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Responses of *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae) to Coloured Polyethylene Films in Storage of *Musa* Chips

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Abstract Problems associated with synthetic pesticides have necessitated the search for an alternative pest control method. The effect of six coloured polyethylene films on *Tribolium castaneum* infestation on stored chips was studied in the Laboratory, from February to May, 2012. Three *Musa* spp (*Agbagba*, *Obino'l ewai* and cooking banana) were used. Dried chips (20 g) of each *Musa* spp were weighed into six different coloured perforated polyethylene bags (blue, red, yellow, green, black, and transparent) after further drying to constant moisture content in the oven. Ten adult beetles, comprising 5 males and 5 females were introduced into each bag tightly closed using rubber band. The experiment was a 6 × 3 factorial (6 colours polyethylene films by 3 *Musa* spp) laid out in a completely randomized design (CRD) with three replications. Results showed that there were significant differences amongst the three *Musa* species on the survival, progeny production and damage caused by *T. castaneum*. Survival counts of adult *T. castaneum* on chips stored in various coloured polyethylene bags within the period of 21 days did not differ significantly from one another. Generally all the coloured films reduced the abundance of *T. castaneum* on chips more than the colourless (transparent) films. Red coloured polybags significantly reduced beetles infestations and retained the highest weight of chips up to three months after infestation. Damage on chips stored in red coloured bags was significantly lower than those of yellow, green and transparent colours but did not differ with those of blue and black. Chips stored in transparent bags had the highest number of beetles and sustained the highest damage than other coloured polybags.

Keywords: *plantain and banana chips, red flour beetle infestation, coloured polybags, spectral qualities, post harvest loss*

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1. Introduction

Musa spp are among the major food crops in the humid and sub-humid parts of Africa and a major source of energy for millions of people in these regions (Isah *et al.*, 2009). Post harvest losses is a major problem limiting the availability of plantain and banana fruits in most *Musa* producing states of Sub-saharan Africa (Sugri and Johnson, 2009). This loss is essentially associated with incorrect systems including harvesting, transportation, packaging and storage techniques (Baiyeri, 2001). Although recent researches have evolved methods of storing fresh fingers, they are still under trial and have kept produce for a few days (Akanonwur and Sodie, 2005). Plantains and bananas can only be stored for a relatively long period of time in the form of dried chips and flour (Fayemi, 1999). Processing crops to chips helps to increase their shelf life, reducing bulkiness, improve handling, remove non-edible and unmarketable parts etc (Eze *et al*., 2006). Despite the above advantages, storage of chips has been faced with the problem of pests and moulds (Chijindu and Boateng, 2008). Various pests have been reported to be associated with stored chips including *Prostephanus spp, Carpophilus spp, Sitophilus zeamais, Cathartus quadricollis, Tribolium castaneum* etc. (Gnonlonfin *et al.,* 2008). The red flour beetle, *Tribolium castaneum* (Herbst), is one of the primary pests infesting dry stored produce. It is widely spread worldwide and very destructive (Garcìa *et al*., 2005). Infestations not only cause significant losses due to the consumption of grains, they also result in elevated temperature and moisture conditions that lead to an accelerated growth of molds, including toxigenic species (Chijindu and Boateng, 2008). To reduce the activities of this organism on stored produce, synthetic insecticides have been used. According to Richards *et al*. (2008), *T. castaneum* has demonstrated resistance to many classes of insecticides used against it especially at the adult stage. Resistance and toxicity problems derived from synthetic insecticides have made it necessary to find more effective, healthier and more ecofriendly alternatives. All living organisms have some link in their lifecycle which could be exploited for controlling their population. Photoperiodism in insects is one example that has lead to the fabrication of electrocutes used against house pest (Cantelo, 1974). In the western countries, light traps have been successfully used against household and field pests (Ashfaq *et al*., 2005). Blackmer *et al.* (2006) and Demirel and Cranshaw, (2006) have worked extensively on traps based on colour characteristics in the field and green house and reported that they are effective for controlling a variety of pests. Insects have been reported to be sensitive to a broad spectrum of light ranging from ultraviolet to red (Homberg *et al* 2008). According to this report, colour sensitivity in the UV spectrum play an important role in foraging, navigation, and mate selection in both flying and terrestrial invertebrate animals. Giurfa and Menzel (1997) also reported that insects have sophisticated visual abilities that allow them to cope efficiently with their environment, more so the compound eyes of insects are adapted not only to detect motion, but also to see colours, polarized light and geometric patterns. Meffert and Smola, (1976) and Campbell *et al.*, (2010) in their separate behavioral and electrophysiological experiments with insects reported that insect's eyes respond to ultraviolet irradiation and this response lead to several different reactions. Much has been done on the use of insects' colour responses in the control of house hold and field pests but very little information exist on the possible utilization of these colour responses in controlling storage pests. The objective of this work therefore was to assess the effect of six different coloured polyethylene (PE) on *T. castaneum* activities in stored chips

2. Materials and Methods

2.1. Tribolium Castaneum Culture

Adult *Tribolium castaneum* was obtained from stock reared in the Dept of Crop Science Teaching Laboratory of the University of Nigeria Nsukka (06° 52'N, 07° 20' E, 447.26 m a.s.l.), in plastic containers, 2000mls by volume. These were maintained in wheat flour mixed with brewer's yeast (at the ratio of 19: 1) at an ambient temperature of 27 to 30°C and relative humidity of 75 ± 5%. The *Tribolium* were sexed as pupa by examining the genital lobe or papillae under a light microscope. At the very end of the pupa are two pointed structures called urogomphi. The genital lobes are two finger-like structures just anterior to the pointed urogomphi. These papillae are much larger, longer and prominent in females while they appear like finger tips in males (Ludovic *et al.,* 2001). Males and females were kept separately until used. The containers were covered with muslin cloth for aeration and to prevent the insects from escaping.

2.2. Processing of Chips

Plantain and cooking banana used for this study [namely (i) False horn (*Agbagba*) (ii) French (*Obino'l Ewai*) and (iii) Cooking banana (*Bluggoe*)] were procured from markets around Nsukka and processed into chips. The fingers used were collected from the second to fourth hand of a fully mature (round full maturity stage) but unripe bunch (Baiyeri, 2001). The fingers were washed, peeled and cut into small round pieces (3.5 - 4 g dry weight) under water and sun dried for about one week. The processing was done during the dry season from January to February and the chips stored in air-tight containers at room temperature (27 - 30°C) and relative humidity (75 ± 5%) until they were used.

2.3. Polyethylene Collection

Bags of equal sizes (20cm × 15cm) made of polyethylene films with similar characteristics e.g. texture and thickness (0.05mm) was used for the study. The PE films were bought from Nsukka main market. Six colours were assessed for their effect on insects' activities. These colours included red, green, yellow, transparent, blue and black. These polybags were perforated using a pair of scissors. Four circular holes were made on each bag; two on each side and the holes (diameter about 0.5cm) were sealed with muslin cloth to ensure proper aeration in the bags. The temperature variation inside the bags was monitored using mercury in glass thermometers which were fastened inside each bag using rubber band.

2.4. Mortality, Progeny Production and Damage Assessment

Twenty grams dried chips of each of the three *Musa* spp were weighed into six different coloured perforated PE bags after further drying to constant moisture content in the oven. Ten adult beetles, comprising 5 males and 5 females were introduced into each bag and the bags tightly closed using rubber band. The experiment was arranged as a 6 × 3 factorial (6 colours PE films by 3 *Musa* spp) and laid out in completely randomized design (CRD) with three replications on the laboratory bench. The beetles were allowed to mate freely and reproduce. The following data were collected; weight of chips before infestation, survival count of beetles on the 7^{th}, 14^{th} and 21^{st} day after infestation, total number of live adult produced after 91 days of infestation, total number of larvae produced 91 days after infestation, weight of powder produced after 91 days of infestation, weight of chips left after 91 days of infestation and weekly temperatures inside the bags.

2.5. Calculations

1. Percentage survival was given by the fomular

$$\frac{\text{Number of live beetles}}{\text{Number introduced}} \times 100$$

2. Percentage weight loss by chips was given by;

$$\frac{\text{Weight lost}}{\text{Initial weight}} \times 100$$

3. Rate of damage was calculated by dividing the weight lost by the storage time

2.6. Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) using Genstat System for Window Version 8. Differences amongst treatment means were separated using Fishers least significant difference (F-LSD) as outlined by Obi (2002).

Table 1. Mean % survival of adult *T. castaneum* exposed to various coloured Polyethylene 7th, 14th and 21st day after infestation

Polybag Colour	Day 7	Day 14	Day 21
Red	94.44	91.1	91.1
Blue	100.0	98.9	98.9
Green	100.0	97.8	97.8
Yellow	98.9	96.7	96.7
Black	96.7	93.3	93.3
Transparent	95.6	94.4	94.4
Mean	97.6	95.4	95.4
F - LSD $_{(0.05)}$	_	_	-
Fpr	0.06	0.26	0.26

3. Results

3.1. Mortality of Adult Insects

Generally the percentage survival of adult *T. castaneum* in *Musa* chips stored in various coloured bags was high and did not differ significantly among the colours on both the 7th, 14th and 21st days after infestation (Table 1). On the 7th day, 100% survival was observed in blue and green coloured polyethylene (PE) bags while the red had the least. Blue colour maintained the highest survival (98.90%) up till the 21st day, while red continued to record the least percentage loss (91.10%).

3.2. Progeny Production and Damage Assessment

Effect of different coloured PE differed significantly across the parameters measured except on mean weight of chips. Red colour retained the highest chips weight (17.57g) 91days after infestation (Table 2) while transparent had the least (17.14g). The weight of powder showed the opposite trend to the weight of chips. Transparent recorded significantly ($p < 0.05$) higher weight of powder (0.85g) than other colours except yellow which had similar powder weight. Transparent PE had the highest percentage loss (14.34%) which was similar to yellow and green but significantly ($p < 0.05$) higher than red (12.13%) and blue (12.59%). Yellow colour (11.89) had significantly ($p < 0.05$) higher beetle count than red (9.56) and black (8.89) but similar to other colours. Larvae count in transparent was significantly higher than yellow, black and red but similar to other colours.

Table 2. Main effects of polyethylene colour on the mean weight of chips left, mean weight of powder produced, mean % weight loss, mean number of adults, mean number of larvae and mean rate of damage on different *Musa* chips 91 days after infestation

Polybag colour	Mean weight of chips left (g)	Mean weight of powder produced (g)	Mean % weight loss (%)	Mean number of adult beetles	Mean number of larvae	Mean Rate of damage (mg/day)
Red	17.57	0.51	12.13	9.56	3.22	26.72
Blue	17.48	0.61	12.59	10.67	4.67	27.52
Green	17.31	0.64	13.43	10.00	4.56	29.52
Yellow	17.24	0.81	13.81	11.89	4.33	30.34
Black	17.41	0.61	12.97	8.89	4.33	28.51
Transparent	17.14	0.85	14.34	10.89	5.78	31.43
Mean	17.36	0.67	13.21	10.31	4.48	29.03
F – LSD $_{(0.05)}$	_	0.20	1.50	1.69	1.28	3.25
Fpr	0.06	0.01	0.05	0.01	0.01	0.05

There were significant differences among chips types (*Musa* spp) on the weight of chips left, percentage weight loss, mean number of adults, mean number of larvae and the rate of damage on chips 91days after infestation (Table 3). *Obinol* had significantly ($p < 0.05$) higher chips weight (17.70g) than both *agbagba* (17.08g) and cooking banana (17.30g). There was no significant difference among the weights of powder produced by various chips. The percentage weight loss by *agbagba* was significantly higher than both *obinol* and cooking banana. *Agbagba* had the highest number of beetles (11.11) which was similar to the number obtained in cooking banana (10.44) but significantly ($p < 0.05$) higher than the number in *obinol* (9.39). Similarly, *agbagba* (5.17) had significantly ($p < 0.05$) higher number of larvae than cooking banana (3.78) but similar to *obinol* (4.50).

Table 3. Main effects of *Musa* spp on the mean weight of chips left, mean weight of powder produced, mean % weight loss, mean number of adults, mean number of Larvae and mean rate of damage 91 days after infestation

Musa chips	Mean weight of chips left (g)	Mean weight of powder produced (g)	Mean % weight loss	Mean number of adult beetle	Mean number of Larva	Mean rate of damage (mg/day)
Agbagba	17.08	0.70	14.62	11.11	5.17	32.13
Cooking banana	17.30	0.70	13.52	10.44	3.78	29.74
Obino'l Ewai	17.70	0.63	11.05	9.39	4.50	25.23
Mean	17.36	0.67	13.21	10.31	4.48	29.03
F – LSD $_{(0.05)}$	0.21	_	1.06	1.20	0.91	2.30
Fpr	< 0.001	0.485	< 0.001	0.021	0.014	< 0.001

There were no significant interaction effects of colours by chips types on survival, progeny production and damage caused by *T. castaneum* on chips as observed across the measured parameters (Table 4) but all the chips × red colour retained the highest weight while all chips types by transparent had the lowest.

Table 4. Interaction effect of polyethylene colour × *Musa* spp on the mean weight of chips left, mean weight of powder produced, mean % weight loss, mean number of adults and mean number of larvae found on the various chips 91 days after infestation

Treatment	Mean weight of chips left (g)	Mean weight of powder (g)	Mean % weight loss	Mean number of adult found	Mean number of larvae
Pa × Red	17.60	0.56	14.22	10.67	3.67
Pa × Blue	17.24	0.63	13.80	11.00	5.33
Pa × Green	17.14	0.63	14.28	9.67	4.33
Pa × Yellow	16.72	1.02	16.38	14.67	6.33
Pa × Black	17.30	0.56	13.50	9.00	5.00
Pa × Transparent	16.89	0.79	15.53	11.67	6.33
Pc × Red	17.56	0.58	12.17	9.67	2.33
Pc × Blue	17.52	0.51	12.40	11.33	5.00
Pc × Green	17.20	0.65	13.98	11.33	2.67
Pc × Yellow	17.31	0.71	13.45	10.00	3.00
Pc × Black	17.33	0.70	13.37	9.33	4.00
Pc × Transparent	16.85	1.04	15.73	11.00	5.63
Po × Red	18.00	0.39	10.00	8.33	3.67
Po × Blue	17.69	0.70	11.57	9.67	3.67
Po × Green	17.59	0.65	12.03	9.00	6.67
Po × Yellow	17.68	0.71	11.58	11.00	3.67
Po × Black	17.59	0.58	12.05	8.33	4.00
Po × Transparent	17.67	0.72	11.75	10.00	5.33
Mean	17.36	0.68	13.21	10.31	4.48
F- LSD $_{(0.05)}$	–	–	–	–	–
FPr	0.50	0.42	0.54	0.35	0.06

Pa = plantain *agbagba*, Pc = Cooking banana, Po = Plantain *Obinol ewai*.

Weekly mean temperatures of various coloured polyethylene were not significantly different from one another (p > 0.05). Transparent PE however had the highest temperature (33.97°C) followed by black PE (33.95°C) where green had the least (Table 5).

Table 5. Effect of colour on mean weekly temperatures (°C) of various polyethylene films

Polybag colour	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10	week 11	week 12	Mean
Red	37.17	35.94	35.50	33.67	33.22	34.94	31.89	32.17	33.00	33.50	32.67	32.83	33.87
Blue	37.50	35.67	35.83	33.50	32.56	34.83	31.67	31.89	33.50	32.83	32.00	32.33	33.63
Green	37.83	35.50	36.00	33.67	32.67	34.78	31.83	32.00	32.33	32.83	32.00	32.17	33.59
Yellow	37.33	35.50	35.33	33.67	32.67	35.11	31.83	32.39	32.33	32.56	32.33	32.44	33.62
Black	38.17	36.00	35.83	34.00	33.00	35.11	32.00	32.33	32.56	33.50	32.50	32.44	33.95
Transparent	37.33	36.00	35.77	34.00	33.33	34.78	31.94	32.33	33.00	34.00	32.17	33.00	33.97
Mean	37.56	35.77	35.72	33.75	32.91	34.93	31.86	32.19	32.70	33.20	32.28	32.54	33.74
F- LSD $_{(0.05)}$	–	–	–	–	–	–	–	–	–	–	–	–	
Fpr	0.09	0.54	0.42	0.66	0.29	0.90	0.97	0.75	0.38	0.01	0.26	0.34	

4. Discussion

All the coloured PE films tested except transparent reduced the multiplication of T. castaneum on chips. Red coloured films however discouraged T. castaneum activities more than other colours tested. There was no significant difference in the survival of adult T. castaneum on chips stored in various coloured bags within the period of 21 days but red colour recorded the lowest survival. This result could be attributed to the sensitivity of the beetles to the various colours. Previous researches have shown that red colour attract fewer insects when varieties of insects were exposed to the colours of the visible spectrum. For instance, Ashfaq et al. (2005) reported that red light due to its low frequency and high wavelength would attract the lowest number of insects while colours with high frequencies and low wavelength attract larger number of insects. Echezona and Offordile (2011) reported that yellow reflectance from the yellow coloured polyethylene film elicited stronger attractive responses in Podagrica spp than red, green, blue and transparent when exposed to these colours. Red colour however attracted the least number of the insects so the shading with red gave the highest yield. They also recorded lower Podagrica counts amongst the red coloured containers than other coloured containers. Chips stored in red coloured bags retained the highest weight at the end of the experimental period having reduced the multiplication and rate of damage caused by T. castaneum than other colours. Transparent PE on the other hand encourages T. castaneum activities leading to higher multiplication, greater attack and damage on chips stored in it. This result could be explained by the report of Meffert and Smola, (1976) and Campbell et al (2010) that insects' eyes respond to ultraviolet irradiation and this response leads to several different reactions. Some recent works showed that low-light orientation occurs in insects at intensities that are well below what was previously thought to be possible. For instance, Dacke et al., (2004), Warrant et al., (2004) and Greiner et al., (2005) reported that nocturnal insects can see colour and negotiate dimly illuminated obstacles during flight. When insects are exposed to light, they may go towards or away from the source of illumination (positive and negative phototaxis), they may increase or decrease the rate of their general activities, they may change their posture or move only part of their body (Bertholf, 1940). Ashfaq et al. (2005) also reported that this response varies with insect species.

5. Conclusion

Red coloured PE discouraged the activities of *T. castaneum* on chips more than other coloured PE evaluated. Red coloured film therefore showed more prospects than other coloured PE for the control of *T. castaneum* activities on stored chips. We therefore, recommend that red coloured materials be further investigated for their incorporation in the fabrication of storage materials and equipments in integrated pest management programs so that even when infestation had occurred pests population could be kept in check while other less hazardous measures are sought and tried. Coloured PE films are readily available and easily accessible in Nigerian markets and do not require special skills to be utilized. More research should be encouraged on insects colour responses and its possible utilization for controlling pests of stored produce so as to minimize the menace of this group of pests without recourse to chemicals.

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