Effects of harvest and insecticide treatment on predominant species of ground beetles (Coleoptera: Carabidae) in alfalfa and sainfoin
by Donald G Lester

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University
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Abstract:
To establish the effects of some Montana farming practices on ground beetle populations in alfalfa and sainfoin, a preliminary survey of ground beetles was conducted, followed by harvest and spray treatments. Ground beetles were sampled with pitfall traps in plots of sainfoin and alfalfa 7.7 km west of Bozeman, Montana.

Results demonstrated that there were more Amara farcta LeConte in sainfoin, and approximately equal numbers of Harpalus amputatus Say and Stenolophus comma Fabricius in alfalfa and sainfoin. Comparisons of uncut alfalfa and sainfoin revealed no significant differences in the number of Pterostichus melanarius Illiger, Harpalus amputatus, and Bembidion lampros (Herbst). However, there were more Amara farcta and Stenolophus comma in alfalfa, and more Agonum dorsale (Pontoppidan) in sainfoin. After cutting, there were significantly more ground beetles in uncut areas versus cut areas and the species composition varied in both cut and uncut sainfoin and alfalfa. After seed harvest there were significantly more Stenolophus comma in alfalfa, more Harpalus amputatus in sainfoin, but there were no significant differences in numbers of Amara farcta or Pterostichus melanarius.

Although sainfoin and alfalfa have different pest populations, their ground beetle complex is similar.

Cutting the crop reduces densities of ground beetles in these areas which is probably a reflection of the population density. Pirimicarb (Pirimor) does not reduce ground beetle populations.

EFFECTS OF HARVEST AND INSECTICIDE TREATMENT ON PREDOMINANT SPECIES OF GROUND BEETLES (COLEOPTERA: CARABIDAE) IN ALFALFA AND SAINFOIN

by

Donald G. Lester

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of

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in

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ABSTRACT

To establish the effects of some Montana farming practices on ground beetle populations in alfalfa and sainfoin, a preliminary survey of ground beetles was conducted, followed by harvest and spray treatments. Ground beetles were sampled with pitfall traps in plots of sainfoin and alfalfa 7.7 km west of Bozeman, Montana.

Results demonstrated that there were more Amara farcta LeConte in sainfoin, and approximately equal numbers of Harpalus amputatus Say and Stenolophus comma Fabricius in alfalfa and sainfoin. Comparisons of uncut alfalfa and sainfoin revealed no significant differences in the number of Pterostichus melanarius Illiger, Harpalus amputatus, and Bembidion lampros (Herbst). However, there were more Amara farcta and Stenolophus comma in alfalfa, and more Agonum dorsale (Pontoppidan) in sainfoin. After cutting, there were significantly more ground beetles in uncut areas versus cut areas and the species composition varied in both cut and uncut sainfoin and alfalfa. After seed harvest there were significantly more Stenolophus comma in alfalfa, more Harpalus amputatus in sainfoin, but there were no significant differences in numbers of Amara farcta or Pterostichus melanarius.

Although sainfoin and alfalfa have different pest populations, their ground beetle complex is similar. Cutting the crop reduces densities of ground beetles in these areas which is probably a reflection of the population density. Pirimicarb (Pirimor) does not reduce ground beetle populations.

CHAPTER 1

INTRODUCTION

The survey was designed to determine the predominant species of ground beetles occurring in alfalfa and sainfoin. The field treatments were designed to determine the effects of some Montana farming practices on densities of these ground beetles in alfalfa and sainfoin grown for forage and seed.

Many ground beetles are predatory and have high potential as biological control agents (Barney and Pass 1986b; Rivard 1966) and constitute the greatest proportion of insects captured with pitfall traps (Luff 1978; Rivard 1964a, 1965, 1966; Barney and Pass 1986a). The best trap for sampling ground beetles is the pitfall trap (Greenslade 1964). In order to determine the impact these predators may exert on pest populations, it is important to understand first the effect various farming practices have on these predators.

Preliminary faunistic studies by Hewitt and Burleson (1976) in Montana sainfoin fields, and by Pimentel and Wheeler (1973) in alfalfa, have been completed but comparisons of ground beetles in the two crops have not been made, nor was the effect of cutting these crops for foliage

on ground beetles studied.

Insect fauna studies have been completed in mowed and burned grassland but these studies did not examine ground beetles (Morris 1979; Bulan and Barrett 1971; Menhinick 1962).

The effects of various insecticide treatments have been studied in depth and will be discussed later, but the effect of Pirimor treatment in Montana, and the effect of cutting alfalfa and sainfoin for seed, on trap catches of ground beetles has not been determined.

I hypothesized that there would be more ground beetles in alfalfa than in sainfoin, more ground beetles in uncut areas than in cut areas, and fewer ground beetles in sprayed areas.

CHAPTER 2

REVIEW OF LITERATURE

Ground Beetles as Predators

One-hundred-fifty ground beetle species have been reported to feed on a wide variety of foods including insect eggs, nematodes, dipterans, and fungi (Sunderland 1975). They also fed on young codling moths, apple maggot pupae, earthworms, and Scarabaeidae larvae (Hagley et al. 1982). Amara sp. are generally considered to be herbivorous because 27 species of Amara have been shown to feed on cereals, grass, grass seed, conifer seed, flower heads, fungi, composites, and peach (Johnson and Cameron 1969). Ground beetles feeding on weed seeds were also reported by Lund and Turpin (1977), Hagley et al. (1982), and Pausch (1979).

Although many ground beetle species eat plant material, they are considered to be beneficial in the control of crop pests (Frank 1971; Coaker and Williams 1963; Wishart et al. 1956), and their carnivorous voracity has been examined by Sunderland (1975). Thomas (1931) stated that only birds consumed more wireworms, Elateridae, than did the Carabidae. A similar account by Dubrovskaya (1970) reported that a 34.8% reduction in the number of ground beetles led to a 75.5% increase in the number of Elateridae. Because of

their great abundance, Amara sp. may be the most important predator of the wireworm, Agriotes sputator (L.) (Coleoptera: Elateridae). The ground beetles Agonum mulleri Herbst and Pterostichus spp. (Coleoptera: Carabidae) also fed on this wireworm (Fox and MacLellan 1956). Pterostichus chalcites (Say)(Coleoptera: Carabidae) has been observed feeding on June beetle eggs and grubs (Seaton 1939), and Young (1985) observed Calosoma sayi Dejean (Coleoptera: Carabidae) consuming fall armyworm pupae Spodoptera frugiperda (J.E. Smith)(Lepidoptera: Noctuidae) . From field observation and lab work, Wishart et al. (1956) judged ground beetles to be the most important predators of cabbage maggot eggs, Hylemya brassicae (Weidemann)(Diptera: Anthomyiidae). The seedcorn beetles Stenolophus lecontei (Chaudoir) and Stenolophus comma F. (Coleoptera: Carabidae) gave significant control of cabbage maggot immature stages in cruciferous crops in Wisconsin (Libby et al. 1976). Coaker and Williams (1963) have shown that in field studies the number of cabbage root fly eggs, Erioischia brassicae (Bouche)(Diptera: Anthomyiidae), is inversely related to the number of ground beetles caught in the same site.

Adults of Pterostichus chalcites, Harpalus pennsylvanicus DeGreer, and Scarites substriatus Haldeman (Coleoptera: Carabidae) were shown to have the capacity to consume large amounts of prey in pest outbreaks (Best et al. 1981). This voracity is apparent in forage systems

involving weevils, for example, Barney et al. (1979) noted that Harpalus pennsylvanicus ate nearly twice as many alfalfa weevils, Hypera postica (Gyllenhal), and clover root curculios, Sitona hispidula (Fabricius)(Coleoptera: Curculionidae), as any other species observed. Barney and Pass (1986b) found that Amara cupreolata Putzeys (Coleoptera: Carabidae) foraged readily on larvae of the alfalfa weevil, Hypera postica. Dubrovskaya (1970) found that a reduction in the number of ground beetles by 34.8% in the field led to an increase in the abundance in the weevils of the genus Sitona by 36%. These ground beetles were probably feeding on eggs and larvae of Sitona which numbered as high as 600-800 per square meter (Dubrovskaya 1970). Both Sitona scissifrons (Say)(Coleoptera: Curculionidae) and Elateridae are present in Montana sainfoin fields (Hewitt and Burleson 1976).

Agonum dorsale (Pontoppidan) is a potentially useful biological control agent because it feeds on a number of crop pests. It has been observed that Agonum dorsale feeds on aphids in wheat (Griffiths et al. 1985) and brussels sprouts (Pollard 1968) which was later proven conclusively with aphids being recovered from the gut of Agonum dorsale (Vickerman and Sunderland 1975). Agonum dorsale was not observed feeding on these crops. Agonum dorsale also feeds in the laboratory on the larvae of the fly, Leptohylemia coarctata (Fall.)(Diptera: Anthomyiidae)(Dobson 1961), and

on the eggs and immature stages of the cabbage root feeding fly, Erioischia brassicae (Coaker and Williams 1963). Agonum sp. in the lab have also been observed feeding on Hyperodes spp. (Coleoptera: Curculionidae) larvae, pupae, and adults (Johnson and Cameron 1969; Wishart et al. 1956).

Harpalus amputatus has been observed in the field feeding on larvae and in the lab feeding on fifth instar and eggs of the redbacked cutworm, Euxoa ochrogaster (Guenee) (Lepidoptera: Noctuidae)(Frank 1971).

Bembidion sp. are important predators of the cabbage root feeding fly eggs and in lab and field studies, but Bembidion lampros has also been shown to eat seed in nursery beds (Hughes 1959; Wishart et al. 1956).

Stenolophus comma is considered to be opportunistic and omnivorous (Pausch 1979). Stenolophus sp. have been observed in the field feeding on chinch bugs, aphids, ants, mites, vegetable matter, June grass, and fungus (Allen 1979).

In lab studies Pterostichus melanarius Illiger was observed feeding on grass seed, Hyperodes sp. (larvae, pupae, adults), and asparagus beetle eggs, Crioceris asparagi (L.) (Coleoptera: Chrysomelidae)(Allen 1979). In another lab study, Pterostichus melanarius was shown to feed on radioactively labelled adults of the northern corn rootworm, Diabrotica longicornis (Say)(Coleoptera:

Chrysomelidae), and was thought to be a primary predator in the field (Tyler and Ellis 1979). Pterostichus melanarius is known to attack only one economically important crop which is strawberries (Briggs 1965). In the field Pterostichus melanarius has been observed feeding on grass and grass seed (Johnson and Cameron 1969; Capinera and Lilly 1975).

Effects of Crop Removal on Ground Beetles

Numbers of Bembidion lampros were inversely correlated to the amount of plant cover (Mitchell 1963), and Coleoptera density in a mowed but unburned grassland increased in one summer (Bulan and Barrett 1971), which suggests that beetle densities would increase if the foliage was cut.

Crop type is a critical factor in determining the number of ground beetles present. When comparing various habitats the highest numbers of Pterostichus melanarius occurred in cereal crops where they may be important as natural pest control agents (Tomlin 1975a). Speight and Lawton (1976) used pitfall traps baited with Drosophila sp. (Diptera: Drosophilidae) fruit fly pupae nearby to monitor predation pressure in England winter wheat. More beetles were caught in areas where Poa annua L. was abundant than scarce.

In another study, Pollard (1968) found that removal of

hawthorn hedgerows reduced captures of Agonum dorsale, Pterostichus melanarius, and Harpalus rufipes (DeGreer), yet numbers of Bembidion obtusum (Serville) and Trechus quadristriatus (Schrank)(Coleoptera: Carabidae) increased. Similar cutting studies were carried out in English grasslands to determine the effects of grass removal on Heteroptera (Morris 1979).

Effects of Insecticides on Ground Beetle Populations

Insecticide tolerant predatory arthropods were judged to be useful for future Integrated Pest Management programs in which insecticides might possibly be applied more judiciously or replaced with other less disruptive control measures (Croft and Brown 1975). Implementation of ground beetles into a control program requires knowledge of their susceptibility to pesticides currently in use (Tomlin 1975b) and relatively little is known about the effects of insecticides on ground beetles (Thiele 1977).

Los and Allen (1983) found more Harpalus pennsylvanicus in untreated areas of alfalfa than in areas treated over a number of years with various insecticides. One year after application, five species of ground beetles were more abundant in control plots than in plots sprayed with sumithion (Frietag and Poulter 1970). The application of disulfoton and parathion to the soil killed most existing beetles in a study by Edwards (1972). Ghoulson et al.

(1978) found that soil applications of terbufos and phorate were extremely toxic to ground beetles while methomyl, carbaryl, trichlorfon, and carbofuran were rated as being less toxic to ground beetles. Tomlin (1975b) concluded that broad spectrum organophosphorus and carbamate insecticides were quite toxic to Stenolophus comma larvae and adults. Populations of adult Stenolophus comma were reduced by the application of the chlorinated hydrocarbon insecticides carbofuran, dieldrin, methomyl, and DDT; and the organophosphorus insecticides chlorfenvinphos, terbufos, fensulfothion, leptophos, and phorate. An increase in the population of this beetle was recorded following the application of the chlorinated hydrocarbon insecticide heptachlor (Tomlin 1975b; Thorvilson and Peters 1969).

In another study, Gray and Coats (1983) found that one year after application carbofuran treated plots actually had higher numbers of Harpalus and Bembidion species, and the effect of the various other pesticides used was judged to be minimal. In contrast, residual pesticides have been demonstrated to have a great effect on the community structure in an experiment by Menhinick (1962) in which areas treated with residual pesticides over a number of years were found to have less diversity but a greater number of ground beetles. In lab studies, Hsin et al. (1979) concluded that populations of Pterostichus chalcites and other ground beetles may be reduced in the field if

carbofuran and terbufos are not used with care. Bioassays with aldicarb and carbofuran showed no lethal effects on Harpalus pennsylvanicus, Pterostichus chalcites, and Calosoma sayi in the field or lab (Lesiewicz et al. 1984). Bembidion lampros adults had population reductions with the application of the chlorinated hydrocarbon insecticide dieldrin and the organophosphorus insecticide thionazin (Critchley 1972a,b).

Fewer Pterostichus melanarius were caught in plots recently treated with DDT, but a large and varied population of ground beetles persisted in areas that had been treated with DDT for as long as ten years which suggested a build up of resistance (Herne 1963). Ground beetles from an Iowa cornfield were analyzed for chlorinated hydrocarbon residues and it was found that these residues built up, and subsequent ground beetle resistance to these residues was confirmed in the lab (Humphrey and Dahm 1976). Pterostichus melanarius adults had population reductions with the chlorinated hydrocarbon insecticides aldrin and dieldrin; and the organophosphorus insecticides carbofenothion, diazinon, disulfoton, fonofos, and phorate. Application of the following compounds had no effect on the population: nicotine, the chlorinated hydrocarbon insecticides rotenone and toxaphene, and the organophosphorus insecticides chlorfenvinphos, dimethoate, malathion, mevinphos, parathion, TEPP, and trichlorphon

(Tomlin 1975b; Herne 1963; Edwards and Thompson 1975; Briggs and Tew 1963).

There were only two accounts of the effects of insecticides on Agonum dorsale and it was found that adults and larvae populations were reduced following the application of the organophosphorus insecticide thionazin (Critchley 1972a,b).

Ghoulson et al. (1978) found that black cutworms Agrotis ipsilon (Hufnagel)(Lepidoptera: Noctuidae) poisoned with carbaryl and carbofuran were highly toxic to ground beetles. Black cutworms laced with trichlorfon, methomyl, and toxaphene were not toxic to ground beetles. Coaker (1966) and Critchley (1972a,b) observed that in some studies sublethal doses of insecticides increase the number of ground beetles trapped. This phenomenon was probably due to increased locomotor activity (Thompson 1973). The activity of ground beetles is greatly increased by the chlorinated hydrocarbon insecticides aldrin, dieldrin, DDT, chlorfenvinphos, and the organophosphate thonazin (Coaker 1966; Critchley 1972a; Edwards 1972; Edwards and Thompson 1975; Dempster 1968). Should other aspects of the beetle behavior remain unchanged, the increased activity may result in increased feeding and subsequent control of pest species (Thompson 1973).

Ground Beetle Sampling

Various methods of ground beetle population monitoring and assessment have been utilized as trapping techniques have evolved (MacFayden 1962). The most practical and cost effective trap for ground beetle studies is the pitfall trap (Greenslade 1964) and a variety of pitfall trap types and their modifications have been devised (Mitchell 1963; Wojcik et al. 1972; Hinds and Rickard 1973; Houseweart et al. 1979).

Pitfall traps catch ground dwelling arthropods over a 24 hour period which ensures that arthropods of varying activity time frames are sampled. For example, Pterostichus melanarius is nocturnal, Agonum dorsale is variable in behavior, and Bembidion lampros is diurnal (Greenslade 1963). Obrtel (1971) found that 12 pitfall traps did not statistically differ from 25 traps in yearly catches of the 14 dominant species studied. It was concluded that capturing the total number of species present would have required more than 25 traps, and even then the additional species captured would be those that are caught irregularly or by accident. Similarly, Niemela et al. (1986) concluded that collections from 15 traps adequately represented a spider community compared to either 30 or 45 traps. Baars (1979) demonstrated that trap spacing is not a crucial consideration in ground beetle studies as long as the traps are all of the same construction and are broadly spaced.

CHAPTER 3

MATERIALS AND METHODS

Trap Construction

The pitfall traps used were a modified design by Morrill (unpublished)[1] which consisted of 8.0 cm funnels with the restricted end removed at the junction of the cone. Holes were drilled through plastic jar lids and bottoms with a drill press and hole cutter. Jar lids were fastened to the funnels and aluminum window screen was secured to the jar bottoms with 100% silicone rubber adhesive sealant. This assembly was placed into a polyvinyl chloride sleeve buried vertically in the soil with the top flush with the soil surface. The sleeve permitted firm soil packing without trap distortion, and removal of traps during servicing with a minimum of habitat disturbance. This design was used because it offered greater durability and easier servicing than did other designs.

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[1] Morrill, W.L. Associate Professor of Entomology, Entomology Department, Montana State University, Bozeman, Montana 59717.

Survey

A preliminary survey was undertaken to determine if there were differences in ground beetle fauna in sainfoin and alfalfa. Data was analyzed from a complementary study (Wrona, Lester, and Morrill 1986 unpublished)[2] in which there were six traps arranged in a completely randomized design in each of four plots of newly established dry land alfalfa, var. 'Ladak' and sainfoin var. 'Remont'. The sainfoin variety 'Remont' is a multi-cut variety with seasonal growth similar to alfalfa (Carleton and Delaney 1972). Traps were spaced 9 m apart in plots 9.1 m X 94.5 m (Fig. 1). The field was located 7.7 km west of Bozeman, Gallatin County, Montana. The first portion of the survey was conducted from July 21, 1985 to September 19,1985. Numbers of the two most common species: Pterostichus melanarius, and Harpalus amputatus were recorded. The second portion of the survey was conducted from April 23, 1986 to May 19, 1986. The three most common species: Stenolophus comma, Harpalus amputatus, and Amara farcta were recorded. The results of this survey prompted the following treatments.

The forage harvest and spray treatments were conducted from May 27, 1986 to October 1, 1986. Traps were spaced 12

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[2] Wrona, A.E., D.G. Lester, and W.L. Morrill. Students and Associate Professor of Entomology respectively. Entomology Department, Montana State University, Bozeman, Montana.

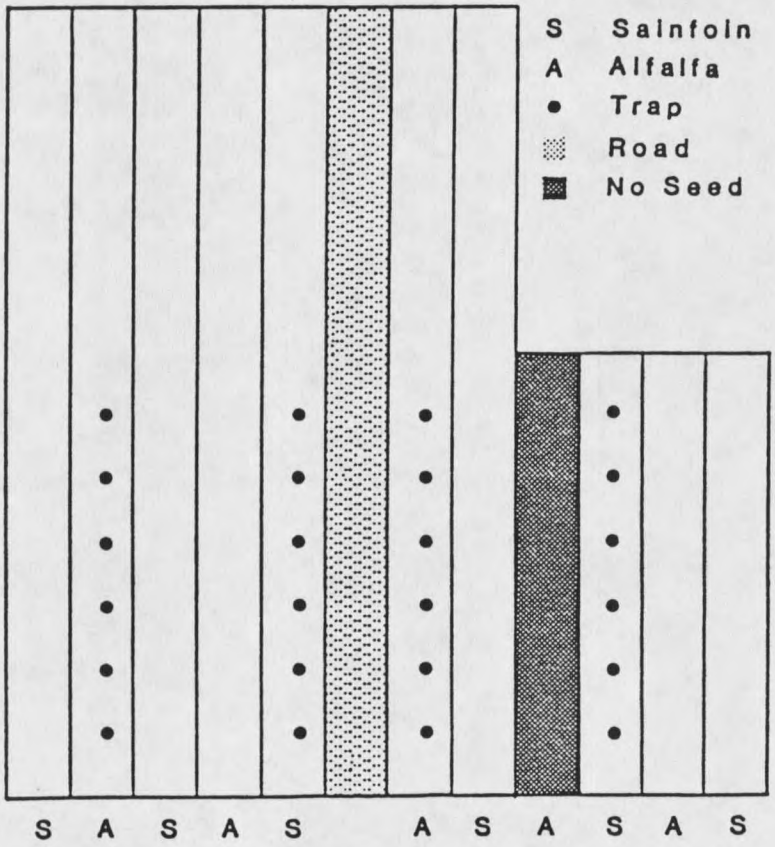


Fig. 1. Field map for first portion of survey. Gallatin Co., Montana. July-September 1985. Scale 1 cm = 709 cm.

m apart in second year growth alfalfa and sainfoin (Fig. 2). There were six prevalent species that were counted and recorded: Pterostichus melanarius, Amara farcta, Harpalus amputatus, Stenolophus comma, Bembidion lampros, and Agonum dorsale. No baits or preservatives were used because of possible repellent and/or attractant qualities associated with them (Greenslade and Greenslade 1971).

Forage Cutting Treatment

The field was cut for forage on July 8, 1986. Catches of beetles were recorded to determine the effect of crop foliage removal on numbers of ground beetles captured.

Spray Treatment

On July 25, 1986 at flowering, one half of the north end and one half of the south end of the field were sprayed with pirimicarb (Pirimor) 50W insecticide at four oz. active ingredient per acre with a CO_2 pressurized backpack sprayer. Harvest and spray treatments were arranged in a split-plot design. Beetles were counted at 5-10 day intervals dependent upon weather conditions and beetles were captured without replacement. Field edges were not sampled because migration from those areas was judged to be minimal. To the north was a fallow field, to the west were farm buildings, to the south was a wheat field, and to the east was a flood irrigation ditch separating the field from an adjacent

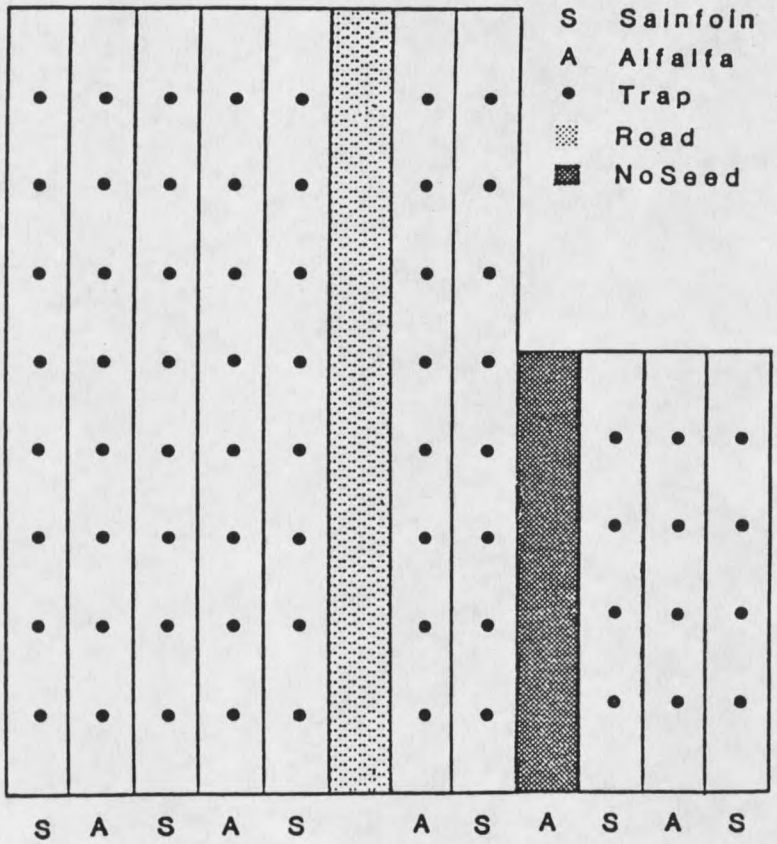


Fig. 2. Field map for second portion of survey and treatments. Gallatin Co., Montana. April-October 1986. Scale 1 cm = 675 cm.

sainfoin field in which no traps could be placed nor harvest controlled. Blocking was undertaken to minimize possible immigration from the remainder of the sainfoin and alfalfa field, and the adjacent sainfoin field to the east. If a rain occurred, at least one day was allowed for drying of the field.

Seed Cutting Treatment

The entire field was cut on August 31, 1986 to simulate seed harvesting. The traps were placed in the field the day after cutting and monitored until frost on October 1, 1986. These traps were in the same configuration and location as those used initially to determine the differences in uncut alfalfa and sainfoin.

Influence of Weather

After the experiments were completed, precipitation and temperature were graphed against trap catches. Catches were standardized to insects/trap/day for comparison to weather data taken from U.S. Weather Bureau records for the weather station 7.7 km west of Bozeman, Montana (U.S. Weather Bureau 1986,1987). These comparisons were made with data taken until August 20, 1986 when the entire field was cut for seed. No separation can be made between the influence of harvesting for seed and the influence of weather.

Statistical Analyses

Due to the aggregated distribution of ground beetles ($S^2 > X$), data were standardized using the logarithmic transformation and analyzed with analysis of variance. All other comparisons were made using the Chi-square goodness-of-fit test (Snedecor and Cochrane 1980). Statistician Dr. Richard Lund[4] advised using the Chi-square test over the 't' test because the beetles were likely to be distributed in an aggregated fashion and more closely follow the Chi-square distribution than the 't' distribution. The alpha level was set at 0.05 for all statistical tests.

The insects captured in this study were compared with pinned specimens identified by Paul M. Choate, Lethbridge, Alberta, Canada. Voucher specimens from this study were submitted to the Montana State University Insect Collection, Bozeman, Montana 59717.

---

[4] Lund, R.E. Agricultural Extension Service Statistician, Montana State University, Bozeman, Montana 59717.

CHAPTER 4

RESULTS

Of the 8,365 arthropods caught over two years, 7,759 were in the insect family Carabidae (Table 1). Pterostichus melanarius, Harpalus amputatus, Amara farcta, Stenolophus comma, Bembidion lampros, and Agonum dorsale represented >90% of all ground beetle species trapped.

Survey

In the first portion of the survey there were significantly more Pterostichus melanarius in alfalfa than in sainfoin. Numbers of Harpalus amputatus in the two crops were not statistically different (Table 2).

In the second portion of the survey, numbers of Pterostichus melanarius, Harpalus amputatus, and Bembidion lampros were not significantly different in sainfoin versus alfalfa. There were significantly more individuals of Amara farcta and Stenolophus comma in alfalfa, and numbers of Agonum dorsale were significantly greater in sainfoin (Table 3).

Table 1. Insects captured in pitfall traps in alfalfa and sainfoin, Gallatin County, Montana. 1985-1986.

INSECTS	Survey[1]	Treatments[2]	
COLEOPTERA			
Carabidae	1194	6565	
Cicindellidae	--	1	
Coccinelidae	--	6	
Curculionidae	--	33	
Dermestidae	--	5	
Elateridae	11	25	
Histeridae	3	77	
Scarabaeidae	--	10	
Staphylinidae	--	359	
DERMAPTERA			
Labiduridae	--	8	
HEMIPTERA			
Miridae	--	18	
Nabidae	1	2	
HYMENOPTERA			
Sphecidae	--	5	
LEPIDOPTERA			
Noctuidae	1	4	
NON - INSECTS (including spiders)	3	25	
ORTHOPTERA			
Gryllidae	2	7	
TOTALS	1215	7150	8365

[1] Total number of insects captured in a two part survey of alfalfa and sainfoin conducted from July 21, 1985 to September 19, 1985 and from April 23, 1986 to May 19, 1986.

[2] Total number of insects captured in harvest and spray treatments in alfalfa and sainfoin conducted from July 8, 1986 to October 1, 1986.

Table 2. Chi-square comparisons of total ground beetles captured in first portion of survey of alfalfa and sainfoin. Gallatin Co., Montana. July-September 1986.

Insect	Crop		X^2
	Alfalfa	Sainfoin	
Pterostichus melanarius	144	92	11.02*
Harpalus amputatus	54	60	0.2

* denotes values are significantly different ($P < 0.05$; Chi-square).

Table 3. Chi-square comparisons of total ground beetles captured in second portion of survey of alfalfa and sainfoin. Gallatin Co., Montana. April-May 1986.

Insect	Crop		X^2
	Alfalfa	Sainfoin	
Pterostichus melanarius	98	73	3.4
Harpalus amputatus	182	178	0.03
Amara farcta	577	374	42.9*
Stenolophus comma	37	6	20.9*
Bembidion lampros	10	8	0.06
Agonum dorsale	26	45	4.6*

* denotes values are significantly different ($P < 0.05$; Chi-square).

Forage Cutting Treatment

The total number of ground beetles caught was significantly greater in uncut versus cut crops. By individual species, catches of ground beetles revealed that there were significantly more Pterostichus melanarius in uncut than in cut areas. There were also more Pterostichus melanarius in sainfoin than in alfalfa regardless of cutting. Numbers of Harpalus amputatus were significantly higher in uncut areas versus cut areas, and were significantly higher in sainfoin than in alfalfa.

Similarly, numbers of Amara farcta were significantly greater in uncut areas than in cut areas. There were significantly more Amara farcta in alfalfa than in sainfoin regardless of cutting. Stenolophus comma had significantly higher numbers in alfalfa, and uncut areas harbored significantly greater numbers of Stenolophus comma than cut areas (Table 4).

Table 4. Chi-square comparisons of ground beetles captured in forage harvesting treatment in alfalfa and sainfoin. Gallatin Co., Montana. July 1986.

	Species							
Crop	Pterostichus melanarius		Harpalus amputatus		Amara farcta		Stenolophus comma	
(U) sainfoin	92		272		367		22	
(U) alfalfa	80	0.70	148	36.0*	613	61.3*	57	14.6*
(U) sainfoin	92		272		367		22	
cut sainfoin	58	7.3*	149	35.4*	208	43.4*	19	0.09
(U) alfalfa	80		148		613		57	
cut alfalfa	44	9.9*	90	13.7*	162	261*	32	6.5*
cut sainfoin	58		149		208		19	
cut alfalfa	44	1.7	90	14.1*	162	5.5*	32	2.8*
cut areas	102		239		370		51	
(U) areas	172	17.4*	420	42.9*	980	275*	79	5.6*
(T) alfalfa	124		238		775		37	
(T) sainfoin	150	2.3*	421	50.3*	370	143*	51	1.9

* denotes numbers are statistically different ($P < 0.05$; Chi-square). (U) = uncut, (T) = uncut plus cut areas.

Spray Treatment

In the insecticide plus cutting portion of the

experiment, the total number of ground beetles captured in sainfoin were not significantly different from those in sainfoin. The effects of cutting and insecticide application in sainfoin and alfalfa on the predominant species showed that Pterostichus melanarius had a significant crop type X cutting interaction in analysis of variance (F 0.05, 1, 2 = 5.1). This means that numbers of Pterostichus melanarius were significantly greater in cut sainfoin, as opposed to uncut sainfoin or alfalfa either cut or uncut. Crop type, cutting, and spraying alone and in combination, had no significant on catches of Amara farcta. Numbers of Harpalus amputatus were statistically significant for cutting when analyzed with analysis of variance (F 0.05, 1, 2 = 13.1). This means that numbers of Harpalus amputatus were significantly greater in uncut areas versus cut areas. Combinations of crop type and cutting were not statistically different. The effect of spraying in sainfoin or alfalfa, harvested or not harvested, or any combination of these, showed that there were no significant differences in numbers of any of the species observed (Table 5).

Seed Cutting Treatment

Analysis of the predominant ground beetle species present in the field after late season crop removal showed that numbers of Amara farcta, Pterostichus melanarius, and Harpalus amputatus were not significantly different in these

crops. Numbers of Stenolophus comma were significantly greater in alfalfa (Table 6).

Table 5. Mean[3] number of ground beetles captured during forage harvest and spray treatments, in alfalfa and sainfoin, arranged in a split-plot design. Gallatin Co., Montana. July-August 1986.

	Species		
Treatments	Pterostichus melanarius	Harpalus amputatus	Amara farcta
Sainfoin			
cut spray	0.81*	0.57*	0.55
no cut spray	0.47	0.58	0.41
cut no spray	0.63*	0.51*	0.61
no cut no spray	0.50	0.60	0.53
Alfalfa			
cut spray	0.48	0.52*	0.42
no cut spray	0.28	0.25	0.59
cut no spray	0.50	0.54*	0.50
no cut no spray	0.37	0.41	0.69

[3] Means were standardized to insects/trap/day and transformed with the logarithmic transformation. (*) denotes values are significantly different from those without (*) by analysis of variance ($P < 0.05$). N = 15.

Table 6. Chi-square comparisons of total ground beetles captured during seed harvesting treatment in alfalfa and sainfoin. Gallatin Co., Montana. August-October 1986.

Insect	Crop		X^2
	Alfalfa	Sainfoin	
Pterostichus melanarius	3	10	2.8
Harpalus amputatus	11	17	0.89
Amara farcta	62	59	0.03
Stenolophus comma	19	7	4.6*

* denotes numbers are statistically different ($P < 0.05$; Chi-square).

Influence of Weather

Temperature and precipitation during the survey and the treatments did not deviate from the average (Table 7). Figure 3 shows that there was no apparent relationship between total weekly precipitation and trap catches of any of the species observed in the first part of the survey (late 1985). Also in the first part of the survey there was no apparent relationship between mean interval high or low temperatures and trap catches (Figs. 3 and 4). Similarly, in the second part of the survey (early 1986) there were no apparent relationships between trap catches and precipitation or mean interval temperatures (Figs. 5 and 6).

Figures 7-9 collectively show that there was no apparent relationship between mean interval high or low temperatures and trap catches of the observed species in the treatments, which is the same result as that of the survey. Overlaying figures 7 and 10 shows that numbers of Stenolophus comma and Agonum dorsale caught did follow

precipitation accumulation, but numbers of Bembidion lampros did not. Overlaying figures 8 and 10 shows that catches of Pterostichus melanarius had no apparent relationship to precipitation, but catches of Amara farcta and Harpalus amputatus did follow precipitation accumulation.

Table 7. Temperature and precipitation averages for Bozeman 7.7 km W., Gallatin Co., MT. 1985-1986.

	Temperature (C)				Precipitation (cm)	
	Ave. Max.	Ave. Min.	Ave.	Departure from norm.	Total	Departure from norm.
1985						
August	26.1	7.3	16.7	--	3.84	--
September	16.8	2.7	9.8	--	4.83	--
1986						
April	13.0	-0.7	6.2	--	4.75	--
May	18.7	2.7	10.7	--	2.90	--
June	26.2	9.0	17.6	--	7.87	--
July	25.4	8.1	16.8	--	3.84	--
August	28.2	9.5	18.8	--	5.41	--
September	16.3	4.1	10.2	--	4.88	--

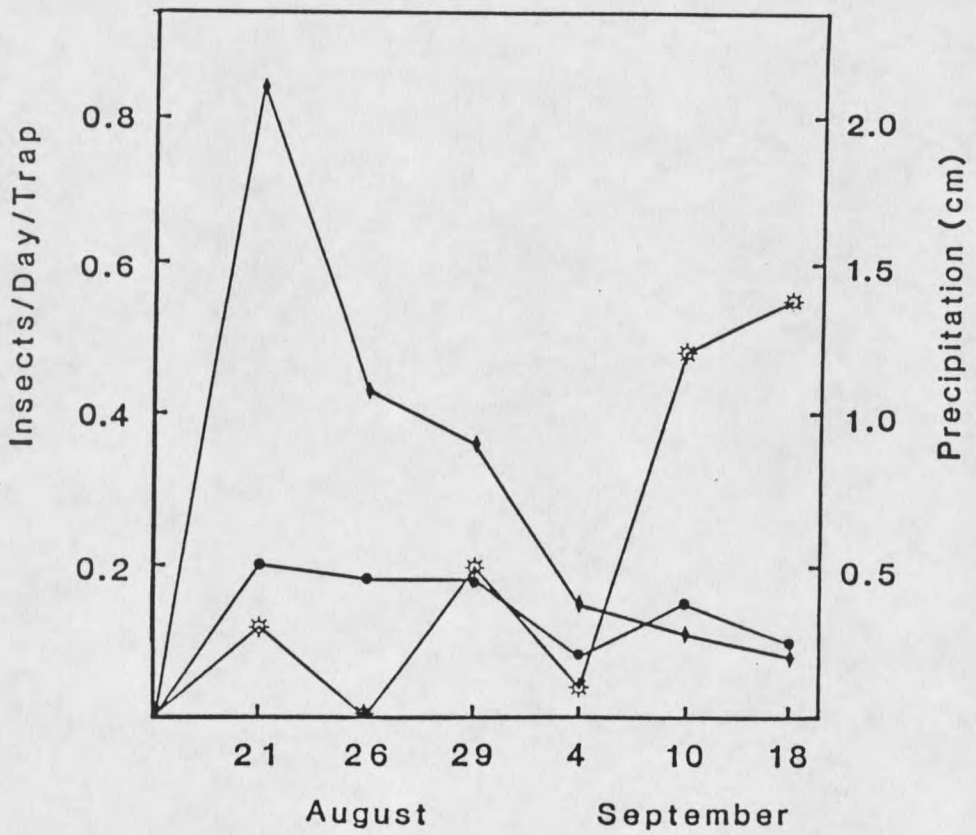


Fig. 3. Seasonal distribution of predominant ground beetle species and weekly precipitation totals during the first portion of survey. Gallatin Co., Montana. August-September 1985. ● = Harpalus amputatus, ♦ = Pterostichus melanarius, and ☼ = precipitation (cm).

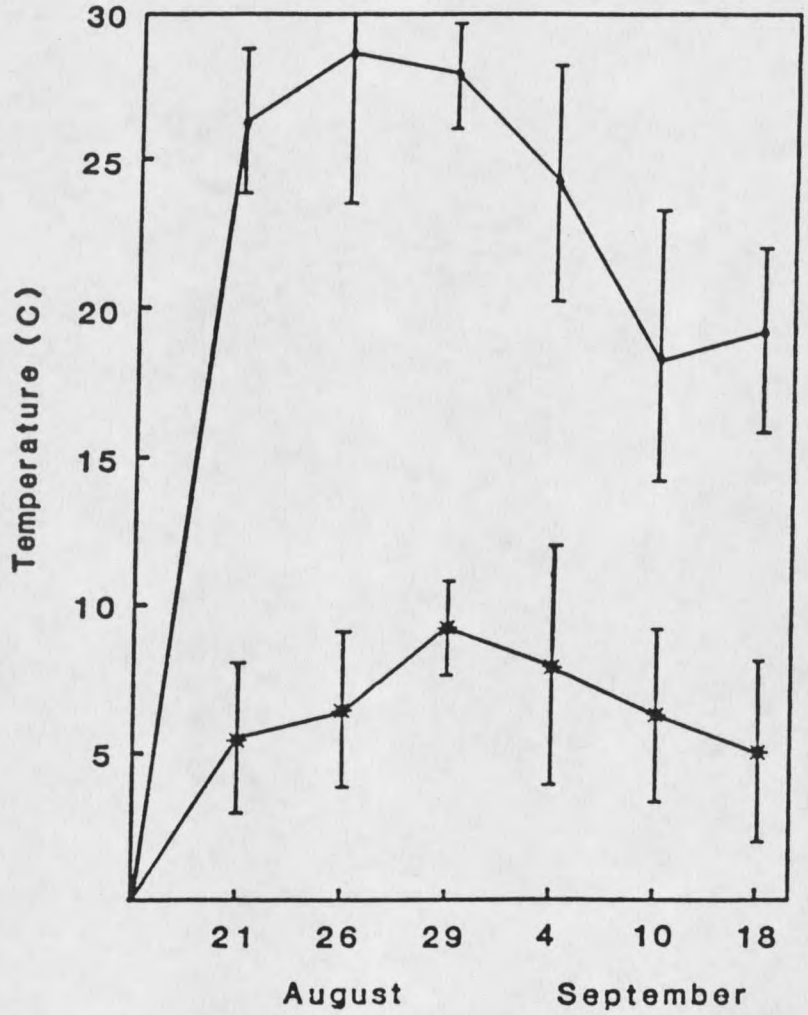


Fig. 4. Mean weekly temperatures and standard deviations during the first portion of survey. Gallatin Co., Montana. August-September 1985. ● = high temperatures, ✷ = low temperatures.

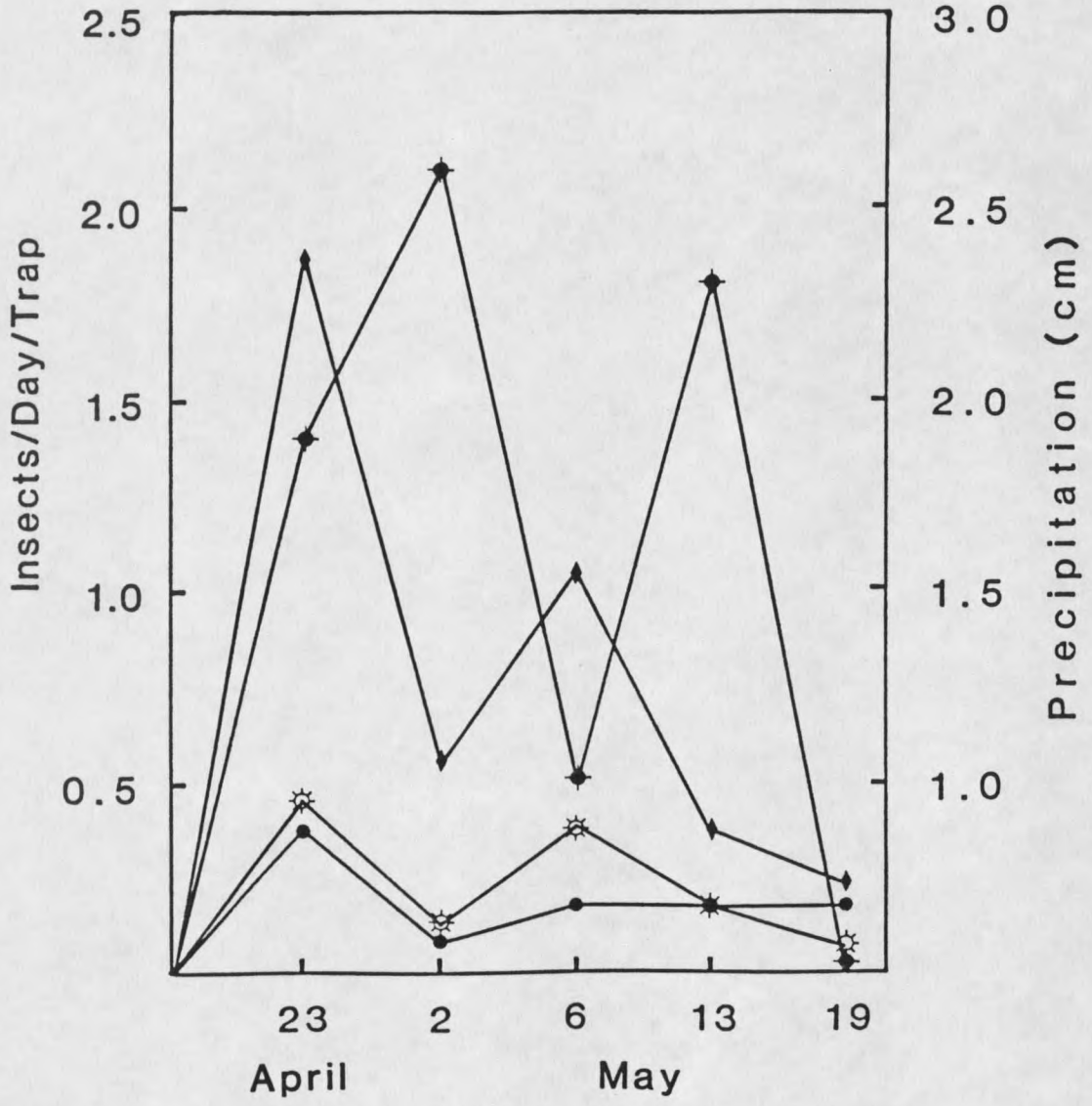


Fig. 5. Seasonal distribution of predominant ground beetle species and weekly precipitation totals during the second portion of survey. Gallatin Co., Montana. April-May 1986. ✦ = precipitation (cm), ☼ = Harpalus amputatus, ♦ = Amara farcta, and ● = Stenolophus comma.

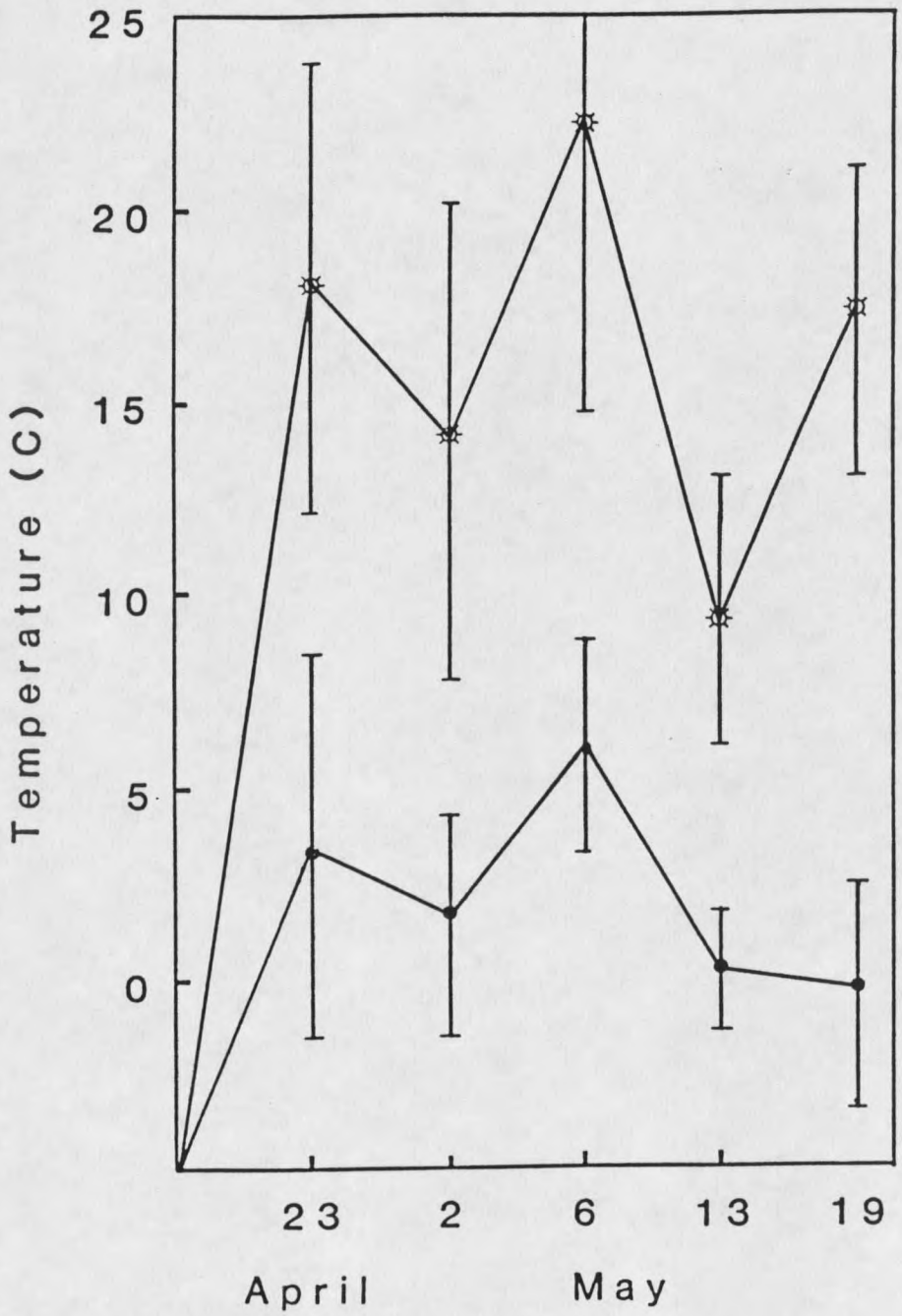


Fig. 6. Mean weekly temperatures and standard deviations during the second portion of survey. Gallatin Co., Montana. April-May 1986. ☼ = high temperatures, ● = low temperatures.

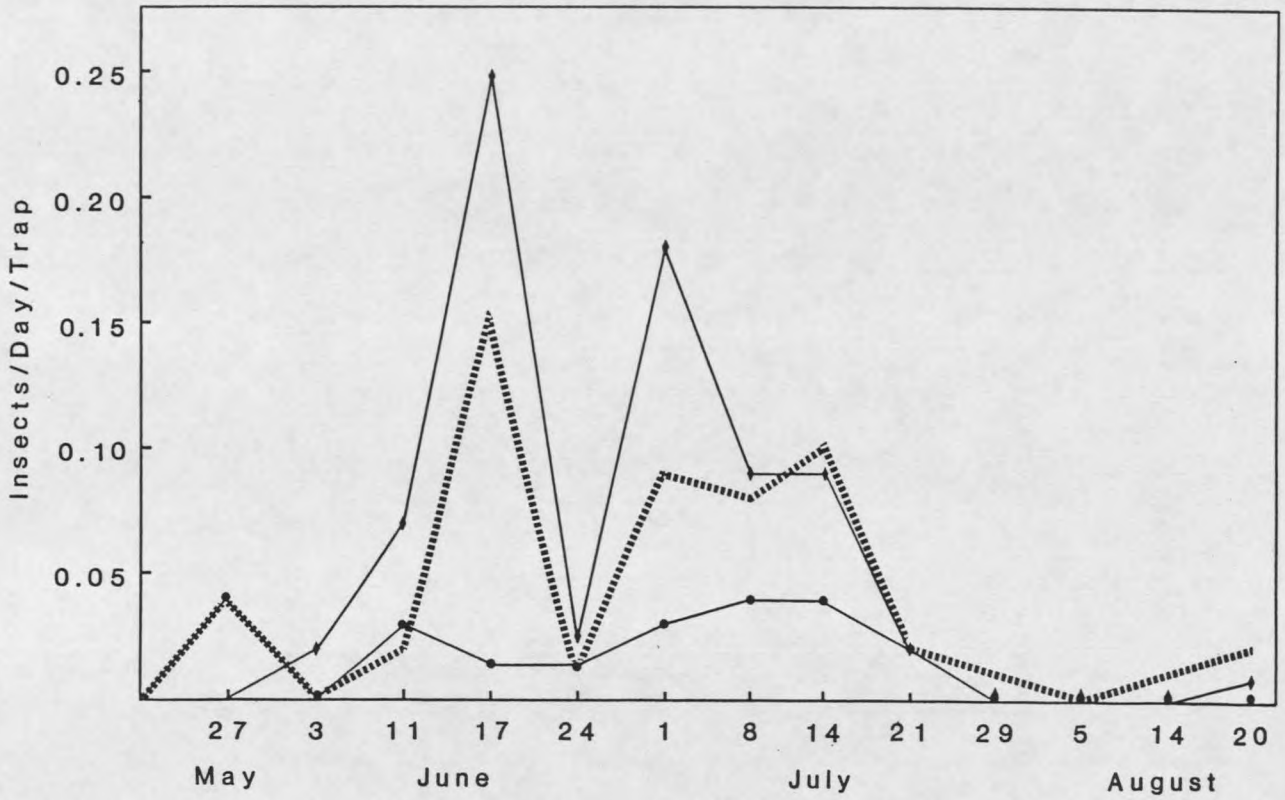


Fig. 7. Seasonal distribution of three predominant ground beetle species during the treatments. Gallatin Co., Montana. May-August 1986. ▪▪▪▪ = Stenolophus comma, ♦ = Agonum dorsale, and ● = Bembidion lampros.

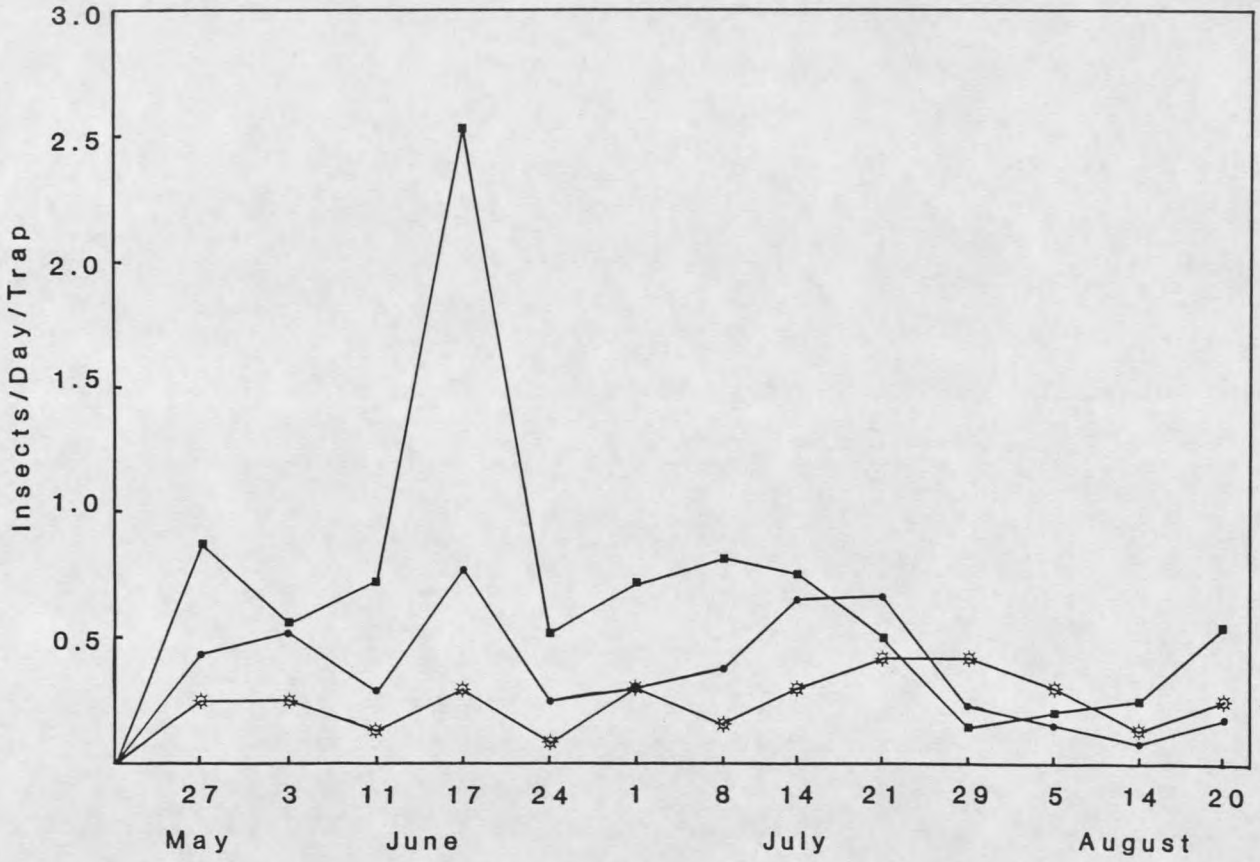


Fig. 8. Seasonal distribution of the remaining predominant ground beetle species during the treatments. Gallatin Co., Montana. May-August 1986. ■ = Amara farcta, ☼ = Pterostichus melanarius, and ● = Harpalus amputatus.

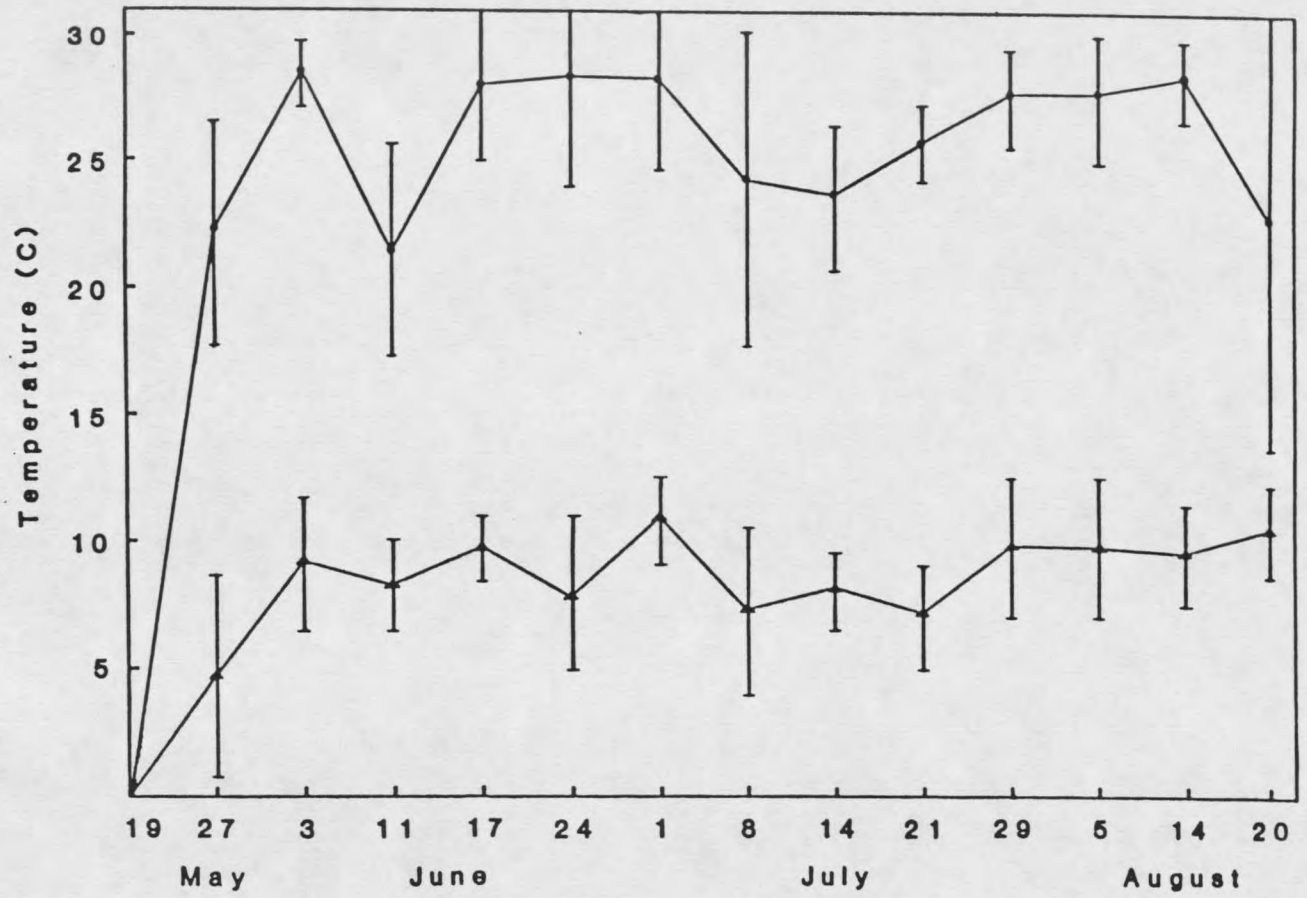


Fig. 9. Mean weekly temperatures and standard deviations during the treatments. Gallatin Co., Montana. May-August 1986. ▲ = high temperatures, ● = low temperatures.

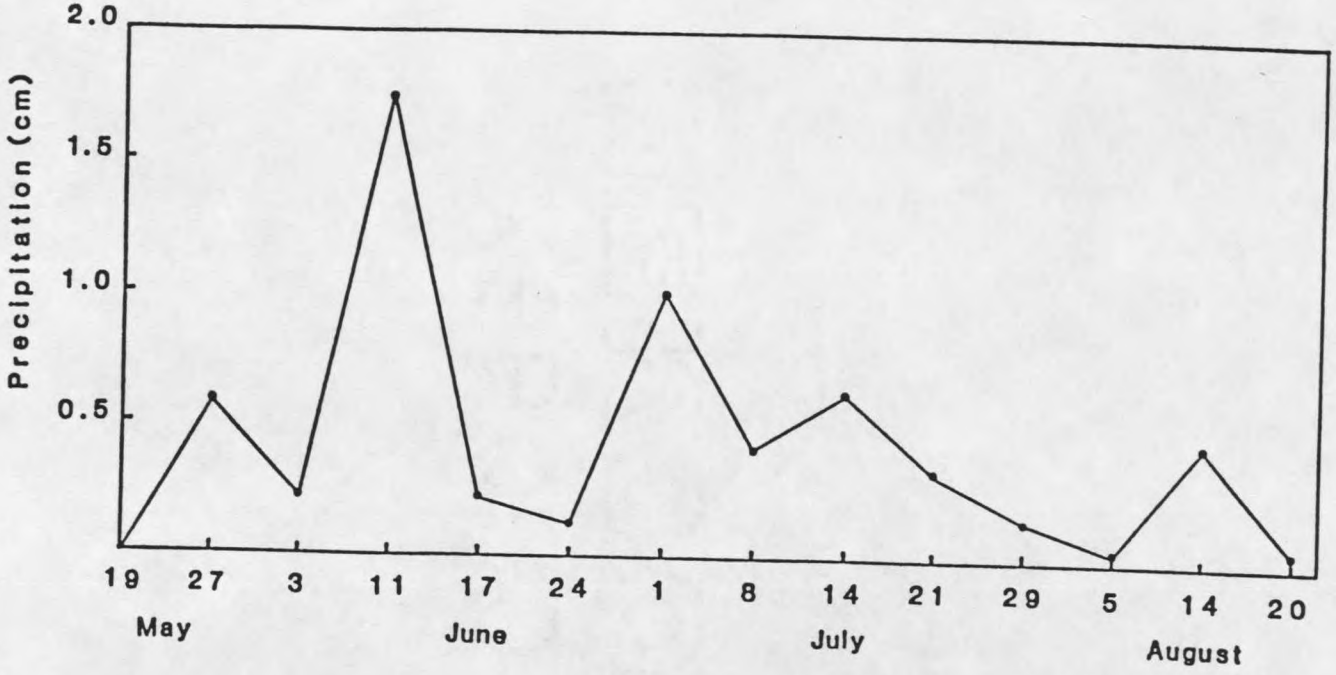


Fig. 10. Weekly precipitation totals during the treatments. Gallatin Co., Montana. May-August 1986.

CHAPTER 5

DISCUSSION

Pitfall trap catches are dependent to a large extent on beetle activity (Greenslade 1964; Mitchell 1963; Briggs 1961). Beetle behavior at certain times during the year is probably a major factor in beetle activity, for example, in the late season portion of this study Pterostichus melanarius might have been scarce due to its tendency toward gregariousness at hibernation (Larochelle 1974). Agonum dorsale is also gregarious at certain times during the year (Allen 1957). The low numbers of Agonum dorsale and Bembidion lampros caught late in the season was probably due to their overwintering in the field boundaries (Sotherton 1984).

Luff (1982) found that numbers of ground beetles caught in pitfall traps fluctuated relatively little from year to year which reflected similar changes in the actual number of beetles present. Luff (1982) also stated that ground beetle population growth and density-dependent mortality rates were low over the nine year study, which contributed to the lack of fluctuation in numbers and thus population stability. Luff (1982) attributed changes in relative numbers of ground beetles to habitat changes. Perhaps the decreased trap

catches following the cutting of these crops can be minimized by the non-disturbance of field margins. In a field study numbers of Bembidion lampros were inversely correlated to the amount of plant cover (Mitchell 1963). Best et al. (1981) found that field edges provided important accumulation sites and shelters for ground beetles dispersing out of arable fields at certain times during the season.

Once the crops were cut no beetles were observed flying or fleeing from the cut areas. This could be explained in two ways. The first explanation is that the ground beetles merely walked to the field edges for refuge. The other possibility is that these ground beetles are nocturnal and did not react to the forage removal until night time. Pterostichus melanarius is known to be nocturnal, Bembidion lampros is diurnal, and Agonum dorsale is variable in behavior (Greenslade 1963). Luff (1978) documented the nocturnal activity of ground beetles in depth. If the second point is true then the Pirimor probably dissipated before individuals of some beetle species were adequately exposed. This brings up an interesting point. Since many growers apply Pirimor in the evening or early morning to minimize pollinator loss, the truly nocturnal species may have been more directly affected than the diurnal or variable behavior species.

One implication from the spray trial results is that

lower doses of biodegradable pesticides such as Pirimor and Dylox might be applied to simply dislodge pests from the plant, rather than kill them, for scavenging ground beetles to consume. Affected individuals that remain on the soil surface are more likely to become desiccated and die, and, being conspicuous, they are more liable to be eaten by predators (Edwards and Thompson 1975).

Temperature had no apparent relationship with catches of the species observed which agrees with data obtained by Hurka (1975) in which Pterostichus melanarius catches plotted against temperature gave no significant correlation (Ericson 1979). There was no apparent relationship of trap catches to precipitation in the preliminary beetle fauna survey and I have no explanation for this phenomenon. The relationship of precipitation to trap catches was very apparent in the harvest and spray treatment experiment in that catches increased after a rain.

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