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ECONOMIC ANALYSIS OF ALFALFA INTEGRATED MANAGEMENT PRACTICES

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Abstract

Integrated pest management (IPM) initially focused on insect pest control. More recently, IPM encompasses a broader concept of management, one which crosses several disciplinary boundaries. This article reports results of research dealing with four integrated management decisions for alfalfa (cultivar selection, insect control, weed control, and end-of-season harvest options).

Key words: integrated pest management (IPM), alfalfa, cultivar selection, harvest management, economic returns

Economic research on Integrated Pest Management (IPM) has focused both on farm-level impacts of pest management strategies, and on aggregate impacts (Rajotte *et al.*). Numerous analytical tools and methodologies have been employed (e.g. mathematical programming, econometric estimation, simulation, stochastic dominance, and Bayesian decision theory, among others). Studies concentrating on individual management decisions, such as the need for pest control and how it affects various aspects of the farm enterprise (e.g. yields, risk, and profitability), have determined that IPM generally decreases pesticide use and/or production costs while increasing net returns (Rajotte *et al.*).

Alfalfa growers make a variety of management decisions that affect profitability (including cultivar selection, fertility program, insect and weed controls, harvest method, and marketing timing). McGuckin expanded the IPM concept for alfalfa to include harvest alternatives along with pest management. Debertin *et al.* also included alfalfa management practices in addition to pest control. Alfalfa IPM programs at Oklahoma State University, developed with research and extension input, have emphasized integration of pest control and agronomic aspects of management (Ward 1988), thereby fitting more closely the broader concept of IPM than is often apparent in the literature.

The objective of this study was to determine the economic returns within and between years resulting from combinations of alfalfa cultivars, end-of-season harvest methods, as well as insect control and weed control alternatives. Therefore, effects on alfalfa yields, forage quality, prices, and production costs were considered. Experimental agronomic data collected over a five-year period were analyzed by binary variable regression.

BACKGROUND AND PREVIOUS WORK

The alfalfa weevil is the most important insect pest of alfalfa in Oklahoma (Berberet *et al.* 1980). Losses result primarily from feeding of larvae during growth of the first crop in March and April (Berberet *et al.* 1981). The timing of larval infestations is determined by the hatching time of eggs laid by adult weevils during the winter months. The highest egg numbers (and subsequent larval infestations) are typically found in those fields having abundant fall growth of alfalfa where habitats are favorable for adults. Winter grazing of alfalfa stands by cattle has been used as a means of reducing overwintering habitat for weevils and may result in 50 to 70 percent fewer eggs being present to contribute to larval populations in the spring (Senst and Berberet). Additionally, some alfalfa cultivars, such as Arc, have been selected for tolerance to feeding of alfalfa weevils. These cultivars may reduce the need for applications of chemical insecticides.

Annual weeds compete with alfalfa for soil nutrients, moisture, and light (Dowdy). If a full stand of alfalfa (25 to 30 stems per square foot) is maintained, weed interference has minimal effects on productivity. However, if alfalfa plants are stressed, as occurs with infestations of weevil larvae, weeds may gain the competitive advantage. High weed populations can then reduce alfalfa forage yields and shorten stand life. Weeds typically have a lower protein content than alfalfa and some less palatable weeds reduce forage intake by animals. Thus, high weed content reduces alfalfa hay quality and price (Dutt *et al.*; Ward 1987). Dormant-season herbicide

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Table 1. Total Adjusted Returns per Acre for Integrated Alfalfa Management Practices, 1983 to 1987

Cultivar	End-of-Season Harvest Practice					
	Fall Cut		Winter Grazed		Unharvested	
	No Herbicide	Herbicide	No Herbicide	Herbicide	No Herbicide	Herbicide
----- (\$/Acre) -----						
WL318						
No Insecticide	2,469	2,541	2,605	2,673	2,369	2,435
Insecticide	2,654	2,613	2,641	2,841	2,745	2,643
Arc						
No Insecticide	2,427	2,452	2,611	2,734	2,414	2,454
Insecticide	2,590	2,592	2,721	2,620	2,540	2,652
OK08						
No Insecticide	1,989	1,987	2,179	2,174	1,968	2,095
Insecticide	2,073	2,246	2,290	2,422	2,245	2,200

application is a common weed control alternative for Oklahoma alfalfa growers and has been found to be an effective weed pest control alternative (Wilson). Winter grazing may assist in reducing annual cool-season weed populations in established alfalfa by inhibiting weed growth.

Little research has focused on the interaction between end-of-season harvest options with insect and weed controls, though research has documented interactions between insect and weed pests (Berberet *et al.* 1987). Some annual weeds are ovipositional sites for the alfalfa weevil and larval feeding damage may be increased with higher populations of certain weeds (Ben Saad and Bishop). In contrast, Norris *et al.* found that effective weed control in alfalfa resulted in higher populations of the Egyptian alfalfa weevil. The higher insect populations led to reduced alfalfa yields, but reductions were not as great as when neither insect nor weed pests were controlled. An Illinois study also showed that yield reductions were greatest when neither insects nor weeds were controlled (Kapusta *et al.*).

RESEARCH DESIGN AND DATA

This research was designed to address effects on economic returns from interactions of cultivar selection and end-of-season harvest options along with pest control alternatives. Alfalfa production data were collected from Oklahoma's South Central Research Station (Dowdy). The experimental design was a split-plot in strip configuration with four replications of three alfalfa cultivars. Two cultivars (WL318 and Arc) had been selected for their tolerance to alfalfa weevils and resistance to some aphid species and alfalfa pathogens, while the third (OK08) had no selection for pest resistance.

Subplots positioned in strips across the main plots consisted of three alternative end-of-season harvest options. The three options consisted of late-fall harvest (November), winter grazing (December and January), and unharvested. Insecticides and/or herbicides were applied annually without consideration of insect and weed populations in a 2 x 2 factorial design on subplots within each cultivar-by-harvest combination. The resulting pesticide treatments included insecticide only, herbicide only, both insecticide and herbicide, and neither insecticide nor herbicide. Alfalfa was irrigated to maintain high forage productivity throughout the growing season.

Yields were recorded from four or five harvests annually during the second through sixth years of stand life for the study area. Weed content of forage was estimated at each harvest, which allowed estimating alfalfa yield separately from total forage yield and adjusting total harvested forage when weeds were present.

At the end of the five-year study, alfalfa was valued based on the average price from 1982 to 1987 in Oklahoma. Alfalfa value was discounted for weed content based on sale data from HAYMARKET in Oklahoma (Ward 1987). Total value for alfalfa produced per acre was adjusted for harvest and pesticide treatment costs, though no adjustment was made for seed cost differences among cultivars. Variable costs for insecticide and herbicide applications and for late-season harvesting were based on 1987 estimates. Cattle grazing costs were assumed borne by the livestock enterprise and not the alfalfa enterprise. The value of grazed alfalfa was also assumed to be attributable to the cattle enterprise in the form of weight gain and thus was not associated with the alfalfa enterprise. Adjusted value of alfalfa

per acre was estimated annually and for the five-year period for each of the 36 combinations (*i.e.* cultivars X end-of-season harvest options X insecticide treatments X herbicide treatments).

Table 1 shows total adjusted returns per acre for the five-year period. Total adjusted returns ranged from \$2,841 to \$1,968 per acre. The 31 percent difference in adjusted returns (\$174.60 per acre per year) suggests a need to understand what management practices explain the wide difference in annual per acre returns.

MODELS SPECIFIED

Tomek discussed the application of zero-one (binary) regression variables in time series analyses. Binary variables (also called dummy variables) are frequently used in price analysis to account for within-period variation (such as seasonal prices) or between-period variation (such as annual price level). Binary variables are also applied in hedonic pricing models to account for quality attributes or other discrete characteristics of the dependent variable.

Many regression models which include binary variables include one or more continuous independent variables. However, there are applications both of time series and cross section regression analyses using multiple binary variables alone, referred to here as binary variable regression (BVR). Madsen and Liu used BVR to study price differences for feeder cattle (incorporating independent variables for grade, weight and sex, market location, and lot size classes). Sersland applied BVR to a cost analysis of meatpacking plants (incorporating independent variables for plant size, hours worked per shift, shifts per day, days per week, and percent of capacity utilized). Regression analyses when all independent variables are binary, such as BVR, yield results similar to those of an analysis of variance (ANOVA) approach.

In this study, two models were specified and estimated for each of the five years and for the five-year period combined. Model A assumed no interaction among the four independent variables, as in a main effects ANOVA model. Model A was:

$$Y = \alpha + \sum_{i=1}^3 \beta_{1i} X_{1i} + \sum_{i=1}^2 \beta_{2i} X_{2i} + \sum_{i=1}^2 \beta_{3i} X_{3i} + \sum_{i=1}^3 \beta_{4i} X_{4i}$$

where

Y was the adjusted value (\$) of alfalfa per acre,

X_{1i} was end-of-season harvest option (*i*=1-3, 1=Fall cut, 2=Winter grazed, 3=Unharvested),

X_{2i} was herbicide treatment (*i*=1-2, 1=No herbicide, 2=Annual herbicide treatment),

X_{3i} was insecticide treatment (*i*=1-2, 1=No insecticide, 2=Annual insecticide treatment, and

X_{4i} was alfalfa cultivar (*i*=1-3, 1=WL318, 2=Arc, 3=OK08).

Of specific interest in this research was the possible three-way interaction between end-of-season harvest option, insect control, and weed control. In model B, end-of-season harvest option (X_{1i}), weed control (X_{2i}), and insect control (X_{3i}), were combined into a single variable (X_{5i}), thereby replacing three variables in Model A (X_{1i}, X_{2i}, and X_{3i}). The combined variable in Model B was X_{5i}, *i* = 1 - 12 (*i.e.* 3 end-of-season harvest options X 2 herbicide treatments X 2 insecticide treatments).

ESTIMATION RESULTS AND IMPLICATIONS

Results from each model are reported here, and groups of variables associated with alternative management options are discussed separately.

Model A

Regression results for Model A are shown in Table 2. One independent variable from each variable group was left out and is referred to as the base variable (Suits). Thus, the intercept for Model A, 1983, can be interpreted as follows. The mean adjusted value for unharvested OK08 without insecticide and herbicide treatments and with no fall cutting was \$474.50 per acre. Beta coefficients are interpreted as differences from the base variable within each variable group. For example, the mean adjusted value for fall-cut alfalfa in 1983 was \$35.34 per acre more than for unharvested alfalfa. Winter grazing increased returns an additional \$7.32 per acre (\$42.66 - \$35.34) compared with fall-cut alfalfa. If the beta coefficient was not significantly different from zero, then adjusted returns for that variable were not statistically different from adjusted returns for the base variable.

End-Of-Season Harvest Options

Winter grazing increased adjusted alfalfa returns each year and for the five-year period in relation to other end-of-season harvest options. Based on previous research (Senst and Berberet; Dowdy), removal of fall alfalfa growth by grazing reduced stress on alfalfa plants resulting from insect and weed infestations. Consequently, increased yields

Table 2. Integrated Alfalfa Management Regression Results Model A 1983 to 1987

Independent Variables	Estimated Coefficient ^a					
	1983	1984	1985	1986	1987	1983-87
	----- (\$/Acre) -----					
Intercept	474.50*** (51.42)	612.32*** (46.72)	591.13*** (46.58)	228.28*** (27.93)	106.64*** (10.11)	2010.02*** (70.07)
<u>Harvest:</u>						
Fall Cut	35.34*** (4.14)	10.42 (.86)	-11.16 (.95)	-33.08*** (4.37)	-6.24 (.64)	-10.45 (.39)
Winter Grazed	42.66*** (4.99)	28.94** (2.38)	53.89*** (4.59)	38.48*** (5.09)	22.60** (2.31)	147.00*** (5.54)
Unharvested	Base	Base	Base	Base	Base	Base
<u>Herbicide:</u>						
None	Base	Base	Base	Base	Base	Base
Treated	-5.40 (.77)	-13.83 (1.40)	-21.47** (2.24)	29.72*** (4.81)	56.68*** (7.11)	46.83** (2.16)
<u>Insecticide:</u>						
None	Base	Base	Base	Base	Base	Base
Treated	6.61 (.95)	-7.13 (.72)	25.07** (2.61)	74.46*** (12.05)	56.99*** (7.15)	153.45*** (7.08)
<u>Cultivar:</u>						
WL 318	2.33 (.27)	27.92** (2.30)	115.03*** (9.79)	150.48*** (19.89)	145.52*** (14.90)	447.42*** (16.85)
Arc	21.04** (2.46)	50.99*** (4.20)	109.60*** (9.33)	129.60*** (17.13)	94.12*** (9.64)	412.11*** (15.52)
OK08	Base	Base	Base	Base	Base	Base
N	36	36	36	36	36	36
R ²	.563	.473	.853	.961	.921	.936

^aNumbers in parentheses are absolute values of calculated t-statistics; and *** = .01, ** = .05, and * = .10 significance levels.

and higher quality alfalfa, which could be marketed at a higher price, enhanced adjusted returns. Removal of fall growth by late-fall harvesting was not cost-effective, *i.e.* returns from small yields did not offset harvest costs.

Weed Control

Applying herbicides in 1983 through 1985 reduced adjusted returns, though not significantly, with the exception of 1985 returns. Weed interference was not serious enough in these early years of the stand to justify economically the application of herbicides. However, herbicide applications increased adjusted returns in 1986 and 1987, as well as for the five years combined. These results were expected, *i.e.*, increasing returns to weed control with increasing age of the alfalfa stand and decreasing competitive ability of alfalfa plants as the stand declined. Decreasing alfalfa plant populations in

older stands provided greater opportunities for weeds to compete for light and nutrients.

Insect Control

Returns resulting from insecticide applications also increased as the alfalfa stand aged. However, the greatest difference in returns was likely due to relatively low population levels for alfalfa weevils in 1983 and 1984 in comparison with later years of the study (Dowdy). Potential savings through reduced use of insecticide are dependent on insect infestation level (*i.e.* damage potential) regardless of alfalfa stand age.

Cultivar Selection

Both improved alfalfa cultivars provided increased returns relative to OK08 for the five-year period. Arc resulted in significantly higher adjusted returns in all years except 1983. For the five years

Table 3. Integrated Alfalfa Management Regression Results, Model B, 1983 to 1987

			Estimated Coefficient ^a					
Independent Variables	Herbicide	Insecticide	1983	1984	1985	1986	1987	1983-87
----- (\$/Acre) -----								
Intercept			462.73*** (39.12)	593.28*** (32.29)	586.52*** (32.39)	219.19*** (19.31)	105.74*** (7.19)	1963.99*** (48.51)
Cultivar:								
WL 318			2.33 (.30)	27.92** (2.32)	115.03*** (9.71)	150.48*** (20.24)	145.52*** (15.11)	447.42*** (16.88)
Arc			21.04** (2.72)	50.99*** (4.24)	109.60*** (9.25)	129.60*** (17.44)	94.12*** (9.77)	412.11*** (15.55)
OKO8			Base	Base	Base	Base	Base	Base
Fall Cut	No	No	65.83*** (4.25)	34.80 (1.45)	20.91 (.88)	26.98* (1.81)	-4.45 (.23)	44.65 (.84)
	Yes	No	42.09** (2.72)	8.63 (.36)	-7.96 (.34)	.27 (.02)	39.12* (2.03)	76.35 (1.44)
	No	Yes	48.43*** (3.13)	27.92 (1.16)	17.00 (.72)	61.24*** (4.12)	53.55** (2.78)	188.59*** (3.56)
	Yes	Yes	34.53** (2.23)	4.59 (.19)	-7.15 (.30)	77.84*** (5.24)	117.77*** (6.11)	233.24*** (4.40)
Winter Grazed	No	No	37.37** (2.41)	68.26*** (2.84)	60.16** (2.54)	53.42*** (3.59)	24.69 (1.28)	214.76*** (4.05)
	Yes	No	66.23*** (4.28)	42.76* (1.78)	17.40 (.73)	93.21*** (6.27)	101.58*** (5.27)	276.27*** (5.21)
	No	Yes	61.38*** (3.96)	13.35 (.56)	98.75*** (4.17)	109.13*** (7.34)	61.65*** (3.20)	302.31*** (5.70)
	Yes	Yes	55.17*** (3.56)	25.63 (1.07)	64.89** (2.74)	142.86*** (9.61)	133.41*** (6.93)	379.33*** (7.16)
Unharvested	No	No	Base	Base	Base	Base	Base	Base
	Yes	No	-1.08 (.07)	-2.97 (.12)	.00 (.00)	34.53** (2.32)	47.21** (2.45)	77.70 (1.47)
	No	Yes	33.45** (2.16)	27.25 (1.13)	33.32 (1.41)	91.86*** (6.18)	73.65*** (3.82)	259.27*** (4.89)
	Yes	Yes	17.13 (1.11)	9.98 (.41)	-7.69 (.32)	118.30*** (7.96)	110.08*** (5.71)	247.67*** (4.67)
N			36	36	36	36	36	36
R2			.727	.607	.887	.972	.942	.954

^aNumbers in parentheses are absolute values of calculated t-statistics; and *** = .01 ** = .05 and * = .10 significance levels.

combined, WL318 had slightly higher adjusted returns than Arc. Nearly the entire OKO8 stand had died by the end of the sixth growing season, suggesting that the level of pest resistance in improved cultivars could be important for increased stand longevity.

Model B

Model B estimated the potential interaction between end-of-season harvest options and both insect and weed controls, while holding cultivars constant (Table 3). The base interaction variable was the

unharvested option with no herbicide and insecticide treatments.

For each year and for the five-year period, nearly all combinations of winter grazing, insecticide treatments, and herbicide treatments increased adjusted returns compared with the base variable (unharvested with no pest control). Fall cutting did not increase adjusted returns when insect and weed pests were controlled. Results suggest alfalfa forage taken from a fall cutting does not offset the additional harvesting costs, nor does fall cutting contribute to reduced pest populations and higher yields when

insecticide and herbicide treatments are employed. Insect and weed control by chemical treatment increased adjusted returns within each harvest option and is more important than the harvest option from an interaction viewpoint.

SUMMARY AND CONCLUSIONS

This study was designed to analyze economic implications of alfalfa production practices, focusing on cultivar selection, insect and weed control alternatives, and end-of-season harvest options. Binary variable regression was applied to mean adjusted returns per acre for years 2 through 6 of an experimental research alfalfa stand, and for the 5-year period combined.

Results indicated there were significantly higher economic returns resulting from improved alfalfa cultivars which have some resistance to insects and plant pathogens. Selection of an improved alfalfa cultivar (either WL318 or Arc) consistently increased adjusted returns compared with OK08, which had no selection for pest resistance.

Winter grazing of fall alfalfa growth increased returns to the alfalfa enterprise relative to other end-of-season harvest alternatives, and without considering any benefit from grazed alfalfa in the live-stock enterprise. Winter grazing contributed to

reduced insect and weed pest populations. Had a value been assumed for alfalfa forage removed by grazing (*i.e.* animal weight gain) the comparative advantage from winter grazing would have been increased further. Late-fall harvesting, while potentially reducing population densities of insect pests and weeds, did not increase adjusted returns because harvest costs exceeded the revenue generated from small yields of the late-fall cutting.

The combined use of insecticides and herbicides produced the highest adjusted returns within cultivar and harvest alternatives. Insect control alone increased adjusted returns more than weed control alone. Use of herbicides was not economical in the early years of the alfalfa stand, since stands were competitive with weeds. However, as the alfalfa stand aged and thinned, interference by weeds increased and the use of herbicides became cost-effective.

Insecticides and herbicides were applied in some cases as part of the research design, regardless of whether economic threshold population levels of insects and weeds were reached. Therefore, treatment of both insect and weed pests only when populations reached economic threshold levels would have further increased adjusted returns in this study.

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