REFERENCES

1. Anonymous. 1978. Rules for testing seeds. Association of Official Seed Analysts. J. Seed Technol. 3(3):29-118.
2. Anonymous. 1985. Association of Official Seed Analysts. Newsletter. 59(3):43-50.
3. Atkins, M.D., and J.E. Smith, Jr. 1967. Grass seed production and harvest in the Grain Plains. U.S. Dept. Agric. Farmers Bull. 2226.
4. Austenson, H.M., and D.V. Peabody, Jr. 1964. Effects of row spacing and time of fertilization on grass seed production. Agron. J. 56:461-463.
5. Blake, A.B. 1935. Variability and germination of seeds and early life history of prairie plants. Ecol. Monogr. 5:405-460.
6. Cosper, H.R., J.R. Thomas, and A.Y. Alsayeh. 1967. Fertilization and its effect on range improvement in the Northern Great Plains. J. Range Mange. 20:216-222.
7. Coukos, C.J. 1944. Seed dormancy and germination in some native grasses. J. Am. Soc. Agron. 36:337-345.
8. Hoover, M.M., J.E. Smith, A.L. Ferber, and D.R. Cornelius. 1947. Seed for regrassing Great Plains areas. U.S. Dept. Agric. Farmers Bull. 1985.
9. Kassel, P.C., R.E. Mullen, and T.B. Bailey. 1985. Seed yield response of three switchgrass cultivars for different management practices. Agron. J. 77:214-218.
10. Kneebone, W.R., and C.L. Cremer. 1955. The relationship of seed size to seedling vigor in some native grass species. Agron. J. 47:472-477.
11. Norris, E.L., and A. Decker. 1943. Report of the committee on range grass studies. Proc. Assoc. Off. Seed Anal. 35:63-67.
12. Robocker, W.C., J.T. Curtis, and H.L. Ahlgren. 1953. Some factors affecting emergence and establishment of native grass seedlings in Wisconsin. Ecology 34:194-199.
13. Sautter, E.H. 1962. Germination of switchgrass. J. Range Mange. 15:108-110.
14. Shaidaee, G., B.E. Dahl, and R.M. Hansen. 1969. Germination and emergence of different age seed of six grasses. J. Range Mange. 22:240-243.
15. Smika, D.E., and L.C. Newell. 1965. Irrigation and fertilization practices for seed production from established stands of side-oats grama. Nebr. Agric. Exp. Stn. Res. Bull. 218.
16. Smika, D.E., and L.C. Newell. 1966. Cultural practices for seed production from established stands of western wheatgrass. Nebr. Exp. Stn. Res. Bull. 223.
17. Smika, D.E., and L.C. Newell. 1968. Seed yield and caryopsis weight of side-oats grama as influenced by cultural practices. J. Range Mange. 21:402-404.
18. Wheeler, W.A., and D.D. Hill. 1957. Great Plains Grasses. pp. 591-592. *In* Grassland seeds. D. Van Nostrands Co., Inc., New York.

Effect of Pesticide Residues in Alfalfa Pollen and Nectar on the Foraging and Reproduction Activities of Alfalfa Leafcutting Bees *Megachile rotundata*[1]

C.M. Rincker and D.A. George[2]

ABSTRACT

Foraging and reproduction activities of alfalfa leafcutting bees (*Megachile rotundata* F.) were not affected when alfalfa was treated with various insecticides. Treatments consisted of recommended and 1.5 times recommended rates of demeton, oxydemeton-methyl, aldicarb, trichlorfon, dimethoate and carbofuran applied to alfalfa grown for seed in 1980 and 1981. Exposure of the bee larvae to insecticide residues in the pollen-nectar ball within the reproductive cell did not adversely affect percent live larvae nor emergence and flight of bees in the succeeding year.

***Additional index words: Medicago sativa,* seed production, pollinators, insecticides.**

INTRODUCTION

Alfalfa leafcutting bees *(Megachile rotundata* F.) are one of the most important pollinators of alfalfa grown for seed in the Pacific Northwest (McGregor, 1976). Seed growers, therefore, must use considerable care to protect these bees from toxic insecticides applied to seed fields for control of insects detrimental to seed production. Use of insecticides is even more of concern to seed growers since leafcutting bees are more susceptible to most insecticides than either honey bees (*Apis mellifera* L.) or alkali bees (*Nomia melanderi* Ckll) (Johansen 1983; Capizzi et al., 1982).

George and Rincker (1982) reported residues of demeton (Systox ®), trichlorfon (Dylox®), dimethoate (Cygon®), carbofuran (Furadan®), and/or their respective metabolites were found in the pollen-nectar ball collected by leafcutting bees. Waller (1969) studied the susceptibility of alfalfa leafcutting bees to various insecticides. He found azinphosmethyl (Guthion®) most toxic and carbaryl (Sevin®) least toxic. More recently we found residues of oxydemeton-methyl (Metasystox-R®) and it's metabolite in pollen-nectar balls.

Leafcutting bees collect pollen and nectar from flowering

[1]Contribution of Agricultural Research Service, USDA. Received 19 Sept. 1985.

[2]Research Agronomist, Agricultural Research Service, USDA, Irrig. Agric. Res. & Ext. Center, Prosser, WA 99350, and Research Chemist, Agricultural Research Service, USDA, Yakima Agric. Res. Lab., Yakima, WA 98902.

alfalfa and store it as a pollen-nectar ball in the reproductive cells they construct in nesting boards. The female bee lays an egg on the pollen-nectar ball before sealing the cell. After egg hatch, the bee larva consumes the pollen-nectar ball as food. This study was initiated to determine if residues of commercially used insecticides applied to alfalfa grown for seed were present in the pollen and nectar collected by the bees, and if so, whether the levels were high enough to be toxic to the bee larvae.

MATERIALS AND METHODS

'Arc' alfalfa was planted August 17, 1977, to supply individual plots, 3.6 × 6.0 m in size. Each plot consisted of four rows, 90 cm apart and was managed for alfalfa seed production in 1978, 1979, 1980 and 1981. A portion of these plots was utilized in 1978 and 1979 for pilot studies. In 1980, the study was expanded to include additional insecticides currently used by growers in seed production. A summary of residue data (George and Rincker, 1982) showing residues found in the pollen-nectar ball from the cell, and leaf from the cell is presented in Table 3. In 1980 and 1981, commercially used insecticides were applied to individual plots of alfalfa at recommended rates (kg a.i. ha^{-1}) as follows: demeton, 0.28; dimethoate, 1.68; trichlorfon, 1.68; carbofuran, 1.12; and at 1.5 times these rates. Aldicarb (Temik®), a pesticide presently unregistered for commercial use on alfalfa, in the Pacific Northwest, was also used in the pilot study in 1978 and 1979 at 3.36 and 5.04 kg a.i. ha^{-1}. It was not applied in 1980 or 1981 but continued observations were made to determine if residues carried over from year to year. Aldicarb was applied to a new plot at the lower rate in 1980 only. Oxydemeton-methyl (0.56 and 0.84 kg a.i. ha^{-1}) was applied in 1981 instead of demeton. Aldicarb was applied as a granular sidedressing in mid-May. All other insecticides were applied as foliar sprays. Carbofuran and dimethoate were applied once about mid-May, but the others were applied three times during bloom stage near June 3, June 24 and July 8, each year.

The first spring-growth of alfalfa was clipped and removed the last week of April each year. Before the alfalfa regrowth began flowering, about June 1 each year, each plot was covered with a Saran screen cage of 18 × 14 mesh (6 × 6 × 1.8 m in height) to prevent the bees from becoming contaminated with unknown insecticides from outside their test area.

Laminated wooden bee nesting boards were provided in insulated shelters inside each cage. A fresh supply of loose cells from wild-trapped leafcutting bees were used in 1980. The loose cells were incubated in a laboratory incubator set at 30 C and 60% R.H. Freshly emerged bees were counted, sanitized (quick dip in a 0.5% solution of sodium hypochlorite) to control chalkbrood *(Ascosphaera aggregata),* and released into each cage after the alfalfa began flower-ing. The bees were introduced into each cage in groups of 10 to 15 over a period of about one month. Total bees/cage were 104 in 1980 and 140 in 1981. Bee cells recovered from each treatment in 1980 were identified and retained for use in plots with the same treatments in 1981 to determine if there was any adverse accumulative treatment effect the following year. Bees from the 1980 demeton treatments were used with the oxydemeton-methyl treatments in 1981.

Pollination activities of the bees were observed at least twice a week to determine if bee numbers were declining or pollination was not being achieved due to loss of bee vigor.

Sampling procedures and results of residue analyses on

Table 1. Number and status of leafcutting bee cells recovered from alfalfa seed plots treated in 1980 and 1981 with various insecticides.

	Rate	Total No. of Cells Constructed		%of Total Cells With Cocoons		%of Cocoons With Live Larvae		%of Total Cells With Pollen Balls	
Insecticide	(kg a.i. ha^{-1})	1980	1981	1980	1981	1980	1981	1980	1981
Control		680	602	74	55	89	93	12	30
Demeton	0.28	870	---	82	--	93	--	8	--
Demeton	0.42	816	---	70	--	90	--	15	--
Aldicarb	3.36	609	---	78	--	96	--	11	--
Trichlorfon	1.8	368	790	58	58	87	90	19	32
Trichlorfon	2.52	848	567	73	52	100	92	12	39
Dimethoate	0.56	653	471	79	44	84	90	9	46
Dimethoate	0.84	558	421	77	61	90	88	11	30
Carbofuran	1.12	452	654	81	46	90	95	9	41
Carbofuran	1.68	366	492	80	57	90	97	10	36
Aldicarb(NT)[1]		566	384	64	70	93	97	15	25
Aldicarb(NT)[2]		585	---	75	--	93	--	11	--
Oxydemeton-methyl	0.56	---	565	--	69	--	95	--	24
Oxydemeton-methyl	0.84	---	801	--	67	--	97	--	25

[1]Treated in 1978 and 1979 @ 3.36 kg of a.i. ha^{-1}, but not in 1980 and 1981.
[2]Treated in 1978 and 1979 @ 5.04 kg of a.i. ha^{-1}, but not in 1980 and 1981.
38T2 - 129 128 723 693 - 09 08 06

Table 2. Residues of oxydemeton-methyl + metabolite (determined as the sulfone) in alfalfa leaves, pollen, nectar, pollen-nectar (p-n) ball, and leaf from bee cells from alfalfa treated with oxydemeton-methyl in 1981.

Treatment	Sampling interval	Residue found (ppm)				
(kg a.i. ha^{-1})	(days)	Leaf	Pollen	Nectar	p-n ball	Leaf-cell
0.50 2nd spray	0.5	28.90	1.34	21.81	---[1]	----
	1.5	20.00	----	----	----	----
	3.0	10.10	ND[2]	2.50	0.91	1.89
	14.0	2.65	----	----	0.60	0.55
3rd spray	4.0	9.05	----	----	1.86	7.55
0.75 2nd spray	0.5	51.80	1.88	20.41	----	----
	1.5	43.28	----	----	----	----
	3.0	42.00	1.47	1.56	2.07	2.18
	14.0	0.10	----	----	0.34	0.70
3rd spray	4.0	36.00	----	----	1.55	2.48

[1]No sample taken.
[2]Below the lower limit of sensitivity of the method: 0.10 ng of sulfone.

alfalfa leaf, pollen, nectar, pollen-nectar balls from the bee cell, and leaf from the bee cell for 1980 are previously reported (George and Rincker, 1982). Over 430 residue samples were collected and analyzed in 1980 and 1981.

After pollination was completed, the alfalfa seed matured, and the bees had ceased activities, all bee nesting boards were identified by plot, removed from the cages and stored at 5 C. During the winter months the cells were carefully removed from the bee boards of each pesticide treatment and counted. Cells with pollen balls only collapsed easily, whereas good cells contained cocoons spun by the fourth-instar larvae and did not collapse when gently squeezed. The percentage of cells with pollen balls only was determined. One hundred cells containing cocoons from each treatment were excised and examined to determine percentage with live larvae. Those cells either incomplete or parasitized were not used in calculating percentages of living larvae.

Due to the nature of the research, availability of screened cages, and the large number of residue samples removed from each plot for analysis, it was not feasible to replicate each year's study; thus eliminating a statistical analysis of the data collected.

RESULTS AND DISCUSSION

Demeton

The effect of previously reported demeton residues (Table 3) upon leafcutting bee activities appear to be nil (Table 1). More bee cells were constructed in the demeton treated plots than the control plots, or most other treatments, which indicates no adverse effect upon the pollination activities in 1980. The percent live bee larvae was slightly higher than the control and about the same as most other treatments. Bee cells recovered from the 1980 demeton treatment were used on the oxydemeton-methyl treatments in 1981, where they performed very well, suggesting no adverse carryover effect (Table 1). The bees produced 6% fewer cells on the higher rate than the recommended rate.

Trichlorfon

The effect of trichlorfon residues (Table 3) upon the pollination activities of the bees appeared to be nil, but not clear cut because of differences between the low and high treatment rates (Table 1). When averaged over two years, the bees on the plots treated at the higher rate performed better than the control or most other treatments, suggesting no adverse effect upon the bees. However, the bees on the plot treated at the recommended rate in 1980 performed rather poorly compared to the control in number of cells constructed, percent cells with cocoons, and percent pollen balls. Apparently trichlorfon was not responsible for this poor comparison since the higher rate did not adversely affect the bees. In 1981, the bees on plots treated at the recommended rate compared very favorably with the control, indicating no carryover affect.

Dimethoate

Residues of dimethoate were not detached in alfalfa pollen, nectar, pollen-nectar balls, or the leaf from bee cells (Table 3). Therefore, logically the pollination activities of the bees should not be impacted. The number of cells constructed in 1980 and 1981 on the dimethoate-treated plots averaged 11% fewer in 1980, and 26% fewer in 1981 than the control (Table 1). This was due to lack of control of the detrimental insects, Pea aphids (*Acyrothosiphon pisum*) and Lygus bugs (*Lygus hesperus* and *L. elisus*) within the plots in mid- to late-season, which in turn adversely affected continued flowering of the alfalfa and reduced the availability of pollen and nectar for the bees. Two year averages for percent cells with cocoons, percent live larvae, and percent pollen balls for the higher rate were comparable to the control. These results from the recommended rate, however, compare less favorably to the control, particularly in 1981. Since the higher treatment rate indicates no adverse effect of this insecticide, the unfavorable comparison for the recommended rate apparently was not due to dimethoate.

Carbofuran

Residues of carbofuran or the metabolites were not detected in alfalfa pollen, nectar or pollen-nectar balls (Table 3). Therefore, as with dimethoate, logically the pollination activities of the bees should not be impacted. However, the number of bee cells constructed on the carbofuran-treated plots averaged 40% fewer in 1980, and 5% fewer than the control in 1981 (Table 1). Lack of control of detrimental insects in mid- to late-season reduced alfalfa flowering. Therefore, the reduced availability of pollen and nectar for the bees accounts for the reduced number of bee cells. The percent cells with cocoons, percent live larvae, and percent pollen-nectar balls compare favorably with the control, with the exception of percent pollen-nectar balls in 1981. We have no explanation for the increased pollen-nectar balls in 1981.

Aldicarb

Residues of aldicarb and its metabolites were previously reported detected in alfalfa leaves, nectar, and leaf from bee cells but not in the pollen-nectar ball (Table 3). Low levels of aldicarb residues and its metabolites (Table 3) were detected in samples from plots not treated in 1980 but previously treated in 1978 and 1979. High levels of residue were detected in samples from the leaf from cells from the single plot treated and sampled in 1980.

The number of cells constructed in 1980 were 10% fewer in the aldicarb plot than the control (Table 1). However, the percent cells with cocoons, percent live larvae and percent pollen-nectar balls generally compares favorably with the control. The one exception is in 1980 when the percent of cells with cocoons from the untreated aldicarb (treated in 1978 and 1979 at 3.36 kg of a.i. ha^{-1} rate) plot produced 64% good cells compared to 74% for the control. Lack of control of detrimental insects in the nontreated plots resulted in fewer alfalfa flowers and thus a diminishing supply of pollen and nectar for the bees. Aldicarb appears to have no adverse effect on leafcutting bees and their pollination activities at the rates used in this study, particularly when the results of 1978 and 1979 are considered. The aldicarb-treated plots produced the highest seed yields and had more live bee larvae than the control or the demeton or trichlorfon treated plots in 1978 and 1979.

Oxydemeton-methyl

Oxydemeton-methyl was applied for the first time in 1981 and residues in alfalfa leaves, pollen, nectar, pollen-nectar balls, and leaf from the bee cells are reported (Table 2). Leaf samples for residues of oxydemeton-methyl and its sulfone metabolite were taken 12 hrs to 14 days after the second spray treatment and 4 days after the third spray treatment. Residues ranged from a high of 28.9 ppm (12 hrs) to 2.65 ppm (14

Table 3. Summary of residues in pollen-nectar (p-n) ball and alfalfa leaf collected by *Megachile rotundata* from alfalfa seed plots treated with several insecticides in 1980. (Condensed from George and Rincker, 1982).

Insecticide	Treatment (kg a.i. ha^{-1})	Sampling interval (Days after application)	Residue found (ppm)	
			p-n ball	leaf-cell
Demeton	0.28	3	0.44	0.02
		8	0.30	ND[1]
		9	0.27	0.07
		21	0.02	0.05
	0.42	3	0.10	0.02
		8	0.03	0.06
		9	0.21	2.97
		21	0.10	0.07
Trichlorfon	1.68	4	----	15.67
		8	5.45	5.77
		9	0.64	1.08
	2.52	4	0.27	1.14
		8	0.75	1.24
		9	0.68	4.48
Dimethoate	0.56	26 to 69	none	none
	0.84	26 to 69	none	none
Carbofuran	1.12	26 to 54	none	0.6 to 10.0
	1.68	26 to 54	none	0.6 to 10.0
Aldicarb	3.36	47	ND	2.09
		56	ND	0.61
		60	0.12	9.27

[1]Below lower limit of sensitivity of the method used.

days) after treatment at the recommended rate and 51.8 ppm to 0.10 ppm, respectively, at the higher rate. High residues were detected in the nectar 12 hrs after treatment. However, these high residues were not detected in the pollen-nectar ball or leaf from the cell. In spite of these levels of residues, the bees performed well in the treated plots and the insecticide provided good control of the detrimental insects in the alfalfa. The number of bee cells constructed in 1981 averaged 13% above those from the control (Table 1). Also, the percent cells with cocoons, percent live larvae, and percent pollen balls reflected no adverse effect of oxydemeton-methyl on the bees or their pollination activities. Oxydemeton-methyl was applied again in 1982 with similar results regarding bee activities (Rincker, unpublished data).

In summary, residues in the leaves and/or the pollen-nectar balls show no adverse effect on bee larvae in this study even at 1.5 times recommended rates. Bees from cells retained from the 1980 treated plots performed as well in 1981 as bees from the control plots. The effect of pesticide residues in the pollen-nectar ball on leafcutting bee larvae has not been reported previously. Results from this study are not a basis for using more than the recommended rates of the respective insecticides but are reported as experimental data only.

ACKNOWLEDGEMENT

We thank the Washington Alfalfa Seed Commission for partial support of this research project.

REFERENCES

1. Capizzi, J., G. Fisher, H. Homan, C. Baird, A. Retan, and A. Antonelli. 1982. Pacific Northwest Insect Control Hand-book. pp 23.
2. George, D.A., and C.M. Rincker. 1982. Residues of commercially used insecticides in the environment of *Megachile rotundata*. J. Econ. Entomol. 75:319-323.
3. Johansen, Carl. 1983. How to reduce bee poisoning from pesticides. Western Region Ext. Publ. (WREP) 15. pp 1-11.
4. McGregor, S.E. 1976. Insect pollination of cultivated crop plants. USDA Agric. Handbook No. 496:36-39.
5. Waller, G.D. 1969. Susceptibility of an alfalfa leafcutting bee to residues of insecticides of foliage. J. Econ. Entomol. 62(1):189-192.

Lodging Control and Yield Enhancement in Morex Spring Barley with Paclobutrazol Treatment[1]

L.A. Morrison and D.O. Chilcote[2]

ABSTRACT

Paclobutrazol, an experimental plant growth regulator (PGR), is reported to control lodging through height reduction and stem strengthening and thereby enhance yield. This field experiment tested Paclobutrazol under two levels of nitrogen on a known lodging-susceptible spring barley cultivar (*Hordeum vulgare* cv. Morex).

Paclobutrazol caused significant shortening of the basal internodes but did not improve stem strength. Due to delayed lodging, treated plots reflected significant yield increases over the control plots. The higher treatment rates (800 and 1000 g ha^{-1}) also showed significant yield increases over the lower treatment rates (400 and 600 g ha^{-1}).

The results point to a clear association of reduced height with lodging control and concomitantly with yield increases. The absence of improved stem strength raises questions concerning the mechanism of Paclobutrazol's effect on lodging in the barley species and the mechanism of its effect in combination with nitrogen fertility.

Additional index words: **Height reduction, *Hordeum vulgare*, Parlay, plant growth regulator, stem strength.**

INTRODUCTION

Lodging can be a management problem in intensive cultural systems where high nitrogen levels and optimum moisture relations are used to promote yield (Mulder, 1954; Pinthus, 1973). Under these conditions, lodging-susceptible cereal cultivars , which are typically tall and weak-strawed, show a greater tendency to lodge. Yield losses can be significant, particularly when plants lodge during the early-lodging period that occurs at heading (Laude and Pauli, 1956; Pinthus, 1973).

Plant growth regulators (PGR's) which affect the stem elongation event by manipulating the endogenous hormone systems have proven useful in controlling lodging (Froggatt

[1]A Contribution of the Crop Science Department, Oregon State University. Received for publication 30 September, 1985.

[2]Formerly Graduate Assistant and Professor of Crop Physiology, respectively, Department of Crop Science, Oregon State University, Corvallis, Oregon 97331, USA.