The effects of crop planting pattern and alternative cropping systems and wild oat population ecology and interference in barley
by Stephen Ronald Canner

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:
Wild oat (Avena fatua L.) is a costly weed problem in wheat and barley production in Montana. Wild oat reduces yield and quality of barley, and is particularly troublesome because of a persistent seed bank. Due to increasing economic and environmental costs of herbicides and instances of wild oat resistance to herbicides, non-chemical management strategies are needed which maximize wild oat seed bank decline and crop competitiveness with wild oat.

Models which predict individual plant size based on the location of neighboring plants may be useful in predicting the economic value of different crop planting patterns in various situations. A simple model was developed which predicts individual plant size based on the distance and dispersion of neighboring plants. This model compared favorably with published models in its ability to predict plant size and in its ease of computation in a variety of applications.

Experiments were conducted in Bozeman in 1993 and 1994 to determine whether different patterns of crop planting at a constant plant density influenced wild oat seed production or barley yield response to wild oat. Barley planted in wide rows (30-36 cm) suffered a significant yield loss due to competition, while there was no significant yield loss when barley was planted in narrow rows (15-18 cm), or in diagonally offset double rows created by driving a grain drill over the plots twice with a 20° angle between the passes. Barley planting pattern did not have a significant impact on wild oat seed production.

Eight different three-year dryland crop rotation treatments were established at two on-farm sites near Big Sandy, MT from 1993-1995 to evaluate the impact of alternative cropping systems on wild oat population ecology and barley yield. The treatment where a grain crop was followed by alfalfa which was cut for hay in the second year and plowed down for green manure in the third year showed the strongest reduction in wild oat seed bank numbers. Pea green manures did not significantly differ from fallow in any effect on wild oat populations. Analysis of wild oat demography revealed that recruitment rates and timing of tillage were strong determinants of wild oat population dynamics. When green manures were properly managed, they did not result in significant yield loss in barley crops in subsequent years, and in one case resulted in yield increase.

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APPROVAL

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Stephen Ronald Canner

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 21 April 1996

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ABSTRACT

Wild oat (*Avena fatua* L.) is a costly weed problem in wheat and barley production in Montana. Wild oat reduces yield and quality of barley, and is particularly troublesome because of a persistent seed bank. Due to increasing economic and environmental costs of herbicides and instances of wild oat resistance to herbicides, non-chemical management strategies are needed which maximize wild oat seed bank decline and crop competitiveness with wild oat.

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Experiments were conducted in Bozeman in 1993 and 1994 to determine whether different patterns of crop planting at a constant plant density influenced wild oat seed production or barley yield response to wild oat. Barley planted in wide rows (30-36 cm) suffered a significant yield loss due to competition, while there was no significant yield loss when barley was planted in narrow rows (15-18 cm), or in diagonally offset double rows created by driving a grain drill over the plots twice with a 20° angle between the passes. Barley planting pattern did not have a significant impact on wild oat seed production.

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CHAPTER 1

LITERATURE REVIEW

Wild Oat

Wild oat (*Avena fatua* L.) is an annual grass (family Poaceae, tribe Avenae) which is a troublesome weed wherever spring-planted cool season small grains are grown. Wild oat is native to Eurasia but has spread throughout the world as an impurity in crop seeds and feed. It is widespread in North America, Europe, North Africa, Asia, Australia, and New Zealand. (Sharma and Vanden Born 1978). Wild oat is primarily a weed of cultivated fields of cool season crops, but is also found in disturbed sites in pastures, roadsides, and waste areas.

Wild oat has been documented to reduce yield and quality of several crops. Wild oat can cause yield and/or quality reduction in wheat (Wilson et al. 1990, Carlson et al. 1981, O'Donovan et al. 1985, Bell and Nalewaja 1968), barley (Bell and Nalewaja 1968, Wilson and Peters 1982, Barton et al. 1992, O'Donovan et al. 1985, Evans et al. 1991, Wilson et al. 1990, Morishita and Thill 1988), flax (Bell and Nalewaja 1968, Dew 1972), and rapeseed (Dew and Keys 1976). Worldwide, wild oat is estimated to cause annual yield losses of wheat and barley of 12,940,100 metric tons, of which approximately half are yield losses in North America alone (Nalewaja 1977). Wild oat is the most costly weed problem in Montana (Fay and Stewart 1981). Yield reductions due to wild oat in Montana are estimated to cost $50 million. An estimated 60% of wild oat infested acres in Montana are treated annually with herbicides valued at about $10 million. Wild oat is a controlled 'noxious weed' under Montana law, which provides for restrictions on the sale of crop seed contaminated with seeds of wild oat.

Description and Biology of Wild Oat

Wild oat resembles cultivated oat (*Avena sativa* L.), to which it is closely related. Crosses between the two species are commonly observed (Coffman and Wiebe 1930). Wild oat may be distinguished visually from cultivated oat by its typically greater height and its loose, large panicle. Wild oat florets disarticulate from their pedicels, leaving a prominent circular basal scar, or "sucker mouth". This feature is absent in cultivated oat. Wild oat florets bear a long awn which is bent at about its midpoint, and which is twisted basal to the point of bending. Awns on cultivated oat florets are absent or confined to the lowest floret, and are usually shorter and straight. The twisted awn of wild oat, which reversibly untwists under humid conditions, facilitates dispersal and burial of the seed (Somody et al. 1985).

Wild oat is genetically variable and phenotypically plastic. Wild oat is generally considered a spring annual in the northern Great Plains of the United States and Canada, although in regions with mild winters it may persist as a winter annual. A variable but significant percentage of wild oat seeds have a degree of dormancy which prevents germination in the first season after seed shed (Wilson 1978). However, Wilson (1978) emphasizes that wild oat seeds are relatively short lived compared to many other annual weeds with dormant seed banks. He found that wild oat seed banks declined at a rate of about 80% per year when seed return was not permitted. This rate varied with tillage regime. Wilson (1978) also found that wild oat seeds experienced significantly higher mortality when they were allowed to remain on the soil surface without tillage over a winter than when they were tilled into the soil in the fall.

Sexsmith (1969) noted that wild oat is less problematic in warmer, drier portions of Alberta than in the cool and moist sections of the province. He proposed that differences in dormancy of wild oat seeds produced under different environmental conditions could be partially responsible. In a greenhouse study where wild oat plants were grown under varying temperature and moisture conditions, Sexsmith (1969) found that cool and moist conditions were conducive to the production of large numbers of dormant seeds, while warmer and dryer conditions resulted in the production of fewer, less dormant seeds. Similarly, Peters (1982, 1984) found that wild oat plants grown under moisture stress produced fewer seeds than those grown without moisture stress, and that those seeds were less dormant than the seeds produced on non-stressed plants.

Wild oat seed germination and emergence reach maxima in spring and fall, in response to cool temperatures, although germination may occur throughout the growing season. In northern regions of North America, fall germinating wild oats typically do not survive. The dormancy characteristics of wild oat lead to emergence of wild oat over an extended period of time in the spring. The timing of emergence of wild oat is an important factor in both its fecundity and in its capacity to reduce barley yields (Wilson and Peters 1982, Peters 1984, O'Donovan et al. 1985), with earlier emerging wild oat plants producing more seed and causing a greater reduction in barley yield than later emerging plants.

Wild Oat Interference with Barley

Barley is an important crop in Montana, occupying 1.1 million harvested acres with a total crop value of $137.2 million in 1993 (Montana Agricultural Statistics Service 1993). The state of Montana ranks second in the United States in total barley production (Montana Agricultural Statistics Service 1993).

Wild oat has been shown to reduce both yield and quality of harvested barley. The exact magnitude of the reduction has been observed to be widely variable between sites and years (Wilson and Peters 1982). This variability in barley response to wild oat infestation has been attributed to weather conditions, relative time of emergence of crop and weed (Peters and Wilson 1983, Peters 1984, O'Donovan et al. 1985), nitrogen fertility (Bell and Nalewaja 1968), soil type (Firbank et al. 1990), barley density (Wilson et al. 1990, Evans et al. 1991), and barley variety (Dhaliwal et al. 1993, Siddiqi et al. 1985, Ray and Hastings 1992, Konesky et al. 1989). Wilson et al. (1990) also attributed some of the variation between yield loss estimates in reported studies to differences in harvest methods in different experiments.

Wilson et al. (1990) fitted Cousens' (1985) hyperbolic model of crop yield loss as a function of weed density to data from infestations of wild oat in wheat and barley. This model describes crop yield loss due to weed density as a curvilinear function where yield loss increases rapidly with increasing density at low densities, but levels off to an asymptotic maximum total percentage yield loss at higher densities. The two model parameters estimate the maximum yield loss due to high densities of weeds and the yield loss per plant as the density approaches zero. The values of the model parameters led them to conclude that in a range of situations at usual crop densities, the yield reduction due to low infestations of wild oat can be approximated by 1% yield loss for each wild oat plant·m^{-2}. They also concluded that at or near economic threshold densities of wild oats, yield loss would cause a considerably greater economic impact than would contamination of grain by wild oat seeds, unless the grain were being grown for seed, where tolerance for weed seed contamination is much lower.

The timing of the onset of interference between barley and wild oat has been investigated by several researchers, and seems to be highly variable, depending to some extent on crop and weed density as well as on environmental conditions. Chancellor and Peters (1974) investigated the time of onset of the competitive effect of wild oat on barley by weeding different plots as soon as barley emerged or at successively later dates. They concluded that significant yield-reducing competition did not begin until after the four leaf stage of the crop, although they suggested that in higher densities of wild oats, the onset of competition would be earlier. These results were supported by Peters (1984), although Morishita and Thill (1988) did not detect significant wild oat competition until the two node stage of barley growth, while other researchers cited in Sharma and Vanden Born (1978) found significant competition to occur earlier.

Morishita and Thill (1988) investigated the effect of wild oat infestation on the levels of water and nitrogen both in the soil and in barley plants. They concluded that wild oat may reduce barley yield in part by reducing the total water and turgor potential in barley at the time of head formation on tillers. Barley yield loss due to wild oat may also be related to allelopathic chemical exudates of wild oat plants (Ray and Hastings 1992, Schumacher et al. 1983, Fay and Duke 1977).

Dew (1972), Dew and Keys (1976), and Cousens et al.(1987) concluded that barley was more competitive with wild oat than was wheat. Morishita and Thill (1988) grew wild oat and barley plants alone and in mixture. They determined that although the two species had very similar growth patterns throughout the growing season when grown in monoculture, barley was significantly more competitive than wild oat when grown in mixture.

Herbicides and tillage have been key tools for wild oat management in Montana barley production. Concerns about erosion and loss of soil organic matter have led producers to investigate minimum or no-till options for small grain production, while concerns about groundwater quality and economic efficiency have led to substantial interest in the potential for reduction of herbicide use. Widespread resistance of wild oat to many common herbicides has further accentuated the need for profitable alternative management strategies.