Compatibility among Insect Predators and Light Emitting Diodes (LEDs) against the two forms of *Tetranychus urticae* in Greenhouses

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ABSTRACT: Light Emitting Diodes (LEDs) improved predation of *Scolothrips sexmaculatus* Pergande and *Stethorus punctillum* Weise on both morphs of *Tetranychus urticae* Koch under greenhouses circumstances effectively. The successful contribution of LEDs in biological control depending mainly on certain color of each predator, which able to attract it to specific pest.
S. sexmaculatus attracted to the red form ,infested strawberry , mainly under blue LEDs and caused highly reduction of the pest by 89.61 and 92.32% while white LEDs showed reduction by72.86 and 80.34% in 2012 and 2013 resp. with infestation reduction than control by 42.39 and 71.72% in 2012 and 2013, resp. Increase % than control recorded 75.12 and 96.92 with Blue LED and 42.39 and 71.72 with White LED,in 2012 and 2013 ,resp.Therefore, *S. punctillum ,* infested cowpea ,attracted to the green form under White LEDs and caused highly reduction of the pest by 91.79 and 93.20% while Blue LEDs showed reduction by74.06 and 79.27% in 2012 and 2013 resp. with infestation reduction than control by 57.90 and 50.75% in 2012 and 2013, resp. Increase % than control recorded 58.53 and 83.65 with White LED and 27.91 and 56.20 with Blue LED,in 2012 and 2013 ,resp.

Keywords: Diodes, *Scolothrips sexmaculatus* , *Stethorus punctillum* , *Tetranychus urticae* , greenhouses , strawberry and cowpea .

INTRODUCTION

Mites generally, and *Tetranychus urticae* specifically, are the most difficult to control. They cause serious damage to many vegetable crops including beans. Mites are also major problem in fruits like strawberry in greenhouse (Waite 1998). Use of chemicals leads to the development of resistance to many pesticides in many strains. Farmers are presently looking for alternative of insecticides. Biological and physical means are the best solution of this problem.

Biological control, using natural enemies, is an alternative strategy to manage mites in agricultural systems. Natural enemies play a major role in the ecology of spider mites, including ladybird beetles (Coleoptera: Coccinellidae) (Obrycki and Kring 1998; Mori *et al*. 2005), which generally accept a large number of prey species and frequently show a preference for one species (Hodek 1973), and predatory mites (Acari: Phytoseiidae) (Gotoh *et al*. 2004; Friese and Gilstrap 1985). In addition, acarophagous thrips (Thysanoptera: Aeolothripidae, Thripidae) are important natural enemies, and have various degrees of specialization on various mites; however, many species of Scolothrips commonly known as acarophagous ladybird beetles, are predators of agricultural crop pests and significantly contribute to the control of spider mite pests (Lewis 1973; Gilstrap and Oatman 1976; Roy *et al*., 2003; Gotoh *et al*., 2004). The six-spotted thrips *Scolothrips sexmaculatus* Pergande is one of the important predators of spider mite. Its adult consumes about 1000- 3000 *T. urticae* during its lifetime (Hoddle, 2004).

Scolothrips sexmaculatus Pergande and *Stethorus punctillum* Weise are the important predators of two-spotted spider mite (TSSM), *Tetranychus urticae* Koch. *P. persimilis* is available in different parts of the world

(Battablia *et al*. 1990; Bonomo *et al*. 1991; Cross *et al*. 1996; Pickel *et al*. 1996; Spicciarelli *et al*. 1992; Trumble and Morse 1993).

Pests and mainly insects' responses to light are substantially influenced by a variety of factors, including light intensity and wavelength, combinations of wavelengths, time of exposure, direction of light source, and the contrast of light source intensity and color to that of ambient light. In addition, the impact of light on insect behavior varies both qualitatively and quantitatively depending on the light source (light bulb or light-emitting diode (LED)) and material (light-reflecting plate) (Antignus 2000; Honda 2011; Johansen *et al*. 2011; Matteson *et al*. 1992 and Nissinen *et al*. 2008). The effects of lights may be directly or indirectly on pests. Directly, as insects which are able to see ultraviolet (UV) radiation, could be controlled by the same tool while future development and use light-emitting diodes is anticipated for promoting integrated pest management more safely (Shimoda and Honda 2013). Indirectly, as the impact of LEDs on volatile infochemical that elicits a strong olfactory response of the predatory mite *Neoseiulus californicus*, an important natural enemy of the two-spotted spider mite *Tetranychus urticae* (Shimoda 2010).

So the new effective direction of both physical and biological control of pests is using LEDs with its wide spectrum colors. They are able to be used as a direct tool of control and traps of pests (Chu *et al*.2004) or as attractants of predators (Chu *et al*. 2003).Beside LEDs also able to direct olfaction to adjust movements of predators to their preys correctly (Shimoda and Honda 2013).

The target purpose of this study was to determine the effect of light emitting diodes (LEDs) on the predation efficiency of *Scolothrips sexmaculatus* Pergande and *Stethorus punctillum* Weise on the two morphs of *Tetranychus urticae*, resp in 2012 and 2013 in greenhouses. Green and red forms infested cowpea and strawberry plants were exposed to two colors of LEDs and the predation on them was examined.

Materials and Methods

-Light Emitting Diodes (LEDs) in Greenhouses

Light Emitting Diodes (LEDs), with two colors, powered by solar energy were used effectively under field circumstances. LEDs provided provide an 18 h light/6 h dark photoperiod at the duration of exposure. Treatments were done under two different light colors with broad-spectrum-white LED (BSWL, 420-680 nm) and blue LED (460 nm), while control was under normal fluorescent light. Light quality and quantity were estimated using a Testo545 light meter (Testo, Germany). Tow colors, white and blue were used and controlled by Arduino Uno C++ language was used in the programming to On/Off lights automatically).Nine (units of each used color were used and placed, as 1 unit for each 10 plants in the replicate, to attract *Scolothrips sexmaculatus* Pergande and *Stethorus punctillum* Weise respectively depending on last confirmed results of the each predator's preference done by Abd El-Wahab and Abouhatab (2014).

Crops in Greenhouses

Greenhouses of strawberry and cowpea were used to examine the effect of LEDs, with two colors, on the control of the two forms of *Tetranychus urticae* as attractants of certain predators as a part of biological control. 2 greenhouses were used in this study in 2012 and 2013, resp., and each one was constructed on 200m^2. Separators were placed among treatments in the greenhouses to prevent interaction between them.

Predators Release

The predators *S. sexmaculatus* and *S. punctatum* used in these experiments were collected form bean plants. They were cultured on red and green forms of T. *urticae* infested potted bean plants in the laboratory. The predators were released on the plants under greenhouses' conditions after three weeks of mite infestation.60 individuals of *S. sexmaculatus* and *S. punctatum* were used in these experiments. The predators were transferred on to the host leaf with the help of fine hair- brush.

Counting Mite population

Tetranychus urticae with two forms were checked after treatments on all the plants for three weeks. Thirty leaves were chosen randomly from each treatment and kept in a paper bags, then transmitted to the laboratory where binocular microscope was used to count *Tetranychus urticae* individuals. Mite and predator population were checked on both the surface of each leaf. Plants in Control were just exposed to fluorescent lights. Reduction percentages were estimated according to Henderson and Tilton (1955).

Data Analysis

SPSS (V.16) was used to show differences among treatments with LEDs. Friedman Test and Kendall's W was used to test significance in the same experiment done in both experimental years.Paired samples test and Kruskal-Wallis Test described differences among groups, pre and post treatments, in both experimental years beside Pearson Correlation estimated at probability with 5% and 1%.

RESULTS

Gained results were analyzed depending on the concerned relation test statics between LED colors and the response of predators to each form of *Tetranychus urticae* on specific plant.

Data revealed that LEDs generally able to attract predators effectively. Table (1) showed the effect of both LEDs colors to attract the released predator, *Scolothrips sexmaculatus,* to feed on the red from of *Tetranychus urticae* infested strawberry. *S. sexmaculatus* attracted to the red form mainly under blue LEDs and caused highly reduction of the pest by 89.61 and 92.32% in 2012 and 2013 resp.With notice of the difference of total effect, results referred to the highest temperature recorded in 2013 in comparison with 2012 expected to led to increase of the quantities and qualities of allelochemicals which allow to attract more numbers of predators able to reduce efficiency the pest'numbers. Percentages of reduced infestation than control in the total effect of the release of 60 predators were 75.12 and 96.92% in 2012 and 2013, resp. While in case of the use of White LEDs, it was so obviously with significant lower effect than Blue LEDs. The total effect recorded 72.86 and 80.34% with infestation reduction than control which could also be mentioned as % predation increase than control by 42.39 and 71.72% in 2012 and 2013, resp.

Table (1) Release of *Scolothrips Sexmaculatus* in Greenhouses Cultivated with Strawberry Infested with

Year	LED Lights	RELEASE 60 PREDATORS 3	7	%IE*	10	14	21	% Latent Effect	% Predation Increase Than Control	% Total Effect	% Predation Increase
2012	Blue	66.41	92.01	79.21^{a}	100	100	100	100^{a}	52.53	89.61^{a}	75.12
	White	43.22	66.06	54.64^{b}	80.52	92.73	100	91.08^{b}	38.93	72.86^{b}	42.39
	Control	29.92	43.64	36.78^{c}	59.04	74.22	63.41	65.56^{c}	--------	51.17^{c}	--------
2013	Blue	74.25	95.02	84.64^{a}	100	100	100	100^{a}	78.03	92.32^{a}	96.92
	White	57.23	71.14	64.19^{b}	89.43	100	100	96.48^{b}	71.76	80.34^{b}	71.72
	Control	33.52	41.33	37.43^{c}	55.03	61.13	52.44	56.17^{c}	--------	46.82^{c}	--------

Red Form of *Tetranychus urticae*

* IE= Initial Effect

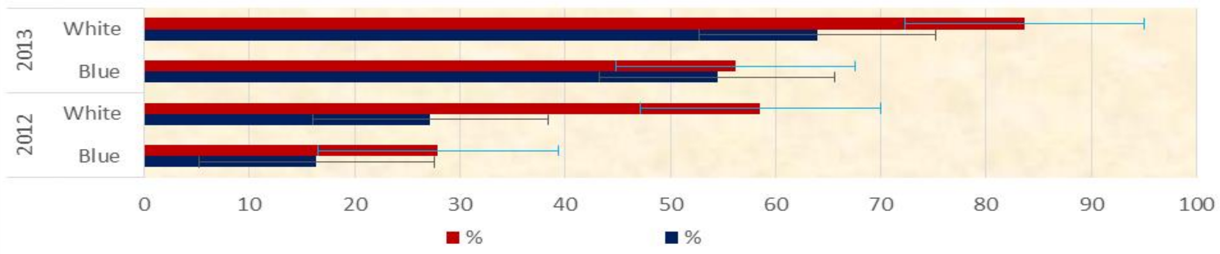


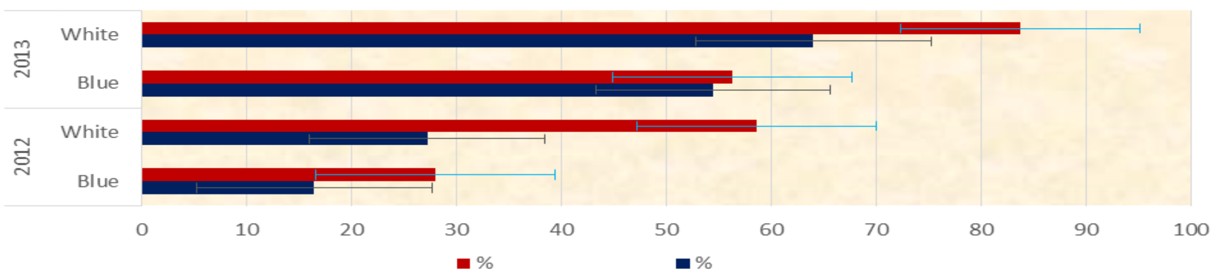
Figure (2) Predation Increase Percentages Than Control of Latent and Total Voracity of *Scolothrips sexmxculatus* on red form of *Tetarnychus urticae* ±SE

Data revealed that LEDs generally able to attract predators effectively. Table (2) showed the effect of both LEDs colors to attract the released predator, *Stethorus punctillium,* to feed on the green from of *Tetranychus urticae* infested Cowpea.Predation increase percentages than control of both latent and total voracity were evaluated . *S. punctillium* attracted to the green form mainly under White LEDs and caused highly reduction of the pest by 100 % in both tested years 2012 and 2013.With noticed the difference of total effect, results referred to the highest temperature recorded in 2013 in comparison with 2012 expected to increase of allelochemicals which allow to attract more numbers of predators able to reduce efficiency the pest numbers. Percentage of increase than control in the total effect of the release of 60 predators were 91.79 and 93.2% in 2012 and 2013, respectively. While in case of the use of Blue LEDs,it was so obviously with significant lower effect than White LEDs. The total effect recorded 74.06 and 79.27 % with increase than control by 27.91 and 56.02 % in 2012 and 2013, resp.

Table (2) Release of *Stethorus punctillium* in Greenhouses Cultivated with Cowpea Infested with Green Form of *Tetranychus urticae*

Year	LED Lights	RELEASE 60 PREDATORS 3	7	%IE	10	14	21	% Latent Effect	% Increase	% Total Effect	% Increase
2012	Blue	50.24	62.94	56.59^{b}	77.02	97.54	100	91.52^{b}	16.39	74.06^{b}	27.91
	White	72.53	94.63	83.58^{a}	100	100	100	100^{a}	27.18	91.79 ^{a}	58.53
	Control	25.73	48.61	37.17^{c}	70.54	91.1	74.24	78.63^{c}	--------	57.9^{c}	--------
2013	Blue	55.63	73.08	64.36^{b}	82.55	100	100	94.18^{b}	54.44	79.27^{b}	56.20
	White	77.24	95.55	86.40^{a}	100	100	100	100^{a}	63.99	93.2 ^{a}	83.65
	Control	29.78	51.23	40.51^{c}	77.12	42.99	62.82	60.98^{c}	---------	50.75^{c}	--------

* IE= Initial Effect



Figure(3) Predation Increase Percentages Than Control of Latent and Total Voracity of *Stethorus punctillium* on green form of *Tetarnychus urticae* ±SE

Depending on Friedman Test and Kendall's W (Coefficient of Concordance= 1) recorded Chi-Square=12 with high significant differences (Asymp. Sig.= .002) among IE , latent effect and total effect of the release of 60 predators under LEDs colors . The most significant treatment was in case of exposure to Blue LED in comparable with other the other treatment and the control occurred with *Scolothrips sexmaculatus,*in the greenhouse cultivated with strawberry infested with red form of *Tetranychus urticae* in 2012 and 2013 , resp.

While,the most significant treatment was in case of exposure to White LED in comparable with other the other treatment and the control occurred with *Stethorus punctillium* in the greenhouse cultivated with cowpea infested with Green form of *Tetranychus urticae* in 2012 and 2013 , resp.

Kruskal-Wallis Test showed significant difference among groups, pre and post treatments, in both experimental years at 5% level and Pearson Correlation was significant at 1% level beside paired samples test showed R=.801,t=-10.644 with .000**.It means that the use of insect predators under greenhouses conditions with the presence of tetranychid mites exposed to LEDs ,will increase the biological control efficiency consequently.

DISCUSSION

Response of predators to their preys exposed to LEDs is depending mainly on allelopathy relation among plant-pest-predator.During foraging, natural enemies of herbivores may employ volatile allelochemicals that originate from an interaction of the herbivore and its host plant. The composition of allelochemical blends emitted by herbivore-infested plants is known to be affected by both the herbivore and the plant.

Moreover, blends emitted by apple leaves infested with spider mites of 2 different species, *T. urticae* and *P. ulmi* , differed less in composition (principally quantitative differences for some compounds) than blends emitted by leaves of two apple cultivars infested by the same spider-mite species,*T. urticae* (Takabayashi *et al*.1991).Even the odors of *T. urticae* adults and their products might influence the attraction of *S. gilvifrons* females(Gencer *et al*.2009).It was observed clearly the attraction of *S.sexmaculatus* to red form of *Tetranychus urticae* .That was related mainly to cyanatelyase encoding gene that might be involved in feeding on cyanogenic plants (Grbić *et al*.2011) and that was avilable in strawberry plants.

The distributions of both predators under greenhouse conditions were reliable on their pests and that was confirmed also by Espinha and Torres (1995). They found the same with *Stethorus punctillum* on *Panonychus ulmi* under field conditions on orchard.

Beside all, LEDs could be used as traps for pests successfully and they showed their quality clearly after baited with the sex pheromone and a green light provided by a solar-powered, light-emitting diode (LED).Traps increased male sweetpotato weevil catching by 5 fold in comparison with no LED usage (McQuate 2014).

In the same trend, Chu *et al*.(2004) The 530 nm lime green LED traps caught 1.3, 1.4, 1.8, and 4.8 times more adult greenhouse whitefly *Trialeurodes vaporariorum* (Westwood), sweetpotato whitefly *Bemisia tabaci* (Gennadius) biotype B, cotton aphids *Gossypium hirsutum* (L.), and fungus gnats *Bradysia coprophila* (Lintner), respectively,compared with standard yellow sticky card traps. Also , LEDs traps as an attractants of predator and parasitoid able to join biological control effectively as we did in this research paper and as the case of *Eretmocerus* spp.,the important *B. tabaci* parasitoids used in greenhouse biological control programs.For whitefly control in greenhouse the 530 nm lime green LED equipped plastic cup trap designed by Chu *et al.* (2003) is the better choice than LED-Yellow Card trap because it catches few *Eretmocerus spp.* and *Encarsia spp*. whitefly parasitoids released for *B. tabaci* nymph control.Moreover, Chu *et al*. (2004) mentioned that the 530 nm lime green LED traps did not catch more *Eretmocerus spp*. than the standard yellow sticky card traps while 470 nm blue LED traps caught 2.0-2.5 times more adult western flower thrips

Franklinella occidentalis (Pergande) compared with the standard yellow sticky card traps .

Concerning the positive relation between higher temperature levels and increase of the predation of *Stethorus punctillum* was noticed clearly through the present paper and was in the main trend with Rott and Ponsonby (2000), beside that the host plant species also strongly influenced the performance of the predator, with it being most active on pepper and tomato and least active on aubergines. While RH had no significant influence on the predator under glasshouse conditions.

Carotenoids are organic pigments commonly synthesized by plants, algae and some micro-organisms. Through absorption of light energy, carotenoids facilitate photosynthesis and provide protection against photo-oxidation. Altincicek *et al*.(2012)mentioned that while it was presumed that all carotenoids in animals were sequestered from their diets, aphids were recently shown to harbour genomic copies of functional carotenoid biosynthesis genes that were acquired via horizontal gene transfer from fungi. Their search of available animal transcripts revealed the presence of two related genes in the two-spotted spider mite *Tetranychus urticae*. Phylogenetic analyses suggest that the *T. urticae* genes were transferred from fungi into the spider mite genome, probably in a similar manner as recently suggested for aphids. The genes are expressed in both green and red morphs, with red morphs exhibiting higher levels of gene expression. That was explained the highly saturated colors of *Tetranychus urticae* which were found on plants exposed to LEDs and specifically red *T.urticae* under blue color.

CONCLUSION

LEDs play an important role in biological control system of any pest even directly or indirectly depending on attraction of natural enemies. So there are main factors constructed on LEDs:

1-The cultured plant

2-The target pest

3-The attractant predator

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