THE PECULIARITIES OF THE HONEYBEE PERCEPTION OF THE WHITE AND BLUE FLAT NEAR-ENTRANCE MARKS

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Summary

The bees have high potential ability to discriminate colours as it was proved in the experiments on the feeders after prolonged appropriate training, when bees could see two stimuli (positive and negative) simultaneously. But this ability is not fully realized by the bees arriving into the near-entrance space, when they see simultaneously training and tested mark at the necessary conditions that they see the tested mark at first. In our experiments the arriving bees clearly distinguished white zinc mark from yellow and "silver" ones, but didn't from grey and blue near-entrance marks. These experiments confirm our preliminary painting recommendations (Komissar 1993, 1996) not to use white and blue colours simultaneously for painting near-entrance marks.

We propose to use additional colour of the surface of aluminium or any white metal. It is supposed that these painting recommendations can be applicable for coloration of the front hive walls, but the direct experiments with hives weren't carried out.

Keywords: honeybee, orientation, dicrimination of colours.

INTRODUCTION

There is maybe the only case, where our knowledge about honeybees colour vision can be useful for beekeepers. It is the appropriate painting of hives' front walls and entrance colour marks in the multiple nucs which reduces the drifting of bees and queens. It was recommended to use only four colours for this purpose: white, blue, yellow and black or red (Frisch 1964, 1971; Free, Spencer-Booth 1961). Karl von Frisch (1964) also wrote, that it is possible to use fifth colour - lead white, as a paint which reflects ultraviolet rays.

In the extra multiple mating hives, where two or more entrances are dispose at every hive wall, appropriate painting of near entrance marks is necessary (Komissar 1993). Our attempts to use classical painting recommendations in these hives didn't give the desirable results - drifting of queens was high. We supposed that the coloration of the marks wasn't optimal and made an attempt to check existing recommendations of Frisch (1964) on the coloration of near-entrance marks. The main purpose of our investigation was the elaboration of practical recommendation for beekeepers on coloration of the near-entrance marks of extra multiple mating hives.

MATHERIALS AND METHODS

The experiments were carried out at the apiary of the Institute of Zoology and in the author's private apiary. The experiments were carried out with the Ukrainian race of bees (*Apis mellifera sossimai*, Engel 1999). Only a few experiments were carried out with Carniolan bees (*A. m. carnica* Pollmann 1979, Ukrainian population) and Caucasian bees (*A. m. caucasica* Gorbachev 1916) in order to check the main conclusions. The coloured

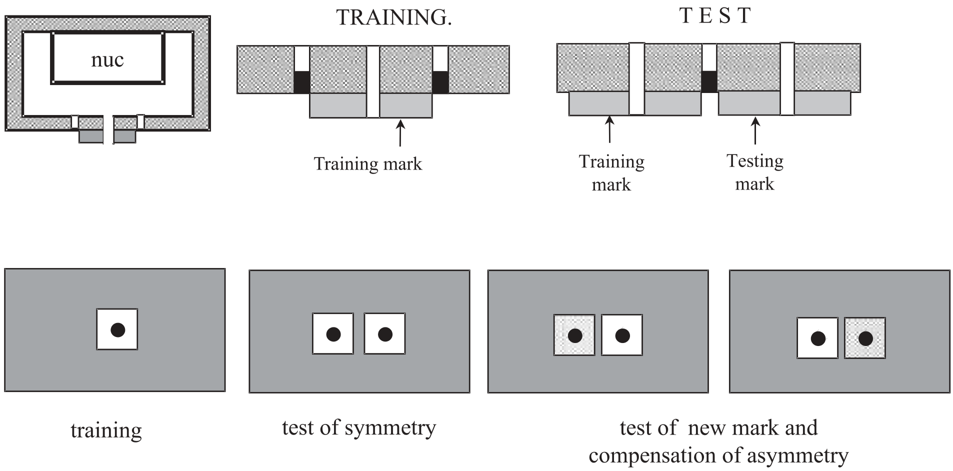

Fig. 1. Experimental device and method of evaluation of colour mark for simultaneous use on one wall of the extra multiple mating hive. Upper row: horizontal section of an experimental hive with three entrance holes; one mark is at the training and two marks are at testing (central hole is closed). Lower row: disposition of marks on a vertical wall of the hive at the training and at the test.

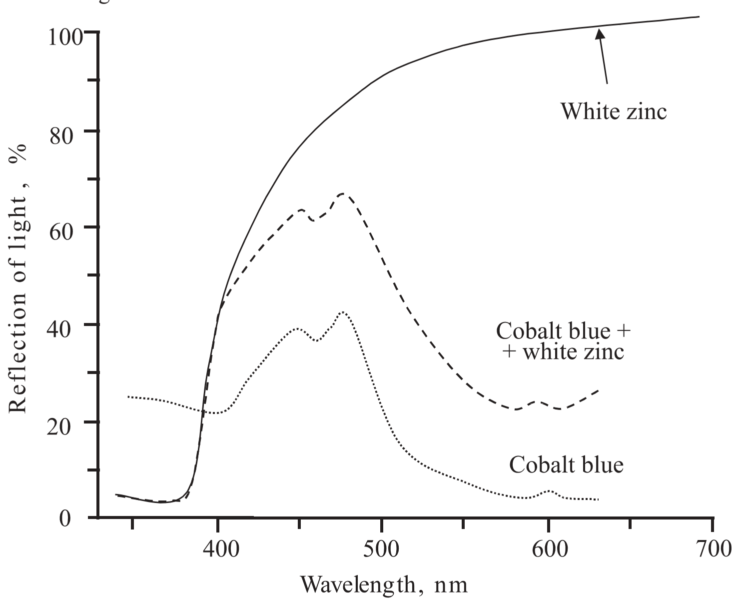

Fig. 2. Reflectance spectra of white zinc, cobalt blue and of the mixture of those paints.

plates 10 10 cm with an entrance hole (diameter 18 mm) in the middle were used as near-entrance marks on a large (50 85 cm) vertical black wall of the special horizontal hive with a weak nucleus colony (Fig. 1). The flight activity of such a colony didn't exceed one bee per 30 seconds and the surface of the mark was free of bees, which could serve as an additional mark of the entrance (Butler, Fletcher, Walter 1970). The disposition of frames with bees far from the entrance hole prevented appearance of the guard bees on the surface of the mark.

Table

Drifting of bees, trained to a white zinc mark,
to a test mark at a simultaneous demonstration of training and test marks

Colour or paint of test mark	Drifted bees, %	
	Mean ±SD	Range
Control and test of the method		
Zinc white (ZW)	49±4	43-59
Silver paint (aluminium)	4±1*	0-7
“Cadmium yellow”*	0*	0
“Cadmium yellow*+4 parts of ZW	12±2*	5-18
White surfaces		
Titanic white	45±4	43-47
Mixture of ZW and white lead	44±4	38-55
White surface of polystyrene	47±4	46-48
White lead (reflects UV rays)	41±3	32-48
Grey surfaces (ZW + soot)		
Light grey	48±4	45-52
Moderate grey	50±4	41-67
Dark grey	35±4**	29-40
Blue surfaces without UV reflection		
Blue paper (2 samples)	44±2	38-49
Household blue paints (3 samples)	49±2	38-60
Ultramarine (dark blue)	43±4	37-49
Ultramarine + ZW	47±4	40-54
“Blue FT”* (dark blue)	53±4	42-64
“Blue FT”* + ZW	50±4	40-58
“Cobalt violet”* + ZW	46±4	39-53
“Cobalt blue”* +ZW	41±4	40-43
Blue surfaces, which reflect UV rays		
“Tseruleum”* (sky blue colour)	28±4**	15-40
“Cobalt violet”*	39±4	23-50
“Cobalt blue”*	35±4**	25-42
“Cobalt light blue”*	27±4**	8-36

* difference from zero hypothesis (from 50% drifting) is significant at P<0.001
** statistically significant difference P<0.05
Name of paint for artists (translation from Russian).

Spectral characteristics of all samples were controlled. The main white colour was zinc white, as it was recommended by Frisch (1964). Main blue colours were the colours of household blue paints (three samples) as the purpose of our investigation was a practical recommendation.

Widely used blue paints for the artists, based on cobalt compounds reflect the ultraviolet rays and aren't real blue for bees. We used these paints as blue in mixture with zinc white paint, which prevents ultraviolet reflection (Fig. 2).

After bees got accustomed to the colour of the base mark we proposed them two marks simultaneously. The bees returning to the hive divided into two nearly equal parts if the marks were identical or if the bees didn't distinguish them. Special experiments with two identical marks were made to control symmetry of bees distribution and possible influence of the odor of the mark on the response to marks, which had already been used and could be marked by bee pheromones (Butler, Fletcher, Walter 1969). The mutual change of disposition of training and testing marks with consequent adding of results permitted to compensate a small asymmetry of bees distribution.

If the bees distinguished the base training colour from the new one, they always preferred the first. This situation is the nearest to the real one when bees or queens return to their hive after the first flight. Only surely refused colours can be recommended for use as the near-entrance hive marks.

In the real situation the near-entrance marks can be disposed at different daylight conditions: in the sunlight, in the shade and at cloudy weather. Every paint was tested under these three conditions of illumination and results were averaged, as the preliminary tests demonstrated almost the same results.

RESULTS

Given two identical marks the bees, returning to the hive, divided into two almost symmetrical flows with 49% of drifting (see table). Sometimes a small asymmetry took place. Every result in the table is the average of three experiments (with 100 arrived bees in each) at different daylight conditions: in sun, in shade and at light cloudy weather.

Bees didn't prefer the old used mark to the new one, that gave evidence that arriving bees didn't use the odor of the track pheromones. Bees didn't differentiate white zink mark from various white surfaces (titanic white, white plastic, mixture of zink and lead white). The white lead surface can be added to this list, as the difference is non-significant ($P>0.05$).

Bees distinguished clearly white marks from yellow and from "silver" ones (aluminium powder-based paint - see also Komissar, 2003 b) ones. Bees didn't distinguish white from light and moderate grey; the drifting to dark grey was also high (35%).

The results of tests of different blue colours were surprising. Bees didn't differentiate between white zinc and any of the tested blue paints in our experiments.

Several experiments were repeated with bees of Caucasian and Carniolan races, but no difference was found. These results were not included in the table.

The opposite experiments, when the training marks were blue, gave the same results: bees didn't differentiate them from white zinc. Two paints were used as blue: mixture of ultramarine with white zinc and mixture of artists' paint "Blue FT" with white zinc.

27-39% of bees drifted to the blue (as perceived by humans) cobalt compound-based paints which reflect the ultraviolet rays. We used these paints as blue in mixture with zinc white paint, which prevents ultraviolet reflection (Fig. 2). Reflectance spectra of the mixture of white zinc and any cobalt based paint coincides with white zinc spectra in the interval from 350 to 400 nm.

DISCUSSION

The accuracy of the recognition of the entrance hole (or of a coloured mark with the entrance hole in the center) position on the hive wall by honeybees is very low (Komissar 2002). This is the basis of the proposed method as, during the test, we can dispose two marks near each other instead of one on the hive wall (at training) without confusing the bees.

The proposed method of the alternative choice between training and novel (test) mark, as far as we know, was used only for the studying of the shape perception of solitary bees *Megahile rotundata* (Campan, Lehrer 2002). The method of prolonged training with two or more stimuli demonstrated simultaneously, where only one set is positive, but the others are negative (without rewards), is used as a rule for the studying of colour vision of honeybees. This classical method, at first proposed by Frisch in 1914, gives the possibilities to study the abilities of bees, which can be very high, but it doesn't demonstrate the manifestation of these possibilities in the real life of bees.

The most surprising result of our investigation was the identical reaction of bees to the white and blue entrance marks and we proposed to name this effect "white-blue phenomenon" (Komissar 1997). Blue and white are a pair from five colours recommended by Frisch (1964) for the colouring of the hive front walls. He described an experiment with colour plates on the hive front wall in a pavillion, when changing of the colour plates disposition resulted in the bees arriving at another hive. Frisch (1964) demonstrated the ability of bees to discriminate between two colours (blue and yellow) in that experiment only.

Apparently he extrapolated the ability of bees to distinguish other colours on the feeders into recommendations for hive coloration. Frisch (1964) was especially confident in bees' ability to discriminate between white and blue colour under any circumstances as it is this pair of colours that was used in his classical experiments on the feeder stations, when colour vision in bees was discovered by him in 1914. He knew about the failures with the use of white colour for painting of hives in pavillions but didn't pay necessary attention to that phenomenon. He wrote in an annex to the 7th German edition of his famous book: "The German beekeepers reported about the failure when using white colour in the pavillions, but I think that the reason of this phenomenon is the lack of knowledge about the bee perception of some paints". He recommended to use zinc white only as the white colour.

Many scientists worked with colour near-entrance marks, but they usually used only blue and yellow marks in their experiments and the phenomenon of bad resolution of white and blue was not discovered. In our case bees saw the second colour (test mark) for the first time during testing and rejected it only if they distinguished it from the training colour.

The similar phenomenon of not discriminating between white and blue was found for the foragers, which didn't tell white from blue artificial flowers at equal rewards (Wells H., Wells P.H. 1986). When blue flowers had a higher quality or frequency of reward than white, bees randomly visiting blue and white flowers became constant to blue ones.

Our experiments at the feeder station confirmed that bees could easily differentiate the same white and blue colours on the feeder after appropriate training with the use of the classical training method with negative and positive stimuli, but upon arrival at the nest bees didn't distinguish these colours, when they were the colours of near-entrance marks with absolutely black hole in the center of marks.

In our opinion the view of the absolutely black hole is the main mark of the hive entrance, as the edge of this hole is the place of landing of bees and they must concentrate their attention on the action of landing. We explain the drifting of the small part of bees (up to 7%, see table) to the aluminium and light yellow colours by the bees being disoriented due to the absolute black hole of the entrance.

The drifting of bees to white lead surfaces was 41%. The difference from 49% for the white zinc test mark is non-significant (P>0.05). From the point of view of the queen breeder the drifting of 25-41% of queens in multiple mating hives to neighboring compartments is extremely large as it is zero in the single mating hives. Therefore white lead paint together with blue paints, which reflected the UV rays, can't be recommended for painting of near-entrance marks as separate colours. This result has only a theoretical value as white lead isn't produced as poisonous paint now and blue cobalt-based paints are very expensive.

The cobalt blue paints are expensive paints for artists and it is unlikely that they would be used for painting of hives, but we checked all accessible blue paints and surfaces.

The test of our painting recommendations in the extra multiple mating hives with three entrance holes on every hive wall in a large-scale mating apiary gave good results: the mating success of queens in the single mating hives was equal to that in the 12-compartment hives (Komissar 2003a).

CONCLUSIONS

1. The method of alternative choice without preliminary training to the test coloured mark by arriving bees can be used for the definition of the adaptability for colorations of the near-entrance marks in the extra multiple mating hives, disposed on the same wall of the hive.
2. Arriving bees clearly distinguished a white zinc mark from yellow and "silver" ones, but didn't from grey and blue near-entrance marks in our experiments. These results don't allow the recommendation of white and blue colours simultaneously to be used for painting of near - entrance marks. We propose to use an additional colour of the surface of aluminium or any white metal.
3. Honeybees are able to distinguish blue and white paints, which reflect ultraviolet (cobalt compounds-based paints and white lead) from white zinc, but drifting to the mark of these colours was large (27-39%), which does not permit the use of these paints simultaneously with white zinc and another white paints for the near-entance mark of the extra multiple mating hives.
4. We suppose that our painting recommendations can be applicable for coloration of the front hive walls, but direct experiments with hives weren't carried out.

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MOŻLIWOŚCI PSZCZOŁY MIODNEJ W POSTRZEGANIU BIAŁYCH I NIEBIESKICH PŁASZCZYZN W OKOLICY WYLOTKOWEJ

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Streszczenie

Pszczoły posiadają potencjalnie wysokie zdolności do rozróżniania kolorów, jak wykazano w badaniach prowadzonych z podkarmiaczkami. Prowadzono długotrwałe treningi, w trakcie których pszczoły mogły obserwować dwa bodźce: pozytywny i negatywny. Te zdolności nie są w pełni wykorzystywane przez pszczoły powracające w okolice przestrzeni okołowylotkowej, kiedy jednocześnie widzą znany sobie kolor i nowy, widziany po raz pierwszy. Nasze badania wykazały, że przylatujące pszczoły łatwo rozróżniały kolor białego cynku od żółtego i „srebrnego", natomiast nie odróżniały koloru białego od szarego i niebieskiego. Te badania potwierdziły poprzednie zalecenia (Komissar 1993, 1996) aby nie wykorzystywać jednocześnie kolorów białego i niebieskiego na jednej ścianie ula. Do malowania okolicy wylotków poleca się również zastosowanie farby w kolorze „aluminium" lub innego białego metalu. Przypuszcza się, że te zalecenia mogą być przydatne przy malowaniu przednich ścian uli. Dotychczas nie przeprowadzono badań jeśli chodzi o kolorystykę całych uli.

Słowa kluczowe: pszczoła miodna, orientacja, rozróżnianie kolorów.