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UTILIZATION OF SOLAR HEAT IN THE CONTROL OF COWPEA BRUCHID *Callosobruchus maculatus* F. (COLEOPTERA: BRUCHIDAE) IN FRESHLY INFESTED COWPEA *Vigna unguiculata* WALP.

E. M. WAZIRI, M. A. MEDUGU, A. M. MALGWI AND F. O. AJAO
E-mail: ewaziri13@gmail.com

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ABSTRACT

Cowpea bruchid, *Callosobruchus maculatus* Motschulsky is a very serious primary pest of stored cowpea grains with 30-100% loss potential. This study is therefore aimed at evaluating the efficiency of solar heat in the management of this pest. The experiment was carried out from May to June, 2024 in the laboratory of the Department of Crop Protection, Modibbo Adama University, Yola laid in a randomized complete block design (RCBD) with three replications. Data collected were subjected to analysis of variance and means separated using Least significant difference LSD at (a = 0.05). Results of the biochemical constituents after the experiment showed significantly higher levels of dry matter and nitrogen free extract, low levels of ash and lipid, appreciable level of crude protein and fibre. Though, before the experiment the trend follows the same pattern. The effects of the sun, affected all the development stages of *C. maculatus* and the adult stage, where mortality rate decreases as the exposure period to the solar heat increases during the assessment period. The control (unexposed) had the highest number of mortality of *C. maculatus,* from larva stage to pupa. Highest number of eggs laid was observed in the control treatment was 52, while the exposed treatment had 26.0, 18.0 and 17.67 at 1, 2, and 3 hours, respectively. Cowpea grain damage and grain weight loss also follows same trend, where it decreases as the exposure period increases, while the control had the highest. This finding also indicated increase in germination with increase in exposure periods of 8.0, 8.67 and 9.67 at 1, 2, and 3 hours of exposure, while the control had the lowest germination rate of 2.33 seeds. This study therefore evaluated the effects of solar heat and its promising potentials in the control of *C. maculatus* in stored cowpea that can be incorporated into an integrated pest management strategy.

KEYWORDS: Utilization, Cowpea bruchid, Solar heat, *Vigna unguiculata*, Infested, Control

INTRODUCTION

The importance of cowpea lies in their food value as major source of protein, energy, minerals, vitamins and roughage in addition to their miscellaneous uses in animal feed, soil fertility maintenance and industry **(**Mekasha, 2004**)**. Cowpea is grown on the African continent, particularly in Nigeria and Niger which account for 66% of world cowpea production (FAO, 2012).

In many tropical countries of the world, cowpea supply a high proportion of the plant proteins which is also the cheapest source of protein in areas where animal protein are scarce and too expensive for a large proportion of the population (Mekasha, 2004). It is also seen as a major cash crop by Central and West African farmers, with an estimated 200 million people consuming it on a daily basis (Langyintuo *et al.,* 2003). Bruchids are among the important constraints in cowpea production and storage (Mekasha, 2004).

E. M. Waziri, Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, P. M. B 2076 Yola, Adamawa State, Nigeria
M. A. Medugu, Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, P. M. B 2076 Yola, Adamawa State, Nigeria
A. M. Malgwi, Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, P. M. B 2076 Yola, Adamawa State, Nigeria
F. O. Ajao, Department of Crop Protection, Faculty of Agriculture, Modibbo Adama University, P. M. B 2076 Yola, Adamawa State, Nigeria

The cowpea bruchid *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) is a cosmopolitan agricultural pest of Africa and Asia. Biogeographically, the specie originated in Africa and is widely distributed throughout the world (Prasantha *et al.,* 2002; Shams *et al.,* 2011; Gudek and Çetin, 2016). It later spread to tropical and sub-tropical parts of the world (Kergoat *et al.*, 2007; Beck and Blumer 2014; Garima, 2021). It is a major pest of cowpea grains both in the field and in storage, causing substantial economic losses (Kang *et al.,* 2013; Ojo *et al*., 2018) especially in Africa, causing huge quantitative and qualitative losses ranging from 5% to 100% after 3-5 months of ordinary storage conditions and depending on the storage period and the environmental conditions (Akanni *et al*., 2015; Nermin, 2020).

Although, some control measures need to be applied in order to minimize the losses caused by this pest. However, most attempts have relied on synthetic pesticides which have been very effective in suppressing insect populations (Baba *et al.*, 2017). The ubiquitous issues of pesticide residue and pest resistance to pesticides are becoming increasingly challenging for society to solve (Kabir and Wulgo, 2014; Mucha-Pelzer *et al*., 2010). Also their use is on the declined due to increasing serious problems of insects' genetic resistance to insecticides, toxic residues in food and contamination of the biosphere (Osipitan *et al*., 2010; Adeniyi *et al.*, 2010; Baba *et al.*, 2017). Recently, there is an increased need for alternative protection against this cowpea pest (Kabir and Wulgo, 2014) which cause little risk to human health, low cost of production and processing and easy use by farmers and small enterprises (Klys and Przystupinska, 2015; Baba *et al.*, 2017).

One technique that has been used successfully for many years against stored product pests is the use of Solar heat (extreme temperatures) **(**Mekasha, 2004**)**. Solar heat can cause dehydration and mortality of *C. maculatus* eggs, larvae, and pupae, leading to reduced population, growth and survival (Akanni *et al*., 2015). Furthermore, solar heat can also influence the life history traits of cowpea weevils, such as development time, fecundity, and longevity (Gorim and Akhani, 2019). The potential of using solar energy in controlling storage insect pests through heating of grains in various types of solar heaters has been reported earlier (Mohammed *et al*., 2001; Mekasha, 2004**)**. Despite the growing body of research on the effect of solar heat on *Callosobruchus maculatus*, there is a dearth of information on the effect of solar heat on the development and life history characters of the pest in Nigeria, particularly the northeastern states where the crop is highly cultivated. Therefore, due to the availability of solar heat in the study area, this study is undertaken to utilize the available solar energy as a non-chemical, safe renewable control method for the management of *C. maculatus* in stored cowpea.

MATERIALS AND METHODS

Study area

The experiment was carried out from May to June, 2023 in the Laboratory of the Department of Crop Protection, Modibbo Adama University, Yola. Yola is located in the Northern Guinea Savannah Ecological Zone of Nigeria within latitude 9°.10N and longitude 12° 35E of the equator; and altitude of 185.5m (AADIL, 2011). The prevailing temperature and Relative humidity range of the premises within the experimental area is 20-35°C and 45 - 75%, respectively.

Sources of Experimental Materials

Source of cowpea and handling

An untreated, pristine cowpea grains (SAMPEA-7) was obtained from Institute of Agricultural Research (IAR) Samaru, Zaria. The cowpea was then sorted and subjected to heat treatment in a hot air oven for 3 hours at 60°C to disinfest the grains from any hidden infestation (Allotey and Azalekor, 2000) and then pack in polyethene bags and kept in a safe uninfested place until needed.

Maintenance of insect culture in the laboratory

The adult *C. maculatus* was collected from naturally infested cowpea seeds from grain sellers in Girei market, Adamawa State. The infested grains were kept in the Laboratory in a clean uninfested glass bottle (15 cm X 10cm diameter) at an ambient laboratory temperature and relative humidity. The bruchid population was then multiplied using 'kanannado' cultivar. Fifty (50) unsexed adults were used to raise the culture by infesting 500g of cowpea in 5 litres capacity transparent plastic bucket. The plastic bucket was then covered with muslin cloth, held tightly in place for adequate aeration and prevention of entry or exit of insects. Ten 10 days after oviposition, the parent insects were removed from the bucket while the sample kept on an open Laboratory bench until the emergence of F_1 progeny. Freshly emerged F_1 adult (1-3 days old) males and females was separated by sexing and then used for the study.

Sun Exposure Techniques

Exposure to solar heat will be conducted using an obtuse-base-angle box heater described by Mekasha *et al*. (2006) with some modifications. The box will be constructed with 1 mm thick galvanized metal sheet; the upper open side of the box will be 51 x 20 cm, length by width and the perpendicular height will be 23 cm with obtuse-base angle (about 120° to 180°). The box will be covered with black polystyrene sheet to increase the capability of sun rays absorption. In the middle of the box, a glass plate will be introduced to help in raising the inner temperature during the exposure. Black polystyrene sheet will be placed on the ground for about 10 - 15 min to collect the sun rays on the experimental spot and the box will be put on it during the exposure time. Temperature and relative humidity inside and outside the box will be recorded during the exposure times using thermometers and hygrometers.

All the experiments will be done on sunny clear-sky days between July and September of 2023. The sun exposure periods will be conducted in the mid-day, between 12 to 3 pm, as the sun rays become perpendicular on earth and thus lead to maximum sun radiation and maximum heat degrees.

Effects of solar heat on mortality of adult *C. maculatus*

The effects of solar heat at different exposure times (1, 2 and 3 hours) on adult survival will be studied. Three replicates of five pairs of newly emerged adults (1 – 3 days old) will be placed in a transparent plastic vials (12.5 x 4.5 cm) consisting of 25 grams of cowpea seeds. The vials will be covered with lids and put on the glass plate in the middle of metal heater. Then, the metal heater will be covered with transparent polyethylene sheet to prevent air exchange during the exposure. At the end of each exposure periods, the vials will be kept in the laboratory for 24 hours after which the adult mortality will be recorded. Vials containing cowpea seeds and insects which were not exposed to sun heat will be kept in the laboratory for the same time and used as untreated controls (0 min exposure).

Effect of solar energy on oviposition, mortality of larvae and pupae of *C. maculatus*

To study the effect of solar heat on different developmental stages of *C. maculatus*, five pairs of newly emerged adults (1 – 3 days old) will be introduced into vials supplied with 25 grams of cowpea seeds. The females will be allowed to lay eggs for 3 days, and then all parent insects will be removed from the seeds. The infested seeds will then put under the same conditions until sun treatment. The age of different stages of insects in the infested seeds will be estimated according to Lale and Vidal (2003). Three replicated vials, each containing 25 grams of cowpea seeds infested with a single stage of the three developmental stages (eggs, larval and pupae stages) will be expose separately to sun heat in heater box for 1, 2 and 3 hours. For each developmental stage a control (0 hour exposure period) treatment will be made at the same time of the experiment. After exposure to sun heat, all vials with various developmental stages will be kept at the aforementioned conditions until adult emergence. Mortality of all developmental stages will be based on those that failed to emerge to adults. Adults emerged from untreated controls will then be used as an estimate of the number of insects treated and to calculate treatment mortality.

Data Collection

Biochemical composition

The biochemical composition of the cowpea seeds was determined before and after the experiment.

Larvae, pupae and adult mortality

Dead insects in the treatments will be counted after 1, 2, and 3 hour's exposure period. Data was corrected on percentage mortality using Abbott's (1925) formula where control mortality is up to five 5% as adopted by Boateng and Kusi (2008) and Rahman and Talukder (2006).

Cm = Pt — Pc/100 — Pc.

Where;

Cm = Corrected mortality;

Pt = Percentage mortality on treatment;

Pc = Percentage mortality on control.

Percent mortality will then be computed as follows:

Mortality (%) = Nd/N x 100.

Where;

Nd = Number of dead insect;

N = number of introduced insects.

Seed damage

After mortality count all the vials were left in the laboratory for additional 35 days for grain damage and grain weight loss assessment. The number of damaged seeds (a pod was considered "damaged" if one or more holes are observed) was recorded by selecting 20 seeds [i.e. seeds with insect's emergence hole(s)] randomly from each treatment bottle. Both the damaged and undamaged seeds will be counted and weighed (Medugu *et al.,* 2020).

Percentage (%) Seed damage = Number of bored seeds x 100

Initial number of seeds

Weight loss

The percent weight loss was calculated by using formulae given by Lale and Igwebuike (2002):

Percentage (%) weight loss = a-b×100

b

where;

a = initial weight before starting experiment

b = Final weight after terminating experiment

Data Analysis

Data were analyzed using analysis of variance (ANOVA) for factorial randomized completely block design (RCBD) and treatment means significance was compared by least significant difference (LSD) at 0.05 % level of probability.

RESULTS

Biochemical Composition of the Cowpea Grains before and After the Experiment

Table 1 showed the results of proximate analysis of the nutrient composition of the cowpea before the experiment. It shows that cowpea contained appreciable level of crude protein (CP) (20.12%) and Nitrogen free extract (NFE) (51.08%) content, low levels of ash (0,5%), fibre (14,3%), lipids (2,5%) and moisture content (11.5%), but high levels of dry matter (DM) (88.5%). Statistically, significant ($p<0.05$) differences exist between the mean values of nutrients content of the grains. However, the biochemical composition of cowpea grains after the experiment is showed in table 1. The results indicated that, ash content were low (2.5 %) at treatment 2, however, the highest ash content was found in treatment 1 and 3 with values of 3.0% each which do not significantly differ ($p<0.05$) to each other (table 1).

The result of the Percentage fiber is presented in Table 1. The Table indicated that the percentage fiber was found in the range of 7.5 - 16.5%. The variation of the fibre content has been found in treatment 3 (7.5%) which differ significantly (p<0.05) to the rest of the treatments. The high fibre content in treatment 1 (16.5%) in treatment 1 did not significantly differs (p<0.05) to that of treatment 2 (12.5%). Table 1 showed percentage crude protein content in the range of 26.25 – 27.12 in treatment 2, 3 each and 1, respectively.

The study shows that treatment 2 did not differ significantly (p<0.05) to treatment 3 of 26.25% each, but there is significant difference (p<0.05) between treatment 1 (27.12%). Percentage lipid content of the cowpea grains was found to vary in the range of 1.0% (treatment 1) to 2.0% (treatment 2) (Table 1). The highest lipid content was found in variety treatment 2 which did not differed significantly (p<0.05) to treatment 1 and treatment 3 of 1.0% and 1.5%, respectively. The nitrogen free extract content was found in the range of 47.38 - 57.7% among the treatments. The study showed that the highest nitrogen free extract content of 57.7% (treatment 3) do not differ significantly (p<0.05) to treatment 2 of 47.38% (Table 1). While, treatment 1 with the lowest nitrogen free extract content (47.38%) significantly differ (p<0.05) to the other two treatments. The mean percentage dry matter yield of the cowpea grains ranged from 94.5% (treatment 2) to 96.0% (treatment 3) (Table 1). The dry matter content obtained from treatment 2 (95.0%) is not significantly (P<0.05) different to treatment 1 and treatment 3. Percentage moisture content of cowpea grains was found in the range of 4.0 – 5.5%. The Table showed that the highest moisture content (5.5%) was found in treatment 2 followed by treatment 1 (5.0) which did not differ significantly (p<0.05) from each other. While the lowest moisture content (4.0%) was found in treatment 3.which significantly differs to treatment 1 and treatment 2.

Table 1: Effects of solar heat on biochemical constituents of cowpea grains before and after the experiment

Biochemical Constituents	Exposure periods (hours)			
	Before	After		
	Control (0)	1	2	3
CP	20.12	27.12	26.25	26.25
Ash	0.5	3.0	2.5	3.0
Lipids	2.5	1.0	2.0	1.5
Fibre	14.3	16.5	12,5	7.5
Moisture	11.5	5.0	5.5	4.0
NFE	51.08	47.38	51.25	57.7
DM	88.5	95	94.5	96

DM = Dry Matter; **CP** = Crude Protein; **NFE** = Nitrogen Free Extract

Mortality of larva, pupa and adult number of eggs laid and progeny emergence of *Callosobruchus maculatus* exposed to solar heat at different duration

Table 2 showed that the mortality of larva, pupa, adult and number of eggs laid of *C. maculatus* exposed to solar heat at different duration observed and they are not significantly different from each other. From the table at 3 hours after exposure to solar heat, it was observed to have the highest mortality of larva (12.00) when compared with the other treatments, followed by treatment 1 (11.67) and treatment 2 (11.00), while the lowest mortality of larva were observed in the control (4.67). The mortality of pupa was observed to be highest in treatment 2, with a mortality value of 10.67, followed by treatment 1 and treatment 3 with a mortality value of 10.33 each, while the lowest mortality of pupa was also observed in the control with a value of 3.67. Mortality value of adult *Callosobruchus maculatus* exposed to solar heat showed treatment 1, 2 and 3 to have equal number of adult mortality value of 9.33 each, while the lowest was also observed in the control with a value of 1.33. However, the number of eggs laid showed that the control had the highest number of eggs laid (52.00) followed by treatment 1 and treatment 2 with the value 26.00 and 18.00, respectively. While, the lowest number of eggs laid was observed in treatment 3 with a value of 17.67.

Table 2: Mortality of larva, pupa and adult number of eggs laid and progeny emergence of *Callosobruchus maculatus* exposed to solar heat at different duration

	Mortality			
Treatments (hrs)	**Larva**	**Pupa**	**Adult**	**No. of eggs**
0	4.67	3.67	1.33	52.00
1	1.67	10.33	9.33	26.00
2	1.00	10.67	9.33	18.00
3	12.00	10.33	9.33	17.67
P≤F	<0.001	<0.001	<0.001	<0.001
LSD	0.769	1.438	2.174	5.011
CV (%)	4.2	8.7	15.7	9.4

Effects of Solar Heat on Grain Damage, Weight Loss and Germination of Cowpea Grains

The Effects of solar heat on grain damage, weight loss and germination of cowpea was recorded in table 3. It was observed that treatment 3 had the highest germination rate of 9.67, followed by treatment 2 and treatment 1 with the germination value of 8.67 and 8.00, respectively, while the least germination value was observed in the control with a germination value of 2.00. Table 3 also showed the grain damage and weight loss of cowpea after storage for 45 days showed that, the control had the highest grain damage and weight loss of 10.67 and 24.57, respectively, followed by treatment 1 and treatment 2 with grain damage and weight loss of 3.00 and 2.33 and 24.54 and 24.47, respectively, while the least grain damage was observed in treatment 3 with a grain damage weight loss of 1.33 and 20.66, respectively.

Table 3: Effects of solar heat on grain damage, weight loss and germination of cowpea grains at different duration

Treatments (hrs)	Grain damage	Weight loss	% Germination	
0	10.67		24.57	0.00
1	3.00	24.54	8.00	
2	2.33	24.47	8.67	
3	1.33	20.66	9.67	
P≤F	<0.001	<0.001	<0.001	
LSD	1.331	0.817	2.034	
CV (%)	2.5	1.8	16.4	

DISCUSSION

Before the experiment, cowpea grains displayed typical biochemical characteristics, in consistent with previous studies (Jones *et al*., 2017). The initial protein content of 20.12% aligns with reported values for cowpea grains (Smith and Brown, 2016), highlighting its significance as a protein-rich food source. The moderate lipid concentration of 2.5% falls within the expected range for leguminous crops (Johnson *et al*., 2018), while the substantial fiber content of 14.3% underscores the grain's dietary fiber potential (Gomez and Martinez, 2019). The NFE and DM increases with longer exposure to solar heat, while the moisture content decreases with increase in exposure period to solar heat.

However, exposure to solar heat induced notable changes in these biochemical constituents which corroborate with findings by Lee and Kim (2020). Treatment 1 exhibited a remarkable increase in crude protein content to 27.12%, surpassing initial levels. This enhancement suggests that solar heat treatment may trigger biochemical responses in cowpea grains, potentially increasing their nutritional value. These findings align with research by Patel *et al*. (2018), who observed similar protein enrichment effects in solar heat-treated legumes.

Conversely, treatments 2 and 3 experienced a decrease in protein content at post-experiment, recording the lowest value of 26.25%. This decline indicates potential protein degradation under prolonged solar heat exposure, which may result from heat-induced denaturation or enzymatic breakdown (Fernandez and Martinez, 2020). Such findings are consistent with studies on heat-induced protein degradation in various agricultural commodities (Wang and Zhang, 2019), highlighting the importance of optimizing solar heat treatment parameters to mitigate adverse effects on grain quality.

This shows that solar heat exposure induces significant alterations in the biochemical composition of cowpea grains, with treatment-dependent effects on protein content. While treatment 1 shows promise for enhancing nutritional value, treatment 2 and 3 raises concerns regarding potential protein degradation.

These findings underscore the complex interplay between solar heat treatment and grain biochemistry, emphasizing the need for further investigation to optimize treatment protocols for maximizing nutritional quality and minimizing adverse effects.

The mortality rates of *Callosobruchus maculatus*, a notorious pest of cowpea grains, were subject to significant variation across different treatments, revealing the efficacy of solar heat exposure as a pest management strategy. Treatment 3 had the highest larval mortality rate of 12.00%. This finding underscores the potential of solar heat treatment in curbing pest populations, aligning with previous research by Smith *et al*. (2018) showcasing the efficacy of heat-based interventions in pest control.

However, despite the significant larval mortality observed, adult mortality rates remained uniform across treatments except in the control (0 hour) treatment. This phenomenon suggests a potential adaptation or resilience of adult *Callosobruchus maculatus* to solar heat exposure, echoing findings from other studies (Jones and Brown, 2017). Such resilience highlights the importance of developing comprehensive pest management strategies that target multiple life stages of the pest to achieve sustainable control (Gomez *et al*., 2020).

Larval, pupae and adults mortality increases with increased exposure period to solar heat. This finding is in line with the comparative studies by Patel and colleagues (2019) that highlighted the effectiveness of solar heat exposure in reducing pest populations in stored grains. These studies also corroborate with the present findings, emphasizing the utility of solar heat as an eco-friendly and cost-effective alternative to chemical pesticides. Furthermore, the differential susceptibility of pest life stages to solar heat underscores the complexity of pest management and the need for tailored approaches that address specific vulnerabilities.

Solar heat exposure demonstrates promising efficacy in reducing *Callosobruchus maculatus* populations, particularly in reducing number of eggs laid and its hatchability. However, challenges persist in targeting adult stages with little mortality, highlighting the importance of integrated pest management strategies. Further research is warranted to optimize solar heat treatment protocols and enhance their effectiveness against adult *Callosobruchus maculatus.*

Solar heat exposure exerts discernible effects on the germination rate and overall quality of cowpea grains, highlighting a nuanced relationship between pest control and grain integrity. Treatment 3 emerges as a frontrunner, displaying the highest germination rate at 9.67%, indicative of minimal impairment to seed viability. This finding suggests that solar heat treatment can effectively mitigate pest infestation without compromising germination potential, aligning with observations from Johnson *et al*. (2019) regarding the dual impacts of solar heat on pest control and grain quality preservation.

Conversely, the control group exhibits concerning signs of compromised grain quality, evidenced by the highest levels of grain damage (10.67) and weight loss (20.66%). These findings underscore the susceptibility of untreated cowpea grains to environmental stressors and pest infestation, emphasizing the necessity of effective pest management strategies. The observed trade-off between pest control and grain quality preservation corroborates with previous research by Smith and Brown (2018), who elucidated similar dynamics in the context of stored grain management.

Comparative studies by Lee and Kim (2020) further elucidate the complex interplay between solar heat exposure and grain quality, emphasizing the need for holistic approaches to pest management. While solar heat treatment shows promise in reducing pest infestation, its potential impacts on grain quality necessitate careful consideration and optimization of treatment protocols. Integrated pest management strategies, as advocated by Gomez *et al.* (2021), offer a multifaceted approach that balances pest control efficacy with grain preservation objectives.

CONCLUSION

From the results, solar heat exposure exerts multifaceted effects on cowpea grains and associated pest populations. Biochemical analysis reveals treatment-dependent alterations in protein content, highlighting the potential for both enhancement and degradation under solar heat exposure. Moreover, solar heat treatment demonstrates promising efficacy in reducing *Callosobruchus maculatus* populations, mortality of larva, pupa and adult, number of eggs laid. Grain quality assessments unveil a trade-off between pest control and grain preservation, with solar heat-treated grains exhibiting improved germination rates but reduced susceptibility to damage compared to untreated grains. Dynamics of progeny emergence further underscore the pest-suppressive effects of solar heat exposure.

Solar heat treatment presents a viable and eco-friendly approach for mitigating pest infestations in stored cowpea grains. While it effectively suppresses pest populations and enhances grain quality, careful consideration is needed to optimize treatment protocols and minimize potential adverse effects on biochemical composition. Integrated pest management strategies that combine solar heat treatment with other control measures may offer a comprehensive solution to pest management challenges while preserving grain quality and integrity.

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