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Extermination of Insect Pests (Coleoptera: Bruchidae) and Damage of Stored Pulses by Different Methods in Market

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Abstract

Pulses or grain legumes occupy an important place in the world's food and nutrition practicality. These are among few important constituents in the diets of a very large number of peoples, especially in the developing countries, as pulses are good sources of protein which help to supplement cereal diets improving their protein nutritive value. These also provide substantial quantities of minerals and vitamins to the consumer's diet. Although most legumes are consumed as dry grains, yet immature green pods or green seeds are also used as vegetables. This publication describes insect pests of stored pulses and outlines methods for their detection, prevention and control. Pulses are more difficult to store than cereals and they suffer much greater damage from insects, which not only results in quantitative losses, but also in qualitative reduction of the nutritive value because of vitamin loss and deterioration of protein quality. The milling losses in insect-damaged pulses are even higher as more breakage and powdering occur with such grains. There are a number of species of Callosobruchus (Bruchidae) that may be found attacking pulses, of which the most common and well known are *Callosobruchus maculatus* (Fabricus), C. *analis* (Fabricius) and C. *chinensis* (Linnaeus). Damage ranging from 30 to 70 per cent of the grains has been reported in various publications. High temperature, high humidity, softness and high nutritive quality, as well as storage in small quantities, are all conducive to insect damage. To avoid or control damage caused by pests, the producers and dealers needs to understand the problem and use current control practices. Losses may be aggravated by protracted storage, unhygienic warehouse conditions and left-over infested sweepings. A clean, dry and cool store together with clean and dry grain is the first and most important steps to successful storage of pulses. Regular monitoring and pest forecasting, use of natural plant products and bio-pesticides alone or in combination with synthetic pesticides, deployment of insect resistant varieties, and rational use of selective chemicals can keep the stored products free from insect pests.

Keywords

Bruchid, Callosobruchus, Storage Pests, Pulse, Legume

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1. Introduction

Insects need food, air and water to live, and in many cases stored grain provides a perfect place for insects to live and grow because food, air and water are available in sufficient quantities. This is why some insect species infest stored products and the major insect pests in stored grains and pulses are beetles. The larvae of beetles are totally unlike to the adult forms, they look a little like worms and sometimes are not discovered because these develop inside the kernel. Insect pests can damage stored grains by reducing dry weight, nutritional value and seed viability. Prolong storage of such crops occurs mainly on the farm, so pests are most likely to cause damage in farm stores. Pulses (Fabaceae [Leguminosae]) are important sources of protein, fats, carbohydrates, sugars and vitamin- B. Pulses include faba

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beans, chickpea, field pea, navy bean, soybean, pigeon pea, lentil, sweet pea, *Vigna radiata* (mung bean), *Vigna unguiculata* (cowpea), black gram (*Vigna mungo*), and moth bean (*Vigna aconitifolia*) (Semple et al., 1992; Deeba et al., 2006; Sarwar, 2013 a).

Insects are rarely a problem in stored pulse crops, but the exceptions are bruchids of the family Bruchidae which can infest seed in the field and continue to multiply during storage. Heated or pest infested crops in storage quickly lose weight and quality and may cost to individual farmers with thousands of dollars lost in income. Storing pulse grains cool and dry in clean and uninfested bins that are weather proof and well-aerated prevents such losses, maintains quality, and assures saleability. The small and light-avoiding insect pests of stored pulses can penetrate deep into bulk-stored grains. In empty bins, these hide in cracks and crevices where they survive in residues until a newly harvested grain arrives. Of more than hundred species of stored-product insects, beetles are the most-common stored-product pests and the larva is the only stage during which the insect grows that consumes several times more food than its own body weight. The pulse beetles, *Callosobruchus maculatus* (Fabricus), C. *analis* (Fabricius) and C. *chinensis* (Linnaeus) are the most serious pests of pulses in tropical and subtropical countries. They infest pulses both in the field and in storage, causing considerable economic losses (Ramzan et al., 1990; Bousquet, 1990).

2. Insects Infesting Stored Pulses

The most common insect pests of stored pulses that cause extensive losses worldwide are:-

2.1. Bean Weevil *Acanthoscelides obtectus* (Say) Coleoptera Family Bruchidae

Despite its name, this pest is not a true weevil because its head is not prolonged into a beak like structure. The adults are 2 to 3 mm long, robust, somewhat triangular (cut off squarely at the rear and narrowing toward the front), almost flat above, and are velvety gray or brown, with pale, linear markings on the elytra, which do not cover the tip of the abdomen. The thorax is covered with fine, yellowish-orange hairs, the legs are reddish yellow and the antennae have serrate (sawtooth like) segments. The female lays an average of 75 eggs, singly on or near the beans or related seeds. The eggs hatch in 5 to 20 days, and the tiny, legless larvae proceed to bore into the seed, and several larvae can develop in a single bean. The life cycle requires 21 to 80 days, and the newly emerged adult makes an exit hole and leaves the seed. The adults do not eat legume seeds and they fly actively. This beetle is the principal pest of stored legumes (kidney beans, peas, lentils) and certain other seeds, attacking them both in the field and in storage if these are stored in a warm place. If the field-infested material is brought into storage, this insect can re-infest the dried seeds. The bean weevil can be eliminated by destroying infested legumes because it does not attack grains, cereals, or other stored food products (Majka and Langor, 2011).

2.2. Pea Weevil *Bruchus pisorum* (L.) Coleoptera Family Chrysomelidae

Pea weevils are 4 to 5 mm long, grey to brownish gray, with small, distinct, white spots on the elytra. Adults are globular in shape with long legs, elytra do not reach the end of the abdomen, leaving the last terga exposed, and last abdominal terga is covered with black and white setae, and the inner ridge of the ventral margin of the hind femur has a single spine. Larvae are white and grub-like, having reduced legs. Females lay eggs on outside of pod, larvae develop in growing seeds within pods, and after pupation within the seed, the adult chews an exit hole through the seed coat. Main sources of pea weevil are broken peas, volunteer peas and stored infested seeds. They attack peas in the field and the females must lay their eggs on the pods of growing pea plants in the spring or perish without ovipositing. Infested peas may be brought into storage, but eggs are never laid on dried peas, and there is no re-infestation in storage. Therefore, it is a relatively unimportant pantry pest compared with the bean weevil. Both adults and larvae feed on the inside of seeds, damage is distinctive, feeding causes tiny dot-like entrance holes, feeding also causes larger round exit holes with a diameter of 2.5 mm and excavated seed, and large populations may reduce stored crop to little more than dust.

2.3. Broadbean Weevil *Bruchus rufimanus* Boheman Coleoptera Family Chrysomelidae

The adults weevil are 3.5 to 5 mm, prothorax a little shorter than wide, anterior legs entirely yellow, middle and posterior legs black and posterior tibiae bearing a long spike on the internal angle. Pale grey pygidium, reddish white pronotum, but is otherwise almost identical to pea weevil in appearance and habits. The young larva hatching from the egg bores directly downward through the egg and pod into a developing bean. The entrance hole, or sting, can easily be seen on the green or dry bean as a small dark spot. When full grown, the larva cuts a circular window in the bean, for the subsequent emergence of the adult and then pupates within the bean. The adult can easily push off this circular cap and emerges out. It prefers broad beans (*Vicia faba*), but also attacks other peas and vetches, and several weevils may be found in a single seed. Other food includes stored beans; Phaseolus, Vicia, Lathyrus, Lupinus, Pisum, Lens and Cicer species.

2.4. Bruchid Beetles (Coleoptera: Bruchidae) in Storage

Historically, bruchids are a major, widespread and increasing pest problem of stored pulse grains industry and their infestations have been worse. Adults are small, about 3.0 mm long, with a tear-shaped body. Bruchids breed rapidly in storage and by the time they are detected, the infested grain is usually unmarketable. Eggs are easily visible, white in color and laid on surface of individual beans. Larvae develop within the seeds, from where they emerge as adults, leaving a perfectly round hole in seeds. Adults are strong fliers and lay about 100 eggs in their 10-12 days lifespan. While crops may be infested in the field, infestations are often too low to detect at harvest. Bruchids are most often not detected until seed has been stored for a reasonable period (e.g., for longer than three months). The bruchid are responsible for causing most infestations on dried pulses in store (Sarwar and Tofique, 2006; Sarwar, 2012). Adults of most species known from stored pulses may be identified using the bruchid Key by Haines (1991).

2.4.1. *Callosobruchus chinensis* (Linnaeus)

It is a major pest, especially of cowpeas and grams, especially common in the oriental region, but also found throughout the tropics and subtropics. Eyes are not so prominent, elytral pattern relatively simple, cuticle black and reddish-brown, setae whitish, yellowish and dark brown or black, male antennae pectinate, segments 4-10 conspicuously expanded antero-laterally, female antennae serrate, antennae of both sexes usually with segments 4-l 1 dark brown (rarely yellow-brown). Pygidiums of female and male are covered with white or silver setae. Inner tooth of hind femur is with sides more or less parallel and converging near apex. Male genitalia: median lobe more elongate, apex with exophallic valve spearhead-shaped, and base with two sclerotized plates, parameres normal and rather broadly spatulate (Haines, 1991).

2.4.2. Cowpea Weevil *Callosobruchus maculatus* (Fabricius)

This insect is similar in size and habits to the bean weevil, but infests only cowpeas. The elytra are reddish brown, and each has 2 large, red spots. The thorax is covered with fine, white hairs, whereas in the bean weevil the basal segment and the last segment of the antenna are reddish yellow, in the cowpea weevil only the basal segments are of that color and the remainder of the antenna is dark. It is the major pest of several pulses, but especially cowpeas and grams, throughout the tropics and subtropics. Pronotum is black or reddish-brown and never with dark brown marks on a lighter background. Inner tooth of hind femur is as long as outer tooth, or shorter. Male genitalia are distinctive, median lobe with two longitudinal sclerotized denticulate areas near its middle, parameres rather stout and broadly spatulate. Inner carina of hind femur is smooth, inner tooth typically as long as, or very slightly longer than, outer tooth. Pronotum of mature specimens is with black cuticle, and with golden setae, except on the basal median gibbosities, which extend well beyond the posterior margin and are covered with white scale-like setae. Eyes are very deeply emarginated, prominent and bulbous (Haines, 1991).

2.4.3. *Callosobruchus analis* (Fabricius)

At present, it is known infesting green gram and white soya. Inner carina of hind femur is with numerous irregularly spaced small denticles along its proximal two-thirds, and inner tooth rather shorter than, or as long as outer tooth. Pronotum is with uniformly reddish-brown cuticle, and with sparse golden setae, except on the basal median gibbosities, which extend only slightly beyond the posterior margin and have sparse white setae. Eyes are less deeply emarginated, rather flattened and less prominent. Male genitalia are median lobe without sclerotized areas near its middle, parameres rather slender and only narrowly spatulated (Haines, 1991).

Post-harvest. Infestation commonly begins in the field, where eggs are laid on maturing pods. As the pods dry, the pest's ability to infest them decreases. Thus, dry seeds stored in their pods are quite resistant to attack, whereas the threshed seeds are susceptible to attack throughout storage. In the early stages of attack the only symptoms are the presence of eggs cemented to the surface of the pulses. As development occurs entirely within the seed, the immature stages are not normally seen. The adults emerge through windows in the grain, leaving round holes that are the main evidence of damage. Cowpea bruchids breed rapidly in stored seed and can complete a lifecycle in as little as 28 days (at 30°C). Adults live only 10-12 days and females lay about 100 eggs. Adults are strong fliers and can travel up to 2-3 km. Because infestations are often difficult to detect at harvest, carefully check for live insects and the characteristic grain damage at intake and at regular intervals during storage (Desroches et al., 1997; Wijeratne, 1998; Ishimoto et al., 1999).

3. Inspection and Identification

There are several methods to precisely determine the infestation and identification degrees for small-scale storage and grains stored in sacks.

3.1. Inspection of Pulse

Inspection of the stored products should be carried out frequently so that an infestation can be discovered in an early phase and be able to take measures in time. The method to determine the infestation degree for small-scale storage should be to check grain and store regularly by looking for insect's incursion. If the grain is stored in sacks, hit a sack against the floor and then let it rest in a shaded place (no direct sunlight). After a while check to see if there are any weevils on the outside of the sack. Also inspect some grains from inside the sack or container. Dump part of the grain out of the sack or take some out from the middle of the storage container. Check the grain sample for the presence of insects or signs of insects either by putting the grain through a sieve or sorting through it by hand (Groot, 2004).

3.2. Identification of Pest Insects

Identifying the main pests in store is important in order to be able to assess whether the insects found are likely to cause serious damage and to decide which control measures should be taken since many treatments are selective in their action and many pests have their specific strong and weak characteristics. Unfortunately, the majority of storage pests are so small that it is very difficult for non-specialists to identify them. A self-made reference collection may be of great help by collecting the most common pest species in a particular area and have them identified by a specialist (Groot, 2004).

4. Protecting Stored Pulses

Protecting of stored pulses from spoilage by pests is an essential part of their production, and failure to do so may result in their being downgraded. Because they are a threat at all stages of the bean supply chain (from field to export and beyond), bruchids should be regarded as a ´whole industry problem. Basically, there are two strategies to counter bruchid damage:-

4.1. Pre-harvest Measures in the Field

Take the following prophylaxis measures before the crop is harvested to prevent infestation and spoilage during storage. Pre-harvest prophylaxis is the insecticidal treatment of the mature grain before harvest in order to prevent carryover of field infestation to the warehouse. Dusting of the crops with appropriate insecticides when the first ripe pods appear, followed by a second application ten days before harvest, has also been suggested as a prophylactic control measure (Rani, 1997).

4.1.1. Preventive Measures Against Insects

Preventive measures against insects start already at the time of growing the crops that might be stored later in storage. In general it can be said that a farmer can influence the occurrence of pests in the stored crops by carefully choosing certain resistant varieties, planting or sowing and harvesting in the optimum season, properly treating the crop before storing, siting the store in a favorable place and keeping it very clean. To prevent and control infestations, it needs to know where and when insects occur. Surveys have shown that most empty granaries are infested with low numbers of insects. Animal feeds, trucks and farm machinery are other sour of insect infestations. Some insects can fly as well as walk, which increase their ability to infest stored pulses (Amevoin et al., 2005).

4.1.2. Choice of Varieties

Selection by breeding of resistant varieties is one method of pest control and when choosing the seed varieties, a farmer can already take into account the susceptibility of the crop to storage pests. Through experience the farmer can learn to select varieties which are pest resistant. For example, a hard seed coating or tightly closed husks act as a barrier to larvae which die before they are able to bore their way to the inside of the kernel. Early-ripening, large-seeded varieties of field beans (*Vicia faba*) are reported to be more heavily infested by certain species of bean weevils than are late-ripening, small-seeded varieties. The physical characteristic of the seed coat and the starch composition of the cotyledons are considered to be factors in determining infestation (Sarwar et al., 2003; Sarwar et al., 2005).

4.1.3. Time of Harvesting

Pulse crops should be harvested as quickly as possible to avoid infestation of the grain in the field. A problem with high yielding and early ripening varieties is that the harvest period can be in the wet period and this causes new storage problems (Olubayo and Port, 1997).

4.2. Post Harvest Measures in and Around the Store

Good store cleanliness plays an important role in limiting infestation by the pests species. The removal of infested residues from last season's harvest is essential as a general sanitation.

4.2.1. Site Selection

Selection of a good place for grain storage is very important and grain stores must be built on well-drained ground so that the building or container does not get flooded by ground water run-off during heavy rains or take on too much moisture from the ground. The storage should be placed as far away as possible from grain standing in the fields. This helps to protect the grain against insects flying from the field to the storage area. The storage should not be built near places where animals are kept. Certain insects found near animals and their food also attack stored grains (Kossou et al., 2001).

4.2.2. Hygiene and Inspection

Hygiene is vital at all stages of the bean supply chain, from on farm to export. Cleaning out old seed residues in storage sheds, silos, trucks, elevators, etc., before harvest or intake might remove potential infestation sources. Old planting seed in shed or from elsewhere poses a major infestation threat. Beans should be inspected for insects once a fortnight in summer and once a month in winter. Controlling bruchids in the field is not an effective option and would not guarantee immunity from storage damage. Anything less than 100% in-field control of bruchids could still result in significant bruchid damage in storage.

4.2.3. Treating Insect in Infested Seed

Targeting high-risk bagged and bulk pulses is a more effective strategy to minimize bruchid damage in storage. Carryover bag stocks and bulk pulses stored under warm conditions in un-aerated silos would be considered high-risk. A regular sampling and monitoring program is essential. Phosphine fumigation is the only chemical treatment approved for cowpea bruchid control in pulses and should be considered for all at risk loads at intake, whether bruchids are detected or not. Correct fumigation is vital for successful bruchid control, with best results achieved in sealed bag stacks applied at recommended doses (two tablets per tonne capacity or three tablets per two cubic meters or if silo has the capacity of 100 tonnes then always use 200 tablets for phosphine fumigation (Mohamed, 1996).

4.2.4. Slowing Bruchid Development in Storage

This can be achieved by cooling aeration, and seed temperature and moisture should be monitored regularly during aeration. Bruchid development may cease at grain temperature lower than 20°C. Physical treatment such as exposure of grains to temperature -10°C or heating the grain at 55-60°C for 12 minutes after spreading it in a layer of 4-5 cm has been tried to take good result (Mohemed and Ismail, 1996).

4.2.5. Biological Control

Biological methods to prevent and control infestation are also being thoroughly investigated. Use of predacious parasites, hormone analogs that block embryonic development, chemosterilants, and chemical pesticides are all under active study. Seven Pakistani strains of entomopathogenic nematodes belonging to the genera Steinernema and Heterorhabditis have been tested against last instar and adult stages of the pulse beetle *C. chinensis*. Overall, *Heterorhabditis bacteriophora* Poinar, *Steinernema siamkayai* Stock, and *S. pakistanense* Shahina, Anis, Reid and Maqbool, are among those that showed the highest virulence to pulse beetle larvae and adults. For all nematode species, the last larval stage of the pulse beetle seems to be more susceptible than the adult (Shahina and Salma, 2009).

4.2.6. Chemical Control

To find out the eco-friendly management of pulse beetle *C. chinensis* on stored mungbean, experiments using some promising fumigants viz., Camphor @ 1.0 g/ kg mungbean grains, Phostoxin tablet @ 200 mg/ kg mungbean grains, and Naphthalene @ 500 mg/ kg mungbean grains have been undertaken. From this study, it is observed that the treatment comprised with Camphor @ 1.0 g/ kg mungbean grains reduced the highest percent of grain infestation by number and weight (49.65% & 49.54%, respectively) over control and other fumigants (Khan et al ., 2015).

Parts of plants can act as insecticides or repellants and the usefulness of the various parts of the plant varies according to the type of plant. Powder made from the dried leaves of plants can protect against bruchids or weevils. It should be used in a concentration of 40-80 gm varied from plant to plan to protect 1 kg of pulses against pests. Seeds of the neem tree can be used as a powder or as oil. To produce neem oil by hand, use the dried kernels and these have to be decorticated first. They are crushed in a mortar, so that the outer husks are freed from the inner seed. The shells are removed by winnowing and the decorticated kernels are then pounded in the mortar until they form a brown, slightly sticky mass. A little water is added so as to form a workable paste which forms an almost a solid ball. This ball is kneaded for several minutes over a bowl until oil collects on the surface of the ball. It is then pressed firmly, and oil will come out in drops. Alternate kneading and squeezing will separate the oil. With this method 100-150 ml of oil can be extracted from 1 kg of neem kernels (Groot; 2004; Sarwar, 2010; Sarwar et al., 2012; Sarwar et al., 2013).

4.2.7. Irradiation

Employment of X-rays and gamma rays is another prospective as pest control measure. Irradiation by ionizing gamma radiation has proved effective in controlling *C. maculatus* in stores, although the practice is not widely allowed and may be costly. Hatching of eggs appears to be prevented at 10 Gy, larval development is arrested at 20 Gy, and pupal development is arrested at 150 Gy. Up to 1500 Gy may be required to kill adult, although sterilization of adult males and females may be achieved at doses of less than 100 Gy (Diop et al., 1997).

5. Integrated Pest Control

Because of development of resistance to insecticides in several insect species, there is a need to integrate different control tactics. Sources of resistance to insects in grain legumes have been identified, but these have not been used effectively in crop improvement. There is a need to place greater emphasis on utilization of wild relatives of crops with different resistance mechanisms, genetic engineering of plants for insect resistance, and identification of molecular markers associated with resistance to insect pests. Cultural manipulation of the crop and its environment, population monitoring and pest forecasting, manipulation of the crop environment to encourage the activity of natural enemies, use of natural plant products and bio-pesticides alone or in combination with synthetic pesticides, deployment of insect resistant varieties derived through conventional breeding, wide hybridization or genetic engineering, and rational use of selective chemicals can be exploited for pest management in food legumes (White, 2001; Sarwar, 2013 b).

6. Conclusion

Grain legumes can remain in edible condition for several years if properly stored. Grain legumes, processed and converted into primary products, are further utilized in various ways after cooking, or are processed to make different products in the home or in commercial catering establishments. However, they are susceptible to infestation, both in the field and during storage, by weevils, which are prolific, breed rapidly and cause serious deterioration in the nutritive value of the grain. In the tropics, leguminous grains need continuous protection against insect attack at all stages as field to storage infestation is common. Inadequate storage methods immediately after harvest and before processing add to the problem, and infestation continues to increase during transportation and long-term seasonal storage before processing, causing an estimated overall loss of over 30 per cent. The types of structures and containers used for drying and storing are as important as the infestation and insecticide treatments (including fumigation) employed to counteract pests. The storage facilities of traders as well as those of subsistence farmers should be usually better. Warehouses for large-scale, long-term storage have generally proved superior to those available and used by the traders. Implementing an integrated approach by combining the advantages of the different practices can give a better result with less frequent applications of insecticides.

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