Evaluation of susceptibility of some elite cowpea cultivars to attack by *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae)

S. K. ASANTE & G. W. K. MENSAH
(S. K. A.: CSIR-Savanna Agricultural Research Institute, P. O. Box 52, Tamale, Ghana; G. W. K. M.:University for Development Studies, P. O. Box 1350, Tamale, Ghana)

ABSTRACT

Fifteen elite cowpea cultivars were evaluated for their susceptibility to attack and damage by the most destructive storage pest, *Callosobruchus maculatus* (F.), based on the number of eggs laid, total developmental time, percentage adult emergence, seed weight loss, and growth index. Significantly, more eggs were laid on the seeds of Bengpla, California and Clemson genotypes than on those of the other cultivars. The mean developmental time (days) of *C. maculatus* ranged from 21.4 days on California 20 to 25.7 days on Sul 518-2 (Marfo tuya), and was significantly different between the cowpea cultivars. Adult emergence was considerably high on Bengpla, California and Clemson genotypes, but low on IT94K-445-2, Melack, and Sul 518-2. Weight loss ranged from 7 to 35.6 per cent and was significantly different between cultivars. The IT94K-445-2, IT98K-279-3 and Valenga cultivars had the least damage whilst California 11, IT87KD-1951 and Bengpla had the highest loss in seed weight. Overall, the susceptibility indices which ranged from 4.8 to 9.4 indicated that IT94K-445-2, Melack, Sul 518-2 and IT98K-279-3 were the least susceptible, whereas Bengpla, California and Clemson were the most susceptible cultivars. Therefore, it is recommended that IT94K-445-2, Sul 518-2, Melack, and IT98K-279-3 that have some degree of resistance to *C. maculatus* in this study should either be promoted or incorporated into breeding programmes because this will help to considerably reduce storage losses that farmers incur.

Original scientific paper. Received 16 Mar 05; revised 07 Mar 06.

RÉSUMÉ

ASANTE, S. K. & MENSAH, G. W. K.: *Évaluation de prédisposition de quelques variétés de dolique élite à l'attaque par* Callosobruchus maculatus (*F.*) (*Coleoptera: Bruchidae*). Quinze variétés de dolique élite étaient évaluées pour leurs prédispositions à l'attaque et au ravage par le ravageur de stockage le plus destructeur, *Callosobruchus maculatus* (F.) fondées sur les variables suivantes; la quantité d'œufs pondus, la totalité de temps de croissance, le pourcentage d'émergence en adultes, la perte de poids de graine et l'indice de croissance. Considérablement, plus des œufs étaient pondus sur les graines de génotypes de Bengpla, de Californie et de Clemson que sur les autres variétés. Le temps (jours) moyen de croissance de *C. maculatus* variait de 21.4 jours sur Californie 20 à 25.7 jours sur Sul 518-2 (Marfo tuya) et était considérablement différent entre les variétés de dolique. Emergence en adultes était considérablement élevée sur les génotypes de Bengpla, de Californie et de Clemson et faible sur 1T94K-445-2, Melack et Sul 518-2. La perte de poids variait entre 7% et 35.6% et était considérablement différente entre les variétés. 1T94K-445-2, IT98K-279-3 et Valenga ont subi le moindre ravage alors que Californie 11, IT87KD-1951 et Bengpla avaient les pertes de poids de graine les plus élevées. D'ensemble, les indices de prédisposition qui variaient de 4.8 à 9.4 indiquent que 1T94K-445-2, Melack, Sul 518, 1T98K-279-3 étaient les moindres prédisposées alors que Bengpla, Californie et Clemson étaient les variétés les plus prédisposées. Il est donc recommandé que 1T94K-445-2, Sul 518-2, Melack et 1T98K-279-3 qui avaient une certaine mesure de résistance à *C. maculatus* dans l'étude actuelle, devraient être soit encouragés soit incorporés dans les programmes de reproduction puisque cela va aider à réduire considérablement les pertes de stockage que les agriculteurs subissent.

Introduction

Cowpea, *Vigna unguiculata* (L.) Walpers, is a staple grain legume of worldwide importance (Singh & van Emden, 1979; Jackai & Daoust, 1986). Cowpea provides over half of the plant protein consumed by many poor people in the tropics and is a source of income (Labeyrie, 1981; Rachie, 1985). It also contributes to animal feed and soil nitrogen (Rachie, 1985). However, a wide spectrum of insect pests attack cowpea in the field and in storage, causing severe economic damage (Prevett, 1961; Booker, 1967; Caswell, 1981). These include the cowpea storage beetle, *Callosobruchus maculatus* (F.), a cosmopolitan and the most important pest of stored cowpeas (Southgate, 1979; Jackai & Daoust, 1986) that can render the unprotected grain unsuitable for food or seed in 4 to 6 months (Seck *et al.*, 1991; Wolfson *et al*., 1991). The control of this important seed pest is crucial to the sustainable production of cowpea worldwide.

Several commercial insecticides are available for controlling *C. maculatus*, but these are often too expensive for low-resource farmers and are unavailable in village markets (Wolfson *et al*., 1991), and can also contaminate food or pollute the environment (Egwuatu, 1987). To reduce overdependence on chemicals for control and seed loss due to bruchid attack, the search for host plant resistance in cowpea seeds has increasingly become the option of choice in recent years. The development and use of resistant cowpea cultivars offer a simple, cheap and attractive option for reducing bruchid damage because it requires little knowledge by farmers, it is free of extra cost to farmers, and also increases the effectiveness of other pest management tactics such as cultural and biological control. Hence, it is pertinent that bruchid responses to improved cowpea cultivars be studied periodically in different ecologies.

This study was designed to evaluate the susceptibility of some elite cowpea cultivars to infestation and damage by the cowpea bruchid, *C. maculatus*, aiming at selecting genotypes with inherent resistance, and to recommend them to breeders and farmers.

Materials and methods

Source of cowpea cultivars

Sixteen cowpea cultivars were used for the study in the Entomology Laboratory of the Savanna Agricultural Research Institute (SARI), Nyankpala, Tamale, in the Tolon-Kumbungu District of the Northern Region of Ghana, between September and November 2004. These included a local germplasm line and improved genotypes collected from the SARI breeding programme. The genotypes were a resistant Local Check, California 24 (941-11), California 19 (941-20), California 11 (95-SPC-506), California 20 (P-43), California 21 (Bombay 23), Clemson 21, IT98K-279-3, Valenga, Bengpla, IT94K-445-2, Melack, IT87KD-1951, IT×P148-2 (Apaagbala), Sul 518-2 (Marfo tuya), and Sul 87KD. Before the experiment, the seeds were stored in the SARI cold room maintained at 10 ºC to ensure that they were free from infestation by any post-harvest pest.

Source of experimental insects

The adults of *C. maculatus* used in the study were originally collected from infested samples of cowpea purchased from Aboabo Market, Tamale. The infested cowpea was kept in Kilner jars in the laboratory (24-32 ºC, mean 26.9 ± 0.1 ºC; 66-90% RH) for 7 days after which it was sieved to remove the emerged adult bruchids. They were then used to infest Ife Brown cowpea, known to be very susceptible to bruchids. Four 500-ml Kilner jars, each half-filled with cowpea, were used for rearing to make sure that the F1 adults used in the investigation had the same conditioning.

Experimental procedure

Fifty sound seeds from each cowpea cultivar were placed in a Petri dish (9 cm × 1.5 cm). Before use, the cowpea seeds were disinfested by leaving them in deep freeze overnight. They were then kept in an oven at 50 ºC for 6 h to kill all insects and mites which may be present. After removal, the seeds were left to equilibrate at room temperature for 24 h. Thereafter, the seeds (in each Petri dish) were weighed to determine the initial weight. Each sample (in a Petri dish) was infested with five pairs of newly emerged (0-12 h old) *C. maculatus*. Each treatment was replicated four times. The insects were allowed 24 h to mate and lay eggs and were then removed. The number of eggs on the seeds and Petri dishes were counted separately and recorded for each sample 7 days after infestation, by which time most had hatched and the larvae had bored into the seeds, leaving behind cream shells. The various treatments were left in the laboratory and examined daily for adult emergence. The emerged adults were removed from the Petri dish with an aspirator and counted daily under an illuminated magnifier. The observations ended 3 weeks from the date the first adult emerged, and the final weight of seeds in each Petri dish was determined.

Data collection and analyses

The variables that were determined from the data were number of eggs per seed, total developmental time (TDT), percentage adult emergence (i.e., proportion of adults that emerged from the number of eggs laid on seeds, including hatched + unhatched), percentage weight loss of seeds (Jackai & Asante, 2003), and the index of susceptibility (SI) given after Howe (1971) and Dobie (1974) as follows:

$$\text{Index of susceptibility} = \frac{\text{Log}_e \text{ F1}}{\text{D}} \times 100$$

where F1 is the total number of emerging adults and D is the developmental time (TDT). Low SI values indicate tolerance or resistance, whereas varieties with high values are susceptible.

Differences between cultivars were examined based on the parameters estimated above, using one-way analysis of variance (ANOVA). Numerical and percentage data were log and arcsin transformed, respectively, before analysis. Means were separated using Fisher's LSD when ANOVA indicated significant difference.

Results

Table 1 presents the number of eggs laid on seeds and Petri dish. The number of eggs laid on seeds was significantly different between cultivars ($F = 3.71$, df = 15, 48, $P < 0.001$). More eggs were laid on the seeds of California 11 and 21, Bengpla and Clemson 21; whereas IT98K-279-3, Melack, IT94K-445-3 and Valenga had the least eggs. Similarly, significant differences were observed between cultivars in the number of eggs laid on Petri dish ($F = 2.11$, df = 15, 48, $P < 0.05$). More eggs were laid on Petri dishes containing the Sul 87KD, IT94K-445-2, IT98K-279-3 and IT × P148-2 cultivars than in the other improved cultivars. Although the bruchid tended to lay several eggs on the Petri dishes, the difference between these and those laid on seeds was highly significant ($t_{21} = 6.7$, $P < 0.001$). Thus, more eggs were laid on the cowpea seeds than on the Petri dishes.

The mean developmental period (days) of *C. maculatus* ranged between 4 days on California 20 and 25.7 days on Sul 518-2 (Marfo tuya) (Table 2), and was significantly different between the cowpea cultivars ($F = 39.6$, df = 15, 3002, $P < 0.001$). The developmental time was found to be significantly longer on cultivars such as Melack, Valenga, Sul 87KD, IT87KD-1951 and Sul 518-2 than on the California and Clemson genotypes (*viz*. California 19, 20, 21 and Clemson 21). Although percentage adult emergence was not statistically different between cultivars ($F = 1.55$, df = 15, 58, $P = 0.13$), comparatively, more adults emerged from Bengpla, California and Clemson cultivars than from Melack, IT94K-445-2 and Sul 518-2 (Table 2).

Table 3 shows seed weight loss due to infestation. Twelve cultivars recorded over 10 per cent weight loss which was found to be significantly different between cultivars ($F = 8.89$, df = 15, 48, $P < 0.001$). Only three cultivars (*viz.* IT94K-445-2, IT98K-279-3 and Valenga) recorded lower weight loss than the Local Check. Among

TABLE 1

Mean Number of Eggs Laid by Adult Females of C. maculatus *F. on Seeds of Different Cowpea Cultivars at Nyankpala, Northern Ghana in 2004*

Cowpea cultivar	*Number of eggs on seeds (n = 50)*	*Number of eggs on Petri dish*	*Total number of eggs laid*
Valenga	56.75	10.00	66.8
IT98K-279-3	35.75	34.25	70.0
Melack	66.00	13.50	79.5
California 19	75.50	8.75	84.3
IT94K-445-2	48.25	41.30	89.3
Sul 518-2	75.25	18.40	93.5
IT×P148-2	64.25	33.25	97.5
Local Check	44.75	61.75	106.5
California 20	87.75	21.75	109.5
California 24	87.00	31.25	118.3
IT87KD-1951	97.50	30.50	128.0
Sul 87KD	94.50	43.25	137.8
California 11	108.75	30.25	139.0
Bengpla	129.00	16.25	145.3
California 21	125.50	21.25	146.8
Clemson 21	139.00	7.75	146.8
LSD (5%)	46.04	28.83	NS
CV (%)	11.40	19.65	9.54

TABLE 2

Developmental Period (days) and Adult Emergence of C. maculatus *F. on Different Cowpea Varieties at Nyankpala, Northern Ghana in 2004*

Cowpea cultivar	*Mean developmental period (days)*	*% adult emergence*
California 20	21.40	68.4
California 21	21.61	62.5
Clemson 21	21.66	63.2
California 19	21.74	69.9
IT×P148-2	22.09	63.3
IT98K-279-3	22.10	63.4
California 11	22.11	51.7
Bengpla	22.27	72.5
IT94K-445-2	22.42	39.3
Local Check	22.43	65.7
California 24	22.43	62.0
Melack	23.46	39.4
Valenga	23.51	67.0
Sul 87KD	23.73	49.1
IT87KD-1951	23.81	51.5
Sul-518-2	25.72	40.3
LSD (5%)	3.13	NS
CV (%)	23.40	26.03

the four cultivars released by CSIR-SARI, Valenga was superior with 8.4 per cent weight loss, followed by IT × P148-2 (13.7%), Sul 518-2 (15.1%), and Bengpla (35.6%). Also, weight loss was generally higher in the California and Clemson genotypes (13-23%) than in the other cultivars.

Table 4 presents the susceptibility indices (SI) of cowpea cultivars to *C. maculatus*. The SI of the cultivars ranged from 4.8 on IT94K-445-2 to 9.4 on California 21, and was found to be significantly different between cultivars ($F = 8.4$, $df = 15, 48$, $P < 0.001$). The IT94K-445-2, Melack, Sul 518-2 (Marfo tuya) and IT98K-279-3 cultivars were the least preferred (i.e., tolerant or resistant cultivars) with lower SI, whereas Bengpla, Clemson 21 and California 21 with higher SI were the most susceptible. The Valenga, Sul 87KD, IT ×P148-2 and IT87KD-1951 cultivars were found to be moderately resistant. All the California and Clemson genotypes were very susceptible to attack and damage by the bruchid, whereas Valenga, Sul 87KD and IT×P148-2 were moderately susceptible (Table 4).

TABLE 3

Weight Losses of Cowpea Cultivars Due to Infestation by C. maculatus *F. at Nyankpala, Northern Ghana in 2004*

Cowpea cultivar	*Weight loss (g)*	*% weight loss*
IT94K-445-2	0.53	7.1
IT98K-279-3	0.60	7.3
Valenga	0.72	8.4
Local Check	0.44	9.8
Melack	0.70	12.4
California 19	1.18	13.3
IT×P148-2	0.77	13.7
Sul 87KD	1.38	14.0
California 20	1.30	14.1
Sul 518-2	1.18	15.1
California 21	1.90	18.0
California 24	1.12	19.7
Clemson 21	1.54	21.8
California 11	1.51	23.0
IT87KD-1951	1.07	28.8
Bengpla	2.56	35.6
LSD (5%)	0.58	7.51
CV (%)	24.63	24.3

Discussion

Host plant resistance is considered to be an important part of a sustainable pest management strategy (Thomas & Waage, 1995). It has been particularly effective in reducing post-harvest cowpea losses by *C. maculatus* (Dobie, 1974). Similarly, this study has shown that cowpea cultivars such as IT94K-445-2, Melack, Sul 518-2, and IT98K-279-3 have genes that confer some degree of resistance to *C. maculatus*. The susceptibility of the cultivars to *C. maculatus* attack was based on the number of eggs laid, TDT, percentage adult emergence, and seed weight loss. Although this study indicated that significantly more eggs were laid on seeds of most susceptible cultivars such as Bengpla, California 21 and Clemson 21, the total number of eggs laid (on seeds + Petri dish) was not significantly different between the cultivars.

In general, egg counts have not been shown to be predictive enough in resistance studies as other variables such as percent adult emergence, TDT, growth (susceptibility) index, and percent loss in weight (Redden & McGuire, 1983; Jackai & Asante, 2003). The suitability of type of cowpea seed for *C. maculatus* oviposition is known to be influenced by surface area and curvature of the seeds (Avidov, Berlinger & Applebaum, 1965; Nwanze & Horber, 1976; Wasserman, 1981; Fitzner *et al.*, 1985). Mbata (1992) reported that the surface area of cowpea seeds varies among varieties, and the number of eggs laid per seed is positively correlated with the surface area. Also, Nwanze, Herber & Pitts (1975) reported that *C.*

TABLE 4

Susceptibility Indices (SI) of Cowpea Cultivars to Infestation by C. maculatus *F. at Nyankpala, Northern Ghana in 2004*

Cowpea cultivar	*Index of susceptibilities*[1] *(mean)*
IT94K-445-2	4.8
Melack	5.3
Sul 518-2 (Marfo tuya)*	5.4
IT98K-279-3	5.7
Local Check	6.1
Valenga*	6.4
Sul 87KD	6.6
IT×P148-2*	7.4
IT87KD-1951	7.5
California 24	7.7
California 19	7.8
California 11	8.2
California 20	8.5
Bengpla*	9.0
Clemson 21	9.1
California 21	9.4
LSD (5%)	1.43
CV (%)	37.3

*Cowpea varieties released in Ghana by CSIR-SARI
[1]Cultivars with low SI values are tolerant or resistant whereas those with high values are susceptible

maculatus prefers smooth-coated and well-filled seeds to rough and wrinkled varieties for oviposition. Although the surface area and smoothness of seed coat were not determined in this study, these factors may explain why eggs were not equally distributed among seeds of the different cowpea cultivars used in the study.

Adult emergence, growth or susceptibility index, and seed weight loss were significantly higher on California 11, 21 and 24, IT87KD-1951, Clemson 21 and Bengpla than on Sul 518-2, Melack, Valenga and IT94K-445-2 (Tables 2, 3 and 4). Mbata (1992) reported that weight loss is generally correlated with susceptibility (growth) index. Singh, Singh & Adjadi (1985) also found that the number of emerging adults determines the extent of damage. Consequently, seeds permitting more rapid and higher levels of adult emergence will be more extremely damaged. These observations agree with this study in which cultivars from California, Clemson and Bengpla, which had high percent adult emergence, recorded the greatest damage and weight loss.

Ndlovu & Giga (1988) reported that the emergence pattern and percent adult emergence in resistant cowpea lines are characterized by delayed, staggered and slow adult emergence while in susceptible lines, the adult emergence is relatively early and extremely rapid. Through systematic screening of over 10,000 cowpea germplasm lines, Singh (1977) and Singh *et al.* (1985) identified Tvu 2027, Tvu 11952 and Tvu 11953, local lines from Nigeria, as moderately resistant to bruchids. The resistance in these lines was later found to hold against several geographical strains of *C. maculatus* (Dick & Credland, 1986). Also, Ndlovu & Giga (1988) found Tvu 2027-derived lines such as IT81D-1032 and IT81D-1064 to be moderately resistant to *C. rhodesianus* (PIC).

Many studies have indicated a chemical factor to be responsible for bruchid resistance. Adjadi, Singh & Singh (1985) studied the genetics of bruchid resistance in detail in cowpea and observed that two recessive genes (rcm1 rcm1, rcm 2 rcm 2) are required in the homozygous condition to confer resistance to bruchid. Gatehouse *et al.* (1979) found a higher level of trypsin inhibitor (about 2-fold increases) in Tvu 2027 compared to the susceptible varieties, and attributed the bruchid resistance in cowpea to this factor. They also showed that trypsin inhibitor isolated from cowpea and mixed in ground cotyledons of a susceptible cowpea variety Tvu 57 reduced the survival of bruchid eggs.

Baker *et al.* (1989) analysed trypsin inhibitor activity in 10 Tvu 2027-derived bruchid-resistant breeding lines, including Tvu 2027 and five susceptible lines, and concluded that the trypsin inhibitor activity in resistant breeding lines was higher than in susceptible lines. However, other studies have shown that trypsin inhibitor alone may not account for bruchid resistance in cowpea. For instance, Osborn *et al*. (1988) identified arcelin, a major seed protein in wild *Phaseolus vulgaris* L., as the factor responsible for resistance to bean bruchid, *Zabrotes subfasciatus* (Boheman).

Similarly, para-aminophenylalanine in several wild *Vigna* species was shown to be toxic to *Z. subfasciatus* and *C. maculatus* (Birch *et al*., 1986). Also, Ishimoto & Kitamura (1988) showed that a water-soluble substance present in kidney beans strongly inhibits the larval growth of *C. chinensis*. Therefore, further work is needed to explain the factor(s) responsible for the differences in the susceptibility of these 15 cowpea cultivars to *C. maculatus* attack.

Acknowledgement

The authors are thankful to Mr Sayibu Alhassan and Miss Alice Wasaal of the Savanna Agricultural Research Institute for helping in data collection.

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