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Research Article

Integration of leaf extracts from *Helianthus annuus* and varietal resistance in the control of *Sitotroga cerealella* (Lep.: Gelechiidae) infesting paddy rice

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Abstract: The bioactivity of leaf extracts of *Helianthus annuus* L. against *Sitotroga cerealella* (Olivier) in stored paddy rice varieties was evaluated in the laboratory of the Federal University of Technology, Akure, Nigeria at ambient temperature of 28 ± 2 °C and 75 ± 5% relative humidity. Standard methods were used to determine toxicity of the plant powders and extracts, to *S. cerealella* based on weight loss, adult emergence, adult mortality and developmental periods. Paddy rice from previously categorized susceptible and moderately susceptible varieties was used for the research work. The adult mortality was assessed at 24, 48 and 72 hours of application. The solvent extracts of the plant significantly reduced or prevented adult emergence of *S. cerealella*. Also there was an increase in the developmental period ($P > 0.05$) and reduction or prevention of seed weight loss. Adult mortality of 100% was observed in *S. cerealella* in paddy treated with 4% petroleum ether leaf extract in FARO 44 as compared with 100% mortality in FARO 52 paddy treated with 3% petroleum ether leaf extract. Lowest adult moth mortality of 30.33% and 35.20% were observed in 1% ethanolic leaf extract treated in FARO 44 and FARO 52 respectively. Results showed that *H. annuus* plant parts in combination with the susceptible paddy variety, FARO 52 increased mortality of adult *S. cerealella* and prolonged developmental periods. Both the powder and the extracts of this plant could be produced on commercial scale and incorporated into pest management programmes.

Keywords: *Helianthus annuus*, *Sitotroga cerealella*, paddy rice varieties, susceptibility, mortality

Introduction

Safety and protection of foods is one of the many challenges confronting the grain-handling, local farmers in combating hunger and food insecurity and this applies to many developing countries across the world (Hawksworth, 1985)**.** Inability to store these grains for a very long period without losing a sizeable proportion to pests is further aggravated by the simple reason that the main bulk of the cereal grain and storage in the third world countries like Nigeria is in the hands of small scale peasant farmers with little resources to produce adequate storage facilities and chemicals for protection against pests (Akpabot *et al*., 2010).

Paddy (Rice) is the staple food of more than 60 percent of the world population and the most important staple food for about half of human race and extensively grown food crop in the World (Ashamo et al., 2011). During storage, especially before processing, paddy rice is vulnerable to

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attack by many insect pests (Adeyemo, 2015), notable among them is Angoumois grain moth, *Sitotroga cerealella* Olivier which may be one of the most destructive of them all (Ashamo and Khanna, 2006). The moth is one of the serious insect pests of stored grains in Nigeria. It is a primary pest of grains, although most damages occur in storage. It attacks all types of cereal grains, particularly corn, paddy rice and wheat (Adeyemo, 2015).

In Nigeria and many developing countries, the use of botanicals as an anlternative to synthentic chemicals with attendant drawbacks has been advaocated (Gbaye *et al*., 2016).

Considering the trend of research in stored products protection, a promising way to reduce dependence on pesticides in agriculture is to grow crops resistant to insect pests (Ashamo, 2010). However, since it is not likely to achieve a complete resistance to all insect pests by a particular variety, it is therefore important that resistance can be combined with eco-friendly methods such as use of plant oils and powders in the managements of stored insect pests such as *S. cerealella* in paddy. Many of the botanicals used in the control of insect pests are medicinal and the tropical regions of the world including Nigeria are well endowed with such plants (Akinkurolere *et al.,* 2006). The domesticated sunflower, *Helianthus annuus* L, is one of the many promising botanicals in the world that can be combined with plant resistance. The plant was originally cultivated by North American Indians, and has a long and interesting history as a food plant (Moerman, 1986). There is scanty information on the use of *H. annuus* in the control of *S. cerealella* unlike other botanicals. Therefore, this research investigated the insecticidal activities of powder and oil extracts of *H. annuus* leaf in combination with varietal resistance in paddy rice against *S. cerealella* infestation.

Materials and Methods

Insect culture

The culture of *S. cerealella* used for this research was obtained from the Storage Research Laboratory, Department of Biology, Federal University of Technology, Akure, Nigeria. Clean uninfested paddy rice FARO 44 (F44) (moderately susceptible) and FARO 52 (F52) (susceptible) collected from Agricultural Development Project, Akure, Nigeria were used to rear the insects inside 2 liters jars covered with muslin cloth. The varieties were categorized based on their susceptibility indices as susceptible and moderately susceptible according to the modified method of Ajayi and Lale (2001) in a previous research work. The jars were kept in insect cages and the culture was maintained by replacing the devoured grains with fresh uninfested grains. The research environment was maintained at 28 ± 2 ^{o}C and 75 ± 5% relative humidity.

Preparation of plant powder

The plant materials used in this study were leaves of *H. annuus.* These leaves were sourced fresh from Aule farm settlement, Akure, Nigeria. The leaves were air dried in the laboratory and were milled into fine powder. The powder was further sieved to pass through 1 mm^2 mesh and kept inside different plastic containers with tight lids until use.

Preparation of leaf extracts

Pulverized plant leaves (20g) was put in a muslin cloth and transferred into the thimble and extracted with four different solvents namely Ethanol, Acetone, Petroleum ether and N-hexane in a soxhlet apparatus. The extraction was carried out for 3-4 h depending on the solvent and the extraction was terminated when the solvent in the thimble became clear. Then, the thimble was removed from the unit and the solvent recovered by distilling in the soxhlet extractor. The resulting extracts contained both the solvent and the leaf extract. The solvents were separated from the oil using rotary evaporator, after which the oils were exposed to air so that traces of the volatile solvent evaporated, leaving the oil extracts.

Toxicity of plant powders to adult *S. cerealella*

Twenty grams of paddy rice (varieties F44 and 52) were separately weighed into 250ml plastic containers and the leaf powder weighing 0.1, 0.2, 0.4, 0.6 and 0.8 g was separately added. The powder was mixed thoroughly with the paddy varieties to ensure uniform spread. Untreated paddy rice was set as control. Ten pairs of adult moth (24 h old) were introduced into containers with treated paddy and the containers were arranged in a Completely Randomized Design with six replications. Adult mortality was observed after 24, 48 and 72 h of introduction of adult moths. Both dead and live insects were removed on the fifth day and experiments were left for 28days to allow for emergence of F_1 generation and the number of adult emerged was counted. Developmental period was calculated from the day of middle of oviposition to the day of 50% adult emergence. The weight loss of the stored paddy varieties were calculated using the AOAC method cited in Odeyemi and Daramola (2000), as follows:

$$\%\text{weight loss} = \frac{\text{initial weight - final weight}}{\text{initial weight}} \times \frac{100}{1}$$

The percentage reduction in adult emergence of F_1 progeny or inhibition rate (IR) was calculated according to the methods of Tapondju *et al*., (2002).

$$\%IR = \frac{Cn - Tn}{Cn} \times \frac{100}{1}$$

Where C*n* is the number of emerged insects in the untreated container and T*n* is the number of insects in the treated container.

Toxicity of plant extract to adult *S. cerealella*

Paddy rice (20g) of varieties F44 and 52 were separately weighed into 250 ml plastic containers and 1mls leaf extracts at 1, 2, 3, 4 and 5% concentrations were separately added. The extracts and the paddy varieties were separately thoroughly mixed together to ensure uniform spread coating of the seeds. Untreated paddy rice was set as control while solvent controls were also set up. Ten pairs of adult moths (24 h old) were introduced into containers with treated paddy and were arranged in a completely randomized design with six replications. Adult mortality was observed after 24, 48 and 72 h of introduction of adult moths. Both dead and live insects were removed on the fourth day and experiments were left for 28 days to allow for emergence of F_1 generation and the number of adult emerged was counted. Developmental period was calculated from the day of middle of oviposition to the day of 50% adult emergence. The weight loss of the stored paddy varieties were calculated using the method of Odeyemi and Daramola (2000).

Statistical analysis

Data were subjected to analysis of variance and where significant differences existed, treatment means were compared at 0.05 significant levels according to the New Duncan's Multiple Range Test using SPSS 17.0 software package (Zar, 1984).

Results

Effect of powder of *H. annuus* on mortality of adult

Mortality caused by leaf powder of *H. annuus* is presented in Table 1. The percentage moth mortality varied with the period of exposure, and the concentration of the powders. There was significant ($P < 0.05$) differences in the effectiveness of the powders. Within 24h of application, 13.33% adult moth mortality was achieved on FARO 44 at 0.8g while 35.00% was observed at this same concentration in FARO 52 and mortality recorded was significantly ($P < 0.05$) different from others. The leaf powder of *H. annuus* achieved more than 90% adult moth mortality within 72h in F44 while 100% mortality was observed in F52 at 0.8g concentration. Therefore, more adult mortality was recorded in variety FARO 52.

The number of adult emergence, developmental period of adult moth as well as weight loss of paddy rice treated with powders of *H. annuus* is presented in Table 2. The leaf powder was unable to totally prevent adult moth emergence but it reduced the number of emerged adults at all the application concentrations compared to the control. The least number of emerged adult moth of 12.33 was observed in FARO 44 at 0.8 g while 16.00 adult moth was recorded for FARO 52 at the same application concentration and this was significantly ($P < 0.05$) different from other application concentrations and the control. Leaf powder of *H. annuus* was able to prevent the emergence of adult moth and as well the weight loss of the two varieties of treated paddy rice. The powder showed greater effect on the emergence of adult moth as well as their developmental period at highest concentration of 0.8g with the longest developmental period of 33.33 observed in FARO 44 at 0.8gwhile the developmental period at this same concentration in FARO 52 was 30.00 and its effect was significantly ($P < 0.05$) different from the control. Also, the seed powder of *H. annus* plant at 0.8g concentration greatly reduced the weight loss of the treated paddy varieties. The lowest weight loss of 6.84% was observed in FARO 44 at 0.8 g while in FARO 52, 9.59% weight loss was recorded at the same concentration. However, the number of adult moth that emerged on treated FARO 52 was higher than the ones on FARO 44 and although the developmental period was still short, there was significant effect ($P < 0.05$) when compared with the control.

Effect of *H. annuus* extract on mortality of *S. cerealella* infesting two paddy rice varieties

The effect of extracts of leaf of *H. annuus* on *S. cerealella* infesting two paddy varieties is shown in Table 3. After 72 h of treatment at 1% concentration, none of the extracts was able to achieve 100% moth mortality, however highest mortality of 41.67% was observed in acetone extract in case of F 44. The leaf extract at 4 and 5% concentration achieved 100% mortality of *S. cerealella* in both ethanolic and petroleum ether extracts, and this was observed on FARO 44 and FARO 52 and its effect was significantly ($P < 0.05$) different from others within 24h of application. Moreover, petroleum ether extract at higher concentrations achieved 100% moth mortality on both treated paddy varieties within 72 h of application.

Table 1 Percentage mortality of *Sitotroga cerealella* on paddy rice treated with leaf powder of *Helianthus annuus*.

Concentration (g/20 g of paddy rice)	%Mortality (Mean ± S. E)					
	FARO 44			FARO 52		
	24h	48h	72h	24h	48h	72h
0.1	2.00 ± 0.00^{a}	10.00 ± 2.89^{b}	35.00 ± 0.00^{b}	5.67 ± 1.67^{ab}	20.00 ± 1.89^{b}	38.42 ± 1.67^{b}
0.2	3.67 ± 1.67^{b}	13.33 ± 1.67^{b}	48.00 ± 5.00^{c}	17.67 ± 2.89^{b}	28.33 ± 4.41^{c}	50.00 ± 2.89^{c}
0.4	5.00 ± 0.00^{c}	25.00 ± 2.89^{c}	58.33 ± 4.41^{d}	20.00 ± 2.89^{c}	41.67 ± 1.67^{d}	61.67 ± 2.89^{d}
0.6	10.00 ± 0.00^{d}	25.00 ± 1.67^{c}	70.67 ± 2.89^{e}	30.67 ± 1.67^{d}	45.00 ± 0.00^{d}	80.00 ± 0.00^{e}
0.8	13.33 ± 1.67^{e}	26.67 ± 1.67^{c}	90.00 ± 0.33^{f}	35.00 ± 1.33^{e}	61.67 ± 1.67^{e}	100^{f}
0	2.00 ± 0.00^{a}	10.00 ± 2.89^{b}	35.00 ± 0.00^{b}	5.67 ± 1.67^{ab}	20.00 ± 1.89^{b}	38.42 ± 1.67^{b}

Means in a column followed by the same letter are not significantly different ($P < 0.05$) using New Duncan's Multiple Range Test.

Table 2 Mean adult emerged, developmental period of *Sitotroga cerealella* and weight loss in seeds (± SE) treated with leaf powder of *Helianthus annuus*.

Concentration (g/20 g of paddy rice)	%Mortality (Mean ± S.E)					
	FARO 44			FARO 52		
	Adult emergence	Developmental period (Days)	Weight loss (%)	Adult emergence	Developmental period (Days)	Weight loss (%)
0.1	21.67 ± 0.67^{c}	31.33 ± 0.67^{b}	9.40 ± 0.34^{b}	31.67 ± 0.23^{c}	26.67 ± 0.67^{a}	12.03 ± 1.03^{b}
0.2	20.67 ± 1.20^{c}	31.33 ± 0.88^{b}	8.76 ± 0.53^{a}	30.00 ± 0.58^{c}	28.33 ± 1.20^{ab}	12.16 ± 1.41^{b}
0.4	18.33 ± 1.45^{b}	30.33 ± 0.33^{a}	7.82 ± 0.68^{a}	23.33 ± 1.43^{b}	29.33 ± 0.69^{ab}	10.72 ± 0.45^{b}
0.6	16.33 ± 2.73^{b}	31.00 ± 0.58^{a}	7.17 ± 0.55^{a}	17.33 ± 0.67^{a}	30.00 ± 0.00^{b}	8.75 ± 0.62^{a}
0.8	12.33 ± 2.73^{a}	33.33 ± 0.33^{c}	6.84 ± 0.78^{a}	16.00 ± 1.16^{a}	30.00 ± 0.00^{b}	9.59 ± 0.55^{a}
0	29.00 ± 2.64^{d}	31.67 ± 0.33^{b}	18.48 ± 1.33^{c}	42.33 ± 6.23^{d}	28.00 ± 0.58^{ab}	14.05 ± 0.42^{c}

Means in a column followed by the same letter are not significantly different ($P < 0.05$) using New Duncan's Multiple Range Test.

Table 3 Percentage mortality of adult S*itotroga cerealella* on paddy rice treated with leaf extracts of *Helianthus annuus* after treatment.

Varieties	Concentration (g/20g of paddy rice)	%Mortality ± SE in hours/extracts			
		Ethanol	Petroleum ether	Acetone	n-hexane
FARO 44	1	30.00 ± 0.00[b]	36.37 ± 0.20[b]	41.67 ± 0.24[b]	32.70 ± 0.33[b]
	2	33.33 ± 1.67[b]	41.67 ± 1.67[b]	55.00 ± 0.89[c]	38.00 ± 0.33[bc]
	3	36.67 ± 1.67[bc]	60.00 ± 0.00[c]	73.00 ± 1.67[d]	43.00 ± 0.33[c]
	4	40.00 ± 0.00[c]	100[f]	78.33 ± 1.67[de]	47.00 ± 0.05[cd]
	5	45.00 ± 0.28[c]	100[f]	83.33 ± 0.89[e]	51.76 ± 0.67[d]
FARO 52	1	35.20 ± 0.88[b]	40.00 ± 0.00[b]	64.33 ± 1.28[c]	40.67 ± 1.67[c]
	2	42.33 ± 1.67[c]	59.67 ± 4.41[c]	73.51 ± 1.33[d]	46.33 ± 2.24[cd]
	3	48.00 ± 2.88[c]	100[f]	88.33 ± 4.41[e]	58.33 ± 1.67[d]
	4	76.00 ± 0.24[d]	100[f]	100[f]	72.67 ± 1.67[e]
	5	89.54 ± 2.89[e]	100[f]	100[f]	92.40 ± 5.00[f]
SC	0	0[a]	0[a]	0[a]	0[a]
UC	0	0[a]	0[a]	0[a]	0[a]

Means followed by the same letter along the column are not significantly different ($p < 0.05$) using New Duncan's Multiple Range Test.
SC: Solvent control, UC: Untreated control.

Adult emergence, developmental period of *S. cerealella* and weight loss in paddy varieties

The mean number of adult emergence, developmental period of adult moth as well as percentage weight loss of paddy rice treated with extracts of *H. annuus* is presented in Tables 4-6. All the concentrations of the different solvents used for extraction greatly reduced the emergence of the adult *S. cerealella* and the weight loss of the treated paddy varieties and as well increased the developmental period of the adult moth. On varieties FARO 44 and 52, all the leaf extracts of *H. annuus* were able to reduce the emergence of adult moths and percentage seed weight loss at higher concentrations and their effect was significantly ($P < 0.05$) different from the controls. The leaf extract of the plant could not totally prevent emergence of adult moths and percentage weight loss in the paddy seeds in either FARO 44 or 52, however, at higher concentrations lower numbers of adult moths emerged and percentage weight loss in all the extracts were low compared to the control. The lowest adult emergence of 2.67 was observed at 5% concentration in petroleum ether extract of variety FARO 44 while the highest emergence of 23.00 was recorded in acetonic extract of variety FARO 52. They were significantly different ($P < 0.05$) from the other treatments and the controls. The developmental period (in days) ranged from 28.33 in 1% ethanolic extract of variety FARO 44 to 35.00 in petroleum ether extract of variety FARO 44 at 5% concentration (Table 5). The weight loss ranged from 1.53% at 5% concentration of Petroleum ether in variety FARO 44 to 12.95%in 1% n-hexane extract of variety FARO 52 (Table 6) and their effects were significantly ($P < 0.05$) different from others and the controls.

Percentage reduction in F_1 progeny increased with increase in concentration in each plant extract and varieties, and the highest reduction of 90.79 was obtained in 5% petroleum ether in variety FARO 44 (Table 7) Almost all the solvents in both varieties were able to achieve 50% reduction except in 1 and 2% concentrations of ethanol and petroleum ether extracts of variety FARO F52 and this was significantly different from others.

Table 4 Mean number of emerged adults of *Sitotroga cerealella* (± SE) in paddy varieties treated with. *Helianthus annuus* leaf extracts.

Concentration (g/20 g of paddy rice)	FARO 44				FARO 52			
	Emerged				Adults			
	Ethanol	petroleum ether	Acetone	n-hexane	Ethanol	Petroleum ether	Acetone	n-hexane
1	16.00 ± 1.15^{c}	8.67 ± 2.67^{c}	9.67 ± 0.67^{b}	10.67 ± 0.67^{c}	28.00 ± 1.73^{d}	8.67 ± 0.67^{c}	23.00 ± 0.67^{c}	12.67 ± 1.76^{c}
2	14.67 ± 1.33^{b}	7.00 ± 0.58^{c}	8.67 ± 0.33^{b}	9.00 ± 1.52^{c}	22.33 ± 1.47^{c}	7.00 ± 0.58^{c}	20.33 ± 0.88^{c}	9.00 ± 1.52^{b}
3	14.00 ± 1.73^{b}	4.67 ± 1.20^{b}	7.33 ± 0.33^{b}	7.33 ± 1.76^{b}	15.00 ± 2.65^{b}	5.67 ± 0.88^{b}	15.00 ± 1.16^{b}	7.33 ± 1.76^{a}
4	12.33 ± 1.86^{ab}	4.33 ± 0.88^{b}	5.00 ± 1.73^{ab}	6.67 ± 0.67^{ab}	11.67 ± 2.19^{ab}	5.67 ± 0.88^{b}	7.67 ± 1.86^{ab}	6.67 ± 0.67^{a}
5	9.00 ± 1.00^{a}	2.67 ± 0.67^{a}	3.67 ± 1.33^{a}	4.67 ± 0.67^{a}	9.00 ± 1.00^{a}	3.62 ± 0.67^{a}	5.00 ± 0.58^{a}	5.67 ± 0.88^{a}
SC	28.67 ± 2.60^{d}	28.00 ± 1.00^{d}	28.16 ± 0.25^{c}	27.76 ± 0.67^{d}	29.68 ± 1.97^{d}	29.73 ± 1.60^{d}	29.11 ± 0.85^{d}	29.96 ± 1.15^{d}
UC	29.00 ± 2.65^{d}	29.00 ± 2.65^{d}	29.00 ± 2.65^{d}	29.00 ± 2.65^{d}	30.67 ± 0.43^{f}	30.67 ± 0.43^{d}	30.67 ± 0.43^{d}	30.67 ± 0.43^{d}

Means followed by the same letter along the column are not significantly different ($p < 0.05$) using New Duncan's Multiple Range Test.
SC: Solvent control, UC: Untreated control.

Table 5 Developmental period (± SE) (days) of *Sitotroga cerealella* in paddy varieties treated with leaf extracts of *Helianthus annuus*.

Concentration (g/20 g of paddy rice)	FARO 44				FARO 52			
	Emerged				Adults			
	Ethanol	Petroleum ether	Acetone	n-hexane	Ethanol	Petroleum ether	Acetone	n-hexane
1	28.33 ± 0.61a	32.00 ± 0.00b	30.67 ± 0.33a	30.67 ± 0.33b	28.33 ± 0.67ab	30.67 ± 0.33bc	30.33 ± 0.33b	26.33 ± 3.18a
2	28.67 ± 0.33a	34.33 ± 0.33c	32.33 ± 0.33b	32.33 ± 0.16c	28.67 ± 0.33ab	32.33 ± 0.33c	32.33 ± 0.33b	28.67 ± 0.33ab
3	29.33 ± 0.33ab	32.67 ± 0.33b	32.30. ± 0.33b	32.17 ± 1.13c	28.67 ± 0.33ab	32.33 ± 0.33c	32.33 ± 0.33b	28.67 ± 0.33ab
4	30.00 ± 0.00b	34.00 ± 1.16c	32.33 ± 0.30b	32.33 ± 0.33c	29.67 ± 0.33b	32.33 ± 0.33c	32.33 ± 0.33b	29.67 ± 0.33b
5	31.00 ± 0.13b	35.00 ± 0.58c	32.00 ± 0.58b	32.67 ± 1.10c	30.00 ± 0.00b	32.33 ± 0.16c	32.33 ± 0.33b	30.00 ± 0.00b
SC	28.67 ± 2.60a	30.10 ± 0.58a	30.33 ± 1.45a	27.00 ± 2.60a	28.67 ± 0.33ab	28.67 ± 0.33b	28.67 ± 0.33ab	28.67 ± 0.33ab
UC	29.66 ± 0.33ab	29.66 ± 0.33a	29.66 ± 0.33a	29.66 ± 0.33a	24.88 ± 0.33a	24.88 ± 0.33a	24.88 ± 0.33a	24.88 ± 0.33a

Means followed by the same letter along the column are not significantly different ($p < 0.05$) using New Duncan's Multiple Range Test.
SC: Solvent control, UC: Untreated control.

Table 6 Percentage weight loss (± SE) in paddy varieties treated with leaf extracts of *Helianthus annuus*.

Concentration (g/20g of paddy rice)	FARO 44				FARO 52			
	Emerged				Adults			
	Ethanol	petroleum ether	Acetone	n-hexane	Ethanol	Petroleum ether	Acetone	n-hexane
1	8.02 ± 0.05d	7.05 ± 0.67cde	8.05 ± 0.05d	12.87 ± 1.20c	11.37 ± 0.40c	7.05 ± 0.60c	8.02 ± 0.05c	12.95 ± 1.14c
2	8.00 ± 0.01d	5.42 ± 0.56c	5.19 ± 1.67c	11.87 ± 1.34b	10.62 ± 0.99c	5.42 ± 0.55b	5.19 ± 1.67b	12.87 ± 1.39c
3	6.35 ± 0.47c	3.31. ± 0.40b	4.72 ± 0.92b	11.17 ± 1.57b	6.35 ± 0.41b	3.30. ± 0.94a	4.72 ± 0.92a	9.55 ± 0.29b
4	4.91 ± 1.89b	3.30 ± 0.94b	4.68 ± 0.52b	9.55 ± 0.29ab	5.41 ± 0.43b	3.31 ± 0.40a	4.68 ± 0.52a	9.55 ± 0.29b
5	2.32 ± 0.21a	1.53 ± 0.64a	3.02 ± 0.60a	8.30 ± 1.10a	3.34 ± 0.30a	2.32 ± 0.60a	3.34 ± 0.43 a	4.30 ± 1.10a
SC	14.31 ± 0.16e	14.55 ± 0.91e	14.01 ± 0.63e	14.67 ± 1.12e	14.03 ± 0.46d	14.63 ± 0.14d	14.11 ± 0.33d	14.68 ± 0.13d
UC	14.43 ± 1.33e	14.43 ± 1.33e	14.43 ± 1.33e	14.43 ± 1.33f	14.05 ± 0.43d	14.05 ± 0.43d	14.05 ± 0.43d	14.05 ± 0.43d

Means followed by the same letter along the column are not significantly different ($p < 0.05$) using New Duncan's Multiple Range Test.
SC: Solvent control, UC: Untreated control.

Table 7 Percentage reduction in F_1 progeny (± SE) of *Sitotroga cerealella* in paddy varieties treated with. *Helianthus annuus* leaf extracts.

Concentration (g/20 g of paddy rice)	FARO 44				FARO 52			
	Emerged				Adults			
	Ethanol	Petroleum ether	Acetone	n-hexane	Ethanol	Petroleum ether	Acetone	n-hexane
1	44.82 ± 1.05c	70.10 ± 0.67b	66.66 ± 0.13a	63.21 ± 0.17b	8.71 ± 1.05a	71.73 ± 0.17b	25.00 ± 0.47b	58.69 ± 1.76b
2	49.41 ± 1.53c	75.86 ± 1.58b	70.10 ± 0.13b	68.97 ± 1.06b	27.10 ± 1.47b	77.18 ± 0.18b	33.71 ± 0.18c	70.66 ± 0.02c
3	51.72 ± 1.33d	83.90 ± 0.20c	74.72. ± 0.69b	74.72 ± 0.16c	51.09 ± 0.65c	81.52 ± 0.67c	51.09 ± 1.16d	76.10 ± 0.06c
4	57.48 ± 1.06d	85.07 ± 0.09c	82.76 ± 1.73c	77.00 ± 0.07c	61.95 ± 0.19ac	81.52 ± 0.88c	4.99 ± 1.86e	78.25 ± 0.17c
5	9.00 ± 1.00b	90.79 ± 0.17d	87.35 ± 1.03c	83.90 ± 0.66d	70.66 ± 1.33d	91.29 ± 0.37d	83.70 ± 0.562e	81.51 ± 0.48c
Control	100a	100a	100a	100a	100a	100a	100a	100a

Means followed by the same letter along the column are not significantly different ($p < 0.05$) using New Duncan's Multiple Range Test.

Discussion

Biopesticides which are economically cheaper, ecofriendly and easily accessible and processed by the farmers and industries are being advocated for in pest management programs. The application of *H. annuus* in this study greatly reduced the infestation by *S. cerealella* in variety FARO 52 which was originally susceptible which after the application of the plant products had number of adult emerged and percentage weight loss values close to the moderately susceptible variety FARO 44. The effect of the leaf powder on the mortality of adult *S. cerealella* were significantly lower compared to that of the extracts, this may be due to the fact that the moths are good fliers and have less contact with the particles except when they want to oviposit. However, during oviposition, the powder may adhere to the bodies of the moth and block their spiracles and consequently lead to their death through desiccation. The mortality observed in the powder could also be due to respiratory imbalance in the insects which may lead to disruptions in the metabolic system of the moth and subsequently leads to their death. (Adedire *et al*, 2011). The powders may have also blocked the spiracle of the insects thereby causing suffocation. Adesina (1986) reported that this cause of death may be due to presence of secondary metabolites in the plant. The powder caused 100% mortality in the variety FARO 52 at 0.8g/20g of paddy rice within 72h of application.

The petroleum ether extract of *H. annuus* proved to be the most effective out of all the extracts evaluated for their insecticidal activities. The highest adult moth mortality of 100% was observed in both varieties at 4 and 5% concentrations. This is in agreement with the works of Adeyemo *et al*, 2014 who reported that *Aframomum melegueta* K. Schum extracts completely inhibited emergence of adult *S. cereallela* on treated paddy rice and Iqbal *et al* (2010) who reported that the petroleum ether of *Acorus calamus* (L.) and *Aframomum melegueta* K. Schum extracts completely inhibited emergence of adult *S. cereallela* from its eggs reared on wheat. The high mortality rate of *S. cerealella* achieved by *H. annuus* (L) extracts may be associated with the bioactive constituents of the plant materials and this may be more available in the petroleum ether extract than the other solvents.

Present observation corroborated the report of Odeyemi and Ashamo (2005) on toxic effect of plant parts on survival and development in insects. Also it agreed with the work of Ashamo and Akinnawonu (2012) who reported that the powders and extracts of *A. ringens* caused 100% mortality in adult *S. cerealella* within seven days of application. Petroleum ether extracts is the most promising growth inhibitor because of being highly volatile due to low polarity of this compound according to Iqba *et al.*, (2010). Plant extracts according to Lale and Mustapha (2000) are widely known to cause insect larvae mortality when used to protect against infestation. This could be responsible for the reduced number of emerged adults in the treated paddy varieties compared to the controls. The developmental periods in the treated paddy varieties were prolonged more in variety FARO 52 compared to FARO 44. According to the work of Adeyemo *et al*, (2014) long developmental period observed in insect that emerged on FARO 44 may be as a result of the antinutrient factors that are present in them more than in FARO 52. This agreed with the work of Yang *et al*. (2010) which suggested that phytochemicals present in plant prolong the developmental period of insects and also affect their life cycle.

Insecticidal properties of biopesticides have been linked to the active components of the compounds present which are linked to secondary metabolites present in the plant materials. Sunflower (*Helianthus annuus*) are potent allelopathic plants and have been reported to have allopathic effects on other plants and contains allelochemicals which have a potential as possible alternative for achieving sustainable weed management. (Mohammad and Majid, 2011**)**. *H. annuus* leaves contains sesquiterpenes, heliannuol A and helibisabonol A and the sesquiterpene lactone leptocarpin (Francisco *et al*. 2002) which might be responsible for its insecticidal activities.

Since multiple resistances to insect is not achievable, there is the need for incorporating other mechanisms such as combination of plant products with the resistance abilities of stored products in combating insect pest infestations. According to the work of Adesuyi (1979) cited by Ashamo, (2001) several factors notable among which are presence of alkaloids or amino acids, insect feeding deterrents, seed coats that discourage oviposition, seed hardness, anti-nutritional factors and digestive enzymes inhibitors can contribute to resistance of stored products to insect infestation. Lale and Mustapha (2000) reported the potentials of combining partial varietal resistance and insecticidal properties of neem seed oils with cowpea varieties. Ajayi and Lale (2001) also reported on the combined effects of varietal resistance and essential oils against infestation by *Callosobruchus maculatus* in bambara groundnut cultivars. Majority the harvested paddy varieties are in the hands of peasant farmers, so a cheaper and affordable means of pest management is necessary to reduce to the nearest minimum losses that occurred at post-harvest stages and reduce the level of poverty among the peasant farmers who are at the receiving ends. *Helianthus annuus* is used for medicinal purposes in treating different ailments such as rheumatism and high fevers and is available all the year round in different geographical zones.

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تلفیق عصاره برگ آفتابگردان و ارقام مقاوم برنج در کنترل برنج‌های آلوده به بید غلات *Sitotroga cerealella* (Lep.: Gelechiidae)

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چکیده: اثر عصاره برگ آفتابگردان *Helianthus annuus* L. روی ارقام مختلف برنج انباری آلوده به بید غلات *Sitotroga cerealella* (Olivier) در آزمایشگاه دانشگاه فدرال تکنولوژی نیجریه در دمای ۲ ± ۲۸ درجه سلسیوس و رطوبت نسبی ۵ ± ۵۷ درصد مورد ارزیابی قرار گرفت. براساس یک روش استاندارد سمیت پودر عصاره روی کاهش وزن، خروج حشرات کامل و طول دوره رشد تعیین شد. این آزمایش روی دو رقم برنج حساس و نیمه‌حساس انجام گرفت. مرگ‌ومیر حشرات کامل پس از ۲۴، ۴۸ و ۷۲ ساعت بعد از تیمار ارزیابی شد. عصاره‌ها به‌طور معنی‌داری باعث کاهش یا جلوگیری از خروج حشرات کامل بید غلات شدند. هم‌چنین طول دوره رشد افزایش یافت و کاهش وزن بذرهای برنج متوقف شد. مرگ‌ومیر حشرات کامل بیدغلات در رقم فارو ۴۴ که با عصاره پترولیوم اتر تیمار شده بودند، به صددرصد رسید.اما رقم فارو ۵۲ با ۳ درصد از همان عصاره مرگ‌ومیر به صددرصد رسید. کم‌ترین مرگ‌ومیر حشرات کامل روی رقم فارو ۴۴ و فارو ۵۲ با عصاره برگ اتانولی ۱ درصد به‌ترتیب به ۳۰/۳۳ و ۳۵/۲۰ درصد رسید. نتایج نشان داد که تلفیق عصاره برگ آفتابگردان با رقم حساس فارو ۵۲ مرگ‌ومیر حشرات کامل بید غلات و طول دوره رشد را افزایش می‌دهد. پودر و عصاره‌های این گیاه می‌توانند در مقیاس تجاری برای مدیریت این آفت مورد استفاده قرار گیرند.

واژگان کلیدی: آفتابگردان، بید غلات، ارقام برنج، حساسیت، مرگ‌ومیر