Identification of Farm Management Systems at Risk for ACCase Inhibitor-Resistant Wild Oat (*Avena fatua* L.)

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Are Farm Management Practices Important?

Wild oat populations resistant to ACCase-inhibitor herbicides typically develop after 5 to 10 applications (Bourgeois and Morrison 1997). The choice of herbicide is only one component of the management package used by producers. Do other farm management practices contribute to the risk of developing ACCase-inhibitor resistance in wild oat? No previous research has attempted to answer this question. The answer has potential implications for reducing the risk of developing resistance and for the long-term management of resistant populations.

Objectives

1. To group the fields at risk for developing ACCase inhibitor-resistant wild oat populations into management systems based on farm practices.
2. To determine the relationship between management system and the occurrence of ACCase inhibitor-resistant wild oat.

Data Sources

1995 Saskatchewan weed survey collected weed density data from 1178 fields (Thomas et al. 1996). Fields with high densities of wild oat were considered at risk for resistance development. Detailed management questionnaires were completed by producers who participated in the 1995 survey (Thomas et al. 1999). Fields with > 50% use of ACCase-inhibitor herbicides between 1990 and 1995 and producers who suspected resistance were also considered as high risk. These three criteria for high risk were used to select 95 of the surveyed fields. Wild oat seed samples were collected from these fields in 1996 and tested for ACCase-inhibitor resistance (Beckie et al. 1998). Complete data on farm practices used in the fields were available for 68 of the 95 fields.

Farm Practice Variables

Thirteen variables describing farm practices were used to describe farm management systems (Table 1). Specific use of ACCase-inhibitor herbicides was not included as a variable. Seeding rate and depth were adjusted to eliminate bias from specific crops and locations by expressing the variables as proportions of recommended. Also nitrogen and phosphate applied were calculated as proportions of recommended for crop, location and previous crop. Seeding date was calculated as deviance from the median date for crop and location.

Table 1. Range of values for farm practice variables

Variable	Low	High
fallow frequency	0	0.50
crop diversity	0.17	0.83
cereal frequency	0.17	0.83
tillage disturbances	0	4
harrow passes	0	7
seedling disturbance	1	6
seeding rate	0.57	1.60
seeding date	-24	23
seeding depth	0.42	1.6
nitrogen applied	0	3.68
phosphate applied	0	1.10
herbicide groups	1	6
herbicide passes	0	3.26

Analysis

Classification and ordination was performed on the data matrix of 68 fields by 13 variables using the program PC-ORD (McCune and Mefford 1997). Prior to the analyses, farm practice variables were standardized by maximum and fields were standardized by chord distance. Euclidean distance measure was used in both classification and ordination analyses. Ward's minimum variance method was used for classification and non-metric multidimensional scaling (NMS) was used for ordination.

Comparisons were made between the average values of each farm practice variable (median values for fertilizer placement and seeding disturbance) associated with each group of fields. F-tests indicated that variances were not always equal in each group; therefore, Welch’s approximate t-test was used to determine if the means were significantly different. Wilcoxon’s two-sample test was used to determine if the medians significantly differed between groups for the ranked variables. Chi-square test for goodness of fit was used to determine if the percentage of resistant sites differed between groups.

Classification

Fields separated into five clusters with significant differences in average (or median) values ($p<0.001$) for phosphate applied, tillage disturbances, seeding disturbance, fallow frequency, and herbicide passes (Figure 1).

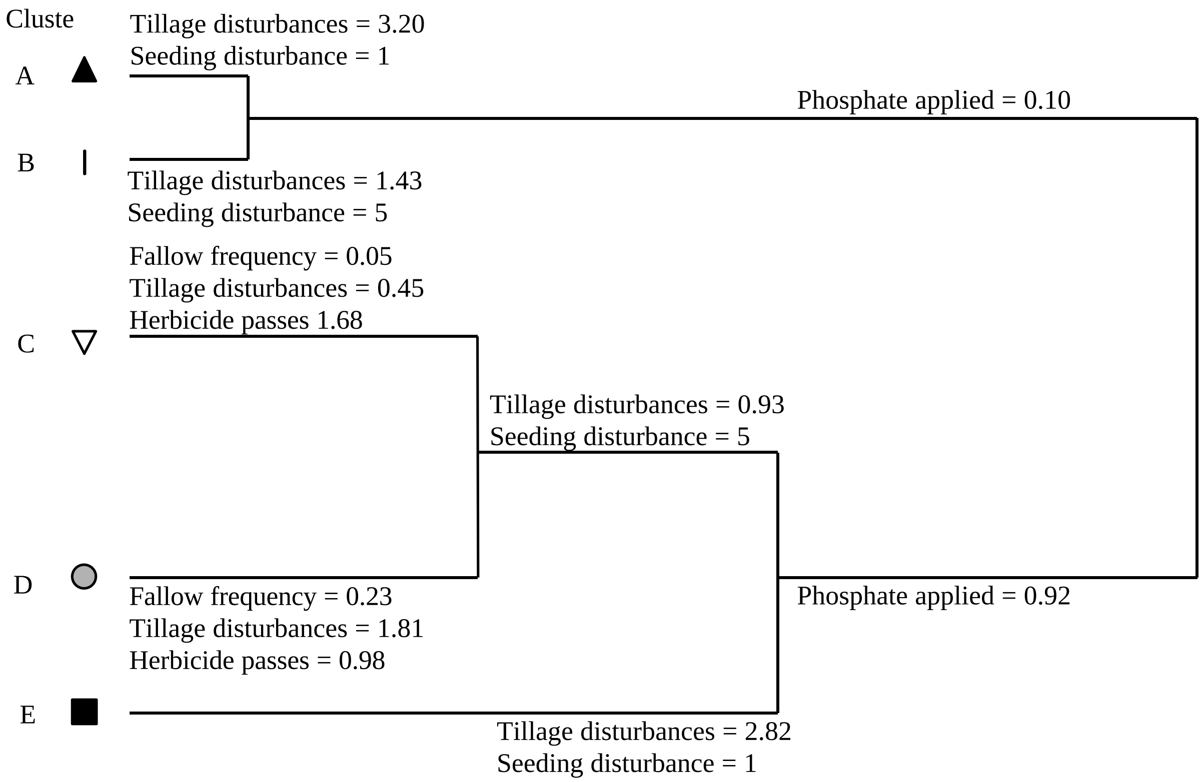

Figure 1. Five clusters of fields formed by Ward's classification and average (or median) values for significant variables.

Ordination

Five clusters formed by classification occupy different areas in the NMS ordination space (Figure 2). Fields separated along the first axis by a positive correlation with tillage disturbances (r^2=0.74) and a negative correlation with seeding disturbance (r^2=0.49). Fields separated along the second axis by a positive correlation with fallow frequency (r^2=0.34) and a negative correlation with phosphate applied (r^2=0.68) and herbicide passes (r^2=0.30).

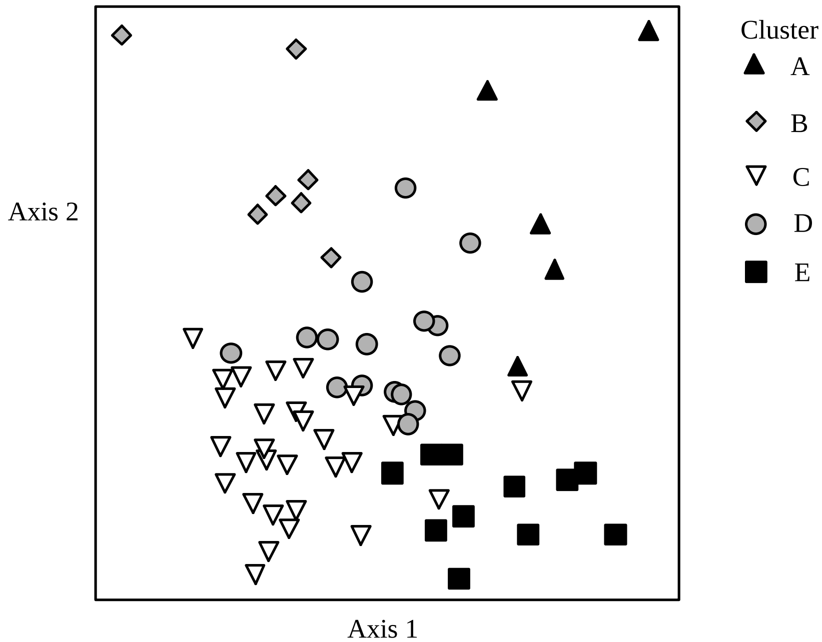

Figure 2. NMS ordination of fields on the basis of farm practices with Ward's classification superimposed

Farm Management Systems

Clusters identified by classification and confirmed by ordination represented five distinct management systems that can be described by the five significant farm practices (Table 2). System C can be considered zero tillage, system B and D as reduced tillage and A and E as conventional tillage.

Table 2. Relative values of significant farm practices in each management system.

System	Tillage disturbances	Seeding disturbance	Fallow frequency	Phosphate applied	Herbicide passes
A	+++	+	+++	++	+
B	++	+++	++	+	++
C	+	++	+	+++	+++
D	++	+++	++	+++	++
E	+++	+	+	+++	+++

Farm practice values with relatively high numbers, frequent occurrences or large amounts are indicated by "+++", with moderate numbers, occurrences and amounts are indicated by "++", and with relatively low numbers, infrequent occurrences and small amounts are indicated by "+".

Resistance and Management System

The frequency of resistance was not significantly different among the systems. Percent of fields with resistant wild oat populations ranged from 40% in system A to 86% in system B. Frequency of resistance in systems C, D, and E were 62%, 63%, and 73% respectively. Lack of significant association with management system is illustrated by plotting the presence of resistance as an overlay on the NMS ordination (Figure 3).

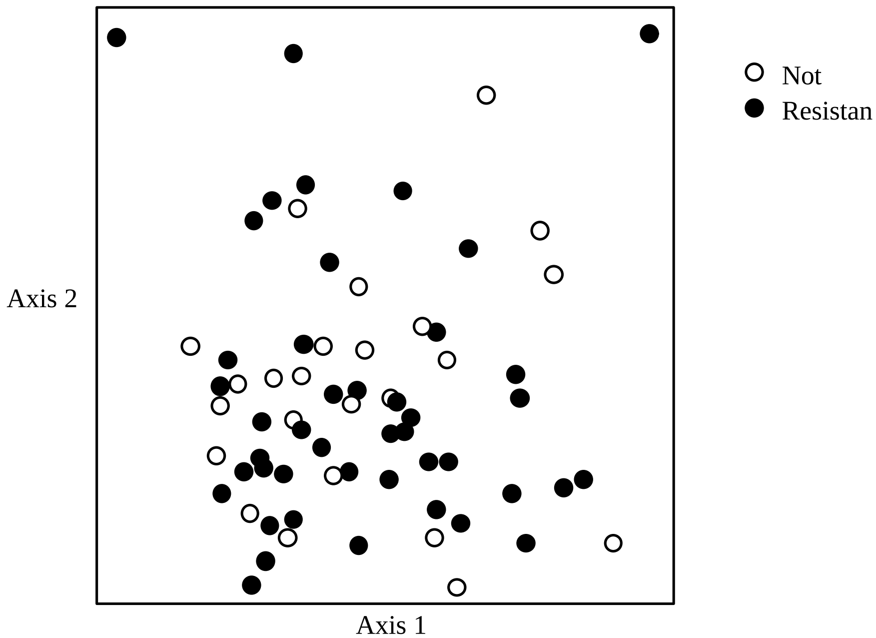

Figure 3. NMS ordination of fields on the basis of farm practices. Fields with wild oat resistant populations are superimposed on the ordination.

Implications For Management

Farm management practices, other than repeated use of herbicides with the same mode of action, do not alter the risk of developing resistance in wild oat. The frequency of ACCase-inhibitors is still the most important risk criterion for predicting the development of resistance in wild oat to these herbicides. Herbicide group rotation should be encouraged to reduce the risk of resistance in weeds.

Literature Cited

Beckie, H.J., A. Légère, A.G. Thomas, F.C. Stevenson, J.Y. Leeson, L.T. Juras, and M.D. Devine. 1998. Saskatchewan Weed Survey of Herbicide-Resistant Wild Oat and Green Foxtail in 1996. Weed Survey Ser. Publ. No. 98-3. Agriculture and Agri-Food Canada, Saskatoon, SK. 77 pp.

Bourgeois, L. and I.N. Morrison. 1997. Mapping risk areas for resistance to ACCase-inhibitor herbicides in Manitoba. Can J. Plant Sci. 7:173-179.

McCune, B. and M.J. Mefford. 1997. PC-ORD. Multivariate Analysis of Ecological Data, Version 3.17. MjM Software, Gleneden Beach, OR. 126 pp.

Thomas, A.G., J.Y. Leeson, R.F. Wise, L.T. Juras and C. Brenzil. 1999. Farm Management Practices in Saskatchewan. Results of the 1995 Saskatchewan Weed Survey Questionnaire. Weed Survey Ser. Publ. No. 99-1. Agriculture and Agri-Food Canada, Saskatoon, SK. (in preparation)

Thomas, A.G., R.F. Wise, B.L. Frick, and L.T. Juras. 1996. Saskatchewan Weed Survey. Cereal, Oilseed and Pulse Crops 1995. Weed Survey Ser. Publ. No. 96-1. Agriculture and Agri-Food Canada, Saskatoon, SK. 419 pp.

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