ACTA UNIVERSITATIS PALACKIANAE OLOMUCENSIS
FACULTAS RERUM NATURALIUM
1988 BIOLOGICA XXVIII VOL. 93

Katedra zoologie a ekologie člověka přírodovědecké fakulty
Univerzity Palackého v Olomouci
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YELLOW AND GREEN STICKY TRAP ATTRACTIVENESS FOR GLASSHOUSE WHITEFLY, TRIALEURODES VAPORARIORUM (HOMOPTERA, ALEYRODIDAE)

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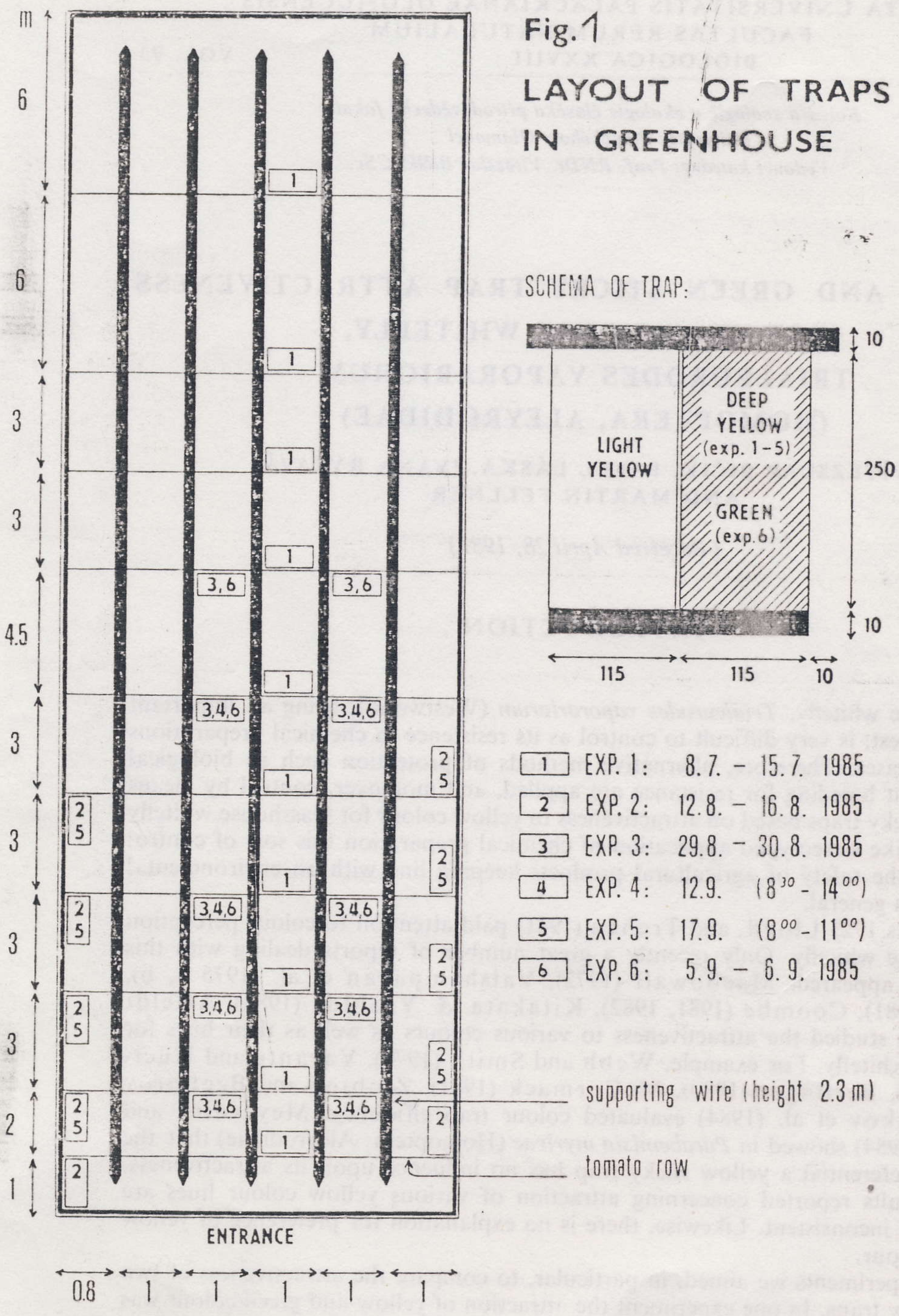
(Received April 28, 1987)

INTRODUCTION

Glasshouse whitefly, *Trialeurodes vaporariorum* (Westwood), being an important glasshouse pest, is very difficult to control as its resistence to chemical preparations always increases. Therefore, alternative methods of protection such as biological control, plant breeding for resistance are applied, and moreover, control by means of yellow sticky traps based on attractiveness to yellow colour for glasshouse whitefly is used. Unlike stereotyped application of chemical preparation this sort of control can ensure the safety of agricultural products keeping line with an environmental protection in general.

As early as 1921 Lloyd, and Trehan (1941) paid attention to colour perception in glasshouse whitefly. Only recently a great number of reports dealing with this subject has appeared. Macdowall (1972), Vaishampayan et al. (1975 a, b), Ekbom (1981), Coombe (1981, 1982), Kitakata & Yoshida (1982), Affeldt et al. (1983) studied the attractiveness to various colours as well as their hues for glasshouse whitefly. For example, Webb and Smith (1979), Vacante and Nucifora (1980), Berlinger (1980), McCormack (1981), Zlobina and Begljarov (1982), Mitkov et al. (1984) evaluated colour trap efficiency. Meyerdirk and Moreno (1984) showed in *Parabemisia myricae* (Homoptera: Aleyrodidae) that the shape of preferential a yellow sticky trap has no influence upon its attractiveness. Some results reported concerning attraction of various yellow colour hues are found to be inconsistent. Likewise, there is no explanation for preference of yellow to green colour.

In our experiments we aimed, in particular, to compare the attractiveness of two yellow sticky traps. In one experiment the attraction of yellow and green colour was



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also compared. In the discussion there is an attempt to account for a greater attractiveness of yellow over green.

MATERIAL AND METHOD

The experiments were conducted in glasshouse of ca. 200 m^2 where tomato plants (Swedish hybrid cv. Ida F$_1$) using hydroponics were grown in rows arranged north-southwards and 1 m apart. During the experiments tomato plants were about 2.3 m high and were strongly infested by glasshouse whitefly, the occurrence of which was gradually rising. Glasshouse temperatures were ranging from 20° to 30° C.

Two types of commercially produced traps such as pale - yellow plastic plate (Czechoslovak production - Chemika, Bratislava), deep - yellow cardboard being a part of the set »*Soveurode*« (Celamerck), and green plastic plate were used for testing. One side of all the plates (to be easier handled) was sprayed by an adhesive from the set Soveurode. The plates were uniformly sized to be 25×11.5 cm, and two different plates were positioned in pairs near each other by their longitudinal sides and placed at the height of 2.0 m above the floor (Fig. 1).

Both yellow hues and the green colour, were measured by means of the device Spectrogard color system using C - source. Measured spectral curves are illustrated in Fig. 2. Calculated natural coordinates of colours are given in Tab. 1.

Tab. 1.
Natural coordinates of tested colours

Colour	Wavelength of maximum reflectance λ_d (nm)	Colour brightness $(\beta)_\tau$	Saturation p_e
pale-yellow	574.81	0.597	0.763
deep-yellow	579.82	0.584	0.838
green	520.12	0.242	0.149

To calculate them, both data on spectral sensitivity of the human optic organ and the spectral curve of C - luminous source were involved. The plates were semi-transparent of which pale-yellow ones were approximately three-times more transparent than those being deep-yellow.

Survey of the experiments carried out:

Experiment 1. Ten pairs of yellow traps were spaced out midway between tomato plant rows keeping spacings of trap pairs to be 3 m. The traps were exposed to glasshouse whitefly alighting from 10.00 a. m. on 8 July till 10.00 a. m. on 15 July, i.e. for 168 h in total, therein 52 sunny hours. Baited trap sides were orientated southwards.

Experiment 2. Similar to the previous experiment but trap pairs were situated along two marginal rows of tomato plants with baited sides directed inward so that five trap pairs were orientated eastwards and another five pairs westwards.

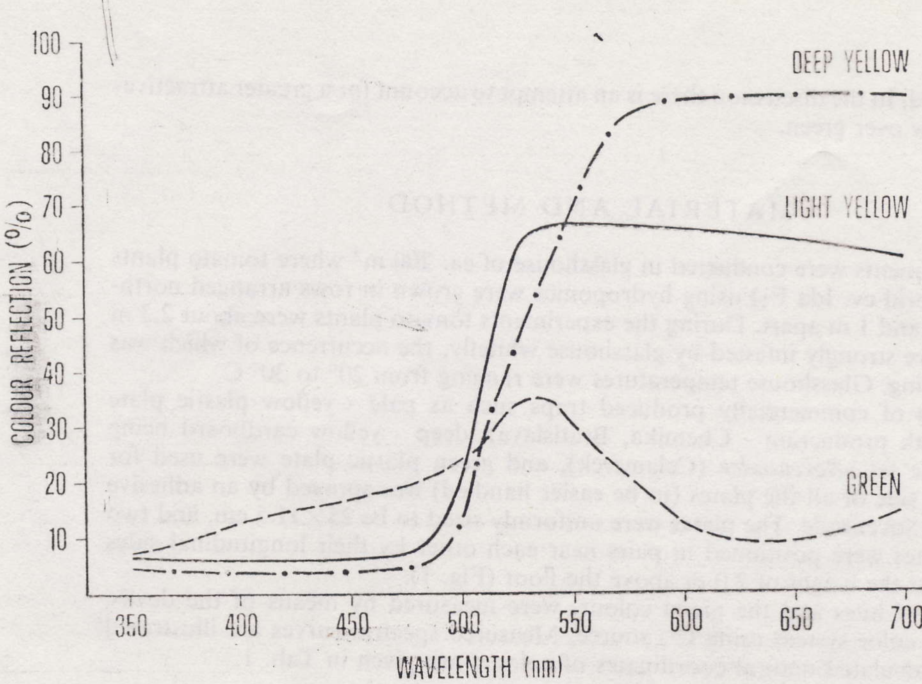

Fig. 2. Spectral curves of tested colours

The traps were exposed to glasshouse whitefly alighting from 11.00 a. m. on 12 August till 10.00 a. m. on 16 August, i.e. for 95 h in total, therein 48.4 sunny hours.

Experiment 3. Similar to Exp. 1, but trap pairs were spaced out in two paths with baited sides directed northwards. They were exposed to glasshouse whitefly alighting from 10.00 a. m. on 29 August till 10.00 a. m. on 30 August, i.e. for 24 h in total, therein 6.1 sunny hours.

Experiment 4. Eight pairs of yellow traps were positioned similarly to Exp. 3. They were exposed to glasshouse whitefly alighting from 8.30 a. m. till 14.00 p. m. on 12 September, and out of 5.5 h as many as 5 h were sunny.

Experiment 5. Eight pairs of yellow traps were positioned similarly to Exp. 2. Traps were exposed to glasshouse whitefly alighting from 8.00 a. m. till 11.00 a. m. on 17 September (which was a cloudy day).

Experiment 6. Ten trap piars consisting of one green and one pale-yellow plate were spaced out similarly to Exp. 3. They were exposed to glasshouse whitefly alighting from 11.00 a. m. on 5 September till 8.00 a. m. on 6 September, i. e. 21 h, of which 4.5 were sunny.

RESULTS

As mentioned above six experiments in total, using 56 colour traps, were carried out during the period from 8 July till 17 September, 1985. 46 traps were presented in pairs of pale-yellow and deep-yellow colour (Exps. 1 – 5). In Exp. 6 the pale-yellow was combined with green colour in 10 trap pairs.

Tab. 2.
Numbers of whiteflies on individual traps

N° of trap	Experiment 1		Experiment 2		Experiment 3		Experiment 4		Experiment 5		Experiment 6	
	pale-yellow	deep-yellow	pale-yellow	deep-yellow	pale-yellow	deep-yellow	pale-yellow	deep-yellow	pale-yellow	deep-yellow	pale-yellow	green
1	543	497	1,495	908	5,442	3,846	8,480	5,403	4,460	1,927	3,736	119
2	1,067	646	1,124	1,117	5,743	5,247	8,159	7,812	3,435	3,174	4,954	176
3	569	561	2,369	1,467	6,584	4,134	8,217	4,288	2,308	806	4,919	170
4	939	1,036	2,523	3,165	5,179	4,124	7,863	6,500	4,258	3,228	4,945	262
5	493	496	3,452	1,998	4,666	3,257	6,855	5,963	2,502	2,507	4,530	213
6	605	428	1,319	908	5,572	5,245	6,868	5,094	3,555	1,310	6,346	302
7	500	409	677	879	5,556	5,097	6,915	6,100	5,119	6,157	4,638	104
8	473	422	1,266	547	7,494	4,722	7,603	4,551	8,904	4,384	5,700	162
9	545	657	614	634	7,011	3,981					5,885	321
10	229	265	568	442	7,384	5,253					7,069	252

Tab. 3.
Total sum of whiteflies in individual experiments

Number of experiment	Colour of sticky trap						α
	pale-yellow		deep-yellow		green		
	N° of specimens	%	N° of specimens	%	N° of specimens	%	
1	5,963	52.4	5,417	47.6	—	—	—
2	15,407	56.08	12,065	43.92	—	—	—
3	60,631	57.45	44,906	42.55	—	—	0.001
4	60,960	57.15	45,711	42.85	—	—	0.005
5	34,541	59.52	23,493	40.48	—	—	0.1
6	52,722	96.20	—	—	2,081	3.80	0.0005

A total of 363,897 glasshouse whiteflies were captured on individual traps during the six experiments. The number of individuals captured was directly proportional to the glasshouse whiteflies density in the glasshouse.

Table 2 gives numbers of the insects captrued on all of the available traps (10 or 8) in each of the experiments. Table 3 summarizes data obtained in individual experiments.

Two - factor analysis of scattering demonstrated in three from five experiments statistically significant preference for pale-yellow colour to deep yellow. Also in experiments 1 and 2 pale-yellow colour was more attractive than deep-yellow (the difference, however, was not so significant, as the density of whiteflies in the greenhouse had not yet culminated at that time). Trifactor analysis of scattering of all the five experiments (1—5) showed significant preference for pale-yellow colour to deep-yellow ($\alpha = 0.0005$).

Green colour of traps in Exp. 6 appeared to be 25-times less attractive than pale-yellow ($\alpha = 0.0005$). So there were substantially and significantly less numbers of glasshouse whitefly alighting on green plates than on those being pale-yellow.

DISCUSSION

To objectively measure the characteristics of light in monochromatic filters it is possible to use the wavelength whereas it is found to be a much more complicated problem to objectively measure the light reflected by objects. The reflected light is composed by means of a spectral curve. Although it is possible to calculate and characterize a real colour using natural coordinates such as wavelength of maximum reflectance, colour brightness and saturation, these values are not, however, of universal validity, namely they are valid for human sense-perception only, so that is why they cannot substitute the spectral curve. Nevertheless, a certain correlation between human and glasshouse whitefly sight can be found as far as, e.g. real yellow colours, is concerned. We suppose that it is of use to give the wavelength of maximum reflectance but there is a need, however, to be aware of its relativity.

Mitkov et al. (1984) observed the greatest colour attraction to deep-yellow sticky plates ($\lambda_d = 580$ nm), followed by those with orange-yellow ($\lambda_d = 586$ nm) and then with lemon-yellow colour ($\lambda_d = 574$ nm).

In our experiments the pale-yellow plates ($\lambda_d = 574.81$ nm) were found to be more attractive rather than deep-yellow ones ($\lambda_d = 579.82$ nm). Even their increased translucence may have contributed to a greater colour attractiveness of our pale-yellow plates, especially during sunny days, with baited side orientated northwards. Results reported by Kitakata and Yoshida (1982) are similar to ours and they also show a great influence of other characteristics, except for the calculated wavelength. With colour brightness and saturation decreasing a decrease in colour attractiveness occurred as well. The brightness factor will play an important role in the colours represented by similar spectral curves. Presumably, the greater brightness of a colour is, the greater will be its attractiveness.

In our experiment green colour was 25-times less attractive than was pale-yellow. In addition, many other authors reported the lower attractiveness of green compared to yellow colour as to the light reflected.

On the other hand, using monochromatic filters the greatest attractiveness was recorded in green colours (Macdowall, 1972) ranging from 540 to 550 nm. Coombe

(1981) also finds the wavelength 550 nm to be the most attractive. Vaishampayan et al. (1975 a, b) observed that yellow colour of leaves attracted glasshouse whitefly rather than green, even in the case of green colour in preferential host-plant (bean), while yellow was the plant to non-host-plants (croton). However, these authors obtained analogous results even when lighting leaves of various plants with monochromatic yellow light. Thus, the whole problem is somewhat more complicated, and either interpopulation differences in glasshouse whitefly or other specific physical conditions of experiment might be, eventually, taken into account. We plan, however, to revert to these problems after accomplishing our experiments the aim of which is to study the glasshouse whitefly response to monochromatic light of various wavelengths and intensity.

Let us attempt, however, to explain the basic question as follows: Why are positively phototactic glasshouse whitefly responses (as to the light reflected) demonstrably more expressive to yellow over green colour if host-plants are green?

The eye of glasshouse whitefly may be the most sensitive to green colour, but this sensitivity is likely characterized by a wide range (similarly to e.g. human receptor for green colour). Physical properties of real yellow colours, reflecting more light in total than green colours, are then a further factor to consider. This is illustrated in Fig. 3 demonstrating sight-perception of green and pale-yellow colours by human eye receptors for green colour. The spectral curve and product values of trichromatic distribution curves in a normal observer were used to construct Fig. 3. The graph indicates that the entire perception of green (given by the area under the curve) is lower than of light (pale)-yellow colour, despite the fact that the maximum sensitivity of human retina for green colour is at 555 nm.

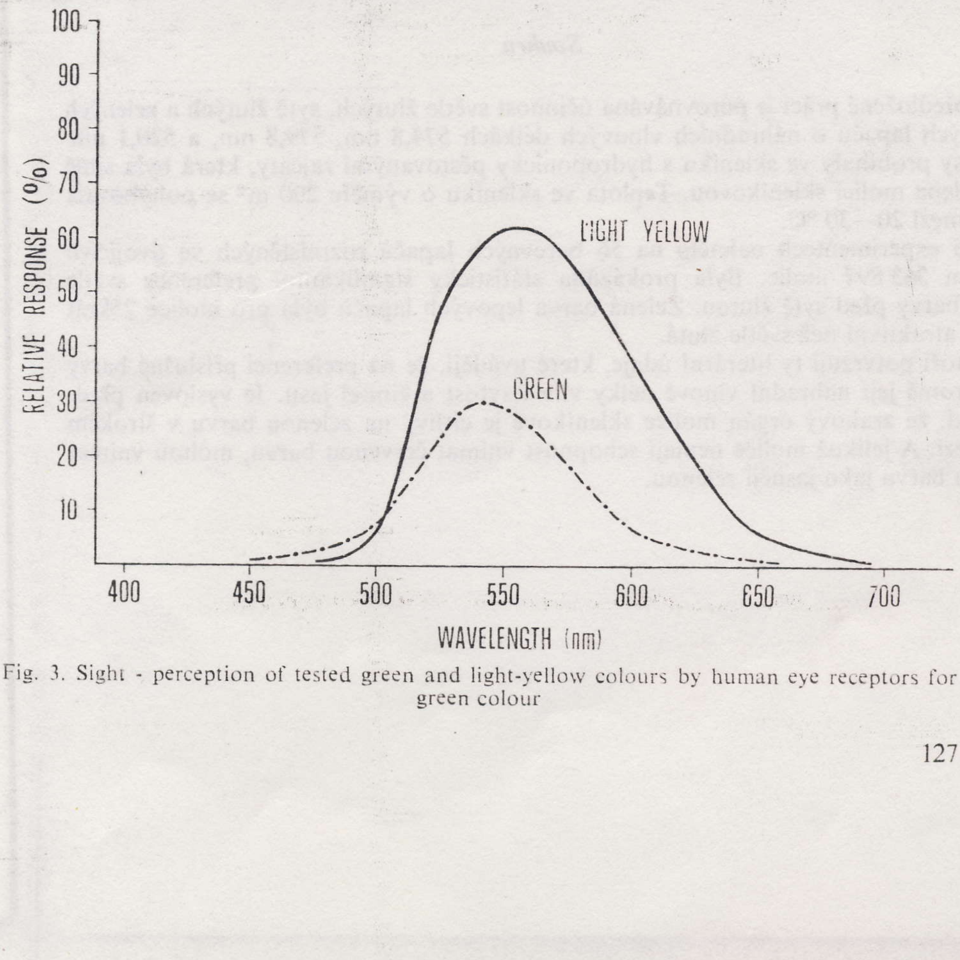

Fig. 3. Sight - perception of tested green and light-yellow colours by human eye receptors for green colour

Hence, if man were not capable of perceiving red colour, he would perceive yellow colour as a green one being of higher brightness. For similar reasons mentioned above the same situation might also occur in glasshouse whitefly if it could be demonstrated that it has no capability to perceive red colour.

SUMMARY

The experiments were conducted in glasshouse where tomato plants were strongly infested by glasshouse whiteflies. The attractiveness of pale-yellow, deep-yellow and green sticky traps with wavelength of maximum reflectance 574.81 nm, 579.82 nm, 520.12 nm compared and the influence of colour brightness and saturation was evaluated.

Statistically significant preference of pale-yellow colour to deep yellow was proved. Green colour of traps appeared to be 25-times less attractive than pale-yellow.

There is an assumption that visual organ of glasshouse whitefly is sensitive to green colour within a wide range. As the glasshouse whiteflies do not posses the ability to perceive red colour they may be expected to react to yellow colour as to brighter green.

ATRAKTIVITA ŽLUTÝCH A ZELENÝCH LEPOVÝCH LAPAČŮ PRO MOLICI SKLENÍKOVOU, TRIALEURODES VAPORARIORUM (HOMOPTERA, ALEYRODIDAE)

Souhrn

V předložené práci je porovnávána účinnost světle žlutých, sytě žlutých a zelených lepových lapačů o náhradních vlnových délkách 574,8 nm, 579,8 nm, a 520,1 nm. Pokusy probíhaly ve skleníku s hydroponicky pěstovanými rajčaty, která byla silně napadena molicí skleníkovou. Teplota ve skleníku o výměře 200 m² se pohybovala v rozmezí 20–30 °C.

V 6 experimentech naletělo na 56 barevných lapačů rozmístěných ve dvojicích celkem 363 897 molic. Byla prokázána statisticky signifikantní preference světle žluté barvy před sytě žlutou. Zelená barva lepových lapačů byla pro molice 25krát méně atraktivní než světle žlutá.

Autoři potvrzují ty literární údaje, které uvádějí, že na preferenci příslušné barvy má kromě její náhradní vlnové délky vliv i sytost a činitel jasu. Je vysloven předpoklad, že zrakový orgán molice skleníkové je citlivý na zelenou barvu v širokém rozmezí. A jelikož molice nemají schopnost vnímat červenou barvu, mohou vnímat žlutou barvu jako jasněji zelenou.

ПРИВЛЕКАТЕЛЬНОСТЬ ЖЕЛТЫХ И ЗЕЛЕНЫХ КЛЕЕВЫХ ЛОВУШЕК ДЛЯ БЕЛОКРЫЛКИ ТЕПЛИЧНОЙ, TRIALEURODES VAPORARIORUM (HOMOPTERA, ALEYRODIDAE)

Резюме

В предлагаемой работе сравнивается эффективность светло-желтых, ярко-желтых и зеленых клеевых ловушек для белокрылки тепличной с максимумом светового отражения при 574,8 нм, 579,8 нм и 520,1 нм.

Эксперименты проводились в оранжерее с помидорами, выращиваемыми в условиях водной культуры (гидропоники). Отдельные растения помидоров были сильно заражены белокрылкой тепличной. Температура в оранжерее с площадью в 200 м^2 колебалась в пределах от 20 до 30^0 С.

В 6 проведенных экспериментах налетело на 56 цветных клеевых ловушек, размещенных парами, всего 363 897 белокрылок. Количество особей при полете было прямо пропорционально количеству белокрылок тепличных в оранжерее.

Была доказана статистически достоверная предпочтительность светло-желтых ловушек перед ярко-желтыми. Зеленый цвет ловушек был для белокрылок в 25 раз менее привлекательным чем светло-желтый цвет.

Авторы подтверждают литературные данные, что на преференцию данного цвета влияет кроме волновой длины также фактор блеска и насыщенность цвета.

Высказано предположение, что орган зрения белокрылки тепличной чувствителен к зеленому цвету в широком диапазоне. Вероятно, если белокрылка не обладает способностью воспринимать красный цвет, то она может реагировать на желтый цвет как на ярко-зеленый.

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