INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
1560–8530/2004/06–3–440–446
http://www.ijab.org

Integrated Management of *Callosobruchus maculatus* (F.) Infesting Cowpea Seeds in Storage Using Varietal Resistance, Application of Neem (*Azadirachta indica* A. Juss) Seed Oil and Solar Heat

Y.T. MAINA AND N.E.S. LALE†
Department of Crop Protection, Faculty of Agriculture, University of Maiduguri, P.M.B. 1069, Maiduguri, Nigeria
†Department of Animal and Environmental Biology, Faculty of Science, University of Port Harcourt, P.M.B. 5323, Port Harcourt, Nigeria

ABSTRACT

The integrated management of *Callosobruchus maculatus* (F.) infesting cowpea seeds in storage using varietal resistance, application of neem (*Azadirachta indica*) seed oil (NSO) and solar heat was investigated in three separate experiments. In the first experiment, the potency of three doses of neem seed oil application in controlling *C. maculatus* infesting cowpeas was assessed on four cowpea cultivars (Borno brown, Kanannado, Peugeot and TVx 3236). There were no significant differences in the mean number of eggs laid by *C. maculatus* on the four-cowpea cultivars. Fewer eggs were laid on seeds treated with NSO at the rate of 0.16 mL/20 g seed than on those treated with 0.08 mL or 0.04 mL/20g seed or on those that were not treated. Adult emergence of *C. maculatus* also followed similar trends. Susceptibility indices (SI) values for cowpeas that were treated with NSO at the rate of 0.08 mL/20g seed were 0.00, 0.71, 0.34 and 5.43 for Borno brown, Kanannado, Peugeot and TVx 3236, respectively. In the second experiment, the effects of solar heat and duration of exposure to sun were evaluated against three different doses of NSO using cowpea seeds (cv. TVx 3236). Adult emergence was significantly reduced as time of exposure and doses of NSO increased. Adult emergence was significantly lower in seeds that were exposed to sun for 1 h than in those that were not exposed to sun. Similar trends were observed for percentage and severity of seeds damaged by *C. maculatus*. The effects of solar heat and duration of exposure to sun were evaluated against four cowpea cultivars in the third experiment. Difference in the response of various cowpea cultivars to the effects of solar heat was significant.

Key Words: Cowpea; Solar heat; *Azadirachta indica*; Integrated pest management; *Callosobruchus maculatus*

INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walpers, is a very important grain legume in West Africa (Stanton, 1966). It is widely cultivated and consumed in Nigeria (Ohiagu, 1986); the most important producing areas in Nigeria are located in the savanna (Agboola, 1979). According to Blade *et al*. (1997), Nigeria accounts for 70% of the world's production. Cowpea is an extremely valuable crop both as a source of revenue and an important source of cheap dietary protein for the third world where meat is expensive (Stanton, 1966; Algali, 1991; Lale, 1991). High protein and lysine contents of cowpea make it a natural supplement to staple diets of cereals, roots, tuber and fruits (Bressani, 1985). As common to many leguminous crops, insects attack stored cowpea seed. All major pests belong to the family Bruchidae (Centre Overseas Pest Res., 1981). The cowpea bruchid, *Callosobruchus maculatus* (F.) (Coleoptera, Bruchidae) is a cosmopolitan field-to-store pest ranked as the principal post harvest pest. It causes substantial quantitative and qualitative losses manifested by seed perforation, reduction in weight, market value and germinability of seeds (Anonymous, 1989). About 4% of the total annual production or about 30,000 tonnes values at over 30 million US dollars is lost annually in Nigeria alone to cowpea bruchid (Caswell, 1980; Singh *et al*., 1983). Under traditional storage conditions, 100% infestation of cowpea occurring within 3 to 5 months of storage is common (Booker, 1967; Caswell & Akibu, 1980).

Over the years, different methods of controlling this bruchid have been employed, which range from treating grains with synthetic insecticides (Bato & Sanchez, 1972; Caswell & Akibu, 1980) and the use of plant oils to protect cowpeas from damage in storage (Singh *et al*., 1978; Pereira, 1983). Traditionally, other products such as ashes, sand and leaves of some plants are also used (Singh & Van Emden, 1979). Oil and powder obtainable from neem (*Azadirachta indica* A. Juss) seed have been reported to provide sustained protection of stored grains (Jotwani & Scircar, 1965; Ivbijaro, 1983a, 1983b; Makanjuola, 1989; Ogunwolu & Idowu, 1994; Lale & Ajayi, 1996; Ogunwolu & Odunlami, 1996). The oil obtainable from neem seeds has been shown to be more effective than the powder formulation in reducing egg-laying and adult emergence of the bruchid (Lale & Abdulrahman, 1999). The exploitation of solar heat for bruchid control is based on the fact that insects die when exposed to high temperatures because of their limited physiological capacity to thermoregulate (Murdock *et al*., 1997). Bruchid eggs, larvae and pupae do not thermoregulate and, being immobile, are unable to escape from the hot environment. Furthermore, eggs deposited on the surface of the seeds exposed to high temperature and low humidity conditions will dry out. Therefore, bruchids living within grain are excellent targets for management using elevated temperatures (Murdock *et al*., 1997). Farmers in many parts of the tropics are already using solar heat as a means of driving out insects from infested grains and, perhaps, in an attempt to kill any larvae which may be inside the grains (McFarlane, 1989). The effectiveness of the technique, however, depends upon spreading the grains in thin layer and exposing them to the sun for a long period.

MATERIALS AND METHODS

Insect rearing and oil extraction. Adult bruchids used to established the culture were obtained from an infested batch of cowpeas purchased from a local market in Maiduguri (Northeastern Nigeria) and these were subsequently maintained on a local cultivars of cowpea (cv. Borno brown) in 500 mL kilner jars under prevailing conditions (30-35^{o}C and 60-65% R.H.). Mature, fallen neem seeds were picked from a floor of a neem plantation. These were washed, sun-dried, decorticated and pulverized using an electric kitchen mill. An 800 g of the pulverized material were weighed into 5-litre plastic bowl. Per-boiled water was added gradually from a kettle and mixed into the neem seed powder. This procedure was repeated until a dough-like material was formed. The oil was pressed out manually. This procedure yielded about 300 mL of the oil, which was collected into a 250 mL volumetric flask and stored at room temperature.

Effect of neem seed oil on *C. maculatus* development in four cowpea cultivars. Four cultivars (Borno brown, Kanannado, peugeot and TVx 3236) of cowpea obtained from local market in Maiduguri (Northeastern Nigeria), were used for the study. Three doses (0.04, 0.08 and 0.16 mL) of neem seed oil (NSO) were applied separately in 0.2 mL of analytical grade of acetone to 20 g each of the four cowpea cultivars in100 mL glass jars. Treated seeds were stirred with a glass rod until seeds were uniformly coated and until the acetone was completely evaporated. Control seeds were treated with 0.2 mL of pure acetone and stirred as described previously. The experiment was set up as Randomized Complete Block Design with three replications.

Three pairs of 2-day old *C. maculatus* were then introduced into each glass jar with the aid of a pooter and the female bruchids were allowed to lay eggs for 5 days. On day 5, all insects were removed and the eggs laid on seeds in each glass jar were counted. Adult progenies that developed were counted and the number of damaged seeds (seeds bearing adult emergence holes) was expressed as percentage of the total number of seeds in each replicate. Severity of seed damage (number of adult emergence holes per seed) was obtained by dividing the number of emergence holes by the number of damaged seeds. Susceptibility index (SI) was obtained for each cultivar according to the method of Dobie (1974) and is given as:

$$SI = \frac{log_e F_1 \; x \; 100}{D}$$

Where F_1 is the total number of emerging adults and D is the median developmental period (estimated as the time from middle of oviposition to the emergence of 50% of the F_1 generation).

Effect of solar heat on *C. maculatus* development in cowpea seeds treated with NSO. Cowpea seeds (cv. TVx 3236) were used for this study because it was more susceptible to *C. maculatus* infestation than the other cultivars. A 20 g of cowpea seeds (cv. TVx 3236) was weighed into 100 mL glass jars. Three doses (0.04, 0.08 and 0.16 mL) of neem seed oil (NSO) were applied separately in 0.2 mL of analytical grade of acetone to 20 g of the seeds. Treated seeds were stirred with a glass rod until seeds were uniformly coated and acetone was completely evaporated. Control seeds were treated with 0.2 mL of pure acetone and stirred as described previously. Five pairs of 2-day old *C. maculatus* were then introduced into each jar with the aid of a pooter and female bruchids were allowed to lay eggs for 3 days. On day 3, all insects were removed and eggs laid on seeds, in each jar were counted.

The effect of solar heat and duration of exposure to sun (0, 1, 2 and 4 h) were evaluated against doses of NSO in a Randomized Complete Block Design replicated three times. This experiment was conducted during the hot season in April, 2003 with maximum duration of 4 hours. Outside temperature and humidity were recorded in the morning (10:00 GMT), afternoon (13:00 GMT) and evening (14:00 GMT). At the indicated time, glass jars were exposed to sun. Exposure for 1h was done between 12:00 to 1:00 pm; that of 2 h was done between 12:00 to 2:00pm, while that of 4 h was done between 11:00 to 3:00 pm, when the sun was at its peak. Outdoor ranges of temperature and humidity during the period were (40-52^{o}C and 22-32% R.H.). At the end of each exposure period, the glass jars were taken back to the laboratory. Controls were also set up for each of the durations of the exposure and kept in the laboratory where the insects were reared throughout the durations of the experiment. Adult progenies that developed and damaged seeds in each jar were counted. The number of damaged seeds (seeds bearing adult emergence holes) was expressed as a percentage of the total number of seeds in each replicate. Severity of damage (number of adult emergence holes per seed) was obtained by dividing the number of emergence holes by the number of damaged seeds.

Effect of solar heat on *C. maculatus* development in four cowpea cultivars Four cowpea cultivars (Borno brown, Kanannado, peugeot and TVx 3236) and four durations of exposure (0, 1, 2, and 4h) were used for this aspect of the study. A 20 g seeds of each cowpea cultivar were weighed into 100 mL glass jars. Five pairs of 2-days old *C. maculatus* adults were introduced on seeds in each glass jars. Female bruchids were allowed to lay eggs for three days after which all insects were removed and laid eggs were counted. The effects of solar heat and duration of exposure to sun (0, 1, 2 and 4 h) were then evaluated against cowpea cultivars in a randomized complete block design replicated three times. This experiment was conducted during the hot season in April, 2003 with maximum duration of 4 h. Outside temperatures and humidity were recorded in the morning (10:00 GMT), afternoon (13:00 GMT) and evening (14:00 GMT). At the indicated time, glass jars were exposed to sun. Exposure for 1 h was done between 12:00 to 1:00 pm; that of 2 h was done between 12:00 to 2:00 pm, while that of 4 h was done between 11:00 to 3:00 pm, when the sun was at its peak. Outdoor ranges of temperatures and humidity during the period were (40-51^{o}C and 24-34% R.H.). At the end of each exposure period, glass jars were returned to the laboratory. Control containers were kept in the laboratory where the insects were reared throughout the duration of the experiment. *C. maculatus* adult progenies that developed in jar were counted. Damaged seeds in each jar were counted and expressed as a percentage of the total number of seeds in each jar

Statistical analysis. Data obtained were subjected to two-way analysis of variance and means were compared using the Least Significant Difference statistic at the 5% level of probability.

RESULTS

Effect of neem seeds oil on *C. maculatus* development in four cowpea cultivars. There were no significant differences in the mean numbers of eggs laid by *C. maculatus* on four cowpea cultivars treated with NSO. However, significantly fewer eggs were laid on seeds treated with NSO at rate of 0.16 mL/20 g seed than on those treated with 0.08 ml or 0.04 mL/20 g seed or those that were not treated (Table I). There were no significant differences in the numbers of *C. maculatus* adult progeny that developed in cowpea cultivars. Significantly higher numbers of adult progeny developed in untreated seeds than those treated with 0.08 ml or 0.04 mL/20 g seed. No adult progeny developed in cowpea seeds that were treated with 0.16 mL of NSO (Table II).

At the application rate of 0.04 mL/20 g seed, TVx 3236 was damaged to a significantly greater extent than Borno brown, Kanannado or peugeot. Treatment of seeds with NSO at the rate of 0.08 mL/20 g seed reduced damage from 52.19, 46.84, 40.11 and 50.04% in untreated Borno brown, Kanannado, Peugeot and TVx 3236 to 0.71, 0.61, 0.41 and 5.18%, respectively (Table III). In untreated seeds TVx 3236 was the most severely damaged of all the cultivars infested with *C. maculatus* (Table IV). Application of NSO at the various doses obliterated observable differences in susceptibility of the cultivars. Susceptibility indices (SI) values for unprotected cowpeas were 15.98, 15.41, 16.07 and 16.66 for Borno brown, Kanannado, peugeot and TVx 3236, respectively; comparable SI values

Table I. Mean number of eggs laid by C. maculatus on seeds of four cowpea cultivars treated with NSO

Cultivar	Dosage of neem seed oil (mL/20g seed)				Mean
	0	0.04	0.08	0.16	
Borno brown	76.00	54.67	51.67	31.33	53.42
Kanannado	93.00	37.67	20.67	4.67	39.00
Peugeot	95.33	36.00	23.67	21.00	44.00
TVx 3236	98.00	63.00	34.00	22.00	54.25
Mean	90.58	47.83	32.50	19.75	

SED = 8.98; LSD (0.05) = 18.34 (Cultivar)
SED = 8.98; LSD (0.05) = 18.34 (Dosage of NSO)
SED = 17.96; LSD (0.05) = 36.68 (Interaction)

Table II. Mean number of C. maculatus adult progenies that developed in seeds of four cowpea cultivars treated with NSO

Cultivar	Dosage of neem seed oil (mL/20g seed)				Mean
	0	0.04	0.08	0.16	
Borno brown	75.00	16.67	0.67	0.00	23.08
Kanannado	81.33	7.33	0.67	0.00	22.33
Peugeot	92.67	23.67	0.67	0.00	29.25
TVx 3236	96.67	54.67	7.67	0.00	39.75
Mean	86.42	25.58	2.42	0.00	

SED = 8.99; LSD (0.05) = 18.36 (Cultivar)
SED = 8.99; LSD (0.05) = 18.36 (Dosage of NSO)
SED = 17.98; LSD (0.05) = 36.72 (Interaction)

Table III. Mean percentage of seeds of four cowpea cultivars treated with NSO that were damaged by *C. maculates*

Cultivar	Dosage of neem seed oil (mL/20g seed)				Mean
	0	0.04	0.08	0.16	
Borno brown	52.19	14.18	0.71	0.00	16.77
Kanannado	46.84	6.67	0.61	0.00	13.53
Peugeot	40.11	11.82	0.41	0.00	13.09
TVx 3236	50.04	25.02	5.18	0.00	33.15
Mean	47.29	14.42	1.73	0.00	

SED = 3.66; LSD (0.05) = 7.47 (Cultivar)
SED = 3.66; LSD (0.05) = 7.47 (Dosage of NSO)
SED = 7.32; LSD (0.05) = 14.95 (Interaction)

Table IV. Mean severity of damage (number of adult emergence holes per seed) caused by *C. maculatus* to seeds of four cowpea cultivars treated with NSO

Cultivar	Dosage of neem seed oil (mL/20g seed)				Mean
	0	0.04	0.08	0.16	
Borno brown	1.57	1.29	0.67	0.00	0.88
Kanannado	1.59	1.00	0.33	0.00	0.73
Peugeot	1.37	1.13	0.33	0.00	0.71
TVx 3236	1.73	1.64	1.14	0.00	1.13
Mean	1.56	1.27	0.62	0.00	

SED = 0.118; LSD (0.05) = 0.240 (Cultivar)
SED = 0.118; LSD (0.05) = 0.240 (Dosage of NSO)
SED = 0.237; LSD (0.05) = 0.484 (Interaction)

Table V. Mean susceptibility indices of four cowpea cultivars treated with neem seed oil and infested with *C. maculates*

Cultivar	Dosage of neem seed oil (mL/20g seed)				Mean
	0	0.04	0.08	0.16	
Borno brown	15.98	9.93	0.00	0.00	6.48
Kanannado	15.41	6.24	0.71	0.00	5.59
Peugeot	16.07	9.44	0.34	0.00	6.46
TVx 3236	16.66	13.49	5.43	0.00	8.89
Mean	16.03	9.77	6.48	0.00	

SED = 0.86; LSD (0.05) = 1.76 (Cultivar)
SED = 0.86; LSD (0.05) = 1.76 (Dosage of NSO)
SED = 1.73; LSD (0.05) = 3.53 (Interaction)

Table VI. Mean number of eggs laid by *C. maculatus* on cowpea seeds that were treated with NSO for exposure to different durations of solar heat

Duration of exposure (h)	Dosage of neem seed oil (mL/20g seed)				Mean
	0	0.04	0.08	0.16	
0	85.00	59.00	56.00	30.33	57.58
1	73.00	66.00	57.00	37.33	58.33
2	80.00	61.67	42.33	35.33	54.83
4	90.33	64.33	52.00	39.67	61.58
6	86.00	72.67	49.33	29.00	59.25
Mean	82.87	64.73	51.33	34.33	

SED = 7.09; LSD (0.05) = 14.33 (Cultivar)
SED = 6.34; LSD (0.05) = 12.82 (Dosage of NSO)
SED = 14.18; LSD (0.05) = 28.66 (Interaction)

for cowpeas that were treated with NSO at the rate of 0.08 mL/20 g seed were 0, 0.71, 0.34 and 5.43 for Borno brown, Kanannado, peugeot and TVx 3236, respectively (Table V).

Effect of solar heat on *C. maculatus* development in cowpea seeds treated with neem seed oil. There were no significant differences in the mean number of eggs laid on cowpea seeds exposed for different durations to solar heat. Significantly fewer eggs were laid on seeds treated with NSO at rate of 0.16 mL/20 g seed than on those treated with 0.08 ml or 0.04 mL/20 g seed or on those that were not treated (Table VI). Significantly fewer adult progeny of *C. maculatus* developed in seeds exposed for 1h to sun than in those that were not exposed to sun. No adult progeny developed in seeds exposed for 4 h. Significantly fewer adult progeny developed on seed treated with NSO at the rate of 0.08 mL/20 g seed than in those treated with 0.04 mL/20 g seed or in those that were not treated (Table VII). The mean percentage damage and the mean severity of damage also followed similar trends (Table VIII & IX).

Effect of solar heat on *C. maculatus* development in four cowpea cultivars. The differences in the response of various cowpea cultivars to the effect of solar heat were significant. Considerably fewer eggs were laid on Kanannado than those laid on Borno brown or TVx 3236. There were no significant differences in the mean number of eggs laid on cowpea seeds exposed for different durations to solar heat (Table X), however, significantly higher number of adult progeny developed in cowpea seeds that were not exposed to solar heat than in those exposed to solar heat for 1 or 2 h. No adult progeny developed in seeds exposed for 4 h. A significantly higher number of adult progeny developed in TVx 3236 than in Borno brown (Table XI). At the exposure time of 2h, TVx 3236 was damaged to a significantly greater extent than Borno brown, Kanannado or Peugeot (Table XII). TVx 3236 was the most severely

Table VII. Mean number of *C. maculatus* adult progenies that were developed in cowpea seeds treated with NSO and exposed for different durations to solar heat

Duration of exposure (h)	Dosage of neem seed oil (mL/20g seed)			Mean
	0	0.04	0.08	
0	81.67	46.67	6.00	42.78
1	10.67	0.00	0.00	3.56
2	5.00	0.00	0.00	1.67
4	0.00	0.00	0.00	0.00
Mean	24.33	10.17	1.5	

SED = 2.04; LSD (0.05) = 4.23 (Duration of exposure)
SED = 1.77; LSD (0.05) = 3.67 (Dosage of NSO)
SED = 3.53; LSD (0.05) = 7.32 (Interaction)

Table VIII. Mean percentage damaged of cowpea seeds that were treated with neem seed oil and exposed for different durations to solar heat

Duration of exposure (h)	Dosage of neem seed oil (mL/20g seed)			Mean
	0	0.04	0.08	
0	52.69	30.96	5.68	29.78
1	9.67	0.00	0.00	3.22
2	4.69	0.00	0.00	1.56
4	0.00	0.00	0.00	0.00
Mean	16.76	7.74	1.42	

SED = 1.116; LSD (0.05) = 2.315 (Duration of exposure)
SED = 0.967; LSD (0.05) = 2.006 (Dosage of NSO)
SED = 1.932; LSD (0.05) = 4.007 (Interaction)

Table IX. Means severity of damage (number of adult emergence holes per seed) caused by *C. maculatus* to seeds of cowpea treated with NSO and exposed for different durations to solar heat

Duration of exposure (h)	Dosage of neem seed oil (mL/20g seed)			Mean
	0	0.04	0.08	
0	1.56	1.31	1.08	1.32
1	1.10	0.00	0.00	0.38
2	1.05	0.00	0.00	0.35
4	0.00	0.00	0.00	0.00
Mean	0.93	0.33	0.27	

SED = 0.025; LSD (0.05) = 0.059 (Duration of exposure)
SED = 0.025; LSD (0.05) = 0.051 (Dosage of NSO)
SED = 0.049; LSD (0.05) = 0.101 (Interaction)

Table X. Mean number of eggs laid on seeds of four cowpea cultivars for exposure to different durations of solar heat

Cultivar	Duration of exposure (h)					Mean
	0	1	2	4	6	
Borno brown	89.00	113.00	130.00	105.00	95.00	106.40
Kanannado	92.33	67.00	71.00	64.67	71.33	73.27
Peugeot	113.67	99.00	90.33	93.33	101.33	99.53
TVx 3236	122.67	117.67	103.00	113.33	105.00	112.33
Mean	104.42	99.17	98.58	94.08	93.17	

SED = 13.12; LSD (0.05) = 26.52 (Duration of exposure)
SED = 14.66; LSD (0.05) = 29.63 (Dosage of NSO)
SED = 28.33; LSD (0.05) = 59.28 (Interaction)

damaged of all the cultivars infested with *C. maculatus* (Table XIII).

Table XI. Mean number of *C. maculatus* adults progenies that developed in different cultivars of cowpea seeds that were exposed for different durations to solar heat

Cultivar	Duration of exposure (h)				Mean
	0	1	2	4	
Borno brown	73.00	5.33	0.00	0.00	19.58
Kanannado	86.67	5.67	0.33	0.00	23.67
Peugeot	112.67	3.00	0.00	0.00	28.92
TVx 3236	121.00	7.67	4.33	0.00	33.25
Mean	98.83	5.42	1.67	0.00	

SED = 6.22; LSD (0.05) = 12.70 (Duration of exposure)
SED = 6.22; LSD (0.05) = 12.70 (Dosage of NSO)
SED = 12.42; LSD (0.05) = 25.36 (Interaction)

Table XII. Mean percentage of damaged seeds of four cowpea cultivars that were exposed for different durations to solar heat

Cultivar	Duration of exposure (h)				Mean
	0	1	2	4	
Borno brown	51.81	4.95	0.00	0.00	14.19
Kanannado	56.04	5.25	0.31	0.00	15.41
Peugeot	49.06	1.87	0.00	0.00	12.73
TVx 3236	67.23	7.28	4.11	0.00	19.66
Mean	56.04	4.84	1.11	0.00	

SED = 2.67; LSD (0.05) = 5.46 (Duration of exposure)
SED = 2.67; LSD (0.05) = 5.46 (Dosage of NSO)
SED = 5.35; LSD (0.05) = 10.91 (Interaction)

Table XIII. Mean severity of damaged (number of adults emergence holes per seed) caused by *C. maculatus* to seeds of four cowpea cultivars exposed for different durations to solar heat

Cultivar	Duration of exposure (h)				Mean
	0	1	2	4	
Borno brown	1.54	0.75	0.00	0.00	0.57
Kanannado	1.44	1.05	0.33	0.00	0.71
Peugeot	1.36	0.67	0.00	0.00	0.51
TVx 3236	1.36	1.09	1.06	0.00	0.98
Mean	1.53	0.89	0.35	0.00	

SED = 0.116; LSD (0.05) = 0.237 (Duration of exposure)
SED = 0.116; LSD (0.05) = 0.237 (Dosage of NSO)
SED = 0.232; LSD (0.05) = 0.473 (Interaction)

DISCUSSION

The study has shown that none of the four cowpea cultivars was immune to infestation by *C. maculatus, but* had different susceptibilities to *C. maculatus* infestation. The application of NSO especially at the rates of 0.08ml and 0.16 mL/20 g seed, reduced egg-laying considerably or significantly; no adult progeny developed in seeds treated with 0.16 mL of NSO. Dick and Credland (1984, 1986) reported that the number of adults of *C. maculatus* that can emerge from infested cowpea seeds depended amongst other factors on the number of eggs initially present. Successful infestation is, however, determined by the number of eggs that hatch as well as the number of first instars larvae that are able to penetrate the cotyledons. Interfering with any of these processes leads to a reduction in the population of the bruchid and the degree of seed damage (Lale & Mustapha, 2000). It is now well-established that reduction of infestation and seed damage in pulse seeds treated with NSO is achieved mainly through reduced egg-hatch and increased mortality (Lale & Abdulrahman, 1999; Lale & Mustapha, 2000). The combination of varietal resistance with application of NSO has been shown in this study to be a possible integrated pest management strategy that could be used to protect cowpeas against *C. maculatus* infestation in storage. Lale & Mustapha (2000) showed that treating seeds of different cowpea cultivars with NSO at the rate of 50 mg/5 g and 75 or 100 mg/5 g reduced seed damage from over 25% in controls to less than 5%, respectively, in all cultivars.

The study has also shown that integrating solarization for 1 or 2 h with 0.04 or 0.08 mL of NSO reduced the population of adult progeny that developed considerably in cowpea seeds. No adult progeny developed in seeds exposed to solar heat for 4 h. Lale and Maina (2002) reported that no adult progeny of *Caryedon serratus* developed in groundnut seeds infested with different larval instars exposed to solar heat for 6 h. More recently, Lale and Vidal (2003) reported that no adults of *C. maculatus* and *C. subinnotatus* developed after exposure to 50^{o} C of seeds harbouring first instar larvae exposed for 2, 4 or 6 h. The results of the present study confirm observations of the previous studies which found solarization to be cheap, safe and effective method of managing bruchid and weevil populations in stored grains and cereals in parts of tropical Africa and Asia (Begum *et al*., 1991; Kitch *et al*., 1992; Chinwada & Giga, 1996; More *et al*., 1996; Murdock *et al*., 1997; Ntoukanm *et al.*, 1997; Lale, 1998, Ghaffar & Chauhan, 1999; Lale & Vidal, 2000; Lale & Ajayi, 2001). The fact that solarization causes reduced oviposition and adult emergence as well as mortality of adult bruchids (Lale 1998), egg and larval mortality as demonstrated in this study suggests that the method has a broad base of biological activity.

Reports of integration of crop cultivars and solarization for the management of stored product coleoptera are not common in literature. However, in the present study, integrating cowpea cultivars with solarization provided adequate protection of cowpea seeds against infestation by *C. maculatus*. Exposing seeds to solar heat for 1 h reduced damage from 51.81, 56.04, 49.06 and 67.23% in unexposed Borno brown, Kanannado, Peugeot and TVx 3236 to 4.95, 5.28, 1.87 and 7.28%, respectively. The exposure times found to be effective in this study are considerably much lower than those that were reported in previous studies (Lale, 1998; Lale & Ajayi, 2001; Lale & Maina, 2002). This observation is attributable to two main reasons. First, exposure was done during the peak of the heat; secondly, the glass jar used is an extremely good conductor of heat hence it enhanced heat absorption during the solarization.

In previous studies, it was reported that the germinability of cowpea seeds exposed to a temperature of 57.3°C (Murdock & Shade, 1991) or sorghum seeds exposed to much higher temperature of 67°C for 2.5 h (More *et al.*, 1996) was not adversely affected. Recently, Lale and Ajayi (2001) reported that the germinability of bambara groundnut seeds exposed for 7 h to solar heat of up to 57°C was also not adversely affected. In this study, cowpea seeds were exposed for a maximum duration of 4 h, and this should not affect their germinability adversely. Already a solar heater has been used successfully for bruchid control (Kitch *et al*., 1992) and it is evident from the present work that solarization offers a great prospect for successful protection of grain legumes against attack by bruchids and does not require any extra financial investment in equipment or technical know-how on the part of farmers; equally neem seed oil has a good prospect of being adopted especially by subsistence farmers in the tropics for storage of cowpeas against bruchid infestation.

REFERENCES

Anonymous, 1989. Intern Institute of Tropical Agriculture. *Research Brief*, vol. 9. Ibadan, Nigeria

Agboola, S.A., 1979. *An Agricultural Atlas of Nigeria.* p: 239 Oxford University Press. London

Alghali, A.M., 1991. Studies on cowpea farming practices in Nigeria, with emphasis on insect pest control. *Trop. Pest Manag*., 37: 71–4

Bato, S.M. and F.F. Sanchez, 1972. The biology and chemical control of *Callososbruchus chinensis* (Linn.) (Coleoptera: Bruchidae). *Philipp. Entomol*., 2: 167–82

Begum, S., A. Mannan, and A. Begun, 1991. Effect of sunning on different pulse seeds infested by the pulse beetle *Callosobruchus chinensis* (L.). *Bangladesh J. Zool*., 19: 262–5

Blade, S.F., S.V.R. Shetty, T. Terao and B.B. Singh, 1997. Recent developments in cowpea cropping systems research. In: *Advances in Cowpea Research*, pp: 114–28. B.B. Singh, D.R. Mohan Raj, K.E Dashiel, and L.E.N. Jackai (eds), Intern. Instt. Trop. Agric. and Japan Intern. Res. Cent. Agric. Res. Ibadan, Nigeria

Booker, R.H., 1967. Observation on three bruchids associated with cowpea in Northern Nigeria. *J. Stored Prod. Res*., 3: 1–15

Bressani, R., 1985. Nutritive value of cowpea. In: *Cowpea Research, Production and Utilization*, pp: 353–9. S.R. Singh, and K.O. Rachie, (eds), John Wiley and Sons Chichester, New York

Caswell, G.H., 1980. A review of the work done in the entomology section. Instt. Agric. Res. Pests Stored grain. *Samaru Miscellan*. 99: 12

Caswell, G.H. and S. Akibu, 1980. The use of Primiphos–Methyl to control bruchids attacking selected varieties of stored cowpea. *Trop. Grain Legume Bull*., 17/18: 9–11

Centre Overseas Pest Res., 1981. Pest Control. *In:* Tropical Grain legumes. pp:1–17. Centre Overseas Pest Research, London

Chinwada, P. and D.P. Giga, 1996. Sunning as a technique for disinfesting stored beans. *Post harvest Biol. Technol*., 9: 335–42

Dick, K.M. and P.F. Credland, 1984. Egg Production and development of three strains of *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae). *J. Stored Prod. Res*., 20: 221–7

Dick, K.M. and P.F. Credland, 1986. Changes in the response of *Callosobruchus maculatus* (Coleoptera: Bruchidae) to a resistant variety of cowpea. *J. Stored Prod. Res*., 22: 227–33

Dobie, P., 1974. The Laboratory assessment of the inherent susceptibility of maize varieties to Post–harvest infestation by *Sitophilus zeamais* mot. (Coleoptera: Curculionidae). *J. Stored Prod. Res*., 10: 183–7

Ghaffar, M.A. and Y.S. Chauhan, 1999. Solarization to protect pigeon pea seeds from bruchid damage during storage. *Int. Chickpea Pigeonpea Newsletter*, 6: 50–2

Ivbijaro, M.F., 1983a. Preservation of Cowpea, *Vigna unguiculata* (L.) Walp. with the neem seed *Azadirachta indica* A Juss. *Protect. Ecol*., 5: 177–82

Ivbijaro, M.F., 1983b. Toxicity of neem seed, *Azadirachta indica* A Juss, to *Sitophilus oryzae* (L.) in stored maize. *Protect. Ecol*., 5: 353–7

Jotwani, M.G. and P. Scircar, 1965. Neem seed as a protectant against stored grain pests infesting wheat seed. *Indian J. Entomol*., 27: 160–4

Kitch, L.W., G., Ntoukam, R.E., Shade, J.L Wolfson and L.L. Murdock, 1992. A Solar heater for disinfesting stored cowpeas on subsistence Farm. *J. Stored Prod. Res*., 28: 261–7

Lale, N.E.S., 1991. The biological effects of three essential oils on *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *J. African Zool*., 105: 357–62

Lale, N.E.S., 1998. Preliminary studies on the effect of solar heat on oviposition, development and adult mortality of the cowpea bruchid *Callosobruchus maculatus* (F.) in the Nigeria Savanna. *J. Arid Environ*., 40: 157–62.

Lale, N.E.S. and F.A. Ajayi, 1996. Comparative effects of extraction solvents on the persistence and acute toxicity of seed extracts against the cowpea bruchid, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *Samaru J. Agric. Res*., 13: 49–57

Lale, N.E.S. and H.T Abdulrahman, 1999. Evaluation of neem (*Azadirachta indica* A. Juss) seed oil obtained by different methods and neem powder for the management of C*allosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in stored cowpea. *J. Stored Prod. Res*., 35: 135–43

Lale, N.E.S. and M. Mustapha, 2000. Potential of combining neem (*Azadirachta indica* A. Juss) seed oil with varietal resistance for the management of cowpea bruchid, *Callosobruchus maculatus* (F.). *J. Stored Prod. Res*., 36: 215–22

Lale, N.E.S. and S. Vidal, 2000. Mortality or different developmental stages of *Callosobruchus maculatus* (F.) and *Callosobruchus subinnotatus* (Pic.) (Coleoptera: Bruchidae) in bambara groundnut *Vigna subterranea* (L.) Verdc. seeds exposed to simulated solar heat. *J. Pl. Diseases Protect*., 107: 553–9

Lale, N.E.S. and F.A. Ajayi, 2001. Suppression of development of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in bambara groundnut seeds exposed to solar heat in the Nigerian savanna. *J. Pest Sci*., 74: 133–7

Lale, N.E.S. and Y.T. Maina, 2002. Evaluation of host resistance, solar heat and insecticidal essential oils for the Management of *Caryedon serratus* (Olivier) (Coleoptera: Bruchadae) infesting groundnut seeds and tamariad pods in storage. *J. Pl. Diseases Protect*., 109: 410–20

Lale, N.E.S. and S. Vidal, 2003. Simulation studies on the effects of solar heat on egg–laying, development and survival of *Callosobruchus maculatus* (F.) and *Callosobruchus subinnotatus* (Pic.) in stored bambara groundnut *Vigna subterranea* (L.) Verdcourt. *J. Stored Prod. Res*., 39: 447–58

Makanjuola, W.A., 1989. Evaluation of extracts of neem (*Azadirachta indica* A. Juss) for the control of some stored product pests. *J. Stored Prod. Res*., 25: 231–7

McFarlane, J.A., 1989. Guidelines for pest management research to reduce stored food losses caused by insects and mites. Bulletin No. 22. *Overseas Development Natural Resources Institute*, Chatham, Kent, U.K.

More, H.G.; P.A. Unde and S.R. Pabalka, 1996. Effects of solar disinfestations on quality of sorghum and storage insect mortality. *J. Maharashtra Agric. Univ*., 21: 215–8

Murdock, L.L. and R.E. Shade, 1991. Eradication of cowpea weevil (Coleoptera: Bruchidae) in cowpeas by solar heating. *American Entomol*., 37: 228–31

Murdock, L.L., R.E. Shade, L.W. Kitch, W. Noar, O.L. Chambliss, C. Endodno and J.L. Wolfson, 1997. Post harvest stored of cowpea in sub–saharan Africa. In: Singh, B.B., D.R., Moham Raj, K.E., Dashiell, L.E.N. Jackai, (eds), *Advances in Cowpea Research*, pp:

302–12. International Institute of Tropical Agriculture and Japan International Research Centre of Agriculture Research.

Ntoukam, G., L.W. Kitch, R.E. Shade, and L.L Murdock, 1997. A novel method for conserving cowpea germ plasm and breeding stocks using solar disinfestations. *J. Stored Prod. Res*., 33: 175–9

Ogunwolu, O. and O. Idowu, 1994. Potential of powdered *Zanthoxylum zunthoxyloides* (Rutaceae) root bark and *Azadirachta indica* (Maliaceae) seed for control of cowpea seed bruchid *Callosobruchus maculatus* (Bruchidae) in Nigeria. *J. African Zool*., 108: 521–8

Ogunwolu, O. and A.T. Odunlami, 1996. Suppression of seed bruchid (*Callosobruchus maculatus*) development and damage on cowpea *Vigna unquiculata* with *Zanthoxylum zanthoxyloides* (Lam.) Weterm. (Rutaceae) root bark powder. *Crop Protect*., 15: 603–7

Ohiagu, C.E., 1986. Grain legumes, production and storage methods in Nigeria. 13th November, Symp. Devel. Storage Methods in Nigeria, *Department Agriculture Science*, Ramat Polytechnic Maiduguri Nigeria

Pereira, J., 1983. The effectiveness of six vegetable oils as protectants of cowpeas and bambara groundnuts against infestation by *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). *J. Stored Prod. Res*., 19: 57–62

Stanton, W.R., 1966. *Grain legume in Africa*. p: 183 FAO. Rome

Singh, S.R., R.A. Luse, K. Leuschner, and D. Nangju, 1978: Groundnut oil treatment for the control of C*allosobruchus maculatus* (F.) during cowpea storage. *J. Stored Prod. Res*., 14: 77–80

Singh, S.R., B.B SinghL E.N. Jackai, and B.R. Ntare, 1983. Cowpea research, p: 20. Information Serial 14. International Institute of Tropical Agriculture, Ibadan, Nigeria

Singh, S.R. and H.F. Van Emden, 1979. Insect Pests of grain Legumes. *Ann. Rev. Entomol*., 24: 255–78

(Received 08 January 2004; Accepted 26 March 2004)