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Color preference and phototactic behavior in *Aphidius gifuensis* (ashmead) (hymenoptera: braconidae)

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Aphidius gifuensis, is an important natural enemy of various types of aphids. In this article the color preference behavior in response to the light intensity of Wasp (*A.gifuensis* (Ashmead) was investigated. *A.gifuensis*, is an important natural enemy of the many green plant aphids. Ten monochromatic lights of wavelengths (380 to 655 nm) were used for evaluating the reaction of *A. gifuensis* (Ashmead) to a different wavelength of light color. We used 10 monochromatic lights (emitting various specific wavelengths from 380 to 655 nm). The strongest response was observed by Blue (495nm), Green (575nm), Violet (425 nm), Ultraviolet (380nm)) and low response is stimulated to Yellow (550nm) and Purple (565nm). There was no significant spectrum response to Orange (607nm) and Red (655nm). Here we noticed that the visual system of *A. gifuensis* is composed of three spectrum receptors, adjusted to blue, green, and UV light.

Keywords: *A gifuensis*; phototaxis, light, behavior

INTRODUCTION

Wasp basically belongs to order Hymenoptera (suborder Apocrita). Usually, they are found in tropical region (Chen et al. 1979; Chen et al. 1990; Chen et al. 1991; Chen et al. 2012). They provide ecologically some important benefits, i.e. they perform a very important role as predator and also help in pollination (Chen et al., 1979; Chen et al. 1990; Chen et al. 1991; Chen et al. 2012; Wackers et al. 1994). Some of the Wasp is a natural enemy which protects our vegetables, fruits, and crops from the attack of pest. They are considered to be originated in the Jurassic Period; they are present throughout the world except for the Polar region (Schmidt et al. 1993; Laird and Wynberg, 2008). They are found in various groups, consisting of thousands of species (Chen et al. 1979; Chen et al. 2012; Wackers et al. 1994 Schmidt et al. 1993; Laird and Wynberg, 2008). Many species are explored whereas a maximum of them are not exposed or studied. *A.gifuensis* (Ashmead) is only one endoparasitoid that is suitable for biological control compare to *M. persicae* especially found in Japan and China (Fraenkel, et al. 1961; Chen et al. 1979; Zhao, et al. 1980; Menzel, and Greggers, 1985; Bi & Ji, 1993; Zhang, and Yang, 2007; Dong, 2012).

A.gifuensis (Ashmead) (Adlerz, 1976; Goldsmith, 1990; Longley, 1999; Lobdell et al. 2005; Osorio and Vorobyev, 2008; Osorio and Vorobyev, 2008; Lucchetta, et al. 2008) mostly attack on aphids in different habitats such as in the vegetables, wheat, tobacco and even found in the gardens. This species is found all over the world and also in some parts of Pakistan like Khyber Pakhtun Khwa Punjab, Sindh, and Balochistan. The introduction of the parasitoids before in the field is very helpful to control the aphid ratio in the field in the crop rising period, which can decrease the population of aphid (Powell, 1986; Lu et al. 1994; Ohta et al. 2001, 2005; Li, 2003; Kindlmann and Dixon, 2010).

A phototactic response has a very important role in animals that they move towards the light (positive phototaxis) or left from it (negative phototaxis) Lobdell et al. 2005; Osorio and Vorobyev, 2008; Osorio and Vorobyev, 2008; Lucchetta, et al. 2008). Insects can detect various spectra of light, from the wide (Chen et al. 1979; Chen et al. 2012).

Several insects display a preference for smaller wavelength such as violet, ultraviolet, and blue light but wasp *A.gifuensis* shows three points of sensitivity, at 380, 492, and 568 nm (Chen et al. 1979; Chen et al. 2012), meanwhile behavior is simply caused and reasonably stable, it has become a suitable for visual abilities in animals, mostly in insects (Schmidt et al. 1993; Laird and Wynberg, 2008). Phototaxis is an essential behavior of insects, and many years ago people using insect phototaxis to reduce pests (Chen et al. 1979; Chen et al. 2012). Color board and light trap are used to observe pests such as aphids (Schmidt et al. 1993; Powell, 1986; Lu et al. 1994; Ohta et al. 2001, 2005; Li, 2003; Laird and Wynberg, 2008; Kindlmann and Dixon, 2010).

Hymenoptera parasitoids are very important natural enemies for aphid pests as biological control and they also joined by integrating pest management to protect the crops globally (Chen et al., 1979; Chen et al. 2012). In this system (Biological control) predators, parasitoids, pathogens, herbivores, and antagonists are used to decrease populations of pests, etc. It is perceived biological control as adept over the last 120 years during which at least 166 pest and weed species have been taken under stable or short-term control. This system of pest control plays an important role in an environmental and economic sense the use of natural enemy to decrease the population density of another organism, is the cost-effective pest management methods (Chen et al. 1979; Chen et al. 1990; Chen et al. 1991; Chen et al. 2012).

Color vision:

The response of various insects to colors has been applied, or the monitoring populations of insects are used by populations (Adlerz, 1976; Goldsmith, 1990; Longley, 1999; Lobdell et al. 2005; Osorio and Vorobyev, 2008; Osorio and Vorobyev, 2008; Lucchetta, et al. 2008). Various pest management programs regularly use the color board or color sticky traps to screen or eradicate the insects (Chen et al. 1979; Chen et al. 1990; Chen et al. 1991; Chen et al. 2012).

In the animal, the visual signals are very important to conclusions, such as habitat discovery, mating, foraging, shelter, host, prey, and places for oviposition (Adlerz, 1976; Goldsmith, 1990; Longley, 1999; Lobdell et al. 2005; Osorio and Vorobyev, 2008; Osorio and Vorobyev, 2008; Lucchetta, et al. 2008). Wasps are used as biological control agent parasitoid to control several agricultural pests globally (Osorio and Vorobyev, 2008; Lucchetta, et al. 2008). Numerous species of wasp have been exposed that color can be connected with a nutrition recovery (Osorio and Vorobyev, 2008) or accessible for host Lucchetta, et al. 2008.

Hymenopterans are also very important insect pollinators. In Hymenoptera the trichromatic visual method is joint (Osorio and Vorobyev, 2008; Lucchetta, et al. 2008) and it is open to demonstrate real color vision, free of relative intensity (Peitsch et al. 1992; Chittka, and Menzel, 1992). Trichogramma can use long-range and short-range for their location cues. The long-range cues contain explosive compound signals such as male and female pheromones (Chen et al. 1979; Osorio and Vorobyev, 2008; Lucchetta, et al. 2008) that it may show common habitat zones where the hosts are likely to be recognized.

However, it is well known that hymenopterans have the capability to learn color related with a reward, in fact (Chittka, and Menzel, 1992) states that all hymenopteran species before verified exposed this capability. Parasitoids also display the capability to absorb different visual cues, including color array (Wackers & Lewis, 1994), and it has been exposed that parasitoids can absorb colors related to hosts which will successively convince ovipositor searching (Peitsch et al., 1992; Chittka, and Menzel, 1992). The Color is the main feature to distinguish among flowers and there is proof of evolutionary fine-tuning between flower color and hymenopteran color distinguishing capability (Osorio and Vorobyev, 2008; Lucchetta, et al. 2008) definitely *Aphidius* species, hymenopteran use color to differentiate between preferred and less preferred host aphid morphs.

MATERIALS AND METHODS

This experiment was carried out in the laboratory on the *A. gifuensis in* 2018*. A.gifuensis* were collected from the insectarium. The room temperature was 25±2C; 70 ± 80 % relative humidity and photoperiod provided was 16/8(L: D) h in light and dark phase. Water and some sugar solution were provided in the usage of cotton wool cushions. The almost equal population of both sexes was placed on the color board and kept for a minimum of 24 h in the experiment room to confirm sexed. After 2-3 days, we observed that adult males and females mated for some time.

The shape and size of the color board sticky trap were rectangular (25cm x 16cm). The color which is mentioned as Blue, Green, Violet, Ultraviolet, Brown, Yellow, Red, Purple, Orange, and White. The behavioral spectral characteristics of each color are monitored in 10 weeks period and the number of the (*A. gifuensis* (Ashmead) caught was noted. The data of each color board was changed to the total number of (*A. gifuensis* (Ashmead) and converted into Mean. However, the data of each color were recorded for each week separately.

Statistical analysis

The statistical data were analyzed using SPSS software and Excel Sheet 2016.

RESULTS AND DISCUSSION

The response of *A. gifuensis* to monochromatic light

Phototactic responses of *A. gifuensis* to various unicolor lights are presented in Figure 2. A substantial difference in phototactic responses was demonstrated by statistical analysis of *A. gifuensis* among treatment groups. Among the spectral ranges examined, blue light (495 nm) stimulated the strongest behavioral response from *A. gifuensis.* This was followed by green light (575 nm) and violet light (425 nm). UV (380 nm) while a low response is stimulated to Yellow (550nm), Purple (565nm). No significant spectrum response to Orange (607nm) and Red (655nm) was found (Fig 1).

Responses to different Colors

The majority of them responded to blue color second green, third to violet, and so on. The mentioned colors were blue, green, violet, ultraviolet, brown, yellow, red, purple, orange, and white. The most stimulating response color with mean values are blue, green, violet, ultraviolet, pink, and yellow (21.7, 18.4, 15.4, 12.7, 11.5, 11, 9.8) and the low preference response color was Red, purple, orange and white (8.4, 8, 7.6). The behavioral spectral characteristics of each color are mono tried on eight weeks period and the number of (*A.gifuensis* (Ashmead) caught was recorded. The data of each color board, of each color, was changed to the total number of (*A.gifuensis* (Ashmead) and converted into mean. However, the data of each color were recorded for each week separately (Table 1).

The behavioral spectral characteristics of each color at 380-655nnm were labeled. The strongest response was observed by blue, green, violet, ultraviolet (495nm,575nm,550 nm,425nm, 380 nm), and the low response is stimulated to yellow, purple (550,565). *A.gifuensis* cannot display a positive spectrum response orange and red (607,655 nm). The maximum possible reason for this is that maximum insects cannot identify lengthy wavelength light (Adlerz, 1976; Goldsmith, 1990; Longley, 1999; Lobdell et al. 2005; Osorio and Vorobyev, 2008; Osorio and Vorobyev, 2008; Lucchetta, et al. 2008). In Hymenoptera, the three classes of the photoreceptor are found such as ultraviolet, green, and blue (Peitsch et al. 1992; Chittka, and Menzel, 1992). It has been elaborated that the maximum insects keep UV ((λmax = 350 nm), blue (λmax = 440 nm) and green (λmax = 530 nm) photoreceptors (Peitsch et al. 1992; Chittka, and Menzel, 1992). Chen et al. (2012) presented that the *A.gifuensis* were the maximum sensitive to UV (380 nm), blue (492 nm), and green (568 nm) lights, and Cochard et al. in 2017 presented that that *A. ervi* were the most vigorous under UV (361 nm), blue (450 nm) and green (500–600 nm) light using LEDs, i.e. in the spectral range where green pea aphids reflect wavelengths mostly. Several insects prefer UV light (Peitsch et al. 1992; Chittka, and Menzel, 1992), suggest that the preference spectral display is important of UV in orientation methods.

A.gifuensis reacted to a wide range of light intensities (Table 2). For monochromatic light at blue (495nm), parasitoid response was positively correlated to light intensity green (575nm). For this color, the phototactic response was the strongest whereas for the color Blue (495nm), green (575nm), while for violet (425 nm) and ultraviolet (380nm) response was significantly positive and so on.

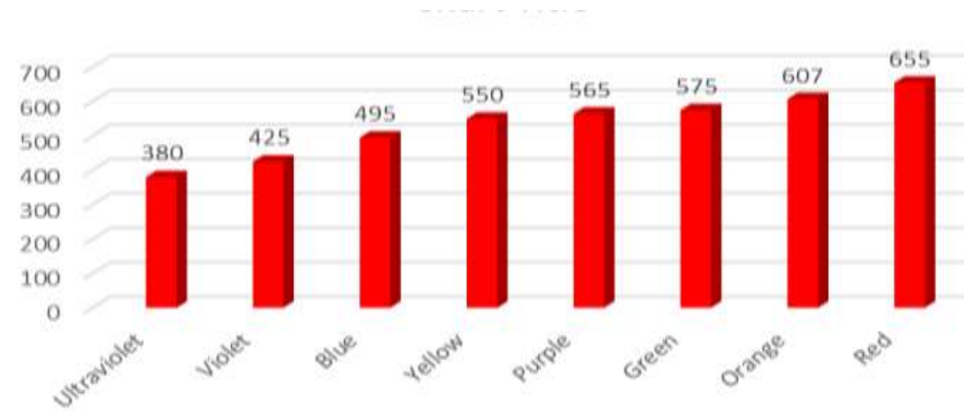

Figure 1: Representation of different wavelengths of light.

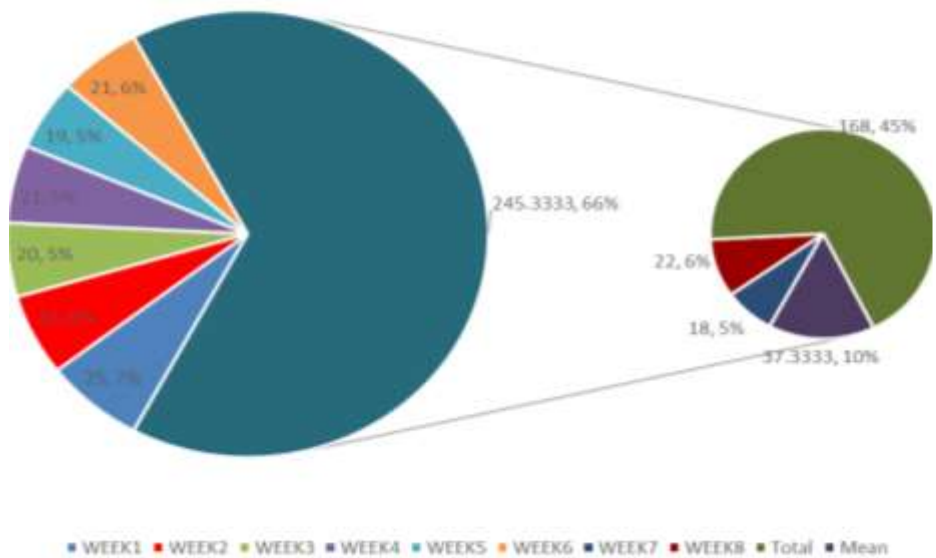

Figure 2: Representing the responses of *A.gifuensis* to a different wavelength of the color

Table 1: Population and mean number of (Wasp *A.gifuensis* (Ashmead) caught on colored sticky board
T= Treatment

Treatment	Color board	WEEK1	WEEK2	WEEK3	WEEK4	WEEK5	WEEK6	WEEK7	WEEK8	WEEK9	WEEK10	Total	Mean
T 1	Blue	25	22	20	21	19	21	18	25	24	22	217	21.7
T 2	Green	20	13	18	22	14	19	15	22	23	18	184	18.4
T3	Violet	18	9	16	19	11	15	13	19	17	17	154	15.4
T4	Ultraviolet	16	8	12	17	13	14	9	12	11	15	127	12.7
T 5	Pink	14	12	9	7	15	11	19	10	9	9	115	11.5
T 6	Yellow	9	8	10	10	16	12	16	9	8	12	110	11
T 7	Red	9	12	17	9	14	10	8	8	7	4	98	9.8
T 8	Purple	5	14	4	11	16	18	2	6	5	3	84	8.4
T 9	Orange	9	10	12	14	8	7	5	5	4	6	80	8
T 10	White	9	11	13	5	7	6	8	4	2	11	76	7.6

Certain studies have exposed that the phototactic behavioral responses of insects are stimulated within a certain spectrum of light intensity, although out of such spectrum they are inhibited (Chen et al., 1979; Chen et al., 1990; Chen et al., 1991; Chen et al., 2012). Color board and light trap are used to observe pests such as aphids (Powell, 1986; Lu et al., 1994; Ohta et al., 2001, 2005; Li, 2003; Kindlmann and Dixon, 2010).

Table 2: Correlation coefficient in response to various color in different treatments

Treatment	Blue T1	Green T2	Violet T3	Ultraviolet T4	Pink T5	Yellow T6	Red T7	Purple T8	Orange T9	White T10
Blue T1	1.0									
Green T2	0.5	1.0								
Violet T3	0.733*	0.4	1.0							
Ultraviolet T4	0.781**	0.3	0.6	1.0						
Pink T5	0.4	0.6	0.0	0.3	1.0					
Yellow T6	0.6	0.6	0.2	0.733*	.749*	1.0				
Red T7	0.688*	0.3	0.4	0.3	0.5	0.3	1.0			
PurpleT8	0.942**	0.5	.699*	.852**	0.5	0.788**	0.642*	1.0		
OrangeT9	0.929**	0.5	.689*	.862**	0.5	0.801**	0.635*	0.995**	1.0	
White T10	0.913**	0.3	.657*	.724*	0.2	0.6	0.670*	0.868**	0.847**	1.0

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

In Hymenoptera, the spectral sensitivity pattern is remarkably stable (Peitsch et al. 1992; Chittka, and Menzel, 1992). Peitsch et al. (1992) In 43 hymenopteran species, spectral sensitivity w as examined for single photoreceptor cells. Their findings indicate that, except for the ant, the visual system of the Hymenoptera consists of a UV, a blue, and a green receptor. Our research ends with, a similar outcome.*A. gifuensis* with a peculiar hymenopteran photopositive conduct. The strongest behavioral reaction from *A. gifuensis* was triggered by blue light (495 nm), accompanied by violet (425 nm) and ultraviolet (380 nm) green light (575 nm).

Our experiment also showed that it is possible and successful to use behavior to analyze insect phototaxis. In both the intensity of light and in their spectral composition, terrestrial ecosystems vary. UV light levels, for example, vary not only in elevation but also between open grasslands and thick vegetation, with forests almost entirely filtering out UV radiation (Peitsch et al. 1992). While adults with *A. gifuensis* demonstrate a kinship for going upward.

This work has confirmed that light intensity is vital in arbitrating the photopositive response behavior of *A. gifuensis*, but it was noticed that the effect differs for different wavelengths. It is still unclear, however, how light spectrum and intensity work to produce *A. gifuensis*'s phototactic behaviors. This calls for further inquiries. It is highly suggestive that *A. gifuensis* 's phototactic reaction has continued to increase with rising intensity, though using the natural enemy (*A. gifuensis*) to control different aphids, to minimize the use of chemicals (pesticides) like *M. persicae,* etc., various colored trap boards are used. Our research will help refine such trapping equipment (trap lights and colored trap boards) so that the pest is more likely to be attracted and not its natural enemy *A. gifuensis.*

CONCLUSION

A.gifuensis, is an important natural enemy of various types of aphids. In this research work, we applied 8 monochromatic lights (wavelengths from 380 to 655 nm).The strongest response was observed by Blue (495nm), Green (575nm), Violet (425 nm), Ultraviolet (380nm)) and low response is stimulated to Yellow (550nm), Purple (565nm). No significant spectrum response was observed to Orange (607nm) and Red (655nm). Here we also saw that the visual system of *A. gifuensis* has consisted of three spectrum receptors, attuned to blue, green, and UV light.

CONFLICT OF INTEREST

The authors declared that the present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

MU did the experimental work, NM analyzed the data, and wrote the paper. AK, MKUK, NU, NA, and MR helped in the analysis of the data.

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