ISSN 1996-3351

Asian Journal of Biological Sciences

http://knowledgiascientific.com

Knowledgia SCIENTIFIC
A Place to Publish Outstanding Research

OPEN ACCESS Asian Journal of Biological Sciences

ISSN 1996-3351
DOI: 10.3923/ajbs.2019.404.411

Research Article

Efficacy of Solar Heat Using Polypropylene Sheets to Manage *Callosobruchus maculatus* (Fab.) Infesting Stored Cowpea

[1,2]Peter Emmanuel and [2]Sule Hassan

[1]Department of Agronomy, Federal University Gashua, Yobe State, Nigeria
[2]Department of Crop Protection, Bayero University Kano, Nigeria

Abstract

Background and Objective: Cowpea bruchid *Callosobruchus maculatus* is one of the most destructive pests of cowpea seed either on the field or in storage and a major constraint to cowpea storage in Nigeria and other Nations. The objective of the study was to evaluate the efficacy of solar heat against *C. maculatus* infestation. **Materials and Methods:** Polypropylene sheets (black, blue, yellow, green and transparent) containing 100 g cowpea seeds were infested with *C. maculatus* and four exposure periods (2, 4, 6 and 8 h) with control (unexposed) were laid out in a completely randomized design and replicated four times. Data was collected on adult mortality, oviposition, egg hatchability, seed germination, weight loss and damage and subjected to two-way analysis of variance (ANOVA) using JMP 13 Computer Software. **Results:** Findings of this study show that solar heat had effect on *C. maculatus* causing significant ($P_{0.05}$) mortality at different exposure periods. Solar treated grains recorded 100% mortality of adult *C. maculatus* when compared to the control. The resulting effect of solar heat led to significant reduction in oviposition and inhibit progeny emergence to an appreciable level in treated seeds (4.7%) when compared to the control (94.7%) and had no significant effect on germination of the seeds. Also no seed damage and weight loss was observed in cowpea seeds stored for 3 months after exposure to solar heat for 6 and 8 h. **Conclusion:** It is concluded that, exposing cowpea in transparent polypropylene sheets to solar heat for 2 h can be used to effectively manage the cowpea bruchid.

Key words: Solar heat, polypropylene sheet, *Callosobruchus maculatus*, cowpea

Received: December 03, 2018 Accepted: January 30, 2019 Published: June 15, 2019

Citation: Peter Emmanuel and Sule Hassan, 2019. Efficacy of solar heat using polypropylene sheets to manage *Callosobruchus maculatus* (Fab.) Infesting stored cowpea. Asian J. Biol. Sci., 12: 404-411.

Corresponding Author: Sule Hassan, Department of Crop Protection, Bayero University Kano, Nigeria Tel: +234 8060615725

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cowpea [*Vigna unguiculata* (L.) Walp.] is a staple food and animal feed crop of significant economic importance to many households in Nigeria and other Nations[1]. It accounts for about 60% of human dietary protein intake and can provide a comparatively cheaper alternative to animal proteins in Nigeria[2]. The nutritive value of cowpea makes it an extremely important protein source to vegetarian and people who cannot afford animal protein[3].

In spite of all these derivable benefits, the production and storage of cowpea in Nigeria and other developing countries is faced with many constraints. The *C. maculatus* is reported to be one of the most destructive pests of cowpea seed either on the field or in storage[4] and a major constraint to cowpea storage[5]. According to Radha and Susheela[6], heavy infestation by *C. maculatus* on stored cowpea may cause up to 90% damage, which lead to great reduction in cowpea production. Damaged cowpea seeds are unsuitable for human consumption and cannot be effectively used for agricultural and commercial purposes as result of the substantial reduction in quality[7].

Management of *C. maculatus* on stored cowpea over the years in Nigeria and other developing nations has been primarily through the use of synthetic insecticides and fumigants. While these chemical control measures are popular and effective, their improper application has resulted to insect resistance, environmental and human health problems[2]. Also other several alternative control methods to synthetic insecticides, used to protect stored-grains from pest infestation, required technical know-how and are commercially unavailable, which our poor resource farmers, may not cope with.

The cowpea bruchids are sensitive to heat and high temperatures are fatal to them. Exposing the bruchids to temperatures above 45°C tend to kill the insects to a large extent. In view of the above; this study was conducted to evaluate the efficacy of solar heat using polypropylene sheets to manage *C. maculatus* infestation and the effect of solar heat on cowpea seed quality.

MATERIALS AND METHODS

Experimental site: The study was conducted in the vicinity of the Faculty of Agriculture, Bayero University, Kano, on sunny clear-sky days, during the months of March-April, 2017 (6 months after the growing season of 2016) and October 2017 (immediately after the growing season of 2017).

Insect culture (source and rearing): Initial culture of *C. maculatus* was obtained from an already infested cowpea seeds at Entomology Laboratory of the Department of Crop Protection, Bayero University, Kano and allowed to massively reproduce in the laboratory at ambient temperature and relative humidity on fresh and uninfested cowpea var. kanannado.

Cowpea seed treatment and maintenance: Cowpea seeds used in the experiment were obtained from the harvested cowpea Var. IT93K-452-1 planted by the Department of Crop Protection, Bayero University, Kano. The cowpea seeds were put in the freezer at temperature below 0°C for 5 days in order to kill and/or prevent any initial infestation in the seeds. After which, the seeds were removed from the freezer and laid out on the laboratory bench and covered with a screen so that the seeds can equilibrate for a period of 3 days[8].

Treatments and experimental design: The treatment consisted of coloured (Black, blue, red, yellow) and transparent (check) polypropylene sheet pouches measuring 15×10.5 cm, prepared with the aid of a press plastic sealing machine and 4 exposure periods (2, 4, 6 and 8 h) with control (unexposed) which were factorially combined and laid out in a completely randomized design with each treatment replicated four times.

Laboratory bioassay

Evaluation of solar heat against *C. maculatus* (fab.) infestation: About 100 g of cowpea seeds were put in the varying coloured polypropylene bag, thereafter the cowpea was infested with 20 sexed newly emerged 2-3 days old *C. maculatus* and the opening edge of the polypropylene bag was folded and held firmly with a masking tape. The bags containing the cowpea seed infested with the *C. maculatus* were laid out on a raised platform and exposed to solar heat for 2, 4, 6 and 8 h and the control treatment (unexposed seeds) were kept in the laboratory. At the end of each exposure periods, each treatment and replicate were returned and kept in the laboratory for evaluation.

Adult mortality of *C. maculatus*: Number of dead insects in each treatments and replicates were removed, counted and recorded at 24, 48 and 72 h after exposure. Insects were probe 3 times with a tip of pen to confirm mortality.

Oviposition: The insects were allowed to mate and oviposit for 7 days, after exposure to solar heat. At the end of the

7th day of oviposition, 50 seeds were randomly selected and number of eggs laid on the cowpea seeds were counted and recorded in each of the treatment and replicates.

Egg hatchability: Fifty seeds (13.5 g) that contain eggs were selected and placed in the varying coloured polypropylene bags containing clean and uninfested cowpea seeds (86.5 g) and exposed to solar heat. At the end of each exposure periods, the cowpea seeds were returned and kept on the laboratory bench for adult emergence. The number of adults that emerged was recorded at 25 days after the exposure.

Seed quality

Seed weight loss: After 90 days, all dead insects and other debris in the cowpea seeds were removed and the cowpea seeds were weighed to obtain the final seed weight.

Percentage seed weight loss were calculated as follows:

$$\text{Weight loss (\%)} = \frac{(\text{IGW - FGW})}{\text{IGW}} \times \frac{100}{1}$$

Where:
IGW = Initial seed weight
FGW = Final seed weight

Seed damage: After 90 days, 100 seeds were taken randomly from the kept lots. The seeds were separated into damaged and undamaged categories. The damaged seeds were counted.

Percentage seed damage was calculated as described by Sibakwe and Donga[9]:

$$\text{Seed damage (\%)} = \frac{\text{Number of seeds damaged}}{\text{Total number of seeds}} \times \frac{100}{1}$$

Seed germinability: Ten seeds were randomly selected from the different polypropylene bags exposed to different solar heat periods including that of the control (not exposed to solar radiation) and another set of cowpea seeds not infested with *C. maculatus* (uninfested control) but exposed to solar heat for 8 h were also set along for the germinability test of the cowpea seed in order to determine the effect of solar heat treatment on the cowpea seeds. The seeds from each treatment were placed on a moistened Whatman filter paper in 9 cm Petri dishes and left on laboratory benches at room temperature and relative humidity[10]. Each treatment was replicated three times. Subsequent watering of the seeds was done with distilled water from a wash bottle to avoid contamination of the seeds. Germination count was taken at the 5th day of sowing. Germination percentage of the cowpea seeds were calculated from germination data according to Olisa *et al.*[11]:

$$\text{Germination (\%)} = \frac{\text{Number of emerged seedlings at the final count}}{\text{Total number of seeds planted}} \times \frac{100}{1}$$

Data analysis: The original mortality data were corrected by Abbott's formula for natural mortality in untreated controls[12]. Numerical data collected were transformed using square root transformation $\sqrt{n+1}$ and the corrected mortality and other data obtained in percentages were arc sine transformed and subjected to two-way analysis of variance (ANOVA) using JMP 13 Computer Software. Differences between significant means were separated using Student-Newman-Keuls (SNK) test at 5% level of probability.

RESULTS

Effect of solar heat enhanced by polypropylene sheets on adult mortality of *C. maculatus*: Results of adult mortality of *C. maculatus* at 24, 48 and 72 h after termination of exposure to solar heat for 2, 4, 6 and 8 h at 6 months and 1 week after harvest are presented in Table 1. At 6 months after harvest, highest mortality (94.2%) was recorded in transparent sheet 24 h after exposure and was significantly different ($p \leq 0.05$) from blue (89.9%) and black (89.3%) coloured sheets. Also at 48 h after exposure, transparent sheet had the highest mortality (95%) and was different ($p \leq 0.05$) from black sheet (91.5%). However, at 72 h after exposure, the highest mortality (97.3%) was recorded in black sheet but different ($p \leq 0.05$) from blue sheet (92.6%). At one week after harvest, there was no significant differences ($p \geq 0.05$) observed in the mortality of adult *C. maculatus* on cowpea seeds in the polypropylene sheets at 24, 48 and 72 h after exposure. This implies that the temperature generated inside the coloured sheets was sufficient enough to kill the insects.

When exposure period was considered, at 6 months after harvest, 100% mortality, was recorded in 4, 6 and 8 h exposure periods, 24 h after exposure and was significantly different ($p \leq 0.05$) from 2 h (97.2%) and control (7.7%) treatment. Conversely, 100% mortality was recorded in 2 h exposure, 72 h after exposure and was different ($p \leq 0.05$) from the control (30.9%) treatment. At one week after harvest, 100% mortality was recorded in all the exposure periods 24 h after exposure and were significantly different from the control (1.4%) treatment.

Table 1: Mean mortality of adult *C. maculatus* at 24, 48 and 72 h after termination of exposure on cowpea seeds in polypropylene sheets exposed to solar heat for 2, 4, 6 and 8 h after infestation

	Mean adult mortality (%)					
	6 months after harvest			1 week after harvest		
Treatments	24 HAT	48 HAT	72 HAT	24 HAT	48 HAT	72 HAT
Polypropylene sheets						
Transparent	94.2 (76.04[a])*	95.0 (77.11[a])	96.4 (79.08[a])	92.2 (73.84)	92.2 (73.84)	92.8 (74.49)
Green	93.3 (75.08[a])	94.3 (76.26[a])	96.9 (79.98[a])	91.4 (72.92)	91.4 (72.92)	91.4 (72.92)
Yellow	91.5 (73.06[ab])	93.6 (75.42[a])	96.9 (79.96[a])	91.3 (72.86)	91.3 (72.86)	92.7 (74.43)
Blue	89.9 (71.50[b])	93.8 (75.60[a])	92.6 (74.21[b])	91.4 (72.92)	91.4 (72.92)	92.6 (74.21)
Black	89.3 (70.97[b])	91.5 (73.04[b])	97.3 (80.57[a])	91.8 (73.33)	92.3 (73.97)	93.0 (74.62)
SE±	1.094	0.740	0.627	1.155	1.141	0.924
Exposure period (h)						
2	97.2 (80.46[b])	98.4 (82.83[b])	100 (90.00[a])	99.97 (89.08[a])	99.97 (89.08[a])	100 (90.00[a])
4	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
6	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
8	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
Control (unexposed)	7.7 (16.19[c])	17.3 (24.61[c])	30.9 (33.81[b])	1.4 (6.80[b])	1.7 (7.45[b])	3.5 (10.68[b])
SE±	1.094	0.740	0.627	1.633	1.141	0.924

*Values in parenthesis are arc sine values to which SE are applicable. Means followed by same letter(s) within same column are not significantly different at p = 0.05 according to SNK test, HAT: Hours after termination of exposure

Table 2: Mean number of eggs laid by adult *C. maculatus* 7 days after introduction on cowpea seed in polypropylene sheets exposed to solar heat radiation for 2, 4, 6 and 8 h

	Mean number of eggs laid	
Treatments	6 months after harvest	1 week after harvest
Polypropylene sheets		
Transparent	3.18[b]	2.16
Green	3.18[b]	2.39
Yellow	3.77[ab]	2.26
Blue	3.21[b]	2.23
Black	4.06[a]	2.21
SE±	0.242	0.202
Exposure period (h)		
2	4.94[b]	1.29[b]
4	2.44[c]	1.00[b]
6	1.60[d]	1.00[b]
8	1.38[d]	1.00[b]
Control (unexposed)	7.02[a]	6.96[a]
SE±	0.242	0.202

Means followed by same letter(s) within same column are not significantly different at p = 0.05 according to SNK test

Effect of solar heat enhanced by polypropylene sheets on oviposition by *C. maculatus*: Table 2 shows the number of eggs laid by adult *C. maculatus* 7 days after introduction on cowpea seeds in polypropylene sheets exposed to solar heat radiation for 2, 4, 6 and 8 h. At 6 months after harvest, lower number of eggs (3.18) were laid in transparent sheet and was significantly different ($p\leq 0.05$) from the highest number of eggs(4.06) in black sheet. At 1 week after harvest, there was no significant difference ($p\geq 0.05$) observed in the number of eggs laid in all the polypropylene sheets.

Table 3: Mean number of *C. maculatus* eggs hatched on cowpea seed in polypropylene sheets 25 days after exposure to solar heat for 2, 4, 6 and 8 h

	Mean number of eggs hatched	
Treatments	6 months after harvest	1 week after harvest
Polypropylene sheets		
Transparent	2.48[c]	3.17[c]
Green	2.81[bc]	3.29[c]
Yellow	4.20[a]	4.20[a]
Blue	3.12[b]	3.66[b]
Black	3.16[b]	3.67[b]
SE±	0.147	0.086
Exposure period (h)		
2	3.30[b]	4.53[b]
4	3.38[b]	3.61[c]
6	2.02[c]	2.62[d]
8	1.67[c]	1.09[e]
Control (unexposed)	5.39[a]	6.14[a]
SE±	0.147	0.086

Means followed by same letter(s) within same column are not significantly different at p = 0.05 according to SNK test

When exposure period was considered, at 6 months after harvest, highest number of eggs laid (7.02) was recorded in the control and was significantly different ($p\leq 0.05$) from the remaining treatments. Lowest number of egg laid (1.38) was recorded in 8 h exposure period but not different ($p\geq 0.05$) from 6 h (1.60). At 1 week after harvest, same trend was also observed, as highest number of eggs laid (6.96) was recorded in the control and was significantly different from the remaining treatments.

Effect of solar heat enhanced by polypropylene sheets on egg hatchability of *C. maculatus*: Table 3 shows the number

Table 4: Mean germination (%) of cowpea seeds infested with *C. maculatus* in polypropylene sheets exposed to solar heat for 2, 4, 6 and 8 h

	Mean seed germination (%)	
Treatments	6 months after harvest	1 week after harvest
Polypropylene sheets		
Transparent	99.60 (86.48)*	91.00 (72.58)
Green	94.09 (76.95)	89.6 (71.22)
Yellow	92.09 (74.58)	88.2 (69.91)
Blue	94.09 (76.95)	86.7 (68.60)
Black	94.02 (76.10)	85.00 (67.20)
SE±	3.164	2.614
Exposure period (h)		
2	98.04 (82.87)	88.7 (70.42)
4	92.07 (74.40)	86.90 (68.80)
6	97.03 (80.66)	87.7 (69.44)
8	94.09 (82.77)	92.1 (73.76)
Control(unexposed/infested)	93.08 (75.63)	86.5 (68.45)
Control (exposed/uninfested)	90.08 (72.38)	86.6 (68.55)
SE±	3.465	2.863

*Values in parenthesis are arc sine values to which SE are applicable

Table 5: Mean seed damage (%) caused by adult *C. maculatus* on cowpea seed in polypropylene sheets exposed to solar heat radiation for 2, 4, 6 and 8 h after 3 months of storage

	Mean seed damage (%)	
Treatments	6 months after harvest	1 week after harvest
Polypropylene sheets		
Transparent	2.5 (9.00)*	7.2 (15.66)
Green	14.1 (22.08)	16.4 (23.95)
Yellow	20.6 (27.00)	20.6 (27.00)
Blue	14.6 (22.50)	14.6 (22.50)
Black	4.0 (11.48)	7.6 (15.98)
SE±	5.562	4.663
Exposure period (h)		
2	7.3 (15.66^{b})	9.4 (17.83^{b})
4	2.5 (9.00^{b})	0.61 (4.50^{c})
6	0.00 (0.00^{b})	0.0 (0.00^{c})
8	0.00 (0.00^{b})	0.0 (0.00^{c})
Control (unexposed)	85.2 (67.40^{a})	98.4 (82.77^{a})
SE±	5.562	4.663

*Values in parenthesis are arc sine values to which SE are applicable. Means followed by same letter(s) within same column are not significantly different at p = 0.05 according to SNK test

of eggs hatched on cowpea seeds in polypropylene sheets 25 days after exposure to solar heat for 2, 4, 6 and 8 h. At 6 months after harvest, yellow polypropylene sheet recorded higher number of eggs hatched (4.20) and significantly different ($p \leq 0.05$) from the remaining sheets. However, least number of eggs hatched (2.48) were recorded in transparent sheet. Same trend was also observed at 1 week after harvest.

When exposure period was considered at 6 months after harvest, highest number of eggs hatched (5.39) were recorded in the control and was significantly different ($p \leq 0.05$) from all the exposure periods, while the lowest number of eggs hatched (1.67) was recorded in 8 h exposure period but not different ($p \geq 0.05$) from 6 h (2.02). At 1 week after harvest, same trend was also observed as the control treatment recorded high number of eggs hatched and was significantly different ($p \leq 0.05$) from the remaining treatments.

Effect of solar heat on seed germination of cowpea seeds: The results obtained from the germination of cowpea seeds infested with *C. maculatus* in polypropylene sheets exposed to solar heat for 2, 4, 6 and 8 h are presented in Table 4. The result shows there was no significant differences ($p \geq 0.05$) observed in the germination of cowpea seed in the different polypropylene sheets and at different exposure periods at both 6 months and 1 week after harvest. This indicates that solar heat had no adverse effect on the germinability of cowpea seeds kept in different polypropylene bags and exposure periods.

Effect of solar heat treatment on weight losses and damage of stored cowpea by *C. maculatus* infestation: Table 5 present the percentage seed damage caused by *C. maculatus* on cowpea seed in polypropylene sheets exposed to solar heat at different exposure periods. The results reveals there were no significant difference ($p \geq 0.05$) in the number of seed damage recorded in all the polypropylene sheets at both 6 months and 1 week after harvest. However, when exposure periods were considered, at 6 months after harvest, highest percentage (85.2%) of seed damage was recorded in the control and was significantly different from all the exposure periods. Same trend was also observed at 1 week after harvest, the control had the highest percentage (98.4%) of seed damage which were significantly different ($p \leq 0.05$) from all the exposure periods.

The results of percentage seed weight loss caused by *C. maculatus* on cowpea seed in polypropylene sheets exposed to solar heat at different exposure periods are shown in Table 6. The results revealed that there was no significant difference ($p \geq 0.05$) in the percentage seed weight loss recorded in all the polypropylene sheets at both 6 months and 1 week after harvest. However, when exposure periods are considered, more percentage (38.60%) of seed weight loss were recorded in the control and was significantly different ($p \leq 0.05$) from all the exposure periods.

DISCUSSION

The prospect of utilizing solar energy for disinfesting stored products has great potential in storage pest management. According to Chauhan and Ghaffar[13] heating

Table 6: Mean seed weight loss (%) caused by adult *C. maculatus* on cowpea seed in polypropylene sheets exposed to solar heat for 2, 4, 6 and 8 h after 3 months of storage

	Mean seed weight loss (%)	
Treatments	6 months after harvest	1 week after harvest
Polypropylene sheets		
Transparent	0.65 (4.61)*	2.6 (9.22)
Green	1.60 (7.21)	2.1 (8.41)
Yellow	4.50 (12.25)	4.5 (12.29)
Blue	4.00 (11.61)	2.1 (8.41)
Black	0.83 (5.24)	1.6 (7.23)
SE±	2.714	2.614
Exposure period (h)		
2	1.20 (6.47[b])	2.3 (8.76[b])
4	0.33 (3.28[b])	0.08 (1.66[b])
6	0.00 (0.00[b])	0.0 (0.00[b])
8	0.00 (0.00[b])	0.0 (0.00[b])
Control (unexposed)	28.40 (32.17[a])	38.60 (38.40[a])
SE±	2.714	2.614

*Values in parenthesis are arc sine values to which SE are applicable. Means followed by same letter(s) within same column are not significantly different at p = 0.05 according to SNK test

grains in polymers, may raise the temperature of the seeds to a level lethal enough to eradicate storage insect like the bruchids. The results of this study showed that exposing cowpea seeds in polypropylene sheets to solar heat at different exposure periods significantly reduced the population of the cowpea bruchid. These findings further supports the ideas of Murdock *et al.*[14] that cowpea grain enclosed in plastic sheeting when exposed to sunlight, the temperature within the envelope rises rapidly more than adequate to kill all stages of the cowpea weevil. The high mortality recorded in cowpea seed exposed to solar heat in transparent polypropylene sheets when compared to the remaining polypropylene colour sheets is in agreement with Prasanthi *et al.*[15] report, which showed seeds can be kept under the sun in small transparent polyethylene bags and if maintained for 10-15 min can increase grain temperature up to 60°C which is lethal to all live stages of pulse beetles present in pulses. It was established in the report of Mounica and Natarajan[16] that mortality of adult *C. maculatus* exposed to solar heat increases with exposure time as seen in the findings of the current study that the mortality of the adult *C. maculatus* increased in proportion to time that the infested grains were kept under the sun. Also the findings further support the idea of Pareek and Kumawat[17], who reported that significantly high mortality of adult *C. chinensis* on cowpea seeds were achieved at different exposure periods when exposed to solar heat.

The current study found that solar heat treatment reduces the number of eggs laid by adult of the cowpea "bruchids" lower than that deposited by adults kept under laboratory condition. These bruchid exposed to the sun heat significantly results match those observed in earlier studies. According to the report of Alice *et al.*[18], it was established that exposure of *C. maculatus* adults to solar heat at a temperature of 50°C for 2, 4 and 6 h decreased the oviposition in *Vigna subterranea*. According to Mounica and Natarajan[16], solarization of seeds infested with bruchid reduced oviposition as time of exposure to the sun increased, with increase in exposure of cowpea seeds infested there was significant reduction in number of eggs laid in the heat-treated cowpea as compared to control.

The resulting effect of solar heat led to significant inhibition of progeny development in exposed seeds when compared with the control. The findings of the current study are in agreement with those of Moumouni *et al.*[19], who reported that exposure of cowpea pods to sun radiations considerably limits the evolution of populations of weevils and their parasitoids. The report of Mounica and Natarajan[16] showed that by exposing eggs of cowpea weevil to increased temperature and time, adult emergence was significantly lower from eggs that were exposed to the sun for 3 h than from those that were exposed for only 1 h which was also observed in this study, egg hatchability decreases as exposure period increases.

This study confirmed that exposing cowpea seeds in polypropylene sheets to solar heat had no significant effect on the germinability of the seeds. This finding is in agreement with previous research works that have examined the effects of solar heat on the germinability of seeds exposed to solar heat. Pareek and Kumawat[17] reported that exposing cowpea seed infested with *C. chinensis* for 7 h to solar radiation showed no any adverse effect on seed germination. The report of Maina and Lale[20] showed that cowpea seeds were expose for a maximum duration of 4 h and does not adversely affect their germinability.

The current study found that exposing cowpea seeds in polypropylene sheets to solar heat for different exposure periods significantly reduced and/or prevent the losses caused by *C. maculatus* infestation on stored cowpea. These findings further support the idea of Prasanthi *et al.*[15] who reported that Solar heating can reduce *Callosobruchus* spp. damage in cowpea. The report of Ragaa *et al.*[21] showed that utilization of heat provides quality grain protection and continues to be one of the best alternatives as it is easy, fast and offers residue-free disinfestations of grain. The results further support the findings of Alice *et al.*[18] which showed that sun drying provided adequate protection of black gram seeds against infestation by *C. maculatus* and by increasing the exposition time to sun light the number of bruchid adults decreased drastically. Also, Maina and Lale[20] report showed that damage on cowpea seeds exposed to solar heat was reduced to a great extent as the exposure time increases.

CONCLUSION AND RECOMMENDATIONS

In the current study, the utilization of solar heat treatment enhanced by polypropylene sheets against the cowpea bruchid significantly suppressed the population and development of *C. maculatus* without affecting seed germinability and was able to prevent the quantitative and qualitative losses caused by the cowpea bruchid in storage. Therefore, based on the outcome of this research work, it is recommended that exposing cowpea in transparent polypropylene sheets to solar heat for 2 h can be used to effectively manage cowpea bruchid and the management practice can be done on a clear sunny sky immediately after harvest.

SIGNIFICANCE STATEMENT

This study discovered that exposing cowpea in transparent polypropylene sheet can be beneficial for the management of *C. maculatus* infestation in storage. The temperature generated within the exposed bags were suitable for heat treatment of stored-product insects which significantly suppressed the population and progeny emergence of *C. maculatus* without affecting seed germinability and was able to prevent the seed damage and weight losses caused by the cowpea beetle in storage. This study will help the researchers uncover critical areas of finding an alternative control measure to chemical pesticides that will be safety to the environment, grain handlers and consumers, lowcost and maintenance of grain cleanliness, that many researchers were not able to explore. To our knowledge is the first report of combine effect of solar heat and polypropylene sheets on oviposition and progeny emergence of *C. maculatus* in Nigeria. Thus a new technique on the utilization of transparent polypropylene sheets as a simple solar collector in controlling storage insect pest using heat treatment may be arrived at in the Nigerian Savanna regions.

REFERENCES

1. Akunne, C.E., B.U. Ononye and T.C. Mogbo, 2014. Evaluation of the efficacy of mixed leaf powders of *Vernonia amygdalina* (L.) and *Azadirachta indica* (A. Juss) against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Adv. Biosci. Bioeng., 1: 86-95.
2. Adesina, J.M., A.R. Jose, Y. Rajashaker and L.A. Afolabi, 2015. Entomo toxicity of *Xylopia aethiopica* and *Aframomum melegueta* in suppressing oviposition and adult emergence of *Callasobruchus maculatus* (Fabricus) (Coleoptera: Chrysomelidae) infesting stored cowpea seeds. Jordan J. Biol. Sci., 8: 263-268.
3. Adeyemi, S.A., F.B. Lewu, P.O. Adebola, G. Bradley and A.I. Okoh, 2012. Protein content variation in cowpea genotypes (*Vigna unguiculata* L. Walp.) grown in the Eastern Cape province of South Africa as affected by mineralised goat manure. Afr. J. Agric. Res., 7: 4943-4947.
4. Moravvej, G. and S. Abbar, 2008. Fumigant toxicity of citrus oils against cowpea seed beetle *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Pak. J. Biol. Sci., 11: 48-54.
5. Musa, A.K., A.A. Oyerinde and F.O. Owolabi, 2009. Evaluation of the efficacy of mixed leaf powders of *Vernonia amygdalina* L. and *Ocimum gratissimum* Del. against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Acad. J. Entomol., 2: 85-87.
6. Radha, R. and P. Susheela, 2014. Efficacy of plant extracts on the toxicity, ovipositional deterrence and damage assessment of the cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae). J. Entomol. Zool. Stud., 2: 16-20.
7. Lale, N.E.S. and F.A. Ajayi, 2001. Suppression of development of *Callosobruchus maculatus* (F.) (Col.: Bruchidae) in bambara groundnut seeds exposed to solar heat in the Nigerian savanna. J. Pest Sci., 74: 133-137.
8. Ileke, K.D., O.O. Odeyemi and M.O. Ashamo, 2013. Varietal resistance of some cowpea cultivars to cowpea bruchid, *Callosobruchus maculatus* (Fab.) [Coleoptera: Chrysomelidae] infestation. FUTA J. Res. Sci., 9: 72-81.
9. Sibakwe, C.B. and T. Donga, 2015. Laboratory assessment of the levels of resistance in some bean varieties infested with bean weevils (*Acanthoscelides obtectus* and *Zabrotes subfasciatus*). Int. J. Plant Soil Sci., 4: 124-131.
10. ISTA., 2006. International Rules for Seed Testing. International Seed Testing Association, Zurich, Switzerland, pp: 33.
11. Olisa, B.S., S.A. Ajayi and S.R. Akande, 2010. Physiological quality of seeds of promising African yam bean (*Sphenostylis stenocarpa* (Hochst. ex A. Rich) Harms) and pigeon pea (*Cajanus cajan* (L.) Millsp) landraces. Res. J. Seed Sci., 3: 93-101.
12. Abbott, W.S., 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol., 18: 265-267.
13. Chauban, Y.S. and M.A. Ghaffar, 2002. Solar heating of seeds-a low cost method to control bruchid (*Callosobruchus* spp.) attack during storage of pigeonpea. J. Stored Prod. Res., 38: 87-91.
14. Murdock, L.L., D. Seck, G. Ntoukam, L. Kitch and R.E. Shade, 2003. Preservation of cowpea grain in sub-Saharan Africa-Bean/Cowpea CRSP contributions. Field Crops Res., 82: 169-178.
15. Prasanthi, S.J., K. Rajesh and M.K. Chakravarty, 2017. Non-chemical methods for the management of pulse beetles-A review. J. Entomol. Zool. Stud., 5: 1526-1533.
16. Mounica, D. and N. Natarajan, 2016. Bio-thermal seed treatment device-an innovative technology of heat treatment for the management of bruchids, *Callosobruchus maculatus* Fab on black gram. Int. J. Farm Sci., 6: 176-186.

17. Pareek, Y. and K.C. Kumawat, 2013. Effect of sunshine exposure and different colour polythene bags on pulse beetle, *Callosobruchus chinensis* (Linn.). Pest Manage. Hortic. Ecosyst., 18: 226-227.
18. Alice, J., R.P. Sujeetha and N. Srikanth, 2013. Effect of hot and cold treatments for the management of Pulse beetle *Callosobruchus maculatus* (Fab) in pulses. IOSR J. Agric. Vet. Sci., 3: 29-33.
19. Moumouni, D.A., A. Doumma and I.S. Seyni, 2014. Effect of solar drying on the biological parameters of the cowpea weevil, *Callosobruchus maculatus* Fab. (Coleoptera-Bruchinae), in Sahelian area. J. Applied Biosci., 84: 7723-7729.
20. Maina, Y.T. and N.E.S. Lale, 2004. 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. Int. J. Agric. Biol., 6: 440-446.
21. Ragaa, M.E.E., M.A. Rita, O. Dzolkhifli, R.S. Uma and V.G. Ionel, 2017. Effect of solar heater boxes and constant temperatures on mortality and developmental stages of *C. maculatus*. IOSR J. Agric. Vet. Sci., 10: 33-38.