The Great Lakes Entomologist

Volume 27
Number 1 - Spring 1995 *Number 1 - Spring 1995*

Article 2

April 1995

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Kathy L. Flanders
University of Minnesota

Edward B. Radcliffe
University of Minnesota

Craig A. Krueger
University of Minnesota

NATURAL ENEMIES OF ALFALFA WEEVIL, *HYPERA POSTICA* (COLEOPTERA: CURCULIONIDAE), IN MINNESOTA

Kathy L. Flanders,[1,2] Edward B. Radcliffe,[1] and Craig A. Krueger[3]

ABSTRACT

Alfalfa weevil, *Hypera postica*, is present throughout Minnesota. However, economically damaging populations seldom occur, due to a combination of natural enemies and adverse climatic conditions. Five natural enemies of alfalfa weevil were found in Minnesota. *Microctonus aethiopoides* (Hymenoptera: Braconidae), a parasitoid of adults, was recovered from 43 of 65 counties surveyed during 1984 and 1985. *Tetrastichus incertus* (Hymenoptera: Eulophidae) and *Bathyplectes curculionis* (Hymenoptera: Ichneumonidae), parasitoids of larvae, were each recovered from 13 of 15 counties surveyed during 1991-1993. *Bathyplectes anurus*, another parasitoid of larvae, was recovered from one county in 1991, four counties in 1992, and six counties in 1993. *Zoophthora phytonomi* (Entomophthora: Entomophthoraceae), a pathogen of larvae, was recovered from 14 of 15 counties surveyed in 1991-1993. Winters with low minimum temperatures and little snow cover were detrimental to the weevil. Usually, southeastern Minnesota has milder winters and higher alfalfa weevil populations than other areas of the State. However, even here, because of natural enemies, weevil populations seldom reach economically damaging levels.

The eastern strain of alfalfa weevil, *Hypera postica* (Gyllenhal) (Coleoptera: Curculionidae), a potentially devastating pest, reached Minnesota in 1970 (Radcliffe and Chiang 1972). The weevil rapidly expanded its range and by 1975 was present throughout the southern half of the State (D. Sreenivasam, Minnesota Department of Agriculture, pers. comm.). Objective of this research was to determine distribution of alfalfa weevil parasitoids and pathogens in Minnesota. A secondary objective was to assess possible effects of winter weather on alfalfa weevil.

Establishment of alfalfa weevil in the eastern United States necessitated greatly increased insecticide use on alfalfa in the 1960's. Alfalfa once ranked sixth among U.S. crops in treated hecterage (National Academy of Sciences 1975). Beginning in 1957, USDA APHIS implemented a classical biological control program which has proven highly successful (Kingsley et al. 1993). Six species of parasitoids are now widely distributed on the eastern seaboard, and insecticide use on alfalfa has dramatically declined with establishment of these parasitoids (Day 1981). Four of these six parasitoids were intentionally

[1]Department of Entomology, University of Minnesota, St. Paul, MN 55108.

[2]Current address: Department of Entomology, Cornell University, Ithaca, NY 14853.

[3]formerly, Department of Entomology, University of Minnesota, current address 1519 E. County Rd B, Maplewood, MN 55109.

introduced: *Bathyplectes curculionis* (Thomson) and *B. anurus* (Thomson) (Hymenoptera: Ichneumonidae); *Tetrastichus incertus* (Ratzeburg) (Hymenoptera: Eulophidae); and *Microctonus aethiopoides* Loan (Hymenoptera: Braconidae). *Microctonus colesii* Drea (Hymenoptera: Braconidae) apparently was introduced accidentally. *Anaphes luna* (Girault) (Hymenoptera: Mymaridae) probably originated from releases in Indiana intended to control *Hypera nigrirostris* (F.) (Dysart and Day 1976). *Anaphes luna* attacks eggs; *B. curculionis, B. anurus*, and *T. incertus* attack larvae; *M. colesii* attacks larvae, but kills adults; and *M. aethiopoides* attacks adults. A pathogenic fungus that attacks alfalfa weevil larvae, *Zoophthora phytonomi* (Arthur) (Entomophthora: Entomophthoraceae), has become an important mortality agent (Harcourt et al. 1974).

Alfalfa weevil arrived in Minnesota with one natural enemy, *B. curculionis*. A second natural enemy, *M. aethiopoides*, obtained from Ohio, was released in two Minnesota counties in 1978–1980 (Radcliffe et al. 1983). Three other natural enemies, *B. anurus, M. colesii*, and *Diabrachoides dynastes* (Hymenoptera: Pteromalidae) were subsequently released in Minnesota by APHIS during 1979 to 1988 (Bryan et al. 1993). However, through 1990, when the APHIS program ended, only *M. colesii* had been recovered. *Tetrastichus incertus* was not released in Minnesota, but prior to our study had been recovered in two counties.

Alfalfa is grown extensively in Minnesota, primarily for on-farm use as feed for dairy cows. Of the state's 650,000 ha of alfalfa (Rock et al. 1991), 60% is located in 34 contiguous counties, an area known to Minnesotans as the dairy belt. Surveys in 1984–1985 were statewide to determine the extent of spread by *M. aethiopoides*. Surveys in 1991–1993 were conducted in the dairy belt to determine occurrence and impact of natural enemies attacking alfalfa weevil larvae.

MATERIALS AND METHODS

Sampling to determine the distribution of *M. aethiopoides*, 1984–1985. Overwintered weevils were collected from alfalfa fields in 48 counties in 1984 and 42 counties in 1985. One field was sampled per county. Fields sampled in 1984 were in eastern and southern Minnesota. The survey was expanded in 1985 to west central and northwestern counties. Twenty-four of the counties sampled in 1984 were resampled in 1985. Counties were resampled for one of three reasons: *M. aethiopoides* was not recovered in 1984, weevil density was high in 1984, or percent parasitism was high. Our purpose in the latter two instances was to monitor population trends the succeeding year. Sampling of ten fields in 1985 was done for us by Minnesota Department of Agriculture personnel. Sampling was targeted for 175–200 cumulative degree-days above a 9°C base. In 1984, sampling was started 18 May and completed 13 June. Sampling for 1985 was started 7 May and completed 19 May. We attempted to collect 100 weevil adults from each field, but this was not always accomplished at fields with densities of less than one per 100 net sweeps. Samples were collected with a standard 38 cm diameter sweep net. Each net sweep consisted of one 180 degree sweep. Weevil population densities were quantified as number per 100 net sweeps. Adult weevils recovered were taken to the laboratory and held in screen-bottomed cages. This allowed emerging parasitoids to drop to a container below where they could spin cocoons on felt strips (Loan and Holdaway 1961). Cocoons were then transferred to individual vials and held in the laboratory for adult emergence.

Sampling to determine the distribution of natural enemies of alfalfa wee-

vil larvae, 1991–1993. Fields sampled were located in 15 counties along the eastern edge of Minnesota's dairy belt. Weevil larvae were collected for rearing using standard 38 cm diameter sweep nets and pendulum sweeps. We attempted to collect 500 larvae per field on each sampling date. If fewer than 500 larvae were collected, a maximum of 2,000 net sweeps were taken. In 1991, a vehicle-towed sled was used in five fields to collect scarce larvae from postharvest stubble and short alfalfa in early to mid-June. Weevil populations were estimated from the first three 300-sweep samples at each field each date. Each year, sampling was targeted to begin with first occurrence of alfalfa weevil larvae. Follow-up samples were taken from fields with high weevil abundance.

Twenty-one fields were sampled in 1991, 11 fields were sampled more than once. Twenty fields were sampled in 1992, 4 fields twice, 16 fields three or more times. Ten fields were sampled in 1993, five fields were sampled three or more times. In 1993, sampling was restricted to fields in southeastern Minnesota (to study the spread of *B. anurus*), or to fields that were part of a separate phenology study (Flanders and Radcliffe, in preparation). Weevil population densities were quantified as number of larvae per 100 net sweeps. Each year, larvae were brought back to the laboratory and reared in brown paper bags according to protocols developed by the USDA APHIS Niles Biological Control Laboratory, Niles, Mich. Larvae were fed every three days for two weeks. After new adults had emerged, number of parasitoid cocoons, cadavers of larvae killed by *Z. phytonomi*, and unparasitized hosts were recorded. Samples of each type of cocoon or diseased larva were sent to the Niles laboratory to confirm identifications. Adults reared from larvae collected in mid-to late June were dissected to determine if they were parasitized by *M. colesii*. In 1991, 130 adults from 5 fields were dissected.

Estimating winter severity. Since alfalfa weevil overwinter in soil and litter, winter soil temperatures may affect weevil survival. Snow of sufficient depth insulates so that soil temperatures are largely independent of air temperature (Sharratt et al. 1992). A snow cover of 10 cm provides insulation such that a change of -1°C in air temperature results in only -0.3°C change in soil temperature at 1 cm depth. For each winter relevant to our survey, days with minimum temperatures below -18°C and snow cover of 10 cm or less were tallied. Days with these temperature and snow-depth threshold conditions were classified as severe winter days for the purposes of this study. They were chosen to illustrate the most severe winter conditions that occur in Minnesota. Data from the nearest available weather station was used for each field. Temperature and snow-depth information were obtained using the Midwestern Climate Information System (MICIS) at the Midwestern Climate Center, Office of Applied Climatology, Illinois State Water Survey, Champaign Illinois.

RESULTS

Alfalfa weevil was recovered from 66 of 67 counties sampled in 1984–1985, and 15 counties and 33 of 35 fields sampled in 1991–1993. Alfalfa weevil densities tended to be higher in southeastern Minnesota than in other areas of the State (Figs. 1–2). Weevil populations were higher in 1984 than in 1985, and higher in 1992 and 1993 than in 1991.

Distribution of *M. aethiopoides*. *Microctonus aethiopoides* was recovered from 35 counties and 35 of 48 fields sampled in 1984 (Fig. 3), and from 23 counties and 23 of 43 fields sampled in 1985. Before 1984, the known Minnesota distribution of *M. aethiopoides* was limited to two southeastern counties.

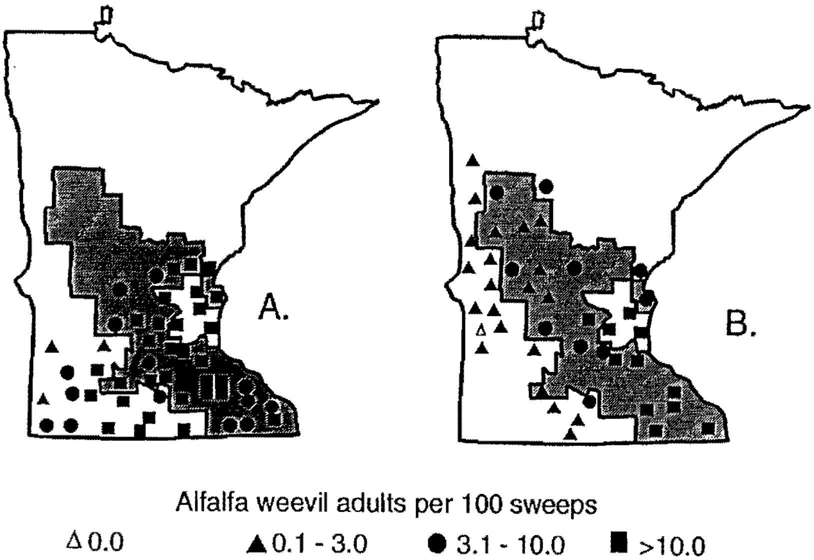

Figure 1. Alfalfa weevil population densities, 1984–1985, based on number of adults per 100 net sweeps. Shaded area indicates the dairy belt. A = 1984, B = 1985.

This rapid expansion range demonstrates the remarkable capacity of this parasitoid for dispersal once established. *Microctonus aethiopoides* parasitized over 30% of weevil adults at four fields in 1984 and one field in 1985. Mean spring parasitism was 14% in 1984, and 16% in 1985 (Table 1). Failure to recover *M. aethiopoides* in fields with extremely low weevil populations may have been due to inadequate sample size. In 1991, *M. aethiopoides* was recovered from the most northern field during our separate survey to determine parasitoid phenology (Flanders and Radcliffe, in preparation).

Distribution of natural enemies of alfalfa weevil larvae, 1991–1993. More than 40,000 alfalfa weevil larvae were reared during the 1991–1993 natural enemy survey. The number of larvae reared per field varied with alfalfa weevil population. The combined impact of the natural enemies of weevil larvae increased from 7% during first crop 1991 to 77% during second crop in 1993 (Fig. 4). Four natural enemies of alfalfa weevil larvae were recovered: *B. curculionis, B. anurus, T. incertus,* and *Z. phytonomi* (Fig. 5). *Bathyplectes curculionis* was recovered in 13 counties and 31 of 35 fields sampled. The only fields where *B. curculionis* was not recovered were those of extremely low weevil abundance. During periods of greatest impact, *B. curculionis* caused an average mortality of 28% in 1991, 43% in 1992, and 46% in 1993 (Table 2). *Bathyplectes anurus*, not previously reported in Minnesota, was recovered in 1991. The parasitoid has since been recovered in 6 counties and 9 of 35 fields sampled, with highest parasitism rates in four southeastern counties. *Bathyplectes anurus* caused <1% mortality in fields where it was recovered in 1991, 1% in 1992, and 4% in 1993. The highest parasitism rate observed to date was 15% in Winona County on 1 June 1993. *Tetrastichus incertus* was recovered in 13 counties and 30 of 35 fields sampled. Parasitism by *T. incertus* did not exceed 17% at any field during May through mid-June, the period of the

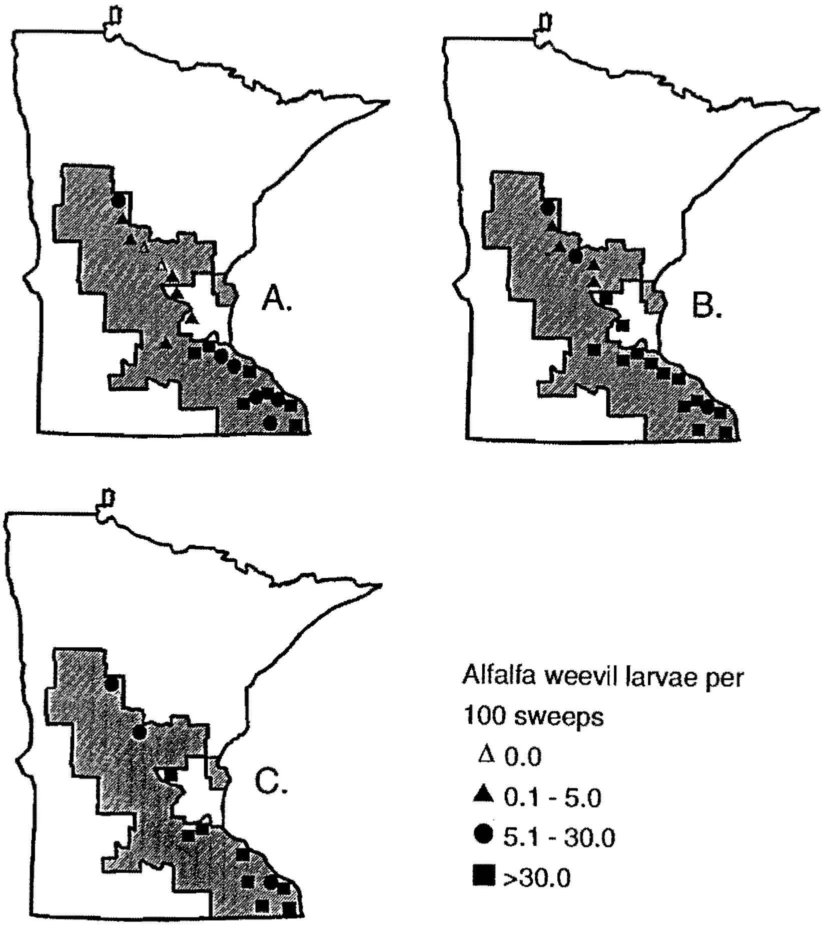

Figure 2. Alfalfa weevil population densities, 1991–1993, based on number of larvae per 100 net sweeps. Shaded area indicates the dairy belt. A = 1991, B = 1992, C = 1993.

survey. However, dissection data from our phenology studies (Flanders and Radcliffe, in preparation) showed that *T. incertus* parasitized an average of 41% of larvae during late second crop (late June, early July), and 73% of larvae during third crop (late July, August). The pathogen *Z. phytonomi*, not previously reported in Minnesota, was recovered from 14 counties and 32 of 35 fields surveyed. The only fields where *Z. phytonomi* was not recovered were those with very low weevil densities. During its seasonal period of greatest impact, *Z. phytonomi* caused an average larval mortality of 10% in 1991, 23% in 1992, and 46% in 1993.

Relation between winter weather and alfalfa weevil density. Years of greatest weevil abundance (1984, 1992, and 1993) followed winters with few

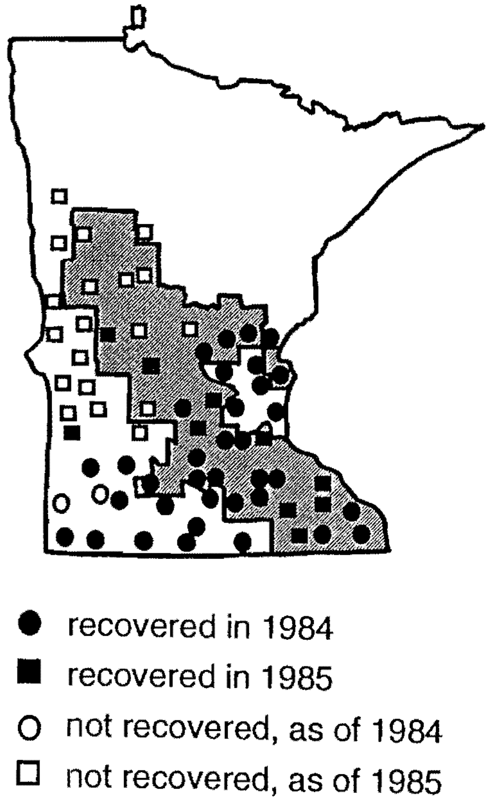

Figure 3. Survey for *Microctonus aethiopoides*, a parasitoid of alfalfa weevil adults, 1984–1985. Symbols refer to a particular county, in which different fields may have been sampled in different years. Shaded area indicates the dairy belt.

Table 1. Survey of alfalfa fields for *Microctonus aethiopoides*, 1984–1985.

H. postica adults/100 sweeps	No. fields sampled	Mean *H. postica* adults/100 sweeps (± SE)	Mean no. *H. postica* adults reared	*M. aethiopoides*	
				No. fields where recovered	% Parasitism (mean ± SE)
1984					
0.0–3.0	3	2.0 ± 0.5	9.0 ± 3.1	0	–
3.1–10.0	14	6.7 ± 0.6	48.8 ± 5.0	8	5.7 ± 2.0
>10.0	31	28.2 ± 2.4	95.9 ± 6.6	27	16.7 ± 2.9
overall	48	20.3 ± 2.2	76.7 ± 6.0	35	14.1 ± 2.4
1985					
0.0–3.0	22	1.1 ± 0.1	4.4 ± 2.0	6	25.3 ± 4.0
3.1–10.0	10	5.8 ± 0.7	43.7 ± 8.4	6	11.7 ± 4.8
>10	11	31.5 ± 12.6	47.8 ± 16.3	11	13.5 ± 2.7
overall	43	10.0 ± 3.8	24.7 ± 5.7	23	16.1 ± 2.4

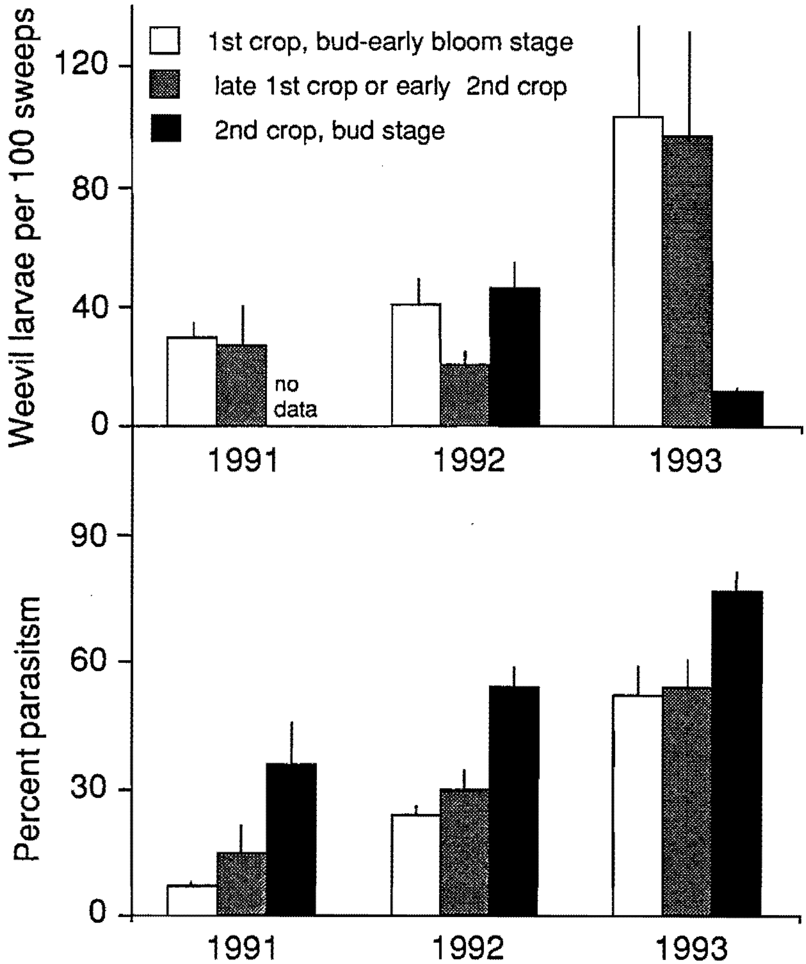

Figure 4. Combined impact of natural enemies of alfalfa weevil larvae, 1991-1993. Error bars indicate standard error of the mean.

severe days. The number of severe days occurring in surveyed fields ranged from 0-1 in winter 1983-1984, 10 to 47 in winter 1984-1985, 11 to 50 in winter 1989-1990, 0-24 in winter 1990-1991, 0 to 21 in winter 1991-1992, and 0 to 13 in winter 1992-1993. In spring 1985, density of weevil adults (y) was inversely related to number of severe winter days (x) during winter 1984-1985 (r^2= 0.25, df=23, y = -0.34x + 15.4). In spring 1991, density of weevil larvae (y) was inversely related to cumulative number of severe winter days (x) during winters 1989-1990 and 1990-1991 (r^2= 0.46, df=17, y = -0.9x + 46.0). In spring 1992, density of weevil larvae (y) was inversely related to cumulative number of severe winter days (x) during winter 1991-1992 (r^2= 0.31, df=14, y = -4.3x

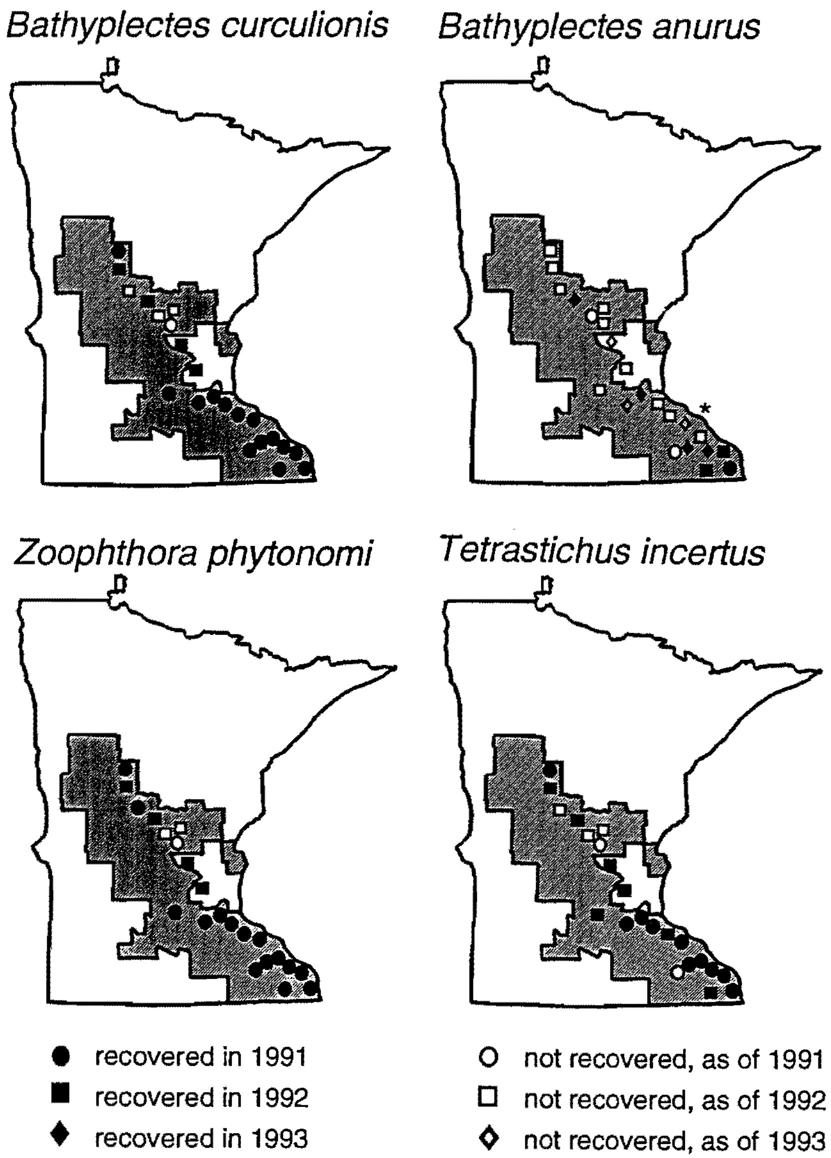

Figure 5. Survey for natural enemies of alfalfa weevil larvae 1991–1993. Symbols refer to a particular farm, in which different fields may have been sampled in different years. Shaded area indicates the dairy belt. Asterisk refers to an additional collection of *B. anurus* in Wabasha Co. by USDA personnel in 1991. A = 1991, B = 1992, C = 1993.

Table 2. Parasitism of alfalfa weevil larvae by *Bathyplectes curculionis*, *B. anurus*, *Tetrastichus incertus*, and *Zoopthora phytonomi*, 1991–1993[a]

Survey Period	Crop Phenology	CDD[b]	No. fields	No. weevil larvae measured (± SE)	Percent mortality (± SE) caused by:			
					B. curculionis	*B. anurus*[c]	*T. incertus*	*Z. phytonomi*
1991								
27 May–1 June	bud-early bloom	280–370	13	356±31	3±1	0.5 (1)	0.6±0.5	4±1
2–8 June	late bloom or regrowth ≤ 15 cm	380–461	7	287±58	2±1	0.0 (1)	0.2±0.1	10±6
12–19 June	regrowth ≤ 25 cm	470–590	4	157±10	28±8	–	3.3±2.7	4±1
1992								
26–30 May	bud-early bloom	220–260	11	537±83	14±2	0.5±0.1 (3)	0.8±0.4	8±1
8–11 June	late bloom or regrowth ≤ 20 cm	310–390	12	421±80	6±2	<0.1 (2)	1.1±0.4	23±5
23–26 June	10–90% bud	450–530	14	524±92	43±5	0.0 (3)	1.6±0.4	10±2
1993								
25–28 May	early bud	160–230	6	348±114	25±4	3.6±1.4 (4)	0.4±0.3	14±2
31 May–4 June	late bud	190–260	4	602±120	30±4	5.9±3.6 (3)	0.1±0.0	18±4
9–11 June	late bud – early bloom	230–310	5	255±45	31±9	0.2±0.1 (2)	0.6±0.3	21±3
14–21 June	late bloom, or regrowth ≤ 30 cm	350–380	4	337±122	19±5	0.6±0.4 (2)	0.6±0.2	46±13
28 June–14 July	bud	470–560	5	191±9	46±5	0.0±0.0 (2)	3.3±2.4	28±4

[a]Results are from rearing field-collected larvae. Sites where fewer than 50 larvae were collected are not included.
[b]Cumulative degree-days (base 9°C).
[c]Each year, parasitism rates by *B. anurus* are for those fields in which the parasitoid was recovered. Number in parenthesis refers to number of fields sampled.

+ 59.4). In spring 1993, density of weevil larvae (y) was inversely related to the cumulative number of severe winter days (x) during the preceding four winters (r^2= 0.68, df=5, y = -7.7x + 363.0). These coefficients of determination, while not large, suggest that winter severity influences alfalfa weevil densities in succeeding years.

DISCUSSION

Alfalfa weevil population densities appear to be severely regulated in Minnesota. Economically damaging populations of alfalfa weevil seldom occur, presumably because of natural enemies and effects of weather. *Microctonus aethiopoides*, *B. curculionis*, and *T. incertus*, and *Z. phytonomi* were found to be generally distributed thoughout the survey area. *Bathyplectes anurus* is newly established. The natural enemies of larvae caused highest mortality in 1993, a year of high weevil density, and lowest mortality in 1991, when weevils were scarce, suggesting a response to changes in the density of the alfalfa weevil.

Where established, *B. anurus* and *M. aethiopoides* usually are the most effective parasitoids of alfalfa weevil (Day 1981). *Bathyplectes anurus* is now the most prevalent parasitoid of larvae in New Jersey and Pennsylvania (Day 1983), Ontario (Harcourt 1990), Illinois (Oloumi-Sadeghi et al. 1993) and Kentucky (Parr et al. 1993). In a Wisconsin study, *M aethiopoides* caused 40% mortality in spring, and 80% mortality in summer (Hogg et al. 1990). *Microctonus aethiopoides* typically has two generations per year, compared to its univoltine host (Van Driesche and Gyrisco 1979, Abu and Ellis 1976). However, we have evidence that three generations of *M. aethiopoides* occurred in Minnesota in 1992 (Flanders and Radcliffe, in preparation).

Bathyplectes anurus is becoming more abundant in Minnesota, and may displace other natural enemies. When *B. anurus* became established in Ohio, *B. curculionis* and *T. incertus* declined in incidence (Dowell and Horn 1977). In Ontario, the appearance of *Zoophthora phytonomi* also led to lower parasitization rates by *B. curculionis* and *T. incertus* (Harcourt 1990). *Zoophthora phytonomi* can cause indirect mortality of *B. anurus*, but apparently causes no long-term reduction of parasitoid numbers (Parr et al. 1993). *Tetrastichus incertus* and *B. curculionis* also compete with each other, especially for 2nd and 3rd stadium larvae, with *B. curculionis* having the advantage (Miller 1970).

The adverse effect of winter weather on weevil populations has been previously reported (Schroder and Dodson 1985). Annual normal temperatures in the Minnesota dairy belt range from 3.9° C in the north to 7.2° C in the south (Baker et al. 1985). These temperatures are lower than the annual mean temperature at Schroder and Dodson's German site (8.6° C), suggesting that, even in southeastern Minnesota, weevils may be limited by winter weather.

Changing insecticide use practices could adversely affect natural control of alfalfa weevil in Minnesota. Growers are increasingly aware of the damage caused by potato leafhopper, and this has resulted in more use of insecticides on the second and third crops (W. D. Hutchison, pers. communication).

ACKNOWLEDGMENTS

Funding for this project was received from the Minnesota Agricultural Experiment Station and the Environment and Natural Resources Trust Fund (funding approved by the Minnesota Legislature (ML 1991, Chapter 254, Art.

DOI: 10.22543/0090-0222.1836

1, Sec. 14, Subs. 6 [a]) as recommended by the Legislative Commission on Minnesota Resources). We thank M. D. Bryan and staff, Niles Biological Control Laboratory, for their help in identifying and rearing alfalfa weevil parasitoids; John Vaadeland, Andrea Heberlein, Eileen Cullen, Dinesh Goyal, Ann Palmer, John McCron, Mary Hu, Tony Chen, Judit Miko, Robert Suranyi, Loan Cao, and Jennifer Langer for their help in collecting and processing samples; D. Sreenivasam, Minnesota Department of Agriculture, and John Hayward, USDA, retired, for their help in the 1984-1985 surveys; W. E. Miller and W. D. Hutchison, Dept. of Entomology, Univ. Minn., for reviewing this manuscript; and G. S. Spoden, Minnesota State Climatologist; D. G. Baker and M. W. Seeley, Dept. of Soil Sci., Univ. Minn., for climatological advice and information.

We thank the following cooperators and their families for allowing us to sample their alfalfa fields: D. Allen, G. Allen, Olmsted Co.; R. Brown, Winona Co.; M. Czech, Morrison Co.; G. Davison, Houston Co.; W. Dilworth, Wabasha Co.; D. Funk, Morrison Co.; D. Heuer, Carver Co.; L. Kaschmitter, Benton Co.; M. Kinnunen, Wadena Co.; J. Knapp, Hennepin Co., C. Meyer, Winona Co.; D. Mickelson, Fillmore Co.; D. Peterson, Benton Co.; R. Radatz, Winona Co.; A. Schaffer, Dakota Co.; R. Sheehan, Olmsted Co.; M. Schwartau, Goodhue Co.; L. Seeley, Sherburne Co.; D. Tyrell, Todd Co.; K. Walter, Rosemount Agricultural Experiment Station, Dakota Co.; M. Wiens, Staples Irrigation Center, Wadena Co.; and B. Zweber, Scott Co.

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