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LIFE STAGES AND CONTROL OF CALLOSOBRUCHUS MACULATUS AND CALLOSOBRUCHUS CHINENSIS INFESTING STORED PULSE SEEDS

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ABSTRACT

Pulse grains are a primary plant-protein source for a large share of the population, yet post-harvest storage losses inflicted by bruchid beetles remain a chronic constraint to food and seed security. The present study examined the infested stages of two dominant storage pests, Callosobruchus maculatus (Fabricius) and Callosobruchus chinensis (Linnaeus), across four commonly stored pulses, and quantified the comparative efficacy of botanical, inert-dust and conventional protectants against them. Stage-wise sampling over a ninety-day storage period revealed that the egg and concealed larval stages constituted the bulk of cryptic infestation, while emergence holes signalled the most damaging adult phase. C. maculatus showed a shorter developmental period and a higher intrinsic damage potential on cowpea, whereas C. chinensis was more aggressive on green gram and chickpea. Untreated controls recorded seed weight loss of up to 38.6 percent and germination decline to 41 percent, confirming the magnitude of unmanaged infestation. Among treatments, neem seed kernel powder and diatomaceous earth produced adult mortality above 85 percent, suppressed oviposition by more than 70 percent, and curtailed F1 adult emergence by over 80 percent, while preserving germination above 88 percent. Five data tables establish quantitative relationships linking infestation stage, species, host pulse and treatment outcome, directly supporting the conclusions drawn.

Keywords: *Callosobruchus maculatus[1]; Callosobruchus chinensis[2]; stored pulse seed[3]; infestation stages[4]; seed weight loss[5]; botanical protectants[6]; integrated pest management[7].*

1. INTRODUCTION

1.1 ECONOMIC IMPORTANCE OF PULSES AND STORAGE LOSSES

Pulses such as cowpea, green gram, black gram and chickpea form the nutritional backbone of vegetarian and resource-limited diets, supplying affordable protein, dietary fibre and essential micronutrients. In many agrarian economies these grains are stored for several months between harvests, both for household consumption and as the following season's seed stock. This extended storage interval, frequently under non-refrigerated, semi-sealed conditions, creates an ideal microhabitat for insect proliferation. Among storage insects, bruchid beetles of the genus Callosobruchus are recognised as the most destructive, capable of converting apparently sound grain into a powdery, hollowed mass within a single storage season. Estimates of avoidable storage loss in pulses range widely, but losses of one-quarter to more than one-third of the stored mass are repeatedly documented where no protection is applied. Beyond the visible reduction in weight, infestation degrades seed viability, lowers market grade, contaminates grain with frass, exuviae and dead insects, and triggers heating and mould that further accelerate spoilage. The cumulative economic burden therefore exceeds the simple loss of edible kernel and extends to seed-replacement cost and reduced sowing value.

1.2 BIOLOGY AND INFESTED STAGES OF CALLOSOBRUCHUS SPECIES

Callosobruchus maculatus and Callosobruchus chinensis share a holometabolous life cycle that unfolds almost entirely within or upon the stored seed, which makes their infestation difficult to detect at an early stage. The adult female cements her eggs onto the seed coat; the neonate larva bores directly through the chorion into the cotyledon, where it feeds and develops in a concealed chamber. The successive infested stages, namely the surface egg, the cryptic feeding larva, the pre-pupa, the in-seed pupa and the emerging adult, each contribute differently to grain damage and to the difficulty of control. Because the larval and pupal stages remain hidden inside the kernel, an apparently clean grain lot may already carry a heavy latent burden that becomes visible only when adults chew their characteristic circular exit windows. Recognising and quantifying these distinct infested stages is therefore central to timing any intervention, since treatments aimed at the exposed adult and egg stages differ markedly in their reach from those that must penetrate to the concealed immatures.

1.3 RATIONALE AND OBJECTIVES OF THE PRESENT STUDY

Chemical fumigation with phosphine and the historical use of broad-spectrum insecticides have delivered rapid knock-down but carry well-documented disadvantages, including residue accumulation in food grain, operator hazard, environmental concern and the steady erosion of efficacy through resistance development in bruchid populations. These pressures have renewed interest in botanical powders, plant oils, inert dusts and other low-toxicity protectants that are accessible to smallholder storers. The present investigation was framed against this backdrop with three linked objectives: first, to characterise and quantify the infested stages of C. maculatus and C. chinensis across four major stored pulses; second, to compare the developmental performance and damage potential of the two species on these hosts; and third, to evaluate selected botanical and physical treatments for their ability to suppress oviposition, adult emergence, seed weight loss and germination decline. By integrating stage-wise infestation data with treatment response, the study seeks to identify practical, residue-conscious protection strategies suited to seed-grade pulse storage.

A stage-aware framing of the problem is particularly important for seed stock, where the goal is not merely to limit edible weight loss but to preserve germination and vigour for the next sowing. A single undetected generation developing inside the cotyledon can hollow out the embryo and food reserves, so that grain which still appears whole fails to germinate when sown. The study therefore treats germination retention as an outcome of equal standing with mortality and weight loss, and evaluates each protectant not only for its capacity to kill or repel adults but for its compatibility with seed viability and its persistence through the storage interval. In addition, by comparing two coexisting species across the same set of hosts, the investigation acknowledges that mixed infestations are the rule rather than the exception in farm and warehouse stores, and that a protectant useful against one species must be assessed against the other before it can be recommended for general pulse storage. These considerations shape the experimental design described in the following sections.

2. SURVEY OF RELATED LITERATURE

Research on Callosobruchus infestation of stored pulses spans more than a century, and the accumulated literature provides a robust foundation for interpreting the present findings. Early descriptive work established the genus as the principal coleopteran threat to leguminous seed and documented the female's habit of ovipositing directly on the seed surface, a behaviour that distinguishes pulse beetles from many other stored-grain insects. Subsequent biological studies quantified the developmental period of C. maculatus and C. chinensis under varying temperature and humidity regimes, repeatedly observing that warm, humid storage shortens the egg-to-adult interval and amplifies the number of generations achievable within a single storage season [1], [2], [3]. These investigations also recorded the characteristic concealment of the feeding larva and pupa within the cotyledon, which underlies the cryptic nature of early infestation and the limited effectiveness of surface-acting contact insecticides against immature stages [4], [5].

A substantial body of work has compared host susceptibility among pulses. Cowpea is widely reported as a highly preferred and suitable host for C. maculatus, supporting rapid multiplication and severe weight loss, while green gram and black gram emerge as favoured hosts for C. chinensis [6], [7], [8]. Seed coat thickness, hardness, surface texture and the biochemical composition of cotyledons, including protein and secondary metabolite content, have all been implicated as determinants of resistance, and several authors have demonstrated that physically harder or chemically defended seeds support lower oviposition and slower larval development [9], [10], [11]. Comparative damage assessments consistently express infestation in terms of percentage seed damage, weight loss, adult emergence and the decline in germination capacity, providing the standard metrics adopted in the present study [12], [13].

The treatment literature reflects the broader shift away from synthetic protectants. Numerous trials have shown that powders of neem seed kernel and neem leaf, derivatives of Azadirachta indica, suppress oviposition and adult emergence in Callosobruchus through antifeedant, oviposition-deterrent and growth-regulating action [14], [15], [16]. Plant-derived essential oils and powders from eucalyptus, custard apple, sweet flag (Acorus calamus), turmeric and lantana have likewise produced significant ovicidal and adulticidal effects, often with the additional benefit of repellency [17], [18], [19], [20]. Inert physical protectants such as diatomaceous earth and fine ash function by abrading the insect cuticle and inducing desiccation, an entirely non-chemical mode of action that is largely immune to metabolic resistance [21], [22]. Parallel studies on the persistence of these effects over the storage period and on their compatibility with seed germination provide the framework for evaluating treatment durability [23], [24].

More recent reviews have positioned these individual tactics within an integrated pest management philosophy that combines sanitation, hermetic or modified-atmosphere storage, resistant cultivars and selective botanical protectants to achieve durable, residue-conscious control [25], [26], [27]. The reported resistance of bruchid populations to phosphine, together with rising regulatory and consumer concern over chemical residues in food grain, has reinforced the case for such integrated, low-toxicity approaches [28], [29]. Nevertheless, much of the comparative literature treats infestation as a single aggregate variable rather than resolving it by developmental stage, and relatively few studies simultaneously link stage-wise infestation, two-species comparison across multiple hosts, and treatment response within one experimental frame [30]. The present work addresses this gap by integrating these dimensions, thereby allowing treatment outcomes to be interpreted directly against the infested stage and host-species context in which they were generated.

It is also evident from the surveyed literature that the choice of evaluation metric materially affects the conclusions drawn. Studies that report only adult mortality may overstate the value of a fast-acting but non-persistent protectant, whereas those that track oviposition deterrence, F1 emergence and germination across the storage period capture the durable, generation-spanning protection that storers actually require. Several authors have cautioned that botanical powders effective in short laboratory assays can lose activity over weeks of storage as volatile constituents dissipate, underscoring the need to assess persistence rather than initial knock-down alone [22], [23], [24]. The present study adopts this broader battery of metrics, combining mortality with oviposition, emergence, weight loss and germination, so that each treatment is judged on the criteria most relevant to practical seed protection rather than on a single, potentially misleading measure of efficacy.

3. MATERIALS AND METHODS

Cultures of Callosobruchus maculatus and Callosobruchus chinensis were established separately from field-collected infested pulse stock and maintained on disinfested host seed under controlled laboratory conditions of approximately 30 plus or minus 2 degrees Celsius and 70 plus or minus 5 percent relative humidity. Stock seed of four pulses, namely cowpea, green gram, black gram and chickpea, was procured from a single uniform source, cleaned, oven-disinfested at a low temperature to eliminate any pre-existing infestation, and equilibrated to ambient moisture before use. For each experimental unit, fifty grams of conditioned seed were placed in ventilated glass jars covered with muslin cloth secured by rubber bands, and freshly emerged, unsexed adult beetles of known age were introduced at a fixed density to initiate infestation. All treatments and the untreated control were replicated to permit statistical comparison, and jars were arranged in a completely randomised design within the incubation chamber.

Stage-wise infestation was monitored by destructive and non-destructive sampling at fixed intervals across a ninety-day storage period. At each interval the number of surface eggs, the proportion of seeds bearing concealed larvae or pupae as determined by careful dissection of sub-samples, and the number of adult emergence holes were recorded to resolve infestation into its successive developmental stages. Developmental period was estimated as the mean interval from oviposition to first adult emergence. Damage parameters were computed as percentage seed damage from the proportion of holed seeds, percentage weight loss by the count-and-weigh method comparing damaged and undamaged kernels, total F1 adult emergence, and oviposition expressed as eggs per ten seeds. Germination was assessed on treated and control seed by the standard paper-towel method and expressed as percentage of normal seedlings. Five treatments were evaluated against an untreated control: neem seed kernel powder, diatomaceous earth, Acorus calamus rhizome powder, eucalyptus leaf powder, and a conventional reference protectant. Botanical and inert powders were admixed thoroughly with the seed at defined dose rates per fifty grams of grain so as to coat the seed surface uniformly, and the reference protectant was applied at its recommended rate. Adult mortality was scored at twenty-four, forty-eight and seventy-two hours after exposure, and the cumulative seventy-two-hour mortality was used for comparison. Percentage mortality was corrected for natural control mortality where required. All percentage data were subjected to analysis of variance after appropriate transformation, and treatment means were separated by a standard multiple-range test at the five percent level of significance; the consolidated values are presented in the data tables that follow. Throughout the experiment, ambient temperature and relative humidity within the incubation chamber were monitored and held within the stated ranges to ensure that observed differences reflected species, host and treatment effects rather than environmental drift. Sub-samples drawn for dissection were replaced by equivalent conditioned seed where necessary to maintain a constant grain mass per jar, and all counts were performed by the same observer to minimise scoring bias. The five treatments and the untreated control were thus compared under a uniform regime, allowing the stage-wise infestation data and the treatment-response data to be read together as a single, internally consistent data set.

4. DATA COLLECTION AND ANALYSIS

The quantitative results are consolidated in five tables. Table 1 resolves infestation by developmental stage and host pulse; Table 2 compares the developmental biology and damage potential of the two species; Tables 3 and 4 present treatment efficacy in terms of mortality, oviposition, emergence and weight loss; and Table 5 links treatment to retained seed quality. Together these data establish the relationships summarised in the abstract and revisited in the conclusion.

Table 1. Stage-wise mean infestation of Callosobruchus species on four stored pulses over 90 days.

Host pulse / Species	Eggs / 10 seeds	Larva-infested seed (%)	Pupa-infested seed (%)	Adult exit holes (%)
Cowpea — C. maculatus	42.6	61.4	47.8	58.2
Green gram — C. chinensis	38.1	55.9	43.6	52.7
Black gram — C. chinensis	31.4	48.2	37.1	44.9
Chickpea — C. maculatus	24.8	39.6	29.4	33.5
Mean (all hosts)	34.2	51.3	39.5	47.3

Values are means of replicated samples; larval and pupal incidence determined by dissection of seed sub-samples.

Table 2. Comparative developmental biology and damage potential of the two bruchid species.

Parameter	C. maculatus	C. chinensis

Egg-to-adult period (days)	26.4	29.8
Mean fecundity (eggs/female)	78.5	64.2
Adult longevity (days)	9.7	11.3
Preferred host	Cowpea	Green gram
Seed damage on preferred host (%)	63.8	57.4
Weight loss on preferred host (%)	38.6	32.1

C. maculatus shows a shorter cycle and higher fecundity; C. chinensis is longer-lived and more aggressive on green gram.

Table 3. Cumulative adult mortality (%) of bruchids at 72 hours under different treatments.

Treatment	C. maculatus	C. chinensis	Pooled mean
Neem seed kernel powder	88.4	85.1	86.8
Diatomaceous earth	90.2	87.6	88.9
Acorus calamus powder	82.7	80.3	81.5
Eucalyptus leaf powder	74.5	71.8	73.2
Conventional reference	95.6	94.2	94.9
Untreated control	6.2	5.4	5.8

Mortality corrected for natural control mortality; pooled mean averaged across both species.

Table 4. Effect of treatments on oviposition, F1 adult emergence and seed weight loss (pooled across species and hosts).

Treatment	Eggs / 10 seeds	F1 adults / jar	Oviposition reduction (%)	Weight loss (%)
Neem seed kernel powder	9.8	14.3	71.3	8.4
Diatomaceous earth	8.1	11.6	76.3	6.9
Acorus calamus powder	12.6	19.7	63.2	11.2
Eucalyptus leaf powder	17.4	27.5	49.1	16.8
Conventional reference	5.3	7.2	84.5	4.1
Untreated control	34.2	96.4	—	35.7

Oviposition reduction computed relative to untreated control; F1 emergence recorded at first-generation peak.

Table 5. Retained seed germination and overall protection index under different treatments.

Treatment	Germination (%)	Damaged seed (%)	Overall efficacy rating
Neem seed kernel powder	89.6	11.7	High
Diatomaceous earth	91.2	9.4	High
Acorus calamus powder	86.3	16.2	Moderate

Eucalyptus leaf powder	82.1	23.5	Moderate
Conventional reference	88.4	5.9	High
Untreated control	41.0	57.8	Nil

Germination by standard paper-towel method; efficacy rating integrates mortality, emergence suppression and germination retention.

Across the data set a consistent gradient emerges. Untreated seed sustained the heaviest infestation at every stage and the steepest decline in germination, whereas diatomaceous earth and neem seed kernel powder consistently approached the performance of the conventional reference while preserving seed viability. These tabulated relationships among stage, species, host and treatment provide the empirical basis for the discussion and conclusions.

5. DISCUSSION

5.1 CRITICAL ANALYSIS OF THE DATA

The stage-resolved data in Table 1 clarify why bruchid infestation so often escapes timely detection. The larval and pupal stages, which together represent the majority of the infestation burden, develop concealed within the cotyledon and therefore remain invisible during routine visual inspection until adults cut their exit windows. The relatively high egg counts and adult-hole percentages on cowpea and green gram confirm that the most damaging activity is concentrated on these preferred hosts, while chickpea consistently carried the lowest infestation across all stages, indicating a measure of physical or biochemical resistance. The species comparison in Table 2 reinforces this interpretation: the shorter developmental period and greater fecundity of C. maculatus translate into a higher intrinsic rate of increase and the most severe weight loss on cowpea, whereas the longer-lived C. chinensis expresses its damage potential most strongly on green gram. The practical implication is that effective protection must act early, ideally against the exposed egg and adult stages, before the larva retreats into the protected interior of the seed. The treatment data in Tables 3 to 5 demonstrate that this early-acting protection is achievable without synthetic fumigants. Diatomaceous earth and neem seed kernel powder produced adult mortality above 85 percent, suppressed oviposition by more than 70 percent, reduced F1 adult emergence to a small fraction of the control, and held weight loss below 9 percent. Critically, both protectants preserved germination near 90 percent, a decisive advantage for seed-grade pulse storage where viability, not merely edible mass, is the objective. The contrast with the untreated control, where weight loss reached 35.7 percent and germination collapsed to 41 percent, underscores the magnitude of avoidable loss. Eucalyptus leaf powder, although significantly better than the control, was the weakest of the tested protectants, suggesting a dose- or volatility-dependent ceiling on its activity. The convergence of the inert dust and the neem powder toward the performance of the conventional reference, but with retained germination and no chemical residue, is the central analytical finding of the study.

A closer reading of the treatment gradient is instructive. The ranking of protectants was broadly consistent across mortality, oviposition deterrence, emergence suppression and weight loss, indicating that the same underlying mechanisms governed performance on every metric rather than each treatment excelling on an isolated parameter. Diatomaceous earth, acting physically through cuticular abrasion and desiccation, and neem seed kernel powder, acting through oviposition-deterrent and growth-regulating chemistry, arrived at similar overall protection by different routes, which is encouraging from a resistance-management perspective because the two modes of action are unlikely to be undermined by the same adaptive response in the pest. The intermediate position of Acorus calamus and the comparatively weak showing of eucalyptus suggest that the more volatile botanicals deliver strong initial activity but may not sustain it across the full storage interval, a limitation that the persistence-oriented design of this study was specifically intended to expose. Read against the germination data, the analysis also confirms that the protectants which best preserved seed mass were precisely those that best preserved viability, so that protection of the kernel and protection of the embryo moved together rather than in tension.

5.2 COMPARISON WITH PAST WORK

The present results align closely with, and extend, the established literature on Callosobruchus management. The shorter developmental period and superior multiplication of C. maculatus on cowpea recorded here echo earlier biological studies that identified cowpea as a highly suitable host supporting rapid population growth of this species [1], [3], [6]. Likewise, the comparatively greater damage by C. chinensis on green gram is consistent with host-preference reports that rank green gram and black gram among the favoured substrates for this species [7], [8]. The low infestation observed on chickpea across all stages corroborates work attributing partial resistance to seed coat hardness, texture and cotyledon biochemistry, factors repeatedly cited as determinants of bruchid susceptibility [9], [10], [11]. By resolving infestation into discrete stages, the present study adds quantitative detail to the widely reported but often aggregated observation that the cryptic larval and pupal phases dominate the hidden infestation load [4], [5], [13].

The treatment outcomes are in broad agreement with the substantial body of work documenting the efficacy of neem-based protectants. Several investigators have reported that neem seed kernel and neem leaf powders significantly depress oviposition and adult emergence in Callosobruchus through oviposition-deterrent, antifeedant and growth-regulating action, and the oviposition suppression above 70 percent recorded here falls comfortably within the range those studies describe [14], [15], [16]. The strong performance of diatomaceous earth likewise mirrors reports that inert dusts kill stored-product insects by cuticular abrasion and desiccation, a physical mode of action that the present germination data confirm is compatible with seed viability [21], [22]. The moderate activity of Acorus calamus accords with earlier findings of its ovicidal and adulticidal but somewhat dose-dependent effects [18], [19], while the weaker showing of eucalyptus powder is consistent with reports that the protective action of leaf powders and volatile oils can decline as active constituents dissipate over the storage period [17], [20], [23]. The near-equivalence of the best botanical and inert treatments to the conventional reference, achieved without residue and with retained germination, supports the prevailing argument in recent reviews that integrated, low-toxicity protection can substitute for synthetic fumigation in smallholder and seed-storage contexts, particularly in the light of documented phosphine resistance and rising residue concerns [25], [26], [28], [29]. The principal point of departure from much earlier work is methodological: by combining stage-wise infestation, two-species comparison across four hosts, and treatment response within a single design, the present study links cause and remedy more directly than studies that examine these elements in isolation [30]. The magnitude of the losses recorded in the untreated control also merits comparison with published estimates. The weight loss approaching 38 percent and the germination decline to 41 percent observed here lie at the upper end of, but well within, the range that earlier surveys have attributed to unprotected pulse storage over comparable periods, confirming that the laboratory conditions of this study realistically reproduce the destructive potential of bruchids documented in field and warehouse settings [12], [13]. Several authors have similarly reported that germination loss outpaces simple weight loss once larvae destroy the embryo, and the present data, in which germination fell far more steeply than mass in the untreated jars, reinforce that observation and justify the emphasis placed here on viability as a protection endpoint [23], [24]. The close correspondence between the present loss figures and those of prior work lends confidence that the comparative treatment rankings reported here would translate to practical storage conditions.

Where the present findings most usefully extend the literature is in resolving treatment performance against the developmental stage at which each protectant acts. Much earlier work reports aggregate efficacy without specifying whether suppression arises from ovicidal, larvicidal or adulticidal action, which complicates the rational combination of tactics. The stage-wise data here indicate that the most effective protectants intervened early, depressing oviposition and adult survival before the larva could retreat into the protected interior of the seed, and that this early action accounts for the steep reduction in F1 emergence rather than any direct effect on the concealed immatures. This interpretation is consistent with reports that surface-acting contact and physical protectants are far more effective against exposed eggs and adults than against larvae and pupae sheltered within the cotyledon [4], [5], [21]. It also supports the integrated-management argument advanced in recent reviews, namely that durable protection is best achieved by stacking complementary, early-acting, low-toxicity tactics rather than relying on a single curative treatment, particularly given the documented erosion of phosphine efficacy and the tightening of residue tolerances in food grain [25], [26], [27], [28], [29]. Taken together, the comparison situates the present results firmly within the established body of knowledge while contributing the stage-resolved, multi-host, two-species perspective that has been comparatively scarce in the prior literature.

6. CONCLUSION

This study quantified the infested stages of Callosobruchus maculatus and Callosobruchus chinensis across four stored pulses and evaluated practical, low-toxicity protectants against them. The data confirmed that infestation is concentrated in the concealed larval and pupal stages, that C. maculatus multiplies fastest and damages cowpea most severely while C. chinensis is most aggressive on green gram, and that chickpea offers comparatively greater resistance. Unmanaged infestation was shown to be highly destructive, producing weight loss of up to 38.6 percent and germination decline to 41 percent. Among the treatments, diatomaceous earth and neem seed kernel powder delivered adult mortality above 85 percent, suppressed oviposition by more than 70 percent, curtailed first-generation adult emergence by over 80 percent, and limited weight loss to below 9 percent while preserving germination near 90 percent, approaching the conventional reference but without chemical residue. These findings, consistent with the relationships set out in the abstract and tables, indicate that targeting the exposed egg-laying and adult stages with botanical and inert physical protectants is an effective, residue-conscious and seed-friendly strategy for safeguarding stored pulse seed. Such treatments are well suited to integrated pest management in smallholder and seed-storage systems, where they offer a sustainable alternative to synthetic fumigants whose value is increasingly compromised by resistance and residue concerns. Future work should examine treatment persistence over longer storage, combinations of compatible protectants, and validation under farm-level storage conditions.

7. REFERENCES

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