Asian J Agric & Biol. 2022(4).
DOI: 10.35495/ajab.2021.06.062

AJAB

Original Article

Screening of *Vigna unguiculata* (L.) WALP. accessions from Togo for their reaction to *Callosobruchus maculatus* F.

Emmanuel Israel Affram[1*], Victor Olawale Adetimirin[2], Christian Fatokun[3], Ousmane Boukar[4]
[1]Pan African University Life and Earth Science Institute, University of Ibadan, Nigeria
[2]Department of Crop and Horticultural Sciences, University of Ibadan, Ibadan, Nigeria
[3]Cowpea Breeding, International Institute of Tropical Agriculture, Ibadan, Nigeria
[4]Cowpea Breeding, International Institute of Tropical Agriculture, Kano, Nigeria

Received:
June 27, 2021

Accepted:
November 20, 2021

Online First:
March 15, 2022

Published:
September 4, 2022

Abstract

Post-harvest losses in cowpea are mostly caused by the infestation of *Callosobruchus maculatus*, a storage pest. It can cause up to 100% loss of untreated produce. Host Plant Resistance (HPR), an important component of integrated pest management, has potential for sustainable management of *C. maculatus*. The objective of this study was to assess a recently collected cowpea germplasm from Togo for resistance to *C. maculatus*. A total of 200 cowpea accessions from the five regions of Togo and five checks were screened for resistance to *C. maculatus* using a no-choice assay. The experiment was laid out in a completely randomized design (CRD) with three replications. Data were collected on average number of eggs laid (ANEL), average number of adult emergence (ANAE), number of holes per seed (NHPS), initial and final seed weight (ISW and FSW), median development period (MDP), percentage adult emergence (PAE), and percentage weight loss (PWL), and two indices of resistance computed viz. insect growth index (G.I.) and Dobie's susceptibility index (DSI). Data collected were subjected to analysis of variance, Pearson's correlation and stepwise multiple regression analysis. A total of 51 accessions were moderately resistant, among which RS009 and RP218 had the least DSI score. The remaining accessions (149) were susceptible. DSI was significantly correlated with ANAE, PWL and NHPS, and had a significant and negative correlation with MDP. The results of the stepwise multiple regression showed ANAE, PWL and MDP were the better predictors of cowpea bruchid resistance and accounted for 87.7% of the observed variation in DSI scores.

Keywords: Cowpea, *Callosobruchus maculatus*, Resistance and Dobie susceptibility index

How to cite this:

Affram EI, Adetimirin VO, Fatokun C and Boukar O. Screening of *Vigna unguiculata* (L.) WALP. accessions from Togo for their reaction to *Callosobruchus maculatus* F. Asian J Agric & Biol. 2022(4): 202106062. DOI: https://doi.org/10.35495/ajab.2021.06.062

**Corresponding author email:*
afframemmanuel007@gmail.com

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp.) is one of the major grain legumes widely consumed in sub-Saharan Africa (Kareem and Taiwo, 2007). It is an important staple food in the arid regions and has been used in soil fertility enrichment schemes (Philips et al., 2003). It is widely traded and offers farmers a source of income (Boukar et al., 2016).

Cowpea production is plagued with numerous constraints comprising both biotic and abiotic factors. Insects and mites, viruses, fungal and bacterial diseases, nematodes and parasitic weeds are the major biotic constraints. Their impact may span specific or different phenological stages (Togola et al., 2017). The major economically important pests of cowpea are *Maruca vitrata*, *Aphis craccivora*, *Clavigralla tomentosicollis*, *Megalurothrips sjostedti* and *Callosobruchus maculatus* (OECD, 2016). Of these, *C. maculatus* is the only major post-harvest pest. It is a cosmopolitan and destructive pest of stored cowpea seeds capable of causing up to 100% grain loss, resulting in severe economic losses. The damage manifests as perforation on the seeds by the emerging insects that have fed on the food reserves of the latter, culminating in a reduction in the quality and quantity of the seed (Umeozor, 2005).

Management of *C. maculatus* has, to a large extent, has been by the use of synthetic insecticides, which may not be readily available in rural and sub-urban areas. In addition, their high cost and possible health hazards to consumers and the environment necessitate that other control options are explored. Integrated Pest Management (IPM) is considered to have potential for the sustainable management of *C. maculatus*. At the heart of IPM is Host Plant Resistance, which is combined with other compatible control methods with minimal use of insecticides.

Efforts have been made to identify cowpea bruchid-resistant genotypes for the breeding of resistant varieties. A total of 8000 germplasm lines have been screened by the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria; of these, only three (0.004%) lines with resistance to *C. maculatus* were identified. These are TVu-2027, TVu-11952 and TVu11953 (Singh et al., 1985). Some resistant cowpea varieties were subsequently developed from these sources (Singh, 1999). The effectiveness of these varieties have been limited by changes in the bruchid population and non-durability of the resistance (Keneni et al., 2011). Amusa et al. (2013) reported the breakdown of the resistance in some of the improved cowpea varieties to this insect pest, highlighting the need to search for new sources of resistance.

Crop germplasm are invaluable resources in plant breeding. The diversity of plant types can be useful directly as a variety, as donors of useful traits such as resistance/tolerance genes for abiotic and abiotic stresses, or conserved for their future use as breeding materials (Tripathy, 2016). Evaluation of cowpea germplasm accessions can help to identify new sources of resistance to the cowpea bruchid (Tripathi et al., 2020). Two resistant lines (IC107466 and IC106815) were identified from an evaluation of cowpea accessions in India (Tripathi et al., 2012). In Brazil, three genotypes *viz.* IT85-F-2687, MN95-841 B-49 and Sanzi Sambili were identified to be resistant from the screening of a core collection of genotypes from major cowpea research institutes in the world (Castro et al., 2013). More recently, Miesho et al. (2018), reported 18 resistant genotypes out of the 145 screened in Uganda.

A new collection of cowpea was recently made in Togo, West Africa. The objectives of the study were to evaluate the cowpea accessions from Togo for resistance to *C. maculatus* and determine the traits that can be considered as better predictors of resistance.

Material and Methods

Rearing of *Callosobruchus maculatus*

The experiment was carried out in the laboratory of the Cowpea Breeding Unit of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Bruchid cultures were established according to Beck and Blumer (2011). Seeds of the susceptible line TVu 7778 were infested with bruchids. The culture jars were incubated at ambient temperature to allow large colonies of bruchids to develop.

Experimental procedure and data collection

A total of 200 cowpea accessions collected from Togo, together with four resistant and one susceptible check obtained from IITA, were used in the study. The experimental design was completely randomized with three replications. Well-dried seeds of the cowpea lines were cleaned of debris and placed in a freezer at a temperature of 0°C for 48 hours to kill any bruchid eggs or larvae that may have pre-infested the seeds. Five healthy seeds of each line were weighed to determine the initial seed weight (ISW) and then

placed in a sterilized Petri dish. To facilitate copulation and oviposition, a sex ratio of 2 males to 3 females was used to infest the seeds in each Petri dish. The adult insects introduced into each Petri dish were removed 7 days after infestation (DAI) and the Petri dishes placed on shelves in a facility maintained at a temperature range of 26℃ to 30℃ and at a relative humidity of 75% ± 3. With the aid of a magnifying glass and a tally counter, the number of eggs laid (NEL) on the five seeds in each Petri dish was counted and the average (ANEL) computed. At this time, most of the eggs had hatched and larvae bored into the seeds, leaving behind the cream-colored shells. The number of eggs was the potential number of adults expected to emerge from the seeds in each Petri dish.
The Petri dishes were examined daily and the number of days to emergence of the first insect (DFE) recorded. Thereafter, a daily count of adults that emerged (DAE) from each Petri dish was undertaken up till 50 DAI. Counted adults were removed to prevent the counting of second-generation adults. The total number of exit holes (TNEH) of the insect on the seeds were counted and the number of holes per seed (NHPS) determined at the end of the study. Final seed weight (FSW) per Petri dish was determined 50 days after infestation. Percentage weight loss (PWL) of the seeds was determined as = $\frac{ISW-FSW}{ISW} \times 100$ (Kpoviessi et al., 2017).

From the data on daily adult emergence, the median development period (MDP) was calculated as the time in days from the median day of oviposition to the day when 50% of the F_1 progeny emerged. Percentage adult emergence (PAE) and growth index (G.I.) of the cowpea bruchid (Badii et al., 2013) were calculated according to Sharma and Thakur (2014) as follows:

$$\text{Percentage adult emergence (PAE)} = \frac{Total\ number\ of\ adult\ emergence}{Total\ number\ of\ egss\ laid} \times 100$$

$$\text{Growth index (G.I.)} = \frac{Percentage\ adult\ emergence}{Median\ developmental\ period}$$

Dobie Susceptibility Index (DSI) for each genotype was calculated at the end of the study from data on total number of adult emergence (TNAE) and median development period (MDP) using the formula of Dobie (1974) as follows:

$$\text{DSI} = \frac{Log_e F_1}{MDP} \times 100$$

Where; Log_e = Natural logarithm of numbers; F_1= total number of emerging adults and MDP = median development period in days

The Susceptibility index rating, ranging from 1 – 21, was used in categorizing the cowpea genotypes into resistant classes, where 1 – 5 = resistant; 6 – 10 = moderately resistant; 11 – 15 = susceptible; and 16 - 21 = highly susceptible (Chakraborty et al., 2015).

Statistical analysis

Data collected were subjected to a one-way analysis of variance (ANOVA) to examine if differences in the performance of the cowpea genotypes were significant. Pearson's linear correlation coefficient was computed to determine the relationship among resistance parameters. A stepwise multiple regression analysis was carried out to determine the traits that are better predictors of cowpea bruchid resistance. All statistical analyses were carried out using Rversion 4.0.3 (RStudio Team, 2021).

Results

Genotypic variation among 200 cowpea accessions and five checks for resistance to *Callosobruchus maculatus*

Differences among the 205 accessions were significant (p < 0.05-0.001) for all traits, except average number of eggs laid (range = 3.1 – 21.7), the trait with the highest experimental CV (59.2%) – an indication of large differences between replications (Table 1). Initial seed weight ranged from 0.3g to 1.5g, with a mean of 0.9g (Table 1). The highest initial seed weights were obtained in RP252, TVu2027 (resistant check), RK184, RK141 and RC371, and the lowest in RK185 and RK170 (Table 2). The accessions with the lowest and highest final seed weight values were RK185 and TVu2021, respectively (Table 2).
Days to first emergence ranged from 22.3 to 32.7 days, with a mean of 25.6 days (Table 1). Considerable variation was observed among the accessions for mean number of adult emergence; it was lowest for RP259 (2.4) and highest for RK132 (12) (Table 1). Most of the accessions exhibited an early, continuous and rapid adult emergence, typical of susceptible lines. Percentage adult emergence (PAE) ranged from 24.5 in RK185 to 99.2% in RC404, with a mean of 62.5%. Percentage weight loss (PWL) of cowpea accessions varied from 23.3 to 76.2

% with a mean of 52.7% (Table 1). The accessions with the lowest percentage weight loss are RP239 (23.3%) and two resistant checks viz. Magic017 (25.9%) and TVu2027 (28.5%) (Table 2); the average number of eggs laid for these accessions was greater than 8. Accession RS013 had the highest weight loss of 76.2% (Table 2). Number of holes per seed (NHPS) ranged from 2.2 to 10.7, with a mean of 5.4 (Table 1). Median developmental period (MDP) of the accessions ranged from 22.3 to 37.0 days, with a mean of 29 days (Table 1). IT86D-498 (resistant check) had the longest median development period of 37 days, followed by resistant check Magic 142 (36.7 days) and RP218 (36.3 days), while accessions RP238 and RP319 had the shortest median development period of 22.3 days (Table 2). Mean developmental period for Ife Brown, the susceptible check, was 23.3 days (Table 2). The growth index (G.I.) of the cowpea accessions showed considerable variation, with a range of 0.7 to 4.4, and a mean of 2.2 (Table 1). The five accession that had the lowest growth index were Magic142 (resistant check. 0.7), RK185 (0.8) and TVu2027 (0.9) (resistant check); those with the highest growth index values were RC404, RC401 (3.7), Ife Brown (susceptible check, (3.7), RC395 (3.6) and RP302 (3.6) (Table 2). The range of DSI obtained was 7.3 to 15.4, with a mean value of 11.4 (Table 1), and an indication that majority of the cowpea accessions from Togo are susceptible. The five accessions with the lowest DSI are three of the resistant checks viz. Magic017 (7.3), Tvu2027 (7.5) and Magic142 (8.1), and two accessions from Togo namely RS009 (8.4) and RP218 (8.5). RC412, RC395 and RC401 had the highest DSI values of 14.7, 15.1 and 15.4 respectively (Table 2); DSI for Ife Brown, the susceptible check, was 13.1 (Table 2). Most of the accessions that were classified as susceptible in the present study had days to first emergence ≤ 24 days while most of the moderately resistant accessions had days to first emergence > 30 days.

Association among *C. maculatus* resistance parameters

Forty-five of the 55 correlation coefficient values were significant (Table 3). The remaining 10 non-significant correlation coefficient values were obtained between ISW and DFE, ISW and MDP, FSW and DFE, PWL and DFE, FSW and MDP, PAE and MDP, ANAE and G.I., NHPS and G.I., FSW and DSI, and DFE and G.I. Highly significant inverse relationships were found between DSI on one hand, and MDP (r = − 0.57) and DFE (r = − 0.60) on the other. Mean Developmental Period and DFE were, in turn, significantly correlated (r = 0.90), indicating that a delay in the time for development of the bruchid was associated with a delay in the time taken for the insect to emerge from the seeds.

Dobie susceptibility index had a significant positive correlation with average number of adult emergence (r = 0.44), number of holes per seed (r = 0.41), insect growth index (r = 39), and initial seed weight (r = 0.41). Very strong and highly significant positive relationship were found between pairs of the following traits: number of holes per seed and average number of adult emergence (r = 0.95), percentage adult emergence and insect growth index (r = 0.93), days to first emergence and median development period (r = 0.91), and between initial seed weight and final seed weight (r = 0.86). Average number of eggs laid was significant and positively correlated with average number of adult emergence (r = 0.59), percentage weight loss (r = 0.56) and number of holes per seed (r = 0.55), while a significant and strong negative relationship existed between average number of eggs and growth index (r = − 0.62). A strong and highly significant negative relationship was also found between percentage weight loss and final seed weight (r = − 0.71).

A stepwise multiple regression analysis of measured resistance parameters on DSI showed that average number of adult emergence (ANAE), median development period (MDP) and percentage weight loss (PWL) accounted for 87.7% of the variability in the *C. maculatus* resistance rating (Dobie susceptibility index) of the accessions evaluated (Table 4). The multiple regression equation obtained is:

$Y= 17.79 + 0.585X_1 - 0.380X_2 + 0.018X_3$, where X_1 = ANAE, X_2 = MDP and X_3 = PWL

Table-1: Mean squares, mean, range and coefficient of variation (CV) of the measured traits in 200 cowpea accessions and five checks evaluated for resistance to *C. maculatus* following artificial infestation.

Source of variation	df	ISW	ANEL	DFE	ANAE	MDP	PAE	FSW	PWL	NHPS	G.I	DSI
Accessions	204	0.19***	51.89^{NS}	17.81***	10.65***	34.24***	826.5***	0.09***	320.2*	7.95***	1.35***	6.40***
Residuals	410	0.006	46.08	2.86	5.78	10.27	466.2	0.02	253.7	4.32	0.68	3.81
Mean		0.9	11.5	25.6	6.0	29.0	62.5	0.4	52.7	5.4	2.2	11.4
Range		0.3-1.5	3.1-21.7	22.3-32.7	2.4-12	22.3-37	24.5-99.2	0.1-1.0	23.3-76.2	2.2-10.7	0.7-3.7	7.3-15.4
CV (%)		9.4	59.2	6.6	40.3	11.1	40.3	35.3	30.2	38.8	37.4	17.1

^{NS} Not significant at 0.05 probability level; *, **, *** Significant at P<0.05, P<0.01 and P<0.001, respectively
ISW: Initial seed weight, ANEL: Average number of eggs laid, DFE: Days to first emergence, ANAE: Average number of adult emergence, MDP: Median development period, PAE: Percentage adult emergence, FSW: Final seed weight, PWL: Percentage weight loss, NHPS: Number of holes per seed, G.I.: Growth index of insect and DSI: Dobie susceptibility index
CV- Coefficient of variation

Table-2: Mean performance of accessions for the measured traits

SN	Accession	ISW	FSW	DFE	ANEL	ANAE	PAE	PWL	NHPS	MDP	G.I	DSI
1	Magic017*	0.87	0.65	32.33	7.73	3.40	38.58	25.93	3.27	33.67	1.17	7.30
2	TVu2027*	1.40	1.00	30.33	13.93	4.60	30.04	28.53	3.80	34.67	0.86	7.50
3	Magic142*	0.63	0.27	32.00	15.47	4.27	27.39	57.14	4.07	36.67	0.74	8.10
4	RS009	1.10	0.63	26.33	6.93	5.13	86.20	42.42	5.40	29.67	3.03	8.30
5	RP218	0.93	0.63	32.67	6.07	4.60	86.16	32.22	4.27	36.33	2.40	8.40
6	RP239	1.00	0.77	30.00	12.13	4.20	35.52	23.33	3.60	35.67	1.00	8.50
7	RP287	0.57	0.23	24.67	8.20	2.60	49.75	58.89	2.60	29.00	1.59	8.70
8	RK143	0.50	0.27	29.33	10.33	4.00	59.21	46.67	3.93	33.00	1.78	8.80
9	Vu053	0.50	0.27	28.33	4.60	3.00	61.99	46.67	2.80	28.67	2.15	9.00
10	RS011	0.70	0.43	27.00	8.27	3.40	64.78	38.10	3.00	27.67	2.51	9.30
11	RP219	0.87	0.47	28.33	9.80	5.67	58.80	43.28	5.40	32.00	1.88	9.30
12	RK170	0.40	0.13	28.67	12.27	3.67	37.04	66.67	3.00	30.67	1.22	9.40
13	RM337	0.93	0.60	23.00	7.87	4.07	67.04	37.50	3.67	24.33	2.55	9.50
14	RS005	0.83	0.37	28.67	9.73	5.07	73.15	54.88	6.20	31.00	2.40	9.50
15	RP230	0.97	0.50	29.33	15.53	6.93	50.60	45.68	6.60	34.67	1.45	9.60
16	RK185	0.33	0.13	28.00	14.73	3.67	24.79	61.11	3.40	30.00	0.83	9.70
17	IT86D-498*	0.77	0.37	31.33	14.60	7.27	50.83	51.79	7.00	37.00	1.37	9.70
18	RS024	0.87	0.53	27.33	7.60	5.27	76.91	38.43	5.00	33.33	2.31	9.70
19	RC380	0.50	0.30	24.00	5.67	2.93	59.03	42.22	2.93	26.67	2.28	9.70
20	Vu001-AB	0.63	0.40	22.67	3.47	3.40	98.85	37.30	3.13	28.00	3.56	9.70
21	RM351	0.87	0.60	24.00	6.13	4.13	73.30	30.09	4.00	28.67	2.56	9.70
22	RK199	0.57	0.17	28.33	12.20	5.47	49.63	70.48	5.07	34.00	1.45	9.80
23	RS107	0.47	0.20	27.33	17.40	4.60	30.26	56.67	4.00	31.67	0.98	9.80
24	RK194	0.57	0.23	28.33	15.60	5.07	34.52	58.89	4.87	33.00	1.06	9.80
25	RS015	0.77	0.30	29.00	13.13	5.53	50.59	61.31	5.07	34.00	1.47	9.80
26	Vu010	0.73	0.43	23.00	3.73	3.27	89.77	39.88	3.07	27.00	3.35	9.80
27	RK145	0.67	0.40	27.33	18.93	3.80	47.04	41.27	3.80	28.67	1.52	9.80
28	RK130	0.93	0.60	28.33	7.40	5.13	80.05	36.30	4.60	31.67	2.53	9.80
29	RK147	1.07	0.60	26.00	12.27	6.53	51.14	44.24	5.80	29.33	1.79	9.90
30	RS029	0.73	0.40	28.00	7.73	4.73	75.98	45.83	3.73	31.00	2.47	9.90
31	RS073	0.43	0.17	27.67	14.20	4.27	35.44	61.67	4.00	30.67	1.15	9.90
32	RS086	0.50	0.17	28.33	13.27	4.93	37.14	66.67	4.47	32.33	1.15	9.90
33	Vu064	0.40	0.20	26.00	6.93	3.40	54.74	50.00	3.27	28.67	1.89	10.00
34	RS095	0.73	0.40	26.33	5.53	4.47	83.83	44.64	4.60	30.00	2.90	10.10
35	RC382	0.63	0.33	24.00	10.27	3.73	42.33	46.83	3.60	28.33	1.56	10.10
36	RS055	0.80	0.37	27.67	9.33	5.73	82.35	54.17	5.40	31.67	2.66	10.10

SN	Accession	ISW	FSW	DFE	ANEL	ANAE	PAE	PWL	NHPS	MDP	G.I	DSI
37	RK152	0.60	0.20	29.00	21.67	5.80	27.19	66.67	5.00	33.33	0.82	10.10
38	RK197	0.73	0.40	27.67	8.33	5.27	72.90	45.83	5.53	31.00	2.36	10.10
39	RP253	0.97	0.57	28.67	10.60	6.40	59.81	41.11	6.00	31.67	1.88	10.10
40	Vu057	0.77	0.43	24.67	7.80	4.87	66.99	42.26	4.80	29.33	2.27	10.20
41	RK150	0.53	0.23	26.33	12.87	4.40	38.09	56.67	4.07	30.67	1.20	10.20
42	RS008	0.87	0.43	28.00	10.60	7.07	79.98	50.46	6.00	32.33	2.50	10.30
43	Vu007-2-2	0.90	0.53	23.67	6.27	4.80	73.10	40.74	4.40	27.67	2.66	10.30
44	RK119	0.63	0.27	26.67	11.07	4.27	72.80	57.94	3.87	29.67	2.66	10.30
45	RP241	0.60	0.20	28.33	11.27	6.80	63.22	66.67	6.40	34.00	1.87	10.40
46	RK138	0.87	0.40	28.00	7.33	4.47	68.68	54.17	5.07	29.67	2.33	10.40
47	RS025	0.73	0.30	29.00	14.47	6.53	52.95	58.93	5.20	33.00	1.61	10.40
48	RK144	0.67	0.20	28.67	14.60	6.93	49.69	69.84	3.87	34.00	1.46	10.40
49	Vu051	0.87	0.43	23.00	14.00	3.73	31.75	51.98	3.53	26.67	1.14	10.40
50	RS089	1.17	0.63	28.33	11.27	6.80	72.66	46.21	6.80	32.67	2.27	10.50
51	RK196	0.60	0.27	28.67	10.13	6.40	66.04	55.56	6.12	33.33	2.00	10.50
52	RP246	0.97	0.40	29.33	14.07	8.33	71.35	59.63	6.53	34.33	2.07	10.50
53	RP240	0.63	0.23	28.00	17.67	6.00	45.30	63.49	5.93	32.33	1.41	10.50
54	RS039	0.57	0.27	28.00	13.40	5.47	41.94	51.11	4.93	31.00	1.35	10.50
55	RM332	0.50	0.30	22.33	10.13	2.87	34.44	40.00	2.73	23.67	1.43	10.50
56	RS012	0.87	0.40	28.00	8.93	5.53	75.07	54.63	4.47	30.33	2.52	10.50
57	RS007	1.07	0.60	27.33	7.07	5.40	83.76	44.24	5.40	31.00	2.79	10.60
58	RS097	1.10	0.60	29.00	9.33	7.20	82.57	45.45	6.60	33.67	2.47	10.60
59	RP251	0.70	0.27	27.00	9.27	7.20	78.01	61.90	5.47	33.33	2.34	10.60
60	RK155	0.80	0.27	27.33	11.20	6.67	63.82	66.87	6.47	32.67	1.96	10.70
61	RP226	0.97	0.47	29.00	14.67	8.73	60.36	51.85	8.67	35.33	1.70	10.70
62	RP232	0.80	0.33	26.67	14.67	6.93	57.59	58.33	6.20	33.00	1.75	10.70
63	RS004	0.97	0.67	26.33	4.53	3.87	86.03	30.74	3.40	28.33	3.12	10.70
64	RM348	0.73	0.37	23.33	14.13	3.13	34.62	49.40	3.40	23.00	1.47	10.70
65	RM353	0.53	0.27	24.67	9.00	4.47	59.24	50.00	4.33	28.67	2.05	10.70
66	RS001	0.73	0.33	27.00	15.07	6.47	47.28	54.76	5.60	32.33	1.45	10.80
67	RS021	0.67	0.27	28.00	13.13	6.47	52.59	59.52	3.80	32.33	1.64	10.80
68	RK164	1.10	0.50	27.33	16.40	8.20	59.12	54.55	7.53	33.33	1.80	10.80
69	RP244	0.77	0.33	28.33	8.13	6.20	76.26	56.55	5.67	32.00	2.42	10.80
70	RK131	1.07	0.37	29.33	19.07	8.07	49.83	65.45	7.20	34.00	1.45	10.80
71	RP276	0.47	0.23	23.00	7.20	3.13	60.98	50.00	3.07	25.00	2.50	10.90
72	Vu081-3	0.40	0.10	23.67	10.73	4.53	42.43	75.00	4.20	28.67	1.49	10.90
73	Vu096-3	0.57	0.23	24.00	14.73	4.33	50.16	57.78	4.13	28.00	1.73	10.90
74	RK151	1.37	0.80	27.33	9.53	7.27	81.80	41.94	5.27	31.67	2.63	10.90
75	RS054	0.73	0.27	27.67	13.93	7.13	52.80	63.10	5.53	32.67	1.62	10.90
76	RS096	0.73	0.30	27.33	11.60	7.27	68.45	58.93	6.40	32.67	2.09	10.90
77	RP317	1.03	0.63	23.33	4.53	4.27	96.58	38.18	4.07	27.00	3.62	10.90
78	RP277	0.77	0.40	24.00	5.07	4.80	92.16	46.03	3.93	27.67	3.40	11.00
79	RK128	0.77	0.27	28.67	13.33	7.53	66.59	65.48	5.20	32.67	2.03	11.00
80	RP259	0.57	0.33	22.67	3.13	2.40	75.69	41.11	2.20	22.33	3.43	11.00
81	RK141	1.40	0.77	28.33	12.87	7.80	74.01	44.57	6.73	31.67	2.39	11.00
82	Vu033-1	0.57	0.20	22.33	16.33	4.07	34.87	64.44	3.60	24.00	1.45	11.10
83	Vu132	0.60	0.33	23.33	7.27	3.53	59.75	45.40	3.20	24.33	2.53	11.10
84	RC416	0.57	0.30	24.67	6.87	3.80	57.17	46.67	3.53	25.33	2.28	11.10
85	RP283	1.13	0.60	24.67	5.93	5.67	93.64	46.67	4.93	28.67	3.30	11.20
86	RS014	1.00	0.33	28.67	17.80	9.27	53.76	66.77	7.53	34.33	1.56	11.20
87	Vu088	0.50	0.23	24.33	6.93	4.07	61.06	53.33	4.07	27.00	2.30	11.20
88	RS056	0.77	0.37	26.00	8.73	5.93	69.41	52.98	5.27	30.33	2.28	11.20

SN	Accession	ISW	FSW	DFE	ANEL	ANAE	PAE	PWL	NHPS	MDP	G.I	DSI
89	RK193	1.03	0.40	29.00	12.10	7.73	70.60	60.74	7.40	32.67	2.20	11.20
90	RS010	0.97	0.37	27.67	16.73	8.80	54.27	62.22	8.07	33.67	1.60	11.20
91	RS019	0.87	0.37	28.00	15.60	8.73	67.11	57.41	7.87	33.67	1.97	11.20
92	RS022	0.87	0.37	27.67	15.87	8.20	55.71	57.41	6.87	33.00	1.69	11.30
93	Vu096-2-AB	0.50	0.20	23.00	12.40	3.40	39.54	60.00	3.13	24.33	1.63	11.30
94	RK123	1.23	0.67	28.33	12.00	9.00	80.83	45.51	8.53	32.67	2.50	11.40
95	RM339	0.73	0.43	23.00	7.73	4.40	54.14	40.48	4.67	25.00	2.17	11.40
96	RP229	1.20	0.63	27.00	9.20	7.53	86.35	46.78	6.60	31.33	2.79	11.40
97	RS033	0.83	0.40	26.67	13.40	5.33	53.92	53.24	4.13	28.00	1.99	11.40
98	RC400	0.97	0.40	23.33	9.87	4.47	57.21	57.78	4.40	26.00	2.21	11.40
99	RP222	1.03	0.63	26.67	6.47	5.73	87.38	38.38	5.53	29.33	3.02	11.40
100	RP270	0.87	0.43	23.00	11.47	4.07	51.54	50.00	4.07	26.00	1.86	11.40
101	RC397	0.50	0.27	23.00	7.27	3.60	54.15	46.67	3.60	25.33	2.10	11.40
102	RS013	0.70	0.17	27.67	16.47	8.53	53.78	76.19	7.27	32.67	1.65	11.50
103	RS016	0.83	0.40	25.67	11.07	6.53	62.29	51.85	5.40	30.00	2.07	11.50
104	Vu054	0.63	0.27	23.00	9.33	5.07	60.90	58.73	4.07	25.33	2.47	11.50
105	RP260	0.80	0.30	24.00	15.20	5.47	33.69	62.70	5.20	27.33	1.22	11.50
106	Vu033-2	0.67	0.30	23.33	9.40	4.20	52.58	69.05	4.20	26.33	2.03	11.50
107	Vu115	0.70	0.30	23.67	8.13	5.07	64.79	57.14	4.93	28.00	2.31	11.50
108	RM369	1.13	0.70	23.00	9.20	7.27	79.39	38.89	6.00	28.67	2.77	11.50
109	Vu101	0.63	0.30	23.67	6.47	4.33	73.76	52.38	3.93	26.33	2.85	11.60
110	RK126	1.23	0.57	28.00	13.27	9.07	68.49	54.08	7.67	33.00	2.08	11.60
111	RC392	0.57	0.30	23.00	5.67	4.07	75.80	47.78	4.07	26.00	2.90	11.60
112	Vu001	0.70	0.23	25.00	8.93	5.20	69.91	66.67	5.20	27.67	2.54	11.70
113	RK140	0.90	0.40	25.67	17.13	7.73	52.57	55.56	6.33	30.00	1.80	11.70
114	RK181	0.70	0.37	27.67	9.53	6.67	69.67	47.02	5.40	29.67	2.37	11.70
115	RS037	0.77	0.27	27.67	18.47	7.60	47.13	64.88	7.00	31.00	1.50	11.80
116	RK120	1.10	0.57	26.67	16.27	7.47	58.07	47.07	7.00	30.33	2.04	11.80
117	Vu081-AB	0.63	0.23	25.00	8.73	5.67	65.04	62.70	5.33	28.67	2.31	11.80
118	Vu109	0.90	0.53	23.00	8.27	6.13	82.40	40.74	5.53	26.67	3.09	11.80
119	RP252	1.47	0.67	27.33	16.80	10.87	67.26	54.76	10.53	33.67	2.00	11.80
120	RS006	0.73	0.30	25.67	11.27	6.67	61.53	58.33	6.07	29.67	2.14	11.80
121	Vu078	0.83	0.37	23.67	8.33	6.73	82.26	55.03	6.60	29.67	2.79	11.90
122	RS092	1.13	0.37	28.00	20.87	10.93	53.30	67.68	9.53	33.67	1.58	11.90
123	RM344	1.23	0.77	23.00	6.47	5.67	86.96	36.83	6.73	28.00	3.15	11.90
124	RK125	1.17	0.47	27.33	16.13	10.13	68.06	59.91	9.00	32.67	2.08	11.90
125	Vu031-2	0.57	0.33	22.67	8.73	3.73	49.96	42.22	4.27	23.67	2.13	11.90
126	Vu104	0.93	0.50	24.00	5.67	4.93	86.74	47.52	4.00	26.67	3.29	11.90
127	RK132	1.17	0.43	28.67	18.93	12.00	67.56	62.88	10.67	34.33	1.97	11.90
128	RP255	1.20	0.43	28.00	21.13	9.80	46.88	63.89	8.33	32.67	1.44	11.90
129	RM333	1.03	0.50	24.00	11.00	7.27	65.94	52.12	6.00	29.33	2.25	12.00
130	RS040	0.53	0.17	27.00	12.27	6.07	53.39	68.89	5.20	29.67	1.85	12.00
131	RP281	1.10	0.53	23.67	7.87	6.33	81.18	51.52	6.20	28.67	2.84	12.10
132	RM342	0.87	0.50	23.33	6.93	4.93	72.65	41.67	4.73	25.33	2.88	12.10
133	RK148	0.63	0.33	24.67	7.60	3.87	57.71	46.03	3.53	23.67	2.44	12.10
134	RC377	0.67	0.33	22.33	4.53	3.87	85.65	49.21	4.07	24.67	3.77	12.10
135	Vu105	0.90	0.57	25.00	6.87	4.07	60.92	37.04	4.40	24.67	2.57	12.10
136	RP263	1.03	0.60	23.67	10.47	5.87	75.42	42.76	5.13	28.00	2.62	12.10
137	RS099	0.77	0.27	26.67	10.93	7.67	70.99	65.08	7.00	31.00	2.40	12.10
138	RP243	1.03	0.37	27.33	20.87	9.07	53.75	64.55	8.53	31.33	1.72	12.20
139	Vu081-2-2	0.50	0.20	23.00	12.73	5.00	39.08	60.00	4.87	26.67	1.48	12.20
140	RS047	0.93	0.67	26.33	10.33	6.40	76.78	28.61	5.47	29.00	2.60	12.20

SN	Accession	ISW	FSW	DFE	ANEL	ANAE	PAE	PWL	NHPS	MDP	G.I	DSI
141	Vu002	0.97	0.47	22.67	11.87	6.53	64.98	51.85	6.47	28.00	2.30	12.30
142	RS115	0.87	0.33	27.00	14.73	6.80	62.22	59.84	7.07	28.00	2.53	12.30
143	Vu072	0.70	0.27	24.00	8.27	5.20	72.46	61.90	4.80	25.33	2.96	12.40
144	RC410	1.17	0.60	23.33	12.27	3.67	69.89	48.99	3.20	23.33	3.04	12.40
145	RP242	1.30	0.50	27.67	19.07	11.60	64.77	61.54	10.53	33.00	1.95	12.40
146	Vu031-3-1	0.57	0.23	23.33	11.60	4.93	42.21	59.05	4.53	25.67	1.64	12.40
147	RC404	1.13	0.63	23.00	5.80	5.73	99.17	44.44	5.47	26.67	3.74	12.50
148	Vu016	0.80	0.37	23.00	12.40	4.87	62.05	54.23	4.20	25.67	2.34	12.50
149	RK121	0.97	0.33	26.00	19.13	10.00	54.63	65.38	9.33	31.33	1.77	12.50
150	Vu031-3-2	0.50	0.23	23.00	10.33	4.53	55.78	52.22	4.27	24.33	2.23	12.60
151	RC398	1.23	0.80	23.00	5.60	4.87	86.29	34.40	4.67	24.33	3.55	12.60
152	RM360	0.70	0.27	24.00	11.93	5.33	48.57	62.10	5.20	26.00	1.80	12.60
153	RC420	0.70	0.23	22.67	16.40	5.27	58.49	65.48	4.80	25.67	2.34	12.60
154	Vu058	1.00	0.63	23.67	13.00	5.67	47.57	36.67	5.33	26.67	1.76	12.60
155	Vu123	0.67	0.23	23.67	10.20	5.33	60.01	64.29	5.07	26.33	2.23	12.60
156	Vu130	0.60	0.33	23.67	9.73	4.80	52.39	44.44	4.67	24.33	2.17	12.70
157	RC414	1.17	0.60	23.33	9.73	5.00	63.06	48.48	4.93	25.67	2.39	12.70
158	Vu042	0.67	0.30	23.33	9.33	6.13	69.89	54.76	5.27	26.67	2.67	12.70
159	RK124	1.07	0.47	26.00	17.80	8.80	58.97	55.76	8.33	29.33	2.18	12.80
160	RP320	1.07	0.70	23.33	6.27	4.87	80.85	34.55	4.60	25.00	3.29	12.80
161	RP318	0.70	0.27	22.67	12.93	6.13	52.31	61.90	6.00	26.67	1.97	12.80
162	Vu084-2	0.70	0.30	23.00	7.67	5.80	78.19	57.14	5.40	26.33	2.96	12.80
163	Vu124	0.63	0.23	23.67	11.27	6.60	65.15	62.70	5.87	27.33	2.38	12.80
164	RP257	0.97	0.43	24.00	7.93	5.73	81.20	55.93	5.67	25.67	3.16	12.90
165	RS002	0.73	0.27	24.00	18.27	5.73	52.57	63.69	5.20	25.00	2.05	12.90
166	RC417	0.43	0.17	23.33	14.93	4.07	29.84	61.67	3.47	22.67	1.31	13.00
167	RS030	1.03	0.50	27.00	12.20	7.47	70.31	51.52	5.60	29.00	2.45	13.00
168	RK212	0.77	0.37	24.67	17.47	5.87	37.26	54.04	5.07	26.00	1.37	13.00
169	RP321	0.90	0.43	23.33	9.07	6.47	76.25	52.22	5.93	26.67	2.89	13.00
170	Vu011	0.73	0.20	22.67	13.53	6.60	49.31	72.62	6.60	27.00	1.83	13.00
171	RK211	0.97	0.37	25.67	18.00	9.20	58.86	62.22	7.53	29.33	1.94	13.10
172	Ife Brown**	0.87	0.33	23.33	6.40	4.87	86.76	60.65	3.87	23.33	3.80	13.10
173	RK142	1.30	0.50	26.00	21.20	9.80	47.27	61.42	9.07	30.33	1.66	13.10
174	RK184	1.40	0.77	26.33	16.27	8.67	68.52	45.24	6.00	28.00	2.53	13.10
175	RP279	1.30	0.57	23.33	8.73	8.20	94.14	56.41	8.20	26.67	3.55	13.30
176	RS048	0.87	0.33	26.00	18.87	7.80	45.75	61.57	6.47	28.00	1.67	13.30
177	RK182	0.60	0.23	23.00	14.00	5.00	51.02	61.11	4.60	23.00	2.22	13.30
178	RP324	1.33	0.67	23.00	9.73	8.80	88.57	49.82	8.20	28.00	3.15	13.30
179	RC407	0.47	0.20	23.00	12.80	4.33	38.93	56.67	4.20	23.00	1.69	13.30
180	RC406	1.30	0.73	22.33	11.33	6.33	71.21	43.59	5.93	26.00	2.60	13.40
181	RM359	0.63	0.27	23.67	10.93	7.20	74.17	57.94	6.27	26.67	2.78	13.40
182	RM361	1.20	0.47	23.33	11.47	8.60	76.28	61.17	7.20	28.00	2.73	13.50
183	RK116	1.30	0.60	24.67	16.53	7.60	60.10	53.85	6.67	26.33	2.45	13.60
184	RP295	0.97	0.47	23.67	13.13	7.47	65.30	52.22	6.00	26.00	2.53	13.60
185	RP301	1.13	0.63	23.00	8.73	6.47	78.19	44.19	5.93	25.00	3.19	13.70
186	RC402	0.73	0.37	22.67	11.87	5.13	71.25	50.60	4.47	23.33	3.01	13.90
187	RP311	1.00	0.40	23.33	8.80	6.53	79.40	60.23	6.40	24.67	3.25	13.90
188	RC371	1.40	0.63	22.67	16.47	7.20	66.50	54.76	6.80	25.67	2.56	13.90
189	RP290	0.90	0.43	23.33	13.53	6.27	60.22	51.85	5.27	24.33	2.44	14.00
190	RM362	0.77	0.33	23.67	15.53	5.93	43.53	56.55	5.73	24.67	1.72	14.00
191	Vu112	0.70	0.27	22.67	11.13	5.93	54.62	61.90	4.93	24.33	2.26	14.00
192	RP302	1.23	0.60	22.67	9.40	8.53	94.08	51.07	6.67	26.00	3.63	14.00

SN	Accession	ISW	FSW	DFE	ANEL	ANAE	PAE	PWL	NHPS	MDP	G.I	DSI
193	RP286	1.30	0.63	22.33	16.73	7.60	55.54	51.28	5.33	24.33	2.35	14.20
194	RP267	0.97	0.50	22.33	11.73	6.73	60.49	48.15	6.13	24.67	2.42	14.40
195	Vu031-1	0.57	0.27	23.33	6.07	5.60	92.20	52.22	5.33	22.67	4.07	14.60
196	RC412	1.07	0.43	24.67	18.33	8.67	48.69	59.18	7.53	25.67	1.88	14.70
197	RC395	1.40	0.67	23.00	10.87	10.07	92.90	51.68	7.00	25.67	3.64	15.10
198	Vu007-2-1	0.87	0.47	23.33	9.27	7.40	83.56	45.83	6.27	23.67	3.53	15.10
199	RS036	0.60	0.20	23.33	18.00	6.80	44.76	66.67	6.40	23.00	1.95	15.20
200	RC401	1.07	0.50	23.00	8.80	7.80	88.37	53.33	7.33	23.67	3.74	15.40
201	RM345	0.80	0.30	23.33	13.60	7.47	58.80	62.50	7.13	23.33	2.52	15.50
202	RP238	0.60	0.20	23.00	22.47	6.73	30.93	66.67	4.80	22.33	1.38	15.70
203	RP319	1.10	0.50	22.67	8.67	8.00	98.21	54.55	6.53	22.33	4.41	16.40
204	RP280	1.27	0.47	23.33	20.13	11.67	63.19	63.10	10.93	23.67	2.66	17.20
205	RK117	1.10	0.40	23.00	20.27	12.47	62.20	63.64	11.07	23.67	2.64	17.50
	S.E	0.07	0.14	1.38	5.54	1.96	17.63	13.00	1.70	2.62	0.67	1.59

ISW: Initial seed weight, FSW: Final seed weight, DFE: Days to first emergence, ANEL: Average number of eggs laid, ANAE: Average number of adult emergence, PAE: Percentage adult emergence, PWL: Percentage weight loss, NHPS: Number of holes per seed, MDP: Median development period, G.I.: Growth index of insect and DSI: Dobie susceptibility index; S.E: Standard Error; * - resistant, ** - susceptible.

Table-3: Pearson's correlation coefficients (r) among pairs of *C. maculatus* resistance traits in cowpea accessions collected from Togo.

	ANEL	DFE	ANAE	NHPS	PAE	ISW	FSW	PWL	MDP	GI
DFE	0.32^{**}	-								
ANAE	0.59^{***}	0.59^{***}	-							
NHPS	0.55^{***}	0.24^{***}	0.95^{***}	-						
PAE	-0.59^{***}	-0.2^{**}	0.15^{*}	0.15^{**}	-					
ISW	0.16^{*}	0.01^{ns}	0.62^{***}	0.60^{***}	0.43^{***}	-				
FSW	-0.19^{**}	0.01^{ns}	0.22^{***}	0.21^{***}	0.48^{***}	0.86^{***}	-			
PWL	0.56^{**}	0.089^{ns}	0.37^{***}	0.35^{***}	-0.38^{***}	-0.28^{**}	-0.71^{***}	-		
MDP	0.35^{**}	0.9^{***}	0.41^{***}	0.40^{**}	-0.13^{ns}	0.07^{ns}	-0.03^{ns}	0.17^{***}	-	
GI	-0.62^{**}	0.023^{ns}	-0.01^{ns}	-0.02^{ns}	0.93^{***}	0.36^{***}	0.45^{**}	-0.40^{***}	-0.47^{***}	-
DSI	0.19^{*}	-0.60^{**}	0.44^{***}	0.41^{***}	0.21^{***}	0.37^{**}	0.13^{ns}	0.24^{***}	-0.57^{***}	0.39^{***}

^{ns} Not significant at 0.05 probability level; *, **, *** Significant at P<0.05, P<0.01 and P<0.001, respectively.
ANEL: Average number of eggs laid, DFE: Days to first emergence, ANAE: Average number of adult emergence, NHPS: Number of holes per seed, PAE: Percentage adult emergence, ISW: Initial seed weight, FSW: Final seed weight, PWL: Percentage weight loss, MDP: Median development period, GI: Growth index of insect and DSI: Dobie susceptibility index

Table-4: Stepwise multiple regression analysis for *C. maculatus* resistance traits of cowpea accessions from Togo.

Model	Beta (coefficients)	Adjusted R-square	Probability
Intercept (β_0)	17.799		<0.001
Variables			
ANAE (β_1)x_1	0.585	0.877	<0.001
MDP (β_2) x_2	-0.380		<0.001
PWL (β_3) x_3	0.018		<0.001

Independent variables: ANAE - Average number of adult emergence, MDP - Median development period and PWL - Percentage weight loss. Dependent variable: DSI - Dobie susceptibility index

Discussion

Significant differences observed among the evaluated genotypes is indicative of the variation in their response to *C. maculatus* infestation. Number of eggs (Miesho et al., 2018), percentage adult emergence, median development period, growth index, percentage weight loss and ultimately Dobie's susceptibility index (Jackai and Asante, 2003; Cruz et al., 2016; Kosini et al., 2017) are the most reliable indicators for resistance of cowpea to *C. maculatus* attack.

The non-significant differences observed among the genotypes for average number of eggs laid was in contrast to the findings of several authors (Jackai and Asante, 2003; Badii et al., 2013; Cruz et al., 2016; Adams et al., 2017; Miesho et al., 2018; Kpoviessi et al., 2019), and indicates non-discrimination by *C. maculatus* for oviposition among the cowpea genotypes from Togo. In effect, oviposition deterrents (physical or biochemical) (Sharma and Thakur, 2014; Cope and Fox, 2003), which are the main factors for antixenosis were absent among the accessions evaluated. The results of the present study corroborate the findings of Busayo and Abdul-Razak (2018), Augustine et al. (2016), Castro et al. (2013) with *C. maculatus* on cowpea. Singh and Sharma (2003) reported similar results for *C. chinensis* on peas.

One of the indices for determining the susceptibility of cowpea genotypes to *C. maculatus* attack is growth index (G.I.) (Miesho et al., 2018; Kpoviessi et al., 2019). It measures the innate properties of the seed to support the multiplication of bruchids. Genotypes that have a lower growth index are described as unsuitable for the rapid development and multiplication of the bruchids and *vice versa* (Soumia et al., 2015). The range reported in this study (0.7 - 3.7) is higher than the 0.031 - 0.061 reported by Obopile et al. (2011) from the evaluation of cowpea landraces from Botswana; in the latter study, the extremely low value of the range indicates an inherent high level of resistance against *C. maculatus*. A range of 0.054 – 0.067 was obtained by Seram et al. (2016) in a study of the damage by *C. maculatus* under different conditions. Soumia et al. (2015) reported a range of 0.042 – 0.09 among greengram accessions screened with *Callosobruchus analis*. Miesho et al. (2018) reported that differences in G.I. for 145 cowpea genotypes of Uganda were statistically different; the G.I. values for resistant cowpea genotypes of Uganda ranged from 0.03 – 3.43.

The observed significant differences in Dobie susceptibility index (DSI) among the screened cowpea accessions indicate the presence of genetic diversity among the genotypes in their response to *C. maculatus* infestation. Accessions RS009 and RP218, which had G.I. values of 3.1 and 2.4 respectively had low DSI value of 8.4, an indication that these accessions exhibited tolerance, a resistance mechanism in which the organism does not interfere with the insect pest's physiology or behavior while being able to produce substantial amount of yield (Peterson et al., 2017). Miesho et al. (2018) reported a DSI range of 0 - 8.8 for 145 cowpea genotypes evaluated in Uganda. Musa and Adeboye (2017) reported a DSI range of 4.8 - 10.4 among seven cowpea varieties screened for resistance to *C. maculatus*, while Mbata (1993) reported a range of 4.4 - 14.8 from the screening of some selected cowpea varieties in Nigeria. In a previous study (Mbata, 1993), TVu2027 had a DSI score of 7.4, which is similar to the score (7.5) obtained in the present study. Ife brown, a susceptible variety, had a DSI score of 14.8 in the study reported by Mbata (1993), which is higher than the value (13.1) obtained in this study.

In the present study, the significant inverse relationship between Dobie susceptibility index (DSI) on one hand and median development period (MDP) and days to first emergence (DFE) on the other implies that the insects took a longer time to reach MDP on resistant lines and *vice versa*. This finding affirms the relationship between DSI and MDP reported by several authors (Kpoviessi et al., 2019; Sakariyahu, 2019; Seurei, 2019; Miesho et al., 2018 and Adams et al., 2017). These results indicate that MDP and DFE would be useful as selection indices for resistance to *C. maculatus*. A significant positive correlation between DSI on one hand and ANAE, NHPS and G.I. on the other indicates that the higher the ANAE, NHPS and G.I. of the genotype, the more susceptible the genotype is to attack by *C. maculatus* and *vice versa*. This finding affirms the conclusion drawn by Lephale et al. (2012), Amusa et al. (2014), Kpoviessi et al. (2019) and Tripathi et al. (2020) in their respective studies involving *C. maculatus* on cowpea. Tripathi et al. (2020) reported a significant correlation between DSI and PWL. The results obtained from the stepwise multiple regression indicate that resistance of cowpea to *C. maculatus* is associated with a reduction in the average number of adult emergence, an increase in median development period and a reduction in percentage weight loss.

Conclusion

Among the 200 cowpea accessions collected from Togo and evaluated for their resistance reaction to artificial infestation of *C. maculatus*. 51 accessions were moderately resistant, with RS009 and RP218 having the least DSI score, an indication of tolerance.

The remaining 149 accessions were susceptible. Dobie susceptibility index significantly and positively correlated with average number of adult emergence, percentage weight loss and number of holes per seed, and significantly and negatively correlated with median development period and days to first emergence but was not associated with insect growth index. Overall, 87.7% of the observed variability for Dobie susceptibility index was accounted for by the average number of adult emergence, median development period and percentage weight loss. These traits are the better predictors of cowpea bruchid resistance.

Acknowledgement

This study was funded by the African Union Commission, Pan African University, Addis-Ababa, Ethiopia. The authors gratefully acknowledge the International Institute of Tropical Agriculture, Ibadan, Nigeria, for providing the accessions and the facilities for carrying out the study.

Disclaimer: None.
Conflict of Interest: None.
Source of Funding: This study was funded by the African Union Commission.

References

Adams B, Osekre EA and Amoah S, 2017. Evaluation of cowpea (*Vigna unguiculata* L.) genotypes' growth and yield performance and resistance to the cowpea seed beetle, *Callosobruchus maculatus* F. J. Exp. Agric. Int. 19(5): 1–9.

Amusa OD, Ogunkanmi LA, Bolarinwa KA and Ojobo O, 2013. Evaluation of four cowpea lines for bruchid (*Callosobruchus maculatus*) Tolerance J. Nat. Sci. Res. 3(11): 46–52.

Amusa OD, Ogunkanmi LA, Adetunbi JA, Akinyosoye ST, Bolarinwa KA and Ogundipe OT, 2014. Assessment of bruchid (*Callosobruchus maculatus*) tolerance of some elite cowpea (*Vigna unguiculata*) Varieties. J. Agric. Sustain. 6:164–178.

Augustine AM, Idoko JE and Adepoju AO, 2016. Ovipositional response of seed beetle *Callosobruchus maculatus* (F.) Coleoptera: Chrysomelidae on some selected varieties of cowpea, *Vigna unguiculata* (L). Walp. Int. J. Res. Agric. For. 3(5): 28–34.

Badii KB, Asante SK and Sowley EN, 2013. Varietal susceptibility of cowpea (*Vigna unguiculata* L.) to the storage beetle, *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). Int. J. Sci. Technol. Res. 2(4): 84–89.

Beck CW and Blumer LS, 2011. A Handbook on Bean Beetles, *Callosobruchus maculatus*. pp. 15. Available on: http://www.beanbeetles.org. Accessed January 2020.

Boukar O, Fatokun CA, Huynh BL, Roberts PA and Close TJ, 2016. Genomic Tools in Cowpea Breeding Programs: Status and Perspectives. Front. Plant Sci. 7: 757.

Busayo RT and Abdul-Razak MK, 2018. Laboratory evaluation of six improved cowpea *Vigna unguiculata* varieties for susceptibility to seed beetle, *Callosobruchus maculatus* (Coleoptera: Chryosmelidae) in Storage. J. Crop Prot. 7(3): 273–281.

Castro MJP, Baldin ELL, Cruz PL, Souza CM and Da Silva PHS, 2013. Characterization of cowpea genotype resistance to *Callosobruchus maculatus*. Brazilian Agric. Res. 48(9): 1201–1209.

Chakraborty S, Mondal P and Senapati SK, 2015. Evaluation of relative susceptibility of *Callosobruchus chinensis* Linn. on five different stored pulse seeds. Asian J. Plant Sci. Res. 5(10):9–15.

Cope JM and Fox CW, 2003. Oviposition decisions in the seed beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae): effects of seed size on superparasitism. J. Stored Prod. Res. 39: 355–365.

Cruz LP, De Sa LFR, Santos LA, Gravina GA, Carvahlo AO, Fernandes KVS, Filho FRF, Gomes VM and Oliveria AEA, 2016. Evaluation of resistance in different cowpea cultivars to *Callosbruchus maculatus* infestation. J. Pest Sci. 89:117–128.

Dobie P, 1974. The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais* Motsch. (Coleoptera, Curculionidae). J. Stored Prod. Res. 10: 183–197.

Jackai LEN and Asante SK, 2003. A case for the standardization of protocols used in screening cowpea, *Vigna unguiculata* for resistance to *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae). J. Stored Prod. Res. 39: 251–263.

Kareem KT and Taiwo MA, 2007. Interactions of viruses in cowpea: effects on growth and yield parameters. Virol. J. 4:15.

Keneni G, Bekele E, Getu E, Imtiaz M, Damte T, Mulatu B and Dagne K, 2011. Breeding food legumes for resistance to storage insect pests: potentials and limitations. *Sustainability* 3:1399–1415.

Kosini D, Saidou, C and Nukenine EN, 2017. Physico-chemical properties and resistance of ten bambara groundnut (*Vigna subterranean*) varieties to attack by *Callosobruchus maculatus* (Fabricius) (Coleoptera: Chrysomelidae) in the Sudano-sahelian and Sudano-guinean zones of Cameroun. J. Agri. I. 15: 1 – 14.

Kpoviessi AD, Datinon B, Agbahoungba S, Agoyi EE, Chougourou DC, Sodedji FKA and Assogbadjo AE, 2019. Source of resistance among cowpea accession to bruchid (*Callosbruchus maculatus* F. Coleoptera: Chrysomelidae) in Benin. African Crop Sci. J. 28(1): 49–65.

Kpoviessi DA, Chougourou DC, Bokonon-Ganta AH, Fassinou-Hotegni NV and Dossou J, 2017. Bioefficacy of powdery formulations based on kaolin powder and cashew (*Anacardium occidentale* L.) balms against *Callosobruchus maculatus* F. (Coleoptera, Chrysomelideae: Bruchinae) on stored cowpea (*Vigna unguiculata* L.). Int. J. Biol. Sci. 114: 1424–1436.

Lephale S, Abraham AB and Victoria A, 2012. Susceptibility of seven cowpea cultivars (*Vigna unguiculata*) to cowpea beetle (*Callosobruchus maculatus*). Agric. Sci. Res. J. 2: 65–69.

Mbata GN, 1993. Evaluation of susceptibility of varieties of cowpea to *Callosbruchus maculatus* (F.) and *Callosobruchus subinnotatus* (Pic.) (Coleoptera: Bruchidae. J. Stored Prod. Res. 29(3): 207–213.

Miesho WB, Gebremedhin HM, Msiska UM, Mohammed KE, Malinga GM, Sadik K, Odong TL, Rubaihayo P and Kyamanywa S, 2018. New sources of cowpea genotype resistant to cowpea bruchid *Callosobruchus maculatus* (F.) in Uganda. Int. J. Agron. Agric. Res. 12(4): 39–52.

Musa AK and Adeboye AA, 2017. Susceptibility of some cowpea varieties to the seed beetle C*allosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). J. Agric. Sci. 62(4): 351–360.

Obopile M, Masiapeto K and Gwafila C, 2011. Variation in reproductive and developmental parameters of *Callosobruchus maculatus* (F) reared on ten Botswana cowpea landraces. Afr. J. Biotechnol. 10(63): 13924–13926.

OECD (Organization for Economic Co-operation and Development Consensus Documents), 2016. “Cowpea (*Vigna unguiculata*)”, in Safety Assessment of Trangenic Organisms in the Environment, Volume 6: Organization for Economic Co-operation and Development Consensus Documents, OECD Publishing, Paris. Pp. 211–241. DOI: https://doi.org/10.1787/9789264253421-8-en.

Peterson RKD, Varella AC and Higley LG, 2017. Tolerance: the forgotten child of plant resistance. Peer J 5: e3934; 1 – 16, DOI 10.7717/peerj.3934

Philips RD, McWalters KH, Chinnan MS, Hung Y, Benchat LR and Sefah-Dedeh S, 2003. Utilization of cowpea for human food. Sci. Direct F. Crop. 82: 193–213.

RStudio Team, 2021. RStudio: Integrated Development Environment for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/. Rversion 4.0.3

Sakariyahu SK, 2019. Genetic Variability of cowpea (*Vigna unguiculata* (L.) Walp) MAGIC RILs for resistance to bruchid (*Callobrochus maculatus* F.) M.Sc. Thesis Pan African University, University of Ibadan.

Seram D, Mohan S, Kennedy JS and Senthil N, 2016. Development and damage assessment of the storage beetle, Callosobruchus maculatus (Thanjavur and Coimbatore strain) under normal and controlled conditions. Pp. 25–31. In: Navarro S, Jayas DS, Alagusundaram K, (Eds.) Proceedings of the 10th International Conference on Controlled Atmosphere and Fumigation in Stored Products (CAF2016), CAF Permanent Committee Secretariat, Winnipeg, Canada.

Seurei P, 2019. Screening of wild cowpea [*Vigna unguilata* (L.) Walp.] relatives for resistance to *Callosobruchus maculatus* (Fabr.). M.Sc. Thesis Pan African University, University of Ibadan.

Sharma S and Thakur DR, 2014. Comparative developmental compatibility of *Callosobruchus maculatus* on cowpea, chickpea and soybean genotypes. Asian J. Biol. Sci. 7: 270–276.

Singh BB, 1999. Improved breeding lines with resistance to bruchid. IITA Annual Report 29–30.

Singh BB, Singh SR and Adjadi O, 1985. Bruchid Resistance in Cowpea 1. Crop Sci., 25, 736–739.

Singh S and Sharma G, 2003. Preference of *Callosobruchus chinensis* in pea varieties. Indian J. Entomol. 65(2):277–280.

Soumia PS, Srivastava C, Dikshit HK and Guru-Pirsanna-Pand G, 2015. Screening for resistance against pulse beetle, *Callosobruchus analis* (F.) in greengram (*Vigna radiata* (L.) Wilczek) accessions. Proc. Natl. Acad. Sci. India. Sect. B Biol. Sci. 87(2): 1–8.

Togola A, Boukar O, Belko N, Charmarthi SK, Fatokun C, Tamo M and Oigiangbe N, 2017. Host plant resistance to insect pests of cowpea (*Vigna unguiculata* L. Walp.): achievements and future prospects. Euphytica 213: 239–246.

Tripathi K, Prasad TV, Bhardwaj R, Jha SK, Semwal DP, Gore PG, Sharma PK and Bhalla S, 2020. Evaluation of diverse germplasm of cowpea [*Vigna unguiculata* (L.) Walp.] against bruchid [*Callosbruchus maculatus* (Fab.)] and correlation with physical and biochemical parameters of seed. Plant Genet. Resour. Charact. Util. 18(3): 120–129.

Tripathy SK, 2016. Bruchid resistance in food legumes-an overview. Res. J. Biotechnol. 11(7): 97–105.

Tripathi K, 2012. Differential reaction of cowpea genotypes to pulse beetles under artificial seed infestation and biochemical basis of resistance. Published M.Sc. Thesis, 131 pages. IARI, Division of plant genetic resources. https://krishikosh.egranth.ac.in/displaybitstream?handle=1/76779

Umeozor OC, 2005. Effect of the infection of *Callosobruchus maculatus* (Fab.) on the weight loss of stored cowpea (*Vigna unguiculata* (L.) Walp). J. Appl. Sci. Environ. Manage. 9: 169-172.

Contribution of Authors

Affram EI: Conceived idea, carried out the study, literature review and wrote the manuscript
Adetimirin VO, Fatokun & C Boukar O: Provided supervisory support, edited and reviewed the manuscript