the development of resistance to indoxacarb and deltamethrin in Heliothis virescens (*Lepidoptera: Noctuidae*). J Econ Entomol. 2008;101 (6):1927-1933.
31. De Groot I. AD18F Protection of stored cereals and legumes. Agromisa Foundation; 2004.
32. Tamgno BR, Tinkeu LN. Enhancement of insecticidal efficacy of neem tree (*Azadirachta indica* A. Juss) leaf or seed powders through formulation with millet stem ash against Sitophilus zeamais motsch. and Sitophilus oryzae L. (*Coleoptera: Curculionidae*). African J Food Agric Nutr Dev. 2018;18(1).
33. Karbache F. Entomotoxic effect of some varieties of bean (*Phaseolus vulgaris*) on the chickpea weevil Callosobruchus maculatus (F.) (Coleoptera, Bruchidae). Doctoral dissertation; 2009. French.

34. Guidaidi SS, Koumey D. Evaluation of the entomotoxic effect of some varietiesof bean against Tribolium castaneum (*Coleoptera: Tenebrionidae*). University of Maroua; 2014.
35. Mebarkia A, Benkohila HS, Hamza M, Makhlouf M. Efficacy of an entomotoxic protein of type A1b from legume seeds; 2012.
36. Petit J, Duport G, Rahbe Y, Guiderdoni E, Breitler JC, Courtois B. Pea albumin 1b (PA1b), an entomotoxic cysteine-rich peptide, protects transgenic rice seeds against the stored-product pest Sitophilus oryzae: [P373]. IRRI; 2005.
37. Nanjou H, salma M. Entomotoxic effects of three varieties of legumes (Phaseolus vulgaris) against old and adult larvae of Tribolium castaneum Herbst (*Coleoptera: Tenebrionidae*); University of Maroua; 2019.
38. Kouninki H, Haubruge E, Noudjou FE, Lognay G, Malaisse F, Ngassoum MB, Hance T. Potential use of essential oils from Cameroon applied as fumigant or contact insecticides against Sitophilus zeamais Motsch. (*Coleoptera: Curculionidae*). Commun Agric Appl Biol Sci. 2005;70(4):787-792.
39. Guèye MT, Seck D, Wathelet JP, Lognay G. Control of pests of cereal and legume stocks in Senegal and West Africa: bibliographical synthesis. Biotechnol agron soc approx. 2011:15(1). French.
40. Mordue AJ, Blackwell A. Azadirachtin: An update. J Insect Physiol. 1993;39(11):903-924.
41. Al-Moajel NH, Coll G. Testing some various botanical powders for protection of wheatgrain against Trogoderma granarium Everts. Pak J Biol Sci. 2004;4(5).
42. Arya M, Tiwari R. Efficacy of some indigenous bioproducts against rice weevil, Sitophilus oryzae (Linn.) on wheat. India J App Res. 2013;3(6):13-15.
43. Suleiman M, Ibrahim ND, Majeed Q. Control of Sitophilus zeamais (Motsch) (Coleoptera: Curculionidae) on Sorghum using some plant powders. Int J Agric For. 2012;2(1):53-57.
44. Nadeem M, Ahmad H, Murtaza B, Shakoori A. Nadeem et al., 2012- MDH published; 2015.
45. Guèye AC, Diome T, Thiaw C, Ndong A, Ndiaye GA, Sembène M. Capacity of biodemographic development of *Tribolium castaneum* Herbst (*Coleoptera, Tenebrionidae*) and Sitophilus zeamais Motschulsky (*Coleoptera, Curculionidae*) in stored cereals in Senegal. South Asian J Exp Biol. 2012;2(3):108-117.
46. Louis S. Structural diversity and biological activity of type 1b entomotoxic albumins from legume seeds (Doctoral dissertation). INSA Lyon; 2004.
47. Kouninki H, Mfouapon A, Mohamadou SB. Biological activities of Cassia mimosoides, Eucalyptus camaldulensis, Vepris heterophylla plant extract toward old larvae and adults of Tribolium castaneum (*Coleoptera: Tenebrionidae*). Int j sci environ technol. 2017 ;6(5):3196-3213.
48. Nukenine EN, Chouka FP, Vabi MB, Reichmuth C, Adler CN. Comparative toxicity of four local botanical powders to Sitophilus zeamais and influence of drying regime and particle size on insecticidal efficacy. Int J Biol Chem Sci. 2013;7(3): 1313-1325.
49. Kassemi N. Biological activity of powders and essential oils of two plants (Pseudocytisus integrifolius Salib and *Nepeta nepetella* L) on pests of wheat and pulses (Doctoral dissertation). University of Tlemcen-Abou Bekr Belkaid; 2014.
50. Younoussa, L. Bioactivity of diatomaceous earth and neem powders against cowpea weevil Callosobruchus maculatus (FAB) (*Coleoptera: Bruchidae*) (Doctoral dissertation). University of Tlemcen; 2011.
51. Girma D, Tefera T, Tadesse A. Efficacy of Silicosec, filter cake and wood ash against the maize weevil, Sitophilus zeamais Motschulsky (*Coleoptera: Curculionidae*) on three maize genotypes. J Stored Prod Res. 2008;44(3):227-231.
52. Nukenin, EN. Stored product protection in Africa: Past, present and future. Julius-Kühn-Archiv. 2010;(425):26.
53. Kellouche A, Soltani N. Biological activity of powders of five plants and the essential oil of one of them on Callosobruchus maculatus (F.). Int J Too Insect Sci. 2004;24(2):184-191. French.
54. Bouchikhi TN. Bioeffectiveness of the substance from the leaves of two varieties of Phaseolus vulgaris bean on the different states and stages of development of the bean weevil Acanthoscelides obtectus. Coleoptera, Bruchidae. Aboubekr Belkaid University - Tlemcen; 2006. French.

55. Feeny P. Plant appearance and chemical defense. In Biochemical interaction between plants and insects. Boston, MA: Springer US; 1976.
56. Hagerman AE, Butler LG. Choosing appropriate methods and standards for assaying tannin. J Chem Ecol. 1989;15: 1795-1810.
57. Meric K. Studies on polyphenolic compounds in relation to spruce budworm feeding (PhD these). Forest sciences. Univ Laval; 2005.
58. Salunke BK, Kotkar HM, Mendki PS, Upasani SM, Maheshwari V.L. Efficacy of flavonoids in controlling Callosobruchus chinensis (L.) (*Coleoptera: Bruchidae*), a post-harvest pest of grain vegetables. Crop Prot. 2005;24(10):888-893.
59. Ivbijaro MF. The efficacy of seed oils of *Azadirachta indica* A. Juss and Piper guineense Schum and Thonn on the control of Callosobruchus maculatus F. Int J Trop Insect Sci. 1990;11(2): 149- 152.
60. Seck D, Sidibe B, Haubruge E, Gaspar C. Protection of stored cowpea (*Vigna unguiculata* (L.) Walp) at farm level: The use of different formulations of Neem (*Azadirachta indica* A. Juss) from Senegal. In International Symposium on Phytofarmacy in Phytiatry. Med Fac Landbouwwet Univ Gent; 1991.

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