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Research Article

Influence of intrinsic factors of cowpea seed varieties on the cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae)

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Abstract: In this study, the roles of proximate composition, mineral profile and heavy metal contamination were investigated on selected biological activities of *Callosobruchus maculatus* (F.) that were maintained on six cowpea cultivars. The levels of heavy metals; cadmium, lead and arsenic in six cowpea cultivars; Ife Brown, Ife BPC, Oloyin, Drum, Sokoto Local, and Niger White were determined by atomic absorption spectrophotometry while those of nutrient elements; zinc, sodium, calcium and potassium were determined using flame photometry. The proximate analyses and physico-chemical characterization of the cowpea cultivars were also performed. *Callosobruchus maculatus* was maintained on the cowpea cultivars and biological activities such as oviposition, adult emergence, percentage seed damage, and weight loss were monitored. The levels of heavy metals, mineral elements and proximate composition differed significantly among the cultivars investigated, and the values were comparable to those reported for cowpea cultivars in other studies. Of the cowpea cultivars, the Ife Brown was the most susceptible to the bruchid *C. maculatus* infestation while the Drum cultivar was the least susceptible. In conclusion, the results from this study show that the cowpea cultivars differed in the levels of toxic and mineral elements. While there were significant relationships between physical parameters (e. g. seed hardness), proximate composition (moisture contents and crude fibre) and adult emergence and oviposition, there was no strong evidence that the levels of heavy metals and mineral elements play significant role on the biology of *C. maculatus*.

Keywords: Cowpea cultivars, mineral elements, proximate composition, toxic elements, weevil susceptibility

Introduction

Cowpea *Vigna unguiculata* seeds provide cheap alternative source of dietary protein for humans and animals in many parts of the world especially in West and Central Africa, where they complement the mainly cereal and starchy tuber diets (Adedire *et al.,* 2011a; Ofuya and Lale, 2001; Philips *et al.,* 2003). The quest to improve the yield of cowpeas has led to development of various varieties of cowpeas, examples of available local varieties in Nigeria include IT80D-699, IT82 (e-18), Ife Brown, Ife BPC, IT870-9411, TVX3236, IT90K-277-2, IT870-9411, IT828-146, Oloyin, Drum, Sokoto local and Niger white cowpea, Olo-1, Olo-2, Banjara, Karadua, Manyan Fari, Kananado Fari, Kananado Yar and Akidi. These varieties differ in various physical and

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functional properties such as seed colour, texture, size, hardness and biochemistry, and these properties have been linked to play important role in resistance against pests and diseases (Agbogidi and Egho, 2012; Olapade *et al.,* 2002).

The infestation of cowpea seeds by *Callosobruchus maculatus* (F.) accounted for the major loss of cowpea both in store and at fields (Adedire, 2001; Jackai and Daoust, 1986; Udo, 2005). The females of the bruchid lay their eggs on the seed surface which hatch into larvae within 5 days. The larvae bore through the seed coat into the underlying cotyledons where development continues until adult emergence; the adults are already sexually mature on emergence (Credland and Wright, 1989; Ofuya and Credland, 1995).

Technological advancement and increasing anthropogenic activities have resulted in the increased levels of heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg) and chromium (Cr) and arsenic (As) in the environments (Li *et al.,* 2014). When heavy metals are disposed into water, soil and air, they could be bioaccumulated by the crops (Fu *et al.,* 2008) and could be harmful to humans when such crops are consumed (Balkhair and Ashraf, 2016; Satpathy *et al.,* 2014). Studies on assessment of toxic elements in foods are important from public health point of view owing to various toxic effects that have been documented for these elements in humans (Adeyemi *et al.,* 2016; Jarup, 2003). The objectives of the present study are i) to determine the proximate compositions, toxic elements (Cd, Pb and As) and mineral profiles (Ca, Na, Zn and K) of six cowpea cultivars that are common in major Nigerian markets, ii) to determine the correlation between toxic elements (Cd, Pb and As) and essential elements (Ca, Na, Zn and K) in different cowpea cultivars and biological activities (such as oviposition, hatchability and growth) of *C. maculatus*, and iii) to investigate the effect of cowpea cultivars on storage loss as well as oviposition and hatchability of *C. maculatus.*

Materials and Methods

Collections of sample and preparation

Six cowpea cultivars were used in this study; Oloyin, Drum, Sokoto local and Niger white cowpea obtained from Oba market in Akure metropolis (7.2571° N, 5.2058° E), Ife Brown and Ife BPC obtained from the Institute of Agricultural Research and Training (I. A. R. & T) Ibadan (7.3775° N, 3.9470° E). The samples were placed in polyethylene bags, and appropriately labeled for proper identification, and transported to the laboratory. In the laboratory, the samples were sorted to eliminate stones, chaff and other unwanted material. The samples were pulverized with mortar and pestle after which the pulverized samples were sieved using a sieve of 0.5mm mesh size to obtain very fine particles.

Proximate and metal analyses of the samples

The proximate compositions of the pulverized samples were determined using the AOAC methods of 2003. The parameters determined included ash content, moisture content, carbohydrates, protein, crude fat and crude fiber. The determination of levels of metals in the samples followed the standard procedures (AOAC, 2003). Approximately 5 g of the pulverized samples were carefully weighed out, and digested in acid mixture (perchloric acid and nitric acid), and placed on a hot plate set at 120 °C (increased gradually) until the samples were digested. The digested samples were diluted with distilled water appropriately in the range of the standards for each metal. The determination of levels of Cd, Pb, As and Zn in digested samples were performed using atomic absorption spectrophotometry (model 210 VGP) while the levels of Na, K and Ca were determined using flame photometry.

Laboratory culturing of *C. maculatus*

The parent stock of cowpea seed beetle, *C. maculatus* was obtained from established laboratory culture in the Biology Laboratory of the Federal University of Technology, Akure, Nigeria as reported by (Adedire *et al.,* 2011b). Briefly, cowpea seeds were disinfected by keeping in deep freezer at -20 °C for 3 days. The disinfested seeds were then air dried in the laboratory to prevent mouldiness before introduction of insects. They were then placed in Kilner jars and covered with muslin cloth. The jars were placed in insect rearing cages at ambient temperature of 30 ± 3 °C and 70 ± 5% relative humidity.

Physical and morphological characterization of cowpea cultivars

The physical characteristics that were determined in the cultivars included colour, length, breadth, width and seed hardness. The colours were observed visually while the length and width of the seeds were measured using the Vernier caliper. The weight per seed was measured using a Metler weighing balance machine by finding the average of 20 seeds. The hardness of the seeds was determined using a compression machine (Model: 200063 Milano, Italy).

Effect of cowpea cultivars on infestation and damage by *C. maculatus*

Approximately twenty gram (20g) of each cowpea cultivar was weighed into 250ml plastic containers and ten (10) copulating pairs of adult *C. maculatus* (2 to 3 days old) were introduced into each container. The containers were covered with tight lid that had been cut at the centre and sealed with muslin cloth for aeration. This was replicated three times. The infested cowpea seeds were left for 7 days in an insect cage in the laboratory during which the insects fed and laid eggs. On the day 7 of infestation, beetles were removed and discarded. The total number of eggs laid were counted and recorded. Twenty five days after infestation with beetles, the containers were checked daily for emerged adults. The emerged F1 adults were counted and recorded. Each trial replicate was terminated when no adult emergence was recorded for five consecutive days. The final weight of each cowpea varieties at the end of the experiment was determined, and the percentage weight loss was determined using the formula:

$$Weight\ loss\ (\%) = \frac{Difference\ in\ weight}{Initial\ weight} \times 100$$

The numbers of damaged cowpea seeds were evaluated by counting wholesome, bored or seed with bruchid emergent holes. Percentage seed damaged (bored seed and seeds with bruchid emergent holes) was calculated according to the method described by Odeyemi and Daramola (2000) as follows:

$$Seed\ damage\ (\%) = \frac{No.\ of\ seeds\ damaged}{Total\ No.\ of\ seeds} \times 100$$

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using SPSS 21.0 software and treatment means were separated using Tukey's test. Data obtained from susceptibility studies were correlated with the heavy metals, proximate composition and mineral profiles of the cowpeas to determine the cause-effect factors. Statistical significance was assumed at $p < 0.05$.

Results

Proximate compositions of the cowpea cultivars

The proximate compositions of the cowpea cultivars used in this study are shown in Table 1. There were significant differences ($p < 0.05$) in the mean values for all the proximate analyses parameters determined in this study. The ash content of the cowpea ranged from 3.77% in Ife BPC to 3.88% in Drum. The highest moisture content and lowest moisture content in the cowpea cultivars were observed in cultivars Ife BPC (9.85%) and Drum (9.54%) respectively. The protein content ranged from 22.88% to 24.69% in Drum and Sokoto Local respectively. Sokoto Local had the highest carbohydrates content (59%) while the lowest (57.40%) carbohydrates content was observed in the Drum cultivar. The crude fibers of the cowpea cultivars ranged from 1.83% to 1.97%

in Niger White and Drum cultivars respectively. The highest percentage of crude fat content was recorded in Sokoto Local (2.59%) while Oloyin had the least (2.43%).

Concentrations of toxic metals and mineral elements in cowpea cultivars

The concentrations of toxic metals (Cd, Pb and As) and mineral elements (Zn, Na, Ca, and K) in the cowpea cultivars are presented in Table 2. The levels of Cd, Pb and As differed significantly ($p < 0.05$) among the cowpea cultivars. The highest Cd concentration was detected in Ife Brown (0.009 ± 0.002µg/g) while the least concentration was detected in the Niger White cultivar (0.003 ± 0.002µg/g). The highest concentration of Pb was detected in Oloyin cultivar (0.033 ± 0.003µg/g) while the Drum cultivar had the lowest Pb concentration of 0.025 ± 0.003µg/g. The Niger White cultivar had the highest As concentration of 0.024 ± 0.003µg/g while the lowest As concentration (0.011 ± 0.002µg/g) was detected in Ife BPC. The mean levels of Zn, Na, Ca and K differed significantly in the cowpea cultivars ($p < 0.05$). The highest levels of Zn (21.67 ± 0.020µg/g), Na (57 ± 20µg/g), Ca (810 ± 20µg/g) and K (16508 ± 60µg/g) were detected in Niger White cultivar while the lowest values of Zn (16.33 ± 0.020µg/g), Na (35 ± 10µg/g), Ca (580 ± 20µg/g) and K (13748 ± 40µg/g) were detected in Sokoto Local cultivar.

Table 1 Toxic metals and mineral profile of the cowpea cultivars.

Cultivars	Cd	Pb	Zn	As	Na	Ca	K
Ife BPC	0.007 ± 0.002^{b}	0.031 ± 0.003^{bc}	17.67 ± 0.020^{b}	0.011 ± 0.002^{a}	43 ± 30^{b}	713 ± 30^{b}	13866 ± 60^{b}
Sokoto Local	0.004 ± 0.002^{ab}	0.029 ± 0.002^{bc}	16.33 ± 0.020^{a}	0.018 ± 0.002^{b}	35 ± 10^{a}	580 ± 20^{a}	13748 ± 40^{a}
Oloyin	0.005 ± 0.003^{ab}	0.033 ± 0.003^{c}	19.03 ± 0.015^{c}	0.016 ± 0.002^{ab}	52 ± 30^{c}	727 ± 30^{b}	14512 ± 40^{c}
Drum	0.007 ± 0.002^{b}	0.025 ± 0.003^{a}	20.67 ± 0.030^{d}	0.021 ± 0.003^{bc}	55 ± 20^{cd}	757 ± 30^{b}	14624 ± 40^{d}
Niger White	0.003 ± 0.002^{a}	0.028 ± 0.003^{b}	21.67 ± 0.020^{e}	0.024 ± 0.003^{c}	57 ± 20^{d}	810 ± 20^{c}	16508 ± 60^{e}

Units are presented in µg/g.
Each value is a mean ± standard error of three replicates. Means within the same column followed by the same letter(s) are not significantly different at $p < 0.05$ using Tukey's test.

Table 2 Proximate composition of the cowpea cultivars.

Cultivars	Ash	Moisture content	Protein	Carbohydrates	Crude fiber	Crude fat
Ife Brown	3.85 ± 0.05^{b}	9.67 ± 0.02^{b}	24.64 ± 0.30^{c}	57.63 ± 0.11^{b}	1.92 ± 0.02^{bc}	2.49 ± 0.03^{a}
Ife BPC	3.77 ± 0.02^{a}	9.85 ± 0.03^{d}	23.79 ± 0.03^{b}	58.15 ± 0.12^{c}	1.88 ± 0.02^{b}	2.56 ± 0.02^{bc}
Sokoto Local	3.83 ± 0.03^{ab}	9.74 ± 0.03^{c}	22.88 ± 0.03^{a}	59.00 ± 0.13^{d}	1.95 ± 0.03^{c}	2.59 ± 0.02^{c}
Oloyin	3.79 ± 0.03^{a}	9.65 ± 0.03^{b}	24.57 ± 0.25^{c}	57.69 ± 0.02^{b}	1.86 ± 0.03^{a}	2.43 ± 0.04^{a}
Drum	3.88 ± 0.02^{b}	9.54 ± 0.03^{a}	24.69 ± 0.02^{c}	57.40 ± 0.03^{a}	1.97 ± 0.02^{c}	2.52 ± 0.02^{b}
Niger White	3.86 ± 0.03^{b}	9.77 ± 0.03^{c}	23.87 ± 0.03^{b}	58.11 ± 0.05^{c}	1.83 ± 0.02^{a}	2.54 ± 0.03^{b}

Units are presented in percent.
Means within the same column followed by the same letter(s) are not significantly different at $p < 0.05$ using Tukey's test.

Physical and morphological characterization of cowpea cultivars

The physical and morphological characteristics of the cowpea cultivars are presented in Table 3. The length, width, weight and hardness of the cowpea cultivars differed significantly ($p < 0.05$). Two of the six cultivars (Sokoto Local and Niger White) were white in colour while the remaining (Ife Brown, Ife BPC, Oloyin and Drum) were brown. All the cowpea cultivars were opaque in appearance. The hardness of the cowpea cultivars ranged from 64.26 ± 3.64 N in Ife Brown to 164.22 ± 16.43 N in Drum cultivar. The Ife Brown cultivar had the highest mean values of length (14.22 ± 2.213 mm), width (9.18 ± 2.159 mm) and weight (0.41 ± 0.002 g) while the Sokoto Local cultivar had the lowest mean values of length (9.51 ± 2.561 mm), width (6.81 ± 1.204 mm) and weight (0.16 ± 0.001 g).

Effect of cowpea cultivars on oviposition and adult emergence and seed damage by *C. maculatus*

The data on oviposition and percentage adult emergence of *C. maculatus* cultured on the six cowpea cultivars are presented in Table 4. There were significant differences (p □ 0.05) in the number of eggs laid by *C. maculatus* on the six cultivars studied. The trend in the number of eggs laid was Ife brown > Ife BPC > Niger White > Oloyin > Sokoto Local > Drum. The highest percentage of adult emergence was recorded in *C. maculatus* cultured on Ife Brown cultivar (77%) while the least was recorded in those cultured on Drum cultivar (43%). The extent of seed damage by *C. maculatus* quantified in terms of percentage weight loss and seed damage are also shown in Table 3. The percentages seed damage and weight loss were highest in Ife Brown cultivar (73% and 30% for seed damage and weight loss respectively) and least in Drum (18.7% and 2.5% for seed damage and weight loss respectively).

Table 3 Physical and morphological characteristics of the cowpea cultivars.

Cultivars	Colour	Appearance	Length (mm)	Width (mm)	Weight (g)	Hardness (N)*
Ife Brown	Brown	Opaque	14.2 ± 2.21^{c}	9.18 ± 2.16^{b}	0.41 ± 0.002^{e}	64.26 ± 3.64^{a}
Ife BPC	Brown	Opaque	13.6 ± 1.79^{c}	8.65 ± 1.79^{ab}	0.26 ± 0.001^{c}	92.74 ± 9.73^{b}
Sokoto Local	White	Opaque	9.51 ± 2.56^{a}	6.81 ± 1.20^{a}	0.16 ± 0.001^{a}	119 ± 13.7^{c}
Oloyin	Brown	Opaque	12.8 ± 3.11^{bc}	7.93 ± 0.76^{ab}	0.37 ± 0.001^{d}	113.72 ± 15.5^{c}
Drum	Brown	Opaque	11.8 ± 1.41^{b}	7.22 ± 1.35^{ab}	0.21 ± 0.001^{b}	164.22 ± 16.4^{d}
Niger White	White	Opaque	10.7 ± 1.76^{b}	7.43 ± 1.47^{ab}	0.20 ± 0.001^{b}	102.34 ± 15.1^{b}

Each value is a mean ± standard error of ten replicates. Means within the same column followed by the same letter(s) are not significantly different at p>0.05 using Tukey's test.
*N = Newton.

Table 4 Oviposition, adult emergence and seed damage by *Callosobruchus maculatus* on different cowpea cultivars.

Cowpea cultivar	Mean number of eggs laid	Adult emergence (%)	Seed damage (%)	Weight loss (%)
Ife Brown	37.7 ± 1.45^{d}	77.2 ± 2.35^{d}	73.4 ± 4.48^{d}	18.7 ± 2.22^{d}
Ife BPC	35.3 ± 0.88^{d}	70.8 ± 3.18c	62.8 ± 4.08^{cd}	9.95 ± 2.15^{c}
Sokoto Local	23.7 ± 1.86^{b}	52.1 ± 4.13^{ab}	38.0 ± 4.97^{b}	6.62 ± 1.19^{b}
Oloyin	25.3 ± 0.89^{b}	61.7 ± 2.54^{b}	53.2 ± 3.22^{c}	5.62 ± 1.66^{b}
Drum	18.0 ± 1.16^{a}	43.2 ± 6.81^{a}	29.8 ± 3.53^{a}	2.45 ± 0.61^{a}
Niger White	30.0 ± 0.58^{c}	60.0 ± 5.00^{b}	59.4 ± 6.76^{c}	9.33 ± 2.23^{c}

Each value is a mean ± standard error of ten replicates. Means within the same column followed by the same letter(s) are not significantly different at p > 0.05 using Tukey's test.

Correlation between toxic metals, mineral elements and activities of *C. maculatus*

The Pearson correlation tests between toxic metals, mineral elements, development of *C. maculatus* (oviposition and adult emergence), seed damage and cowpea weight loss are shown in Table 5. There was no significant correlation between the levels of toxic metals, mineral elements and biological activities (oviposition, adult emergence, seed damage and seed weight loss) of *C. maculatus.* However, there was a weak positive correlation between the mean level of Cd and adult emergence (r = 0.421). Also, a weak negative correlation was observed for the levels of As and adult emergence (-0.45), and oviposition (-0.445).

Correlation between hardness, proximate compositions and biological activities of *C. maculatus*

The Pearson correlation matrix between seed hardness, proximate compositions, development of *C. maculatus* (oviposition and adult emergence), seed damage and cowpea weight loss are summarized in Table 6. There was a negative significant correlation between seed damage and crude fibre (r = -0.59) while there was a positive correlation (r = 0.76) between seed damage and weight loss (Table 5). Seed hardness was strongly negatively correlated with adult emergence (r = -0.84), oviposition (r = -0.89) and weight loss (r = -0.73). The correlation matrix also showed that the moisture content of cowpea seeds was positively correlated with oviposition (r = 0.58) crude protein and fibre, and negatively correlated with parameters such as ash content.

Table 5 Correlation between the toxic metals, mineral elements and biological activities of *Callosobruchus maculatus.*

Parameters	Na (µg/g)	Ca (µg/g)	K (µg/g)	Cadmium (µg/g)	Lead (µg/g)	Zinc (µg/g)	Arsenic (µg/g)	Adult emergence	Oviposition	weight loss
Sodium	1	0.867**	0.763**	-0.036	-0.393	0.795**	0.550*	-0.095	-0.188	-0.176
Calcium		1	0.764**	-0.199	-0.277	0.882**	0.478*	-0.124	-0.069	-0.233
potassium			1	-0.403	-0.63**	0.784**	0.716**	-0.104	-0.031	-0.051
Cadmium				1	0.202	-0.356	-0.267	0.421	0.252	0.13
Lead					1	-0.386	-0.427	0.185	0.04	-0.136
Zinc						1	0.657**	-0.467	-0.436	-0.534
Arsenic							1	-0.45	-0.445	-0.325
Adult emergence								1	0.801**	0.653**
Oviposition									1	0.763**
weight loss										1

**correlation is significant at the 0.01 probability level (2 tailed). *correlation is significant at the 0.05 probability level (2 tailed).

Table 6 Correlation between hardness, proximate compositions and biological activities of *Callosobruchus maculatus.*

Parameters	Hardness	Moisture content (%)	Adult Emergence (%)	Crude protein (%)	Crude fat (%)	Crude fiber (%)	Ash content (%)	Carbohydrate (%)	Oviposition
Hardness	1	-0.49	-0.84**	0.037	0.059	0.44	0.266	-0.123	-0.89**
Moisture content		1	0.46	- 0.60**	0.447	-0.48*	-0.508*	0.585*	0.583*
Adult Emergence			1	0.119	-0.243	-0.46	-0.293	-0.069	0.801*
Crude protein				1	-0.71**	-0.02	0.129	-0.979**	0.039
Crude fat					1	0.3	0.135	0.634**	0.025
Crude fibre						1	0.313	0.007	-0.417
Ash content							1	-0.178	-0.364
Carbohydrate								1	0.01
Oviposition									1

**correlation is significant at the 0.01 probability level (2 tailed). *correlation is significant at the 0.05 probability level (2 tailed).

Discussion

The levels of heavy metals (Cd, Pb and As) in cowpea cultivars in the present study were similar to the levels that have been detected from cowpea cultivars in other parts of the world (Hao *et al.,* 2011). Generally, heavy metals like Cd, Pb and As are toxic to plants with no known physiological importance; they have been shown to cause various adverse effects such as cellular damage, growth impairment, disruption of ionic homeostasis etc. (Kopittke *et al.,* 2007; Piršelová *et al.,* 2015; Yadav, 2010). Also, studies have shown that the presence of heavy metals on the substrate negatively affect the biological activities of insects (Schmidt *et al.,* 1992; Diener *et al.,* 2015). In this study however, there was no significant correlation between the levels of heavy metals and considered biological parameters of *C. maculatus* except for weak negative correlation that was observed for As, adult emergence and oviposition.

The detected levels of mineral elements (Zn, Na, Ca and K) were similar to the levels found in cowpea cultivars from other parts of the world. In a similar work that evaluated the levels of mineral elements in Brazilian cowpea cultivars, Santos and Boiteux (2015) reported range values of 27.5-34.8, 91-140.3, 620-1930 and 14350-18180µg/g for Zn, Na, Ca and K respectively. These values were quite similar to those detected in the cultivars analyzed in the present study. The levels of Zn, Pb, As and Cd in cowpeas could be attributed to untreated sewage water used for irrigation, and also to the plant's natural way of loading heavy metals. For instance, zinc is loaded in seeds for storage at maturity and as a result zinc accumulates in the whole grain and seeds of some plants in unacceptable levels for either human or livestock consumption (Robson, 1993). The proximate analyses of the cowpea cultivars indicated that all the cultivars studied in this research were rich in proteins and carbohydrate. The average percentage protein and carbohydrate were 24 and 58% respectively. These values are quite high and comparable to the levels detected in other cowpea cultivars (Carvalho *et al.,* 2012; Kaptso *et al.,* 2008). Except for the protein and carbohydrate contents, the values of other proximate constituents such as crude fibre, crude fat, ash content and moisture content did not differ significantly from those reported for other cultivars (Kaptso *et al.,* 2008). Overall, the seed length and weight of the cultivars investigated in the current study were higher than those reported for other Nigerian cultivars. For example, the Ife Brown cultivar had a weight of 0.41 g which was almost double the weight of the heaviest cultivar investigated by Olapade *et al.* (2002).

Stored food items especially grains are at risks of constant attack by storage pests, and *C. maculatus* has been recognized as an important storage pest of these items (Pessu and Umeozor, 2003; Umeozor, 2005). Consequently, efforts have been concentrated on production of cultivars that are less prone to attack by insect pests. The results of this study show that the Ife Brown cultivar was the most susceptible to *C. maculatus* infestation having the highest oviposition, adult emergence, percentage seed damage and weight loss. The susceptibility of Ife Brown cultivar to *C. maculatus* infestation could be attributed to its soft testa which could easily be damaged by the cowpea bruchid as demonstrated by its low hardness (Adedire *et al.,* 2011b; Ashamo and Khanna, 2007).

The Pearson correlation coefficients between seed hardness, development of cowpea seed bruchid, seed damage and weight loss in this study were negative and significant at $p < 0.01$. This established a strong relationship between cowpea seed hardness, oviposition, adult emergence, seed damaged and weight loss. There have been reports that the hardness of the grain strongly influenced the number of eggs that are deposited on the grain (Dobie, 1974; Prasad *et al.,* 2015). However, Ashamo and Khanna (2006) observed that seed hardness in paddy did not correlate with susceptibility to *Sitotroga cerealella* whereas amylase content did. Aside from seed hardness, other physical characteristics such as texture, size and thickness of the grain have been linked to resistance to *S. oryzae* in rice cultivars (Dobie, 1974; Prasad *et al.,* 2015). It has been shown that the size of the grain is strongly related to resistance; larger grains supply more food and space for insect growth while smaller grains or grains with less mass offer more resistance to pest infestation than larger grains (Lephale *et al.,* 2012; Singh *et al.,* 1974). In addition, in a comprehensive review, Dordas (2008) pointed out the role of essential nutrients in the susceptibility of plants to pest and diseases. These nutrients, which were not reported in this work, could favour rapid development of the bruchids. Ashamo (2001) and Arnason *et al.* (1993; 2004) reported that increase in phenolic and ferulic acid contents were responsible for the resistance of *S. zeamais* to maize grains.

Other factors which may be responsible include low phytate, saponin and tannin contents which were notconsidered in this research (Ileke, 2014).

In conclusion, the results from this study show that the nutritive values of Nigerian cowpea cultivars investigated in this study are comparable to those of cowpea cultivars from other parts of the world with respect to proximate composition and mineral profiles. Of the cowpea cultivars, the Ife Brown was the most susceptible to the bruchid *C. maculatus* infestation having highest oviposition, adult emergence, percentage seed damage and percentage weight loss while the Drum cultivar was the least susceptible. While there were significant relationships between physical parameters (e.g. seed hardness), proximate composition (moisture contents and crude fibre) and adult emergence and oviposition, there was no strong evidence that the levels of heavy metals in the present study are high enough to negatively impact the development of *C. maculatus.*

References

Adedire, C. O. 2001. Biology, ecology and control of insect pests of stored grains. In: Ofuya, T. I. and Lale, N. E. S. (Eds.) Pest of Stored Cereals and Pulses in Nigeria. Dave Collins Publisher, Nigeria, pp. 59-94.

Adedire, C. O., Akinkurolere, R. O. and Ajayi, O. O. 2011a. Susceptibility of some maize cultivars in Nigeria to infestation and damage by maize weevil, *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). Nigeria Journal of Entomology, 28: 55-63.

Adedire, C. O., Obembe, O. O., Akinkurolere, R. O. and Oduleye, O. 2011b. Response of *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) to extract of cashew kernels. Journal of Plant Diseases and Protection, 118: 75-79.

Adeyemi, J. A., Adedire, C. O., Paulelli, A. C., Martins Jr A. C., Ileke, K. D. and Barbosa Jr, F. 2016. Levels and daily intake of lead (Pb) and six essential elements in gari samples from Ondo State, southwest Nigeria: A potential risk factor Analysis of health status. Journal of Food Composition and Analysis, 45: 34-38.

Agbogidi, O. M. and Egho, E. O. 2012. Evaluation of eight varieties of cowpea (*Vigna unguiculata* L.) Walp) in Asaba agro-ecological environment, Delta State, Nigeria. European Journal of Sustainable Development, 1: 303-314.

AOAC. 2003. Official methods of analysis of the association of official's analytical chemists, 17th edn. Association of Official Analytical Chemists, Arlington, Virginia.

Arnason, J. T., Baum, B., Gala, J., Lambert, J. D. H., Bergvinson, D., Philogene, B. J. R., Serratos, J. A. Mihm, J. and Jewell, D. C. 1993. Variation in resistance of Mexican landraces of maize to maize weevil, *Sitophilus zeamais*, in relation to taxonomic and biochemical parameters. Euphytica, 74: 227-236.

Arnason, J. T., Lambert, J. D. H., Gale, J. and Mihm, J. 2004. Is quality of protein in maize more susceptible than normal varieties to attack by the maize weevil, *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). Postharvest Biology and Technology, 2: 349-353.

Ashamo, M. O. 2001. Varietal resistance of maize to maize weevil, *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae). Journal of Plant Disease and Protection, 108: 314-319.

Ashamo, M. O. and Khanna, S. C. 2006. Resistance to the Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Lepidoptera: Gelechiidae) in some paddy varieties. Annals of Plant Protection Sciences, 1: 368-373.

Ashamo, M. O. and Khanna, S. C. 2007. Varietal resistance to the Angoumois grain moth, *Sitotroga cereallela* (Lepidiotera: Gelechiidae) in wheat seeds during storage. Seed Research, 35: 88-93.

Balkhair, K. S. and Ashraf, M. A. 2016. Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia.

Saudi Journal of Biological Sciences, 23: S32-S44.

Carvalho, A. F. U., de Sousa, N. M., Farias, D. F., Rocha-Bezerra, L. C. B., da Silva, R. M. P., Viana, M. P., Gouveia, S. T., Sampaio, S. S., de Souza, M. B., de Lima, G. P. G., de Morais, S. M., Barros, C. C. and Filho, F. R. F. 2012. Nutritional ranking of 30 Brazilian genotypes of cowpeas including determination of antioxidant capacity and vitamins. Journal of Food Composition and Analysis, 26: 81-88.

Credland, P. F. and Wright, A. W. 1989. Factors affecting female fecundity in the cowpea seed beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae). Journal of Stored Product Research, 25: 125-136.

Diener, S., Zurbrügg, C. and Tockner, K. 2015. Bioaccumulation of heavy metals in the black soldier fly, *Hermetia illucens* and effects on its life cycle. Journal of Insects as Food and Feed, 1: 261-270.

Dobie, P. 1974. The laboratory assessment of the inherent susceptibility of maize varieties to post harvest infestation by *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae) infesting field corn. Journal of Entomological Science, 21: 367-375.

Dordas, C. 2008. Role of nutrients in controlling plant diseases in sustainable agriculture: a review. Agronomy for Sustainable Development, 28: 33-46.

Fu, J., Zhou, Q., Liu, J., Liu, W., Wang, T., Zhang, Q. and Jiang, G. 2008. High levels of heavy metals in rice (*Oryza sativa* L.) from a typical E-waste recycling area in southeast China and its potential risk to human health. Chemosphere, 71: 1269-1275.

Hao, X., Zhou, D., Wang, Y., Shi, F. and Jiang, P. 2011. Accumulation of Cu, Zn, Pb, and Cd in edible parts of four commonly grown crops in two contaminated soils. International Journal of Phytoremediation, 13: 289-301.

Ileke, K. D. 2014. Anti-nutritional factors in cowpea cultivars and their effects on susceptibility to *Callosobruchus maculatus* (Fab.) [Coleoptera: Bruchidae] infestation. Bioscience Methods, 5: 21-28.

Jackai, L. E. N. and Daoust, R. A. 1986. Insect pests of cowpea. Annual Review of Entomology, 31: 95-119.

Jarup, L. 2003. Hazards of heavy metal contamination. British Medical Bulletin, 68: 167-182.

Kaptso, K. G., Njintang, Y. N., Komnek, A. E., Hounhouigan, J., Scher, J. and Mbofung, C. M. F. 2008. Physical properties and rehydration kinetics of two varieties of cowpea (*Vigna unguiculata*) and bambara groundnuts (*Voandzeia subterranea*) seeds. Journal of Food Engineering, 86: 91-99.

Kopittke, P. M., Asher, C. J., Kopittke, R. A. and Menzies, N. W. 2007. Toxic effects of Pb^{2+} on growth of cowpea (*Vigna unguiculata*). Environmental Pollution, 150: 280-287.

Lephale, S., Addo-Bediako, A. and Ayodele, V. 2012. Susceptibility of seven cowpea cultivars (*Vigna unguiculatus*) to cowpea beetle (*Callosobruchus maculatus*). Agricultural Science Research Journals, 2: 65-69.

Li, Z., Ma, Z., van der Kuijp, T. J., Yuan, Z. and Huang, L. 2014. A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. Science of the Total Environment, 468-469: 843-853.

Odeyemi, O. O. and Daramola, A. M. 2000. Storage Practices in the Tropics: Food Storage and Pest Problems. First Edition. Dave Collins Publisher, Nigeria.

Ofuya, T. I. and Credland, P. F. 1995. Responses of three populations of the seed beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) to seed resistance in selected varieties of cowpea, *Vigna unguiculata* (L.) Walp. Journal of Stored Products Research, 31: 17-27.

Ofuya, T. I. and Lale, N. E. S. 2001. Pest of Stored Cereals and Pulses in Nigeria. First Edition. Dave Collins Publishers, Nigeria.

Olapade, A. A., Okafor, G. I., Ozumba, A. U. and Olatunji, O. 2002. Characterization of common Nigerian cowpea (*Vigna unguiculata* L. Walp) varieties. Journal of Food Engineering, 55: 101-105.

Pessu, P. O. and Umeozor, O. C. 2003 Relative susceptbility of stored cowpea, *Vigna unguiculata* Walp and soyabean, *Glycine max* (L.) Merrill to infestation by the cowpea seed beetle, *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae). Indian Journal of Agricultural Research, 38: 101-105.

Phillips, R. D., McWatters, K. H., Chinnan, M. S., Hung, Y., Beuchat, L. R., Sefa-Dedeh, S., Sakyi-Dawson, E., Ngoddy, P., Nnanyelugo, D. Enwere, J., Komey, N. S., Liu, K., Mensa-Wilmot, Y., Nnanna, I. A., Okeke, C., Prinyawiwatkul, W. and Saalia, F. K. 2003. Utilization of cowpeas for human food. Field Crops Research, 82: 193-213.

Piršelová, B., Trebichalský, A. and Kuna, R. 2015. Sensitivity of selected crops to lead, cadmium and arsenic in early stages of ontogenesis. Journal of Central European Agriculture, 16: 476-488.

Prasad, G. S., Babu, K. S., Sreedhar, M., Padmaja, P. G., Subbarayudu, B., Kalaisekar, A. and Patil, J. V. 2015. Resistance in sorghum to *Sitophilus oryzae* (L.) and its association with grain parameters. Phytoparasitica, 43: 391-399.

Robson, A. D. 1993. Development in plant and soil sciences. Zinc in soils and plants. Kluwer Academic Publishers, Dordrecht.

Santos, C. A. F. and Boiteux, L. S. 2015. Genetic control and transgressive segregation of zinc, iron, potassium, phosphorus, calcium, and sodium accumulation in cowpea (*Vigna unguiculata)* seeds. Genetics and Molecular Research, 14: 259-268.

Satpathy, D., Reddy, M. V. and Dhal, S. P. 2014. Risk assessment of heavy metals contamination in paddy soil, plants, and grains (*Oryza sativa* L.) at the East Coast of India. BioMed Research International, 2014: 545473.

Schmidt, G. H., Ibrahim, N. M. M. and Abdallah, M. D. 1992. Long-term effects of heavy metals in food on developmental stages of *Aiolopus thalassinus* (Saltatoria: Acrididae). Archives of Environmental Contamination and Toxicology, 23: 375-382.

Singh, K., Agrawal, N. S. and Girish, G. K. 1974. The oviposition and the development of *Sitophilus oryzae* L. in different high yielding varieties of wheat. Journal of Stored Products Research, 10: 105-111.

Udo, I. O. 2005. Evaluation of the potential of some local pices as stored grain protectants against the maize weevil *Sitophilus zeamais* Motsch (Coleoptera: Curculionidae). Journal of Applied Sciences and Environmental Management, 9: 165-168.

Umeozor, O. C. 2005. Effect of the infection of *Callosobruchus maculatus* (Fab.) on the weight loss of stored cowpea (*Vigna unguiculata* (L.) Walp) Journal of Applied Sciences and Environmental Management, 9: 169-172.

Yadav, S. K. 2010. Heavy metals toxicity in plants: An overview on the role of glutathione and phytochelatins in heavy metal stress tolerance of plants. South African Journal of Botany, 76: 167-179.

بررسی عوامل ذاتی مؤثر در ارقام بذر لوبیا چشم‌بلبلی روی سوسک چهارنقطه‌ای حبوبات *Callosobruchus maculatus* (Coleoptera: Chrysomelidae)

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چکیده: در این پژوهش نقش ترکیبات معدنی و فلزات سنگین و سایر ترکیبات موجود در شش رقم لوبیا چشم‌بلبلی روی فعالیت زیستی سوسک چهارنقطه‌ای حبوبات *Callosobruchus maculatus* مورد بررسی قرار گرفت. سطح فلزات سنگین شامل کادمیوم، سرب و آرسنیک در شش رقم لوبیا چشم‌بلبلی توسط دستگاه اسپکتروفتومتر جذب اتمی مورد مطالعه قرار گرفت. اما عناصر معدنی مانند روی، سدیم، کلسیم و پتاسیم توسط دستگاه فلیم فتومتر (نورسنج شعله‌ای) تعیین شدند. هم‌چنین خصوصیات فیزیکوشیمیایی ارقام لوبیا چشم‌بلبلی تعیین شدند. سوسک چهارنقطه‌ای حبوبات روی ارقام لوبیا چشم-بلبلی پروش داده شدند و خصوصیات زیستی شامل میزان تخم‌ریزی، خروج حشرات کامل درصد خسارت و کاهش وزن بذور مورد بررسی قرار گرفت. میزان فلزات سنگین و عناصر معدنی در بین ارقام مختلف اختلاف معنی‌داری داشت. از میان ارقام، رقم Ife Brown حساس‌ترین و رقم Drum کم‌ترین حساسیت را به حضور آفت نشان داد. رابطه معنی‌داری میان ویژگی‌های فیزیکی (مانند سختی بذر) و میزان رطوبت و فیبر بذر با میزان خروج حشرات کامل و میزان تخم‌ریزی مشاهده شد. اما شواهد معنی‌داری مبنی بر تأثیر فلزات سنگین و عناصر معدنی روی بیولوژی سوسک چهارنقطه‌ای حبوبات مشاهده نشد.

واژگان کلیدی: ارقام لوبیا چشم‌بلبلی، عناصر معدنی، عناصر سمی، حساسیت به آفت