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Grain Morphological Traits Confer Tolerance to Bruchid (*Callosobruchus maculatus*) Infestation of Stored Green Gram (*Vigna radiata* L. Wilczek)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SKK, DCK, OMK, and JMK made significant contributions to the manuscript. Writing—original draft preparation and editing were performed by authors SKK, DCK, OMK, and JMK. Conceptualization, methodology, and investigation were carried out by authors SKK, DCK, OMK and JMK. Writing—review and editing were conducted by authors SKK, DCK and OMK. All authors have read and agreed to the published version of the manuscript. All authors read and approved the final manuscript.

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Abstract

Post-harvest losses due to bruchid (*Callosobruchus maculatus*) infestation in green gram production remain a challenge. The relative tolerance to bruchid infestation of five green gram (*Vigna radiata* L. Wilczek) varieties was evaluated under ambient conditions in a laboratory. The

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green gram varieties were two old varieties: N26 and KS20; and three new varieties: Karembo, Biashara and Ndengu-Tosha. A completely randomized design with four replications was used in the laboratory. *Callosobruchus maculatus* was isolated from infested green gram grain and multiplied on clean grain for artificial infestation. Data collected include seed coat color, seed size, seed weight loss, seed coat thickness, number of holes on grain and oviposition. Analysis of variance at P = 0.05 using GenStat 15th Edition statistical software was done and treatment means separated using the Fisher's Protected Least Significant Difference at 5% probability level. Data were further subjected to simple linear regression analysis to determine relationships among variables. Seed morphological traits mainly thick seed coat and small seed size were associated with reduced oviposition on the grain. Correlation analysis revealed a positive relationship between seed color and egged grain ($0.40 \leq R^2 \leq 0.63$). Ndengu Tosha and Karembo varieties with higher hue angles (100 ± 8.1 H^o) supported fewer dead bruchids (1 and 15 respectively), suggesting reduced suitability for ovipositional preference. The findings highlight the potential of varietal selection as a sustainable strategy for minimizing postharvest losses, reduced pesticide reliance in green gram and increased income of small scale farmers. Future research should focus on developing new varieties with grain traits that are tolerant to bruchid attack.

Keywords: Bruchid; grains; post-harvest; tolerance; varieties.

1. Introduction

Post-harvest losses due to insect pests pose a significant challenge to legume production worldwide, particularly in developing countries where storage facilities are often limited (Kalpna et al., 2022; Kumar et al., 2023). Bruchid beetles (*Callosobruchus maculatus*) are regarded as the most destructive pests to stored green gram (*Vigna radiata* L.) (Soujanya et al., 2024). Green gram is a very important legume crop which is vulnerable due to its soft seed coat and high protein content, making it more preferable by bruchid beetles (Yewale et al., 2020). Bruchids cause approximately 90% of post-harvest losses within three to six months of stored green gram grains in Kenya (Soujanya et al., 2024). These losses reduce the quality and quantity of the grains through seed perforations, weight loss, reduced viability (Kalpna et al., 2022).

Green gram is a leguminous annual crop mainly grown in the semi-arid regions of Kenya, where it contributes significantly to household nutrition, food security, and farm income (Hakim et al., 2023; Kuria et al., 2025). The crop is valued for its carbohydrates (62%), protein (31%), fibers (4%), vitamins, amino acids, minerals, short maturity period, and ability to thrive under low-input conditions (Yumbya et al., 2024; Mugo et al., 2020). The long root system enables it to draw water from deeper depths to maintain crop yields (Mulwa et al., 2023). Drought tolerance allows this crop to survive in diverse agro-ecological zones (Wangui, 2021). Despite its economic importance, green gram production and storage are severely constrained by postharvest losses caused by bruchids (Yewale et al., 2020).

Breeding and selection of bruchid tolerant varieties offer a sustainable and safe strategy for minimizing postharvest losses (Soujanya et al., 2024). Data on green gram varietal tolerance to bruchid infestation among commonly cultivated green gram varieties in Kenya is limited, and the associated mechanisms of tolerance are only partially understood (Mulwa, 2022). A focused evaluation of the varieties KS20, N26, Ndengu Tosha, Karembo, and Biashara under uniform conditions would contribute valuable knowledge for breeding programs and farmer advisories. Green gram breeding efforts have previously concentrated on drought tolerance, early maturity, high-yielding varieties, and little has been done on bruchid tolerance due to poor seed systems (Mulwa, 2022). Several studies have demonstrated that seed morphological traits such as seed coat hardness, thickness, size, and color play an important role in mediating bruchid tolerance (Yewale et al., 2020). However, tolerance levels vary significantly across green gram varieties, and effective evaluation under controlled conditions is necessary to identify varieties with proper morphological and biological characteristics for stable tolerance. Identification of tolerant green gram varieties, therefore, provides a critical avenue for reducing dependence on synthetic pesticides.

In Kenya, there are five main green gram varieties, which comprise two old releases of the 1990's (N26 and KS20), which were developed and released when pest infestation was low, and hence, very little research had been done on green gram breeding (Mulwa,2022; Yumbya et al., 2025). Three modern selections of 2017 (Karembo, Biashara, and Ndengu Tosha) were released by the Kenya Agricultural and Livestock Research Organization, having developed when pressure for pest and disease incidences was very high (Mulwa,2022). However, there is limited research on the susceptibility of different green gram varieties to bruchid infestation and their effectiveness in reducing post-harvest losses in stored green gram grains. This necessitated the need for research on seed varieties that could overcome the serious challenges of pest incidences and low productivity (Mulwa et al., 2023).

Traditional control methods of using pesticides are expensive and pose environmental and health risk and may perhaps lead to pest tolerance (Yewale et al., 2020). As a result, breeding and identification of bruchid-tolerant green gram varieties offer sustainable, cost-effective, and environmentally sound alternative (Tutlani et al., 2022). Genetic variability for bruchid tolerance exists among green gram varieties that can be exploited through breeding (Pawara et al., 2019). Breeding program depends on both abiotic and biotic factors in green gram development stages, which are very essential in the identification of tolerant traits in each stage (Mulwa, 2022). Substantial green gram genetic gain has been in high yield, pests and disease tolerance, and drought tolerance. Green gram breeding in Kenya has been done to produce the latest varieties of Biashara, Karembo, and Ndengu Tosha, which are high-yielding, disease tolerance, and mature early but losses due to insect pest damage still continue to thrive (Mulwa et al., 2023; Bharathi et al., 2024).

Plant breeders face the technical challenge of achieving bruchid tolerance while maintaining desirable agronomic traits (Kalpna et al., 2022). Understanding the relationships among morphological traits, bruchid biological responses, and resulting grain quality indicators is crucial for developing targeted breeding and management strategies. Mwangi et al. (2020) investigated Kenyan green gram varieties and confirmed that N26 and Biashara, exhibited partial tolerance, marked by delayed adult emergence and reduced egg hatchability. Variety Ndengu Tosha is widely promoted in Kenya for its high yield and disease tolerance while Karembo and KS20 are popular for their adaptability and market preference by farmers but are vulnerable to bruchid infestations (Karimi et al., 2019). Development of tolerant varieties against bruchid is the essential step towards the sustainable protection of stored grains, which has not been validated previously (Harshitha et al., 2022). The findings will support the selection of varieties suitable for areas prone to bruchid infestation and contribute to improved postharvest management and food security in green gram production systems (Babu et al., 2020). Hence, this current study aimed to evaluate the relative tolerance of bruchids by screening selected green gram varieties. The study hypothesized that selection for drought tolerance of green gram varieties in Kenya could simultaneously improve bruchid tolerance.

2. Material and Methods

2.1 Experiment Site and Varieties Used

Two grain storage incubation cycles were conducted during 2023-2024 under the ambient conditions at the Entomology laboratory located at latitude 1° 15´ 25´´S, longitude 36° 44´06´´E and 1876 m altitude in the University of Nairobi, Kenya. The laboratory conditions were maintained at 28 ± 2 °C and 70-90% relative humidity, which are optimal for *Callosobruchus maculatus* development. The treatments comprised of five green gram varieties which were two old releases (N26 and KS20) and three modern selections (Karembo, Biashara and Ndengu Tosha) which were sourced from small scale farmers. All seed samples were physically sorted to remove broken grains, debris, and pest infested seeds.

2.2 Source and Rearing of Bruchids

Ten kilograms of infested composite green gram grains were sourced and multiplied on clean green gram grains for artificial infestation and used for harvesting of experiment insects. Laboratory infestation was conducted using cultured *Callosobruchus maculatus* where fifty adult bruchids were reared and multiplied into 1 kg capacity plastic rearing jars with clean healthy susceptible green gram grains.

The jars were covered with muslin cloth and fastened with rubber bands allowing free air circulation for insect survival. The jars were kept undisturbed in the laboratory conditions on a raised platform at temperature of 30 ± 1^{o}C and relative humidity at 70 ± 2%. Close monitoring was done, after 7 days all mature bruchids were discarded from the jars after ovipositing to allow the laid eggs to hatch into freshly emerged adult beetles which were used for the experiment. The culture was refreshed every 30 days to maintain vigor and avoid inbreeding.

2.3 Experiment Design and Set Up

A completely randomized design with four replications was used where sorted green gram grains were stored in a deep freezer at -17 ^oC and 70-100% relative humidity. Later, they were conditioned to 25 ^oC room temperature for experiment use. The study ran for six months in two incubation cycles where twenty transparent 1 kg bottle jars received 200 g of clean green gram grains. Thirty live bruchids of three weeks' age were introduced into each jar, covered with a muslin cloth and secured with rubber bands for oviposition. These jars together with their contents were finally kept and maintained at a temperature of 30 ^oC and relative humidity of 80 ± 10%.

2.4 Data Collection

Seed morphological characteristics were measured prior to infestation such as seed size, 100-seed weight, seed coat thickness and seed coat color. Infestations and damage assessments were made fortnightly from the onset of the incubation cycle such as grain weight loss, number of egged grains, number of holes on grains and bruchid mortality recorded at each sampling stage.

2.4.1 Change in Seed Coat Color

Seed coat color was determined and recorded using a portable digital color meter (Model TES 135A, Taiwan, China) which was calibrated according to manufacturer's instructions. The color meter was first switched on and zeroed using a black background. Five grams of each variety were used for color determination where observations made and returned to the source for subsequent experiment use. The degree of seed color change was calculated and expressed as hue angle where color wheel was used to compare the calculated hue angle with the color of the grains. Two values were noted as a* and b*. Using the two values, the hue angle (H^o) was calculated as:

$$\text{Hue angle } (H^o) = \tan^{-1}(b/a) \text{ ………… Equation (1)}$$

Where, (a*, b*) coordinates are positive.

$$\text{Hue angle } (H^o) = \tan^{-1}(b/a) + 180 \text{…. Equation (2)}$$

Where, (a*, b*) are positive and negative respectively.

2.4.2 Seed Size

Ten green gram grains were randomly picked and counted from each variety to determine their sizes by use of a vernier caliper. The mean seed length and width were determined at the beginning of the experiment to establish whether there was any correlation between seed size and other parameters.

2.4.3 Loss in Seed Weight

The grain weight loss in storage is caused by either weight or moisture loss. The grain weight loss is as a result of insect feeding on the grain leading to grain breakage and holes while moisture loss is brought by evaporation as the grain equilibrates with environmental conditions (Walker et al., 2018). Six samples of 100 green gram grains were randomly picked and weighed using a digital electronic weighing balance (MH-696, China). The weight was recorded and later compared with the magnitude of infestation of the grains by bruchids. The used sample was returned to respective jars for subsequent experimental use. The percent grain weight loss was calculated in Equation 3 (Girish et al., 1975).

$$\text{Weight loss \%} = \frac{(\text{Initial seed weight} - \text{Final seed weight})}{\text{Initial seed weight}} \text{x } 100 \text{ …… Equation (3)}$$

2.4.4 Seed Coat Thickness

Six grains of each variety were randomly sampled for determination of seed coat thickness. Initial length and width of each was determined using a vernier caliper. The whole seed cover was then removed by use of a scalpel. Final length and width of the seed was then recorded where seed thickness was calculated by subtracting the final from initial readings in millimeters (mm) then divided by two.

2.4.5 Number of Holes on Grains

Infestation level was evaluated as shown in Equation 4 (Howe, 1971).

$$\text{Infestation (\%)} = \frac{\text{Number of grains with emerged holes}}{\text{Total number of grains observed}} \text{ x } 100\ldots. \qquad \text{Equation (4)}$$

2.4.6 Number of Egged Grains

The oviposition rate was determined by counting the number of eggs laid on the 100 seed in each replication and expressed as number of eggs laid per female per day (Odjo et al., 2020). This was calculated as oviposition rate as determined in Equation 5 (Howe, 1971):

$$\text{Oviposition rate} = \frac{\text{Total eggs}}{\text{Number of females/day}}\ldots\ldots\ldots\ldots \qquad \text{Equation (5)}$$

2.5 Data Analysis

Before statistical analyses, Shapiro-Wilk test was used to check for data normality and conformation to the requirements of Analysis of Variance (ANOVA). The collected data were subjected to ANOVA at 5% probability using GenStat 15th Edition. The treatment means among all treatments were compared and separated using the Fisher's Protected Least Significant Difference at 5% probability level. Data were further subjected to simple linear regression analysis to determine relationships among variables.

3. Results

3.1 Seed Morphological Traits

Significant variations were observed in the seed morphology of the studied varieties (Table 1). The older varieties (N26 and KS20) were typically smaller in size (17.2 ± 0.8 and 20.5 ± 0.8 mm^2) than the newer counterparts. Variety KS20 had a dull green color (87.7 ± 4.8 H^o) while the rest of the varieties were shinny green. Karembo and Ndengu Tosha, both recently released varieties, had thicker seed coats compared with the other varieties.

3.2 Change in Seed Coat Color

Seed color of different green gram varieties, expressed as hue angle, decreased gradually across all varieties over the storage period (Fig. 1). The three newly released varieties exhibited relatively higher initial hue angles of which are normally shiny green compared to the least recorded by KS20 (92.5 ± 2.6 H^o) which is normally dull green showed more pronounced seed coat discolouration. The higher hue angles observed in Ndengu Tosha, Karembo, and Biashara retained a greener and more uniform seed coat.

3.3 Loss in Seed Weight

The percentage cumulative seed weight loss increased progressively in all varieties across the storage period. The rate of weight loss significantly ($P \leq 0.05$) differed among varieties, with new tolerant varieties showing a slower rate of increase compared to the highly susceptible varieties. Results in Fig. 2 show variety KS20 consistently exhibited the highest weight loss (17.9%) over the storage period.

3.4 Bruchid Mortality

Karembo (15) and Ndengu Tosha (1) recorded significantly ($P \leq 0.05$) low bruchid mortality while KS20 showed the highest count of 42 at the end of 6 months. At the end of the storage period, Karembo and Ndengu Tosha recorded the lowest bruchid mortality due to population decline after peak infestation. Biashara exhibited a steady increase in bruchid mortality over time while Ndengu Tosha significantly ($P \leq 0.05$) maintained a consistently minimal dead bruchid count throughout the storage period (Fig. 3).

Table 1. Morphological traits of the seed of the five green gram varieties used in the study

Experiment	Variety	Seed weight (g)	Seed color (H°)	Seed coat thickness (mm)	Seed size (mm^2)
Experiment 1	N26	5.13 ± 0.034 d	92.5 ± 1.58 abc	0.094 ± 0.0040 c	16.37 ± 0.397 c
	KS20	6.14 ± 0.091 c	88.2 ± 2.15 c	0.076 ± 0.0048 e	19.73 ± 0.362 b
	Biashara	7.20 ± 0.092 a	90.3 ± 2.06 bc	0.091 ± 0.0043 d	22.32 ± 0.476 a
	Karembo	6.56 ± 0.063 b	93.9 ± 1.27 ab	0.108 ± 0.0017 b	20.27 ± 0.474 b
	N. Tosha	6.50 ± 0.063 b	94.3 ± 1.31 a	0.117 ± 0.0024 a	20.60 ± 0.419 b
LSD		0.145	3.21	0.007	0.64
P value		<.001	<.001	<.001	<.001
Experiment 2	N26	5.43 ± 0.064 d	87.15 ± 1.58 a	0.10 ± 0.0041 b	17.88 ± 0.214 e
	KS20	6.21 ± 0.093 c	87.19 ± 1.99 a	0.07 ± 0.0049 d	21.24 ± 0.154 d
	Biashara	6.81 ± 0.083 a	87.87 ± 1.89 a	0.08 ± 0.0039 c	25.07 ± 0.115 a
	Karembo	6.56 ± 0.058 b	90.45 ± 1.34 a	0.11 ± 0.0017 ab	22.98 ± 0.122 b
	N. Tosha	6.54 ± 0.042 b	91.09 ± 1.43 a	0.12 ± 0.0023 a	22.03 ± 0.128 c
LSD		0.140	3.331	0.007	0.632
P value		<.001	<.001	<.001	<.001

Values are means ± standard error of mean. Means followed by the same letter in a column are not significantly different at 5% probability level, LSD = least significant difference

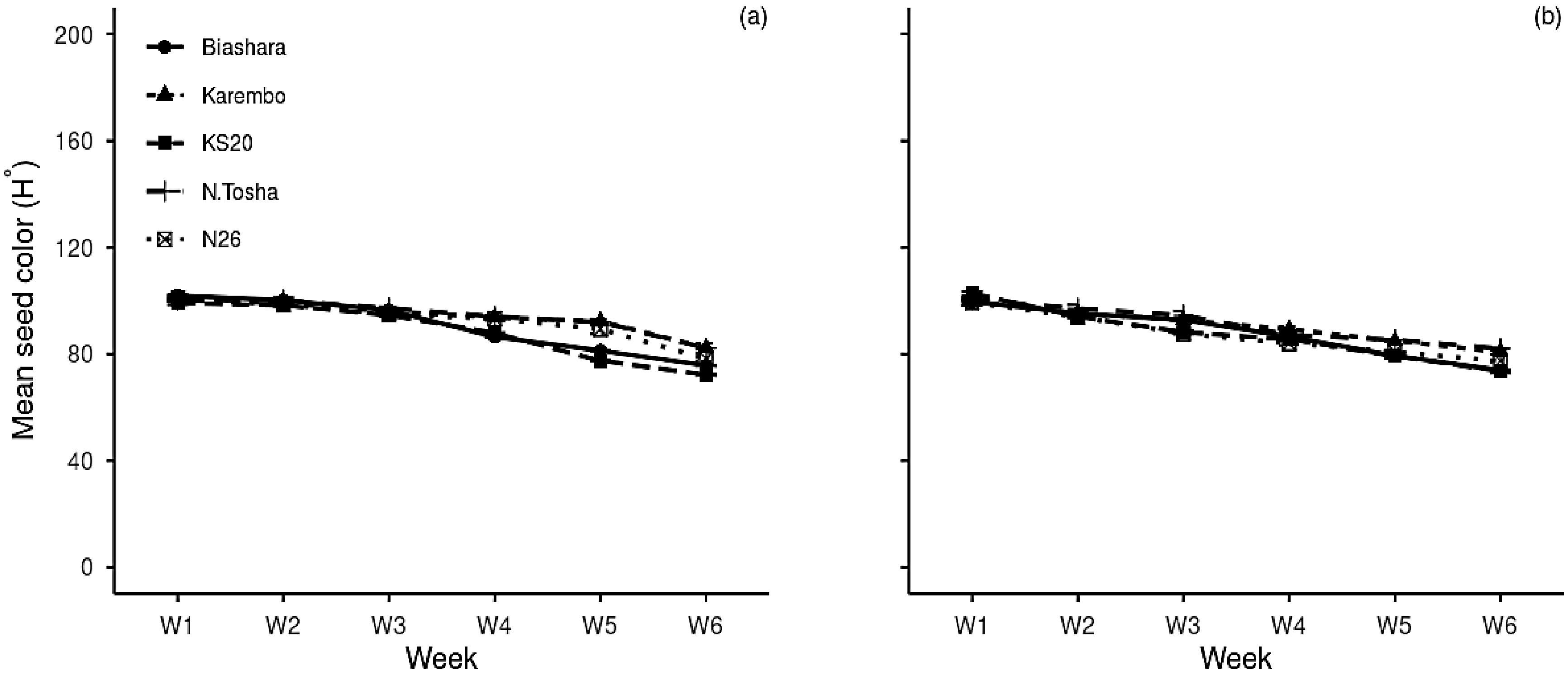

Fig. 1. Changes in seed coat colour (hue) of five green gram varieties under bruchid infestation during the first incubation cycle (a) and the second incubation cycle (b)

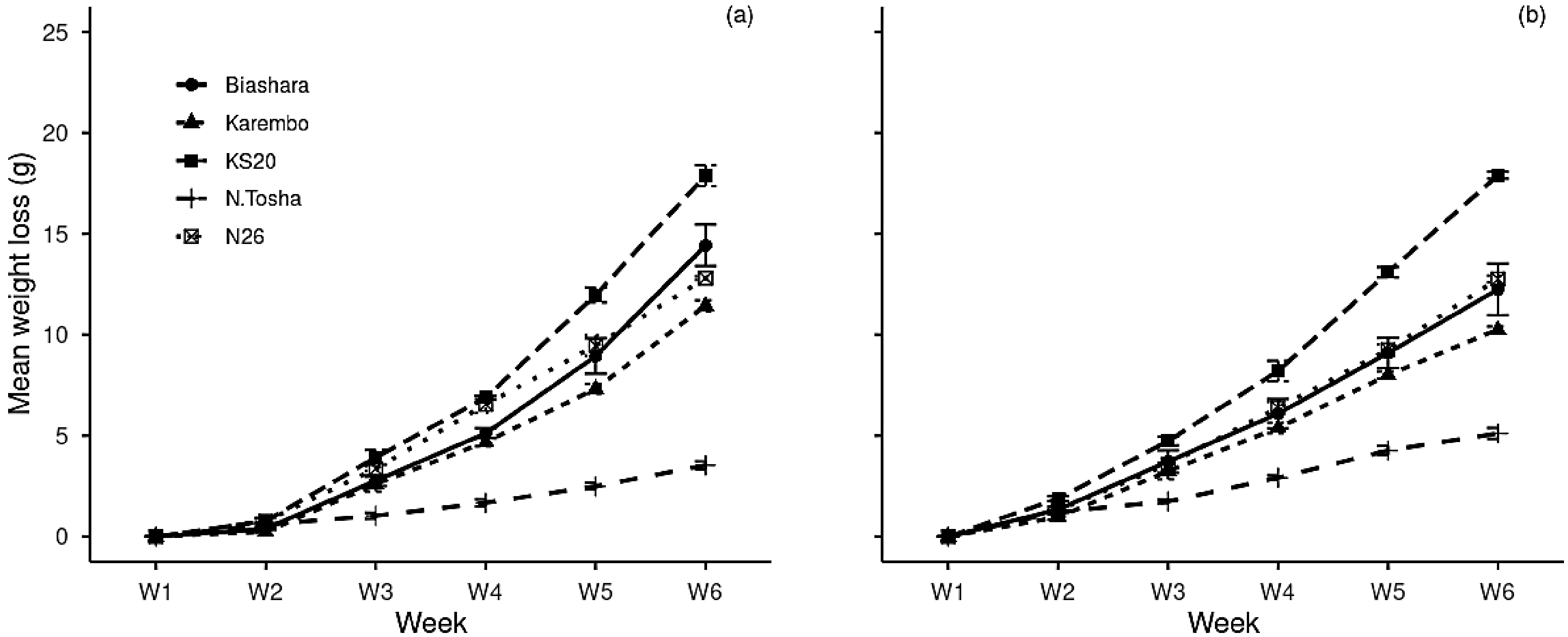

Fig. 2. Mean loss in seed weight of five green gram varieties during the first incubation cycle (a) and the second incubation cycle (b) under bruchid infestation

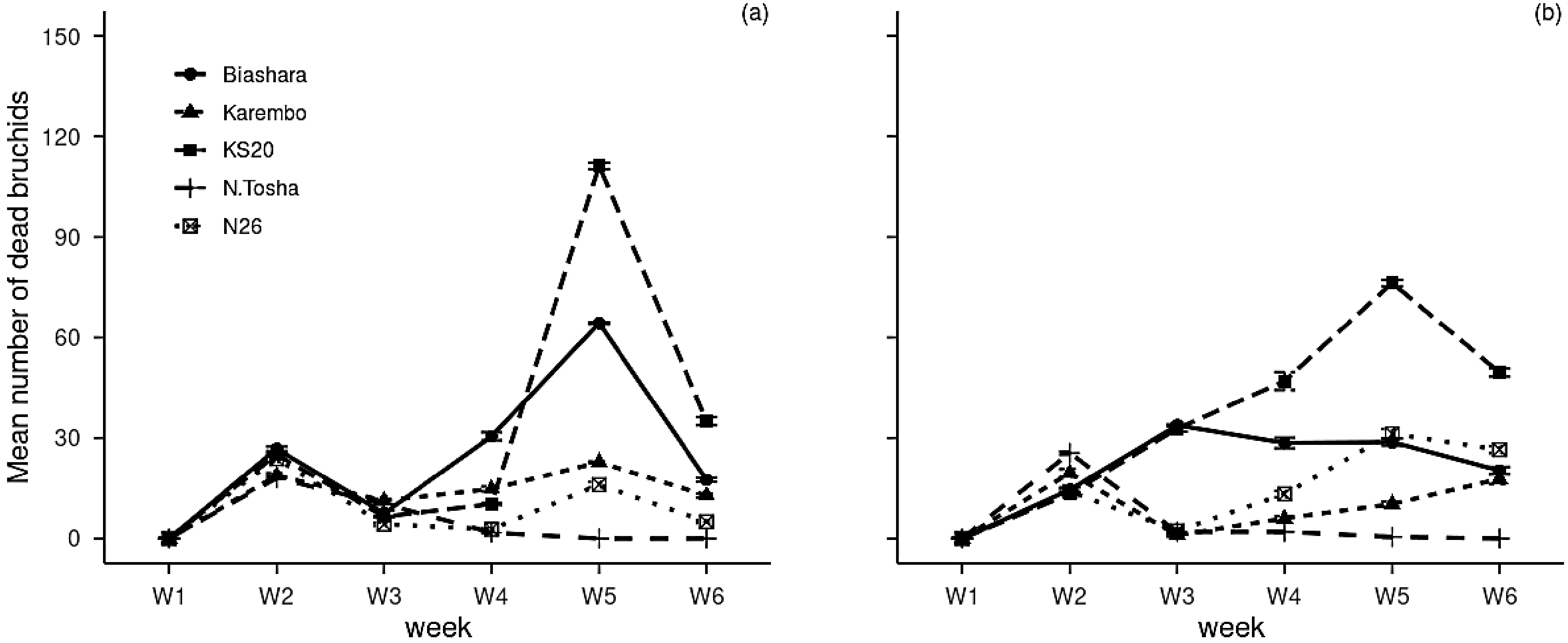

Fig. 3. Mean number of dead bruchids on five green gram varieties during the first incubation cycle (a) and the second incubation cycle (b)

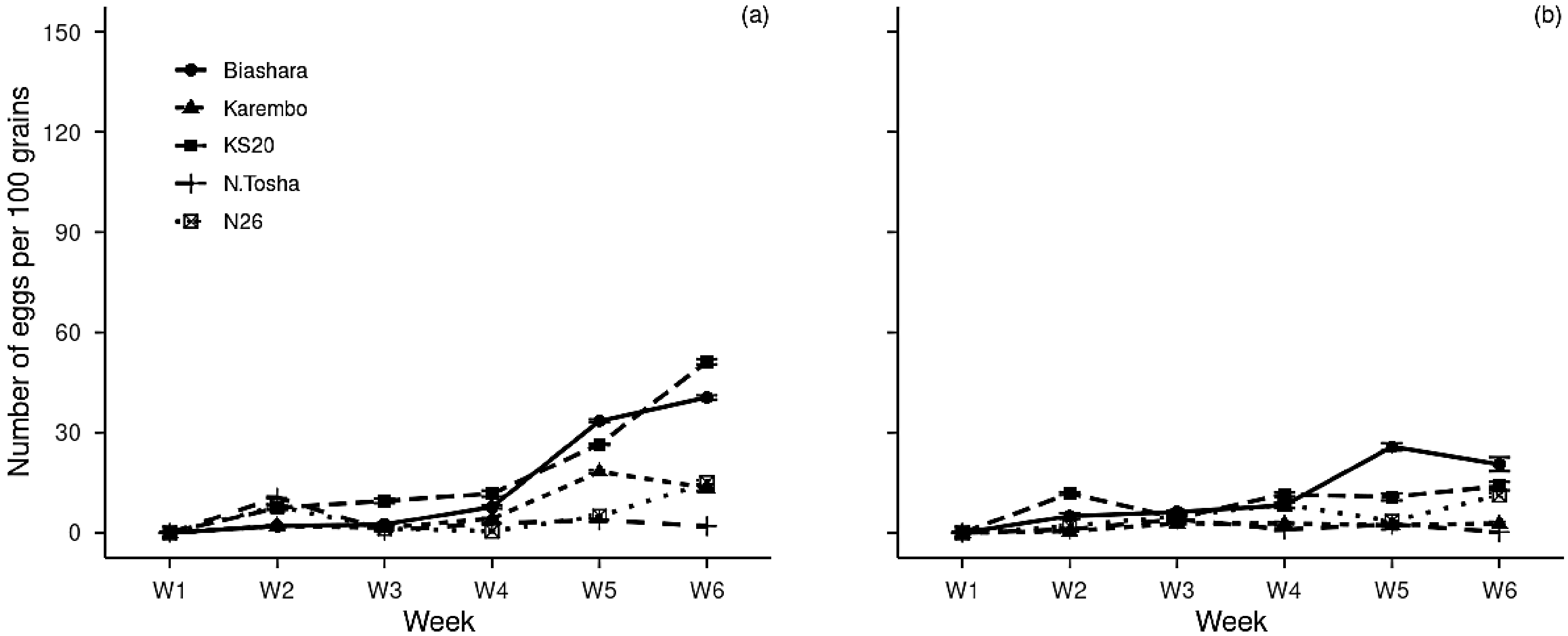

Fig. 4. Mean number of egged grains on five green gram varieties during the first incubation cycle (a) and the second incubation cycle (b)

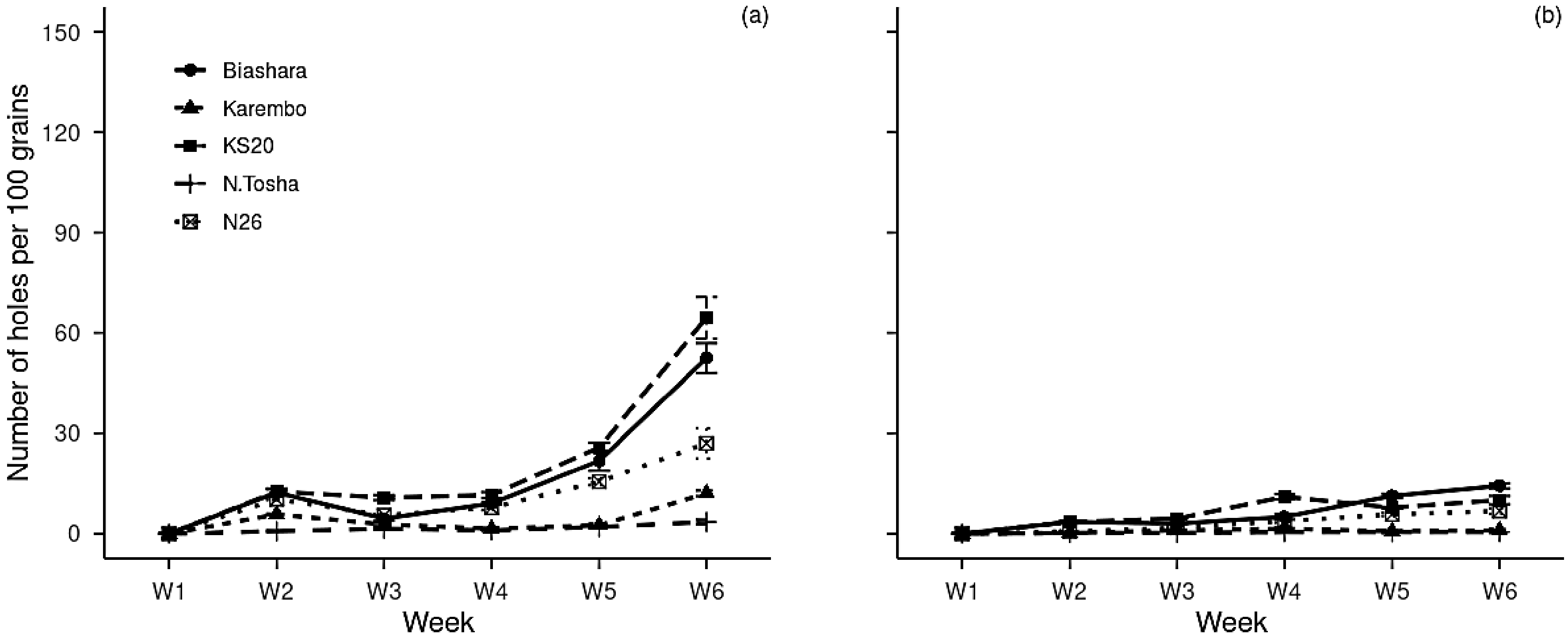

Fig. 5. Mean number of holes on five green gram varieties during the first incubation cycle (a) and the second incubation cycle (b)

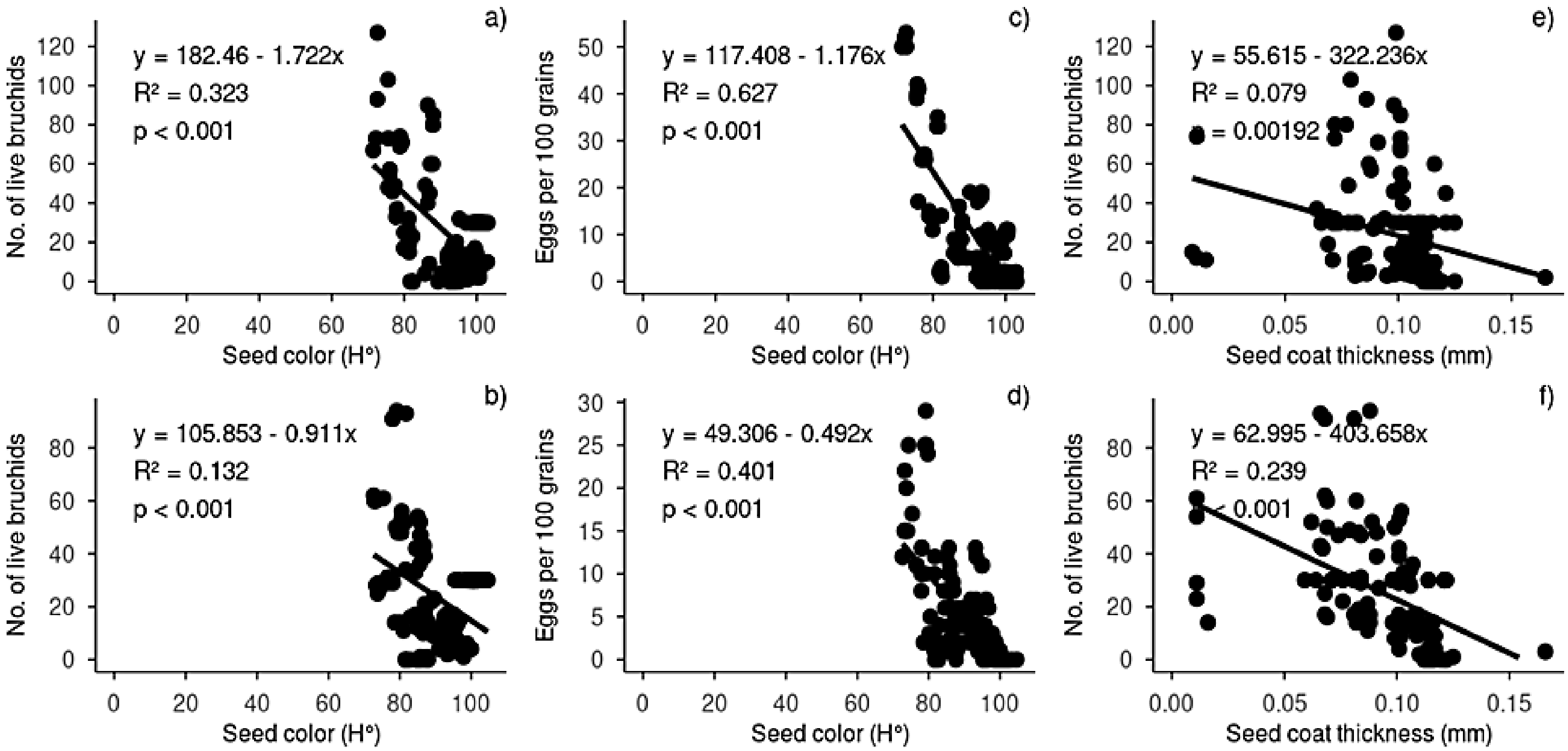

Fig. 6. Correlation between live bruchids and seed color (a), egged seeds versus seed color (c), and seed coat thickness versus live bruchids (e) in first incubation cycle and association between live bruchids and seed color (b), egged seeds versus seed color (d), and seed coat thickness versus live bruchids (f) in second incubation cycle. Lines are least square regressions. N = 15

3.5 Number of Egged Green Gram Grains

Ovipositional behavior of bruchids differed significantly at ($P \leq 0.05$) among the green gram varieties (Fig. 4). During the storage period, bruchids marginally oviposited on Ndengu Tosha and N26. At the end of storage period, Biashara and KS20 had recorded a higher oviposition while Ndengu Tosha variety recorded the least oviposition (1) hence was the least preferred variety by bruchids (Fig. 4).

3.6 Number of Holes on Grain

Results in Fig. 5 shows that the number of holes per 100 grains varied significantly among the four green gram varieties. KS20 recorded the highest number (37 holes per 100 grains), indicating greater susceptibility to damage. In contrast, Ndengu Tosha registered the least number (2 holes per 100 grains), demonstrating superior tolerance. The remaining varieties exhibited intermediate levels of grain damage. These differences highlight varietal variation in tolerance to grain perforation.

3.7 Relationship between Green Gram Grain Parameters

In first incubation cycle, data revealed negative and weak association between live bruchids with seed color and seed coat thickness $0.08 \leq R^2 \leq 0.32$ (Fig. 6). Similarly, in second incubation cycle, data showed negative and weak association between number of egged grains with seed color and seed coat thickness $0.13 \leq R^2 \leq 0.40$. In both cycles, live bruchids and seed color had a weak positive relationship $0.13 \leq R^2 \leq 0.32$ (Fig. 6). There was a strong positive relationship in first incubation cycle between seed color and egged grain ($R^2 = 0.63$) but a weaker association was observed in second incubation cycle ($R^2 = 0.40$) (Fig. 6).

4. Discussion

Bruchid infestation causes severe physical damage during storage to green gram seeds, thus reducing its nutritional quality and its viability (Usha et al., 2018; Yewale et al., 2020). The study confirmed that variation in seed morphological characteristics significantly influenced the relative tolerance of green gram varieties to bruchids. Varieties with smaller seeds, harder seed coats, and dull colors recorded lower infestation, consistent with other studies where seed hardness restricted bruchid penetration (Mwangi et al. 2020).

4.1 Change in Seed Coat Color

A decline in hue angle was observed across all varieties following bruchid infestation, indicating progressive seed coat discoloration. However, KS20 and N26 varieties exhibited significantly lower hue values (88.8 ± 1.1 H^o), reflecting pronounced browning and higher levels of damage. In contrast, Ndengu Tosha, Karembo and Biashara maintained higher hue angles, suggesting better preservation of seed coat color and exhibited high tolerance to bruchid infestation. Transition from green to yellow signified infestation, aging, and degradation of the green gram quality as similarly reported by Mwangi et al., (2020). Muchomba et al. (2023) reported that bruchids feed or lay eggs on shiny coloured grains and avoid dull coloured ones. The dull green color as indicated by the hue angle values was attributed to the biochemical changes and damage caused by the larvae feeding inside the grains (Muchomba et al., 2023).

4.2 Seed Coat Thickness

The present study indicated that Ndengu Tosha variety exhibited the highest seed coat thickness (0.13-0.20 mm) which led to greater tolerance to bruchid infestation compared to a thinner seed coat of both Biashara and KS20 varieties. Similar findings were previously reported by Pawara et al., (2019) and Holay et al., (2018). Seed coat plays a crucial role in the biological activities of *Callosobruchus maculatus* and seed infestation which is an important morphological trait for breeding bruchid-tolerant green gram (Pawara et al., 2019).

4.3 Loss in Seed Weight

Weight is a crucial factor that significantly affects the quality and economic value of agricultural produce (Kalpna et al., 2022). In this study, a progressive weight loss on grain across all varieties highlighted the cumulative effect of bruchid infestation over the storage period. These findings exhibited that the highest weight loss (17.9%) was recorded in susceptible varieties KS20 followed by Biashara, whereas the least was recorded in tolerant varieties Ndengu Tosha and Karembo which maintained higher structural integrity. Significant differences in seed weight loss across varieties were linked to larval feeding intensity of consuming the endosperm and leaving hollowed-out seed coats. Tolerant varieties showed minimal weight loss, aligning with Kalpna et. al. (2022) who observed reduced dry matter removal in tolerant legumes.

4.4 Bruchid Mortality

Bruchid mortality was evaluated on the basis of emergence which is manipulated by the round exit holes carrying a flap formed during the exit of the insect (Tripathi et al., 2020). In this study, it was observed that susceptible varieties (KS20 and Biashara) provided easier access to food sources hence it was where a higher population buildup was experienced. Tolerant varieties (Ndengu Tosha and Karembo), although harbored bruchids, significant differences in low infestation resulted in a low rate of mortality.

4.5 Number of Holes on Grain

Seed tolerance is better indicated by the number of emergence holes than that of laid eggs per seed (Gopal et al., 2023). The bruchids larvae penetrated more into the seed of KS20 and Biashara, developed inside them and excavated an emergence tunnel to the seed surface, forming a translucent window in the seed coat for adult emergence. The findings suggested that superior varieties (Ndengu Tosha and Karembo), which exhibited the significantly lowest number of holes of 2 and 7 respectively on grain were found to be likely tolerant (Pawara et al., 2019).

4.6 Number of Egged Green Gram Grains

Bruchids oviposital preference is guided by surface characteristics such as seed size, colour, seed coat texture, nutritional value and odour of grains emanating from its chemical composition (Tripathi et al., 2020; Soumia et al., 2017). In this study, no variety was immune to oviposition, and the highest number of eggs was observed in susceptible seeds of KS20 (33) followed by Biashara (31). The findings of this study corroborate with the results of Swamy et al. (2019) on chickpea varieties and Gopal et al. (2023) who worked on green gram varieties and found that varietal variations in bruchid susceptibility or tolerance may be attributed to differences in physical traits such as seed size and seed coat texture. However, earlier studies suggested that oviposition preference is more strongly influenced by host availability and susceptibility, which should not be assessed solely based on oviposition (Gopal et al., 2023).

4.7 Relationships Between Green Gram Grain Parameters

Correlation analyses showed negative and weak association between live bruchids with seed color and seed coat thickness, consistent with Somta et al., (2007). There was a strong positive relationship in second incubation cycle between egged seeds and seed color. Variation in the number of live bruchids among green gram varieties was associated with differences in seed coat color, indicating that hue angle contributes to relative tolerance. Varieties (Ndengu Tosha and Karembo) with higher hue angles (lighter seed coats) supported fewer live bruchids, suggesting reduced suitability for oviposital preference. Seed color has been linked to presence of phenolic compounds which may discourage feeding thus affect insect survival (Somta et al., 2007).

Seed coat thickness showed a weak negative association with the number of live bruchids, underscoring its importance as a physical tolerance mechanism. Varieties with thicker seed coats like Ndengu Tosha recorded lower bruchid survival probably due to restricted larval penetration. Thick seed coats can impede egg hatching entry, prolong larval development and increase early mortality (Pawara et al., 2019). This trait represents a stable and reliable morphological trait for improving bruchid tolerance in green gram breeding program.

5. Conclusion

The present study demonstrates that tolerance to bruchids in green gram is governed by combined effects of physical seed traits. The findings indicate that the two new varieties, Ndengu Tosha and Karembo reveal likely tolerance to bruchid attack, while others are more susceptible. Breeding strategies that prioritize thicker seed coats and seed color attributes could enhance post-harvest tolerance without compromising agronomic performance. Incorporating these traits into varietal selection could offer a low cost solution that would reduce bruchid damage to green gram grains. These results highlight the importance of incorporating varietal tolerance into postharvest management strategies that will contribute to reduction of postharvest losses, reduced pesticide reliance and increase income of small scale farmers. Future research should focus on developing new varieties with enhanced tolerance to bruchid infestation and validate performance of tolerant varieties under different environmental conditions.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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