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Assessment of the Curative Potency of Some Plant Materials on Cowpea seeds with Established Infestation of *Callosobruchus maculatus* (Fabricus)(Coleoptera: Chrysomelidae: Bruchinae)

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Abstract
An investigation into the possibility of plant materials affording quick and practicable control where pest populations are approaching economic threshold was carried out in the laboratory. The leaves, barks or seed powders of ten locally available plants, which have been reported to have insecticidal activity on storage pests, were screened to evaluate their curative efficacy relative to a conventional storage chemical, Actellic 2 % dust (Pirimiphos – methyl), as protectants of stored cowpea with established infestation. The cowpea was infested with bruchids 5 weeks before the administration of the test materials and after the emergence of the first filial generation. Each plant material was tested at three rates (2.5, 5.0 and 10.0 g/100.0 g seed). Actellic was applied at the rate of 1.0, 2.0 and 3.0 g/100.0 g seed. The treatments were replicated thrice. Seeds not treated with the test materials served as the control. Data were collected weekly over a 10 – week period on adult emergence, percentage adult mortality and seed damage. The seed damage data were used to estimate the weevil perforation index (WPI). The most effective materials and Actellic 2 % dust only gave marginal protection. At week 10 of the experiment, *Moringa oleifera*, *Piper guineense* and *Ocimum gratissimum* had WPI of 46.7 %, 46.7 % and 50.0 %, respectively at their highest rates of application. Though Actellic dust effected higher mortality of the insects, it could hardly protect seeds that were already heavily infested with only 50% WPI at the highest rate (3.0 g/100 g seed).
Key Words: *Callosobruchus maculatus,* Curative, Plant Materials, Progeny, Weevil Perforation Index (WPI).

1. Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is a major staple food crop and essential source of protein in sub-Saharan Africa, especially in the dry savanna regions of West Africa where animal protein is rarely available. The seeds are a major source of plant proteins and vitamins for man, feed for animals, and also a source of cash income. The young leaves and immature pods are eaten as vegetables (Dugje *et al.*, 2009). They are attacked by a complex of insect pests, particularly towards the end of the planting season. In storage, the bruchid, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae: Bruchinae), causes the major losses. They are field – to - store agricultural insect pests of Africa and Asia that presently range throughout the tropical and subtropical world (Beck and Blumer, 2011).

More than 5.4 million tons of dried cowpeas are produced worldwide, with Africa producing nearly 5.2 million. Nigeria, the largest producer and consumer, accounts for 61% of production in Africa and 58% worldwide (IITA, 2013). Losses due to infestation of between 87 to 100% within 3-5 months of storage have been reported (Singh, 2011). Damage is done to the seeds by the exit holes created during the emergence of adult bruchid and includes reduction in kernel weight, caused by the burrowing larvae as they feed, and diminished market value due to the presence of insects inside the kernels. Bruchid infestation also decreases the germination potential of the kernel (Munthali and Sondashi, 2004; Maina *et al.*, 2006).

In Nigeria, fumigants like aluminum phosphide, dusts like 0.5% Gamma BHC available as Gammalin “A” dust, Lindane dust and Pirimiphos-methy1 (Actellic) has been extensively used to control these bruchids (Caswell and Akibu, 1981).

However, one of the explosive and argumentative issues affecting agricultural production today is the perception that pesticide residues in food supplies constitute serious health risk (FAO, 2005). This concern for pesticides have found expression, in most countries, irrespective of location and developmental ranking: In Nigeria (Ogah *et al*, 2002, Gwary *et al*, 2012); India (Savvy, 2011); Brazil (Lorini and Galley, 2001); Australia (Collins *et al.,* 1993); Britain (Renwick, 2002); Cambodia, China, India, Indonesia, Malaysia, Philippines, Sri Lanka and Vietnam (Whittle, 2010); Japan (Kao and Tzeng, 1992) and USA (Spann *et al.,* 2000) to mention but a few countries. Given this widespread occurrence of persistent organic pollutants in food supply and the serious health risks associated with even extremely small levels of exposure, prevention of further food contamination must be

a national policy of every country (Schafer and Kegley, 2002).
Biopesticides are, unarguably, better and safer than chemical pesticides and can be produced locally with cheap materials and simple equipment (Tamo, 2012). In the last three decades, considerable efforts have been directed at screening plants in order to develop new botanical insecticides as alternatives to the existing synthetics which are associated with problems such as phytotoxicity, pest resurgence and resistance, widespread environmental and health hazards, high costs and counterfeiting (Lale, 2001; Bloch, 2012; Grzywacz and Leavett, 2012). These plants are rich sources of mostly untapped biotic organic chemicals, very many of which may have evolved to protect the plant from herbivores. Some 2000 plant species are reported to possess pest control properties (Ahmed *et al.,* 1984).
Although very promising results have been achieved in laboratory tests with plant materials, their effectiveness under practical storage condition is limited (Gwinner *et al*, 1990). It has also been stated that one of the disadvantages of other techniques of pest control (as against the use of synthetic chemicals) is that other methods (like the use of plant products) cannot be used in emergency situations (Stiling, 1985).
Various workers (Oparaeke *et al,* 2002; Abdullahi and Mohammed, 2004) have screened some plant materials as protectants of stored produce, especially cowpea, against storage insect pests. In most of these works, however, seeds or grains to be tested by researchers were initially disinfested before the application of the test materials. Under such experimental condition, the bio-pesticides mostly come out highly effective.
However, *C. maculatus* are field-to-store pests and so; some damaged seeds (with the insects in various developmental stages) must necessarily be carried into the store. From our observations, most grain dealers in Nigerian local markets, mix heavily infested seeds with fresh ones to maximize profit. Could these plant products also be useful in such situations when partly or wholly infested seeds are treated? This investigation, therefore, is aimed at finding out whether these plant materials, all of which have been adjudged 'effective', could afford practicable and quick control methods where pest populations are approaching economic threshold.

2. Materials and Methods

2.1. Insect Culture

The laboratory culture of *C. maculatus* was reared under ambient temperature of 28±3 ^{0}C and relative humidity of 75±5 % with adult insects collected from infested cowpea seeds at a local market in Ilorin, Kwara State, Nigeria. The insects were introduced into two breeding containers containing susceptible cowpea seeds Cv. Tvu 3629 (collected from the International Institute for Tropical Agriculture, Ibadan, Nigeria). Cowpea for the experiment was sealed in cellophane bags and disinfested by deep-freezing for 2 weeks. The seeds were air-dried in the laboratory for 24 hours prior to use.

2.2. Preparation of Test Plant Powders

Fresh leaves of siam weed, *Chromolaena odorata* (L.) King and Robinson (Compositae); lemon grass, *Cymbopogon citratus* (DC.) Staph (Graminae); pitanga cherry, *Eugenia uniflora* L. (Myrtaceae); mango, *Mangifera indica* L. (Anacardiaceae); bitter gourd, *Mormodica charantia* L. (Cucurbitaceae) and basil, *Ocimum gratissimum* L. (Labiatae); the seeds of horse radish, *Moringa oleifera* Lam (Moringaceae) and brown pepper, *Piper guineense* Schum and Thonn (Piperaceae) and the barks of the cashew tree, *Anacardium occidentale* L. (Anacardiaceae) and mahogany, *Khaya senegalensis (*Desr.) A. Juss (Meliaceae) were obtained from different locations in Ilorin, Kwara State, Nigeria.
The collected plant materials were dried under shade and processing done within one week of collection to prevent rotting or other problems that may lead to loss of active principles (Sharma, 1982). The plant materials were pulverized into fine powder using a Philips electric blender (Cucina HR 1731/37, 2L/400w.220v-50/60Hz.), passed through 10- micron sieve and sealed in cellophane bags until needed for use.

2.3. Bioactivity Tests

Hundred grams (100 g) of well preserved and air-dried cowpea seeds were placed in a total of 132 (250 mls) plastic tubes. 120 of these tubes were for the four rates of each of the 10 plant products (including the control) replicated thrice (that is 10 plant products x 4 rates x 3 replications). The remaining 12 tubes were for the 4 Actellic treatment rates (0.0, 1.0, 2.0 and 3.0 g/100.0 g seed) replicated thrice.
Five pairs of adult *C. maculatus* aged between 24 - 48 hours were introduced into each of the 132 plastic tubes. The tubes were firmly covered with baft cloth to allow for respiration of the insects and preclude entry or exit of insects.
The experiment was left for 5 weeks after the introduction of the insects and the emergence of the F_1 generation. All the insects (dead and living) were removed from each of the plastic tubes. Another 100 g of clean cowpea seeds from the same source as before were added into each of the 132 tubes. The addition of the clean seeds was to ensure continued supply of food for immature derived from emerged weevils during the experiment and to mimic the common market scenario where local traders mix infested seeds with fresh ones to maximize profit. The clean cowpea seeds were introduced only once during the experimentation.

The plant products from the 10 different plants being screened were measured out in 2.5 g, 5.0 g, 10.0 g and the control, respectively. Each of the rates were replicated thrice (making a total of 12 replicates per plant product and 120 replicates for the 10 plant products) and put into 120 of the 132 tubes. Actellic dust at 0.00 g, 1.0 g, 2.0 g and 3.0 g (and also replicated thrice) were put into the remaining 12 tubes. The 132 plastic tubes now with 100 g infested and 100 g fresh cowpea seeds were thoroughly mixed with the test materials, randomized and laid out in the laboratory. The control (0.00 g) had neither plant product nor Actellic dust added. The following parameters were measured.

i. Effect of the plant materials and Actellic dust on adult emergence and mortality: The numbers of dead and living insects were recorded weekly from one to ten weeks after the introduction of the treatment materials. Both the living and dead insects were discarded after each week's recordings.

ii.Damage assessment was done through the counting of the total number and distribution of holes per seed of cowpea. The number of holes per sub-sample of ten randomly selected seeds and the number of these seeds with holes were recorded. This assessment was done twice – at the sixth and tenth week respectively.

The Weevil Perforation Index (WPI) (Fatope *et al.,* 1995) was then calculated thus:

$$WPI = \frac{\%\ \text{Treated cowpea grains perforated}}{\%\ \text{Control cowpea grains perforated}} \times \frac{100}{1}$$

Weevil Perforation Index value exceeding 50 % is regarded as enhancement of infestation by the weevil or negative ability of the plant material or insecticides tested.

3. Results and Discussion

All the ten tested plant materials had been reported to have one form of protective ability or the other on storage pests. The experiment was, therefore, aimed at testing the curative efficacy of these otherwise proven insecticidal plant products for the control of an established infestation by monitoring progeny emergence and damage assessment through weevil protection indices.

In the experiment, a trend towards large numbers of emerged adults was evident for the first, second, fourth and fifth weeks after the application of the treatments (Table 1). Actellic dust treated seeds recorded the least number of emerged insects which were statistically and consistently comparable to the effects of *O. gratissimum, P. guineense and M. oleifera.* Where the emergence was very low (Weeks 3 and 6), the effects of all the materials were distorted and so were almost statistically the same.

Between weeks 6 and 10, the total number of insects that emerged was very low (notice the difference between the cumulative total number of emerged adults between weeks 6 and 10) (Table 2). Actellic dust treated seeds had the lowest average cumulative mean number of emerged insects in weeks 6 and 10 (33.6 and 35.8 insects, respectively) which were significantly different from all other treatments. Tagging behind were seeds treated with *O. gratissimum* (112.0 and 131.9 insects, respectively) and *P. guineense* (124.4 and 129.1 insects, respectively). The control had 378.3 and 379.3 emerged insects, respectively.

At week 10, which is the terminal week of the experiment (after the 2nd filial generation), Actellic treated seeds had the least number of holes per seed and the number of these seeds with holes. This effect was dose related as the highest rate (3.0 g/100 g seed) gave the least number of seeds with holes (Table 3). These were, however, not statistically different from seeds treated with higher rates of *O. gratissimum, P. guineense and M. oleifera.*

At week 6 of the experiment, Actellic dust treated seeds had the highest cumulative mortality rates (70.9 – 89.4 insects) which were statistically more significant than the other treatments. Following were seeds treated with *O. gratissimum* (59.4 – 71.8 insects) and *M. oleifera* (42.7 – 63.5 insects). Seeds treated with *Chromolaena odorata* (45.1 – 55.2 insects) and *Eugenia uniflora* (34.1 – 49.2 insects) were slightly more toxic than the other treatments. The control had an average of just 35.8 dead insects. In most cases, the efficacy of the treatment material type tended to be dose related with the highest rates giving better results (Figure 1).

With regards to the weevil perforation index (WPI) which measures the protection ability of the treatment materials, *M. oleifera* and *P. guineense* (46.7 %, respectively) gave the best WPI at the highest rates of application (Table 3). Actellic dust at the highest rate (3.0 g/100 g seed) recorded a 50.0 % WPI which tallied with the WPI of *O. gratissimum* at the highest rate. *Chromolaena odorata* performed relatively better than the remaining plant materials though its WPI exceeded the 50 % benchmark.

Other plant products; *Anacardium occidentale*, *Cymbopogon citratus, Eugenia uniflora*, *Khaya senegalensis, Mormodica charantia* and *Mangifera indica* basically had WPI which far exceeded the 50.0 % bench mark, suggesting that they had no protection ability on seeds with established infestation. .

The highest rates of *Moringa oleifera* treated seeds were found to have the best protection on already infested seeds. The ground seed of *M. oleifera* is oily and quickly spreads to cover the seeds in storage. Anhwange *et al.* (2004) had isolated hydrogen cyanide (Mg/100 g 0.58), Tannins (2.13 %) and Saponins (2.25 %) from the seeds of *M. oleifera* while Olayemi and Alabi (1994) had earlier found that the seeds contained a steroidal glycoside – trophantidin which they reported as the bioactive agent in the seed. Strophanditin, a cardenolide is a C_{23} steroidal glycone with α, β unsaturated five-member lactone ring and a C_{14} hydroxyl group (Vessal *et al.*, 2006). Wissenberg *et al.* (1998) had reported that steroidal glycosides and glycoalkaloids inhibited the growth of the red flour beetle, *Tribolium castaneum* and the tobacco horn worm, *Manduca sexta*. *M. oleifera* seed powder has also been shown to completely inhibit the mycelial growth of *Aspergillus flavus* isolated from stored maize grains (Balogun *et al.* 2004). Ojiako and Adesiyun (2008) later reported that *M. oleifera* seed powder compared most favourably with Actellic dust (2 %) in the control of *Callosobruchus maculatus* on stored cowpea and had no adverse effect on viability, physical, nutritional and organoleptic characteristics of the stored seeds.

Piper guineense seed powder at the highest rate was the next in potency to *M. oleifera*. Ivbijaro (1990) had reported that 1.00g ground *P. guineense* seed powder per 20g of cowpea seeds protected the seeds from damage by *C. maculatus.* Lale (1992) later found oil extract of *P. guineense* 'extremely toxic' to adult *S. zeamais* when compared to oils of *Denettia tripetala* and *Aframomum melegueta*. Later work of Okonkwo and Okoye (1996) confirmed the insecticidal efficacy of *Piper guineense*.

The potency of *P. guineense* has been attributed to piperine acting in synergism with guineensine (Okogun *et al.*, 1977). The observed action could be probably due to the pungency of various resins, particularly chavicine and a yellow alkaloid, piperine (Cobley and Steele, 1976). Su (1977) and Olaifa *et al.* (1987) had found the fumigant and contact action of *P. guineense* as comparable with those of synthetic organochlorines and organophosphates.

Actellic dust treated seeds had the lowest cumulative mean number of emerged insects and the highest mortality figures. Seeds treated with Actellic also offered good protection against seed damage. Abdullahi and Mohammed (2004) reported that cowpea seeds treated with Actellic dust protected the seeds from damage by *C. maculatus*. They noted, however, that by the 6^{th} month of storage, the potency of Actellic dust had declined considerably to between 26.67–50.00 %. The efficacy of Actellic was clearly dose-related and the performance could be as a result of its ability to impair the insect's central nervous system formation and its muscarinic effects (Abdullahi and Mohammed, 2004).

Ocimum gratissimum came fourth in potency and damage-control ability. The efficacy of *O. gratissimum* was dose related as the highest rate (10g per 100g of cowpea seed) was the most effective. Ofuya (1990) and Oparaeke *et al.* (2002) evaluating the efficacy of leaf powders of *O. gratissimum* against the cowpea bruchid *C. maculatus* on stored cowpea, had reported that the plant product offered protection of the seeds against the bruchid.

The mode of action of *O. gratissimum* as a fast knock-down botanical in adult mortality, reduction of oviposition and suppression of progeny emergence could be attributable to the contact action resulting in high mortality rates (Oparaeke *et al.*, 2002). Weaver *et al.* (1991) and Regnault and Hamraoui (1994) had attributed the efficacy of *O. canum* and *O. basilicum* to linalool respectively.

Though the other plant products used in the experiment had been variously reported by many workers as possessing insecticidal activity on storage pests and or helped reduce grain mycoflora during storage: *Chromolaena odorata* (Niber, 1995; Ewete *et al.* 1996); *Anacardium occidentale* (Echendu, 1991; Dungun *et al.* 2005); *Cymbopogon citratus* (Dike and Mbah, 1992; Adebayo and Gbolade, 1994); *Eugenia uniflora* (Adebayo and Gbolade, 1994); *Khaya senegalensis* (Yusuf *et al.*, 1998; Ewete and Alamu, 1999; Ewete and Babarinde, 2002); *Mormodica charantia* (Lajide *et al.*, 1998) and *Mangifera indica* (Ramadevi *et al.*, 1989; Owolade and Osikanlu, 1999), they were found not to have curative potency on cowpea seeds with established infestation.

It is instructive to note that though the synthetic insecticide, Actellic 2% Dust acted very fast and had very high mortality rates, those plant products with curative efficacy acted more 'coolly' while offering better protective ability at the end of the day. This, most probably, was what Arnason *et al*., (1992) dubbed the 'desirable soft modes of action' of some highly effective natural plant products with potentials for use as pest control agents.

4. Conclusion

This experiment clearly shows that most plant products which were hitherto adjudged effective in controlling storage pests could not stop the further deterioration of stored cowpea seeds with established infestation. Though Actellic dust effected higher mortality of the insects, it could hardly protect seeds that were already heavily infested. *Moringa oleifera*, *Piper guineense* and *Ocimum gratissimum* appeared to have biotic agents that were better than the other plant materials and Actellic in halting the further deterioration of an already infested seed lot.

Since most storage pests like *Callosobruchus maculatus* and *Sitophilus zeamais,* etc. are field – to – store pests, partially infested seeds should be used to adjudge biopesticidal efficacy. The current practice of using very clean and disinfested seeds for experiments is largely deceptive.

Further screening of other plant products already classified as effective against storage pests is recommended. Some of them could eventually turn out to be more effective, environmentally friendlier, applicator – safer and cheaper than the synthetic insecticides.

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Table 1: Effect of treatment materials and their rates of application on weekly emergence of *C. maculatus* on cowpea seeds with established infestation.

Treatment Material	**Rate**	**Mean weekly emergence of adult insects (Dead + Alive)** Week 1		Week 2		Week3		Week 4		Week 5		Week 6	
Actellic Dust	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk	9.3	h	2.7	abcd
	1.0g/100g	21.3	ab	3.0	a	0.3	a	20.7	ab	.7	abc	0.7	ab
	2.0g/100g	7.7	a	8.7	a	0.3	a	6.3	a	5.7	ab	0.0	a
	3.0g/100g	7.3	a	4.7	a	0.3	a	3.3	a	3.7	ab	0.0	a
Anacardium occidentale	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk	9.3	h	2.7	abcd
	2.5g/100g	75.0	bcdefghi	47.7	abcd	0.7	a	40.3	abcdef		abcd	2.0	abc
	5.0g/100g	103.0	ghi	86.0	cdefgh	3.0	abc	65.0	abcdefghi		abcdef	1.3	abc
	10g/100g	117.7	i	68.7	cdefgh	2.7	abc	88.0	cdefghijk		abcdef	2.0	abc
Cymbopogon citratus	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	90.0	efghi	104.0	efghi	10.0	cde	142.0	jk		efgh	0.7	ab
	5.0g/100g	92.3	fghi	138.3	hi	18.7	f	121.7	ghijk		h	2.7	abcd
	10g/100g	92.0	fghi	109.3	fghi	7.0	abcde	90.0	defghijk		bcdefg	2.0	abc
Chromolaena odorata	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	29.7	abcd	17.7	ab	0.0	a	24.0	abcd		abcd	1.0	ab
	5.0g/100g	59.7	abcdefghi	31.7	ab	1.7	ab	37.0	abcde		abc	0.7	ab
	10g/100g	67.0	bcdefghi	67.3	bcdefg	1.0	a	24.7	abcd		abc	1.7	abc
Eugenia uniflora	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	29.3	abcd	20.3	ab	0.3	a	38.7	abcde		abcde	1.3	abc
	5.0g/100g	43.0	abcdefg	100.7	efghi	2.7	abc	42.3	abcdef		abcdef	4.0	abcd
	10g/100g	76.7	bcdefghi	146.3	i	6.0	abcd	68.3	abcdefghi		defg	1.0	ab
Khaya senegalensis	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	105.0	hi	46.0	abcd	1.0	a	47.7	abcdef		abcd	2.0	abc
	5.0g/100g	62.3	abcdefghi	17.0	ab	0.3	a	59.3	abcdefgh		abc	0.7	ab
	10g/100g	69.3	bcdefghi	35.3	abc	0.3	a	65.7	abcdefghi		abc	1.7	abc
Mormodica charantia	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	65.0	abcdefghi	120.0	ghi	8.0	abcde	130.0	ijk		i	13.7	g
	5.0g/100g	89.0	defghi	87.0	defgh	7.0	abcde	147.7	k		i	5.3	cde
	10g/100g	54.3	abcdefgh	119.7	ghi	11.3	def	79.3	bcdefghij		h	6.3	de
Mangifera indica	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	78.7	bcdefghi	118.3	fghi	12.0	def	125.3	hijk		fgh	1.7	abc
	5.0g/100g	60.0	abcdefghi	124.7	hi	14.7	ef	114.7	ghijk		gh	0.3	ab
Moringa oleifera	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	110.3	hi	104.3	efghi	5.3	abcd	46.3	abcdef		abcd	8.0	ef
	5.0g/100g	44.0	abcdefg	53.3	abcde	3.0	abc	47.0	abcdef		abcd	10.3	fg
	10g/100g	33.3	abcdef	64.3	bcdef	3.0	abc	32.0	abcde		abcd	4.3	bcde
Ocimum gratissimum	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	61.3	abcdefghi	26.3	ab	1.3	a	96.3	efghijk		abcdef	2.0	abc
	5.0g/100g	41.0	abcdef	15.7	ab	0.7	a	28.0	abcd		ab	0.7	ab
	10g/100g	20.0	ab	9.3	a	0.0	a	2.3	a		a	0.3	ab
Piper guineense	0g(control)	73.7	bcdefghi	113.3	fghi	13.0	def	106.3	fghijk		h	2.7	abcd
	2.5g/100g	84.3	cdefghi	34.0	ab	1.0	a	56.7	abcdefg		ab	4.0	abcd
	5.0g/100g	68.0	bcdefghi	20.7	ab	0.0	a	30.0	abcd		abc	0.7	ab
	10g/100g	26.7	abc	9.3	a	0.3	a	22.0	abc		a	0.3	Ab
S. E.M.		17.114		15.607		2.348		19.051					

Means followed by the same letter(s) in the same column are not significantly different at P < 0.0 using the New Duncan Multiple Range Test.

Table 2: Effect of treatment materials and their rates of application on the cumulative total number of insects and percentage mortality on cowpea seeds with established infestation

Treatment Material	Rate	Cum. Total insect Week 6		Cum. Perc. Mort. Week 6		Cum. Total insect Week 10		Cum. Perc. Mort. Week 10	
Actellic Dust	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	1.0g/100g	53.7	abc	70.9	ab	56.0	abcd	74.2	ab
	2.0g/100g	29.3	ab	89.4	a	32.7	ab	90.0	a
	3.0g/100g	17.7	a	87.0	a	18.7	a	91.3	a
Anarcardium occidentale	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hijk
	2.5g/100g	181.3	def	35.2	ijkl	183.0	efg	36.7	hij
	5.0g/100g	284.3	fgh	35.9	ijkl	285.0	hij	36.1	hij
	10g/100g	307.3	gh	27.9	kl	308.3	hijk	28.3	j
Cymbopogon citratus	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	395.7	hi	34.2	ijkl	397.0	kl	34.4	hij
	5.0g/100g	440.3	i	40.5	ghijkl	443.3	n	40.9	ghij
	10g/100g	331.3	hi	33.8	ijkl	331.7	ijkl	33.9	hij
Chromolaena odorata	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	84.7	abcd	55.2	defgh	89.7	abcde	58.1	cdef
	5.0g/100g	140.7	cde	45.1	fghij	143.0	defg	46.1	fghi
	10g/100g	169.7	de	47.4	fghi	170.3	efg	47.6	fghi
Eugenia uniflora	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	113.0	abcde	34.1	ijkl	122.7	bcdef	41.3	ghij
	5.0g/100g	219.0	efg	49.2	efghi	221.0	fgh	49.5	efgh
	10g/100g	337.0	hi	38.4	ijkl	337.7	jklm	38.5	hij
Khaya senegalensis	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	213.7	efg	24.4	fghij	220.7	fgh	28.3	j
	5.0g/100g	149.0	cde	30.1	jkl	154.3	defg	32.1	ij
	10g/100g	185.3	def	34.1	ijkl	187.3	efg	34.7	hij
Mormodica charantia	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	437.0	i	40.6	ghijkl	439.7	mn	40.9	ghij
	5.0g/100g	433.3	i	36.4	ijkl	434.7	lmn	36.5	hij
	10g/100g	342.3	hi	44.9	fghij	344.0	jklmn	45.2	fghi
Mangifera indica	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	386.7	hi	37.5	ijkl	387.3	jklmn	37.6	hij
	5.0g/100g	370.3	hi	39.9	hijkl	370.3	jklmn	39.9	ghij
	10g/100g	332.7	hi	38.3	ijkl	333.3	ijkl	38.4	hij
Moringa oleifera	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	294.7	gh	42.7	ghijk	295.7	hijk	42.8	ghij
	5.0g/100g	170.7	de	58.4	bcdef	172.7	efg	59.2	cdef
	10g/100g	149.7	cde	63.5	bcde	153.0	defg	64.3	bcde
Ocimum gratissimum	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	214.0	efg	59.4	bcdef	239.3	ghi	58.7	cdef
	5.0g/100g	90.0	abcd	67.7	bcd	122.7	bcdef	66.2	bcd
	10g/100g	32.0	ab	71.8	b	33.7	ab	73.4	abc
Piper guineense	0g(control)	378.3	hi	35.8	ijkl	379.3	jklmn	36.0	hij
	2.5g/100g	185.7	def	54.1	defgh	188.3	efg	54.7	defg
	5.0g/100g	126.7	bcde	56.2	cdefg	133.0	cdef	58.3	cdef
	10g/100g	60.7	abc	65.0	bcd	66.0	abcd	67.3	bcd
S. E.M.		32.37		4.73		30.35		4.69	

Means followed by the same letter(s) in the same column are not significantly different at P $\leq$0.0 using the New Duncan Multiple Range Test.

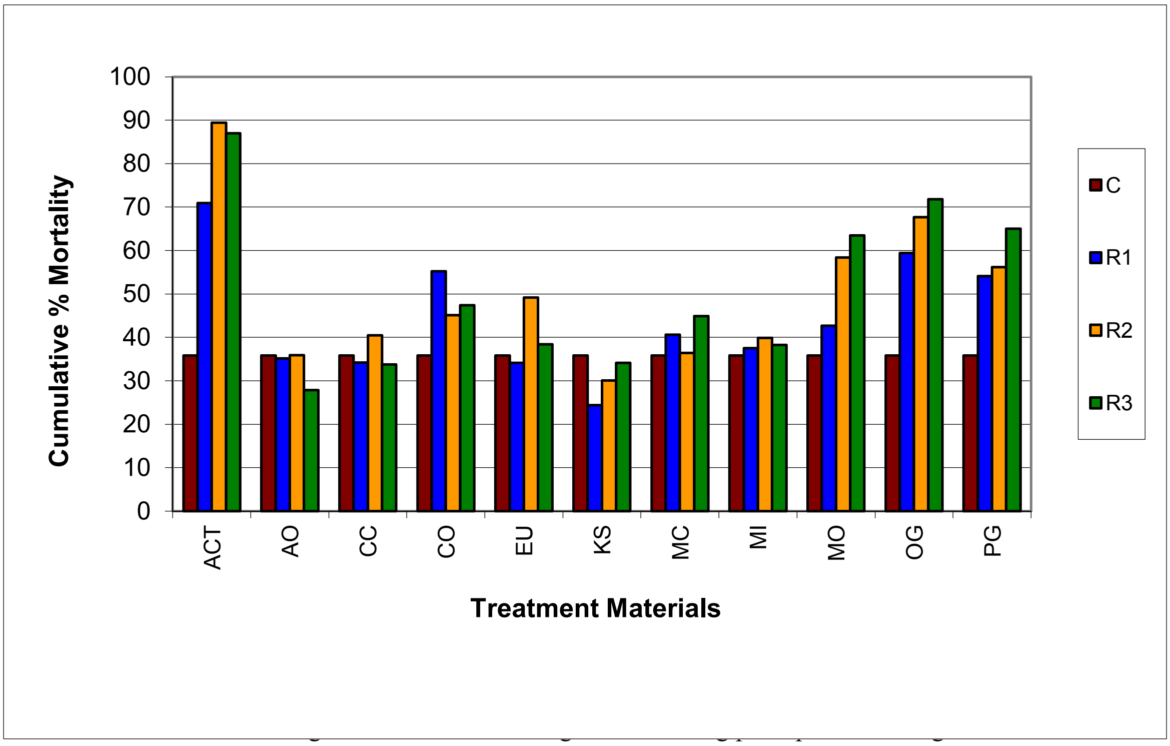
KEY: Cum. total. = Cumulative total
Cum. Perc. Mort. = Cumulative percentage mortality

Table 3: Effect of treatment materials and their rates of application on damage assessment of cowpea seeds with established infestation.

Treatment Material	**Rate**	**No of holes/ seed Week 6**	**No. of seeds with holes Week 6**	**Weevil perforation index (WPI) Week 6**	**No. of holes/ seed Week 10**	**No of seeds with holes Week 10**	**Weevil perforation index (WPI) Week 10**
Actellic Dust	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	1.0g/100g	2.3 abc	6.0 abc	60.0 abcd	2.4 ab	6.3 abc	63.3 abc
	2.0g/100g	2.0 ab	5.3 ab	53.3 abc	2.0 a	5.7 ab	56.7 ab
	3.0g/100g	2.0 ab	4.7 a	46.7 a	2.0 a	5.0 a	50.0 a
Anacardium occidentale	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	3.1 abcdefgh	8.3 defgh	83.3 defgh	4.5 defgh	9.3 efg	93.3 def
	5.0g/100g	3.3 abcdefghi	9.0 efgh	90.0 fgh	4.2 cdefg	9.3 efg	93.3 def
	10g/100g	3.8 abcdefghij	8.7 efgh	86.7 efgh	5.2 fghijk	10.0 g	100.0 f
Cymbopogon citratus	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	6.1 lm	10.0 h	100.0 h	6.8 klm	10.0 g	100.0 f
	5.0g/100g	5.9 klm	10.0 h	100.0 h	7.1 m	10.0 g	100.0 f
	10g/100g	4.7 fghijkl	9.3 fgh	93.3 fgh	6.4 jklm	10.0 g	100.0 f
Chromolaena odorata	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	2.7 abcdef	6.0 abc	60.0 abcd	2.9 abc	6.3 abc	70.0 abcd
	5.0g/100g	2.8 abcdef	7.0 bcde	70.0 bcdef	2.8 abc	7.0 abcd	66.7 abc
	10g/100g	2.3 abc	6.3 abcd	63.3 abcd	3.0 abcd	6.7 abcd	63.3 abc
Eugenia uniflora	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	3.0 abcdefg	8.0 cdefgh	80.0 defgh	3.7 bcdef	8.0 cdefg	80.0 bcdef
	5.0g/100g	2.5 abcd	7.7 cdefg	76.7 cdefgh	3.1 abcd	7.7 bcdef	76.7 bcdef
	10g/100g	4.2 cdefghijkl	9.7 gh	96.7 gh	4.7 efghi	9.7 efg	96.7 ef
Khaya senegalensis	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	2.7 abcdef	7.7 cdefg	76.7 cdefgh	6.3 ijklm	8.3 cdefg	83.3 cdef
	5.0g/100g	2.3 abc	7.3 bcdef	73.3 bcdefg	4.7 efghi	8.7 defg	86.7 cdef
	10g/100g	2.4 abc	8.0 cdefg	80.0 defgh	4.8 efghi	7.3 bcde	73.3 abcde
Mormodica charantia	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	5.8 klm	9.3 fgh	93.3 fgh	7.0 lm	10.0 g	100.0 f
	5.0g/100g	6.7 m	10.0 h	100.0 h	6.9 lm	10.0 g	100.0 f
	10g/100g	4.9 hijklm	9.7 gh	96.7 gh	5.7 ghijklm	10.0 g	100.0 f
Mangifera indica	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	4.4 defghijkl	9.3 fgh	93.3 fgh	5.4 ghijkl	9.7 fg	96.7 ef
	5.0g/100g	5.5 jklm	10.0 h	100.0 h	6.1 hijklm	10.0 g	100.0 f
	10g/100g	4.9 ghijklm	9.7 gh	96.7 gh	5.7 ghijklm	10.0 g	100.0 f
Moringa oleifera	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	6.0 lm	10.0 h	100.0 h	3.7 bcdef	10.0 g	100.0 f
	5.0g/100g	4.2 cdefghijkl	8.7 efgh	86.7 efgh	3.2 abcde	5.0 a	50.0 a
	10g/100g	3.9 bcdefghijk	8.3 defgh	83.3 defgh	2.9 abc	4.7 a	46.7 a
Ocimum gratissimum	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	4.5 efghijkl	9.7 gh	96.7 gh	4.8 fghij	9.3 efg	93.3 def
	5.0g/100g	2.7 abcdef	7.0 bcde	70.0 bcdef	2.9 abc	6.3 abc	63.3 abc
	10g/100g	1.9 a	5.0 a	50.0 ab	2.1 ab	5.0 a	50.0 a
Piper guineense	0g(control)	5.2 ijklm	10.0 h	-	6.1 hijklm	10.0 g	-
	2.5g/100g	2.9 abcde	8.3 defgh	83.3 defgh	3.1 abcd	7.0 abcd	70.0 abcd
	5.0g/100g	2.6 abc	7.3 bcdef	73.3 bcdefg	3.2 abcde	7.0 abcd	70.0 abcd
	10g/100g	2.2 ab	7.0 bcde	70.0 bcdef	2.5 ab	4.7 a	46.7 a
S. E.M.		0.57	0.611	7.06	0.48	0.636	6.361

Means followed by the same letter(s) in the same column are not significantly different at P ≤ 0.0 using the New Duncan Multiple Range Test.

Figure 1: Interactive bar chart of the effect of material type and rate of application on cumulative percentage mortality in week 6 of the experiment.



ACT = Actellic Dust
AO = *Anacardium occidentale*
CO = *Chromolaena odorata*
CC = *Cymbopogon citratus*
EU = *Eugenia uniflora*
KS = *Khaya senegalensi*
MC = *Mormodica charantia*
MO = *Moringa oleifera*
MI = *Mangifera indica*
OG = *Occimum gratissimum*
PG = *Piper guineense*