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Factors affecting pesticides hazard to different kinds of pollinators (*)

Abstract - Ecological factors determining the possibility of intoxication by pesticides of 3 biological groups of pollinators (wild solitary bees, bumble bees and honey bees) were analizied. Toxicity and rate of hazard of 16 insecticides to bees under field conditions were determined.
Different kinds of bees can be ranged by increase of susceptibility to insecticides as follows: bumble bee, honeybee and alfalfa leaf-cutting bee. The less hazardous for pollinators were pyrethroid insecticides, the most hazardous were organophosphorus ones.

Riassunto - *Fattori che condizionano l'impatto dei pesticidi su differenti impollinatori.*
Sono stati analizzati i fattori ecologici che possono determinare l'intossicazione di tre gruppi biologici di impollinatori (api solitarie, bombi e api mellifere). Sono stati determinati la tossicità e il grado di rischio di 16 insetticidi verso gli impollinatori in condizioni di campo. È stato possibile ordinare i pronubi in base all'incremento della loro suscettibilità come segue: bombi, api mellifere e api solitarie. Gli insetticidi meno pericolosi sono risultati i piretroidi, mentre i più pericolosi si sono rivelati gli organofosforici.

Key words: Bees, ecological factors, insecticides, residues, toxicity

INTRODUCTION

Ecologization of a system of chemical crop protection aimed at maximum reduction of chemical impact on agrobiocenosis is an important factor determining the conservation of different kinds of pollinators and efficiency of their beneficial activity.

At the same time, modern technologies of management of many crops include the use of chemical means for crop protection as a necessary element, and production of pesticides is increasing, and their assortment is being enlarged.

However, negative aspects of their use are well known: increasing contamination of environment, death of entomophagous and other beneficial organisms. Among the latter, intoxication

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of insect-pollinators is a significant problem and primarily of bees as essential component of agrocenosis of entomophilic crops.

In connection with this, we have analyzed the available literature resources as well as our own research data and experience on the problem for different kinds of pollinators: honey bee, wild solitary and bumble bees to find out such ways, chemicals and techniques of their application that would be efficient against pests and to the maximum safe to pollinators.

Researches on pesticide effect on bees - crop pollinators were conducted in different countries of the world. The results of those have been generalized by Nazarov (1967); Johansen (1977); Atkins *et al.* (1981); Dobrynin and Illarionov (1996); Dobrynin (1998); Devillers and Pham-Delegue (2002). The majority of researches were devoted to laboratory and laboratory-field determination of pesticide lethal doses and were mainly conducted on one pollinator species – honey bee, more seldom on artificially reared solitary bees *Megachile rotundata*, *Nomia melanderi* and some bumble bee species. The researches of pesticide effect on these pollinator species in field conditions were conducted in a small number. And only unique works touch upon the pesticide hazard to wild bee species under natural conditions (Bogoyavlensky and Zhukovsky, 1948; Birulya, 1949; Serkova, 1956, Way and Synge, 1948; Bohart and Lieberman, 1949; Linsley *et al.*, 1950; Benedek, 1981; Dobrynin, 1982; 1998), obviously because of great methodical difficulties of such works that conditioned obtaining of contradictory results. In some experiments wild bees were found to be less resistant to pesticides than honey bees, in others – more resistant.

Generally, in most of the works it was pointed out that the effect of chemicals in field conditions was much less than in laboratory ones and one of the main causes of bee poisoning at chemical treatments of plants is a violation of pesticide application regulations (S.S.Nazarov, 1984; Atkins, 1993).

The danger of bees poisoning is becoming an important factor of sustainable agricultural system's functioning, particularly for those crops that need cross-pollination by these insects. In this case the main objective of pesticide usage on crops -

prevention of a negative effect of harmful organisms on yield, contradicts the purposes of entomophilic crop cultivation because pollinating activity of bees primarily determines potential cross pollinated crop set.

Even prohibition of chemical treatments of entomophilic crops during their bloom can not fully prevent the possibility of pollinators contacts with pesticides, because bees usually explore larger spectrum of flowering plants than only one target pollinated crop (Dobrynin, 1998) and pesticides can be used not only in a field but in hive itself (S. Bonzini *et al.*, 2004; Tremolada *et al.*, 1996; Tremolada *et al.*, 2004).

The necessity to solve the dilemma forces to search for special approaches in chemical plant protection based on the study of ecological factors determining the possibility of intoxication of pollinators by pesticides, on knowledge of toxicity and rate of pesticides hazard to pollinators.

Biotic factors influencing pollinators' intoxication by pesticides

The consequences of contacts between pesticides and pollinators are determined first of all by the possibility of pollinators' intoxication. The process of intoxication, in turn, can arise as a consequence of coincidence of time and space niches of pollinators and pesticides causing their contact.

Pesticides can contact with pollinators both directly, during pesticide application (the most dangerous but relatively not often occurring), and by residual effect that can be manifested as intestinal — through digestive tract, respiratory — through respiratory tract, and the dermal one — through skin due to the contact of bees with the treated surface. The last variant is the most common.

The probability of emerging, course and consequences of a process of intoxication greatly depends upon biological features of pollinators and pollinated crop, and also upon abiotic environmental features influencing pesticide-pollinators relationships.

Three biological groups of pollinators — wild solitary bees, bumble bees and honey bees differ both in their anatomic-morphological and bio-ecological features, in life cycle and the extent of management by man. These differences significantly influence the probability of contact of every pollinator group with pesticides.

Under natural conditions it is impossible to isolate or move wild solitary bees to another place for a period of pesticide application and action, as in the case with managed populations of honey bee, leaf-cutting bee or bumble bee.

At the same time, due to preimaginal development in an isolated environment, contact of wild bees with pesticides at pre-adult stages is practically impossible. However, it is fully applicable to ground-nesters only.

Megachilid bees (especially of *Megachile* genera) make their brood cells mainly from vegetative parts of plants both entomophilic and non-entomophilic. The last ones are much more often exposed to pesticide treatments during bloom of the former ones that significantly increases probability of megachilid contact with pesticides, including direct action.

However, some of the main ground-nesting bees can nest directly in fields that makes the risk of pesticide hit on their nests great enough.

On the other hand, foraging features of wild solitary bees collecting nectar and pollen in limited amounts and life cycle pattern (spending unfavorable season in non-active status) show trophic and time limitation of their life activity. Besides, most of wild pollinator species belong to the summer phenological group foraging on a limited range of entomophilic crops blooming in a given period of a year. Moreover, most of bee species of the summer group are oligolectic that narrows the spectrum of visited plants even greater and, if also to consider their short flight range, these trophic and space-time restrictions of activity of the group can significantly reduce probability of its contacts with pesticides.

Another large group of wild pollinators - bumble bees - lives in colonies only during vegetative season. In autumn only fertilized females stay to spend a winter. As other social insects bumble bees have different castes that appear in a definite succession during the season in their colony. Therefore, probability of their contacts with pesticides is different.

In spring, after nest establishment, a bumble bee female collects itself the provision for future progeny, visiting a wide range of honey and pollen sources. The danger of its intoxication is great as spring pesticide treatments often affect wild-growing honey plants.

After emerging of the first working bees in a colony, a bumble bee female (queen) fly out of a nest for forage more and more seldom, that is why possibility of its contact with pesticides gradually decreases until minimum.

Worker bumble bees daily collect large amounts of honey and pollen for feeding of larvae. Forage flights are made practically during the whole light day period and even during light nights in more northern regions. Flights become markedly more frequent late in the morning and especially in the evening, owing to what there exist a rather high possibility of pesticide intoxication of working bees especially during evening and early morning treatments.

Emerging by autumn numerous bumble bee males and maiden females forage on flowers of late honey crops mainly from Compositae family. The danger of intoxication of these individuals is extremely low due to virtual absence of pesticide applications at this time.

Honey bees living in large colonies possess high extent of division of functions both among separate castes and within them. In a process of performing these functions there may arise different ecological relations between honey bee colony individuals and pesticides.

Honey bee queen stays within the nest practically all its life due to which it has minimum opportunity to contact with pesticides. Just indirectly through forage brought by bee foragers the queen has hypothetical possibility of intoxication but this possibility, as will be shown further, is highly improbable and such cases have not been registered in literature.

Male honey bee individuals (drones) are present in colony temporary, consume ready-made stores, and as a result, possibility of their contacts with pesticides is as improbable as of the queen.

The most numerous caste of honey bee colony are worker individuals. Depending on age, the main activity of workers may take place within the nest (the first half of life) and outside of it (the second half). In the period of an in-hive life worker bees leave the nest very seldom and therefore their contacts with chemical agents of crop protection are improbable except in the case of pesticide penetration into forage.

In the period of out-hive activity one of the main functions of workers is to collect provision - nectar and pollen. Very wide polilectism of honey bees, their ability of long distance flights, maximum duration of seasonal flight make possible for worker bees to forage on all approachable entomophilic floras growing in the range of 3 - 5 km from the nest during the whole period of vegetation that makes maximum the probability of contact of bee foragers with pesticides and, hence, the danger of their intoxication.

The highest losses are usually incurred by strong colonies having large numbers of old bees and therefore the possibility of contacts of such colonies with pesticide treated plants is much more higher.

As it is clear from the above, forage is an important link for all the members of honey bee colony. That is why the penetration of pesticide into forage could have very dangerous consequences for the whole colony. However, certain features of honey bee behavior, anatomy, and physiology hinder such course of events.

Observations showed that worker bees that got the lethal dose of pesticide often lost their orientation, flight ability and generally died outside of hive. If such bees still did come back to colony with a portion of poisoned nectar or pollen, they acted unnaturally and in-hive bees removed them from the nest before such individuals handed over their load.

If forager bees bring nectar or pollen along with the pesticide not having got the lethal dose, then in-hive reception bees can get it due to multiple taking and processing of poisoned forage. At that they usually strive to hold poisoned forage inside of them and are being removed together with it out of the nest by other bees. Guard-bees also hinder the bees with abnormal behavior, having strange smell of pesticide from entering into the hive.

Thus, mentioned biological features of honey bees contribute to prevention of honey bee product contamination with pesticides. Very few cases of nectar, honey or pollen contamination in hives have been registered under pesticide application in recommended rates (Atkins, 1993). Also, no one case of detection of pesticide residues in honey packed for sale has been recorded (Colombo and Spreafico, 2000; Bonzini *et al.*, 2004).

It is clear from the conducted analysis of biotic factors influencing possibility of pollinator intoxication that trophic factor plays the leading role since foraging activity of pollinators presumes obligatory contact with pollinated plant that, when treated with pesticide, can perform as mediator between toxicant and pollinators.

Abiotic factors influencing pollinators intoxication by pesticides

Forage activity of pollinators is significantly influenced by abiotic environmental factors (first of all, air temperature and relative humidity, light intensity, precipitations, etc.). Different combinations of these factors determine the intensity of pollinator flight on entomophilic crops and hence probability of pollinator - pesticide contact in case of chemical treatment of plants.

For developing the regulations of bee safe pesticide application it is necessary to know values of these factors determining the possibility of emergence and nature of intoxication process in given insects.

Optimum environmental parameters for flight foraging activity of bees (air temperature 25-30° C, relative humidity in limits of 50-60%, number of sunshine daily hours - 10-12, lack of precipitation, speed of wind not more than 4-7 m/sec) contribute also to the most active contact of pollinators with pesticides on treated entomophilic plants. Deviation of mentioned parameters from optimum values causes the reduction of bee flying activity and, as a rule, reduces the connection of pollinators with toxicants.

Abiotic environmental factors influence not only pollinator activity but also pesticide performance on treated plants, causing degradation of toxicants due to temperature increase, sun radiation (especially of the ultraviolet part of the spectrum), volatilization and out-washing of pesticides from plant surface, absorbing by plant and its biochemical responses (Marer *et al.*, 1988). These processes generally lead to the reduction of toxicity of chemical crop protection agents for bees. Air temperature reduction, on the contrary, may extend the dangerous period of pesticides for bees since it reduces the degradation processes of toxicants (Ibid).

Besides, abiotic environmental factors significantly regulate the rate of a plant developmental phases, especially the blooming phase as the most important for insect pollinators. The favorable combination of environmental factors stimulates emergence of new flowers after pesticide treatment of entomophilic plants, thus reducing the probability of pollinator contacts with already treated flowers.

Pesticide properties, methods and objects of application influencing pollinators intoxication

The possibility and performance of pesticide toxic effect on pollinators also depend on the properties of a pesticide itself. Its chemical or biological composition, target direction, character of action on harmful objects, ways of penetration into insect body, time of application and other properties influence greatly the probability of contacts with pollinators and the rise of intoxication process in the latter ones.

The specific nature of harmful organisms related to a great number of different plant and animal species, prompts the necessity of wide assortment of chemicals available for effective inhibition of these species.

However, far from all the products that are in the assortment of plant protection agents can contact pollinators with equal probability, and also have toxic influence on them. Out of more than 300 names of pesticides only about one third is recorded as highly toxic and moderate toxic for bees, whereas the rest constituting two thirds are relatively or entirely non-toxic for them. It is the difference of habitats and nature of harmful organisms and beneficial insects that determines first of all the possibility and consequences of bee contacts with pesticides of different groups and target directions.

Pest control products designed for protection of seed and planting material from harmful organisms (dressing agents and fumigants), stored agricultural products from insect pests and rodents (insecticides, zoocides) are used not in open field conditions (in operational buildings, warehouses, storages) and practically can not contact with pollinators due to alienation of spatial niches.

Products from the group of insecticides, nematocides, fungicides and herbicides applied into soil for control of harmful organisms inhabiting there also have very few chances to contact both with the above-ground nesting bees and the ground-nesters, since the last ones make their nests in firm soil, usually out of crop fields subjected to intensive cultivation.

Products designed for treatment of vegetating plants in open field conditions can contact with pollinators with high rate of probability. The possibility of their intoxication in this case will significantly depend on the time and method of pesticide application, the rate of crop entomophily, and phenological phase of development, target direction of pesticide, its preparative form, proximity of biological parameters of bees and target pests.

Time of pesticide treatment is the most important factor determining the possibility of coincidence of toxicants and pollinators time niches. Since bees visit entomophilic plants only during bloom and their daily flight activity is limited by daylight hours the direct contact of bees with pesticides is possible only when time of pesticide treatment coincides with the period of flight activity of these insects. Take into account also the facts that due to their biological features pests are located all the time in a crop forced to eat permanently because of a low energetic value of plant forage, while pollinators visit a crop only periodically during daytime and deal with flowers that are the least long-lived and daily revitalized parts of plants. Therefore, the use of chemicals that lost their residual toxicity before pollinators resume their daily flight would be the least hazardous to them. According to Atkins (1993,) only the shift of insecticide treatments from daytime to nighttime hours led to more than 50% bee loss reduction in California, USA.

In all other cases just contact of pollinators with pesticide residues mainly by means of plant substrate is possible. At that, the paths of getting pesticide on entomophilic plants during bloom period may be different.

It may be both a direct pesticide treatment of a target entomophilic crop and a drift of pesticide on blooming crop plant or wild entomophilic plants, sometimes even to long distances during treatment at wind speed exceeding admissible limits or as a result of treatment of adjoining crops especially with different bloom time, for example, in mixed orchards where different varieties and sorts grow side by side.

Pesticides can also get on flowering entomophilic weeds growing in fields of non-entomophilic crops or entomophilic crops in non-bloom phase exposed to pesticide treatments. Besides, during treatments of fruit trees pesticides can get on flowering entomophilic cover crops, and during treatments of forests and woodland belts can get on forest margin floats of crops and wild entomophilics.

As a rule, the greatest part of pesticides settles on the surface of plants. Sometimes, usually at exceeding rates of application, pesticides can penetrate into nectar and pollen of entomophilic crops or into honeydew of non-entomophilic ones, sweet excretions of sucking insects, morning dew on plants that is also collected by bees (Leski, 1974; Atkins *et al.*, 1981).

Target assignment of pesticides used for treatment of plants in the field conditions mainly determines their possible toxicity for insect pollinators.

Thus, products designed for control of plant disease causal organisms (fungicides), hazardous mites (acaricides), weed plants (herbicides), defoliants, desicants, plant and pest growth regulators are in the majority relatively non-toxic to pollinators (Nazarov, 1967; Atkins *et al.*, 1981; Johansen, 1983; Atkins, 1993; Colombo *et al.*, 2001), since target objects of these pesticides significantly differ from bees by their bio-ecological parameters.

Pesticides, the target objects of which have to some extent the same behavior as in bees parameters of external or internal structure, phenology, biology and physiology, and feeding, can be highly toxic for pollinators.

To this group of pesticides belong insecticides designed for control of pests that are in the same class of Insects as bees. Science and practice have proved that it is the insecticides when applied for plant protection purposes that represent the greatest danger for pollinators.

However, not all of the insecticides are equally toxic to insect pests and pollinators. Chemical structure features of pesticide compounds and their response ability determine the presence or lack of selectivity of toxic effect of some pesticides only to target pest objects, not affecting beneficial insects. Besides of the chemical compound structure, pesticide toxicity also depends on its preparative form and method of application.

The use of emulsifier concentrate preparative form even of one and the same pesticide is usually less dangerous than of wettable powders; and granulated insecticides are not essentially dangerous to bees. At the same time, the application of pesticides for ULV spraying performs a great danger to pollinators (Johansen, 1980). Already mentioned pesticide drift from the target crop most often takes place during ULV treatment with the help of aviation.

Thus, the analysis of ecological factors influencing pesticide-pollinator relationships shows that application of selective preparations and activation of ecological mechanisms preventing or reducing the realization of pesticide toxic effect on insect pollinators can serve as a basis of bee safe pesticide application in the system of chemical crop protection.

First of all it is necessary to avoid direct getting of pesticide on bees, treating the plants out of pollinators daytime flight. Once insecticide is applied out of pollinator daytime activity, the major factor determining the hazard of a chemical to bees is its residual effect duration.

Period of insecticides residual hazard for bees and their protection

In our research we determined the rate of the insecticides hazard by the length of the period necessary for reducing of the amount of active ingredient of chemicals on treated plants to the level non-hazardous for bees. It was assumed average lethal doze (LD_{50}) to be such a level, because in laboratory conditions when determining LD_{50}, insects in cages are to be in contact with pesticide treated plants 24 hours a day during the whole experiment, whereas in field conditions their daily activity lasts not more than 10 - 12 hours and a considerable part of this time they spend in nests (between flights), having no contacts with plants.

LD_{50} for three commercially used species of bees (honey bee *Apis mellifera L.*, alfalfa leaf-cutting bee *Megachile rotundata F.* and bumble bee *Bombus terrestris L.*) was determined by the method of bees contact with insecticide treated surface (Illarionov and Dobrynin, 1995) earlier in laboratory conditions, since the main cause of pollinator intoxication in field conditions is most often a contact toxicity of insecticide residues on visited plants.

Determination of pesticides LD_{50} is mainly a method of preliminary evaluation and comparison of different chemicals toxic activity and susceptibility of different objects. It cannot fully characterize toxic parameters of pesticides for pollinators because it provides no information for practice about length of the period of insecticide toxic activity in the field. The rate of pesticide hazard under field conditions depends both on its composition, rate, time of application and on environmental factors influencing conservation of pesticide toxic activity on plants and pollinators behavior.

To predict the rate of pesticide hazard and to prove the waiting period for using bees on pollination, we investigated the length of detoxication of insecticides applied on plants of alfalfa (*Medicago sativa* L.) in recommended dosages to the level safe for bees under field conditions. Samples of alfalfa plants were taken periodically (every 12 hours) for analysis of insecticides residues until they reach the LD_{50} level. Experiments were conducted under or close to optimum weather conditions for pollinators flight activity indicated above in part "Abiotic factors…". The amount of each tested insecticide on alfalfa samples was determined using standard method of gas chromatography.

The results of research are presented in the following table.

Table 1 - The Length of the Period of Insecticides Residual Hazard for Different Kinds of Pollinators

№ by the order	Name of Insecticides (and their active ingredients)	Rate of application, l/ha	Period of detoxication (days) of insecticides on plants to the safety level for		
			Honey Bee (*Apis mellifera* L.)	Alfalfa Leaf-cutting Bee (*Megachile rotundata* F.)	Bumble Bee (*Bombus terrestris* L.)
1	2	3	4	5	6
1.	Actellic (Pirimiphos-methyl), 50% EC	0.5 1.0	2.5 3.0	3.5 4.0	0.5 1.5
2.	Ambush (Permethrin), 25% EC	0.3 0.4	1.0 1.5	3.0 3.0	0 0
3.	Bazudin (Diazinon), 60 % EC	1.0 2.0 3.0	4.0 5.0 6.0	6 7.0 8.0	0.5 2.5 2.5
4.	Decis (Deltamethrin), 2.5 % EC	0.1 0.5	0 2.0	2.0 3.5	0 0
5.	Dursban (Chlorpyrifos-methyl), 40.8 % EC	0.8 1.5	5.0 5.5	7.5 8.0	1.5 2.5
6.	Zolone (Phosalone), 35 % EC	0.5 1.0 2.0 3.0	0 0 0 0.5	1.0 1.5 2.0 -	0 0 0 0
7.	Carbofos (Malathion), 50 % EC	0.2 0.5 1.0 2.0	1.0 2.0 2.5 3.0	2.0 3.0 4.0 4.5	0 0 0 0.5
1	2	3	4	5	6
8.	Karate (Lambda-cyhalothrin), 5% EC	0.15 0.2 0.5	2.0 2.5 3.5	2.5 3.0 -	0 0 0
9.	Mavrik (Fluvalinate), 2E, 25% EC	0.1 0.3	0 0	0 0	0 0
10.	Sumi-alfa (Esfenvalerate), 5% EC	0.3 0.5	0 0.5	1.5 2.0	0 0
11.	Sumicidin (Fenvalerate), 20% EC	0.3 0.6	0 0	2.0 3.0	0 0
12.	Talstar (Bifethrin), 10% EC	0.4 0.6	2.0 2.5	4.0 4.5	0 0
13.	Fastac (Alfa-cypermethrine), 10% EC	0.15 0.2	0 0.5	0.5 1.0	0 0
14.	Fosfamid (Dimethoate), 40% EC	0.5 1.0	5.0 6.5	8.0 9.0	3.5 4.5

15.	Hostaquick (Heptenophos), 50%EC	0.3 1.0 1.8	2.0 3.0 3.5	3.5 4.0 5.0	0 1.0 2.0
16.	Cymbush (Cypermethrin), 25% EC	0.1 0.24	2.5 3.0	- 5.0	0 0

The data of the table show that different kinds of bees can be ranged by increase of susceptibility to insecticides as follows: bumble bee, honey bee and alfalfa leaf-cutting bee.

From the point of view of pollinators protection the most ecologically safe chemicals were pyrethroid compounds. Their residues on plant surface (when applied at the recommended rates) were below levels of susceptibility of bumble bee *B. terrestris*. Non toxic to honey bee were the residues of Fastac, Sumicidin, Mavrik, and the residues of Decis, Ambush, Cymbush, Sumi-alfa and Talstar with not long (0.5 – 2.5 days) period of toxic activity were low hazardous to the bee.

At the same time, to alfalfa leaf-cutting bee the only application of Mavrik did not leave toxic residues on plants. Detoxication of other tested pyrethroids to the safe level to the bee, depending on the rate of application, took place during 0.5 – 5.0 days after treatment.

More hazardous for pollinators were organophosphorus insecticides. Long residual toxicity of Bazudin, Fosfamid, Dursban applied even at minimal rates is the reason to characterize them as hazardous, and at maximal rates – as highly hazardous with long toxic activity (6.0 – 7.5 days for honey bee and 8.0 -10.0 - for leaf-cutting bee).

For the bumble bee the residues of Carbofos and Hostaquick were not hazardous at minimal or close to minimal rates of application and also of Zolone at all the dozes. Low hazardous for the bumble bee were the residues of Carbofos and Hostaquick only at maximal dozes, and of Actellic - at all the dozes. These insecticides can also be related to low hazardous for honey bee, but hazardous for leaf-cutting bee at all the rates. Pyrethroid Karate by its residual action took the intermediate position for these two kinds of bees. Slightly toxic action of Zolone for honey bee was observed only at the maximal rate of application.

Generally, it could be noted the following tendency: pesticide residual amount on plants (and correspondingly pesticide hazard) appeared to be the function of the rate of application - the more was the rate the more was the amount of residues the longer was the period of pesticide hazard.

Experiments also showed that upon precipitation more than 5 mm after pesticide treatment or at the air temperature higher than 25^0 C the length of hazardous period for bees increases on 1-2 days, at the temperature below 16^0 C hazardous period for bees increases on 1 day.

Data of the table can help agriculturists to make reasonable decision both for purchase and usage of pesticides, which, on the one hand, could protect plants reliably and, on the other hand, be non- or low hazardous to insect-pollinators.

More over, the data of the table can help the utilization of different techniques for differentiation of bees and toxicants in time and space allowing to the maximum extent to avoid contacts with pesticides. These techniques can be accomplished in two principle ways: the first – by changing the place of foraging, and the second – by isolation of bees.

The first way is the most complicated, requiring great labor and resource expenses and used if it is necessary to separate bees and the plants treated with toxicant for a long period of time. The second way presumes isolation of bees, the duration of which depends on the length of the pesticide action on treated plants.

Practice showed that the most technologically suitable and effective way is the isolation of bees in hives directly in the field for the period of pesticide application and detoxication. From this point of view, the most promising were insecticides with their rates of application (see the table) which period of hazard did not exceed 2.5 days for leaf-cutting bee – the average longevity of female's life without feeding in isolated conditions in a field (Dobrynin, 1998), and 3 days - for honey bee provided with enough forage and water (Dobrynin and Illarionov, 1996).

For bumble bees, they do not need any particular measures of protection from the most of tested insecticides. So it is possible to choose the insecticide non- hazardous to bumble bees and at the same time having the period of hazard not more than 2.5 days for leaf-cutting and honey bees.

As for the protection of other bee species, it is possible to suppose with the high rate of probability that if leaf-cutting bee, according to numerous data, is the most susceptible among main bee-pollinators, hence chemicals non - or low hazardous to leaf-cutting bee will not be more hazardous to wild bee-pollinators.

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