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ABUNDANCE OF CEREAL APHIDS (HOMOPTERA: APHIDIDAE) AND THEIR PREDATORS IN SPRING WHEAT-ALFALFA INTERCROPS UNDER DIFFERENT CROP MANAGEMENT INTENSITIES

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ABSTRACT

Natural infestations of cereal aphids and abundance of their predators were compared from 1990 through 1993 among plots of intercropped spring wheat and alfalfa grown under high, intermediate, or low crop management intensity (CMI). CMI treatments differed in the amount of nitrogen fertilizer applied and herbicide used and in the rigor of tillage operations. Cereal aphids (primarily *Rhopalosiphum padi*, *Sitobion avenae*, and *Schizaphis graminum*) collectively infested a mean of 0 to 5.9 of 15 wheat tillers sampled per plot on various dates from 1990 through 1993, but aphid infestation did not vary by CMI. Seven taxa of aphid predators predominated: *Nabis* spp., *Chrysoperla* spp., *Coleomegilla maculata*, *Hippodamia convergens*, *H. tredecimpunctata tibialis*, *H. parenthesis*, and *Coccinella septempunctata*. *Coccinella transversoguttata richardsoni*, a species in decline in eastern South Dakota, was not collected. Nabids were generally the most abundant predatory taxon. In 1992, coccinellid adults were more abundant in high than low CMI plots. In 1993, *H. tredecimpunctata tibialis* adults were significantly more abundant in high CMI plots on the first three sampling dates but became more abundant in the low and intermediate CMI plots by the fifth sampling date. Regressions between the number of aphid-infested tillers and abundance of some predator taxa were significant in 1990, 1991, and 1992. In 1990, most regressions showed that counts of predators (except *Chrysoperla* spp. adults) were inversely proportional to aphid infestation levels, whereas significant regressions in 1991 and 1992 showed that the abundances of predators were weakly proportional to aphid infestation levels. Adjusted r^2 values for all significant regressions ranged from 0.07 to 0.27. Relationships between crop management, cereal aphid infestation, and aphidophagous predators are discussed.

Both spring wheat (*Triticum aestivum*), an annual row crop, and alfalfa (*Medicago sativa*), a perennial forage crop, are widely grown in the northern Great Plains of the US. In eastern South Dakota, southeastern North Dakota, and western Minnesota, the two are often intercropped for one season so that a harvestable crop of wheat is produced while alfalfa becomes established. Spring wheat is harvested in the summer, and alfalfa is main-

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tained for the remainder of the season and usually an additional one to three years.

Spring wheat-alfalfa intercrops are produced under various cropping systems that differ in the kinds and intensity of individual crop management practices. Crop management practices commonly include nitrogen (N) fertilizer application(s) to increase grain yield of wheat, post-emergent herbicide applications (particularly for broadleaf weeds), and tillage for seedbed preparation and additional weed control. Intensity of these practices can vary according to the amount, frequency, or degree to which they are used in a particular crop management system. Also, spring wheat and alfalfa are often part of cropping systems that include rotation with corn and soybeans.

Some cropping practices are directed specifically toward the management of arthropod pests of spring wheat, e.g., cereal aphids (Homoptera: Aphididae). Four species of aphids commonly infest cereal crops in the northern plains: bird cherry-oat aphid (*Rhopalosiphum padi* [L.]), corn leaf aphid (*R. maidis* [Fitch]), greenbug (*Schizaphis graminum* [Rondani]), and English grain aphid (*Sitobion avenae* [F.]) (Kieckhefer 1975). Cereal aphids (except *R. maidis*) infest and reproduce on spring wheat in the Dakotas and Minnesota from the seedling through dough stages (Wadley 1931, Kieckhefer 1975, Kieckhefer and Gellner 1988, Voss et al. 1997, Boeve and Weiss 1998). Insecticide application is sometimes necessary to prevent economic loss from cereal aphids (Kieckhefer and Kantack 1980). Aphid pests of alfalfa, however, occur at very low population levels and are not problematic during the establishment year in intercropped spring wheat-alfalfa in the eastern Dakotas and western Minnesota.

A rich fauna of aphidophagous insects inhabit spring wheat and alfalfa fields in eastern South Dakota (Elliott and Kieckhefer 1990a, b; Kieckhefer et al. 1992). Several species of aphidophagous insects, especially coccinellids, are significant predators of cereal aphids (Rice and Wilde 1988). Both adult and immature stages of these predators are found in alfalfa and wheat fields in South Dakota (Elliott and Kieckhefer 1990a, Kieckhefer and Miller 1967).

Arthropod management, however, is usually of secondary concern in spring wheat-alfalfa intercrops in the Dakotas and western Minnesota, and crop management practices are driven more by fertility and weed control considerations. Nonetheless, crop management practices used for improving fertility or weed control may inadvertently affect insect population levels. For instance, the use of N fertilizer may influence insect pest levels on plants, as the growth rate and fecundity of phytophagous insects is often greater on plants with high N content (Daniels 1957, van Emden 1966, McNeill and Southwood 1978, Mattson 1980). In contrast, however, the effect of N fertilization on aphid predators has not been well studied.

Herbicides may also affect insect population levels. Rautapää (1972) tested several herbicides individually against *S. avenae* in the laboratory and found that dinoseb was toxic. Some herbicides used in small grain production are acutely toxic in the laboratory to *R. padi* and one of their predators, the seven-spotted ladybird beetle (*Coccinella septempunctata* L.) (Neil et al. 1997). In the field, cereal aphids are more abundant in small grain fields treated with herbicide, as predator levels diminish following treatment (Adams and Drew 1965, 1969; Vickerman 1974). However, Powell et al. (1986) found no effect of herbicides on population levels of cereal aphids in winter wheat.

Such studies show that individual crop management practices can affect insect pest populations, but the effects on insect pests are largely unknown for cropping systems that use various combinations or intensities of crop management practices. Zhou and Carter (1991) studied cereal aphid population development among wheat plots that varied in the amounts of N fertilizer and fungicide applied. They found that N fertilizer applications had no consistent effect on aphid populations and that fungicides had no effect on them.

Studies have not been performed in the eastern Dakotas and western Minnesota in regard to the effects of different crop management practices on insect population levels in intercropped spring wheat and alfalfa. Our goals were to characterize population levels of cereal aphids and their predators in spring wheat-alfalfa plantings in eastern South Dakota and test for differences in abundance under high, intermediate, and low crop management intensity.

MATERIALS AND METHODS

The study was conducted at the Eastern South Dakota Soil and Water Research Farm, about 1.5 mi N of Brookings, South Dakota, USA, from 1990 through 1993. Soil there consists of a Barnes clay loam (fine-loamy mixed Udic Haploboroll) on nearly level topography. Land on the farm has been in crop production for several decades. Prior to the establishment of our plots in 1990, land was planted to soybeans in 1988 and spring wheat in 1989. Pendimethalin and bentazon herbicides were applied at labeled rates once each in 1988. The herbicide MCPA amine (dimethylamine salt of 2-methyl-4-chlorophenoxyacetic acid) and a mixture of the herbicides glyphosate and 2, 4-dichlorophenoxyacetic acid were applied at labeled rates once each in 1989. The spring wheat also received 258 kg/ha of 36-17-0 (N-P-K) fertilizer at planting.

A four-crop rotation with variable crop management intensities (CMI) was established in 1990. The rotations consisted of annual crops of corn, soybeans, and a spring wheat-alfalfa interplanting, with the alfalfa crop continuing an additional year. Hard red spring wheat and alfalfa ('Coyote 990,' 12 kg/ha) were planted simultaneously in 17.6-cm rows using a 16-row John Deere® 750 drill. 'Guard' spring wheat (104 kg/ha) was planted on 26 April, 4 April, and 7 April in 1990, 1991, and 1992, respectively; 'Butte' spring wheat (118 kg/ha) was planted on 20 April 1993. Wheat was harvested in August each year. Each crop was grown in 30.5 by 30.5-m plots under one of three levels of CMI (i.e., high, intermediate and low). Plots were arranged in a randomized block design, and each crop-CMI combination was replicated three times per year. Each block represented a replication.

The levels of CMI differed in the amounts and placement of agrichemical inputs (Table 1) and in the intensity of tillage operations. All agrichemicals were applied before 1 June to high and intermediate CMI treatments in spring wheat-alfalfa. High intensity plots were characterized by soil test-based rates of N-fertilizer application designed to achieve high yield goals, specifically 3.0 Mg/ha in wheat, and by pre- and post-emergent herbicides broadcast over plots at labeled rates. High CMI corn plots preceding spring wheat-alfalfa received insecticides for control of corn rootworms (*Diabrotica* spp.). Tillage in high CMI plots consisted of fall moldboard plowing, spring disking, and two spring field cultivations of corn.

Intermediate CMI plots used half the rate of fertilizer applied to the high CMI plots. Herbicides were broadcast in spring wheat-alfalfa plots and banded along rows of preceding corn and soybean crops. No insecticides were applied to intermediate CMI corn plots. Intermediate CMI plots received fall moldboard plowing in 1989 and 1991 and fall chisel plowing in 1990 and 1992. Spring disking and two field cultivations of corn occurred each year.

Table 1. Agrichemical use in high and intermediate crop management intensity (CMI) treatments in spring wheat-alfalfa intercrops and preceding crops, 1990–1993, Brookings, SD.

		Fertilizer (N-P-K, method), kg/ha		Pesticides (AI, method), kg/ha	
Year	Crop	High CMI	Intermediate CMI	High CMI	Intermediate CMI
1990	Wheat-alfalfa	99 (46-0-0 planting)	50 (46-0-0 planting)	MCPA (post, broad) 0.6	MCPA (post, broad) 0.6
	Soybeans	96 (13-33-13 planting)	53 (13-33-13 planting)	alachlor (post, broad) 2.2; metribuzin (pre, broad) 0.6; bentazon (post, broad) 1.1; acifluorfen (post, broad) 1.5	alachlor (post, broad) 2.2; metribuzin (pre, band) 0.6; bentazon (post, band) 1.1; acifluorfen (post, band) 1.5
	Corn	112 (13-33-13 planting) 224 (46-0-0 sidedress)	53 (13-33-13 planting) 112 (46-0-0 sidedress)	alachlor (pre, broad) 4.5 cyanazine (pre, broad) 1.1; bentazon (post, broad) 1.1; terbufos (planting, band) 7.8	alachlor (pre, band) 4.5 cyanazine (pre, band) 1.1; bentazon (post, band) 1.1
	Alfalfa	69 (0-45-0 planting)	35 (0-45-0 planting)	bromoxynil (post, broad) 0.4	bromoxynil (post, broad) 0.4
1991	Wheat-alfalfa	116 (46-0-0 planting)	58 (46-0-0 planting)	MCPA (post, broad) 0.6	MCPA (post, broad) 0.6
	Soybeans	112 (13-33-13 planting)	53 (13-33-13 planting)	alachlor (post, broad) 2.1; metribuzin (pre, broad) 0.6; bentazon (post, broad) 1.1	alachlor (post, broad) 2.1; metribuzin (pre, band) 0.6; bentazon (post, band) 1.1
	Corn	112 (13-33-13 planting) 139 (46-0-0 sidedress)	53 (13-33-13 planting) 70 (46-0-0 sidedress)	alachlor (pre, broad) 4.5 cyanazine (pre, broad) 2.3; bromoxynil (post, broad) 0.6; fonofos (pre, band) 10.0	alachlor (pre, band) 4.5 cyanazine (pre, band) 2.3; bromoxynil (post, broad) 0.6
1992	Wheat-alfalfa	116 (46-0-0 planting)	58 (46-0-0 planting)	MCPA (post, broad) 0.6	MCPA (post, broad) 0.6
	Soybeans	112 (13-33-13 planting)	53 (13-33-13 planting)	alachlor (post, broad) 2.1; bentazon (post, broad) 1.1	alachlor (post, broad) 2.1; bentazon (post, band) 1.1
1993	Wheat-alfalfa	103 (46-0-0 planting)	51 (46-0-0 planting)	MCPA (post, broad) 0.6	MCPA (post, broad) 0.6

Planting, applied on or near date of planting; pre, preemergence application; post, post-emergence application; broad, broadcast application; band, banded application along crop row.

Table 2. Dates of sampling for cereal aphids and their predators in spring wheat-alfalfa intercrop plots, Brookings, SD.

Year	Sampling date	Developmental stage of wheat, Zadoks[a] scale
1990	13 June	booting, 40–49
	20 June	heading, 50–59
	26 June	anthesis, 60–69
	5 July	watery milk, 71–73
	12 July	late milk, 75–77
1991	11 June	heading, 50–59
	18 June	late anthesis to watery dough, 65–71
	27 June	milk to soft dough, 75–85
1992	2 June	tillering, 20–24
	10 June	booting, 41–49
	22 June	anthesis, 60–69
	8 July	milk, 70–77
	20 July	soft dough, 83–87
1993	11 June	late tillering, 23–24
	28 June	heading, 50–59
	9 July	milk, 73–77
	16 July	soft dough, 83–87
	29 July	hard dough, 87

[a] Zadoks et al. (1974)

The low intensity cropping system used no fertilizer or herbicide. However, low intensity corn and soybean plots were hand-weeded. Low intensity plots received fall chisel plowing each year and spring disking, and two field cultivations of corn.

Sampling. Cereal aphids were sampled from three to five times each year in June and July. Specific sampling dates and growth stages of the spring wheat (Zadoks et al. 1974) are given in Table 2. Samples consisted of five randomly selected groups of three consecutive tillers (15 total) per plot, and the number of aphid-infested tillers per plot was recorded. Sampling occurred midday between 0945 and 1515 h, with temperatures between 20 and 33°C. Population parameters of cereal aphids in the northern plains are similar, and counts of individual species can be pooled (Elliott et al. 1990). An empirical relationship exists between the average number of cereal aphids per tiller and the proportion of tillers infested with cereal aphids (Elliott et al. 1990, Hein et al. 1995). Thus, the percentage of infested tillers provides an estimate of overall cereal aphid density in wheat fields. We recorded the species of cereal aphids seen in the field each sampling date, but did not count aphids by species.

Aphidophagous insects were sampled in the spring wheat-alfalfa plots on the same dates as cereal aphids (Table 2). Samples consisted of 60 pendular sweeps with a 38-cm diam. sweep net along two transects in each plot (30 sweeps per transect). Sweep netting in alfalfa and small grain fields in South Dakota collects both adult and immature stages of many aphidophagous insects (Kieckhefer et al. 1992). Insects collected along each transect were treated with chloroform in the net, transferred to containers, and taken to the laboratory. There, aphidophagous insects were identified to genus or species, and the number collected per sample within individual treatment plots was recorded.

Statistical analyses. The number of aphid-infested tillers per plot and

Table 3. *F* values from repeated measures analysis of the number of cereal aphid-infested tillers in spring wheat-alfalfa intercrop plots, Brookings, SD.

	Source of variation		
Year	SD (df)	CMI (df)	SD × CMI (df)
1990	54.93* (4, 24)	6.08 (2, 4)	1.94 (8, 24)
1991	2.64 (2, 12)	0.51 (2, 4)	0.36 (4, 12)
1992	11.85* (4, 24)	0.35 (2, 4)	2.12 (8, 24)
1993	1.82 (4, 24)	1.47 (2, 4)	0.97 (8, 24)

Asterisks indicate statistical significance ($P < 0.05$).

the numbers of predators per plot were each analyzed using a repeated measures analysis (PROC MIXED, Littell et al. 1996), with CMI and sampling date as non-random independent variables. A spatial covariance model was used in the analyses, because sampling dates were unequally spaced. A separate analysis was performed on each year's data, as the number and timing of sampling dates differed among years (Table 2). Treatment means were separated by using the LSMEANS option (Littell et al. 1996). For predators, analyses were limited to taxa whose means were > 0.2 individuals (per life stage) collected across all sampling dates and treatments per year. Univariate linear regression models were tested to describe the relationship between the number of aphid-infested tillers (independent variable) and the abundance of predators (dependent variable) within each year (PROC REG, SAS Institute 1988).

RESULTS

Cereal aphids. The number of aphid-infested tillers differed by sampling date in 1990 and 1992, but this measure did not vary by CMI in any year (Table 3). The number of aphid-infested tillers declined sharply in 1990, but showed bi-modal peaks in 1992 (Fig. 1). In 1991 and 1993, the mean numbers (± SE) of infested tillers (out of 15 sampled) per plot across CMI treatments and sampling dates were 0.9 (± 0.2) and 0.4 (± 0.1), respectively ($n = 3$). The mean number of aphid-infested tillers ranged from a high of 5.9 (± 0.5) in plots in June 1990 to as low as 0 on several sampling dates in other years ($n = 9$). Tillers were infested mainly with *R. padi*, *S. graminum*, *S. avenae*, and a very few *R. maidis* early each season.

Aphidophagous insects. Seven aphidophagous insect taxa predominated in our samples from intercropped spring wheat-alfalfa plots (Table 4): nabids (*Nabis* spp.); chrysopids (*Chrysoperla* spp.); and coccinellids, i.e., *Coleomegilla maculata* (DeGeer), *Hippodamia convergens* Guerin-Meneville, *H. tredecimpunctata tibialis* (Say), *H. parenthesis* (Say), and *Coccinella septempunctata*. Both adults and immature stages were collected. These seven taxa are the most common aphidophagous insects in small grain fields and alfalfa fields in eastern South Dakota (Elliott and Kieckhefer 1990a, 1990b; Kieckhefer et al. 1992).

Nabids were the most abundant taxon that we collected, except in 1992 when their abundance was slightly less than the combined mean for all coccinellid species (Table 4). Nabids are abundant in spring grain fields in South Dakota (Kieckhefer and Miller 1967), and they are the most abundant insect

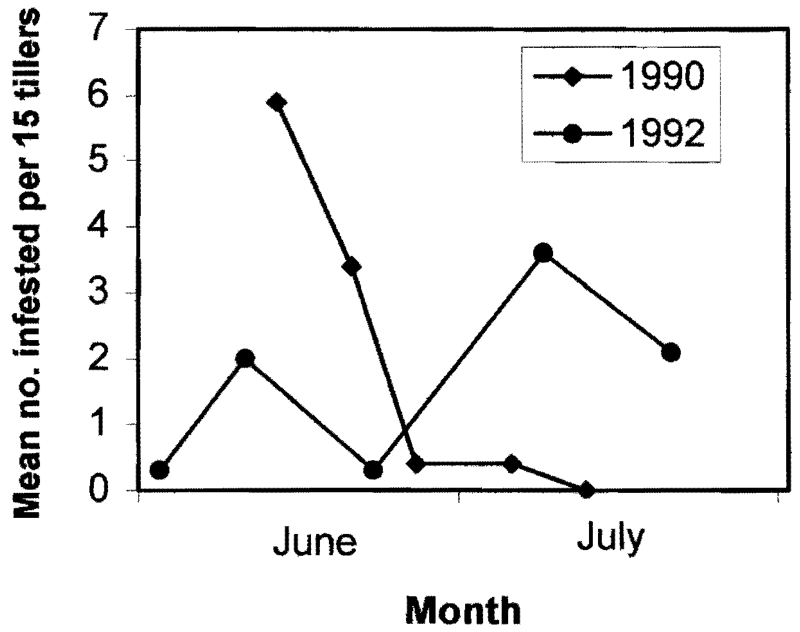

Fig. 1. Mean number of aphid-infested wheat tillers out of 15 sampled per spring wheat-alfalfa plot on 5 dates each in 1990 and 1992 (n = 9 per date). Error bars omitted for sake of clarity.

predator taken in sweep net samples of alfalfa fields in eastern South Dakota (Elliott and Kieckhefer 1990a).

Each year, the numbers of chrysopid larvae were consistently greater than or equal to the number of chrysopid adults (Table 4). For all other aphidophagous taxa, the numbers of adults were always greater than or equal to the number of immatures within a taxon. Varying efficiencies in collecting the life stages of each taxa may have led to these differences. In a 13-year study of alfalfa fields in eastern South Dakota, Elliott and Kieckhefer (1990a) found that chrysopid larvae were more abundant in sweep net samples than adults, and they felt this trend indicated that conditions in alfalfa fields were very conducive to chrysopid reproduction.

The abundance of individual species of coccinellids varied considerably among years (Table 4). *Coleomegilla maculata* was the most abundant coccinellid in 1991 and 1992. However, *C. maculata* is usually not the dominant coccinellid in small grain fields in eastern South Dakota (Elliott and Kieckhefer 1990a, 1990b; Kieckhefer et al. 1992). Thus, it was unexpected for it to be dominant (1991) or co-dominant (1992) in two of four years. Only 2 adult *Hippodamia convergens* were collected in 1993. *H. convergens* is a dominant coccinellid in alfalfa and small grain fields in eastern South Dakota, but years of low abundance have been recorded (Elliott and Kieckhefer 1990a, 1990b; Kieckhefer et al. 1992). Five *Cycloneda munda* (Say) adults were collected in 1992, whereas this species was absent in other years. *C. munda* is

Table 4. Mean ± SE aphidophagous insects collected per 60 sweeps in spring wheat-alfalfa intercrop plots, Brookings, SD.

	Year (number of sampling dates within year)				
Taxon	Life stage	1990 (5)	1991 (3)	1992 (5)	1993 (5)
Nabis spp.	adult	7.9 ± 1.5	9.8 ± 1.5	2.4 ± 0.6	5.1 ± 0.6
	nymph	0.2 ± 0.1	1.8 ± 0.4	0.1 ± 0.1	3.8 ± 1.1
Chrysoperla spp.	adult	0.6 ± 0.1	0.8 ± 0.2	0.4 ± 0.1	0.6 ± 0.1
	larva	1.0 ± 0.2	1.9 ± 0.4	0.5 ± 0.2	2.8 ± 0.6
Coccinella septempunctata	adult	2.1 ± 0.4	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1
	larva	2.4 ± 0.8	0.3 ± 0.1	0.0	0.0
Coleomegilla maculata	adult	0.1 ± 0.0	5.3 ± 1.0	1.2 ± 0.2	0.9 ± 0.2
	larva	0.2 ± 0.1	3.5 ± 0.5	0.2 ± 0.1	1.2 ± 0.3
Hippodamia convergens	adult	0.3 ± 0.1	0.8 ± 0.2	0.9 ± 0.2	0.0[a]
	larva	0.1 ± 0.0	0.9 ± 0.1	0.0	0.0
Hippodamia parenthesis	adult	0.9 ± 0.2	0.2 ± 0.1	1.2 ± 0.2	1.1 ± 0.2
	larva	0.0	0.3 ± 0.2	0.1 ± 0.1	0.1 ± 0.0
Hippodamia tredecimpunctata	adult	0.4 ± 0.1	0.6 ± 0.1	0.1 ± 0.1	1.0 ± 0.2
	larva	0.2 ± 0.1	1.0 ± 0.3	0.0	0.1 ± 0.0

Means (± SE) based on 9 plots per sampling date.
[a] Two individuals collected across all sampling dates and treatments.

rarely captured in alfalfa and small grain fields in eastern South Dakota (Elliott and Kieckhefer 1990a, Kieckhefer et al. 1992). *Coccinella transversoguttata richardsoni* Brown was not collected in our study. Its numbers have declined in agricultural fields in South Dakota since the introduction of *C. septempunctata* (Elliott et al. 1996).

Repeated Measures Analyses. Sampling date often affected the abundance of various taxa, but CMI and the sampling date-by-CMI interaction were seldom significant (Table 5). The frequent statistical significance of sampling date was expected, as the taxa we collected (in their different life stages) vary in abundance throughout the season in small grain and alfalfa fields (Kieckhefer and Miller 1967, Elliott and Kieckhefer 1990a, Elliott et al. 1991).

CMI affected coccinellid abundance in 1992. Coccinellids that year were more abundant in the high CMI plots (3.9 ± 0.9) than in the low CMI plots (1.3 ± 0.4). Abundance of coccinellids in the intermediate plots (2.9 ± 0.7) did not differ from that in either the high or low CMI plots.

Abundance of chrysopid larvae in 1992 and 1993 and abundance of coccinellid larvae in 1992 varied by sampling date and the sampling date-by-CMI interaction. No chrysopid and coccinellid larvae were collected on the first three sampling dates in 1992, and after excluding these dates from the analyses, none of the treatment factors or interactions were significant ($P > 0.05$) for chrysopids (sampling date: $F = 4.50$, df = 1, 6; CMI: $F = 5.37$, df = 2, 4; interaction: $F = 0.37$, df = 2, 6) or coccinellids (sampling date: $F = 4.50$, df = 1, 6; CMI: $F = 0.30$, df = 2, 4; interaction: $F = 4.87$, df = 2, 6). In 1993, no chrysopid larvae were collected on the first two sampling dates. After excluding these dates from analysis, sampling date ($F = 24.83$, df = 2, 12) and the interaction ($F = 3.51$, df = 4, 12) were still significant ($P < 0.05$), but not CMI ($F = 4.43$, df = 2, 4; $P > 0.05$). The number of chrysopid larvae peaked on the second (non-zero) sampling date in all CMI treatments, and the significant sampling date-by-CMI interaction reflects the sharper peaks in the high and intermediate CMI treatments than in the low treatment (Fig. 2).

In 1992, the sampling date-by-CMI interaction was significant for *H. convergens* larvae. Although only 0 to 3 *H. convergens* larvae were collected per plot on each sampling date, the interaction reflects considerable fluctuation in the number of *H. convergens* larvae collected per CMI treatment over the five sampling dates.

In 1993, abundance of *H. tredecimpunctata tibialis* adults was affected by CMI, sampling date, and their interaction. Adults were more abundant in high than intermediate or low CMI plots on the first three sampling dates, did not differ in abundance among CMI treatments on the fourth sampling date, and were less abundant in high CMI plots on the last sampling date (Table 6).

Regressions. Regressions between the number of aphid-infested tillers and counts of some predator taxa were significant in 1990, 1991 and 1992, but not 1993 (Table 7). In 1990, most significant regressions (except for chrysopid adults) showed a weak ($r^2 \leq 0.27$), inverse relation between aphid-infested tillers and predator abundance. This relationship reflected a sharp concomitant decline in the number of aphid-infested tillers after the first sampling date and an increase in the abundance of most predators over the sampling period. Only the abundance of chrysopid adults showed a positive, albeit weak, relation to the number of aphid-infested tillers.

In 1991, *H. tredecimpunctata tibialis* larvae showed a weak but positive relation to the number of aphid-infested tillers. In 1992, the numbers of nabid adults, chrysopid larvae, and *H. convergens* adults each showed weak but positive relationships to the number of aphid-infested tillers.

DISCUSSION

Aphid infestation of spring wheat-alfalfa intercroppings was due to the same species (i.e., *R. padi, S. graminum*, *S. avenae*, and to a minor extent *R. maidis*) that colonize monocultures of small grains in North and South Dakota (Kieckhefer 1975, Boeve and Weiss 1998). Infestation levels of cereal aphids in our study were generally light, varied among sampling dates, and showed different trends among years. These findings are consistent with the results of other studies of cereal aphids in small grain fields of the Dakotas and western Minnesota (Wadley 1931, Kieckhefer 1975, Boeve and Weiss 1998).

CMI did not affect cereal aphid infestation levels in our study. Similar studies have had mixed or contrasting results. For instance, Zhou and Carter (1991) measured relatively low densities of cereal aphids (i.e., *S. avenae* and *Metopolophium dirhodum* [Walker]) in winter wheat plots from May through July, and they found that aphid densities were affected by N fertilizer treatments in one of two years. However, aphid population densities fluctuated within N fertilizer treatments during that year, being greater in plots with the highest N rates on two consecutive sampling dates, but then becoming lowest in the high N plots by the following week.

In contrast, Daniels (1957) showed consistent increases in the numbers of *S. graminum* in winter wheat due to N fertilization. On N-fertilized plants, he found more *S. graminum* and greater foliage weights of wheat per foot of row, but fewer *S. graminum* per gram of foliage. Specifically, the number of *S. graminum* per row-foot increased by less than 30% on N-fertilized treatments, whereas the number of *S. graminum* per gram of foliage decreased by roughly 50% or more.

Table 5. *F* values of repeated measures analyses for the seven most abundant predatory taxa collected from spring wheat-alfalfa intercrop plots, 1990–1993.

		1990			1991		
Taxon	Life stage	SD (df = 4, 24)	CMI (df = 2, 4)	SD X CMI (df = 8, 24)	SD (df = 2, 12)	CMI (df = 2, 4)	SD X CMI (df = 4, 12)
Nabis spp.	adult	40.91*	0.63	1.71	68.25*	1.59	2.34
	nymph	—[a]	—	—	13.60*	0.16	0.49
Chrysoperla spp.	adult	1.61	0.21	0.67	9.26*	1.44	1.57
	larva	22.77*	0.17	1.61	9.46*	2.22	0.67
Coccinella septempunctata	adult	25.56*	0.99	0.83	—	—	—
	larva	11.02*	0.12	0.18	2.21	0.68	1.19
Coleomegilla maculata	adult	—	—	—	17.00*	2.97	0.92
	larva	—	—	—	0.56	0.34	0.63
Hippodamia convergens	adult	0.38	1.50	0.57	1.01	2.11	0.97
	larva	—	—	—	0.64	1.45	3.91*
Hippodamia parenthesis	adult	4.67*	0.15	1.28	—	—	—
	larva	—	—	—	0.93	1.43	0.53
Hippodamia tredecimpunctata	adult	8.76*	0.23	1.97	3.25	3.25	0.50
	larva	—	—	—	4.49*	0.40	0.66
Coccinellidae[b]	adult	25.70*	0.33	0.96	15.32*	4.42	0.80
	larva	13.47*	0.15	0.27	2.27	0.02	0.66

Table 5. F (Continued).

		1992			1993		
Taxon	Life stage	SD (df = 4, 24)	CMI (df = 2, 4)	SD X CMI (df = 8, 24)	SD (df = 4, 24)	CMI (df = 2, 4)	SD X CMI (df = 8, 24)
Nabis spp.	adult	23.91*	1.65	0.61	9.29*	0.27	1.63
	nymph	—	—	—	69.54*	0.62	1.35
Chrysoperla spp.	adult	9.69*	1.87	1.36	1.86	1.68	0.77
	larva	11.10*	1.52	2.46*	34.05*	5.18	3.55*
Coccinella septempunctata	adult	—	—	—	—	—	—
	larva	—	—	—	—	—	—
Coleomegilla maculata	adult	5.88*	5.58*	1.15	2.32	3.21	0.25
	larva	—	—	—	5.85*	3.55	1.34
Hippodamia convergens	adult	13.44*	3.93	1.83	—	—	—
	larva	—	—	—	—	—	—
Hippodamia parenthesis	adult	2.81*	0.62	0.38	0.96	2.73	0.76
	larva	—	—	—	—	—	—
Hippodamia tredecimpunctata	adult	—	—	—	12.10*	9.30*	5.44*
	larva	—	—	—	—	—	—
Coccinellidae[b]	adult	14.99*	8.67*	1.49	5.72*	2.15	0.82
	larva	6.63*	0.18	2.71	8.27*	2.33	1.20

Asterisks indicate statistical significance ($P < 0.05$).

[a] Dashes indicate analyses not performed because means of ≤ 0.2 individuals per taxon collected across all sampling dates and treatments.

[b] Analysis of combined counts of *Coleomegilla maculata*, *Hippodamia convergens*, *H. tredecimpunctata tibialis*, *H. parenthesis*, and *Coccinella septempunctata*.

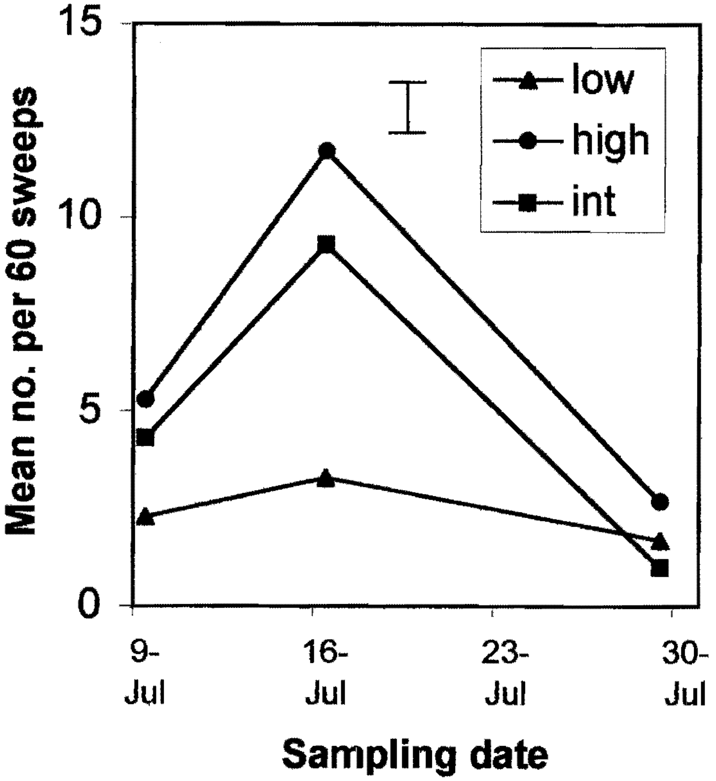

Fig. 2. Mean number of chrysoperlid larvae collected on three sampling dates in 1993 from spring wheat-alfalfa plots under high, intermediate, and low crop management intensity (CMI, n = 3 per sampling date). Bar represents standard error of the least squares mean for the CMI-by-sampling date effect.

CMI affected predator abundance in only two instances in our study. In 1990, when coccinellid abundance was greater in high CMI plots, cereal aphid numbers were actually declining. Thus, coccinellids may have been responding to levels of other prey items in the high CMI plots. The predators we collected feed on many prey items besides cereal aphids such as insect eggs, small insect larvae, mites, and alfalfa-infesting aphids (Hoffman and Frodsham 1993).

In 1993, abundance of *H. tredecimpunctata tibialis* shifted during the season, as adults were more abundant in high CMI plots on the first three sampling dates, but were less abundant in high CMI plots on the last sampling date. Cereal aphid infestation levels were low throughout all sampling dates that year, and *H. tredecimpunctata tibialis* adults may also have been responding to shifts in other prey items between CMI plots.

Table 6. Means ± SE of *Hippodamia tredecimpunctata tibialis* adults in spring wheat-alfalfa intercrop plots under different crop management intensities (CMI), Brookings, SD, 1993.

	No. collected in 60 sweeps per plot (x ± SE, n = 9)				
CMI	June 11	June 28	July 9	July 16	July 29
High	3.7 ± 0.3a	1.0 ± 0.6a	3.7 ± 0.7a	0.3 ± 0.3a	0.0a
Intermediate	2.3 ± 0.9b	0.0b	0.3 ± 0.3b	0.3 ± 0.3a	0.7 ± 0.3b
Low	1.0 ± 0.0c	0.0b	0.5 ± 0.5b	0.0a	1.7 ± 0.9b

Means (n = 9) within a column followed by the same letter do not differ significantly.

Our results also contrast with previous studies on predator abundance in relation to weed control. Plots with low crop management intensity are generally considered to favor predators through their lack of exogenous mortality agents such as pesticides (Adams and Drew 1965, 1969; Neil et al. 1997) and by providing more sources of alternate prey and supplementary food such as weed pollen and nectar (Altieri and Whitcomb 1979). The only herbicide application to high and intermediate CMI plots of spring wheat-alfalfa each year occurred about one month before our sampling began. Predator populations may have recovered from any negative effect of the herbicide, or they may not have suffered any negative effect. Low CMI plots, which received no herbicide, were weedier, but, in a couple of instances, actually had fewer predators than high and sometimes intermediate CMI plots.

Regressions between cereal aphids and their predators showed weak, and in 1990, even inverse relationships. Similarly, in spring wheat fields of eastern South Dakota, Elliott et al. (1991) did not find significant relationships between aphid infestation levels and the number of adult coccinellids collected in sweep net samples, and Elliott et al. (1999) found a significant regression only between cereal aphids and chrysopids. In our study, cereal aphid levels were low and may have had relatively little influence on predator abundance within plots. Generalist predators such as the nabids, chrysoperlids, and coccinellids in our study may have responded more to

Table 7. Equations and adjusted r^2 values for significant ($P < 0.05$) regressions between the number of aphid-infested wheat tillers (x) and number of predators per plot (y).

Year	Taxa	Regression equation	Adjusted r^2
1990	*Nabis* spp. nymphs	$y = 0.28 - 0.49x$	0.09
	Chrysopid adults	$y = 0.36 + 0.11x$	0.09
	Chrysopid larvae	$y = 1.60 - 0.28x$	0.19
	Hippodamia tredecimpunctata adults	$y = 0.58 - 0.10x$	0.13
	H. parenthesis adults	$y = 1.33 - 0.23x$	0.16
	Coccinella septempunctata adults	$y = 3.01 - 0.45x$	0.18
	Coccinellid adults	$y = 5.12 - 0.71x$	0.27
1991	*Hippodamia tredecimpunctata* larvae	$y = 0.52 + 0.55x$	0.20
1992	*Nabis* spp. adults	$y = 1.22 + 0.68x$	0.09
	Chrysopid larvae	$y = 0.15 + 0.23x$	0.16
	Hippodamia convergens adults	$y = 0.51 + 0.24x$	0.07

other prey items in the intercrop plots. However, we did not measure levels of alternate food items and, therefore, cannot estimate what effect these may have had on predator abundance.

Additional studies are needed to more accurately determine factors that influence the abundance of cereal aphids and aphidophagous predators in spring wheat-alfalfa intercrops. Our study took a "systems approach" by measuring aphid infestation levels and predator abundance across three crop management intensities that broadly encompassed differing amounts of fertilizer and pesticide use and differences in the rigor of tillage operations. Future studies may keep a similar scope of treatments but attempt to correlate more variables (e.g., include alternate prey abundance), or studies may be reduced in scope to focus on the effect of particular management practices (e.g., effects of pesticide sprays). We believe that both types of studies are needed to improve understanding of relationships between crop management systems, arthropod pests, and their predators.

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LITERATURE CITED

Adams, J. B. and M. E. Drew. 1965. Grain aphids in New Brunswick. III. Aphid populations in herbicide-treated oat fields. Can. J. Zool. 43: 789–794.

Adams, J. B. and M. E. Drew. 1969. Grain aphids in New Brunswick. IV. Effects of malathion and 2,4-D amine on aphid populations and yields of oats and barley. Can. J. Zool. 47: 423–426.

Altieri, M. A. and W. H. Whitcomb. 1979. The potential use of weeds in the manipulation of beneficial insects. Hort. Sci. 14: 12–18.

Boeve, P. J. and M. J. Weiss. 1998. Spatial distribution and sampling plans with fixed levels of precision for cereal aphids (Homoptera: Aphididae) infesting spring wheat. Can. Entomol. 130: 67–77.

Daniels, N. E. 1957. Greenbug populations and their damage to winter wheat as affected by fertilizer applications. J. Econ. Entomol. 50: 793–794.

Elliott, N C. and R. W. Kieckhefer. 1990a. A thirteen-year survey of the aphidophagous insects of alfalfa. Prairie Nat. 22: 87–96.

Elliott, N C. and R. W. Kieckhefer. 1990b. Dynamics of aphidophagous coccinellid assemblages in small grain fields in eastern South Dakota. Environ. Entomol. 19: 1320–1329.

Elliott, N., R. Kieckhefer and W. Kauffman. 1991. Estimating adult coccinellid populations in wheat fields by removal, sweepnet, and visual count sampling. Can. Entomol. 123: 13–22.

Elliott, N., R. Kieckhefer and W. Kauffman. 1996. Effects of an invading coccinellid on native coccinellids in an agricultural landscape. Oecologia 105: 537–544.

Elliott, N. C., R. W. Kieckhefer and D. D. Walgenbach. 1990. Binomial sequential sampling methods for cereal aphids in small grains. J. Econ. Entomol. 83: 1381–1387.

Elliott, N. C., R.W. Kieckhefer, J.-H. Lee and B. W. French. 1999. Influence of habitat and landscape related factors on aphid predator populations in wheat. Landscape Ecol. 14: 239–252.

Hein, G. L., N. C. Elliott, G. J. Michels, Jr. and R. W. Kieckhefer. 1995. A general method for estimating cereal aphid populations in small grain fields based on frequency of occurrence. Can. Entomol. 127: 59–63.

Hoffmann, M. P. and A. C. Frodsham. 1993. Natural enemies of vegetable insect pests. Coop. Ext. Serv., Cornell Univ., Ithaca, NY. 63 pp.

Kieckhefer, R. W. 1975. Field populations of cereal aphids in South Dakota spring grains. J. Econ. Entomol. 68: 161–164.

Kieckhefer, R. W. and J. L. Gellner. 1988. Influence of plant growth stage on cereal aphid reproduction. Crop Sci. 28: 688–690.

Kieckhefer, R. W. and B. H. Kantack. 1980. Losses in yield of spring wheat in South Dakota caused by cereal aphids. J. Econ. Entomol. 73: 582–585.

Kieckhefer, R. W. and E. L. Miller. 1967. Trends of populations of aphid predators in South Dakota cereal crops—1963–1965. Ann. Entomol. Soc. Am. 60: 516–518.

Kieckhefer, R. W., N. C. Elliott and D. A. Beck. 1992. Aphidophagous coccinellids in alfalfa, small grains, and maize in eastern South Dakota. Great Lakes Entomol. 25: 15–23.

Littell, R. C., G. A. Milken, W. W. Stroup and R. D. Wolfinger. 1996. SAS® system for mixed models. SAS Institute, Inc., Cary, NC. 633 pp.

Mattson, W. J. 1980. Herbivory in relation to plant nitrogen content. Annu. Rev. Ecol. Syst. 11: 119–161.

McNeill, S. and T.R.E. Southwood. 1978. The role of nitrogen in the development of insect/plant relationships, pp. 77–98. *In*: J. B. Harbone (ed.), Biochemical aspects of plant animal coevolution. Academic Press, New York.

Neil, K. A., S. O. Gaul and K. B. McRae. 1997. Control of the English grain aphid (*Sitobion avenae* [F.]) (Homoptera: Aphididae) and the oat-bird cherry aphid *Rhopalosiphum padi* (L.) (Homoptera: Aphididae) on winter cereals. Can. Entomol. 129: 1079–1091.

Powell, W., G. J. Dean and N. Wilding. 1986. The influence of weeds on aphid-specific natural enemies in winter wheat. Crop Prot. 5: 182–189.

Rautapää, J. 1972. Effect of herbicides and chlormequat chloride on host plant selection and population growth of *Macrosiphum avenae* (F.) (Hom., Aphididae). Ann. Agric. Fenn. 11: 135–140.

Rice, M. E. and G. E. Wilde. 1988. Experimental evaluation of predators and parasitoids in suppressing greenbugs (Homoptera: Aphididae) in sorghum and wheat. Environ. Entomol. 17: 836–841.

SAS Institute, Inc. 1988. SAS/STAT user's guide, release 6.03 edition. Cary, NC. 1028 pp.

van Emden, H. F. 1966. Plant insect relationships and pest control. World Rev. Pest Control 5: 115–123.

Vickerman, G. P. 1974. Some effects of grass weed control on the arthropod fauna of cereals. Proc. 12th British Weed Control Conf. 3: 929–939.

Voss, T. S., R. W. Kieckhefer, B. W. Fuller, M. J. McLeod and D. A. Beck. 1997. Yield losses in maturing spring wheat caused by cereal aphids (Homoptera: Aphididae) under laboratory conditions. J. Econ. Entomol. 90: 1346–1350.

Wadley, F. M. 1931. Ecology of *Toxoptera graminum*, especially as to factors affecting importance in the northern United States. Ann. Entomol. Soc. Am. 24: 325–395.

Zadoks, J. C., T. T. Chang and C. F. Konzak. 1974. A decimal code for the growth stages of cereals. Weed Res. 14: 415–421.

Zhou, X. and N. Carter. 1991. The effects of nitrogen and fungicide on cereal aphid population development and the consequences for the aphid-yield relationship in winter wheat. Ann. Appl. Biol. 119: 433–441.