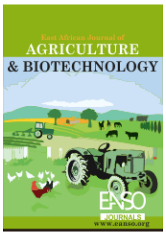

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Original Article

Effectiveness of Chia Seed Plant Powder in Comparison with Malathion in the Control of Bean Weevils

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Bean Weevil, Bean Varieties, Chia Seed Plant Powder, Malathion, Organic Pesticide, Synthetic Pesticide.

ABSTRACT

The primary objective of the research was to contribute to the control of storage pests in beans through the use of chia seed plant powder—an organic control method. The study adopted both descriptive and correlational research designs for data collection and analysis. It comprised: a survey of the chia seed farmers in Kyabugimbi sub-county, Uganda, for the purpose of assessing their perception concerning control of storage pests in beans through the use of chia seed plant powder; and an experiment for assessing the susceptibility of a variety of beans and pesticide application. The experiment had three bean varieties: NAROBEAN3, NABE16, and KAHURA. The type of pesticide had two treatments and control, that is, chia seed plant powder and malathion, and each had three levels. A control consisted of dishes with bean varieties infested with weevils without any pesticide added. Each set was comprised of control without any treatment. A total of 54 samples were used. These were laid out in a completely randomised Block design (CRBD) and replicated three times. Pesticides were applied at 0%, 50%, and 100% rates of application. Data were collected on the following measurements: Number of infested seeds, number of adult bruchids that emerged, and weight of seeds at the end of the experiment. The ANOVA test results found that the effect of pesticide application on the number of infested seeds, number of weevils that emerged, and weight of bean seeds was significant ($P < 0.01$), while the variety of beans was not significant. Although malathion had the lowest bean weevil figures and is therefore more effective in controlling bean weevils, it is a synthetic product, and chia seed would be promoted because it is an organic product because of being more friendly to the human body and the environment than malathion, a synthetic pesticide.

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INTRODUCTION

Leguminous crops are widely grown in the tropics and subtropics for human food as well as for animal feed. Examples include Cowpea (*Vigna unguiculata*), Pigeon pea (*Cajanus cajan*), Soya bean (*Glycine max*), Groundnut (*Arachis hypogea*) and common bean *(Phaseolus vulgaris*). They contain good quantities of most nutrients, especially protein, vitamins and minerals. Common bean (*Phaseolus vulgaris* L.) is one of the most important legumes in Uganda. It is one of the oldest crops known to man (Auma, 2010; Beebe et al., 2011). As food, it is an important source of high-quality proteins. In Uganda, it is consumed all year round because of its good storage properties. Nutritionists characterise it as a nearly perfect food because of its high protein content and generous amounts of fibre, complex carbohydrates, and other dietary necessities and hence view new varieties as powerful means of combating malnutrition. It is grown worldwide for its edible bean, popular as dry, fresh and green beans and can remain in storage for 3–4 years if stored in a cool, dry place, although with time, their nutritive value and flavour degrade and cooking times lengthen as they desiccate and harden (Abate, 2012).

Global bean production is expanding slowly, based on population growth, with the highest usage in poor (developing) countries, where beans provide an alternative to meat as a source of low-cost protein (Bokanga et al., 2008). In Africa, the common bean is recognised as the second most important source of human dietary protein and the third most important source of calories (Bokanga et al., 2008).

In Africa, the leading producers of beans are Tanzania, Uganda and Kenya, whose production volumes in 2010 were estimated at 950,000MT, 455,000MT and 390,598MT, respectively. In 2010, Uganda was ranked the second producer of beans after Tanzania in the East Africa Community region. In Uganda, beans provide 25% of the total dietary calorie intake and 45% of the protein intake (Hüskens 2015). They are also a major source of complex carbohydrates, essential micronutrients, dietary fibre, vitamin B and antioxidants in the nutritionally challenged diets of both the rural and urban poor. For centuries, beans have been produced mainly for food security at the household level and institutional level, especially in schools. However, currently, beans are a major source of income security (FAOSTAT, 2014).

Postharvest Constraints to Bean Production

Large volumes of beans continue to be lost during postharvest handling. At the farm level, postharvest losses occur at different stages of handling, from harvesting to marketing. However, the greatest postharvest losses of beans occur during the seed storage stage. At storage, losses occur mainly due to damage caused by a group of beetles called bruchids (Temu *et al*., 2011). Bruchids are reported to be the most important insect pests on most stored beans in Africa, causing losses of up to 100% (Abate *et al*., 2000). The damage that bruchids create causes extensive grain weight and quality losses through their feeding (Giga *et al*., 1990, Nahdy, 1994) and product alterations such as reduction of nutritional and aesthetic value, alteration of cooking characteristics (Mulungu *et al*., 2007) and

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reduction in viability of bruchid damaged seeds (Nahdy, 1990).

In most developing countries, farmers are faced with serious postharvest problems of weevils, especially in the storage of grains. Eggs are laid in cracks in the seed coat; larvae bore into the seed, making a translucent window in the seed before pupation. Larvae cause damage by eating the inner side of the bean, and this makes the beans unsuitable for consumption and inappropriate for sowing. The adult weevils then emerge through the window, leaving a neat round hole. When beans are attacked by weevils, they become less marketable, and this causes economic loss to the producers and quality loss to the consumers (Upadhyay et al., 2011).

Bean storage, as such, is limited due to bruchid infestations that result in heavy losses (Mushobozy & Swella, 2009). The bean weevil, *Acanthoscelides obtectus* (Say) and the Mexican bean weevil, *Zabrotes subfasciatus* (Boheman), are the common insect pests in a wider area where the common bean is growing (Mushobozy & Swella, 2009). Their attack results in yield reduction, poor grain quality, loss of seed viability, and unsuitable taste for human consumption (Prakash et al., 2008). Nyamweha and Stephen (2017) reported that plant products and insect infestation adversely affected the taste, aroma, and overall acceptability of sauce from beans affected by weevils rendering the seeds unsuitable for human consumption. Farmers commonly use synthetic insecticides to keep common bean grains free of insect infestation and to reduce damage during storage (Taponjou et al., 2002). They use insecticides without having the appropriate knowledge of their application and drawbacks like the development of resistance, environmental pollution and poisoning of fauna and flora (Prakash et al., 2008; Taponjou et al., 2002). To date, attention is being diverted to looking for effective, biodegradable, simple to apply, and homemade control options such as oil extracts of botanical origin for the management of bruchids (Olotuah, 2013). Oils of many plant species are known to have one or more insecticidal properties in terms of pest control such as fumigants, repellents, toxicants and oviposition deterrents among others (Mushobozy & Swella, 2009; Olotuah, 2013).

As a result of weevils, many small-scale farmers prefer to sell most of their crops immediately after harvesting to avoid making losses from the infestation of the weevils. Farmers who want to keep their produce from weevil infestation resort to the use of synthetic pesticides, which are expensive and not affordable by farmers. The misuse of these chemicals frequently occurs since the majority of small-scale farmers in many African countries are illiterate. The chemicals contaminate stored food commodities, leaving behind harmful residue (Maribet & Aurea, 2008). Synthetic pesticides are not only expensive but may also have harmful effects on the health of consumers. That aside, some weevils have developed some resistance to some of the synthetic pesticides. As such, finding alternative natural solutions to the problem of weevils in beans is paramount.

Crude powders of several plant species have been shown to have no adverse effects on the palatability and germination of beans and other grains. This has stimulated researchers to search for natural pesticides that are environmentally friendly, safe for man and other non-target organisms and have no adverse effects on the organoleptic and market quality of stored grains. Chia seed powder is one of the natural pesticides that have been found to control bean weevils (Upadhyay et al., 2011).

Chia seeds plants have been shown to have repellent effects against certain insect pests of stored grains (Peiretti & Gai, 2010), supporting indigenous farmer practice of their widespread use as grain protectants. However, conclusive recommendations on their use can only be made after the effects of these botanicals on grain quality and safety are ascertained.

In Kyabugimbi sub-county Bushenyi district, farmers have adopted planting chia seeds due to the ready market and high prices attached to it. Although farmers are planting chia seeds, they

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have concentrated on harvesting seeds hence neglecting other plant parts like leaves and branches (Bushenyi District, 2018). Due to their repellent characteristics, plant parts of chia seeds have been adopted and used as a possible alternative bio-pesticide in controlling bean weevils by some farmers in the study area, but farmers still have doubts about their efficacy. It is on this basis that the study to establish the efficacy of Chia seed plant powder on the control of bean weevil will be carried out.

Problem Statement

Bean production's postharvest losses are one of the major challenges affecting product quality, farmers' incomes and food security due to bean weevils in the storage process. In Uganda, it is estimated that 20-50% of produce can be lost because of infestations from weevils and other insects (Epidi & Esther 2008). As a result, most farmers do not grow beans in large quantities and if they do, they sell them immediately after harvesting when prices are miserly low (Epidi & Esther, 2008)—still incurring huge losses. Chemicals for fumigation or seed treatment are available, but they might be expensive aside from having health considerations. The current global trend is towards the consumption of food produced using safe and preferably natural plant protection products. Detection of hazardous chemical pesticide residues in foods and increased consumer awareness of food safety has resulted in the ban of certain pesticides in agricultural production; as such plant-based pesticides for organic agriculture are gaining popularity. Traditionally, farmers at the subsistence level use natural methods and products such as ash and powder from plant parts to control weevils' damage in storage. Bio-organic insect control agents enable farmers to increase the storage life of beans for food security (Amoabeng et al., 2020). Organic weevil control also helps the farmers to store the beans and sell them when the market prices are good. Yet there is a scanty investigation on the effectiveness of traditional insecticides' control of pests. It was against this background that current research to investigate the potential effectiveness of chia seed, which is already being used by some farming communities, was initiated.

The purpose of the study was to contribute to the control of storage pests in beans through the use of chia seed plant powder. The study objective was to determine the perceptions of farmers on the use of chia seed plant in the control of bean weevil. It tested the hypothesis stating: "*H_0: There is no significant difference in the control of bean weevils between chia seed plant powder and malathion",* against the alternative hypothesis: "*H1: There is a significant difference in the control of bean weevils between chia seed plant powder and malathion"*.

LITERATURE REVIEW

The common bean (*Phaseolus vulgaris*) is an annual leguminous plant that belongs to the genus *Phaseolus*; order *Rosales*; family *Fabaceae*; subfamily *Papilionoideae* and tribe *Phaseoleae* (Kwak & Gepts, 2009). Cultivated forms are herbaceous annuals, which are determinate or indeterminate in growth habits (Beebe *et al*., 2011).

Bean seeds may be round, elliptical, somewhat flattened or rounded elongated in shape, and a rich assortment of coat colours and patterns exists (Acosta-Diaz *et al*., 2009). Seed size ranges from 50 mg to more than 200 mg seed in some large seeded varieties (Michaels *et al*., 2006). Also, seeds are non-endospermic and vary greatly in size and colour from the small black wild type to the largely white, brown, red, black or mottled seeds of cultivars, which are 7-16 mm long (Katungi *et al*., 2009).

East Africa, especially Uganda, largely grows Nambale, K131 (1994), K132 (1994), NABE 2(1995), NABE 3, NABE 4, NABE 5, NABE 12, NABE 4, NABE 15 to 2 and Narobean 1, 2 and 3 (Africa-Uganda-Business-Travel-Guide, 2022; Farming Uganda, 2022).

According to Kisetu *et al*. (2012), in East Africa, common bean is grown primarily by small-scale farmers who have limited resources and usually produce the crop under adverse conditions such as

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low input use, marginal lands, intercropping with competitive crops and pests and diseases. Bean pests and diseases are among the most serious problems hindering bean production. Currently, the most serious storage pests of beans are weevils (Bautista-Sosa et al., 2021). Postharvest loss caused by pests may exceed 20% in poorly developed and tropical countries due to inadequate management practices and environmental conditions that allow rapid reproduction of pests, especially in developing countries.

Bean Bruchids (Acanthoscelides obtectus)

Bruchids, commonly known as pulse beetles, are a serious threat to legumes worldwide. Many of the bruchid species have crossed geographical boundaries and have become cosmopolitan in distribution through human-mediated migrations and the import/export of food grain (Sayeda et al., 2019). This made these pest species highly adaptive and hence are distributed from temperate to tropical climates.

Bruchids infest seeds of many grain legumes, both in the field and in storage. The Neotropical origin bean weevil, *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchinae), is a serious pest of kidney beans, *Phaseolus vulgaris* L., *P. lunatus* L. and other legume seeds in Africa, Australia, Europe, America, the Mediterranean area, and various other parts of the world. *A. obtectus* infests the different hosts in the fields and stores and is rendered unfit for consumption (Sayeda et al., 2019).

Populations of *A. obtectus* are most commonly detected in stores of dried legumes and their life cycle appears well adapted for reproduction in a storage environment. The females lay eggs in clusters under or nearby a single seed. The first instar larvae burrow into a seed where the beetles spend their larval and pupal stages. The final instar larvae excavate chambers just below the seed and the presence of a larva may be detected by a small "window". They cause damage by reducing the mass and/or volume, reducing the physiological quality and germination capacity, increasing the temperature and water content of the seeds. Unlike most of the other bruchids, *A. obtectus* Say's reproductive cycle is continuous, without imaginal diapause for temperatures between 14-35°C, and it attacks the beans in fields as well as stored seeds. Larvae feed on beans and cause losses of more than 30% of stored products (Sayeda et al., 2019). This insect completes its entire life cycle within stored dry beans without returning to the field. *A. obtectus* may adapt to several leguminosae: its host plant, *P. vulgaris* L. and some non-host plants such as *Vigna unguiculata* (Walp.) and *Cicer arietinum*.

Management of Bruchids

Curative measures are frequently used in the management of bruchids to contain the damage in both large- and small-scale legume grain stores. The commonly used and commercially available chemicals for control of bruchid infestation in stored grain legumes include insecticides in pyrethrins, organophosphates, carbamates, and fumigants (carbon disulfide, carbon tetrachloride, methyl bromide, ethylene dichloride, ethylene dibromide, chloropicrin, and phosphine) groups (Salunkhe *et al.*, 1985). The use of chemical control has been limited by the high cost of the chemicals (Sode et al., 1995), inadequate training and consequently, poor applications leading to insect resistance and human health hazards (Annis *et al.*, 1990). Hence the need to develop the use of nature-friendly bruchid control measures.

However, the practical problems of ensuring the availability of stable insecticide formulations, especially with ready-to-use dusting powders, have proved to be the major constraint on the successful widespread use of the technique. Malathion, in particular, is very prone to instability if formulated as a dilute dusting powder (usually at 2% w/w) on an unsuitable carrier. Spraying the surface of a bulk of uninfested grain in a bin or in flat bulk storage can give quite good protection against reinfestation for a limited period, depending on the persistence of the insecticide used (Course Hero, Inc., 2023). Application rates would be similar to those indicated for other surface treatments. For

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sustained protection, the treatment would have to be repeated rather more frequently than is usually recommended. The decay of insecticidal effectiveness on exposed surfaces is generally faster than in bulk treated by admixture and re-spraying at intervals of more than 1-2 weeks is likely to allow a limited build-up of infestation which, once established in grain below the surface, will be largely unaffected by retreatment.

Chemical Pesticides

Over the years, synthetic chemicals such as ammonia and propionic acid have been used to control stored grains against fungal attacks and have drawn considerable attention (Frazier and Westhoff, 2014). These compounds have been shown to be effective in preventing fungal growth. However, when they are too much on the grains, there could be brought about chemical poisoning, environmental pollution and resistance development by fungi to the chemical agent.

Control of pest insects affecting stored grains is performed principally by using synthetic insecticides, including phosphine (PH3), pyrethroids, and organophosphorus compounds (Gourgouta et al., 2019). However, there is worldwide concern regarding the continued and indiscriminate use of pesticides, which may pose risks to human health as well as the environment, highlighting the need to implement new control strategies for pest management of stored products (Gonçalves et al., 2015;). This concern has increased the necessity for alternative methods of control, such as the use of resistant varieties (Amusa et al., 2018).

Biological Control

Locally available plants in many parts of the world are currently used to confer protection of stored products against insect infestations (Khater, 2012). According to Hassanali and Koppel (1989), neem leaves, and seeds are used by Indian farmers for the control of stored grain pests. Traditionally cowpeas are admixed with ash and then put into granaries or jars of mud and clay in northern Cameroon (Oben & Nebantonifor, 2015)

Plant powders are ecological agents for pest management in grains stored by small-scale farmers. Bautista-Sosa et al. (2021) evaluated the effects of plant powders of leaves of basil (*Ocimum basilicum*), spearmint (*Mentha spicata*), wormseed (*Chenopodium ambrosioides)* and rue (*Ruta graveolens*) on the mortality, repellences, and infestation of *Zabrotes subfasciatus* in stored grains of *Phaseolus lunatus.* The plant powders were applied at a concentration of 1% (weight/weight) to grain samples stored in plastic containers, and subsequently, the grains were infested with Z. *subfasciatus* adults. Results showed that the powder of *C. ambrosioides* caused 96% and 100% mortality in Z. *subfaciatus* adults at 2 and 4 days after exposure, respectively. The powder of C. ambrosioides caused a decrease in oviposition and progeny production. The powder of C. ambrosioides prevented damage to the grain. Plant powders of the other species had minimal repellent effects. The implication was that plant powders represent a feasible alternative to manage pest insects of stored grain. The powder of C. ambrosioides prevents damage by Z. *subfasciatus* in stored grains of P. *lunatus*. However, their efficacy of biological control is not well quantified. Limited research on the biological control agents of *A. obtectus* is attributed to socio-economic practices and biases intolerant of any insect, beneficial or pest, in stored commodities (Arbogast, 1976).

Perception of Farmers on the Use of Chia Seed plant powder on the Control of Bean Weevil

The World Health Organisation estimates pesticide poisoning rates at two to three people per minute (Farmbizafrica, 2019). There are several ways, organically, farmers have been controlling bean weevils by avoiding synthetic pesticides. Syombua (2015) reports that crude plant products have been widely used by different communities in Africa for pest control. Mesele et al. (2019) analysed the Mexican bean weevil, *Zabrotes subfasciatus* (Boheman) and said that it is a major constraint of stored common beans that causes qualitative and quantitative losses.

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Laizer et al. (2019) examined farmers' knowledge, perceptions and practices in managing weeds and insect pests of common beans in northern Tanzania. They state that a survey of 169 smallholder farmers was conducted in two common bean-growing districts. The results revealed insect pest management was mainly achieved through the use of synthetic pesticides; however, only 24% of farmers were able to apply. The rest could not afford it due to high costs, limited access, and lack of knowledge. Only 6.5% of farmers were aware of non-chemical methods and 2.1% did not practice any method in managing insect pests. These findings indicate that there is a need to sensitise and train farmers on sustainable methods for pest and weed management in common bean farming systems in northern Tanzania.

The leaves of chia contain an essential oil that contains β-caryophyllene, globulol, γ-muroleno, β-pinene, α-humoleno, germacren-B, and widdrol. These compounds are believed to have strong repellent characteristics that can assist in controlling major pests, especially weevils, *Rhizopertha dominica*, *Trogoderma granarium*, *Tribolium castaneum*, and *Cadra cautella that affect pulse in stores* (Ahmed et al., 2006).

From the literature review, therefore, it was concluded that even though there is potential for chia seed as a pest control strategy, there are few studies on the use of chia seed in insect pest control. The use of chia seed to control storage pests like bean weevils has not been studied. It is therefore, that a study be carried out on the use of chia seed plant powder in controlling bean bruchids (bean weevils).

METHODS

The study comprised a survey of the chia seed farmers in Kyabugimbi sub-county; and an experiment. The survey served the purpose of getting into the perceptions of farmers concerning chia seeds. The farmers' perception provided valuable insights concerning the control of storage pests in beans through the use of chia seed plant powder compared to malathion, a synthetic alternative. Chia seed farmers were targeted because they were directly concerned with the problem under investigation. According to the Kyabugimbi Sub-County agricultural officer, there are over 500 chia seed farmers in the Sub-county.

The sample size used Gay's (1992) view of the minimum acceptable sample size for a survey, which the scholar stated should be between 10% and 20% for a small population of as low as 500 entities. The study utilised a sample size of 50 chia seed farmers. The study employed a simple random sampling technique in selecting the respondents (Sekaran, 2006).

A questionnaire was used in collecting data for the study. A structured questionnaire that had closed-ended questions was designed and used to generate quantifiable information from the respondents.

The experimental procedure in this study used three varieties of beans: NAROBEAN3; NABE16; and KAHURA with chia seed plant powder and malathion, and each had three levels. Bruchids were collected from farmers' stored beans during the bean genotype collection. They were then reared under ambient conditions within a laboratory.

The grains were obtained from a fresh harvest of dry beans from farmers. The grains were sorted to remove damaged chaff and some deformed seeds. The seeds were packed in a waterproof jerrycan to inactivate any bruchids in the seeds, after which the seeds were spread on a clean, disinfected and dry table and covered with a white Muslim cloth for 2 weeks to observe if there were any emerging bruchids and also to allow the seeds to stabilise at the same moisture content.

Fresh black and white chia seed plants and stems were collected from chia seed farmers and then dried on clean trays for a week. Chia seeds are available in three colours, but black and white chia seeds are only good for health (Yadav, 2022). There is virtually no difference between white and black chia seeds. Nutritionally, they have an

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almost identical makeup, and both colours of chia seed taste precisely the same.

The collected chia seed plants were ground by pestle and mortar and then crashed into powder. The powder was kept in a dry closed tin to be used in the experiment. Malathion of 50g distant powder was bought from the Agro-input shops in Kabwohe town.

One kilogram of bruchids-infested common beans was brought from a beans store. Adult bruchids of *A. obtectus* were removed and introduced into a clean, fresh container. The adult females were distinguished by distinct black spots on both sides of the elytra, while the adult males have brown elytra but without black spots (Allen, 1996). Thirty live bruchids were used to infect the seeds in each container in a female: male ratio of 20:10.

Whole grains of beans were used for rearing. The bruchids were reared on 1kg of seed placed in two-litre plastic buckets. The buckets were covered with a muslin cloth to allow ventilation but restrict the bruchids from running away. The bruchids were allowed to lay eggs and hatch. Sieving was done to obtain bruchids for regular transfers to infest new grain in different jars of beans. Breeding of bruchids was done for two months until when enough population of adult bruchids was obtained to infest the whole experiment.

Experimental Treatments and Design

The study examined two factors: i) Bean variety and ii) type of pesticide; there were two treatments for the pesticide, namely, chia seed plant powder and malathion and control, i.e. No pesticide. Each pesticide had three levels that are 0%, 50% and 100%. There were three bean varieties used: i) NAROBEAN 3, NABE16, and KAHURA. A control consisted of dishes with bean varieties infested with weevils without any pesticide added. Each set comprised a control without any treatment. Therefore, a total of 54 samples were used. These were laid out in a completely randomised block design (CRBD) and replicated three times. The bean variety was the main treatment, while the types of pesticide were the sub-treatments. According to FAO (2018), 90 kg of beans need a dosage of 50g of malathion, and 0.28g of malathion was applied to the experiment’s 500g of beans in a plastic dish of 500 ml.

Applying plant powders of leaves of basil (*Ocimum basilicum),* spearmint (*Mentha spicata),* wormseed (*Chenopodium ambrosioides)* and rue (*Ruta graveolens)* to control bean weevil, Bautista-Sosa (2021 applied at the concentration of 1% (weight/weight) to grain samples stored in plastic containers. Borrowing from Bautista-Sosa, this study used a rate of 5g of chia seed to 500g of beans in a plastic dish of 500 ml.

Farmers can also mix a teaspoon of corn oil such as Elianto with a one-kilogram tin of grains.

Plate 1: Experimental arrangement

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Two hundred fifty grams of bean seeds of each variety were put into plastic dishes of 500ml. Each dish was inoculated with 30 live bruchids, each whereby 20 were female, and 10 were male. Then pesticides were also introduced in each dish. For the control plastic dishes, bruchids were introduced without adding pesticides. The dishes were covered with a white muslin cloth to prevent either entrance or escape of the bruchids as well as to allow ventilation. The dishes were allowed to stand on the table undisturbed for two weeks.

Data collection started 10 days after infestation, and it was done every after 2 weeks when adults started emerging. The seeds were carefully examined and data was collected on the following variables: Number of holes in infested seeds - the number of holes in infested seeds in the plastic dishes was counted after every 2 weeks; Number of bruchids which emerged - the number of bruchids that emerged after oviposition was counted after every 2 weeks and removed from the plastic dishes; and Weight measurement - the weight of the beans in each plastic dish for all the treatments was determined before infestation and after infestation. The weight was determined using an electronic analytic weighing balance. The loss in weight due to bruchid damage was determined using the formula of Seram et al. (2016).

The experimental data collected was captured into an MS Excel sheet, where it was organised and exported to GenStat for analysis. It was analysed using analysis of variance (ANOVA) in GenStat software. The mean pesticide performance in bean weevil control and the susceptibility of bean varieties to bean weevil damage parameters were analysed.

RESULTS

Survey

The survey questionnaire was administered to 50 farmers in the Kyabugimbi sub-county, which is found in Bushenyi District, western Uganda. The response rate was 43/50, representing 86%, which is a good representation.

The results of the survey indicate that the majority of the farmers, 55.8%, were females and the rest, 44.2% were males. The study findings also indicated that 27.9% of the respondents were between 36-45 years, followed by 25.6% who were between 46 – 55 years, 18.6% - 25-35, 16.3% - 56 years and above and 11.6% who were below 25 years. This implied more females were involved in chia seed growing and activities than males. The majority age of respondents was 36 years old and above.

Findings also showed that 32.6% of the respondents studied up to the primary level, 30.2% studied up to the secondary level, 20.9% had informal education, and the rest, 16.3% studied up to a tertiary level. The study also showed that most of the respondents (69.8%) were married, and 11.6% were singles, equivalent to those that were separated/divorced. Survey findings on chia seed growing and usage are shown in the table below.

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Table 1: Technical information on chia seed

Details	Label	Quantity	%
Growing chia seed	Yes	35	81.4%
	No	8	18.6%
The part of the chia seed plant mostly used by farmers	Leaves	2	5%
	Seeds	35	95%
Form in which chia seed plant parts were utilised	No idea	5	12%
	Powder Sprinkled in food	2	2%
	Seeds added to food	33	80%
	Added into tea	1	2%
Soil types favouring growth of chia seed	Loam	10	27%
	Sandy	27	73%
How farmers grew chia seed	Intercropping	12	34%
	Mono cropping	23	66%
If experienced pests if chia seed was grown with other crops	Yes	4	33.3%
	No	8	66.7%
How chia seeds are harvested	By use of hands	37	86.0%
	No idea	6	14.0%
How chia seeds are preserved	Sun drying	31	84%
	Smoking	6	16%
How chia seed residues were disposed off after threshing	Mixing them in stored beans	12	29%
	Discard	25	61%
	No idea	4	10%

Effect of Variety of Beans and Pesticide Application on Number of Infested Seeds

The pesticide effect on variety and pesticide application on the number of holes of infested seeds were generated and are presented in *Table 2* below.

Table 2: Mean number of holes as affected by variety and pesticide application (Experiment 1)

Pesticide Variety	Chia0	Chia50	Chia100	Malathion0	Malathion50	Malathion100	Means
KAHURA	41	30.3	20.7	30.0	25.7	13	26.8
NABE16	40.7	25.0	17.3	41.3	22.3	11	26.4
NAROBEAN3	42.0	24.7	17.0	41.0	22.7	11.33	26.3
Means	41.2	26.7	18.3	37.4	23.6	11.8	
LSD	Variety					3.5	
	Pesticide					5.0	
	Variety* pesticide					8.7	

The mean of the number of holes of infested seeds, in *Table 2*, shows that in Experiment 1, the variety LSD was not significantly different. NAROBEAN3 had only a slightly lower number of holes (26.3) than the other varieties. However, the application of malathion pesticides and chia seed plant powder had significant effects both at half and full doses. For example, the application of 100% malathion pesticide significantly reduced the number of holes (11.8) compared to 37.4 and 23.6 for zero and 50% levels, respectively.

Similarly, the application of 100% chia seed plant powder significantly reduced the number of holes (18.3) compared to 41.2 and 26.7 for zero and 50% levels, respectively.

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Table 3: Mean number of holes as affected by variety and pesticide application (Experiment 2)

Pesticide Variety	Chia0	Chia50	Chia100	Malathion0	Malathion50	Malathion100	Means
KAHURA	41	24.33	17.67	40.33	25.67	11.33	26.7
NABE16	40.67	25.33	17.33	41.33	22.33	11	26.3
NAROBEAN3	42	24.33	17	41.67	22.67	11	26.4
Means	41.2	24.7	17.3	41.1	23.6	11.1	
LSD	Variety				0.6		
	Pesticide				0.8		
	Variety* pesticide				1.4		

The mean of the number of holes of infested seeds, in *Table 3*, shows that in Experiment 2, the variety LSD was not significantly different. NABE16 had only a slightly lower number of holes (26.3) than the other varieties. However, the application of malathion pesticides and chia seeds plant powder had significant effects both at half and full doses. For example, the application of 100% malathion pesticide significantly reduced the number of holes (11.1) compared to 41.1 and 23.6 for zero and 50% levels, respectively.

Similarly, the application of 100% chia seed plant powder significantly reduced the number of holes (17.3) compared to 41.2 and 24.7 for zero and 50% levels, respectively.

Effect of Variety of Beans and Pesticide Application on Number of Weevils that Emerged

The pesticide effect on variety and pesticide application on the number of weevils that emerged was generated and presented in *Table 4* below.

Table 4: Mean effect of variety and pesticide application on the number of weevils that emerged (Experiment 1)

Pesticide Variety	Chia0	Chia50	Chia100	Malathion0	Malathion50	Malathion100	Means
KAHURA	33	25.33	16.33	22.67	16	11.67	20.8
NABE16	37.33	26.33	18	15.33	16	12.33	20.9
NAROBEAN3	33.67	29	24	16.67	14	15	22.1
Means	34.7	26.9	19.4	18.2	15.3	13.0	
LSD	Variety				1.1		
	Pesticide				1.6		
	Variety* pesticide				2.8		

The mean of the number of weevils that emerged, in *Table 4*, shows that in Experiment 1, the variety of LSD was not significantly different. KAHURA had only a slightly lower number of weevils that emerged (20.8) than the other varieties. However, the application of malathion pesticides and chia seed plant powder had significant effects both at half and full doses. For example, the application of 100% malathion pesticide significantly reduced the weevils that emerged (13.0) compared to 18.2 and 15.3 for zero and 50% levels, respectively.

Similarly, the application of 100% chia seed plant powder significantly reduced the weevils that emerged (19.4) compared to 34.7 and 26.9 for zero and 50% levels, respectively.

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Table 5: Mean effect of variety and pesticide application on the number of weevils that emerged (Experiment 2)

Pesticide Variety	Chia0	Chia50	Chia100	Malathion0	Malathion50	Malathion100	Mean
KAHURA	33	25.33	16.33	36.67	22.67	11.67	24.3
NABE16	37.33	26.33	18	32.33	15.33	12.33	23.6
NAROBEAN3	33.67	29	24	35	16.67	15	25.6
Mean	34.3	27.2	19.1	18.6	15	13.3	
LSD	Variety				0.4		
	Pesticide				0.8		
	Variety* pesticide				1.4		

The mean of the number of weevils that emerged, in *Table 5*, shows that in Experiment 2 shows, the variety LSD were also not significantly different. NABE16 had only a slightly lower number of weevils that emerged (23.6) than the other varieties. The application of malathion pesticides and chia seed plant powder had a significant effect both at the half and full doses. For example, the application of 100% malathion pesticide significantly reduced the weevils that emerged (13.3) compared to 18.6 and 15 for zero and 50% levels, respectively.

Similarly, the application of 100% chia seed plant powder significantly reduced the weevils that emerged (19.1) compared to 34.3 and 27.2 for zero and 50% levels, respectively.

Effect of Variety of Beans and Pesticide Application on Weight of Beans

The pesticide effect on variety and pesticide application on the weight of beans were generated and presented in *Table 6* below.

Table 6: Mean effect of a variety of beans and pesticide application on the weight of beans (Experiment 1)

Pesticide Variety	Chia0	Chia50	Chia100	Malathion0	Malathion50	Malathion100	Means
KAHURA	64.6	70.87	73.73	63.7	69.67	90.57	72.2
NABE16	63.37	70.83	71.43	63.9	67.87	88.87	71.0
NAROBEAN3	64	69.53	66.7	61.03	69.7	87.97	69.8
Means	64.0	70.4	70.6	62.9	69.1	89.1	
LSD	Variety				1.54		
	pesticide				2.18		
	Variety* pesticide				3.77		

The mean weight of seeds, in *Table 6* above, shows that in Experiment 1 of the variety, LSD was not significantly different. KAHURA had a slightly higher weight (72.2gm) than the other varieties. However, the application of malathion pesticides and chia seed plant powder had significant effects both at half and full doses. For example, the application of 100% malathion pesticide significantly saw higher weight (89.1gm) compared to 62.9gm and 69.1gm for zero and 50% levels, respectively.

Similarly, the application of 100% chia seed plant powder significantly saw higher height (70.6 gm) compared to 64.0 gm and 70.4 for zero and 50% levels, respectively.

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Table 7: Mean effect of a variety of beans and pesticide application on the weight of beans (Experiment 2)

Pesticide Variety	chia0	chia50	chia100	malathion0	malathion50	malathion100	Means
KAHURA	63.6	70.07	72.73	62.7	70.67	88.57	71.39
NABE16	63.57	69.83	71.03	65.9	65.87	86.87	70.51
NAROBEAN3	63	69.53	67.7	60.03	70.7	86.97	69.66
Means	63.39	69.81	70.49	62.88	69.08	87.47	
LSD	Variety				1. 45		
	Pesticide				2. 81		
	Variety* Pesticide				3.87		

The mean weight of the weight of seeds in *Table 7* above shows that in Experiment 2, the variety LSD was not significantly different. KAHURA had a slightly higher weight (71.39gm) than the other varieties. However, the application of malathion pesticides and chia seed plant powder had significant effects both at half and full doses. For example, the application of 100% malathion pesticide significantly saw higher weight (87.47gm) compared to 62.88gm and 69.08gm for zero and 50% levels, respectively.

Similarly, the application of 100% chia seed plant powder significantly saw higher height (70.49gm) compared to 63.39gm and 69.81 for zero and 50% levels, respectively.

DISCUSSION

The study evaluated the effectiveness of chia seed plant powder and malathion pesticides among three bean varieties, namely: KAHURA, NABE16, and NAROBEAN3. The main parameters used for assessment included the means of the number of holes in infested seeds, the number of weevils that emerged, and the weight of beans.

The mean numbers of holes were significantly higher where no pesticides were applied. The number of holes consistently decreased with an increase in the level of pesticide application. The implication is that the pesticide was effective in controlling the bean weevils. The results are in agreement with Purushothaman et al. (2012)., who said that bio-pesticides of plant origin are efficient as grain protectants, and farmers are adopting and continuing to use them because they are convinced by their efficacy.

Similar results have been observed in the number of weevils that emerged; and the weight of beans. The number of weevils that emerged also steadily decreased with an increase in the level of pesticide application, while the weight of beans increased with an increase in the level of pesticide application.

These findings are in agreement with Eduardo et al. (2016), who stated that the chemical control of bean weevils is effective, quick, secure and economical. However, the scholar also noted that chemical control has some major drawbacks: negative impact on products and the environment; the constant danger of intoxication for humans and animals; the presence of residues in different parts of the plants; the appearance of the pest species of resistance to the pesticide. In light of the application of chia seed pesticide, this study's results are agreement with Grzywacz et al. (2013), who stated that pesticidal plants are proven to be a perfect alternative against insect pests, adding that for many years, indigenous Africans have been using the available pesticides at their disposal from plants and other organisms for different purposes including insect pest control. The findings are also in agreement with Yeboah et al. (2014), who said that chia leaves contain essential oils capable of carrying a repellent action against insects, and thanks to this characteristic, Muñoz et al. (2013) report previous observations that this crop can be grown without pesticides or other chemical compounds.

The important point is that chia seed plant powder is compared quite well with malathion. This is it similarly reduced the number of holes and weevils that emerged. In addition, chia seed is also

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cheaper! On the environment, chia seed is much safer, and farmers should be encouraged to grow it.

CONCLUSIONS

The study concluded that majorly of the respondents faced a problem of pests and diseases. Fortunately, respondents used chia seed plant powder to control weevils as an effective method. The potency of chia seed plant powder at different doses was indicated by increased mortality and reduced reproductive performance of bean weevils during the study period. It was observed that the mortality of bean weevils in stored beans is dependent on the type of traditional insecticide material used, the dose applied to the beans as well as the duration of the treatment. The decreased insect population is a condition of paramount importance in pest control strategies. Based on the increased mortality and/or reduced to no reproduction of bean weevils, it is deduced that the chia seed plant powder form has the potential to control the weevil's storage systems at the determined doses, which decreases the insect population. The damage caused by these weevils resulted in severe weight loss of the legume seeds, thus reducing their quality, quantity, and market value. Uncontrolled attacks of the weevils on stored bean products and subsequent weight loss will invariably lead to reduced food security in society as the original weight and quality of the legumes before infestation that gives maximum satisfaction when beans are consumed are drastically reduced by the bruchids.

Recommendations

Chia seed plant powder was a very promising non-chemical pesticide and therefore could be strongly promoted as one of the effective control materials against bean weevils. This is suggested considering its potential to minimise effects on the environment. It is also less costly. It may be postulated that the potency of the materials adequately demonstrates the ingenuity of the smallholder farmers in combating stored bean loss and enhancing food security. In light of the results and given that the materials are readily available, sustainable, environment friendly (as they are biodegradable) and cost-effective, it is recommended that farm storage trials of the identified insecticide materials should form issues for the next research. Further, investigations of which exact part of the plant contains the insecticidal chemicals and identifying the exact chemicals responsible for the death of insects could be carried out.

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