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Research Article
Potentials of Polypropylene Sheets in Trapping Solar Heat for the Management of *Callosobruchus maculatus* (Fab.) Infestation

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Abstract
Background and Objective: Post-harvest losses and damage caused by *Callosobruchus maculatus* in storage serves as a constraint to cowpea production in most developing Nations. The objective of the study was to evaluate the potentials of polypropylene sheets in trapping solar heat for the management of the cowpea bruchid. **Materials and Methods:** Polypropylene sheets (black, blue, yellow, green and transparent) containing 100 g of cowpea seeds with control (open seeds) was exposed to solar radiation for 2, 4, 6 and 8 h. Temperature inside the sheets was measured and recorded at 30 min' intervals for each treatments and replicates. Consequently, further experiment was conducted to investigate the effects of solar heat trapped by the polypropylene sheets against the cowpea bruchid. Data was collected on adult mortality and subjected to a two-way analysis of variance using JMP 13 Computer Software. **Results:** Findings of the study revealed significant difference in the temperature trapped by the varying coloured sheets at different exposure periods. Black and transparent polypropylene sheets recorded the highest amount of temperature trapped (52.88°C) among the colours evaluated. Furthermore, the results of the study showed that solar heat had significant ($P_{0.05}$) effect on *C. maculatus* causing mortality at different exposure periods. **Conclusion:** The technique had great potential in managing *C. maculatus*, since the highest amount of heat trapped in the polypropylene sheets is sufficiently lethal to all developmental stages stored insect pest.

Key words: Solar heat, polypropylene sheet, trapping, management, *Callosobruchus maculatus*

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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

Post-harvest losses and quality deterioration caused by the cowpea bruchid in storage are major problems throughout the world, most especially in West Africa and other developing Nations[1]. Rural families that make up the larger part of the population of these regions derived from its production, food, nutritious fodder for livestock alongside cash income[2]. In the tropics, most of the harvested produce of the peasant farmers are kept at village level using simple storage facilities[3].

The use of synthetic insecticides is the most widely adopted method of control the pest by peasant farmers[4], despite it been successfully used to protect stored grains from insect infestations, their indiscriminate and massive use have often been associated with serious problems[1] and also due to the subsistence nature of production and high poverty levels of most farmers in Nigeria and other countries in the tropics, they tend to rely on indigenous knowledge systems and use of traditional methods to preserve their stored agricultural produce and products[5].

In many zones of sub-saharan Africa, small scale farmers are harnessing the power of the sun to reduce pest damage in their stored cowpea crops. Sunning is usually done by spreading the grains on mats or threshing yard[6]. Cowpea bruchids are sensitive to heat and high temperatures are fatal to them. Exposing bruchids to temperatures above 45°C tend to kill the insects to a large extent. However, in the tropics at times temperatures from the open air are less detrimental to the insects. Heating grains in polymers as solar heat collectors, tend to rise the temperature of the seeds to a level lethal enough to eliminate the bruchids[7]. In view of the above, this study was conducted to evaluate the solar heat trapping ability of polypropylene sheets for managing cowpea bruchids.

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 and April, 2017.

Treatments and experimental design: The treatment consisted of coloured (Black, blue, green, yellow) and transparent (check) polypropylene sheet pouches measuring 15×10.5 cm and 4 exposure periods (2, 4, 6 and 8 h), with control (open seeds) which was factorially combined and laid out in a completely randomized design with each treatment replicated four times.

Evaluation of polypropylene sheets solar heat trapping ability

Heat trapping: About 100 g of cowpea seeds was place in the different coloured polypropylene bags and control (open seeds) were laid out on a raised platform outside in the vicinity of Faculty of Agriculture and the open edge of the bags were folded underneath to enable taking of temperature reading during the exposure period. The bags were exposed to solar heat for 2, 4, 6 and 8 h between 9.00 AM to 5.00 PM. Temperature inside the bags containing the cowpea seeds was measured and recorded at 30 min' intervals for each treatments and replicates using data logger (Intech Micro 2100-A16).

Effect of solar heat on adult mortality of *C. maculatus*: Different coloured polypropylene bags containing 100 g cowpea seeds were infested with 20 unsexed newly emerged 2-3 days old *C. maculatus* and the open end of the polypropylene bags were folded and held firmly with a masking tape. The bags containing the seed and *C. maculatus* were exposed to solar heat for 2, 4, 6 and 8 h, while the control treatment (unexposed seeds) was kept in laboratory. At the end of each exposure periods, that treatment and it replicates were returned and kept in the laboratory. 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 sharp pin to confirm mortality[8].

Data analysis: Data collected for solar heat trapping was analyzed using excel and data for cowpea bruchid adult mortality were arc sine transformed before subjected to a two-way analysis of variance (ANOVA) using Computer Software JMP 13. Treatment means with significant differences were separated using Student-Newman-Keuls (SNK) test at 5% level of probability.

RESULTS

Solar heat trapping ability of different polypropylene sheets exposed to solar heat: Figure 1 show the temperature trapped at different time intervals by polypropylene sheets exposed to solar heat for 2 h. The result revealed that there is increase in temperature trapped by different polypropylene sheets at different time intervals as exposure time progresses. Transparent sheets recorded the highest temperature (51.75°C) trapped at 120 min of exposure when compared with the remaining treatments, with the lowest temperature (38.00°C) trapped in the control treatment.

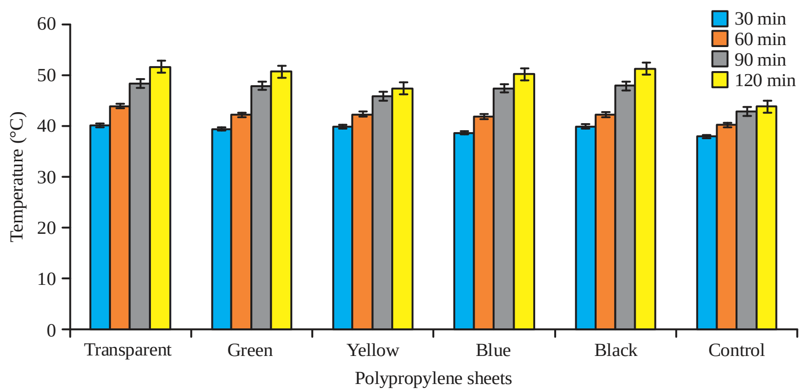

Fig. 1: Temperature trapped at different time intervals by polypropylene colour sheets exposed to solar heat for 2 h

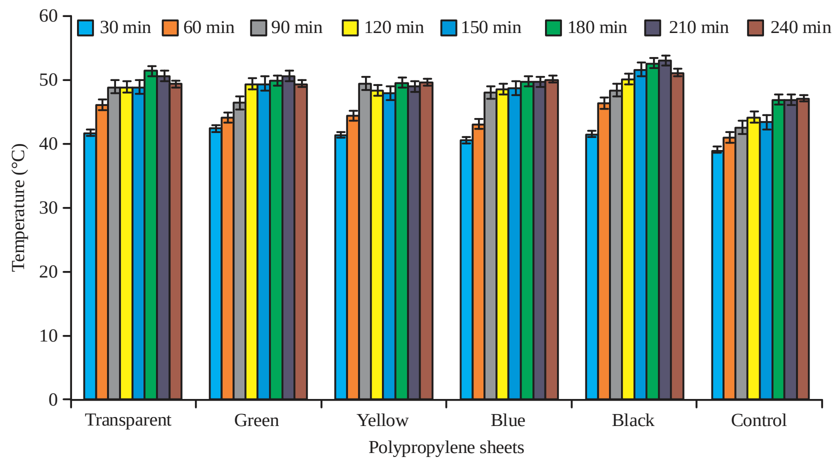

Fig. 2: Temperature trapped at different time intervals by polypropylene colour sheets exposed to solar heat for 4 h

The results from the temperature trapped at different time intervals by polypropylene sheets exposed to solar heat for 4 h are summarized in Fig. 2. Black polypropylene sheet recorded the highest temperature (52.87°C) trapped at 210 min of exposure and the control recorded the lowest temperature (39.00°C) trapped at 30 min of exposure.

Figure 3 present the result obtained from the temperature trapped at different time intervals by polypropylene sheets exposed to solar heat for 6 h. It was observed that the temperature trapped by the polypropylene sheets followed same trend with that exposed for 4 h. Black polypropylene sheet recorded the highest temperature (51.37°C) trapped at 210 min of exposure. While the control treatment recorded the lowest temperature (38.00°C) trapped at 30 min of exposure.

As shown in Fig. 4, transparent sheet at 210 min of exposure recorded the highest temperature (52.50°C) trapped among the polypropylene sheets when exposed to solar heat for 8 h, while the lowest temperature (39.12°C) trapped was recorded at 30 min in the control.

Effect of solar heat on adult mortality of *C. maculatus*: Significant interaction was observed between polypropylene sheets and exposure periods in the percentage adult mortality of *C. maculatus* at 24 h after termination (HAT) of exposure (Table 1). High (100%) mortality of adult *C. maculatus* was recorded in transparent and green sheets exposed to solar heat for 2 h and was significantly different ($p \geq 0.05$) from the remaining sheets. Furthermore, high (100%) mortality was recorded in all the polypropylene sheets exposed to solar heat for 4, 6 and 8 h. While unexposed sheet (control) had the lowest mortality (1.8%).

DISCUSSION

The results of this study indicated that there was rapid increase in the temperature trapped by different polypropylene colour sheets exposed to solar heat at different time interval as exposure time increases. The Earth receives energy radiated from the sun, which amounts to about[9] 1,000 Wm^{-2}. One way to harness that energy lies

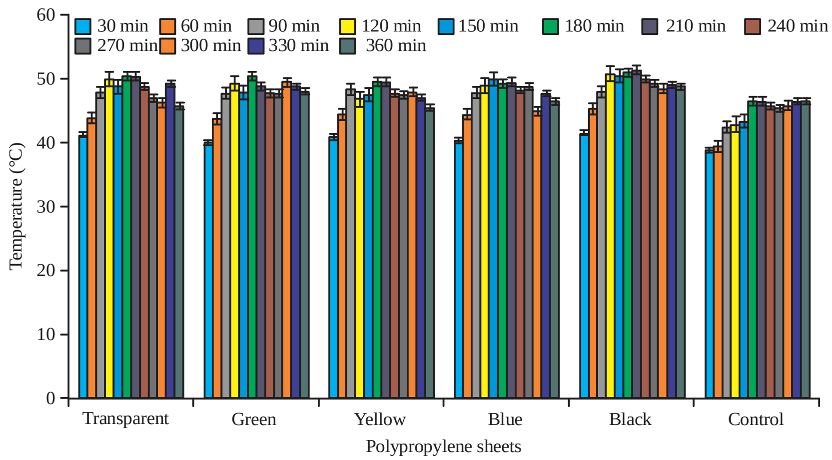

Fig. 3: Temperature trapped at different time intervals by polypropylene colour sheets exposed to solar heat for 6 h

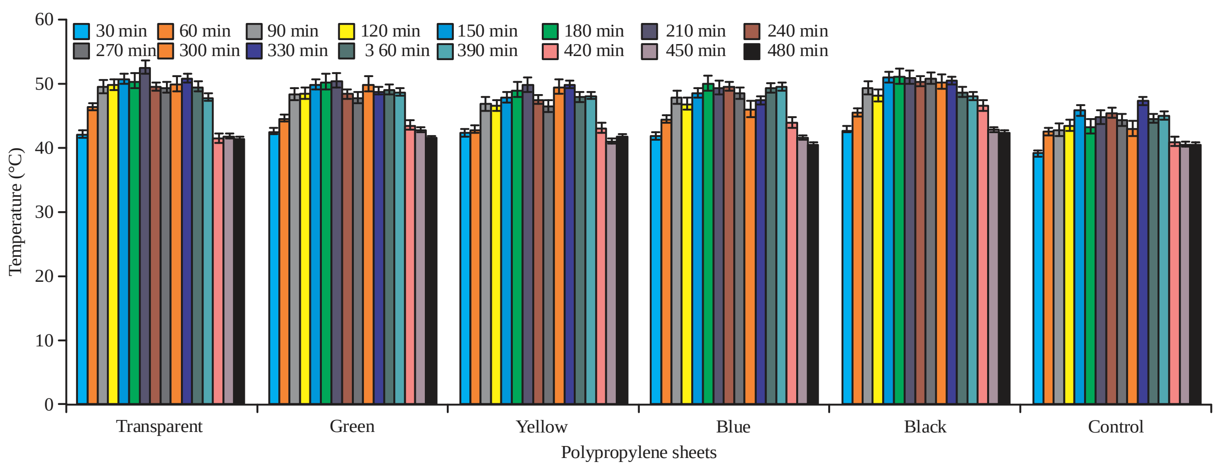

Fig. 4: Temperature trapped at different time intervals by polypropylene colour sheets exposed to solar heat for 8 h

Table 1: Interaction between polypropylene sheets and exposure time on mean adult mortality of *C. maculatus* 24 h after termination of exposure on cowpea seeds exposed to solar heat for 2, 4, 6 and 8 h

	Exposure period (h)				
Polypropylene sheets	0	2	4	6	8
Transparent	11.9 (20.17[de])*	100.0 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
Green	7.0 (15.38[e])	100.0 (90.00[a])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
Yellow	5.8 (7.96[ef])	97.7 (81.33[b])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
Blue	1.8 (7.83[f])	96.8 (79.68[b])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
Black	16.0 (23.59[d])	76.28 (61.28[c])	100 (90.00[a])	100 (90.00[a])	100 (90.00[a])
SE±			2.447		

*Figures 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

in understanding how materials absorb and reflect sunlight, then selecting those materials that are most efficient and cost-effective[10]. Findings of this study revealed that black and transparent polypropylene sheets recorded the highest temperature trapped among the colours evaluated for their ability to trap solar heat. These findings further support the idea of Murmson[11] who highlighted that every material absorbs and reflects some solar energy, the amount of solar energy a material will absorb or reflect depends on a number of physical properties. The colour and coating of a material for instance affect the amount of solar energy that an object can absorb or reflect. Black materials absorb a large amount of visible light. Therefore, darker materials will absorb more solar energy than lighter materials. The report of Papiewski[10], showed material's colour and shade affect the amount of light it absorbs or reflects, window glass for example, a transparent object is highly transparent to visible light but absorbs infrared, giving greenhouses the ability to contain heat. Also, the report of Ghosh and Dolai[12] further explained the reason for the high temperature trapped in transparent polypropylene sheets, which revealed that efficiency of solarization depends on the type of material used for solarization, because global radiation is composed of short-wave solar heat and long-wave terrestrial radiation. The shortwave solar heat passes through transparent polyethylene sheet but the long-wave terrestrial radiation is held back resulting in trapping of the heat and thereby increasing temperature, lethal to pest organisms. This study produced results which corroborates the findings of Elhadaa *et al.*[13], who evaluated the capability of materials with different thermal properties for use in solar heater boxes for trapping solar energy. They observed that at the beginning of exposure time temperatures between the seed increases as time increases, however towards the end of the exposure time temperatures decreased.

In this study high temperature of 52.87°C was achieved using polypropylene sheets as a simple technique for collecting solar energy. The temperatures achieved were suitable for heat treatment of stored-product insects. According to Seidu *et al.*[14], most stored product insects are known to succumb to death at about 40-45°C and 1 h of exposure at 45°C or more is sufficient to wipe out infestation by any developmental stages of insects. The interaction effect between polypropylene sheets and exposure time observed in this study on the mortality of adult *C. maculatus*, corroborates with the findings of Chauhan and Ghaffar[15], who reported that heating grains in polymers, may raise the temperature of the seeds to a level lethal enough to eradicate storage insect like the bruchids. 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 shown in the findings of the current study that the mortality of the weevils increases with increase in time the infested grains were kept under the sun. This study confirmed that solar heat has effect on the cowpea seed weevil causing significant mortality at different exposure periods. These findings further supported the ideas of Murdock *et al.*[17], who reported that, cowpea grain enclosed in plastic sheeting when exposed to sunlight, the temperature within the envelope rises rapidly more than adequate to kill all developmental stages of the cowpea weevil.

In this study, the highest amount of temperature attained in the polypropylene sheets was lethal enough to sufficiently wipe out any developmental stage of *C. maculatus* infesting stored cowpea seeds.

CONCLUSION AND RECOMMENDATIONS

It was observed that there was rapid increase in the temperature trapped by different polypropylene colour sheets exposed to solar heat at different time intervals as exposure time progresses. However black and transparent polypropylene sheets recorded the highest temperature trapped among the colours evaluated for their ability to trap solar heat. The high temperatures achieved (52.87°C) were suitable for heat treatment of stored-product insects which significantly suppressed the population of *C. maculatus*. Therefore, based on the outcome of this research work, it was recommended that this technique if adopted will have great potential for the management of *C. maculatus* in the Nigerian Savanna regions, considering its low cost, safety to the environment, grain handlers and consumers and maintenance of grain cleanliness.

SIGNIFICANCE STATEMENT

This study discovered that exposing cowpea in polypropylene sheets increased the temperature of the cowpea seeds. The temperature generated within the exposed bags (transparent and black sheets) was suitable for heat treatment of stored-product insects which significantly suppressed the population of *C. maculatus*. 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 on the evaluation of polypropylene sheets capacity in trapping solar energy for heat treatment against the cowpea bruchid in Nigeria. Thus a new technique on the utilization of polypropylene sheets as a simple solar collector in controlling storage insect pest may arrive in the Nigerian Savanna regions.

REFERENCES

1. Ratnasekera, D. and R. Rajapakse, 2012. The potential use of indigenous plant materials against *Callosobruchus chinensis* L. and *Callosobruchus maculatus* L. (Coleoptera, Bruchidae) in stored legumes in Sri Lanka. J. Biopest., 5: 88-94.

2. Dugje, I.Y., L.O. Omoigui, F. Ekeleme A.Y. Kamara and H. Ajeigbe, 2009. Farmers' Guide to Cowpea Production in West Africa. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, ISBN: 978-131-332-320, Pages: 20.
3. Iliyasu, M.U., G. Gabriella and C. Claire, 2013. A survey of systems of grain storage and management of insect pests in stored grain in Kebbi state. IOSR J. Agric. Vet. Sci., 3: 51-61.
4. 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.
5. Mihale, M.J., A.L. Deng, H.O. Selemani, M.M. Kamatenesi, A.W. Kidukuli and J.O. Ogendo, 2009. Use of indigenous knowledge in the management of field and storage pests around Lake Victoria basin in Tanzania. Afr. J. Environ. Sci. Technol., 3: 251-259.
6. Golob, P., C. Moss, A. Devereau, A.D. Goodland, F.H. Andan, J. Atarigya and B.M.D. Tran, 1999. Improvements in the storage and marketing quality of grain legumes: Final technical report. NRI Report 2417. Natural Resources Institute, University of Greenwich, Chatham Maritime Kent, UK., pp: 32-35.
7. Gbaye, O.A., J.C. Millard and G.J. Holloway, 2011. Legume type and temperature effects on the toxicity of insecticide to the genus *Callosobruchus* (Coleoptera: Bruchidae). J. Stored Prod. Res., 47: 8-12.
8. Obembe, O.M. and J. Kayode, 2013. Insecticidal activity of the aqueous extracts of four under-utilized tropical plants as protectant of cowpea seeds from *Callosobruchus maculatus* infestation. Pak. J. Biol. Sci., 16: 175-179.
9. REN., 2011. Global status report by renewable energy policy network for 21st century (REN21). pp: 4-9. http://www.ren21.net/
10. Papiewski, J., 2017. Materials that absorb and reflect solar energy. pp: 3. https://education.seattlepi.com/materials-absorb-reflect-solar-energy-6797.html
11. Murmsom, S., 2017. Materials that absorb and reflect solar energy. pp: 2. https://sciencing.com/materials-absorb-reflect-solar-energy-8878.html
12. Ghosh, P. and A.K. Dolai, 2014. Soil solarization, an eco-physiological method of weed control. Global J. Sci. Front. Res.: D Agric. Vet., 14: 42-44.
13. Elhadaa, R.M.E., R.M. Awang, D. Omar, U.R. Sinniah and I.V. Grozescu, 2017. Selection and evaluation of materials for solar heater boxes and their capacity in trapping solar energy. IOSR J. Agric. Vet. Sci., 10: 25-32.
14. Seidu, J.M., G.W.K. Mensah, V.K. Zah, S.A.A. Dankwah, W.K.J. Kwenin and A.A. Mahama, 2010. The use of solar dryer to control insect infestation in stored grains in Ghana. Int. J. Biol. Chem. Sci., 4: 2397-2408.
15. 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.
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. 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.