Reprinted from the
ENVIRONMENTAL ENTOMOLOGY
Volume 1, Number 1, pp. 102–104, February 1972

Toxicity of Herbicides to Newly Emerged Honey Bees[1,2,3]

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ABSTRACT

We fed herbicides to newly emerged worker *Apis mellifera* L. in 60% sucrose syrup at concentrations of 0, 10, 100, and 1000 parts per million by weight.

The following herbicides were relatively nontoxic to honey bees at all concentrations: 2,4-D, 2,4,5-T, silvex, 2,4-DB, dicamba, 2,3,6-TBA, chloramben, picloram, Ethrel®, 2-chloroethylphosphonic acid, EPTC, and dalapon. The following were extremely toxic at 100 and 1000 ppmw concentrations: paraquat, MAA, MSMA, DSMA, hexaflurate, and cacodylic acid. Two compounds, bromoxynil and endothall, were very toxic only at 1000 parts per million by weight (ppmw) concentration. Paraquat, MAA, and cacodylic acid were moderately toxic at 10 ppmw. No significant differences were noted in the toxicity of purified and commercially formulated herbicides.

Studies conducted at this laboratory (Moffett et al. 1972) and elsewhere (Palmer-Jones 1950, 1964; King 1961[6]) indicate that toxicity of herbicides to honey bees, *Apis mellifera* L., depends upon the chemical, the formulation, and the carrier used with the herbicide. Toxicants can kill honey bees as stomach poisons, as contact herbicides, and in the case of herbicides, through destruction of the food source. Anderson and Atkins (1968) reviewed the wide variety of methods which have been used in laboratory and field studies to determine the effects of chemicals on honey bees. Methods of testing seem to have an important influence on the outcome of the test. In this study we attempted to determine the toxicity of herbicides as stomach poisons when fed to honey bees in 60% sucrose solution.

[1] Hymenoptera: Apidae.
[2] In cooperation with the University of Arizona Agricultural Experiment Station, Tucson. Received for publication May 20, 1971.
[3] Company and trade names are given for identification purposes only and do not constitute endorsement by the USDA.
[4] Plant Science Research Division.
[5] Entomology Research Division.
[6] C. C. King. 1961. Effects of herbicides on honey bees and nectar secretion. University Microfilms, Inc., Ann Arbor, Mich. 177 p.

Materials and Methods

Ten grams (approximately 100 individuals) of newly emerged honey bees were placed in 2×6×6-in. screened cages. All honey bees were less than 24 hr old at the time they were placed in the cages. Five grams of maintenance diet, consisting of 2 parts soyflour, 1 part pollen, and 6 parts sucrose with sufficient water to give proper consistency, were placed in each cage at the beginning of the feeding trial. Two 5-dr plastic vials, one containing distilled water and one containing 60% sucrose-herbicide solution, were placed on top of each cage. Two holes were drilled in the cover of each vial through which the bees obtained water and syrup. The herbicide-syrup solution, diet, and water were fed ad lib, checked daily, and replenished when necessary. Dead bees were counted and removed daily from each cage. The herbicides were fed for 60 days or until all bees died in the cage. The herbicides were fed at concentrations of 0, 10, 100, and 1000 parts per million by weight (ppmw) in the 60% sucrose solutions. Honey bees in 5 cages were fed each herbicide at each concentration.

We fed both purified herbicides of technical purity or better and commercial formulations. The purified herbicides were:

2,4-D[e]; butoxyethanol ester of 2,4-D; 2,4,5-T; butoxyethanol ester of 2,4,5-T; silvex; 2,4-DB; dicamba; 2,3,6-TBA; chloramben; endothall; bromoxynil; MAA; cacodylic acid; hexaflurate; picloram; Ethrel®, 2-chloroethylphosphonic acid; and dalapon.

The commercially formulated herbicides and their trade names are:

- dimethylamine salt of 2,4-D (Dow® DMA-4)
- isooctyl ester of 2,4-D (Chipman® 133, 2,4-D low volatile ester 4L)
- triethylamine salt of 2,4,5-T (Veon® 2,4,5)
- butoxyethanol ester of 2,4,5-T (Weedone® 2,4,-5-T)
- propylene glycol butyl ether esters of silvex (Kuron®)
- dimethylamine salt of dicamba (Banvel® D4S)
- dimethylamine salt of 2,3,6-TBA (Benzac® 1281)
- amine salt of endothall (Des-I-Cate®)
- paraquat (1,1′-dimethyl-4,4′-dipyridinium dichloride (Ortho® Paraquat CL))
- EPTC (*S*-ethyl dipropylthiocarbamate (Eptam® 6E))
- 1:2 mixture of triisopropylamine salts of picloram and 2,4-D (Tordon® 212)
- 1:1 mixture of triethylamine salts of picloram and 2,4,5-T (Tordon® 225)
- MSMA (monosodium methanearsonate (Ansar® 170))
- DSMA (disodium methanearsonate (Ansar® 184))

The unformulated herbicides were fed in 60% sucrose syrup in the purest form available. Most of the herbicides were sufficiently soluble in 60% sucrose to remain in solution at room temperature, or they formed a relatively stable suspension in the sucrose. Exceptions were picloram and 2,4-DB. Potassium salts of each were formed by mixing equal molar quantities of 0.10 N KOH and acids of each before adding to the 60% sucrose solution.

Several methods of presenting data are available, but we felt that the number of days required for ½ of the bees in the group to die (half-life) was an accurate index of the toxicity of herbicides to bees when compared with the bees fed only the maintenance diet and 60% sucrose.

Experimental Results

Data in Table 1 show considerable variation in the half-life of bees fed no herbicide. The length of a bee's life is dependent upon several factors, including time of year, physiological state of the colony, genetic makeup, and diet. This study was conducted throughout the year, with bees from several colonies. Therefore, it is not possible to compare data in Tables 1 and 2 except within the same row.

[e] Common names of herbicides are those approved by the Weed Science Society of America, 1971, as listed in Weed Science 19(3), back cover.

Table 1.—Half-life[a] of newly emerged adult honey bees fed herbicides in 60% sucrose solution at 3 concentrations.[b]

	Concentration in 60% sucrose (ppm by weight)			
Herbicide[c]	0[d]	10[d]	100[d]	1000[d]
2,4-D	33.4 b	37.2 a	40.4 a	18.6 c
Ester of 2,4-D	39.0 a	45.2 a	48.2 a	42.8 a
2,4,5-T	29.9 b	40.0 a	42.7 a	24.8 c
Ester of 2,4,5-T	29.5 a	27.0 a	30.4 a	17.7 b
Silvex	21.6 a	27.1 a	31.8 a	21.8 a
2,4-DB	40.5 b	48.8 a	49.2 a	27.5 c
Dicamba	35.2 a	26.8 a	41.5 a	31.6 a
2,3,6-TBA	55.4 a	34.4 b	30.4 b	34.4 b
Chloramben	57.2 a	57.0 a	54.4 a	41.0 b
Endothall	37.2 a	40.2 a	19.2 b	2.7 c
Bromoxynil	17.5 b	34.5 a	33.8 a	2.9 c
MAA	24.5 a	11.4 b	3.3 c	1.5 d
Cacodylic acid	44.2 a	4.1 b	2.6 b	2.1 b
Hexaflurace	26.0 a	18.2 b	10.8 c	5.0 d
Picloram	19.1 c	25.8 bc	33.2 ab	37.1 a
Ethrel	26.8 b	37.0 a	39.0 a	26.5 b
Dalapon	51.8 a	53.2 a	55.8 a	37.0 b

[a] Half-life is number of days required for ½ of bees in cage to die.
[b] Bees in each cage fed 5 g maintenance diet consisting of 1 part pollen, 2 parts soyflour, and 6 parts sucrose.
[c] All herbicides technical grade or higher purity.
[d] Means in the same row followed by same letter do not differ significantly at the 5% level of probability as calculated by Duncan's multiple range test.

No formulation of the substituted phenoxy herbicides significantly shortened the life of honey bees at the 10- and 100-ppmw concentrations; however, the bees fed 2,4-D, 2,4-DB, and 2,4,5-T at 10 and 100 ppmw lived significantly longer than the check bees. The ester of 2,4,5-T and 2,4-D, 2,4-DB, and 2,4,5-T caused significantly lower half-life at the 1000-ppmw concentration.

Dicamba did not cause any significant difference in the half-life of honey bees at any concentration. The acid of 2,3,6-TBA caused reductions in half-life of the honey bees at 10, 100, and 1000 ppmw when compared with the half-life of the check bees, and the acid of chloramben caused a reduction in half-life only at the 1000-ppmw concentration.

Endothall did not reduce the half-life of the honey bees at 10 ppmw; however, there was a significant reduction in half-life at 100 ppmw and a very drastic reduction at 1000 ppmw. Bromoxynil was not toxic to honey bees at 10 and 100 ppmw; in fact, there were significant increases in half-lives of bees fed at these 2 concentrations as compared with the check bees; however, at 1000 ppmw, the half-life was very markedly reduced.

MAA was toxic at all 3 concentrations and the toxicity increased with increasing concentration. Cacodylic acid was also toxic to honey bees at all 3 concentrations. Hexaflurate, the 3rd arsenical fed in this study, also caused significant reduction in half-life at all concentrations.

Table 2.—Half-life[a] of newly emerged adult honey bees fed commercially formulated herbicides in 60% sucrose solution at 3 concentrations.[b]

Trade name	Concentration in 60% sucrose (ppm by weight)			
	0[c]	10[c]	100[c]	1000[c]
Dow DMA-4	25.8 b	44.4 a	43.2 a	15.6 b
Chipman 133	30.2 a	27.2 a	36.4 a	28.9 a
Veon 2,4,5	31.9 a	34.1 a	34.1 a	6.4 b
Weedone 2,4,5-T	40.7 a	39.7 a	39.3 a	15.8 b
Kuron	43.2 a	43.1 a	37.0 a	38.4 a
Banvel D4S	25.3 a	26.7 a	28.8 a	30.4 a
Benzac 1281	28.2 a	33.8 a	39.1 a	30.9 a
Des-I-Cate	27.9 a	28.8 a	9.7 b	3.2 c
Ortho Paraquat CL	31.1 a	12.5 b	6.4 c	3.0 d
Eptam 6E	46.4 a	48.4 a	50.8 a	26.0 b
Tordon 212	20.9 b	33.7 a	30.4 a	20.4 b
Tordon 225	25.0 b	39.9 a	39.7 a	21.7 b
Ansar 170	39.5 a	29.5 b	5.4 c	2.5 c
Ansar 184	41.0 a	20.6 b	4.4 c	1.2 c

[a] Half-life is number of days required for ½ of bees in cage to die.
[b] Bees in each cage fed 5 g maintenance diet consisting of 1 part pollen, 2 parts soyflour, and 6 parts sucrose.
[c] Means in same row followed by same letter do not differ significantly at the 5% level of probability as calculated by Duncan's multiple range test.

Picloram did not cause a reduction in the half-life of the honey bees at any concentration; in fact, there was a significant increase in half-life of bees fed the 100- and 1000-ppmw concentrations when compared with the check bees.

Ethrel was also relatively nontoxic to honey bees. There was a significant increase in half-life of honey bees fed at the 10- and 100-ppmw concentrations, as compared with the check bees fed only 60% sucrose but not of those fed the 1000-ppmw concentration of Ethrel.

Bees fed dalapon at 10 and 100 ppmw lived as long as check bees, but those fed dalapon at 1000 ppmw had a slightly shorter half-life than the checks.

Table 2 summarizes half-life of newly emerged honey bees fed the commercially formulated herbicides at 0, 10, 100, and 1000 ppmw. The amine salt and ester formulations of 2,4-D, 2,4,5-T, silvex, dicamba, and 2,3,6-TBA did not shorten half-life of the honey bees at the 10- and 100-ppmw concentrations; and only the amine salts of 2,4-D and 2,4,5-T and the ester of 2,4,5-T caused significant reductions in half-life at 1000-ppmw concentration.

The amine salt of endothall was as toxic as the technical acid, causing significant reduction in half-life of bees at 100 and 1000 ppmw. Paraquat was toxic at all concentrations causing significant reductions in half-life. Only at 1000 ppmw did EPTC (Eptam 6E) cause a decrease in half-life of honey bees. The commercial formulations of amine salts of 2,4-D and picloram and amine salts of 2,4,5-T and picloram did not cause significant reduction in the half-life of bees when compared with the check; however, there were significant increases in half-life at the 10- and 100-ppmw concentrations.

MSMA and DSMA were toxic to bees, causing significant reductions in half-life of bees at all concentrations.

Discussion

Results of this study indicate that the toxicity of an herbicide to honey bees is relatively unchanged by addition of solvents and surfactants in the formulation process. It further shows that the formulation of an herbicide either as an amine or an ester has little influence on its toxicity to honey bees as a stomach poison. A case in point is endothall which has an LD_{50} for rats of 38–51 mg/kg for technical acid, but the LD_{50} increases to 206 mg/kg for the amine salt (Barrier et al. 1970). All the organic and inorganic arsenic herbicides were highly toxic to honey bees. This result is somewhat surprising as cacodylic acid, MAA, MSMA, and DSMA have relatively high LD_{50} values to warm-blooded animals. Our results differ from those of Atkins et al. (1970). When using their vacuum dusting technique they found DSMA, MSMA, cacodylic acid, and paraquat herbicides were relatively nontoxic to adult honey bees at 11 μg/honey bee. The difference in method of administering the toxicants (dusting vs. feeding) as well as concentration probably accounts for the different results.

Herbicides which may be potential hazards if used on crops visited by honey bees are paraquat, cacodylic acid, MSMA, DSMA, and hexaflurate. We found these herbicides were toxic when sprayed on caged honey bees (Moffett et al. 1972) and they were toxic in this study. It is not yet known if honey bees are able to pick up these herbicides from sprayed plants. A reasonable practice until further information is obtained would be to restrict or limit the use of these herbicides, and if possible substitute nontoxic herbicides where honey bees are foraging, or to remove honey bees from sprayed areas.

REFERENCES CITED

Anderson, L. D., and E. L. Atkins, Jr. 1968. Pesticide usage in relation to beekeeping. Annu. Rev. Entomol. 13: 213–38.

Atkins, E. L., Jr., L. D. Anderson, H. Nakakihara, and E. A. Greywood. 1970. Toxicity of pesticides and other agricultural chemicals to honey bees. Laboratory Studies. Calif. Agr. Exp. Sta. Ext. Serv. M-16.

Barrier, G. E., J. L. Hilton, R. E. Frans, H. M. Hull, W. T. Jackson, E. L. Knake, and D. E. Moreland. 1970. Herbicide Handbook of the Weed Science Society of America, 2nd ed. W. F. Humphrey Press, Inc., Geneva, N. Y. 289 p.

Moffett, J. O., H. L. Morton, and R. H. Macdonald. 1972. Toxicity of several herbicidal sprays to honey bees. J. Econ. Entomol. 65: 32–36.

Palmer-Jones, T. 1950. Chemical weedkillers and the beekeeping industry. N. Z. J. Agr. 80: 129–32.

1964. Effect on honeybees of 2,4-D. N. Z. J. Agr. Res. 7(3): 339–42.