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Rates of Botanical Extracts for the Management of Weevil (*Acanthoscelides obtectus*) in Beans (*Phaseolus vulgaris L*) in The Gambia

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Abstract

The study on the effects of botanicals for the management of storage insects in beans was conducted at the plant pathology laboratory of the National Agricultural Research Institute (NARI) in The Gambia. The objective was to determine the most effective rate of neem leaf (*Azadirachta indica*) and pepper (*Capsicum annuum*) fruit powders in the management of *Acanthoscelides obtectus* on beans. The experiment was laid out in a Completely Randomized Design (CRD) with 10 treatments replicated five (5) times. A chemical called GRANOFORCE seed dressing chemical powder was used as the standard check, while the untreated was used as a control. The duration of the experiment lasted for 90 days. Data were obtained from the number of adult mortalities, the number of live insects, the weight of damaged seeds, the weight of healthy seeds, the number of seeds germinated, and temperature and humidity of the laboratory. There were significant differences among the treatments tested at $p < 0.05$. The application of the botanical extracts significantly reduced the weight of damaged seeds, increased the weight of healthy seeds, and increased the rate of germination compared to the untreated (control). The results of the experiments revealed that all the treatments (plant powders and GRANOFORCE chemical powder) were toxic to the insect. The application of neem leaf powder at 70 grams significantly increased the mortality of storage insects more than all the other rates of the botanical extracts tested, except the application of neem at 60 grams in all the months. Similarly, all the rates of the botanical extracts increased mortality, reduced the number of living insects, reduced seed damage, and increased seed viability more than the control. None of the plant powders caused 100% mortality at 90 DAT. All plant powders, especially neem powder, at a considerable rate (at 70 grams) can be recommended to farmers for bean weevil control. The neem was more potent and was close to the standard check (GRANOFORCE chemical powder) and can be used in the integrated pest management of bean weevil in storage.

Keywords

Rates, Botanicals, Insects, Mortality, Beans

1. Introduction

Beans are a type of legume known scientifically as *Phaseolus vulgaris* [1]. Beans are produced across The Gambia in both large commercial and small subsistence farms; however, they are produced mainly in the Upper River, Central River, and North Bank regions of The Gambia because of the ideal agroecological conditions and rainfall patterns in these regions. It is one of the most significant crops produced in the country due to its abundance in protein, minerals, and vitamin contents [2]. Beans are also economically significant in supporting rural communities in income generation, ensuring food security, and improving soil fertility [3]. However, despite the significance of beans in the nation, crop productivity is affected by several factors. The problem of storage insects impacting the quality and quantity of stored beans is one of the biggest problems that farmers and consumers are affected by [4]. According to [5], beans are extremely vulnerable to damage from a variety of storage insects, including bean weevils, bruchids, and moth larvae. High insect detritus levels can cause seed damage that is unfit for human consumption as well as loss of food commodities in terms of both quality and quantity [4]. Changes in the storage environment brought on by insect infestations may result in warm, wet "hotspots" that favor storage fungi that increase losses. The Food and Agriculture Organization estimated that each year, plant pests and diseases cause up to 40% of the world's crop production to be lost [6]. Invasive insects cost at least $70 per acre, while plant diseases alone cost the global economy more than $220 billion yearly [7]. In addition to lowering the quality and quantity of stored beans, these insects also cause significant financial losses for The Gambia's bean growers and processors [8]. Beans with infestations have a lower market value, and because of storage losses, there are fewer beans available for sale. This, in turn, has an impact on the livelihoods and earnings of bean value chain actors, including farmers and traders.

The application of chemical pesticides is the most common strategy farmers and food processors use to combat infestations of storage insects. However, the misuse and excessive use of chemical pesticides can have negative impacts on the environment, non-target creatures, human health, and the emergence of insect pesticide resistance [9]. To manage the storage of insects in beans, it is therefore necessary to investigate non-toxic, alternative, and environmentally acceptable solutions. Because plant components are more easily biodegradable, environmentally benign, and less hazardous to mammals than other compounds, the use of botanical pesticides to protect plants from pests is very promising [10]. The use of higher plant products as innovative chemotherapeutics in plant protection has received interest recently in many parts of the world. Plant products have the po-

tential to be used for pest control due to their non-phytotoxicity, systematic nature, simple biodegradability, and ability to stimulate host metabolism. Neem leaf extract is one possible natural remedy [11]. It has long been known that the Indian subcontinent's native neem tree (*Azadirachta indica*) contains insecticidal capabilities [12]. Neem oil extracted from the neem kernels has demonstrated promise in warding off and managing a variety of pests, including field insects [13]. Also, studies have shown that neem leaves contain chemicals that are active in repelling and killing a variety of pests, including storage insects [14]. However, very little research has been done to determine the rates that are effective in controlling storage pests in The Gambia. Therefore, the purpose of this study is to find out the effectiveness of different rates of neem leaf and pepper powder in controlling weevils in beans. The research was initiated to determine the effects of rates of neem leaf and pepper powder for the management of weevils in beans in The Gambia.

2. Materials and Methods

A comprehensive laboratory study on "Effects of Botanicals (Neem, Pepper, and GRANOFORCE chemical powder) in the management of storage insect (*Acanthoscelides obtectus*) in Beans (***Phaseolus Vulgari*** *L*)" was undertaken at the National Agricultural Research Institute (NARI) from December 2023 to February 2024. The experimental materials consisted of neem leaf powder, pepper powder, GRANOFORCE seed dressing chemical powder, and dry beans MELAKH variety obtained from NARI. The experiment was laid out in a Completely Randomized Design (CRD) with 10 treatments replicated five times. The bio-efficacy test was undertaken to determine the effects of different rates of neem leaf and pepper powder against bean weevils in bean seed at 350 grams. The treatments tested were as follows: neem powder at 30 g, neem powder at 40 g, neem powder at 60 g, neem powder at 70 g, pepper powder at 2 g, pepper powder at 3 g, pepper powder at 4 g, untreated (control), and GRANOFORCE seed dressing chemical at 100 gram/100kg of seed. The GRANOFORCE chemical powder was used as a positive control, and the Active Ingredients of the product are Imidacloprid 20%, Chlorothalonil 20%, and Difenoconazole 2%. From treated seeds, 350-gram seed was stored in 1.5-litre white-transparent-plastic bottles. The neem leaves were collected from neem trees and air-dried at room temperature (in the shade) for 4 weeks. The dry leaves were ground into powder using mortar and pestle. For the pepper, a yellow pepper (*capsicum annum*) variety called Big Son was used, and the same rates of pepper powders were used by [9]. The fruits were sourced from vegetable farmers, cut into small pieces, and then air-dried under room temperature (in the shade) for about 3 weeks. The insect (*Acanthoscelides obtectus*) was obtained from the culture maintained at NARI Entomology laboratory. The laboratory condition was maintained at a temperature of 30˚C ± 2˚C and 60% ± 10% for the duration of the experiment. Six hundred grams of beans were infested for two weeks and sieved to remove adult insects. The adults were used to infest bean seeds and after five weeks of storage, a new progeny emerged. Ten [10] adults

of *A. obtectus* (5 males and 5 females) of one week old were randomly selected to infest the seeds in the experiment [15]. The moisture content of the bean seeds was taken using Aquamatic 5200 Grain Moisture Meter. The moisture content of seeds was found to be at 13% before storage. The seeds were treated first, followed by infestation with insects on the same day. The observations were recorded on mortality of insects, number of live insects, the weight of healthy seeds, weight of damaged seeds, and number of seeds germinated from December 2023 to February 2024, months after storage period. Also, temperature and humidity of the experimental site were monitored using DWPTU mini digital thermometer 2-pack hygrometer indoor humidity meter during the study period. Damaged and healthy seeds were assessed by separating the damaged seeds from the healthy seeds in a bottle and weighing the ones with holes, visible decay, and affected by bean weevils as damaged seeds. While healthy seeds were those that appeared intact and unblemished.

The germination test of bean seeds was done on 9 cm-diameter plastic petri dishes at a temperature of 25˚C ± 2˚C. The petri dishes were put inside the autoclave and set at 100˚C for 4 hours to disinfect them. Fifty seeds were randomly selected from each treatment. The seeds of each treatment were separately treated in 3% diluted sodium hypochlorite for 3 minutes. The seeds were then rinsed with distilled water to avoid damage. The seeds were placed in a petri dish containing moist filter paper for seven days. The number of germinated seeds was counted seven days after incubation. The germination percentage of the seeds under each treatment was determined using a formula described by [16].

$$\text{Germination } (\%) = \frac{\text{Total No. of Seeds Sprouted}}{\text{Total No. of Seeds in the Petri dish}}$$

The data were analysed with GenStat version 17th Edition, and means were separated using Tukey's Honestly Significant Difference (HSD) at $p < 0.05$.

3. Result and Discussion

3.1. Effects of Rates of Plant Products on Adult *Acanthoscelides obtectus* Mortality

The results in Table 1 showed the effects of the different treatments tested on the mortality of storage insects in bean seeds at 30, 60, and 90 Days After Treatment (DAT). The number of dead insects varies from 9 to 21, 10 to 27, and 10 to 39 at 30 DAT, 60 DAT, and 90 DAT, respectively. The GRANOFORCE chemical powder killed all the insects in the containers before the date of the first observation (30 DAT). This result corroborates the findings of [17], who reported that synthetic pesticide is very effective in controlling insect pests.

There were significant differences among the treatments tested at $p < 0.05$. The application of neem powder at 70 grams significantly increased the mortality of storage insects more than the rest of the treatments tested in all the months, followed by the application of neem at 60 grams and neem at 40 grams. The lowest number of mortalities was observed in the control plots (untreated).

Table 1. Effects of the treatments on the mortality of insects in stored bean seeds at 30, 60, and 90 Days After Treatment (DAT).

Treatments	December (30 DAT)	January (60 DAT)	February (90 DAT)
T1	16 bcd	18 c	24 cd
T2	18 cd	18 c	30 e
T3	18 cd	24 d	35 f
T4	21 d	27 d	39 f
T5	12 ab	14 bc	17 b
T6	14 abc	18 c	18 b
T7	15 abc	17 c	23 c
T8	10 a	10 a	10 a
T9	9 a	11 bc	14 b
Means	15	16	23
CV	18%	13%	10%

T1: Neem at 30 grams T2: Neem at 40 grams T3: Neem at 60 grams T4: Neem at 70 grams T5: Pepper at 2 grams T6: Pepper at 3 grams T7: Pepper at 4 grams T8: GRANOFORCE chemical powder at 0.35 grams T9: Control group CV: Coefficient of Variance DAT: Days After Treatment.

This is in line with [18] findings, who found that a higher concentration of *A. indica* significantly reduced oviposition. [19] also reported that *A. indica* treatments showed increased effects in their rate of mode of action during storage of stored seeds. This may be due to the presence of a chemical called *azadirachtin*, which has been identified as the key compound that works as an insect-feeding deterrent and as an inhibitor of *ecdysis* and growth in larger quantities in *A. indica*. It was observed that the mortality of adult *A. obtectus* increased with time (30 DAYS > 60 DAYS > 90 DAYS) following the application of the treatments, and this corresponds with the mortality result obtained by [20], who stated that with an increase in duration, adult mortality also increased. The significant differences from the result obtained in the mortality of *A. obtectus* by comparing the efficacy of *A. indica* leaf powder with the control are an indication that *A. indica* leaf powder has some insecticidal properties capable of controlling pests of stored beans. This study also supports [21], who reported that neem tops the list of 2400 plant species that are reported to have pesticide properties and is regarded as the most reliable source of eco-friendly bio-pesticide properties. The reason why the combination of neem leaf powder and pepper fruit powder treatment was not effective might probably be attributed to the lower concentration of doses used from each, as it was observed in the single treatments that the higher concentration of doses was more effective compared to the lower concentration of doses.

3.2. Effects of Rates of Plant Products on the Number of Live Insects (*Acanthoscelides obtectus*) in Beans

The effects of seed treatment on the number of live insects in the storage of bean seeds at 30, 60, and 90 DAT (Table 2). The number of live insects varies from 0 to 25, 0 to 35, and 0 to 44 at 30 DAT, 60 DAT, and 90 DAT, respectively. The highest number of live insects was observed in the untreated (control), while the lowest was observed in the application of GRANOFORCE chemical powder. There were significant differences among the treatments tested at $p < 0.05$. The application of GRANOFORCE chemical powder significantly reduced the number of live insects in the stored bean seeds more than the rest of the treatments in all the months, followed by neem leaf powder at 70 grams per 350 grams of seeds and neem leaf powder at 60 grams per 350 grams of seeds. There were significant differences between GRANOFORCE chemical powder and the rest of the treatments. Similarly, the application of neem at 70 grams was significantly different from that of pepper at 2 grams and control (untreated) in all the months observed. However, there were no significant differences among the application of neem at 70 grams, 60 grams, 40 grams, 30 grams, pepper powder at 3 grams, and 4 grams. The results from this study show that the synthetic pesticide GRANOFORCE CHEMICAL POWDER was effective and fast-acting in controlling *A. obtectus.* All insects were observed to be killed by GRANOFORCE chemical powder within the first 30 days. Chemical insecticides have a very fast mode of action; they can act quickly and kill all the insects in an environment within the shortest possible time [22].

Table 2. Effects of seed treatment on the number of live insects in stored bean seeds at 30, 60, and 90 Days After Treatment (DATS).

Treatments	December (30 DAT)	January (60 DAT)	February (90 DAT)
T1	12 bc	4 abcd	3 bcd
T2	14 bc	3 abcd	2 abc
T3	8 b	2 abc	2 abc
T4	8 b	1 ab	1 ab
T5	14 c	7 d	6 d
T6	13 bc	6 cd	5 cd
T7	11 bc	5 bcd	5 cd
T8	0 a	0 a	0 a
T9	25 d	35 e	44 e
Means	12	7	7
CV	21%	30%	22%

T1: Neem at 30 grams T2: Neem at 40 grams T3: Neem at 60 grams T4: Neem at 70 grams T5: Pepper at 2 grams T6: Pepper at 3 grams T7: Pepper at 4 grams T8: GRANOFORCE chemical powder at 0.35 grams T9: Control group CV: Coefficient of Variance DAT: Days After Treatment.

3.3. Effect of Rates of Plant Products on the Weight of Healthy Seeds

The weight of healthy seeds in the storage of bean seeds at 30, 60, and 90 Days After Treatment (Table 3). The weight of healthy seeds differs from 280 to 347, 266 to 345, and 255 to 345 at 30 DAT, 60 DAT, and 90 DAT, respectively. The highest weight of healthy seeds was recorded in the application of GRANOFORCE chemical powder, while the lowest was recorded in untreated (control). There were significant differences among the treatments tested at $p < 0.05$. The application of GRANOFORCE chemical powder has significantly recorded the highest weight of healthy seeds in the stored bean seeds compared to the rest of the treatments in all the months, followed by neem leaf powder at 70 grams per 350 grams of bean seeds and neem leaf powder at 60 grams per 350 grams of bean seeds. There were significant differences between GRANOFORCE chemical powder and the rest of the treatments. Similarly, at 30 DAT, there was a significant difference between the application of neem leaf powder at 70 grams and the untreated (control) seeds. However, no significant differences were observed between 70 grams per 350 grams of bean seeds and the rest of the botanical treatments at $p < 0.05$. At 60 and 90 DAT, the application of 70 grams of neem leaf powder was significantly different from 30 grams of neem powder, pepper powder at 2 grams, 3 grams, 4 grams, and untreated (control). There were no significant differences among the application of neem leaf powder at 70 grams, 60 grams, and 40 grams at 60 and 90 DAT. This result implies that *A. indica* can preserve the quality of bean seeds in the store. The increase in the weight of healthy seeds of beans treated with *A. indica* might be due to the toxic and antifeedant effects of chemicals present in the botanical powders. Most botanical pesticides affect insect pests by either deterring them from eating the stored crops or causing direct toxic effects that lead to their death [23].

Table 3. Effects of seed treatment on the weight of healthy seeds in stored bean seeds at 30, 60, and 90 Days After Treatment (DAT).

Treatments	December (30 DAT)	January (60 DAT)	February (90 DAT)
T1	286 ab	274 bc	264 b
T2	287 ab	279 bcd	270 c
T3	287 b	279 cd	271 c
T4	288 b	282 d	273 c
T5	282 ab	272 ab	262 b
T6	283 ab	273 bc	262 b
T7	285 ab	273 bc	263 b
T8	347 c	345 e	345 d
T9	280 a	266 a	255 a

Continued

Means	291	282	273
CV	1.2%	1.1%	0.9%

T1: Neem at 30 grams T2: Neem at 40 grams T3: Neem at 60 grams T4: Neem at 70 grams T5: Pepper at 2 grams T6: Pepper at 3 grams T7: Pepper at 4 grams T8: GRANOFORCE chemical powder at 0.35 grams T9: control group CV: Coefficient of Variance DAT: Days After Treatment.

3.4. Effect of Rates of Plant Products on Weight Loss of Bean Seeds during Storage

The weight of damaged seeds in the storage of bean seeds at 30 DAT, 60 DAT, and 90 DAT correspondingly (Table 4). The weight of damaged seeds varies from 3 to 70, 4 to 83, and 5 to 95 at 30 DAT, 60 DAT, and 90 DAT in that order. The highest weight of damaged seeds was recorded in the untreated seeds (control), while the lowest seed damage caused by insects was observed in the application of GRANOFORCE chemical powder. There were significant differences among the treatments tested at $p < 0.05$. The weight of damaged seeds in the stored bean seeds was significantly higher in the untreated (control) than the rest of the treatments in all the periods of observation, followed by pepper powder at 2 grams per 350 grams of bean seeds and pepper powder at 3 grams per 350 grams of bean seeds. There were significant differences between GRANOFORCE chemical powder and the rest of the treatments. Also, the application of 70 grams of neem powder differed significantly from the untreated treatment (control). The application of neem leaf powder at 70 grams, 60 grams, 40 grams, and 30 grams, pepper powder at 2 grams, 3 grams, and 4 grams at 30 and 60 DAT was not significantly different from one another. The effectiveness of *A. indica* in killing *A. obtectus* observed in this study might be due to the presence of volatile compounds with toxic, antifeeding, and larvicidal effects. [24] reported that these naturally occurring compounds include alkaloids, amino acids, flavonoids, and others which have been screened in several plants found to be toxic to the stored grain pests. The larvicidal property of *A. indica* is very important in the management of *A. obtectus* since the larval stage is the most destructive because the larvae bore a hole into the seeds to hide and feed [24].

Table 4. Effects of seed treatment on the weight of damaged seeds in stored bean seeds at 30 DAT, 60 DAT, and 90 DAT.

Treatments	December (30 DAT)	January (60 DAT)	February (90 DAT)
T1	64 bc	76 cd	86 c
T2	65 bc	72 bcd	80 b
T3	63 bc	71 bc	79 b
T4	62 b	68 b	77 b

Continued

T5	69 bc	78 de	88 c
T6	67 bc	77 cde	88 c
T7	65 bc	76 cd	87 c
T8	3 a	4 a	5 a
T9	70 c	83 e	95 d
Means	59	68	77
CV	7%	5%	3%

T1: Neem at 30 grams T2: Neem at 40 grams T3: Neem at 60 grams T4: Neem at 70 grams T5: Pepper at 2 grams T6: Pepper at 3 grams T7: Pepper at 4 grams T8: GRANOFORCE chemical powder at 0.35 grams T9: control group CV: Coefficient of Variance DAT: Days After Treatment.

3.5. Effect of Rates of Plant Products on Germination Viability of Bean Seeds after Storage

The effects of seed treatment on the viability of stored bean seeds at 30, 60, and 90 DAT, respectively (Table 5). The number of seeds germinated ranged from 63% to 97%. The highest seed germination was observed in the application of neem at 70 g, while the least was observed in the untreated (control). There were significant differences among the treatments tested at $p < 0.05$. The application of neem leaf powder at 70 grams significantly increased the percentage germination of bean seeds in store more than the rest of the treatments, followed by GRANOFORCE chemical powder at 0.35 grams per 350 grams of seeds and neem leaf powder at 60 grams per 350 grams of seeds. There were significant differences between neem leaf powder at 70 grams and the rest of the treatments. Similarly, the application of GRANOFORCE chemical powder was found to be significantly different from all other botanical treatments. There were no significant differences between the applications of pepper at 2 grams, 3 grams, and 4 grams. Also, there were no significant differences among the applications of neem at 40 grams and 60 grams, at $p < 0.05$. This could be attributed to the fact that neem leaf powder acts as an anti-feedant or modifies the micro storage environment, preventing the bean weevils from entering the seed to feed on the germ, thereby increasing their germination percentage. [25] reported that seeds treated with botanical extract did not lose their viability. [26] stated that various botanical extracts were effective in reducing oviposition and damage to *A. obtectus*, seed quality and viability were not affected. [27] reported that powders made from different botanical extracts provided complete protection against *A. obtectus*, and also did not show a significant effect on the seed germination rate.

Table 5. Effects of seed treatment on germination percentage of seeds (viability) in stored beans at the end of the experiment.

Treatments	Percent Germination (%)
T1	83 c

Continued

T2	86 d
T3	88 d
T4	97 f
T5	73 b
T6	75 b
T7	75 b
T8	92 e
T9	63 a
Means	82
CV	1.9%

T1: Neem at 30 grams T2: Neem at 40 grams T3: Neem at 60 grams T4: Neem at 70 grams T5: Pepper at 2 grams T6: Pepper at 3 grams T7: Pepper at 4 grams T8: GRANOFORCE chemical powder at 0.35 grams T9: control group CV: Coefficient of Variance DAT: Days After Treatment.

4. Conclusion

The results obtained from the study showed that neem leaf (*A. indica*) pepper (*C. annuum*) fruit powders and GRANOFORCE chemical powder tested against *A. obtectus* showed insecticidal activity. The application of neem leaf powder at 70 g and 60 g was found to increase mortality in bean weevils, weight of healthy seeds, reduce seed damage, and enhance seed viability more than the rest of the rates of the botanical extracts. Similarly, the application of dry pepper fruit powder at 3 g and 4 g significantly increased weevil mortality and reduced seed damage more than 30 g and 40 g of neem leaf powder. Therefore, this study has proved that the higher rates of neem leaf powder and dry pepper fruit powders are better in the storage of bean grains against *A. obtectus* than the control (zero application). Findings from the study recommend that neem leaf powder at the rates of 60 g and 70 g/350g bean seed is an effective alternative option to chemicals as seed treatment against *A. obtectus* for 90 days. This could address the problem of the inorganic pesticide residual effect in beans.

5. Limitations

This study was conducted in a laboratory setting over 90 days, which may not fully represent the complexities and variations of on-farm storage conditions. Future research should confirm the efficacy of these treatments under practical storage scenarios to ensure their effectiveness in real-world applications.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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