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Response of Selected Local Cowpea *Vigna unguiculata* (Walpers) Grain Varieties to Postharvest Infestation by *Callosobruchus maculatus* (Fabricius)

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Abstract

An assessment of susceptibility of selected predominant local varieties of Vigna unguiculata in Adamawa State, Nigeria to postharvest cowpea bruchid (Callosobruchus maculatus) infestation was carried out for a period of 2 months (56 days). The study was organized in a completely randomized design (CRD) with 3 replications. Four commonly grown local cowpea varieties viz; Bakin hanchi, Banjiram, Mai madara and Jan wake sourced from farmers in Yola town were used. Parameters measured includes the susceptibility index (SI), grain damage and weight loss. Data collected were analyzed using Variance analysis and means were separated using Duncan Multiple Range Test (DMRT) at 5% level of probability. Results showed that SI was significantly different ($p < 0.05$) among the cowpea cultivars – range; 4.4 to 6.2. Based on the Dobie rating; Banjiram and Mai madara were moderately resistant with lower F_1 progeny production of 33.3 and 35.0, respectively - with Mai madara having the highest median developmental time of 35 days. However, Bakin hanchi and Jan wake were moderately susceptible with higher F_1 progeny production of 53.3 and 54.0, respectively. Results on grain damage and weight loss showed that Bakin hanchi and Jan wake recorded the highest grain damage and weight loss of 58.9% and 54.6%; 44.1% and 39.4%, respectively. Correlation and linear regression analyses detected positive and significant relationships between grain damage and susceptibility index ($r = 0.962$, $R^2 = 0.926$, $p = 0.038$) and between grain weight loss and grain damage ($r = 0.995$, $R^2 = 0.991$, $p = 0.005$). While it is needful to source and screen more local varieties in the study area, the current study shows that Banjiram and Mai madara have promising potentials to withstand C. maculatus infestation – an information which could be helpful for farmer and grain merchants education and for incorporation into integrated pest management strategies against the cowpea bruchid.

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1. Introduction

Belonging to the family leguminosae, subfamily Papilionaceae and tribe Phaseolae, Cowpea [*Vigna unguiculata* (Linnaeus) Walpers], is widely cultivated both in the tropical and sub-tropical countries of the world [1]. In Africa and Nigeria in particular, it is largely grown in the semi-arid locations as it is moisture stress tolerant [2]. Its health benefits are high, and with a protein content of 23 - 25%, it suits the diet of many families in the third world countries who most times cannot afford other protein sources e.g meat and fish [3]. These benefits notwithstanding, production and productivity of cowpea is low in Nigeria with a resultant inability to meet increasing demands largely attributable to high infestation by insect pests both in the field and during storage which causes grain weight loss, loss in nutritional value, and loss in viability of stored grains [4, 5].

A key insect pest of stored cowpea is *Callosobruchus maculatus* (F.), commonly referred to as the cowpea seed beetle or cowpea weevil.Within a storage duration of 3 - 6 months, an estimated 87 – 100% grain loss have been attributed to the weevil [2, 6] - resulting also in qualitative loss which causes food insecurity, nutritional insecurity, and low income to small scale-farmers in particular. There are several local and improved varieties of cowpea seeds in Nigeria with different levels of resistance to infestation by *C. maculatus* [7]. However, breakdown of genetic resistance of some improved varieties to *C. maculatus* have been reported [3]. Therefore, it becomes necessarily important to evaluate/re-evaluate commonly found cowpea varieties, local in particular, for resistance against cowpea weevils. Hence, the thrust of this study was to evaluate the relative response of some local cowpea varieties (mostly cultivated by farmers in the study area) to *C. maculatus* infestation during storage. Information herein generated will be useful not only for grain merchants or farmers, but also to plant breeders who will be interested in resistant lines of local cowpea varieties and also for incorporation into the integrated pest management strategies of cowpea bruchids.

2. Methodology

2.1 Study Site

This work was conducted for a period of eight (8) weeks (56 days) in the Laboratory of the Department of Crop Protection, Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria. Yola is located in the Northern Guinea Savannah Agro-ecological Zone at latitude 90^o 14`N, longitude $12^o$ 28`E and altitude 190.5m with minimum and maximum rainfall, temperatures and relative humidity of 0.80 and 4.92ml, 27 and 42^oC, and 35 and 75%, respectively [8].

2.2. Sources of Materials

Clean seeds of selected local varieties of cowpea commonly grown in Adamawa State, Nigeria (*Bakin hanchi*, *Banjiram*, *Mai madara* and *Jan wake*) were obtained from farmers in Yola town. Adult cowpea bruchids (*C. maculatus*) were also collected from already naturally infested cowpea grains from grain merchants in Yola town.

2.3. Insect Culture

The bruchids collected were used to establish a laboratory colony on disinfected cowpea seeds to obtain similar aged bruchids for the experiment at ambient laboratory temperature and relative humidity (35 ± 2^oC; 65 – 85%, respectively). This was done by placing 50 pairs of unsexed adult *C. maculatus* into 1-litre capacity bottle containing 500g cowpea seeds. The bottles were then covered with muslin cloth and secured with rubber band to prevent escape of the insects and to allow for aeration. After one week of oviposition, the parent stock of the bruchids were removed. The oviposited ova carrying seeds were then left under laboratory conditions for F_1 progeny emergence. The F_1 progenies (0 - 3 days old) from the culture were then used for the experiment [3, 8].

2.4 Preparation of Cowpea Varieties and Experimental Bottles

Newly harvested untreated local cowpea grain varieties (*Vigna unguiculata*) obtained from farmers and the experimental bottles were examined, cleaned and sterilized thermally in a hot-air oven (Hot Air Circulated Oven; OV95c) at 60^oC for 1 hour to kill any insect pest and/or pathogen that might be present, and afterwards the seeds were allowed to equilibrate for 24 hours in the laboratory, while the moisture content was reduced to 12%. The above preparation was carried out prior to screening as described by Medugu et al. [8] and Medugu [9].

2.5 Experimental Procedure and Data Collection

To screen the cowpea varieties for relative resistance to *C. maculatus*, five pairs of (1 - 3 days old) adult *C. maculatus* were introduced into separate bottles containing 100g of each cowpea variety [laid out in Completely Randomized Design (CRD) in 3 replicates] weighed on a sensitive electronic balance (Electronic Compact Weighing Scale BL20001). The containers were then covered with muslin cloth and secured with rubber band to prevent insect escape and to allow for aeration. The infested cowpea seeds were left for 7 days for oviposition to take place. On day 7th day after infestation, the bruchids were removed and discarded while individual jar contents were carefully returned, kept on the shelf and left undisturbed for additional 21 days. Thereafter, the bottles were examined daily to record the emergence of F_1 adults. Adult count continued until no adult(s) emerged for 3 consecutive days from each jar – a procedure modified after Throne and Eubanks [10].

The median developmental period (MDP) which is the time (in days) from the middle day of oviposition period to 50% emergence of F_1 adults [11] was computed. Dobie index of susceptibility was then used as a criterion to separate cowpea cultivars into different resistance groups using the formula described by Dobie [11];

$$SI = \log F_1/D \times 100. \quad (1)$$

Where; SI = Susceptibility Index,
Log F_1 = Log number of F_1 emerged adults, and
D = Mean length of developmental period (days).

The Dobie Index was further used to classify the cowpea cultivars into susceptibility classes using the scales;

≤ 4 = highly resistant;
4.1 - 6.0 = moderately resistant;
6.1 - 8.0 = moderately susceptible;
8.1 - 10 = Susceptible; and
>10 = highly susceptible [12].

Grain damage was assessed using the method described by Abebe et al. [13];

$$\text{Grain damage (\%)} = \text{Total number of damaged grains/Total number of grains} \times 100. \quad (2)$$

Grain weight loss was assessed by count and weight method which was described by Lale [14] as;

$$\text{Weight loss (\%)} = [UaN – (U + D)]/UaN \times 100. \quad (3)$$

Where; Ua = average weight of one undamaged grain;
N = total number of grains in the sample;
U = weight of undamaged fraction in the sample; and
D = weight of damaged fraction in the sample.

2.6 Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SAS statistical software, version 9.2 [15]. Statistically significantly different treatment means were then separated using Duncan Multiple Range Test at 5% level of probability. The relationships between the parameters that determine susceptibility were determined by correlation and linear regression analyses using IBM® SPSS® Statistics software, version 23.0 (SPSS Inc., Chicago, Illinois).

3.0 Results and Discussion

3.1 F_1 Progeny Production, Development and Susceptibility Index of *C. maculatus*

The number of F_1 progeny produced by *C. maculatus* is presented in Table 1. There were significant differences ($p < 0.05$) among the cowpea varieties with respect to the number of progeny produced. The highest number of progeny was counted in bottles containing *Jan wake* followed by *Bakin hanchi* - 54.0 and 53.3, respectively. An appreciable high number of progeny were also counted from *Mai madara* 35.0. The table also shows that the lowest ($p < 0.05$) number of progeny was produced in *Banjiram* variety - 33.3.

Significant differences ($p < 0.05$) among the varieties was also detected with respect to the median developmental time (MDT) (Table 1). The MDT ranged from 28.0 to 35.0 days. *C. maculatus* reared on *Jan wake*, *Banjiram* and *Bakin hanchi* had relatively lower and statistically comparable MDT of 28.0, 28.0 and 28.3, respectively which varied significantly ($p < 0.05$) from that of *Mai madara* variety which had the highest MDT of 35 days. Overall, the MDT trend was apparently similar to that of F_1 progeny emergence.

Table 1 also shows the index of susceptibility which indicates that the SI ranged from 4.4 in *Mai madara* to 6.2 in *Jan wake* variety. Of the four cowpea varieties screened for *C. maculatus* resistance, two - *Mai madara* and *Banjiram* with index of susceptibility of 4.4 and 5.4, respectively were resistant at moderate levels to bruchid attack. *Bakin hanchi* and *Jan wake* with SI of 6.1 to 6.2 were moderately susceptible.

Table 1: F_1 progeny emergence, median developmental time (MDT) and susceptibility index (SI) of selected local cowpea varieties to *C. maculatus*.

Variety	F_1 progeny Emerged	MDT (days)	Susceptibility index (SI)	Susceptibility status
BK	53.3^{b}	28.3^{b}	6.1	moderately susceptible
BJ	33.3^{cd}	28.0^{b}	5.4	moderately resistant
MM	35.0^{c}	35.0^{a}	4.4	moderately resistant
JW	54.0^{a}	28.0^{b}	6.2	moderately susceptible
SE±	0.12	0.98	0.15	
CV (%)	3.32	4.88	5.66	

Means followed by same superscript(s) along a column are not significantly different ($p < 0.05$) from each other using Duncan Multiple Range Test (DMRT); BK – *Bakin hanchi*; BJ – *Banjiram*; MM – *Mai madara*; JW – *Jan wake*.

3.2 Cowpea Varieties Grain Damage and Grain Weight Loss induced by the activities of *C. maculatus*

The mean percentage grain damage of cowpea varieties caused by *C. maculatus* is presented in Table 2. The table shows that cowpea grain damage among the varieties caused by *C. maculatus* differ significantly ($p < 0.05$). The highest percentage grain damage was observed in *Bakin hanchi* followed by *Jan wake* variety - 58.9% and 54.6%, respectively. On the other hand, significantly ($p < 0.05$) lower percentage grain damage was observed in *Mai madara* followed by *Banjiram* - 38.1% and 46.3%, respectively (Table 2).

Results on the assessment of the effects of *C. maculatus* on the selected local cowpea varieties with respect to percentage weight loss is also shown in Table 2. The trend was similar with that of grain damage. Significant difference ($p < 0.05$) was recorded among the varieties with regards to weight loss. The highest and lowest percentage weight loss of 44.1% and 23.8% was observed on *Bakin hanchi* and *Mai madara* varieties, respectively.

Table 2: Mean percent grain damage and weight loss on selected local cowpea varieties by activities of *C. maculatus*.

Variety	Grain damage (%)	Weight loss (%)
BK	58.9^{a}	44.1^{a}
BJ	46.3^{c}	29.9^{c}
MM	38.1^{d}	23.8^{cd}
JW	54.6^{ab}	39.4^{ab}
SE±	0.83	1.07
CV (%)	3.86	9.28

Means followed by same superscript(s) along a column are not significantly different ($p < 0.05$) from each other by Duncan Multiple Range Test (DMRT); BK – *Bakin hanchi*; BJ – *Banjiram*; MM – *Mai madara*; JW – *Jan wake*.

3.3 Relationships between the Variables

Table 3 shows that the relationships tested were insignificant ($p > 0.05$) except for those between grain damage and susceptibility index ($r = 0.962$, $R^2 = 92.6\%$, $p = 0.038$), and between grain weight loss and grain damage ($r = 0.995$, $R^2 = 99.1\%$, $p = 0.005$).

Table 3: Relationships among adult emergence, median development time (MDT) of *C. maculatus*, and grain damage (%), weight loss (%) and susceptibility index (SI) of cowpea varieties using correlation and linear regression analyses.

Variable	Correlation coefficient (r)	Regression equation	Coefficient of determination (R^2)
Adult emergence x MDT	-0.509^{ns}	Y = 93.498 – 1.663x	0.259
Adult emergence x SI	0.838^{ns}	Y = -19.060 + 11.395x	0.703
SI x MDT	-0.896^{ns}	Y = 11.948 – 0.215x	0.802
Grain damage x SI	0.962^{*}	Y -9.510 + 10.676x	0.926
Grain damage x Adult emergence	0.883^{ns}	Y = 17.838 + 0.721x	0.779
Grain weight loss x SI	0.940^{ns}	Y = -22.994 + 10.370x	0.883
Grain weight loss x Adult emergence	0.075^{ns}	Y = 33.171 + 0.035x	0.006
Grain weight loss x Grain damage	0.995^{**}	Y = -14.659 + 0.990x	0.991

^{ns} = not significantly different ($p> 0.05$);
* = significantly different ($p< 0.05$);
** = significantly different ($p< 0.01$)

Considerable differences were observed among the cowpea grain varieties with respect to F_1 progeny production, median developmental time and ultimately, the susceptibility index. Variations in the resistance of the cowpea varieties screened showed the extent or otherwise of the inherent abilities of each variety to resist *C. maculatus* infestation. These inherent responses of cowpea varieties to infestations have been shown to be related to differences in some morphological, physical and chemical factors [16] or non-nutritional factors, particularly phenolic compounds [17]. These factors either acting individually or in combinations are shown to induce different levels of resistance to specific species of storage insect pests [18]. Grain hardness was reported by Bamaiyi et al. [19] as a key resistance factor against *Sitophilus oryzae* infesting stored sorghum.

Shade et al. [20] reported a highly pestiferous strain of *C. maculatus* capable of causing severe damage to a hitherto resistant cowpea genotype in Nigeria. This indicates that tolerant strains of bruchids could continue to evolve thereby making ineffective the qualities for resistance of cowpea grains – hence, the need for continuous evaluation and re-evaluation for resistance. Goftishu and Belete [21] noted that progeny emergence highly correlated with the susceptibility of different grain varieties to insect pest infestations. Mbata [22] also reported that weight losses due to *C. maculatus* infestation correlated very strongly to the susceptibility indices. Similar, findings were also reported by Musa and Adeboye [23]. The current study meanwhile shows that, as the MDT increases, the F_1 progeny emergence decreases. Hence, a shorter MDT triggers more F_1 progeny production. It was also observed that the SI is inversely related to MDT with the number of F_1 progeny showing a positive relationship with the SI. However, despite the correlation analysis detecting insignificant relationships between most of the variables evaluated, the pattern of the relationships agrees with the previous reports – of interest is the significant positive and high correlation between grain damage and susceptibility index, and between grain weight loss and grain damage as also detected in the study of Musa and Adeboye [23].

The susceptible varieties to cowpea bruchids produced higher number of progeny relative to the resistant varieties. The substantial difference between the number of F_1 progenies produced by the resistant and susceptible varieties is an important factor in the management of *C. maculatus* in stored cowpea. Of the four cowpea varieties tested against *C. maculatus* in the current study, two (*Bakin hanchi* and *Jan wake*) were moderately susceptible. The other two varieties (*Banjiram* and *Mai madara*) were moderately resistant. Comparatively longer developmental time for the bruchids was required on the resistant varieties than on the susceptible. Similarly, bruchids on varieties with higher index of susceptibility completed their developments within shorter time period. Lower survival rate and establishment reduces pest populations and the resultant damage, while longer development periods result to fewer generations per season. Abebe et al. [13] showed that, the index of susceptibility is hinged on the assumption that the greater number of F_1 progeny produced within shorter duration, the more susceptible the grains. Genetic resistance of grain varieties to stored pest infestations depends on a number of factors which influences fecundity and development of the pest [24]. It has been shown that antixenosis (non-preference) and/or antibiosis mechanisms are key in varietal resistance. This view has been authenticated by several authors who showed that non-preference and antibiosis interact as mechanisms of resistance in stored grains [25, 26]. Hence, the level of depredation during storage depends on the number of adults that emerge in each generation and the length of the developmental time. Therefore, varieties favouring faster and more adult emergence will suffer more depredation.

4.0 Conclusion

The study showed differentials in the responses of the local cowpea varieties screened for bruchid infestation. We found *Banjiram* and *Mai madara* varieties to be resistant at moderate levels. This could be attributed to their morphological, physical and chemical properties which conferred on them lesser utilization by the bruchids with a resultant longer storability and comparatively lower grain loss. While we recommend that more local varieties in the study area should be sourced and screened alongside those screened in the current study, the information here gathered may be useful for educating local growers and traders on choice of varieties and also in devising integrated management strategies against this key pest of cowpea grains.

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