



Management of *Callosobruchus maculatus* Fab. (Coleoptera: Chrysomelidae) in Stored Cowpea Using Varietal Resistance and Diatomaceous Earth

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Abstract

The cowpea seed beetle, *Callosobruchus maculatus* (Fab.) is among the most important insect pest of stored cowpea, *Vigna unguiculata* (L.) Walp. Synthetic insecticides are heavily relied upon for the control of this pest. However, the problem of insecticide resistance and environmental hazards associated with synthetic grain protectants underscore the need to explore reduced risk control measures. Laboratory studies were conducted to evaluate the efficacy of varietal resistance and diatomaceous earth (DE) against *C. maculatus* in stored cowpea, under ambient laboratory conditions (27-32°C and 48-55% R.H.). Six improved cowpea varieties (IT89KD-288, UAM09-1046-6 -1, UAM09-1051-1, UAM573-1-1, UAM573-2-1 and ITI79K-499-35) and one local cultivar (Borno Brown) were evaluated for their resistance to infestation by *C. maculatus*, then treated with DE and bio-assayed. The results showed significant variations among the tested varieties in their susceptibility to *C. maculatus* infestation. According to susceptibility indices the varieties were ranked: UAM573-2-1, IT89KD288 and UAM09-1046-6-1 (moderately resistant), Borno Brown, IT97K499-35 and UAM1051-1 (susceptible) and UAM573-1-1 (highly susceptible). Efficacy of DE increased with increase in dosage. Diatomaceous earth applied at the rates of 750 -1000 mg/kg of seed consistently resulted in very few eggs laid in the moderately resistant varieties compared to the susceptible ones and which also prevented seed damage and weight loss. These results indicate that DE could be combined with varietal resistance for use against *C. maculatus* in stored cowpea.

Keywords: Stored cowpea, *C. maculatus*, Varietal resistance, Diatomaceous earth.

INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walp. is an important grain legume in tropical and subtropical regions of the world, the seeds

being a rich source of potent nutritional elements. The dry seeds contain about 25 percent protein and 64 percent carbohydrate. Cowpea is also a good source of calcium, iron, vitamins and carotene (Adedire and Akinneye, 2003). It provides more than half the plant protein in human diets and it is the key source of protein for the poorest sector

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of many developing countries (Remya, 2007). More than 5.4 million metric tons of dried cowpeas are produced worldwide, with Africa producing nearly 5.2 million tonnes. Nigeria is the largest producer and consumer and accounts for 61% of total production in Africa and 58% worldwide (AgroNigeria, 2017). The production of cowpea in many regions is constrained by a number of biotic and abiotic factors, both in the field and in storage and insect pests are major, among the very important biotic constraints (Swella and Mushobozy, 2007).

The cowpea seed beetle, *C. maculatus* is an important, oligophagous and cosmopolitan insect pest of stored pulses in the tropics and subtropics (Khashaveh *et al.*, 2011). It is among the most important insect pests of stored cowpea (Denloye, 2010). It causes substantial quantitative and qualitative losses by seed perforation and reduction in weight, market value and germinability of seeds (Umeozor, 2005). Infestation and losses in stored cowpea by the *C. maculatus* is the most serious storage problem of cowpea grains (Turaki, 2012). In Nigeria, the dry weight loss due to cowpea infestation by *C. maculatus* exceeds 2900 tonnes each year (Keita *et al.*, 2000). In some cases, seed damage by *C. maculatus* can increase to 99% after 6 months of storage (Ngamo *et al.*, 2007). A 100% infestation of cowpea occurring within 3-5 months under traditional storage conditions is common (Parsaeyan *et al.*, 2012). According to Ntoukan *et al.* (2000), this insect pest can destroy a granary full of cowpea in two or three months.

Several measures of protecting cowpea in storage are in use such as application of synthetic insecticides and fumigants, naturally-obtained botanical insecticides, admixture with sand, clays and ash as well as storage in devices with hermetic properties and use of varietal resistance. These have

been investigated and many of these are already being adopted to varying degrees by farmers (Singh *et al.*, 2002; Ogunwolu and Odunlami, 1996). Use of resistant varieties is effective and ecologically safe method of protecting grains against insect pests since there is no special technology, which has to be adopted by the farmer (Helbig, 1997). The expenses to the farmer are limited only to obtaining the seed (Lale and Efevbokhan, 1991). The use of a resistant or partially resistant cowpea variety in an integrated bruchid control programme (IBCP) may improve the effectiveness of insecticides. It also makes it possible to omit or reduce treatments and thus; avoid undesirable residues or side-effects (Lale and Makoshi, 2000). However, the ability of *C. maculatus* to infest cowpea is unparalleled. For instance, Jackai and Singh (1988) found that out of 7,000 varieties of cowpea germ plasm screened for resistance, only one variety (TVu2027) was resistant to *C. maculatus*. Even then, the antibiosis resistance of TVu2027 was broken down after a relatively short time by certain biotypes of the bruchid (Lale and Makoshi, 2000). Likewise, some other researchers who evaluated the resistance of varieties of cowpea to this insect found that none was totally resistant to its attack (Olakojo *et al.*, 2007). This situation apparently show that varietal resistance alone could not provide the desired level of protection against bruchid attack and therefore necessitates the search for new approaches to complement varietal resistance, in order to prevent the losses caused by this insect pest.

According to Wakil *et al.* (2010), admixture of diatomaceous earth (DE) formulations with dry grain could be an excellent method of protecting stored products. Diatomaceous earth products are composed of microscopic fossils of diatoms. Insecticidal activity depends on the DE

capacity to damage insects' cuticle and cause water loss from their bodies, so that they die of desiccation (Athanassiou *et al.*, 2005). These products are attractive because they have very low mammalian toxicity. They are inert and leave no toxic residues on grains. They control the insecticide-resistant pests, longer-lasting and are applied using the same technology for conventional grain protectants (Vayias *et al.*, 2006; Athanassiou *et al.*, 2007). The insecticidal properties of DE have already been established for stored product insect by numerous authors (Ebeling, 1971; Quarles, 1992, Golob, 1997; Korunic, 1998; Subramanyam and Roesli, 2000).

In this study, the integrated approach to managing *C. maculatus* was explored. The objective was to evaluate the efficacy of combining varietal resistance in cowpea seeds with DE against *C. maculatus*.

MATERIALS AND METHODS

Test insects

The test insect, *C. maculatus* was obtained from field population, subsequently cultured and maintained on cowpea seeds in the laboratory. Cultures were reared on the cowpea seeds *var.* Borno Brown. For this purpose, 200 g of cowpea seeds were placed in 500 ml capacity bottles and 50 mixed-sex adult insects were introduced into each culture bottle. The insects were allowed seven days to mate and lay eggs, after which they were removed and discarded. The first filial generation (F₁) adults aged 1-24 h old were used for the experiments.

DE formulation

The DE formulation used in this study was *Protect-It*[®] (Hedley Technologies Inc., Canada); an enhanced DE that contains 83.7% SiO₂ with 10% silica aerogel. The particle size distribution is between 5 and 6 µm (Vayias *et al.* 2006). The DE formulation

was obtained from Diatom Research and Consulting Inc. Toronto, Canada.

Cowpea seeds

The seeds of the cowpea cultivar: Borno-Brown were obtained from Teaching and Research Farm, University of Maiduguri from the 2015 harvest. The seeds of the varieties: IT89KD-288, UAM09-1046-6 -1, UAM09-1051-1, UAM573-1-1, UAM573-2-1 and ITI79K-499-35 were obtained from IITA Kano Station and BOSADP Station at Biu, Borno State. The physical characteristics of the different cowpea seeds are presented in Table 1. The seeds were cleaned and disinfested by fumigating with phosphine for 120 h and thereafter ventilated for 10 d in a plastic basin covered with muslin cloth to allow entire volatilization of the phosphine gas from the seeds.

Screening Cowpea Varieties for resistance to *C. maculatus*

For each cowpea variety, 30 pairs of adult *C. maculatus* aged 1-24 h were introduced to 50 g seed samples placed in 150 ml capacity bottles capped with perforated lids. The insects were allowed to oviposit for five days after which they were carefully sieved out and discarded. The infested seeds were kept under ambient laboratory conditions stated above. Each treatment (cowpea variety) was replicated three times and were arranged on a laboratory shelf in a completely randomized design (CRD). Observation for emergence of progeny commenced after 20 days from the day of infestation. Emerging adults were counted and removed every day, until there was no emergence in all replicates for five consecutive counting days. The adult emergence data were used to calculate:

- (i) Mean number of adults emerged by physical counting number of adults that emerged per variety

- (ii) Median length of developmental period from oviposition until 50% of F_1 progeny have emerged.
- (iii) Susceptibility indices for all the varieties tested were calculated as described by Dobie (1974), thus:

$$SI = \log^e F_1 / D \times 100$$

where, F_1 – number of emerged progeny, D – median length of developmental period (days).

Bioassays with DE

The efficacy of DE was tested at different rates: 0 (untreated control), 250, 500, 750 and 1000 mg/kg of seed. Each of the DE treatment was applied to 60 g of cowpea seeds of each variety placed in 150 ml glass bottles and mixed manually tumbled for five minutes by turning the bottles to achieve uniform distribution of the dusts in the seeds. Each treatment was then sub-sampled to yield three replications of 20 g and placed in separate bottles. Into each replicate five pairs of *C. maculatus* adults aged 1-24 h old were placed and covered with perforated lids. Adults were removed after five days of oviposition, then the seeds were examined for number of eggs laid and returned to their respective jars under the same conditions. After additional 35 days, the jars were opened and the total number of F_1 adults were counted. Thereafter, 50 seeds were randomly taken from each jar and examined for exit holes. The number of seeds with exit holes (damaged seeds) and those without exit holes (undamaged seeds) were counted and weighed using an electronic balance (Mettler Toledo, USA).

The following parameters were determined from the data collected:

- (i) Percentage seed damage (SD) was determined according to Rahman and Talukder (2006):

$$SD = Nd/Nt \times 100 \%;$$

Where:

Nt-total number of seeds in sample;

Nd- number of damaged seeds in sample).

- (ii) Percentage seed weight loss (WL) was determined according to (Abebe *et al.*, 2009):

$$WL = [Und- DNu/ U (Nd +Nu)] \times 100, \%$$

Where:

U=Weight of undamaged grain;

D=Weight of damaged grain;

Nd=Number of damaged seeds; and,

Nu= Number of undamaged seeds.

Data Analysis

Data on number of eggs laid and emerged adults were square root $\sqrt{(x + 0.5)}$ transformed while those relating to seed damage and weight loss were arcsine-transformed. The transformed data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of Statistics 8.0 (Statistix Inc., 2005). Differences between treatment means were compared by Tukey-Kramer HSD test at $\alpha=0.05$.

RESULTS

Table 2 shows the mean number of *C. maculatus* adults, median length of developmental period, susceptibility indices and ranking of the cowpea varieties used in the study. Significant differences ($p<0.05$) were observed among the varieties for mean number of adults that developed as well as length of developmental period. The highest number of adults were produced on varieties UAM573-1-1 and UAM09-1051-1 and least on UAM09-1046-5-1 and IT86KD-288. The length of developmental period ranged from 22.7 to 35.3 days. Generally, the duration of

development was shorter in varieties where high number of adult emerged. The susceptibility index of the varieties ranged from 6 to 11; from moderately resistant to highly susceptible. The cowpea varieties were variously ranked: UAM573-2-1, IT89KD288 and UAM09-1046-6-1 (moderately resistant), Borno-Brown, IT97K499-35 and UAM09-1051-1 (susceptible) and UAM573-1-1 (highly susceptible).

The effect of cowpea variety and DE on reproduction of *C. maculatus* and the losses caused are presented in Table 3. The mean number of eggs laid differed significantly ($p<0.05$) among the cowpea varieties. The

highest number of eggs were laid on varieties Borno-Brown, and UAM-573-1-1 and least on UAM09-1046-1-1 and IT89KD-288. Similarly, the effect of DE varied significantly ($p<0.05$) among treatment dosages. The untreated control had the highest number of eggs laid, while cowpea treated with the lowest DE dose had about 70 eggs and the numbers progressively declined to about 8 eggs at the highest DE dose. The number of adults that emerged also significantly ($p<0.05$) differed among varieties and DE doses. So also were the percentage seed damage and weight loss.

Table 1: Physical characteristics of cowpea varieties tested

Variety	Weight of 100 seeds (g) ⁱ	Seed dimensions ⁱⁱ			Seed coat ⁱⁱⁱ		
		Length (mm)	Width (mm)	Thickness at centre (mm)	Thickness (mm)	Colour	Texture
Borno Brown	21.6 ^a	9.8 ^{ab}	6.9 ^a	5.2 ^{ab}	0.39 ^e	Brown	Rough
UAM573-1-1	19.5 ^b	10.4 ^a	7.0 ^a	5.5 ^a	0.49 ^a	cream	Wrinkled
UAM573-2-1	18.7 ^c	9.0 ^{bcd}	5.3 ^{ab}	5.3 ^{ab}	0.39 ^e	Light cream	Wrinkled
IT97K499-35	13.4 ^e	9.5 ^{abc}	4.8 ^{bc}	4.8 ^{bc}	0.43 ^c	Light cream	Wrinkled
IT89KD-288	17.9 ^d	8.1 ^d	4.8 ^{bc}	4.8 ^{bc}	0.45 ^b	Light cream	Wrinkled
UAM09-1051-1	17.3 ^d	8.6 ^{cd}	4.4 ^c	4.4 ^c	0.41 ^{cd}	Light brown	Smooth
UAM09-1046-6-1	22.0 ^a	10.2 ^a	5.0 ^{ab}	5.0 ^{ab}	0.40 ^d	Buff	Smooth

Means within a column followed by same superscript letters are not significantly different according to Tukey-Kramer HSD test ($p<0.05$).

ⁱ – means of 10 replicates; ⁱⁱ – means of 10 seeds; ⁱⁱⁱ – means of five replicates.

Table 2: Susceptibility of tested cowpea varieties to *C. maculatus* infestation

Variety	Mean number of adults emerged	Median length of developmental period (days)	Susceptibility index (SI) *	Rank
Borno Brown	214b	23.4cd	10	Susceptible
UAM573-1-1	264a	22.7d	11	Highly Susceptible
UAM573-2-1	123c	30.3abc	7	Moderately resistant
IT97K499-35	220ab	25.7bcd	10	Susceptible
IT89KD-288	144c	35.3a	6	Moderately resistant
UAM09-1051-1	263a	23.3d	10	Susceptible
UAM09-1046-6-1	114c	33.3a	6	Moderately resistant

Means within a column followed by same letters are not significantly different (HSD test, $P>0.05$).

*(0 to 11 scale for Susceptibility Index ranking (0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and 11 = highly susceptible (Abebe *et al.*, 2009)

Table 3: Effect of cowpea variety and DE dose on number of *C. maculatus* eggs laid, emerged adults, seed damage and weight loss

Treatment	Number of eggs laid	Number of emerged adults	% seed damage	% weight loss
Variety (A)				
Borno Brown	76.1a	52.8a	24.8a	11.6a
UAM573-1-1	80.1a	61.7a	27.8a	13.6a
UAM573-2-1	47.3b	29.5b	218.5b	6.9b
IT97K499-35	51.7b	25.2bc	14.7bcd	5.8bc
IT89KD-288	31.3c	11.7d	8.9d	4.5c
UAM09-1051-1	42.7b	27.2b	15.9bc	6.2b
UAM09-1046-6-1	27.7c	15.9cd	11.3cd	4.1c
SE	4.5	4.6	1.9	
DE dose (mg/kg) (B)				
0	125.2a	98.2a	57.9a	23.9a
250	70.9b	37.3b	19.1b	8.4b
500	32.1c	13.9c	6.7c	3.2c
750	18.4d	7.0d	2.7d	1.5d
1000	8.3e	3.2e	0.8e	0.6e
SE	3.8	3.9	1.6	0.8
Interaction (A x B)	*	*	*	*

Means within a column accompanied by same letters are not significantly different from one another according to Tukey Kramer HSD test ($p>0.05$).

* – Significant

Table 4: Interaction of cowpea variety and DE dose on number of eggs laid by *C. maculatus*

DE Dose (mg/kg)	Cowpea variety						
	Borno Brown	UAM573-1-1	UAM573-2-1	IT97K499-35	IT89KD-288	UAM09-1051-1	UAM09-1046-6-1
0	199.0a	1698a	124.3b	129.0b	70.0d-g	109.0bcd	74.7def
250	81.7cde	121.0bc	67.0e-h	73.0d-f	60.0e-h	57.3e-l	36.3f-k
500	50.0e-j	46.7e-k	31.0g-l	35.0f-l	15.3j-l	31.7g-l	15.3i-l
750	35.0f-l	33.0g-l	12.0j-l	17.7i-l	8.3k-l	12.3j-l	10.3jkl
1000	15.0h-l	30.0h-l	2.0l	4.0kl	2.0l	3.3l	2.0l
SE				9.7			

Means accompanied by same letters are not significantly different from one another according to Tukey-Kramer HSD test ($p>0.05$).

For all the parameters measured there were significant differences between all the DE doses including the untreated control.

Table 4 shows the interaction effect of cowpea variety and DE dose on number of eggs laid by *C. maculatus*. The highest numbers of eggs were laid in untreated Borno-Brown and UAM-573-1-1, these were followed by UAM573-2-1 and IT97K-499-35 while the least number of eggs were laid on variety UAM573-2-1 and UAM091046-6-1. The DE treatment significantly reduced the number of eggs laid by *C. maculatus*. In all the tested varieties, increase in DE dose significantly reduced number of eggs. The numbers of eggs laid in all the varieties treated at 1000 mg/kg were less than 5 except on Borno Brown and UAM 573-1-1. The interaction effect of cowpea variety and DE dose on adult emergence is presented in Table 5. Significant differences ($p < 0.05$) were observed among the treatment combinations. The number of emerged adults, though lower than the corresponding

number of eggs laid illustrated similar effect of variety and DE dose. The resistant varieties had the lowest number of adults. The numbers of emerged adults in all the varieties treated were less than 51 for the variety UAM573-1-1 treated at 250 mg/kg.

Tables 6 and 7 show the interaction of cowpea variety and DE doses on seed damage and weight loss, respectively. Seed damage were higher in the untreated control. Furthermore, the susceptible varieties (Borno Brown, UAM573-2-1 and IT97K-499-35) sustained significantly higher seed damage. Again, except on these two varieties, no seed damage was recorded when DE was applied at 1000 mg/kg. In all varieties except Borno Brown seed damage was $< 10\%$ when DE was applied at ≥ 250 mg/kg, and no damage recorded except on Borno Brown and UAM 573-2-1 (Table 5). Generally, the same trend was observed with regards to seed weight loss. In this case also with the exception of Borno Brown and UAM 573-2-1, weight loss was $< 9\%$ treated at the lowest (250 mg/kg) DE dose.

Table 5: Interaction of cowpea variety and DE on number of *C. maculatus* adult emergence

DE Dose (mg/kg)	Cowpea variety						
	Borno Brown	UAM573- 1-1	UAM573- 2-1	IT97K499- 35	IT89KD- 288	UAM09- 1051-1	UAM09- 1046-6-1
0	167.3a	155.6a	87.3bc	94.3bc	36.3efg	91.6bc	55.0cde
250	50.6def	100.3b	39.3efg	6.3g	15.7efg	21.7efg	14.5efg
500	26.3e-g	21.7efg	17.7efg	4.7g	4.6g	13.3fg	7.07
750	13.0fg	17.3efg	2.7g	4.5g	1.3g	7.0g	2.7g
1000	6.7g	13.7fg	0.3g	1.0g	0.3g	0.3g	0.3g
SE	10.2						

Means accompanied by same letters are not significantly different from one another according to Tukey-Kramer HSD test ($p > 0.05$). SE = Standard Error DE = Diatomatous Earth

Table 6: Interaction between cowpea variety and DE on percentage seed damage by *C. maculatus*

DE Dose (mg/kg)	Cowpea variety						
	Borno Brown	UAM573- 1-1	UAM573- 2-1	IT97K499- 35	IT89KD- 288	UAM09- 1051-1	UAM09- 1046-6-1
0	74.3ab	97.3a	59.3bc	63.6ab	30.3de	59.0bc	39.4cd
250	24.0def	42.6d-g	25.0h-k	5.7h-l	8.0g-k	13.3f-i	10.7g-j
500	16.3e-h	8.0h-k	6.7klm	2.3j-m	3.3i-m	4.6h-l	5.0h-l
750	4.2h-l	6.3klm	1.3j-m	1.3klm	0.3j-m	2.3j-m	1.3klm
1000	2.3j-m	3.0i-m	0.0m	0.0m	0.0m	0.0m	0.0m
SE	4.2						

Means followed by same letters are not significantly different from one another according to Tukey-Kramer HSD test ($p > 0.05$). Standard Error DE = Diatomatous Earth

Table 7: Interaction between cowpea variety and DE on percentage weight loss caused by *C. maculatus*

DE Dose (mg/kg)	Cowpea variety						
	Borno Brown	UAM573- 1-1	UAM573- 2-1	IT97K499- 35	IT89KD- 288 @	UAM09- 1051-1	UAM09- 1046-6-1
0	36.9a	34.5a	20.8bc	22.2b	11.4bcd	21.3bc	14.0cde
250	11.3def	21.9bc	8.7efg	4.3g-j	3.6g-k	5.1ghi	4.0g-j
500	5.5fgh	4.4g-j	4.2g-j	1.5i-m	1.1j-n	3.0h-l	1.6i-m
750	2.6h-l	4.0g-j	0.6lmn	0.9k-n	0.2mn	1.6i-m	0.9lmn
1000	1.7h-m	3.3h-l	0.0n	0.0n	0.0n	0.0n	0.0n
SE	1.9						

Means accompanied by same letters are not significantly different from one another according to Tukey-Kramer HSD test ($p > 0.05$). Standard Error DE = Diatomatous Earth

DISCUSSION

This study has revealed the effectiveness of varietal resistance and DE for the management of *C. maculatus* in stored cowpea. One of the methods being explored for controlling this insect pest is the introduction of cowpea varieties resistant to bruchid attack (Olakojo *et al.*, 2007). There are several varieties of cowpea and these differ in size, shape, length, seed coat colour, hardness, nutrient and allelochemical composition (Henshaw, 2008). They also differ in their susceptibility or resistance to *C. maculatus* (Jackai and Asante, 2003). In

agreement with these statements, the cowpea varieties tested in this study considerably varied in their susceptibility to *C. maculatus* infestation, falling into susceptible, moderately susceptible, and moderately resistant categories. The type and size of host on which *C. maculatus* develops is important, because it affects the oviposition behaviour, fecundity, developmental period, progeny survival and adult weight (Soares *et al.*, 2007). The grain properties may also affect the efficacy of a given control measure against insect pest attack (Kavallieratos *et al.*, 2010).

DE represents one of the most effective and safest non-chemical methods for controlling storage insects (Korunic, 2013). Several studies have documented the efficacy of various DE formulations against *C. maculatus* (Rohitha-Prasantha *et al.* 2003; Stathers *et al.*, 2004; Wakil *et al.*, 2010; Shams *et al.*, 2012, Kabir and Gaya, 2013; Kabir and Wulgo, 2014). In addition, very few studies concluded that varietal resistance could be combined with DE for the management of stored product insects (Throne *et al.*, 2000; Chanbang *et al.* 2008; Kavallieratos *et al.*, 2010; Kabir, 2013).

The results of this study have shown that DE could be combined with varietal resistance in order to manage *C. maculatus* populations in stored cowpea. In this study, oviposition and adult emergence were severely reduced in the moderately resistant varieties UAM573-2-1, IT89KD288 and UAM09-1046-6-1 compared to the susceptible and highly susceptible varieties, especially when DE was applied at the 750 - 1000 mg/kg. In addition, seed damage and weight losses were prevented. In agreement with the results of this study, Kabir (2013) found substantial variation in efficacy of *Protect-It^R* against *C. maculatus* among four cowpea cultivars. *Protect-It^R* was most effective on Borno Brown and Banjara, which had larger seeds than Bokoloji and Yari cultivars. In a similar study, Chanbang *et al.* (2008) showed that varietal resistance in rice grains was compatible with DE against *R. dominica*. They observed that, the highest label rate of 1000 mg/kg DE produced 46% to 100% *R. dominica* mortality, depending on the variety, with the greatest mortality in the resistant varieties.

The results of this study also indicated that *C. maculatus* was controlled with DE *Protect-It^R* at the rate of 750 mg/kg and 1000 mg/kg on the moderately susceptible and susceptible varieties, respectively. The

benefits of combining varietal resistance with DE accrues not only from controlling the pest but also reduces DE application rate. Furthermore, since DE is an inert material an extended residual protection is expected in a sufficiently dry stored cowpea seeds.

In conclusion, the results obtained from this study have shown that cowpea varieties differed in their susceptibility to infestation by *C. maculatus*. Moderately resistant varieties required lower dose of DE than the susceptible varieties. Varietal resistance in cowpea could be combined with DE to effectively manage *C. maculatus* populations in stored cowpea, hence reducing the huge losses caused by this serious pest. In order to benefit from DE-varietal resistance management strategy efforts should be focused on storing dry cowpea seeds treated with DE. Farmers' awareness, cultivation and storage of resistant and moderately resistant varieties would help reduce losses caused by *C. maculatus*.

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