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Varietal influence of cowpea (*Vigna unguiculata* (L.) Walpers) on the pulse beetle (*Callosobruchus Maculatus* (F.) infestation at storage in Northern Region of Ghana

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Abstract
Callosobruchus maculatus (F.), a cosmopolitan and most destructive pest of stored pulse grains, causes severe post-harvest and economic losses to farmers and traders. The results showed that Padi-tuya, Apagbaala, Marfo-tuya and the local check are susceptible to *C. maculatus*, recording the highest egg load progeny emergence and highest seed weight loss, as well as shortest developmental period. Songotra was the least preferred, followed by Zaayura and Bawutawuta. Results from susceptibility indices further indicated that Songotra and Zaayura were the least susceptible to *C. maculatus*, while Padi-tuya and Apagbaala were the most susceptible. Songotra and Zaayura should therefore be promoted to help control the pest during storage.

Keywords: *Callosobruchus maculatus*, cowpea, improved varieties, susceptibility

Introduction
A major constraint to postharvest preservation of cowpea in the tropics is infestation by the pulse beetle, *Callosobruchus maculatus* (F.), a cosmopolitan and most destructive pest of stored pulse grains which causes severe post-harvest and economic losses to farmers and traders. This pest is capable of rendering unprotected grains unqualified for food or seed within few months of storage through its post-harvest feeding and reproductive activities [1, 2].
Control of this pest is therefore necessary to the increase and sustainable production and preservation of cowpea in the production areas. While there are several synthetic insecticides such as chemical grain protectants and fumigants for the control of *C. maculatus* in cowpea, their use has not been sustainable owing to their high costs, unavailability in local markets and associated health and environmental risks including insect resistance [1, 2].
In order to reduce both over-reliance on chemicals for control, and seed loss due to bruchid attack, the search for host plant resistance in cowpea which is an environmentally safer and cheaper alternative to the killer synthetic insecticides has increasingly become the option of choice in recent years. Host plant resistance to insect pests provides a potential and sustainable option in insect pest management [3]. The use of resistant cowpea cultivars offer a simple, cheap and attractive way for the reduction of bruchid damage as it requires little knowledge by farmers, free of extra cost to farmers and also enhances the effectiveness of other pest management tactics such as cultural and biological control [4]. Hence, it is pertinent that a study of bruchid responses to improved cowpea varieties be conducted.
This study seeks to evaluate the susceptibility of improved varieties to infestation and damage by *C. maculatus* with the aim of selecting those with inherent resistance for controlling the pest at the store.

Materials and Methods
Cowpea varieties: Grains of seven cowpea varieties obtained from the breeding unit of SARI, Nyankpala were used for the study. The varieties were Padituya, Songotra, Apagbaala, Zaayura, Bawutawuta, Marfo-tuya and a local variety all obtained from the breeding section of CSIR-SARI in Nyankpala.

These grains were then sorted out to remove all the unwanted or foreign materials. Prior to the experiment, the grains were kept in a deep freezer after drying at 2°C for at least 72 h to ensure the death of any unseen eggs and internal infestations. These grains were then allowed to dry for at least an hour prior to weighing [5]. This was done to condition them to room temperature before using them for the experiment [6].

Bruchid culture: The method for rearing the experimental insects followed the procedure described by Swella [25]. Adults *C. maculatus* were originally obtained from infested samples of cowpea in a laboratory stock at CSIR-Savanna Agricultural Research Institute, Tamale, Ghana. They were reared and bred under diet of cowpea seeds inside a growth chamber of temperature 27±3°C and 50-70% relative humidity. A total of hundred (100) pairs of newly emerged (1-24 h old) adults were introduced into each rearing jar containing 500g of cowpea grains.

The jars were covered with pieces of fine nylon mesh cloth at the open ends, and fastened with rubber bands to prevent the contamination of the seeds and escape of the beetles. A maximum of 5 days was allowed for mating and Oviposition. The parent beetles were removed afterward, and the seeds containing the eggs were transferred to fresh seeds in rearing jars which were also covered as described above. The rearing was done at the above-mentioned temperature and relative humidity after collection for several generations to allow for the multiplication of the weevil for the experiment [7]. The subsequent progenies emerging from the stock were used as parental generation for the experiment [8].

Experimental design and procedure: The experiment was a single factor (Variety) at seven levels. It was arranged using Completely Randomized Design (CRD). Thus, seven treatments that were replicated four times given twenty-eight treatments in all.

Two hundred sound grains of each variety of known weight were placed in each experimental jar for the infestation. All the treatments were infested with *C. maculatus* obtained from the stock culture of the Entomology Section of the institute. Each treatment was infested as described above. Each experimental jar was then well labeled, well closed and placed in the laboratory under the same temperature of 27±3°C and 50-70% relative humidity. These were then monitored for the period of the insect's life cycle during which period, all the necessary data were taken. Parameters measured included: Oviposition, adult developmental period, F1 progeny emergence, adult mortality, grain damage, grain weight loss, and susceptibility index.

Data collection: One week after the infestation of the insects on the grains, the grains were accessed for Oviposition. The number of eggs deposited on each grain was counted and recorded after which the grains were then kept for F1 progeny test. After the Oviposition, the developmental period was observed. This was done by counting the number of days it takes the insect to emerge from each treatment through monitoring every day after Oviposition.

The day the first insect emerged was noted and monitored for some time to get the maximum number of emergence and to the end of the insects' life cycle. F1 progeny assessment started from the time of the adult emergence. This was done by counting all emerged insects both live and dead once. After the first emergence, treatment jars were monitored for an additional week to make sure that all eggs laid that were capable of hatching are hatched. Progeny emergence was concluded after four weeks of storage where some of the insects' life cycle started ending and an account of adults emerged in each jar recorded [9].

Adult mortality count was done at the end of the insects' life cycle by sieving out the entire adults that emerged. The dead ones were then counted and discarded while keeping the survived once. The survived once were then returned to the stock culture to continue with their activity of mating and Oviposition for the next generation of adult emergence. To identify the dead once out of the survived once, the probing method was employed. This was done after sorting them out in to the assumed dead and live once based on movement by disturbing them with a camel hair brush. Those insects sorted to be dead once were subjected to piercing using the hair of the brush to confirm they are really dead. If the insect moves its body to the response of the disturbance, then it was considered as being alive and not dead as they are capable of fooling man by playing it dead.

Grain damage assessment was determined on all the varieties. To determine grain damage rate, samples of 100 grains were taken randomly from each treatment jar. The number of damaged (grains with characteristic holes) and undamaged grains were counted and the rate calculated using the formula below deduced from [10].

Rate of damage = [Nd / (Nd + Nu)] x 100 [11, 12]

Where; Nd = Number of damaged grains and Nu = Number of undamaged grains.

Weight Loss caused by the insects assessment was done on treated and untreated grains after four weeks of the grain's storage. The damage and undamaged grains after being sorted and counted was then weighed and the weight loss assessment computed using the formula: Percentage grains weight loss = [(UNd)-(DNu)/ U (Nd + Nu)] x 100

Where, U = Weight of undamaged grain, D = Weight of damaged grain, ND = Number of damaged grains and Nu = Number of undamaged grains [13].

In determining the susceptibility index, the F1 progeny emerged and the developmental period were considered. Thus, susceptibility index was determined using Dobie's equation adopted by (Badii *et al.*, 2011, Musa and Adeboye, 2017) as follows:

Susceptibility index (SI) = ($Log_e\, F_1/D$)*100 [14, 15, 16]

Where; F_1 = total number of adults emerged, D = Median developmental period (estimated as the time from the middle of Oviposition to the emergence of 50% of the F_1 generations).

The Dobie's index of susceptibility adopted by [2] was used to classify the cowpea varieties into different groups using the following scale.

Scale index of < 4.1 as highly resistant; Scale index of 4.1 - 6.0 as moderately resistant; Scale index of 6.1-8.0 as moderately susceptible; Scale index of 8.1 - 10 as susceptible; Scale index of >10 as highly susceptible.

Data analysis: Data collected were subjected to analysis of variance using Genstat Statistical Package, 12th edition and the means separated using Standard Error of Differences

(SEDs) at 5% probability level. In addition, correlation analysis was done to ascertain the relationship between grain susceptibility and the damage related parameters using Spearman's correlation Co-efficient.

Results

Oviposition: Mean Oviposition on the cowpea grains was significantly ($p<0.05$) influenced by the varieties tested. The local check recorded the highest number of eggs laid. This was however, not significantly different ($p>0.05$) from Padi-tuya. Apagbaala recorded the next heaviest egg load followed by Marfo-tuya both of which were significantly different ($p<0.05$) from Padi-tuya and the local check. Songotra on the other hand, recorded the least significant ($p<0.05$) number of eggs followed by Zaayura and Bawutawuta. There was no significant difference ($p>0.05$) between Zaayura and Songotra. Similarly, Zaayura and Bawutawuta were not significantly difference ($p>0.05$). However, the number of eggs on Bawutawuta was significantly higher ($p<0.05$) than that of Songotra (Figure 1.).

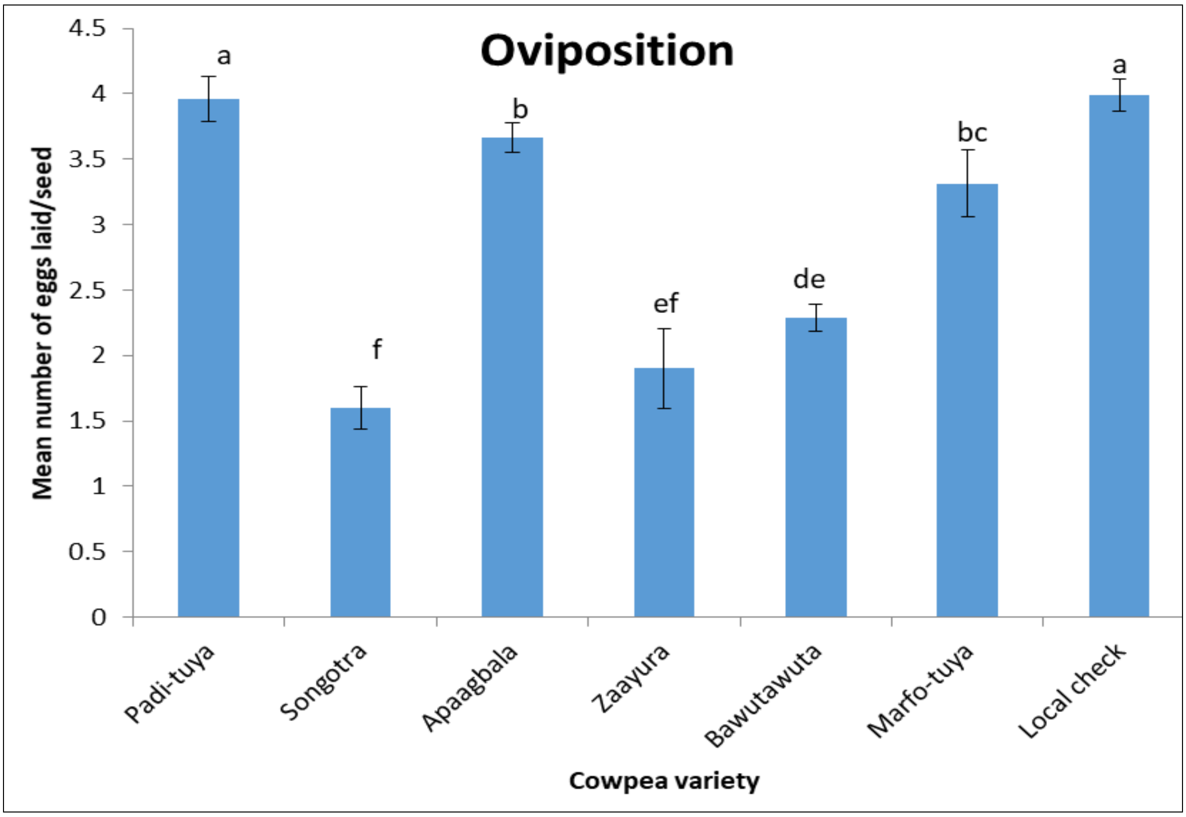

Fig 1: Effect of cowpea variety on mean number of eggs laid by the pulse beetle, *Callosobruchus maculatus* (F.). Bars represent Standard Error of the Means (SEMs). Collums with different letters are significantly different at 5% probability level.

Developmental period: The influence of cowpea variety on the time taken by the adult pulse beetle to develop from egg to adult is presented in (Figure 2). Developmental period was significantly influenced ($p<0.05$) by the cowpea varieties tested. The local check recorded significantly shorter developmental period (19 days) than the improved varieties. This was followed by Padituya, Marfotuya and Apagbaala. The latter varieties were however, not significantly different ($p>0.05$) from each other. Also, the beetle took significantly ($p<0.05$) more number of days (23.75 days each) to complete its development in Songotra and Zaayura. This was followed by Bawutawuta with 23.25 days. There was however, no significant difference ($p>0.05$) between the two varieties and Bawutawuta.

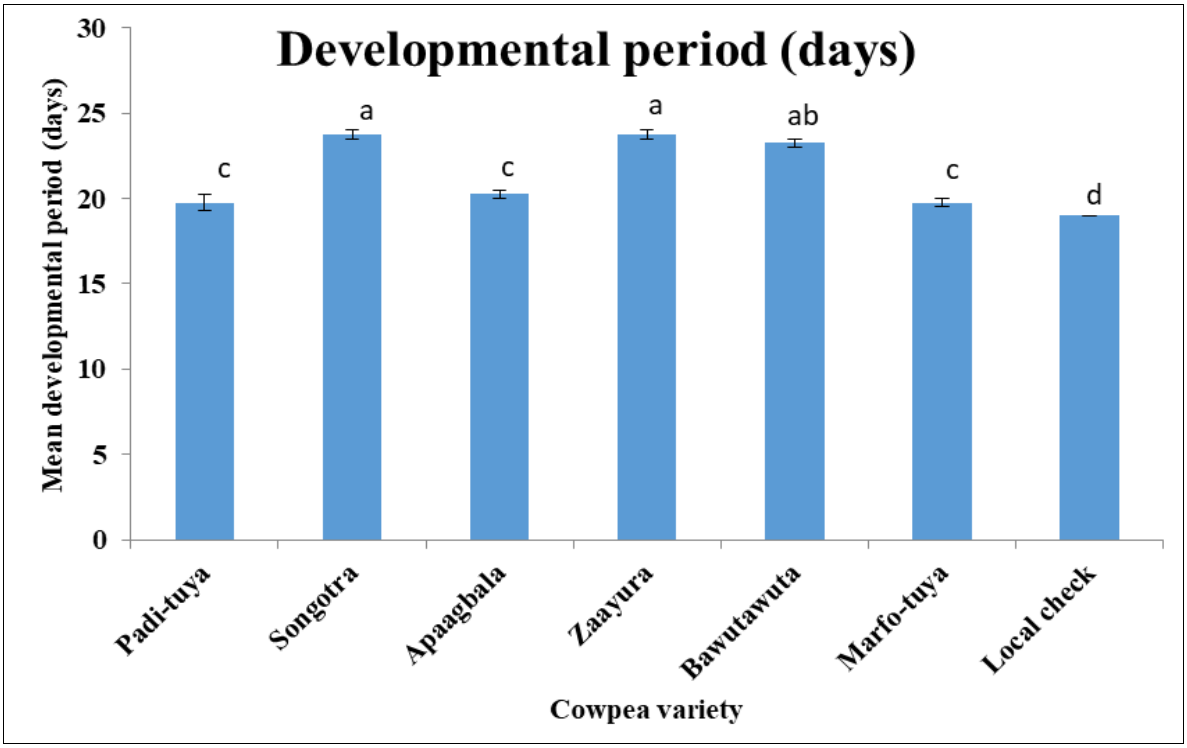

Fig 2: Mean developmental period of the pulse beetle, *Callosobruchus maculatus* (F.) as influenced by cowpea variety. Bars represent Standard Error of the Means (SEMs). Collums with different letters are significantly different at 5% probability level.

Adult emergence: Figure 3 shows the effect of cowpea varieties on the mean adult emergence of *C. maculatus* (F.) from the seed grains during the storage period. The local check recorded significantly ($p<0.05$) higher number of adult emergence (79) but not significantly different from Apagbaala and Padi-tuya. These were followed by Marfo-tuya which was not significantly different ($p>0.05$) from Apagbaala and Padi-tuya. Adult emergence in Marfo-tuya was however, significantly differed ($p<0.05$) from the local check. In contrast, Zaayura had the lowest number of adult insect emergences, but this was not significantly different ($p>0.05$) from Songotra and Bawutawuta. Emergence in these three varieties (Zaayura, Songotra and Bawutawuta) however, differed significantly from that of the remaining four varieties (Padi-tuya, Apagbaala, Marfo-tuya and the local check).

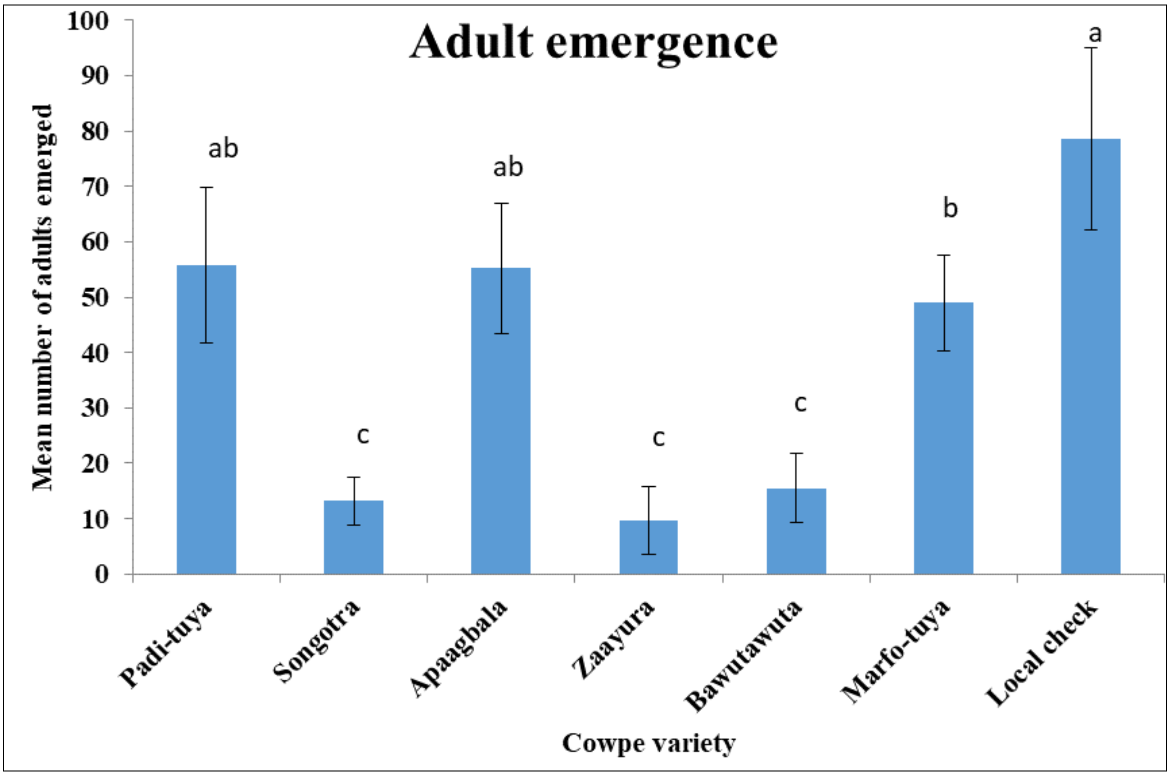

Fig 3: The influence of cowpea variety on adult emergence of the pulse beetle, *Callosobruchus maculatus* (F.). Bars represent Standard Error of the Means (SEMs). Collums with different letters are significantly different at 5% probability level.

Grain damage: Damage by *C. maculatus* as influenced by the different cowpea varieties tested is presented in Table 1. The number of damaged and undamaged grains was significantly affected ($p<0.05$) by the cowpea variety. Significantly highest ($p<0.05$) damage was recorded on the local followed by Apagbaala. Padi-tuya also recorded high number of damaged grains and percentage grain damage. This was however not significantly different ($p>0.05$) from Apagbaala. In contrast, number of damaged grains and percentage damaged grains were significantly ($p<0.05$) lowest on Zaayura. This was followed by Marfo-tuya, Songotra and Bawutawuta. Songotra and Bawutawuta were also not significantly different ($p>0.05$) from each other. However, these two varieties were significantly different ($p<0.05$) from Zaayura.

Grain weight loss: Mean and percentage grain weight loss were significantly ($p<0.05$) highest in Apagbaala, Padi-tuya and the local check. On the other hand, Bawutawuta, Zaayura, Songotra and Marfo-tuya recorded significantly ($p<0.05$) the lowest mean and percentage grain weight loss are presented in (Table 2).

Table 1: Effect of cowpea variety on percentage grain damaged by the pulse beetle, *Callosobruchus maculatus* (F.)

Cowpea variety	Number of undamaged grains	Number of damaged grains	Percentage damaged grain
Padi-tuya	73.0d	27.0b	25.50b
Songotra	93.0b	7.0d	11.00c
Apagbaala	72.0d	28.0b	26.50b
Zaayura	97.0a	3.0e	8.00d
Bawutawuta	94.0a	6.0de	11.50c
Marfo-tuya	89.00c	11.00c	10.50cd
Local check	67.0e	33.0a	31.50a
*SED	3.238	3.238	2.540
*CV	5.5	28.6	20.2

Note: Means with different letters are significantly different at 5% probability level. *SED = Standard Error of Difference, CV= Coefficient of Variation.

Mean grain weight loss and percentage grain weight loss in Bawutawuta was significantly ($p<0.05$) lower than that of Songotra, Zaayura and Marfo-tuya. There were significant differences among Songotra, Zaayura and Marfo-tuya in terms of their mean grain weight loss. However, there were no significant difference between Songotra and Zaayura for their percentage grain weight loss but these differed from Marfo-tuya. Also, grain weight losss in Padi-tuya and Apagbaala were not significantly different ($p>0.05$) from the local variety.

Susceptibility index: Grain Susceptibility to the beetle was significantly ($p<0.05$) influenced by the varieties tested. The local variety (check) had a significantly ($p<0.05$) higher susceptibility index but it was not significantly different ($p>0.05$) from Padi-tuya. Zaayura recorded significantly ($p<0.05$) lower susceptibility index followed by Songotra and Bawutawuta. Grain susceptibility was not different ($p>0.05$) among Marfo-tuya, Apagbaala and Padi-tuya though Padi-tuya recorded a higher susceptibility than the others (Figure 4).

Table 2: Effect of cowpea variety on grain weight loss due to the pulse beetle, *Callosobruchus maculatus* (F.) infestation

Treatment/ Cowpea variety	Weight of undamaged grains	Weight of damaged grains	Mean Grain weight loss	Percentage Grain weight loss
Padi-tuya	16.39c	3.61b	2.000a	9.09c
Songotra	15.13d	0.62de	1.250cd	7.35e
Apagbaala	13.23f	2.77c	2.000a	11.11a
Zaayura	19.32a	0.18ef	1.500b	7.14e
Bawutawuta	17.70b	1.17d	1.125d	5.63f
Marfo-tuya	16.11c	0.52e	1.375c	7.64d
Local check	14.38e	4.49a	2.125a	10.12b
SED	0.497	0.559	0.1890	0.956
CV	4.4	41.5	16.4	16.3

Note: Means with different letters are significantly different at 5% probability level. *SED = Standard Error of Difference, CV= Coefficient of Variation.

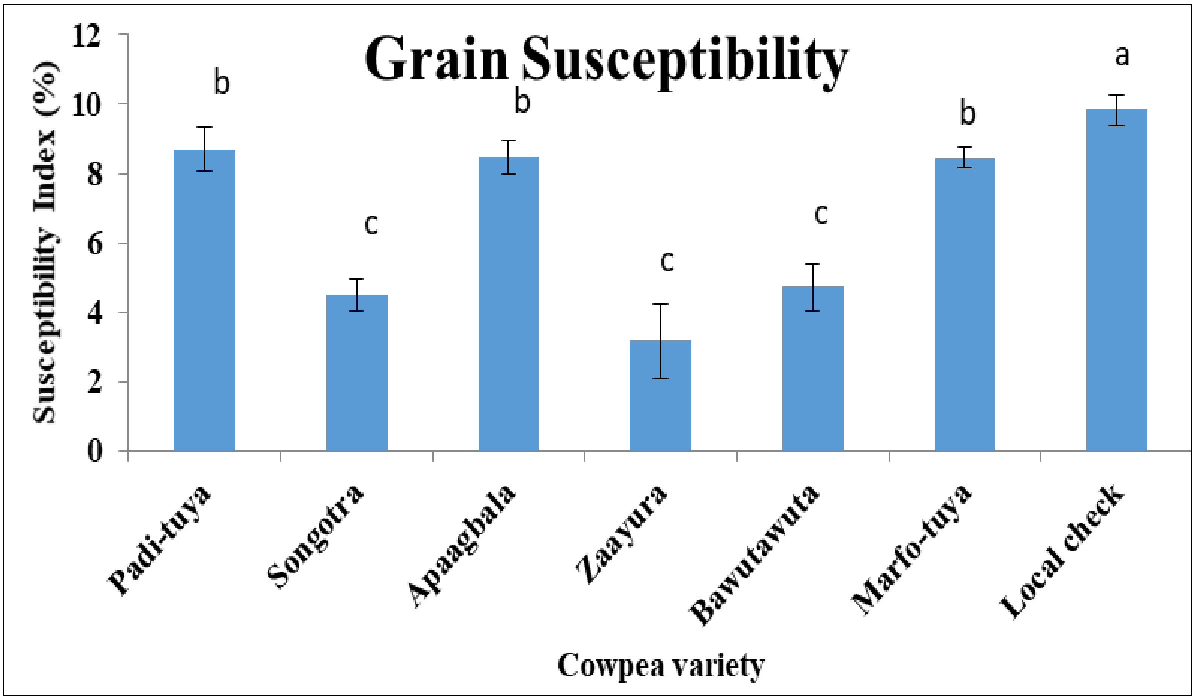

Fig 4: Cowpea grain susceptibility to the pulse beetle, *Callosobruchus maculatus* (F.) as influenced by varietal differences. Bars represent Standard Error of the Means (SEMs). Collums with different letters are significantly different at 5% probability level.

When the seven varieties were ranked in order of their relative susceptibilities using parameters such as Oviposition, developmental period, adult emergence, grain damage and grain weight loss, Zaayura, Songotra and Bawutawuta were still found to be the least preferred/resistant varieties while Marfo-tuya, Apagbaala, Padi-tuya and the local check were the highly preferred/susceptible varieties to *C. maculatus* infestation (Table 3).

Table 3: Ranking of the different cowpea varieties in order of relative susceptibility to *Callosobruchus maculatus* (F.)

Cowpea varieties	Mean No. of eggs laid	Mean developmental period	Mean number of adults emerge	% grain damage	% Grain weight loss	Susceptibility index	Total ranks	Mean ranks
Padi-tuya	6	2	6	5	5	6	30	5
Songotra	1	5	2	3	3	2	16	2.7
Apagbaala	5	3	5	6	7	5	31	5.2
Zaayura	2	5	1	1	2	1	12	2
Bawutawuta	3	4	3	4	1	3	18	3
Marfo-tuya	4	2	4	2	4	4	20	3.3
Local check	7	1	7	7	6	7	35	5.8

*Infestation and damage: 1 = least susceptible/infested, 7 = most susceptible/infested

Seed viability: Germination was significantly different among the varieties. The local check recorded the lowest germination percentage while Songotra was the highest. The local check was however not significantly different (p>0.05) from Apagbaala and Padi-tuya. Germination percentage of seeds of Songotra was not also significantly (p>0.05) different from those of Zaayura. Bawutawuta and Marfo-tuya were next in decreasing order of germination (Figure 5).

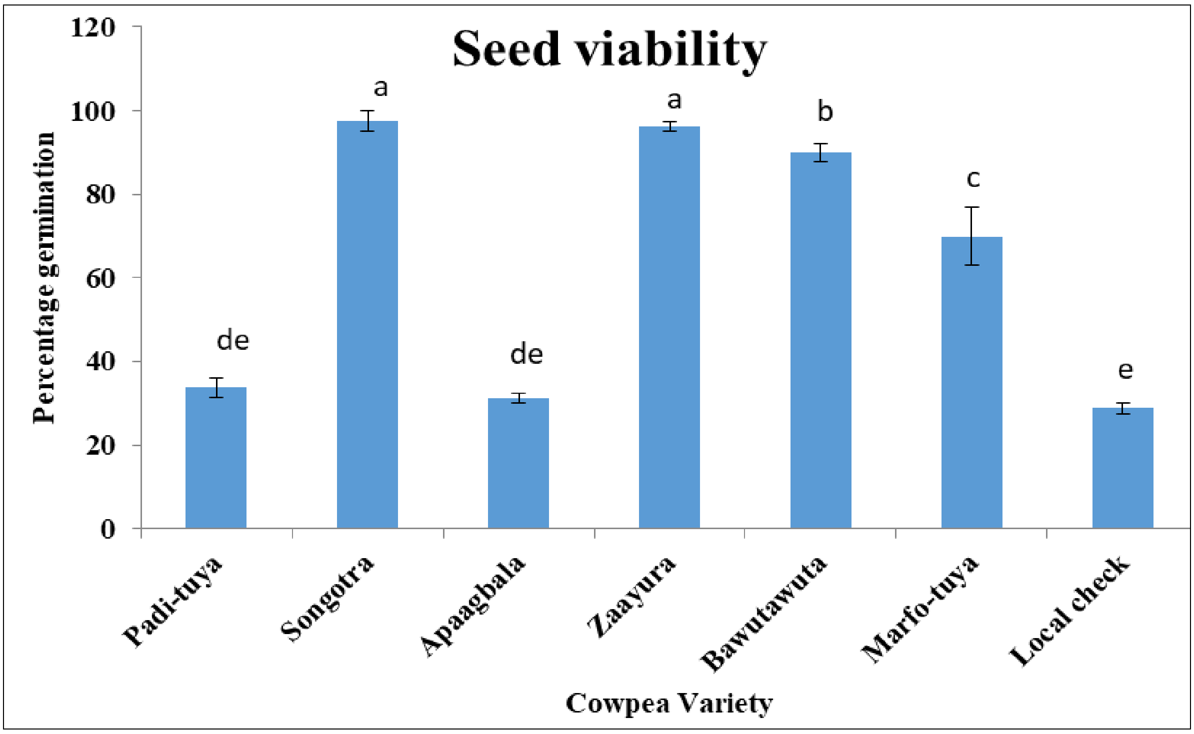

Fig 5: The effect of variety on viability of cowpea seeds after infestation with the pulse beetle, *Callosobruchus maculatus* (F.)**.** Bars represent Standard Error of the Means (SEMs). Collums with different letters are significantly different at 5% probability level

Relationship between the damage parameters

Table 4. Correlation coefficients of damage related parameters used to determine the susceptibility of cowpea varieties to *Callosobruchus maculatus* (F.).

	% Susceptibility	Oviposition	Developmental period	Adult insect emergence	Grain Damage	% Grains weight loss	Seed Viability
%Susceptibility	1.000						
Oviposition	0.843**	1.000					
Developmental period	-0.865**	-0.825**	1.000				
Adult insect emergence	0.984**	0.834**	-0.805**	1.000			
Grain Damage	0.729**	0.766**	-0.658**	0.743**	1.000		
% Grains weight loss	0.599**	0.470*	-0.556**	0.629**	0.639**	1.000	
Seed viability	-0.768**	-0.809**	0.847**	-0.757**	-0.801**	-0.744**	1.000

*Significant at p≤0.05, **highly significant at p≤0.01.

The results showed that susceptibility correlated positively with Oviposition, grain damage, adult emergence and percentage grain weight loss but negatively with adult developmental period and seed viability. There was highly significant difference ($p<0.001$) between susceptibility and these parameters. Seed viability and developmental period showed a significant negative correlation with susceptibility.

Grain weight loss correlated positively and significantly ($p<0.05$) with Oviposition, grain damage and adult emergence but negatively with adult developmental period and seed viability.

Also, grain damage correlated positively with adult insect emergence but negatively with the adult developmental period and seed viability. There was positive correlation between Oviposition and adult insect emergence as well as grain damage.

Discussion

Oviposition: The differences in Oviposition exhibited by the different varieties could be due to their different sizes. This finding supports the statement made by [2] that the size of the seeds may have been responsible for provision of a favorable site and nourishments for egg-laying and subsequent development. The finding also agrees with the findings of [8] which states that the suitability of cowpea seed type for Oviposition by *C. maculatus* is influenced by surface area and curvature of the seeds. According to [17], bruchids females do not only deposit more eggs on the larger grains but, also distributes their eggs according to the relative mass of the grains available hence the choice for Padituya and Apagbaala in this study. Another reason could be due to their seed coat textural differences resulting in the differences. According to [18], at the stage of Oviposition, a female bruchid has to choose wisely Oviposition site for her offspring since it will influence their growth, survival and reproduction. This therefore goes to suggest that Apagbaala and Padituya both of which have larger grain sizes and very soft seed coats compared with Zaayura, influenced the choice of the adult females for their Oviposition. This revelation goes to confirm the finding made by [19] that grains with thinner seed coats are better accepted for Oviposition than grains with thicker seed coats. [20] also attributed the different Ovipositional choice on different pulses to surface odors and for that matter, the chemical composition of the seed coat. According to [21], there exist secondary metabolites (polymers like lignins and tannins, alkaloids, quinines, etc.) that play an important role in the seed defense against insects such as repellents, feeding inhibitors and anti-nutritional factors. It therefore goes to suggest that though, Zaayura a bigger and heavier grain than Songotra, both varieties might have more of these metabolites making them less susceptible to the insect. Generally, grain properties such as testa colour, mass, size and moisture content influence the susceptibility of cowpea and other cereals grains to *C. maculatus* in storage [22].

Developmental period: The least median developmental period observed on Padituya and Apagbaala indicated that they might have soft and preferable endosperm without chemical constituents or insecticidal properties that could hinder the insects' developmental period thus, making them grow fast from one instars to the other there by making the varieties susceptible to the insect. The developmental period for the insect recorded in this study ranges between 19 days and 24 days. The resistant varieties ranges between 22 and 24 days whilst that of the susceptible varieties ranges between 19 and 21 days under the temperature of 27±3°C and 50-70% relative humidity. This observation partially agrees with that of [23], who reported that the mean life cycle of *C. maculatus* ranged between 21 and 25 days on a susceptible variety. It also partially supported the findings of [2] who reported the median developmental period of the insect as being ranged between 23 and 31days. According to [24], the period of development from egg to adult varies with environmental conditions such as temperature and relative humidity but, [25] stated that, at 27ºC and 70% RH, the developmental period of the insect is about 30 days which was in disagreement with these findings. Same findings was also documented by [26] and supported by [27] at 28.5±2.0°C and 78.5±3.0% relative humidity which is also contrary to this findings though they did not state whether resistant or susceptible varieties.

Adult emergence: The less number of adult emergences on Songotra and Zaayura was probably due to the less Oviposition and high developmental period recorded on these grains. This finding conforms to that of [27] who stated that the prolonged egg development and few progenies emerging from a legume variety means that variety is resistant. according to [28], the pattern of adult emergence of *C. maculatus* in resistant cowpea varieties are characterized by delayed, staggered and slow adult emergence whilst in the susceptible varieties, adult emergence are relatively early and extremely rapid leading to the extensively damaging results obtainable from those varieties. The finding also goes in line with that of [2] which states, a higher number of adult *C. maculatus* emerging on a cowpea variety with the shortest median developmental period suggest that the median developmental period influenced the grain infestation [22]. Also reported that when a variety showed higher mean number of eggs deposits and similar result obtained in the number of hatched eggs, it is an indication of its susceptibility to *C. maculatus*. This therefore goes to suggest that, Padituya and Apagbaala both of which recorded highest number of egg deposits similar to the number of progenies emerged are susceptible varieties since both will as well, record the highest percentage grain damage. This result also confirms that of [19] who reported that the number of emerging adult determines the extent of damage, and consequently, grains permitting more rapid and higher levels of adult emergence will be more extensively damaged by *C. maculatus*. It also agrees with the findings of [29] who stated that higher emergence of adult insects' results in higher quantitative damage, loss of bean nutritional quality, and negative effects on bean appearance, which makes them unsuitable for commercialization and consumption.

Grain damage, weight loss and susceptibility: The low damage of Songotra and Zaayura might be due to their inherent chemical constituents such as tannins and viclin which makes them unacceptable to the insect as was discussed by [19, 29] who both attributed the resistance of the grain legumes to the presence of these chemicals in the grain [3]. Also reported that the chemical factors responsible for resistance to storage pest included; arcelin in the cotyledons, tannins in the seed coat, and phytohemagglutinin (PHA) within the seed including α-amylase inhibitors. According to [3], antibiosis or non-preference resistance mechanisms to bruchid infestation by the legume grains are explained using the presence of these chemical factors in the legume grains. This was also supported by [19], who explained that the lightcoloured seeds, even though higher in protein and carbohydrates have poor resistance to cowpea beetle infestation during storage. Apagbaala and Padituya both of which recorded higher Oviposition, F1 generations and perforations also recorded the greatest grain weight loss. These explain how susceptible these grains are to *C. maculatus*. The grains loss more than 50% of their weight to the insect's damage making them unacceptable by the consumers since the nutritional and physical qualities are also lost as a result of these damages. According to [29], higher emergence of adult insects' results in higher quantitative damage, loss of bean nutritional quality, and negative impacts on bean appearance, which makes them unsuitable for commercialization and consumption by the public.

Based on the observations made in this study, Padituya and Apagbaala with the susceptibility index ranging between 6 and 10 are identified as being susceptible. Songotra and Zaayura with the susceptibility index ranging between 3 and 6 are also identified as moderately resistant varieties. This finding supports that of [2] who classified varieties with the susceptibility index between 6.1 and 10 as susceptible and those with the susceptibility index between 4.1 and 6 as moderately resistant based on the Dobies' index of susceptibility [14-16].

Table 4. Shows the correlation coefficients of the damage related parameters measured under this experiment. Those varieties with high Oviposition, grain damage, adult insect emergence and percentage grain weight loss are susceptible and those with lower records of these parameters are resistant. This conforms the finding of [30] who recorded a positive correlation between susceptibility and number of adult emergences hence greater damage and infestations on those varieties to the higher adult emergence. It also indicates that the lower the developmental period, the higher the susceptibility and those varieties that recorded the lower developmental periods of the adult insect are susceptible whilst those with the higher developmental period are non-susceptible. Another observation was made between mortality rate and susceptibility. Though there was highly significant difference between the two parameters, there existed negative correlation between them implying, the lower the adult mortality on a given variety, the higher the susceptibility and the vice versa. Grain weight loss correlated positively with Oviposition, grain damage and adult insects' emergence but negatively with adult developmental period and mortality of the insects. There existed highly significant difference between percentage gain weight loss and these parameters. Grain damage was also observed to be positively correlated with adult insect emergence but negatively with the adult developmental period and mortality of the insect. In both cases a highly significant difference was observed. Oviposition also correlated positively with adult insects' emergence and grain damage meaning, the higher the Oviposition on a particular variety, the more the adult emergence and the more grain damage on that variety.

Conclusion

The following conclusions could be made from the findings of this study. Among the cowpea varieties tested, Zaayura, Songotra and Bawutawuta exhibited lower susceptibility to infestation and damage by *C. maculatus*. Zaayura was highly resistant while Songotra and Bawutawuta were moderately resistant. It was also found that the local variety (check), Padi-tuya, Apagbaala and Marfo-tuya were highly susceptible. These varieties coherently exhibited higher susceptibility to infestation and damage by *C. maculatus.* The results showed that resistance in these cowpea grains was as a result of physical characteristics such as surface area, smoothness and curvature of the grains. In addition, it was also noted that the resistance could be due to chemical inhibitors such as trypsin, arcelin, aminophenylalanine, α-amylase inhibitors and lectins which may be present in grain legumes seeds conferring resistance in them.

Recommendations

From the conclusion above, the following recommendations could be made; Zaayura, Songotra and Bawutawuta which are resistant varieties can therefore be recommended to farmers for the management of *C. maculatus* in storage. These resistant varieties can be included in breeding programmes that aim at producing varieties that are resistant to *C. maculatus* in storage. Further work should be conducted to assess the role of these physical characteristics as well as the chemical composition and phenol content of these cowpea varieties in relation to the seed damage indices. There is also the need to conduct studies on the varieties to document the relationship between storage period and susceptibility of these varieties to *C. maculatus* infestation.

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