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DRONE WITH EMBEDDED LIGHT EMITTING DIODES (LEDS) AGAINST INSECTS AND MITES IN GREENHOUSES

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Abstract

Light Emitting Diodes (LEDs) accentuated their effects against agricultural pests physically and biologically. The drone of embedded LEDs is utilized to spread the effect of LEDs colors with their different wavelengths at the wide area vastly. LEDs were integrated with their supplements to the drone that is powered by solar energy and controlled through wireless protocol. The drone can cause high mortality ratios up to 80% as direct effect against the most certain pests. Insects with biting mouthparts such as Spodoptera littoralis was affected by white LEDs and showed 100 and 96.67% mortality against the second larval stage which infested cotton, while they caused 96.67 and 90% mortality against the fourth larval stage which infested potato. On the other hand, the both exposed larval stages of S.littoralis which infested cotton and potato were also affected by blue LEDs but lower than white LEDs. In the same trend, concerning piercing-sucking mouthparts insects, they were represented by two aphids, Aphis gossypii and Myzus persicae which showed generally the highest mortality percentages when exposed to white LEDs. Furthermore, exposed mites to the main LEDs colors showed almost different responses. White and blue LEDs caused 100 and 91.35% mortality, respectively, against the green form of Tetranychus urticae infested cowpea. The same occurred in case of Panonychus ulmi that infested apple with 100 and 87.04% mortality by the two colors of LEDs, respectively. Conversely, the exposed red form of T. urticae infested strawberry, to both white and blue LEDs, showed 84.26 and 100% mortality. Besides, the drone with LEDs colors was able to control certain insects and mites biologically. By such simple structure, LEDs were able to increase the voracity of each categorical predator which can come and victual its prey more facile than occurred in control. Such mentioned mechanism is provided the indirect control that recorded 90% and more reduction of pests' numbers. LEDs colors were facilely transmuted depending on the infested plant, pest, place and required mode of action of LEDs. Also, the olfactory responses of each used predator to the exposed pest to specific color of LEDs, was assessed and showed highly significant differences in comparable with control. To recapitulate, such drone can provide biological and physical betokens under greenhouses' conditions to solve the quandary cognate to several agricultural pests effectively.

Keywords: diodes, drone, greenhouses, insects, mites.

1. INTRODUCTION

Importantly, herbivores including both mites and insects caused high infestation of various crops and then reduction of final yields. Mites generally and *Tetranychus urticae* precisely, are the most obstinate. They cause earnest damage to many vegetable and field crops. They are additionally major quandary in fruits like strawberry in greenhouse (Waite, 1998).

Besides, piercing-sucking pests as *Myzus persicae* and *Aphis gossypii* are exceedingly polyphagous and wide range of vegetable and ornamental crops grown in greenhouses (Bilu et al., 2006). They are withal responsible for causing viral diseases such as Potato Virus Y (PVY) and potato leafroll virus (PLRV), then yield losses can be up to 85% (Raman and Midmore, 1983). There are many

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natural enemies of aphids principally *Coccinella septempunctata* (L), belonging to order Coleoptera, family Coccinellidae, that is predating *M. persicae* in the potato crop through biological tools to control aphids. (Saljoqi and Van Emden, 2003).

Consequently, biological control, utilizing 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 an immense number of prey species and frequently show a predilection for one species, and predatory mites (Acari: Phytoseiidae) (Gotoh et al., 2004; Friese and Gilstrap, 1985). Furthermore, *Scolothrips sexmaculatus* Pergande, *Stethorus punctillum* Weise and P*hytpseiulus persimilis* Athias-henriot are the paramount predators of two-spotted spider mite, *Tetranychus urticae* Koch on protected strawberry (Gilstrap and Oatman, 1976; Battablia et al., 1990; Cross et al., 1996).

Pests and mainly insects' reactions to light are substantially influenced by a variety of factors, including light intensity and wavelength, coalescences 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 deportment varies both qualitatively and quantitatively depending on the light source (light bulb or light-emitting diode (LED) and material (Honda, 2011; Johansen et al., 2011), thereby the effects of lights may be directly or indirectly on pests. Directly, as insects which are able to optically discern ultraviolet (UV) radiation, could be controlled by the same implement 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 vigorous olfactory replication of the predatory mite *Neoseiulus californicus*, a consequential natural enemy of the two-spotted spider mite *Tetranychus urticae* (Shimoda, 2010). Subsequently, the incipient direction of both physical and biological control of pests is utilizing LEDs with its wide spectrum colors. They are able to be utilized as a direct implement of control and traps of pests (Chu et al., 2004) or as attractants of predators (Chu et al., 2003). Besides, LEDs withal able to direct olfaction to adjust forms of kinetics of predators to their preys correctly (Shimoda and Honda, 2013). Therefore, predatory action of both *Scolothrips sexmaculatus* Pergande and *Stethorus punctillum* Weise was improved by light emitting diodes (LEDs) against both morphs of *Tetranychus urticae*. By exposure to LEDs colors under greenhouses circumstances, more numbers of preys can be eaten. Accordingly, predation activity of both *Scolothrips sexmaculatus* Pergande and *Stethorus punctillum* Weise was enhanced by LEDs against both transforms of *Tetranychus urticae*. By presentation to LEDs hues under nurseries conditions, more quantities of preys can be eaten. Attracted S. sexmaculatus to the red shape of *T. urticae*, invaded strawberry, fundamentally under blue LEDs and brought about exceptionally decrease of the pest by 89.61 and 92.32% while white LEDs demonstrated diminishment by 72.86 and 80.34% in 2012 and 2013 resp. (Abd El-Wahab et al., 2014).

Thereafter, the use of drones or airplanes could be used also as a rapid and effective release technology of *Trichogramma sp.* to control *Helicoverpa armigera*, and to enhance the release of natural enemies in large crops (Parra, 2014).

Purposefully, direct and indirect effects of LEDs conjugated in a drone against different insects and mites infested main plants under greenhouses conditions, were the main target of the present study.

2. MATERIALS AND METHODS

-Drone with Embedded Light Emitting Diodes (LEDs) in Greenhouses

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Drone did about 2 hrs duration per full flight with high quality CC3D quadcopter flight controller LED control power distribution board. The drone was powered by solar energy and 100 units of embedded light emitting diodes (LEDs) were conjugated to it. Used LEDs were with many colors but after many experiments, it was emphasized that three mainly colors which had the best effect against target pests were white (420-680 nm), blue (460 nm) and red (635 nm nm), while control was under the effect of drone with normal fluorescent light. LEDs were used and controlled by Arduino Uno C++ language that was used in the programming to On/Off lights automatically.

-Crops in Greenhouses

Some crops such as strawberry, okra, apple, cotton and potato were planted under greenhouses conditions. Mainly they were to examine the effect of LEDs colors, to control certain agricultural pests. Each treatment was replicated triple and each replicate was constructed on 200m². Beside so, separators were set among treatments to avert interactions among them. Drone was able to go through their flights which presented 16 hours' exposure to each infested plants with certain insects and/or mites.

-Predators Release

Collected predators from different infested plants with various pests and then they were reared under laboratory conditions. They were *S. sexmaculatus* and *S. punctatum*, *Coccinella septempunctata* and *Chrysoperla carnea*. Predators were released at both greenhouses, thereafter, flights of drone were started.

-Voracity and Olfaction Assessments

All insects and mites were checked after flights of drone with LEDs on all plants for three weeks. Thirty leaves were picked arbitrarily from every treatment and kept in a paper sacks, and then transmitted to the laboratory, where they would to be fixed. Predators' populaces were checked on both the surface of each leaf. Plants in Control were recently presented to bright lights. Diminishment rates were evaluated by Henderson and Tilton (1955). Olfaction tests of all used predators were done under laboratory conditions according to Abd EL-Wahab and Abouhatab (2015).

-Data Analysis

SPSS (V.16) was used to show differences among treatments exposed to drone with LEDs relative to control.

3. RESULTS

Resulted data were demonstrated relying upon the demonstrated connection test statics among colors of LEDs and the reaction of predators to insects and mites on particular plant. Data revealed that LEDs' effects were appeared even directly or indirectly to control different insects and mites on specific plants. Fig.1 showed that mortality percentages of both second and fourth larval stages of *Spodoptera littoralis* were higher by white LEDs than blue LEDs. In the same way white LED was the most effective color against all tested pests except the case of the red form of *Tetranychus urticae* which affected more with blue LED. Consequently, response of all exposed pests to LEDs' colors which included escape, malformation and others was recorded results in the same trend with higher effects of white LED than blue LED, except with red form of *T. urticae.*

There was high significant difference upon Nonparametric Tests, Paired Samples Test between colors - mortality (t=58.979**) with Std. Deviation=6.93114 and Std. Error Mean=1.54985. Through Jonckheere - Terpstra Test, the observed J-T Statistic for mortality (25*) and for other response (37) with no significant difference in the relation with LEDs colors. Independent Samples Test showed that relation between mortality and colors was significant at 5%. Levene's Test for

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Equality of Variances recorded significant variables for both (F=.142* and t=2.127*). While other responses were not significant at 5% (F=.104 and t=.970). Beside so, the Reliability Statistics showed that (Cronbach's Alpha=.492*). While relations among mortality response of *S. littoralis* larvae, crops and LEDs colors were determined through Mann-Whitney Test showed that Z=1.637** and Mann-Whitney U=2.500**. On the other hand, other responses with the same factors showed that Z=1.029* and Mann-Whitney U=4.500*. Runs Test of both colors and other responses relation was significant at 5% (Z=1.909*) and little significant appeared in case of colors and mortality relation at 5% (Z=.382*).

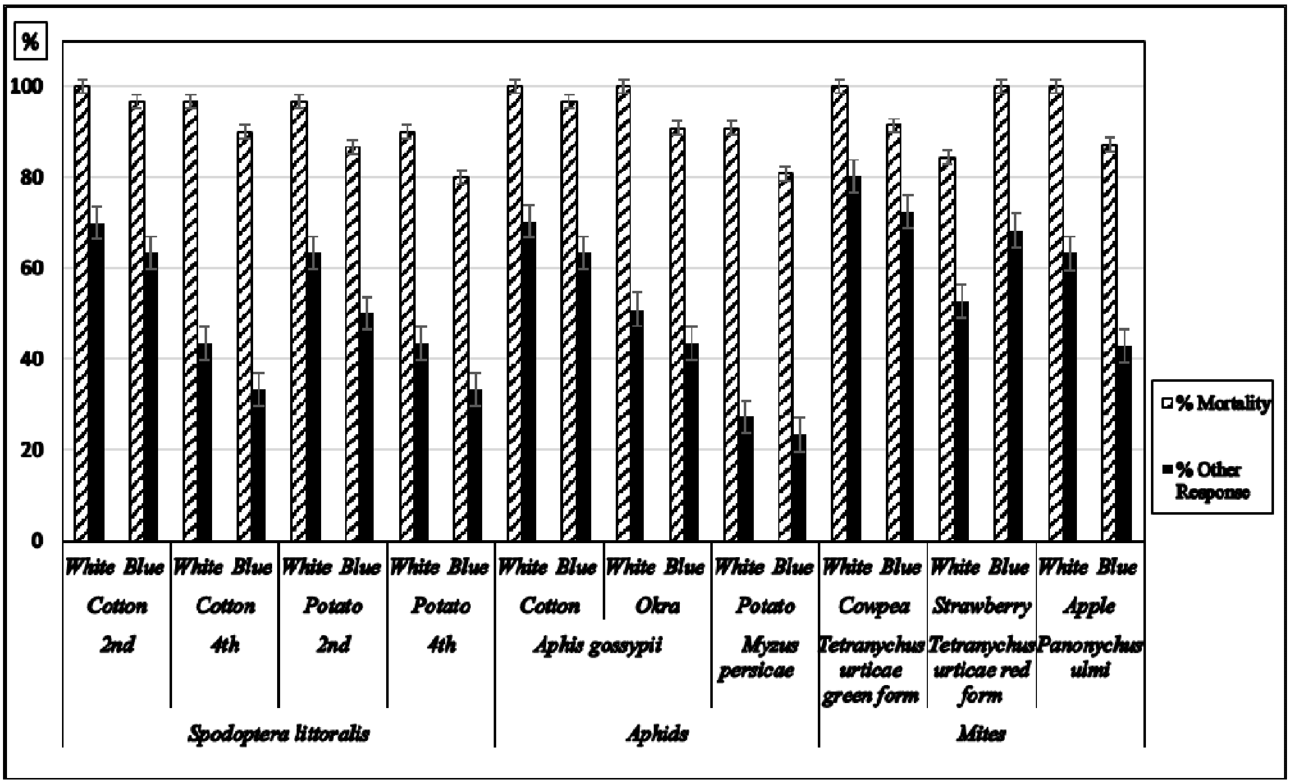

Figure 1. Direct Effects of Drone with Embedded Light Emitting Diodes (LEDs) Colors against Certain Agricultural Pests

-Voracity and Olfaction Assessments

The voracity of specific predators to certain agricultural pests under effective colors of LEDs was estimated and showed at the Table 1. Voracity values in all treatments increased than control with percentages 90% and 77.78%, of the same arrangement, in comparable with the negative control (0%). Among treatments, there was a significant difference at 95%, depending on T Test (t=9. 514) at Sig. (2-tailed) =.021*. Kruskal-Wallis Test was done among treatments, voracity and olfaction, in both experiments at the 5 % level. Chi-Square recorded significant value of the voracity (2.991*), while it was insignificant (1.525) of olfaction treatments. The same was occurring in case with Runs test and it showed significant difference of LEDs colors use (Z=. 992**) at the 1 % level and both voracity (Z=. 871*) and olfaction treatments (Z=. 522*) at was significant at the 5 % level. That means LEDs colors have highly significant effects on both voracity and olfaction of different predators against certain pests.

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Table 1. Voracity and Direct Olfactory of Predators against Certain Agricultural Pests Exposed to Drone with Embedded LEDs' Colors

Pests	Predator	LEDs	Crop	% Voracity	% Olfaction
Tetranychus urticae Green Form	*Sethorus punctillium*	Blue	Cowpea	97.25b	98a
		White		100a	100a
	Scolothrips sexmaculatus	Blue		90.89b	83.33b
		White		97.78a	66.67b
	Sethorus punctillium	Control		57.78c	66.67b
	Scolothrips sexmaculatus			47.78c	40c
Tetranychus urticae Red Form	*Sethorus punctillium*	Blue	Strawberry	91.89b	94.33b
		White		92.06b	94.05b
	Scolothrips sexmaculatus	Blue		100a	96.67a
		White		90.67b	89.69a
	Sethorus punctillium	Control		33.33c	63.33c
	Scolothrips sexmaculatus			51.11b	50c
Panonychus ulmi	*Sethorus punctillium*	Red	Apple	100a	97.35a
		White		91.21a	69.34b
	Scolothrips sexmaculatus	Red		90.38b	74.87c
		White		100a	95.36a
	Sethorus punctillium	Control		60.28c	54.21c
	Scolothrips sexmaculatus			53.10c	42.04c
Spodoptera Spodoptera littoralis	*Chrysoperla carnea*	Blue	Cotton	100a	100a
	Coccinella septempunctata	White		96.94a	72.39b
	Chrysoperla carnea	Blue	Potato	95.61a	78.24b
	Coccinella septempunctata	White		100a	100a
	Chrysoperla carnea	Control	Cotton	48.24c	35.14c
	Coccinella septempunctata		Potato	53.12c	40.21c
Aphis gosypii	*Coccinella septempunctata*	Green	Cotton	97.28a	80.06
	Chrysoperla carnea	White		100a	100a
	Coccinella septempunctata	Green	Potato	92.70b	42.69d
	Chrysoperla carnea	White		98.04a	65.25c
	Coccinella septempunctata	Control	Cotton	40.57c	16.97d
	Chrysoperla carnea		Potato	52.80c	21.29c
Myzus persicae	*Coccinella septempunctata*	Green	Potato	100a	100a
	Chrysoperla carnea	White		95.78b	79.35c
	Coccinella septempunctata	Control	Potato	53.41c	40.97d
	Chrysoperla carnea			44.68c	39.01d

Pearson Correlation was significant at the 1 % level beside paired sample test showed r=. 902**, t=50.644. It means that the use of insect predators with the presence of LEDs drone can play an important role to improve voracity and the attraction of predators on each pest infested certain crops. Results demonstrated that LEDs conjugated with the drone were able to attract predators successfully. Table 1 declared the interaction among LEDs colors, crops, pests and predators under quantities and qualities of allelochemicals which released and then allowed to attract more numbers of predators able to reduce efficiency the pest' numbers.

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4. DISCUSSION

Rejoinder of predators to their preys exposed to embedded LEDs is depending mainly on allelopathy cognation 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 kenned to be affected by both the herbivore and the plant.

There are some factors which could guarantee maintainable agrarian improvement that exploit the stimulatory/inhibitory impact of allelopathic plants to direct plant development and advancement and to stay away from allelopathic autotoxicity. Allelochemicals can conceivably be utilized as GRs, pesticides and products of plant protection (Cheng and Cheng, 2015). Light (e.g., light emitting diodes (LED), photoselective screens (e.g., UV absorbing), and changes in photoperiod have neutral effect on the biological control of aphids by the endoparasitoid, *Aphidius colemani* Viereck (Hymenoptera: Braconidae) under greenhouses conditions. Reduced UV light has no effects on *A. colemani* performance (Davis et al., 2006). While the same factors have variable indirect effects which represented as changes in lighting, they can alter plant nutritional quality, physical or chemical defenses, and/or volatile emissions or profiles, which in turn could affect *A. colemani* and others (Chiel et al., 2006).

Consequently, Rechner et al. (2016) detected that Short-wavelength radiation (like UV) can activate bulwark pathways in plants and enhance the biosynthesis of secondary metabolites responsible for resistance against certain herbivorous insects. *Brevicoryne brassicae* adult weights and fecundity were lower on UV-B treated plants compared to UV-A or violet light-treated plants. Adult weights and fecundity of *M. persicae* were incremented under UV-B and UV-A treatments. Moreover, Yang et al. (2015) stated that other colors were able to attract *Myzus persicae* adults but with lower ratios than green color. Such colors were blue (470 ± 10 nm, 75.0 %), yellow (590 ± 5 nm, 73.7 %), and red LED (625 ± 10 nm, 69.7%).

Notably, free and embedded LEDs could be also used as traps of the greenhouse whitefly (Stukenberg et al., 2015). The utilization of light emitting diodes (LEDs) is a promising approach to increment the attractiveness, specificity and adaptability of visual traps. Green LED traps (517 nm peak wavelength) of *Trialeurodes vaporariorum,* were commensurably alluring even they were alone or in the presence of yellow traps. While in experiments between LED traps emitting green light only or in coalescence with UV (368 nm), the green-UV combination was preferred because UV is stimulating influence on flight activity of insects. In the same trend, the green LED (520 ± 5 nm) showed the highest potential attraction of *Myzus persicae* adults with approximately 1.4 times (61.7 %) more captivating than that of the black light bulb, which accommodated as the positive control (Yang et al., 2015). In the same direction, 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), sweet potato 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 (Chu et al., 2004). Moreover, 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*., to control *B. tabaci* nymph control. On the other hand, 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 (Chu et al., 2004). Therefore, blue LED as a short-wavelength showed its direct lethal effects and developmental changes which caused against many pests such as fruit flies, flour beetles and others (Shibuya et al., 2018).

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Additionally, mixes discharged by apple leaves plagued with *Tetranychus urticae* and *Panonychus ulmi*, contrasted less in structure (basically quantitative contrasts for a few mixes) than blends radiated by leaves of two apple cultivars pervaded by a similar arachnid parasite species, *T. urticae* (Takabayashi et al., 1991). Even the emissions of *T. urticae* grown-ups and their items may impact the fascination of *S. gilvifrons* females (Gencer et al., 2009). It was watched plainly the fascination of *S. sexmaculatus* to the red type of *T.urticae*. That was connected essentially to cyanatelyase encoding quality that may be included in nourishing on cyanogenic plants (Grbić et al., 2011) and that was available in strawberry plants. Thereby, the allocation of predators under greenhouse conditions was credible on their pests and that was substantiated withal by Espinha and Torres (1995). They found the same with *Stethorus punctillum* on *Panonychus ulmi* under field conditions. In such a way carotenoids are organic pigments ordinarily synthesized by plants, algae, and some micro-organisms. Through absorption of light energy, carotenoids encourage photosynthesis and provide prognostic against photo-oxidation. Additionally, carotenoids in animals were sequestered from their diets such as occurred with aphids which were recently shown to harbor genomic replicas of carotenoid biosynthesis genes that were acquired via horizontal gene transfer from fungi (Altincicek et al., 2012). Animal transcripts revealed the presence of two cognate genes in *Tetranychus urticae* which transferred from fungi into the spider mite genome as recently suggested for aphids. With the same trend, the genes are expressed in both green and red morphs, with red morphs exhibiting higher calibers of gene expression. That was explicated the highly saturated colors of *T. urticae* which were found on plants exposed to LEDs and concretely red morph under blue color.

Even LEDs could contribute successfully to prove predation on non-acceptable prey such what occurred in case of *Propylea quatuordecimpunctata* L. that is incipiently as an insect predator in Egypt against *Phenacoccus solenopsis*. Voracity was recorded 90 % in case of exposed *P.solenopsis* to white LEDs than blue LEDs (77.78%) while the predation was 0% in control under dark conditions but it was 1.11% of control with fluorescent light. (Abd El-Wahab and Abouhatab, 2015).

Not only LEDs have their effects on the interaction among many factors exposed to them but they have specific effects on each factor individually such as exposed plants also such as rice (Tran and Jung, 2017). Specific wavelengths of LED greatly influence characteristics of growth in plants partly through altering the metabolic regulation of the porphyrin biosynthetic pathway, and possibly contribute to affect retrograde signaling. Leaf area and shoot biomass were greater in seedlings grown under white and blue LEDs compared with those of green and red LEDs. Even so, both green and red LEDs drastically decreased levels of protoporphyrin IX (Proto IX) and Mg-porphyrins than those of white LED, while levels of Mg-Proto IX monomethyl ester and protochlorophyllide under blue LED were decreased by 21% and 49%, respectively. This would in impact lead to an increment in efficiency and a diminish within the price of agrarian items, hence empowering the fissure between current generation and requirements of the developing worldwide populace to be locked (Sylvester, 2018).

5. CONCLUSIONS

Purposefully, LEDs can do many tasks in both physical and biological control against agricultural pests. But with contribution of drone with embedded LEDs, the tasks were expanding at the wide area with fast performance. Highest mortality ratios were successfully got and in the same time through allomones, predation increased and it is so close then to pesticides results with no side

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effects. By drone with embedded LEDs, there is an ability to get highly benefits from the efficient interaction among LEDs' colors, plant, pest and predator.

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