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

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

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Agronomy

MONTANA STATE UNIVERSITY
Bozeman, Montana

May 1987

APPROVAL

of a thesis submitted by

Donald G. Lester

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Date May 17, 1987

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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.

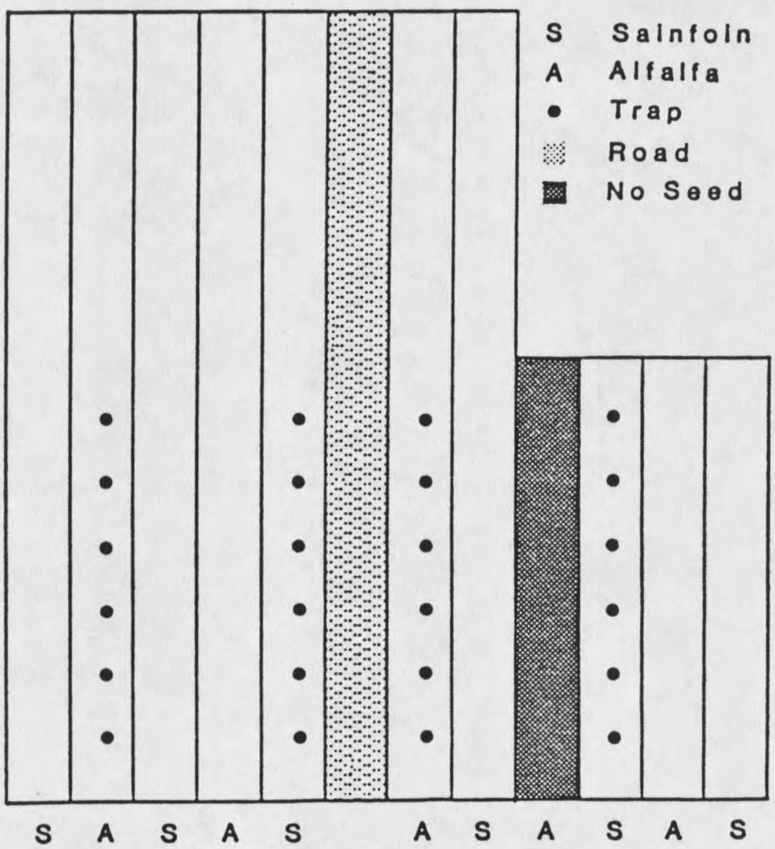

Fig. 1. Field map for first portion of survey. Gallatin Co., Montana. July-September 1985. Scale 1 cm = 709 cm.

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

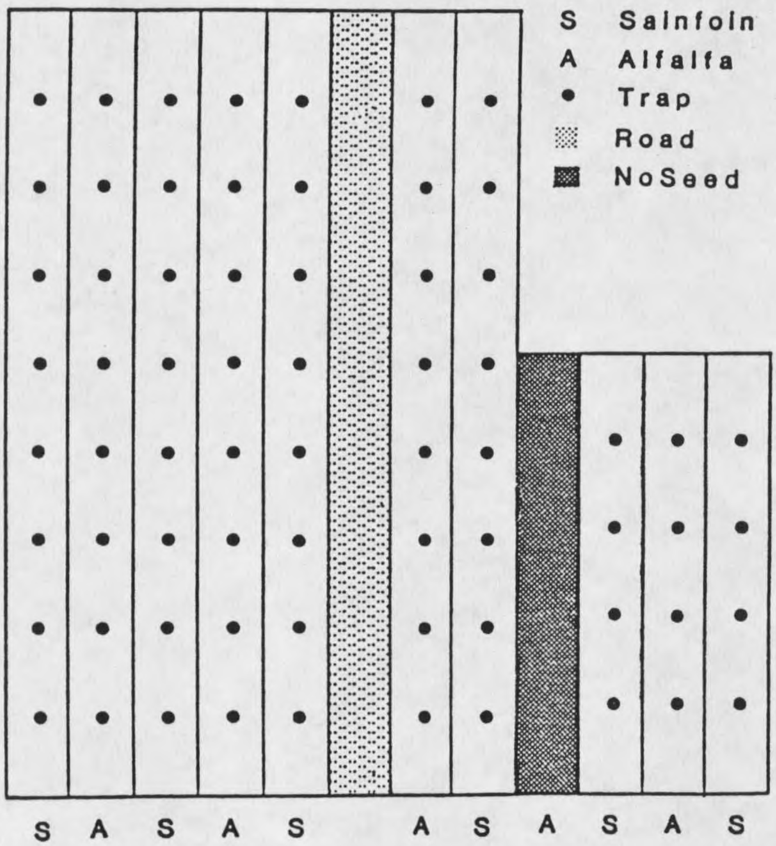

Fig. 2. Field map for second portion of survey and treatments. Gallatin Co., Montana. April-October 1986. Scale 1 cm = 675 cm.

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.

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[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: Alfalfa	Crop: Sainfoin	X^2
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: Alfalfa	Crop: Sainfoin	X^2
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.