Harvest with Raking for Control of Alfalfa Weevil (Coleoptera: Curculionidae)[1]

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J. Entomol. Sci. 35(2): 129-135 (April 2000)

Abstract Successful implementation of early harvest techniques for alfalfa weevil larval, *Hypera postica* Gyllenhal, management depends on synchronization between alfalfa growth sufficient for harvest and economic populations of the insect, conditions that frequently occur in Montana. Field trials were conducted in 1996 and 1997 to determine if the addition of raking to timed harvest would improve the efficacy of alfalfa weevil larvae management, an important cultural control of alfalfa weevil larval populations. Post-baling mean number of alfalfa weevil larvae in stubble were 4.3 (SE = 1.6) and 7.5 (SE = 1.1) per 0.1 m^2 for cutting with raking and cutting alone, respectively, ($P = 0.06$). Nutritive value of forage, as estimated by crude protein and neutral and acid detergent fiber concentrations, did not differ between treatments. Harvest combined with early raking effectively reduced alfalfa weevil larvae populations over cutting alone without compromising nutritive value of forage.

Key Words *Medicago sativa, Hypera postica,* forage quality, integrated pest management, cultural control

Alfalfa, *Medicago sativa* (L.), the premier forage crop in temperate and semiarid regions, is grown on more than 10.6 million ha in the United States (Bailey 1994). The alfalfa weevil, *Hypera postica* Gyllenhal, is the most important phytophagous pest of alfalfa in the United States. Biological and chemical controls, host plant resistance, and cultural techniques have been examined for alfalfa weevil management. While various biological control agents successfully reduce alfalfa weevil larvae populations below economic levels in many regions (Richardson et al. 1971), these agents have not been as successful at reducing economic populations of alfalfa weevil in the western USA (van den Bosch 1972, Kingsley et al. 1993, Brewer et al. 1998, Radcliffe and Flanders 1998). Alfalfa cultivars currently available to producers do not have resistance sufficient to preclude the implementation of additional tactics for alfalfa weevil control. Chemical controls are still widely used with approximately 34% of the alfalfa acreage in the United States treated with insecticides, primarily targeting alfalfa weevil (Bailey 1994). In the western USA, alfalfa weevil management has typically focused on chemical and cultural control measures.

Numerous cultural methods have been examined for alfalfa weevil management including cultivation, disking, grazing (Senst and Berberet 1980, Pelton et al. 1988), burning (Bennett and Luttrell 1965) and early harvest (Essig and Michelbacher 1933,

[1]Received 02 February 1999; accepted for publication 04 April 1999.

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Casagrande and Stehr 1973, Harper et al. 1990). Grazing (Senst and Berberet 1980) and burning (Bennett and Luttrell 1965) before alfalfa breaks dormacy in the spring are based on removal of overwintering alfalfa weevil eggs to decrease subsequent larval populations. While these practices have been successfully implemented in the southern United States where there is substantial winter alfalfa weevil activity and egg lay, these techniques are not effective in northern growing areas where little or no winter egg lay occurs. Cultivation and disking were investigated for impacts on alfalfa weevil populations (Arledge 1978). However, cultivation can cause alfalfa crown injury (Dawson et al. 1969) and subsequent stand loss and is no longer recommended for alfalfa weevil management.

Spring harvest management, as reviewed by Smith (1988), has important implications for crop productivity, disease prevention and stand longevity, especially in northern growing areas where winter injury is more likely. Essig and Michelbacher (1933) stated that early harvest, if properly timed to remove the bulk of eggs and young larvae, could prove to be highly effective for limiting alfalfa weevil damage. Early harvest is practiced when the crop is cut before it has attained a desired physiological stage for harvest yet yield is sufficient for swathing (Smith 1988). Benefits of early harvest for alfalfa weevil management include potential elimination of an insecticide application for alfalfa weevil control and conservation of natural enemies (Casagrande and Stehr 1973, Harper et al. 1990). However, early cutting for alfalfa weevil management must also consider impact on yield and stand longevity. Early cutting when root carbohydrate reserves are low or plants have sustained winter injury will weaken them further, causing thinned stands susceptible to weed invasion.

Under optimal conditions, early harvest exposes some alfalfa weevil larvae to adverse environmental conditions, causing death, minimizing crop damage and precluding use of insecticides (Hamlin et al. 1949, Casagrande and Stehr 1973, Harper et al. 1990). Surviving larvae located in or under the swathed forage are buffered from high temperatures and reduced relative humidity. However, if alfalfa weevil control is not sufficient, larvae can continue to feed and may damage regrowth and reduce yield in subsequent harvest cycles (Essig and Michelbacher 1933). An insecticide treatment applied to stubble following harvest may be needed to prevent damage to regrowth by larvae surviving the harvest process (Manglitz and Ratcliffe 1988).

In Montana, alfalfa weevil populations increase rapidly as the normal timing for first harvest approaches. Therefore, early cutting in Montana does not represent a significant compromise in harvest timing as it does in areas further south where peak alfalfa weevil populations and timing of first alfalfa harvest are less synchronous. Producers sometimes rake swathed forage to accelerate drying, but raking usually is done just prior to baling by most Montana producers. Raking hastens drying of swathed forage in more humid regions, but raking just prior to baling when alfalfa forage typically has dried to 10 to 15 percent dry matter, produced 25% less hay (by weight) and 30% less nutrients than did alfalfa that was raked earlier, at higher moisture levels (Dobie et al. 1963). The influence of raking on alfalfa weevil larval survival is unknown. We conducted field trials in 1996 and 1997 to determine if raking swathed alfalfa earlier than just prior to baling in an early harvest alfalfa weevil management system improves alfalfa weevil control compared to early harvest alone.

Materials and Methods

Research was conducted during the 1996 and 1997 growing seasons in Broadwater Co., southwestern Montana, on irrigated, production alfalfa fields. Alfalfa in this region is usually harvested three times per season, with rapidly increasing alfalfa weevil larvae populations coinciding with first harvest. Starting in late May (1996) or early June (1997), alfalfa fields were monitored weekly for adult and larval populations of alfalfa weevil by sweep net sampling. Fields with sufficient weevil larval populations were then selected for our trials.

In 1996, three fields were selected for the raking trials based on numbers of alfalfa weevil larvae present. Although intended treatments were early harvest alone, normal harvest timing (typical of local producer-managed alfalfa), and early harvest plus early raking, environmental conditions and the influence of the timing of our early cutting treatment resulted in the coincidence of normal harvest timing for that production area and early cutting. Therefore, the treatments were harvest alone and harvest with early raking, replicated four times at each location. Mean field plot area was 5.7 ha (SEM = 2.6 ha), selected to accommodate equipment operation and then sampled for yield. In 1997, trials were conducted in two fields with individual plot areas measuring 8 × 18 m. Both years the experimental design was a randomized complete block, with four replications at each field site.

Two 0.1-m^2 quadrats were hand harvested in each plot prior to harvest. Crop phenology was determined by selecting 10 stems from each plot and rating plant development stage using the method of Kalu and Fick (1981). Forage samples were placed in paper bags, weighed, transported to a laboratory and placed in Berlese funnels to extract alfalfa weevil larvae. After forage samples were air dry, they were placed in a forced-air oven at 55°C for 48 h and reweighed. Sample dry matter was calculated as (dry wt/fresh wt) × 100.

Immediately following cutting, approximately 24 h post-cutting, before early raking, and 2 d post raking, windrow slices (30 cm wide by the width of the windrow) were taken from four windrows in each plot using the method of Arledge and Melton (1984). Samples were dried as described previously and dry matter determined. Alfalfa weevil larval numbers were counted in four 0.1-m^2 quadrats directly under swathed forage and between windrows in each plot. In 1996, the forage was raked using a tractor-pulled, 5-bar, side delivery rake, 1 to 3 d before baling. In 1997, windrows were turned by hand to simulate the use of a side-delivery rake. In both years raking turned the windrow over and moved it to a new location immediately adjacent to its original position. After forage was baled and removed from the field, alfalfa weevil larvae were again quantified by sampling a 0.1-m^2 quadrat in each plot area.

The influence of raking on alfalfa quality was evaluated with samples from the 1996 field trials. The oven-dried preharvest and windrow slice forage samples were ground to pass a 1.0-mm sieve with a rotary mill, then reground with a cyclone mill to pass a 0.5-mm sieve. Crude protein and acid and neutral detergent fibers, were determined by near infrared spectroscopy with a NIRSystems Model 4500 (NIRSystems, Silver Spring, MD) equipped with Infratech 2 software, Version 3.10.

Analysis of variance procedures were done using PC-SAS for a split plot design for all parameters measured (SAS Institute 1988). Pre- and post-harvest larval counts were analyzed following a log transformation to stabilize variance (Snedecor and Cochran 1982).

Results and Discussion

Harvest and baling dates, cultivars, and equipment information are summarized for each trial location (Table 1). None of the cultivars tested were resistant to alfalfa

Table 1. Harvest and baling dates, alfalfa cultivars, and equipment specifications from five fields with and without early raking for alfalfa weevil management

Field and year	Date			Cultivar	Swather	
					Header width	Crimper width
	Swathed	Raked*	Baled		m	
			1996			
1	27 June	1 July	5 July	LegenDairy	4.3	2.4
2	25 June	26 June	4 July	Ladak 65	3.7	2.4
3	25 June	26 June	4 July	NK919MF	3.7	2.4
			1997			
4	19 June	25 June	28 June	LegenDairy	4.3	2.4
5	23 June	28 June	7 July	LegenDairy	4.3	2.4

* Date of early raking; producer-managed plots were raked on date of baling.

weevil. Alfalfa weevil larval populations were high both years, exceeding the economic threshold level of 20 larvae per sweep used in Montana (Blodgett 1996). Significant differences between 1996 and 1997 in the preharvest number of weevil larvae ($F = 98.0$, $P > F = 0.01$), prevented combining data across years (Table 2.).

Mean number of alfalfa weevil larvae present in preharvest samples were not significantly different between treatments (Table 3). Larvae present in stubble after baling were lower in the raked plots ($P > F = 0.06$) with a 43% reduction in number of larvae compared to cutting alone. Mean larval numbers in the unraked controls nearly reached the treatment threshold of 8.6 larvae per m^2 (Blodgett 1996). Raking following cutting substantially reduced the number of weevil larvae present in the stubble following baling and in some years may eliminate the need for a pesticide application to stubble.

Alfalfa growth stages of 3.7 (SE = 0.1) and 3.6 (SE = 0.1) were not significantly

Table 2. Mean of alfalfa yields and alfalfa weevil populations (SEM) in alfalfa harvested between years 1996 and 1997.

Treatment	Alfalfa weevil larvae	
	Preharvest no./0.1 m^2	Post bale no./0.1 m^2
1997	362.0 (17.3)	8.0 (1.4)
1996	54.6 (9.8)	2.6 (0.7)
$P > F$	>0.01	>0.01

Table 3. Mean of alfalfa yields and alfalfa weevil populations (SEM) in alfalfa harvested with and without early raking for alfalfa weevil management

	Alfalfa weevil larvae	
Treatment	Preharvest no./0.1 m^2	Post bale no./0.1 m^2
Raking	256.2 (39)	4.3 (1.6)
Control	222.0 (35)	7.5 (1.1)
$P > F$	0.11	0.06

different for the raking and cutting treatments, respectively. Forage yields of 7334 kg/ha (SE = 318) and 6788 kg/ha (SE = 450) for raking and cutting treatments, respectively, were nonsignificant ($P > F = 0.36$) and were typical for first harvest in this production area. In 1996, forage in Field 1 was drier and raked at a dry matter concentration of 85%, only 1 d prior to baling due to the occurrence of several rain showers. Swathed forage in Fields 2 and 3 was raked at 64 and 58% dry matter, respectively. In 1997, forage in Fields 1 and 2 were raked at 70 and 75% dry matter, respectively. The correlation of percent dry matter at raking with post-baling larval counts in stubble or percent reduction of larval populations was nonsignificant.

Concentrations of crude protein and neutral and acid detergent fibers did not differ between normal harvest and raked forage (Table 4). Forage that was harvested and raked was ready for baling without spoilage at least 1 d earlier compared with cutting alone in two of the three field trials in 1996 (data not presented).

In much of Montana and other northern alfalfa production areas, the period of

Table 4. Mean forage quality of alfalfa forage (SEM) with and without early raking for alfalfa weevil management, 1996

Parameter*	Treatment	Precut	Postcut	Prerake	Postrake	2 Days postrake
			% dry matter			
CP	Early Raking	20.5 (0.2)	20.3 (0.3)	19.6 (0.8)	19.8 (0.5)	19.6 (0.3)
	Control	20.6 (0.2)	19.8 (0.7)	19.5 (0.5)	–	19.7 (0.4)
NDF	Early Raking	35.9 (0.6)	35.6 (0.6)	38.2 (1.1)	38.2 (1.1)	37.1 (1.0)
	Control	35.8 (0.3)	36.7 (0.9)	38.1 (1.4)	–	37.4 (0.9)
ADF	Early Raking	30.6 (1.2)	31.8 (0.8)	32.4 (2.1)	32.8 (2.0)	31.9 (1.7)
	Control	31.0 (0.9)	33.2 (1.1)	33.2 (1.8)	–	32.2 (1.1)

* CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber.

normal first harvest of alfalfa coincides with increasing alfalfa weevil populations. Where winter egg lay occurs, damaging weevil populations reach peak densities at early plant growth stages when early cutting would have a deleterious effect on yield and stand persistence. Successful early harvest for alfalfa weevil management depends on the harvest timing relative to the developmental stage of the plant and the life cycle of the weevil.

In other regions of the USA producers commonly turn over swathed forage with rakes or other equipment to expose the wetter underside to better drying conditions. However, many producers in Montana do not rake swaths until immediately prior to baling because raked alfalfa swaths are more susceptible to movement during the regions frequently windstorms, resulting in substantial losses in yield and quality. Harvest followed by raking provides an effective management tool for reducing alfalfa weevil larvae and reducing harvest duration which results in a higher value product. Raking may also reduce insecticide applications without compromising nutritive value of forage.

Acknowledgments

We gratefully acknowledge alfalfa producers H. Hensley, R. Kitto, and K. Kovanda for their input and cooperation in conducting this research, and P. Denke, B. Blanchard, D. Higham, B. Larson, and D. Waters for field and laboratory assistance. This research was funded by USDA, CSREES, Pest Management Alternatives Grant #9601485. Montana Agric. Exp. Stn. number J-5189.

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