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Research Article

Collonization and Oviposition Preference of Six Weevil Species on Various Colors of Storage Container

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ABSTRACT

Color preferences on stored product pests are useful for monitoring instrument development which based on the collonization and oviposition behavior. The research was aimed to determine the most attractive color with a certain wavelength for the tested insects. The research was conducted in laboratory condition of Plant Pest Laboratory, Department of Plant Pests and Diseases, Faculty of Agriculture, University of Brawijaya at 27 ± 2°C, RH 65 ± 5%; and day:light 12:12 hours. Study of color preferences on six species of weevil used free choice test method and set by CRD with four replications using eight colors: white, red, orange, yellow, green, blue, indigo, and purple. The observed parameters were the number of adults and eggs laid. Results showed that each stored product pest had a different preference for various colors in the range of 380–450 nm wavelength. Adults of *Sitophilus oryzae, Oryzaephilus surinamensis, O. mercator*, and *Tribolium castaneum* were more preferred to feed and lay eggs in blue color (451–495 nm), *Lasioderma serricorne* was more preferred in indigo color (445–450 nm), and *S. zeamais* was more preferred in purple color (380–444 nm). The oviposition preference revealed that there was a positive correlation between the number of females and the eggs laid.

Keywords: color, control, preference, stored product pest

INTRODUCTION

Pest attacks occur not only in plantations but also in storage areas. Stored product pest attacks on stored materials cause yield losses of 5–10%, even in severe attacks in some tropical and subtropical countries reach 50% losses (Wilbur, 1971). In addition to direct damage in reducing the weight and contaminating of storage materials, stored product pest attacks also cause indirect losses, i.e. product rejection by consumers (Rees, 2004). Some species of stored product pests that are attack on storage product, i.e. *Sitophilus oryzae, S. zeamais, Oryzaephilus surinamensis, O. mercator*, *Tribolium castaneum*, and *Lasioderma serricorne*. *S. oryzae* and *S. zeamais* are important pests in cereals, especially rice, wheat, sorghum and corn. The feeding activity of *S. oryzae* and *S. zeamais* pests cause the seeds to perforate and turn into flour due to further damage. *O. surinamensis* and *O. mercator* are secondary pests that also infest on cereals, flour, dried fruits and various types of beans. Feeding activity of *O. surinamensis* larvae in cereals can reduce the nutritional content. *T. castaneum* is the main pest in feed such as flour and is a secondary pest infesting on cereals, various types of beans, spices, coffee, cocoa, and dried fruits. At the level of severe attacks can cause discoloration and cause disagreeable odor. *L. serricorne* is the main pest in tobacco storage and also a minor pest that infests other storage product such as cereals and spices. *L. serricorne* cause a decrease in the economic value of commodities due to contamination of exuviae and the bodies of insects both living and dead (Hodges *et al*., 1996; Rees, 2004; Emery & Nayak, 2007; Sarwar, 2015).

Control technique in handling stored product pests mechanically can be done by drying, cooling and sanitizing (Sarwar, 2015). In addition, the use of synthetic insecticides through fumigation and spraying is a control technique that frequently used because it is effective and efficient in controlling stored product pests (Yuantari, 2011; Chu *et al*., 2012). Although the actual use of synthetic insecticides have a negative impact by leading to pest resistance and the presence of pesticide residues in stored materials which is unsafe for consumers (Tarwotjo *et al*., 2014). Thus, the development of control technique for several pest insect species has now led to environmental manipulation by utilizing the behavior of insects due to the stimulation (Atakan & Canhilal, 2004). One of manipulations that has been done is the use of bait with adding pheromone aggregation to attract *T. castaneum* (Rostaman *et al*., 2003). In addition, the environmental manipulation to suppress stored product pest attacks can also be done by utilizing the color preferences of storage containers. The study about the effect of stored product pest on the color preference of storage containers is limited. Every pest insect including stored product pests has a certain preference for various colors. Preferences in various colors of *Ryzhopertha dominica* and *S. oryzae* can influence the presence and number of progeny (F1) of these insects (Abo-Arab & Nariman, 2015). This study aimed to determine the collonization and oviposition preference of six stored product pests on various colors of storage containers. By understanding the color preferences to the stored product pest behaviour, it can be used as an instrument of monitoring and pest control strategies in the storage.

MATERIALS AND METHODS

The study was conducted at the Laboratory of Plant Pest, Department of Plant Pests and Diseases, Faculty of Agriculture, University of Brawijaya on February-July 2017. Insects tested were *S. oryzae, S. zeamais, O. surinamensis, O. mercator, T. castaneum,* and *L. serricorne.* This research consisted of two stages: research preparation and research implementation. Research preparation included the provision of feed, feed sterilization, measurement and adjustment of feed water content, and insect rearing. The research was carried out using the free choice test method.

Research Preparation

The feed used for mass rearing and treatment were sterilized and measured its water content. Sterilization aimed to prevent the feed from being contaminated by other organisms. The sterilization technique adopted the method by Heinrichs *et al.* (1985): the feed was put into a glass tube then placed in the freezer at -15°C for 7 days, then transferred to a refrigerator at 5°C for 7 days and then transferred to a room at 27 ± 2°C for at least 2 weeks. The water content of the feed was measured using grain moisture tester with three replications. The range of water content used was from 13.5–14% (Heinrichs *et al*., 1985).

Each type of tested insect was reared in a plastic box (1.5 cm in length, 11.5 cm in wide, and 12 cm in high). IR64 variety was used for the rearing of *S. oryzae*, Bisma corn seeds for *S. zeamais*, rolled oats for *O. surinamensis* and *O. mercator*, and wheat flour for *T. castaneum* and *L. serricorne*. Each media, consisted of feed and yeast with a composition of 19:1 (Lord, 2001; Saeed *et al*., 2008; Subedi *et al*., 2009; Mostakim & Khan, 2014). The addition of yeast to the feed is to enrich feed nutrition (Sacakli *et al*., 2013). Rearing media that have been mixed evenly were infested with tested insects in each rearing box without distinguishing the sexes. 300 adults of *S. oryzae* and *S. zeamais* were infested in a rearing box (Abo-Arab & Nariman, 2015), while *O. surinamensis, O. mercator, T. castaneum,* and *L. serricorne* was using 100 adults (Rust & Kennedy, 1993; Beckel *et al*., 2007; Sackali *et al*., 2013).

Research Implementation

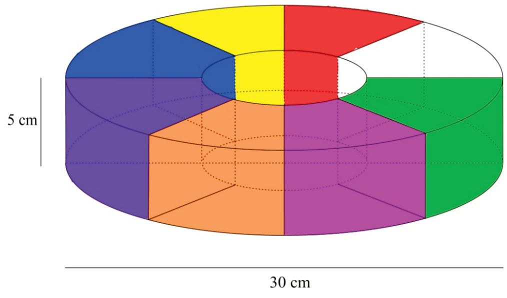
The study was conducted with free choice test method consisting of eight color treatments: white, red, orange, yellow, green, blue, indigo, and violet with the wavelengths based on Bruno & Svoronos (2005) and Starr (2005) (Table 1). The various colors used in this study refer to the seven colors of the rainbow included in the visible light spectrum, and the white color as a control (Avison, 1989). These colors are the basic colors adjusted to the Cyan, Magenta, Yellow, Black (CMYK) coloring system for red, orange, yellow, green, blue, violet and the Red, Green, Blue (RGB) coloring system for indigo (Table 1).

The study was conducted using a preference cage divided into eight colored containers according

Table 1. Wavelengths of visible and ultraviolet light

Light spectrum		Wavelength (nm)
Ultraviolet (UV)		200–379
Visible light	Violet	380–444
	Indigo	445–450
	Blue	451–495
	Green	496–570
	Yellow	571–590
	Orange	591–620
	Red	621–750

Source: Bruno & Svoronos (2005), Starr (2005)



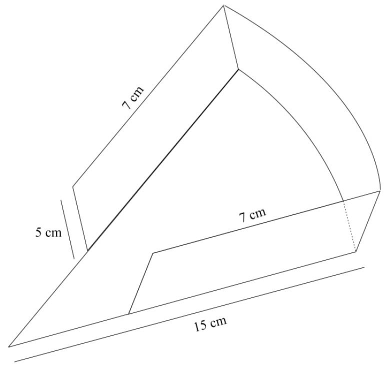


Figure 1. Preference cage: structural design (a), container structure (b)

to treatment (Figure 1). Each type of tested insects, *S. oryzae, S. zeamais, O. surinamensis, O. mercator, T. castaneum,* and *L. serricorne* were tested for their preference to the color of the storage container using preference cage. This study was arranged in a completely randomized design (CRD) with four replications. Each chamber in the cage preference was added with 30 g of feed. 40 males and 40 females of aged 1–2 weeks were infested in each preference cage. Females of aged 1–2 weeks were considered as ready to lay eggs (Stubbs, 1982). Tested insects were placed in the middle of the cage, allowed to choose the tested containers to feed and then maintained until laying eggs.

The observed variables were the number of male and female present and the number of eggs laid by tested insect in each treatment. Observation of the number of adults present and the number of eggs laid at each treatment was carried out on the seventh day after infestation (DAI). The sexing technique used for each tested insect is different. *S. oryzae* and *S. zeamais* male have relatively short rostrum with heavy irregular pitting, whereas female have relatively long rostrum with light regular pitting (Rees, 2004; Ojo & Omoloye, 2012). For *T. castaneum* adults, the distinguishing feature between male and female is on the anterior femur on the ventral surface. Male has hairy punctures while the female does not (Wahedi *et al*., 2015). Male and female of *O. surinamensis* and *O. mecator* can be distinguished by observing at the posterior femur. Male has a thorn in the middle of the hind femur, whereas the female does not (Bousquet, 1990). The difference between male and female of *L. serricorne* could be observed after immersed in 70% alcohol for 5 minutes. For the female, a V-shaped apodeme was present, while in male it is invisible (Papadopoulou & Buchelos, 2002). Egg observation techniques in *Sitophilus* spp. was done by opening the grains of rice and corn because *Sitophilus* spp. laid the eggs in the grains. *T. castaneum* laid eggs among the flour substrates, whereas *Oryzaephilus* spp. and *L. serricorne* eggs were observed between substrates and in feeding crevices (Rees, 2004).

Data Analysis

Data normality test was performed by IBM® SPSS Statistics version 20. Data were analyzed using analysis of variance (ANOVA) ($\alpha = 5\%$) and further tested using the DMRT (Duncan Multiple Range Test) ($\alpha = 5\%$). The data analysis program used was DSAASTAT® version 1.101 in Microsoft Office® Excel 2007 software.

RESULTS AND DISCUSSION

Each insect has a different preference to various colors with certain wavelengths. The visual pigment found in each insect functions as a wavelength receptor that plays a role in determining the insect preference for color. In general, the color vision system in insects depends on three or four receptors ranging from 300 nm (ultraviolet) to 700 nm (red). In flies, the wavelength that can be captured is only three spectra (trichromatic insects). Trichromatic insects are insects that have receptor pigments which sensitive to three monochrome colors, i.e. green, blue, and ultraviolet (UV). This group of insects is the numerous insect in nature and responsive to short wavelengths (Arikawa *et al*., 1987).

Preference for the Tested Insects on Various Colors of Storage Container

In general, the total adult of stored product pest species in colored storage container was more dominant in three colors, i.e. blue, violet and indigo. *O. surinamensis* was more preferred in blue container (16.50 insects) and was not significantly different from red container (12.25 insects). *S. oryzae* was more preferred in blue container (16.50 insects) while *S. zeamais* was more preferred in violet container (16.75 insects). *T. castaneum* was more preferred in blue container (13.25 insects) and was not significantly different from violet (10.75 insects), green (10.00 insects), orange (11.00 insects), and red (11.25 insects) containers, whereas *L. serricorne* was more preferred to feed in indigo container (17.75 insects) and not significantly different from blue (16.75 insects) and violet (14.25 insects) containers. The number of *O. mercator* adults present was not significantly different in all colored containers (Figure 2).

The results showed that *O. surinamensis, O. mercator, S. oryzae* and *T. castaneum* adults were more preferred in blue container, while *S. zeamais* and *L. serricorne* were in violet and indigo containers. Blue, indigo, and violet are the colors with higher mean number of adults compared to other type of color treatments (Figure 2). This is due to these colors are classified as near UV blue (380–495 nm) with the wavelength close to UV light (200–379 nm) (Table 1). Some insects are sensitive to colors with wavelengths ranging from 350–450 nm (Barghini & Souza, 2012).

In addition to genetic factors that are controlled by wavelength receptors, insect preference in color is also influenced by host conditions and insect habitat. In general, insects are attracted to colors that resemble their host color (Reza & Parween, 2006). In stored product pests, the host color is quite diverse but is dominated by white and brown colors. Stored product pest habitat on stored materials with poor lighting conditions makes the actual host color invisible or dark. This is in line with the results revealed that the mean total of adults was more preferred in the blue, indigo, and violet colors. This type of color has a lower brightness value compared to other colors (Table 2). The lower the brightness value, the darker the color is. Such conditions are similar to the habitat of stored product pest that live in storage materials.

Table 2. Brightness value of each color used in this study

Light spectrum	Brightness value
White	100
Violet	69
Indigo	51
Blue	55
Green	61
Yellow	100
Orange	94
Red	90

Remarks: Based on the brightness value in the digital hue, saturation, brightness (HSB) code in CorelDRAW® X7 software

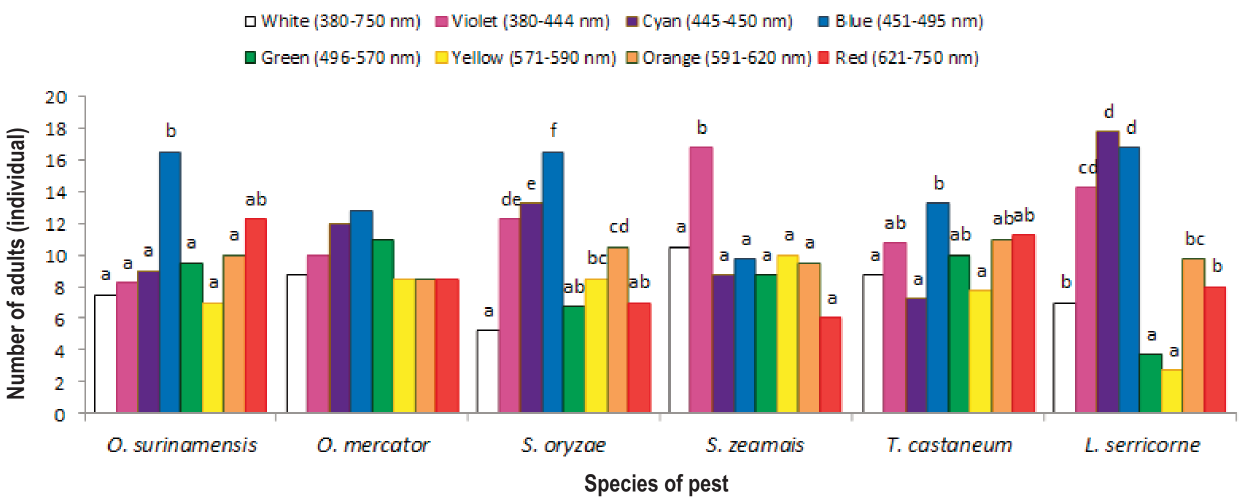


Figure 2. The total number of *Oryzaephilus surinamensis, O. mercator, Sitophilus oryzae, S. zeamais, Tribolium castaneum,* and *Lasioderma serricorne* adults were present in various colors

Table 3. The number of females and number of eggs laid of *Oryzaephilus surinamensis, O. mercator, Sitophilus oryzae, S. zeamais, Tribolium castaneum,* and *Lasioderma serricorne* on various colors

Species of pest	Research variable	Color treatment							
		White 380–750 nm	Violet 380–444 nm	Indigo 445–450 nm	Blue 451–495 nm	Green 496–570 nm	Yellow 571–590 nm	Orange 591–620 nm	Red 621–750 nm
O. surinamensis	Number of females	4.00± 0.57a	3.75± 0.47a	4.25± 0.47a	9.00± 0.41b	4.50± 0.28a	3.50± 0.64a	5.00± 0.57a	6.00± 0.57ab
	Number of eggs	30.75± 0.85a	34.25± 0.25a	35.00± 0.40a	39.25± 3.63a	39.00± 3.76a	30.75± 0.85a	30.75± 1.03a	29.00± 1.47a
O. mercator	Number of females	3.75± 0.47a	4.75± 0.47a	6.00± 0.91a	6.25± 0.47a	5.00± 0.41a	4.75± 0.47a	4.00± 0.57a	5.50± 0.75a
	Number of eggs	14.00± 0.91a	21.50± 4.25a	27.25± 8.81a	29.00± 10.41a	21.75± 5.05a	19.25± 3.92a	24.50± 6.93a	24.50± 5.63a
S. oryzae	Number of females	3.00± 0.81a	6.50± 0.57bc	6.50± 0.57bc	7.50± 0.51c	3.75 ± 0.47a	4.50± 0.28ab	5.00± 0.41ab	3.25± 0.25a
	Number of eggs[1)]	8.50± 1.55a	17.50± 0.28bcd	20.00± 0.23cd	38.75± 0.47e	16.50± 0.86bcd	13.25± 0.94bc	12.25± 0.25ab	24.25±0.47de
S. zeamais	Number of females[1)]	3.50± 0.64a	8.00± 1.58a	6.50± 1.04a	5.50± 1.19a	5.00± 0.91a	4.25± 0.75a	4.50± 0.64a	2.75± 0.47a
	Number of eggs[1]	6.50± 1.04a	36.50± 4.25d	13.75± 0.25bc	13.75± 0.47bc	12.25± 1.88ab	20.25± 3.06bcd	13.50± 0.28bc	23.00±2.34cd
T. castaneum	Number of females	4.75± 0.85a	4.50± 0.64a	5.25± 0.85a	8.00± 0.91b	5.25± 0.85a	2.75± 0.47a	5.00± 0.71a	4.50± 0.64a
	Number of eggs	43.00± 9.70a	37.50± 8.78a	60.50± 23.09a	77.00± 30.16a	72.00± 27.28a	47.25± 13.23a	70.25± 26.30a	40.50± 9.50a
L. serricorne	Number of females[2]	3.75± 0.25bc	8.75± 1.32e	9.00± 0.41e	7.00± 0.91de	1.75± 0.47ab	1.50± 0.28a	3.75± 2.50bcd	4.50±0.28cde
	Number of eggs	20.50± 0.28d	20.75± 0.95d	37.50± 1.44e	20.00± 0.71d	14.50± 0.55bc	17.50± 0.86cd	10.25± 0.25a	11.25±0.75ab

Remarks: Mean ± SD followed by the same letters in the same rows (left-right) was not significantly different according to DMRT (α = 5%), 1) data is transformed into log (x), 2) data transformed into log(x+1) for analysis purposes

Capinera & Walmsley (1978) stated that insect preferences for color can be different in each species. Stored product pests in one family (Dryophthoridae) i.e. *S. oryzae* and *S. zeamais* showed an interest in different colors, whereas in the family (Silvanidae) i.e. *O. surinamensis* and *O. mercator* have the same color preferences. In addition, three species with different families such as *S. oryzae* (Dryophthoridae), *O. surinamensis* (Silvanidae) and *T. castaneum* (Tenebrionidae) have the same color preference. This is due to the diversity of visual pigments in insects to species level (Wakakuwa *et al*., 2004).

Oviposition Preferences of Tested Insects on Various Colors of the Storage Container

Females preferred to lay eggs in blue containers were *O. surinamensis, O. mercator, S. oryzae*, and *T. castaneum,* while *S. zeamais* and *L. serricorne* were more preferred in violet and indigo containers. The observations showed that the number of females of *O. surinamensis* was more commonly found in blue containers (9 insects) and not significantly different from red (6 insects). This is in line with the number of eggs laid was more in a blue container (39.25 eggs). *O. mercator* females were more commonly found in blue container (6.25 insects) which are also directly proportional to the number of eggs laid (29 eggs). *S. oryzae* females were more preferred to feed and lay eggs in blue container (7.50 insects and 38.75 eggs). *T. castaneum* females were more commonly found in blue container (8 insects) that were significantly different from all colors of storage containers. However, the number of eggs laid by females in the blue container (77 eggs) was not significantly different from all colors of the storage container. *S. zeamais* was more commonly found in violet container (8 insects) and in line with the number of eggs laid (36.50 eggs). *L. serricorne* females were more preferred to feed and to lay eggs in indigo container (9 females and 37.50 eggs) (Table 3). The results of the correlation analysis showed that there was a positive correlation between the number of females and the number of eggs laid (Table 4).

Observing the number of eggs of *O. surinamensis, O. mercator* and *T. castaneum* showed that there were no significant differences in the entire color of the storage container (Table 3). This might be due to the color that is not a major factor in determining insects in a suitable environment for growth and development, especially for a long time. Insect preference in

Table 4. Correlation of the number of females with the number of eggs laid of each tested insect

	Species of Coleopteran tested insect					
	A	B	C	D	E	F
Correlation	0.438*	0.434*	0.399*	0.147	0.264	0.544**
Sig.	0.012	0.013	0.024	0.423	0.144	0.001

Remarks: A = *Oryzaephilus surinamensis,* B = *Oryzaephilus mercator*, C = *Sitophilus oryzae*, D = *Sitophilus zeamais*, E = *Tribolium castaneum*, and F = *Lasioderma serricorne*

oviposition is more influenced by feed availability. The feed is a source of energy for moving and copulation to lay eggs. Sjam (2004) stated that feed is a major influencing factor for insects in choosing a habitat and laying eggs. In addition, Curtis & Clark (1974) revealed that some insects can live longer and lay eggs in the environment with suitable feed conditions.

CONCLUSION

Each stored product pest species tested in this study had different preferences for collonization and laying eggs on various colors of storage containers. Adults of *S. oryzae, O. surinamensis, O. mercator*, and *T. castaneum* were more preferred to feed and lay eggs in blue container, while *L. serricorne* and *S. zeamais* were more preferred in indigo and violet container. The results of this study can be used as an alternative control by modifying the color of the storage container (silo) or warehouse paint colors other than blue, indigo, and violet in the wavelength range of 380–450 nm.

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