Rotational Benefits of Forage Crops in Canadian Prairie Cropping Systems

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Including perennial forages in cropping systems is recognized as one of the best ways to enhance agricultural sustainability. While rotational benefits of forages have been established in small plot research trials, there is no documentation of whether these benefits are being observed on commercial farms, or whether producers manage forage stands to maximize rotational benefits. A survey of 253 Manitoba and Saskatchewan producers known to include forages in their crop rotations was conducted in 1992. The survey area was divided into six agroclimatic zones and correspondence analysis was used to test whether responses differed across the survey area. Sixty-seven percent of respondents indicated a yield benefit from including forages in the crop rotation, with the greatest yield benefit observed in wetter zones of the survey area. Eighty-three percent of the respondents observe weed control benefits for one (11% of respondents), two (50% of respondents), or more (33% of respondents) years after forages. The majority of respondents indicated that their forage acreage would not increase in the future. Average forage stand duration varied significantly ($P < 0.10$) with agroclimatic zone, ranging from 3 to 5 yr in wetter areas (south-central Manitoba) to 6 to 9 yr in the driest areas (south Saskatchewan). The two most common reasons cited for forage stand termination were reduced forage yield and damage by pocket gophers (presumably Thomomys talpoides and Geomys bursarius). Less than 12% of respondents cited rotational considerations as their primary reason for terminating forage stands, indicating that producers are not managing their forage crops to maximize rotational benefits. Producers relied heavily on tillage in both forage crop establishment and forage stand termination phases of the production system. It was suggested that decreasing the amount of tillage and fallow associated with forage-based cropping systems would not only facilitate increased cycling of forages in rotations, but also increase agricultural sustainability.

There is considerable interest in developing cropping systems that reduce the use of pesticides, protect the soil from erosion, improve soil quality, and reduce reliance on external inputs of nonrenewable energy (Morrison and Kraft, 1994). Therefore there is understandably renewed interest in traditional practices such as the inclusion of perennial forage crops in crop rotations. Benefits of incorporating alfalfa (Medicago sativa L.) or alfalfa/grass mixtures into cropping systems include increased soil organic matter (Campbell et al., 1990), improved soil physical properties (Blackwell et al., 1990), reduced soil erosion (Stinner and House, 1989), suppression of weeds (Harvey and McNevin, 1990), and disruption of plant disease cycles (Campbell et al., 1990). Because of their ability to contribute N to the soil, forage legumes significantly reduce reliance on nonrenewable energy to produce N fertilizer (Rice and Biederbeck, 1983).

Rotational yield benefits of forages have been investigated in small plot trials in western Canada for many decades. Results of these trials indicate that in wetter regions (i.e., Black and Gray soil zones; Weir and Matthews, 1971) grain yields are enhanced when alfalfa or alfalfa/grass mixtures are included in the rotation (Ferguson and Gorby, 1971; Baddarunin and Meyer, 1990). However, in drier areas (i.e., brown and Dark Brown soil zones; Weir and Matthews, 1971), perennial forage crops dry the soil to the point where yields of following grain crops are often reduced (Zentner et al., 1990). Most previous studies on yield response to forages in rotations in the northern Great Plains have focused on the N contribution by legumes (e.g., Baddarunin and Meyer, 1990); however, other yield enhancing benefits such as improved soil physical properties (Blackwell et al., 1990) have also been implicated (Hoyt and Leitch, 1983).

In one of the only long-term Canadian crop rotation studies to consider the impact of perennial forage crops on weeds (crop rotation trials conducted at Brandon, MB, between 1911 and 1958), a 3 yr alfalfa hay crop in a 6 yr rotation virtually eliminated wild oat (Avena fatua L.) problems, while annual crop rotations—even where summerfallow was used—became heavily infested with the weed (Dryden et al., 1983). Weed suppression by forage hay crops has been attributed to competition by the forage crop, and the cutting regime (Harvey and McNevin, 1990). Nonherbicial weed management approaches such as the use of perennial forage crops are especially important in western Canada, where two of the most abundant weeds, namely wild oat and green foxtail (Setaria viridis (L.) Beauv.), have developed widespread resistance to herbicides (Morrison and Devine, 1994).

Approximately 15 million acres in the prairie provinces of Canada are seeded to introduced forage species (about 7.5 million acres each of seeded pastures and seeded hay fields) (Anonymous, 1993). Because this area represents only 15.9% of the total arable land base in the region (Anonymous, 1993), only a small proportion of land in the area can receive the benefits of forages at any one time. Two approaches to increase exposure of agricultural lands to the rotational benefits of forage crops are to increase total forage acreage, or cycle forages through rotations more quickly. This second strategy probably would involve reducing the number of years a forage crop is included in the rotation (i.e., reducing forage stand duration). Previous research has shown that the minimum alfalfa stand duration for optimum N accumulation (Heichel et al., 1984; Kelner, 1994) and weed suppression (Dryden et al., 1983) is 2 to 3 yr, while the econom-

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Table 1. Outline of survey content and questions.

I. Characterization of farm enterprise
   A. Circle primary enterprise on your farm.
      (1) Mixed farm (grain and livestock), (2) Livestock, (3) Dairy,
      (4) Grain and forage seed, (5) other.
   B. What is the total tillable acreage on your farm?
   C. What is the acreage in the following categories? (a) alfalfa hay
crops, (b) alfalfa/grass mixtures for hay, (c) tame pastures, (d) forage seed production.

II. Benefits associated with forages in crop rotations
   A. On your farm, are grain yields following a forage stand (a) higher,
      (b) lower, (c) not noticeably different than grain yields after
      other grain crops?
   B. On your farm, do you observe (a) more weeds, (b) fewer weeds,
or (c) no difference in weed populations in grain crops follow-
ing a forage stand compared with grain crops following other
      grain crops?
   C. On your farm, which weeds are best controlled by including a
      forage crop in your rotation?
   D. If you observe fewer weed problems in grain crops following forages
      following than other grain crops, how long does this effect last? (a) 1 yr,
      (b) 2 yr, (c) more than 2 yr.

III. Forage crop management
   A. Is a companion crop used in the forage establishment year? (a)
      wheat, (b) oats, (c) barley, (d) canola, (e) flax, (f) winter rye, (g) other.
   B. What type of equipment is used to seed forages? (a) press
      drill, (b) air seeder, (c) hoe drill, (d) discer, (e) broadcast seed-
ing, (f) other.
   C. How many hay cuts are taken each year? (a) one, (b) two, (c)
      three, (d) more than three.
   D. What is the average forage stand length on your farm? (a) al-
      falfa hay crops, (b) alfalfa/grass mixture hay crops, (c) tame
      pastures, (d) forage seed production.
   E. What is the main reason for terminating forage stands on the
      farm? (a) reduced yield, (b) weed problems, (c) disease
      problems, (d) need land for more profitable crops, (e) drought,
      (f) rotational considerations, (g) other.
   F. What method is used to terminate forage stands? (a) tillage,
      (b) herbicides, (c) combination of tillage and herbicides.
   G. Is the land summerfallowed the year after forage stand termin-
      ation? (a) yes, (b) no, (c) depends on moisture conditions.
   H. Has the forage acreage on your farm (a) increased, (b)
      decreased, (c) remained the same over the past 8 yr? What are
      the major reasons for the change?
   I. Do you anticipate an (a) increase, (b) decrease, or (c) no change
      in the forage acreage on your farm? What are the major rea-
      sons for the change?

ic optimum alfalfa stand duration in Manitoba was found to be 4 or 5 yr (Jeffrey et al., 1993).
Two factors which are thought to discourage producers in western Canada from cycling forages through rotations more frequently are the difficulties of establishing (Kilcher and Heinrichs, 1960) and terminating (Bullied and Entz, 1994) perennial forage stands. Forage establishment can be improved by using the soil-and-water conserving zero tillage seeding system (Allen and Entz, 1994), and by choosing less competitive companion crops (Klebesadel and Smith, 1959). Effectiveness of forage stand termination may be improved by substituting herbicides for some tillage operations (Bullied and Entz, 1994). Another point worth mentioning here is that although perennial forages are considered to be soil-improving crops (Morrison and Kraft, 1994), traditional forage stand establishment and termination techniques rely heavily on intensive tillage, which can lead to soil erosion both during the forage establishment phase (Sturgul et al., 1990), and after forage stand termination (Campbell et al., 1990).

Research and extension agencies in western Canada are making serious efforts to intensify the role of forages in cropping systems as a means of enhancing agricultural and environmental sustainability. Many of these programs are based on the assumption that rotational benefits and improvements to cropping system sustainability (e.g., reduced soil erosion) are routinely captured when forages are included in a crop rotation. In fact, little of this has been documented in commercial agriculture in western Canada. Before effective and meaningful research and extension programs related to forage-based cropping systems can be developed, a more thorough understanding of the state of commercial forage management is required. Also, any analysis of crop production in western Canada must consider the great diversity of climatic and soil conditions in the region. Hence, the objectives of this study were: (i) to determine whether rotational benefits of forages observed in small plot research trials are actually perceived by producers on commercial farms, and if so, whether these benefits are observed uniformly across the different agroclimatic zones of western Canada; (ii) to better understand whether producers manage forage stands to maximize rotational benefits; we were especially interested in knowing whether management practices are aimed at quickly cycling forages through rotations or whether producers strive to maximize forage stand duration; (iii) to learn which techniques are employed in forage stand establishment and termination, and to critically analyze these technologies on the basis of how they may help or hinder adoption of shorter forage stand durations and their impact on agricultural sustainability.

MATERIALS AND METHODS

A survey was mailed to 500 forage producers in Manitoba and Saskatchewan in early 1992. All producers were members of either the Manitoba or Saskatchewan Forage Councils, or progressive forage producers selected by extension agents. The survey distribution was intended to sample progressive producers who would have well developed forage production systems, as well as well-defined rationales for their production practices.

Content areas and questions from the survey are shown in Table 1. The survey was designed to characterize the respondents’ farm enterprises, with particular emphasis on forage crop production practices and the role of forages in the cropping system. Space for comments was available after each question, and comments were encouraged.

Responses were divided into six unique agroclimatic zones based on soil and climatic limitations. The zones in Manitoba were divided according to the Manitoba crop adaptation zones (Ash et al., 1992), and these zones were extended into Saskatchewan by following the major western Canadian soil zone boundaries (Weir and Matthews, 1971) (Fig. 1). The major and secondary limitations to crop production in these zones are: Zone 1—drought; Zone 2—drought, excess water; Zone 3—drought, frost; Zone 4—excess water, drought; Zone 5—excess water, drought; and Zone 6—frost, excess water (Ash et al., 1992).

Statistical analysis performed on information derived from producers of the six agroclimatic zones included a chi-square test (P < 0.10 or less), and two-dimensional graphing with correspondence analysis (Greenacre, 1984).
Correspondence analysis is a multivariate technique that provided a descriptive summary of the raw data by summarizing the association between the six agroclimatic zones and the producer responses. The strength of the relationship between a zone and a response was inversely proportional to the distance between their plotted positions on the scattergram. Symmetric scaling of the zones and responses was performed in order to display relationships more appropriately.

RESULTS AND DISCUSSION

Characterization of Farm Enterprise and Forage Acreage Trends

A total of 253 surveys were returned by forage producers across the six agroclimatic zones in Manitoba and Saskatchewan. The number of responses in each of Zones 1, 2, 3, 4, 5, and 6 were 227, 34, 46, 51, 62, and 33, respectively. The average farm size across all regions was 1324 acres, ranging from an average low of 919 acres in Zone 5 to an average high of 2279 acres in Zone 1. The majority of respondents (62%) classified their farms as mixed (both grain and livestock) (Table 2), while 10% of respondents classified their farms in each of the following three categories; dairy, livestock only, or grain and forage seed. Forage seed production accounted for less than 8% of the total forage acreage in all zones except Zone 5, where forage seed production accounted for 17% of the total forage acreage. About 6% of respondents were classified as other (a number of these were cash hay producers).

Over all zones, the percentage of tillable land on survey farms dedicated to forage production was 30%. The percentage of tillable acres dedicated to forages by agroclimatic zone (Zones 1 through 6) were as follows: 21, 32, 22, 32, 44, and 23%, respectively. The greatest percentage of farmland devoted to forage production was reported in Zone 5 (44%), where there was also the greatest diversification of forage crop use, including dairy, livestock, and forage seed (Fig. 2a). Forage producers in Zone 1 maintained the lowest proportion (21%) of forage crops on their farms. Zones 3, 6, and 4 had the greatest proportion of mixed farms (Fig. 2a).

The past 8-yr forage acreage trend, as well as the future forage acreage intentions of the respondents, are given in Table 2. One feature of the data is the low frequency of respondents indicating a past or future forage acreage decrease. This observation may reflect the fact that only committed forage producers were surveyed; however, it does indicate that forage crops will continue to play a major role in prairie crop rotations in the future. Another observation was that the majority of producers do not intend to increase their forage acreage in the near future.

![Map of Agroclimatic Zones](image)

**Agroclimatic Zones**
1. Brown soils + Dark Brown soils
2. Black soils (thin) + MB zone 1
3. Black soils (thick) + MB zone 2
4. MB zone 3
5. MB zone 4
6. Gray + Dark Gray soils + MB zone 5

* one dot represents one survey respondent

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Fig. 1. Geographic distribution of the survey respondents, and location of the six agroclimatic zones. Manitoba (MB) zones correspond to agroclimatic zones as defined by Ash et al. (1992). Saskatchewan zones correspond to soil zones (Weir and Matthews, 1971).
Table 2. Frequency of response to questions relating to farm enterprise, forage crop management, acreage trends, and rotational benefits of forage crops averaged across all six agroclimatic zones.

<table>
<thead>
<tr>
<th>Question</th>
<th>Mixed</th>
<th>Dairy</th>
<th>Grain</th>
<th>Livestock</th>
<th>Other</th>
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<td>Annual grasses</td>
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<td>Annual broadleafs</td>
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<td>&lt;= 3 Yr</td>
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<td>12.4</td>
<td>16.8</td>
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<td>3.8</td>
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<td>4 Yr</td>
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<td>10.5</td>
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<td>7. Reasons for stand termination</td>
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<td>Reduced yield</td>
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<td>Weeds</td>
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<td>Switch to higher value crop</td>
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<td>Rotation</td>
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<td>Gophers</td>
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<td>Tillage</td>
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<td>9. Summerfallow (the year after forage stand removal)</td>
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<td>Fallow</td>
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<td>No fallow</td>
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<td>Depends on moisture</td>
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<td>10. Forage seeding equipment</td>
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<td>Press drill</td>
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<td>11. Companion crop type</td>
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<td>Wheat</td>
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<td>Oats</td>
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<td>Fall rye</td>
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Results of the correspondence analysis indicated significant ($P < 0.05$) differences in forage acreage trends among agroclimatic zones. Zone 1 was most closely associated with a decrease in forage acreage both in the past and the future, while Zones 2 and 4 were most closely associated with past and future acreage increases (Fig. 2b). Zone 2 generally has greater moisture availability than Zone 1, therefore Zone 2 has higher potential to support forage crops. Zone 5 is associated with a stable forage acreage (Fig. 2b), possibly due to higher moisture, which is more conducive to growing forages than annual crops. Respondents who reduced their forage acreage in the last 8 yr gave the following reasons: drought, difficulties in stand establishment, low yields, lack of government programs to provide financial incentive, and reduced demand for hay. Respondents who increased forage acreage included expanded beef or dairy herd (30% of respondents indicating a forage acreage increase), a need to reduce grain crop acreage due to low grain prices (25% of respondents), use of marginal land (14% of respondents), rotation for weed management and soil improvement (12% of respondents) as their most important reasons.

Rotational Benefits of Forage Crops

Grain Yield

Sixty-seven percent of respondents indicated that yields of grain crops following forages were higher than yields of grain crops following annual crops (Table 2). This observation supports numerous similar reports in the literature. For example, Badaruddin and Meyer (1990) found that wheat (Triticum aestivum L.) following alfalfa yields up to 42% higher than wheat following wheat in North Dakota. Both Ferguson and Gorby (1971) and Hoyt (1990) observed that wheat yields following alfalfa-bromegrass (Bromus inermis L.) mixtures were only slightly less than wheat yields after alfalfa alone.

Grain yield responses following forage crops differed significantly ($P < 0.05$) with agroclimatic zone. Increases in crop yield following forages occurred primarily in Zones 4, 5, and 6 of the survey area (i.e., in the wetter areas) (Fig. 3a). Successive crops following forages in Zones 4, 5, and 6 are not influenced by the soil water depleting nature of forages to the same extent as other zones because fall and winter precipitation in the Black and Gray soil zones is generally sufficient to replenish soil water (Hoyt and Leitch, 1983). Hence, it could be assumed that higher grain yields in these zones were due to the soil-improving properties of forages, including N contribution by legumes, organic matter increases, improved soil tilth, and water infiltration. Zones 1 and 3 were most closely associated with lower yields after forages than after annual crops (Fig. 3a). The percentage of respondents indicating lower grain yields after forages was 25% in Zone 1 and 17% in Zone 3, compared with an average of less than 6% in the remaining zones. Lower yields in Zone 1 can be explained on the basis of excessive soil water depletion by forage crops (Campbell et al., 1990; Zettner et al., 1990). Therefore, despite a 30% fallowing rate after forage stand termination in Zone 1, yields of grain crops grown after forages in this area were still lower than after other annual crops. It was interesting to note that Zone 3 corresponded closely to grain yield decrease after forages while Zone 2, which is drier, was more closely associated with similar yield after forage.
Weeds

Eighty-three percent of respondents indicated fewer weeds in grain crops following forages than with grain crops in annual crop rotations (Table 2). Respondents indicated good control for wild oat, Canada thistle [Cirsium arvense (L.) Scop.], green foxtail, and wild mustard (Sinapis arvensis L.), and indicated that forages suppressed weeds for 1 (11% of respondents), 2 (50% of respondents), or more (33% of respondents) years. Harvey and McNevin (1990) observed a 90% decrease in wild proso-millet (Panicum miliaceum L.) seed germination in corn (Zea mays L.) following four years of cropping to alfalfa. In the present study, many of the respondents indicated a reduced need for herbicides in crops sown after forages. Responses to the question “which weeds are best controlled by including forages in your crop rotation?” (Table 1) differed significantly (P < 0.01) with agroclimatic zone (Fig. 3b). Zones 1 and 3 were most closely associated with a decrease in annual broadleaf weeds, while producers in Zone 2 reported the greatest decreases in annual grass weeds, predominantly wild oat and green foxtail. Decreases in Canada thistle populations were most notable in Zones 5 and 6 (22 and 19% of respondents, respectively) where thistles tend to be more abundant in the wetter, clay soils.

This study points out the important role that forages can play in weed management and supports the previous observations by Dryden et al. (1983). Of special significance was the fact that two of western Canada’s most abundant weeds (i.e., wild oat and green foxtail), which also happen to be resistant to a number of herbicide groups (Morrison and Devine, 1994), were suppressed when forage crops were included in the rotation. Because of their weed suppressing ability, forage crops in rotations should allow farmers to reduce the herbicide selection pressure on weed populations, thereby slowing the development of herbicide resistant weeds.

Forage Stand Management

Forage Stand Duration

The most frequent forage stand duration reported in the survey was 5 yr (Table 2), while the average stand
duration of pure alfalfa and alfalfa-grass mixtures was 6.5 yr. Therefore, forage stand duration appeared to be longer than necessary for maximum N accumulation (Heichel et al., 1984; Kelner, 1994) and weed suppression (Dryden et al., 1983), but close to the economic optimum of 4 to 5 yr reported by Jeffrey et al. (1993).

Forage stand duration differed significantly ($P < 0.10$) across agroclimatic zones with producers in Zone 1 reporting the longest duration of forage stands (average 8.0 yr) (Fig. 4a). This observation is not surprising given the low success in forage establishment in this zone due to low soil water availability (Kilcher and Heinrichs, 1960). Producers from Zone 2, the area with a moisture limitation second only to Zone 1, reported the second longest forage stand durations (average of 7.1 yr). Even though water availability for crop growth in Zone 5 is not considered limiting, average stand duration was longer than in many other regions (Fig. 4a). This may be due to the heavy clay soils, and excessive soil water, which discourage stand termination and prompt producers to delay stand termination. This observation may also be attributed to the relatively high percentage of forage seed fields in this zone (17% of the total forage acreage). Forage seed fields are often maintained for more than 5 yr. The shortest stand duration occurred in Zone 3 (average of 5.1 yr) (Fig. 4a), where moderate soil moisture and loam soils facilitate termination and re-establishment of forage stands.

**Reasons for Terminating Forage Stands**

When asked why forage stands were removed, the majority (58%) of respondents indicated reduced yield as the primary reason (Table 2). Reduced yields were attributed mainly to stand age, however winterkill and drought were also mentioned. Problems with pocket gophers, which are known to be a common problem in the study area (Bonnefoy et al., 1994), ranked as the second most important reason for stand termination. Rotational considerations were cited by only 11.6% of respondents as the main reason for terminating forage stands.

Reasons for forage stand termination differed significantly ($P < 0.10$) with agroclimatic zone. Reduced herbage yield was common to all zones (Fig. 4b), while pocket gophers were cited as a major reason for forage stand removal in Zones 2, 3, and 4. These mammals prefer well drained loam soils (Bonnefoy et al., 1994), which occupy much of this area. Of all the producers surveyed, those in Zones 3, 4, and 5 were most inclined to remove forage crops for rotational considerations (14.5, 14.0, and 17.0% of respondents, respectively) (Fig. 4b), while less than 3% of producers in Zones 1, 2, and 6 cited rotational considerations as a primary reason for terminating forage stands. Producers in Zones 3 and 4 also maintained shorter stand durations than other zones (Fig. 4a), which supports the observations that these producers rotate forage crops more effectively. A possible explanation for greater rotational consideration by producers in Zones 3, 4, and 5 is that these zones are where the greatest rotational yield benefits were observed (Fig. 3a). Greater crop diversification in Zones 3, 4, and 5, due to greater seasonal moisture, may also explain the incentive for removing forages to grow more valuable crops (Fig. 4b).

Weeds were the most frequent reason for forage stand termination in Zones 1 and 6 (Fig. 4b). Greater weed problems in Zone 1 may be related to the very long stand duration (Fig. 4a), which allows weeds to invade. Greater weed problems in Zone 6 may be related to the fact that much of the alfalfa in this area is grown for processing (mainly dehydrated alfalfa pellets and cubes). These fields are cut frequently and encroachment by weeds, especially dandelion (*Taraxacum officinale* Weber), is common (H. Loepsky, Agric. and AgriFood Canada, Melfort Research Station 1994, personal communication).

Observations in this study suggest that the strategy of most producers is to maximize forage stand life and rotate forages only when necessary due to declining hay yields or invasion by weeds. Only a small percentage of producers, concentrated mostly in the wetter zones of the study area, terminate forage stands for rotational reasons. Given that the forage acreage in the study area is not expected to increase dramatically in the near future (Table 2), the most effective way to increase exposure of arable lands to rotational benefits of forages is to increase cycling of forage crops in rotations.

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**Appendix:**

**Table 2.** Reason for Termination of Forage Stands

<table>
<thead>
<tr>
<th>Reason for Stand Termination</th>
<th>% of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gophers</td>
<td>14.5% (Zone 3)</td>
</tr>
<tr>
<td>Reduced Yield</td>
<td>14.0% (Zone 4)</td>
</tr>
<tr>
<td>Rotational Considerations</td>
<td>17.0% (Zone 5)</td>
</tr>
<tr>
<td>Weeds</td>
<td>58% (All Zones)</td>
</tr>
</tbody>
</table>

**Figure 4.** Correspondence association of the six agroclimatic zones and a) forage stand duration, and b) reason for forage stand termination.

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Forage Stand Termination Management

The most common method of perennial forage stand termination across all zones was tillage (Table 2). Less than 2% of respondents indicated using herbicides alone to terminate perennial forage stands. The advantages of using herbicides over tillage include greater soil water conservation, improved suppression of the forage crop, and reduced risk of soil erosion (Bullied and Entz, 1994). An average of 24.9% of respondents indicated that they fellow land for a full year after forages while 9.3% stated that they fellow only if soil water is too limiting for grain crop production (Table 2). While there was no significant (P < 0.10) relationship between use of fallow after forage stand termination and agroclimatic zone, Zones 1 and 2 had the highest frequency of fallow following forage stand termination (33%), while Zones 3 and 5 had the lowest (less than 15%). Also, respondents who removed forage stands using a combination of herbicides and tillage did not fallow as frequently as those who terminated stands using tillage alone (19 vs. 27%). Reduced reliance on fallow in instances where forage stands were removed using a combination of herbicides and tillage may be related to better soil water conservation (Bullied and Entz, 1994).

Observations in this study point out that producers rely heavily on tillage and summerfallow in their forage-containing cropping systems. Problems associated with intensive tillage and fallowing after forage stand termination include exposure of soil to wind and water erosion (Bullied, 1993, unpublished data) and nitrate leaching (Campbell et al., 1994). Evidence in the present study suggests that using a combination of herbicides and tillage to terminate stands may reduce reliance on summerfallow the year after forage stand termination. Since rotational yield benefits were greatest in wetter areas (Fig. 3a), it could be suggested that adoption of water-conserving forage stand termination techniques may also increase the probability of capturing positive rotational yield benefits.

Forage Stand Establishment

The most common implement for seeding forage crops was the press drill (48% of respondents) followed by air-seeders/hoe drills (Table 2). Implement type varied significantly (P < 0.10) with agroclimatic zone (Fig. 5a), however. For example, use of discers was more closely associated with Zone 5 (Fig. 5a) where heavy clay soils and excess soil moisture predominate. Zone 4 was closely associated with the use of the press drill. Hoe drills and air seeders are typical of a once-over operation and were more common in Zones 1, 3, and 6 (Fig. 5a). This observation may indicate some conservation-tillage or even zero-tillage forage establishment. The broadcast seeding method was used by an average 18% of respondents, and was most commonly reported in Zones 2, 3, and 4 (Fig. 5a). These zones tend to be intermediate in soil water, and enable light tillage or soil packing, which incorporates the seed and firms the seedbed. While the broadcast seeding system may not always meet the requirements for optimum forage establishment (i.e., seeds placed shallow into a firm, moist soil [Sheaffer, 1989]), especially in dry years, the popularity of this system is based on its speed and ease of operation, and because many producers lack access to specialized forage seeding equipment (Gramiak, 1991).

The majority of seeding equipment used by producers in this study would require soil to be tilled prior to seeding. Preseeding tillage dries the soil and unless precipitation occurs within several weeks after seeding, forage stand establishment is reduced (Allen and Entz, 1994). In the latter study, superior alfalfa and meadow bromegrass (Bromus biebersteinii) Roem and Shult.) establishment under zero tillage (compared with where preseeding tillage was used), was attributed to higher levels of soil water in the top 4 in. (10 cm) of soil, which buffered the seedlings against a 30 d postseeding drought.

Ninety percent of respondents reported using companion crops when establishing forage crops. This compares with 74 to 84% of producers in Wisconsin (Martin et al., 1991) and 85% of producers in Minnesota (Simmons et al., 1992). Previous workers (Kilcher and Heinrichs, 1960; Simmons et al., 1992) found that type of companion crop used is related to local growing conditions, requirement for erosion and weed control, and economic return.

![Diagram](image_url)

**Fig. 5.** Correspondence association of the six agroclimatic zones and a) forage seeding equipment, and b) companion crop used.
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REFERENCES

Agronomic Responses of Winter Wheat Cultivars to Management Systems

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Management of winter wheat (Triticum aestivum L.) should include N fertilization, crop protection, and seeding rates that allow efficient production based on cultivar and environmental yield potential. These studies were conducted to evaluate regionally grown cultivar responses to crop management systems in northern Idaho. In three environments, four cultivars were grown using management treatments (MT) similar to current recommended practices (MT3); a treatment with conservative N fertilization (MT2); a low input treatment with lower N, lower seeding rate, and minimal herbicide (MT1); and a high input treatment with higher N with split applications, plus a fungicide and growth regulator application (MT4). Data on grain yield, protein, test weight, plant height, and lodging were collected in all studies. In the two studies in 1992, leaf tissue N and soil N were analyzed and yield components were determined. Environment × MT and environment × cultivar interactions were found for grain yield, test weight, and protein. In 1991 at Moscow, the hard red wheat 'Weston' produced the highest grain yields across MTs and was the only cultivar to produce highest yields with MT4. Also in that environment, the three soft white cultivars produced higher yield and test weight and lower protein in MT2 than in MT3. In 1992 at Pothatch, limited soil water restricted yield, and MT1 had lower yields than other MTs, but protein content increased with higher N fertility. At Moscow in 1992, agronomic performance appears better in MT1 than in other treatments due to abundant early vegetative growth in the higher N fertility treatments that was followed by a soil water deficit throughout reproductive stages. Weston produced the lowest yield, heads per acre, and kernels per head at Moscow in 1992, but was highest in test weight, grain protein, and plant height. At both sites in 1992, yield components were positively correlated to yield, indicating treatment differences were influencing yield throughout several plant growth stages. High inputs (MT4) can be beneficial under some circumstances, but conservative N fertilization with conventional practices (MT2) gave the best overall agronomic performance across the tested environments and cultivars.

Winter wheat yields in northern Idaho frequently average 70 to 80 bu/acre (Idaho Agricultural Statistics Service, 1992). Inputs to achieve these yields are relatively modest compared with intensive cereal management (ICM) systems used in Europe (Effland, 1981). Fertilizer, mostly N, herbicide treatment, and seed are the usual purchased inputs for production of a winter wheat crop in the region (Painter et al., 1992). Foliar fungicides and plant growth regulators (PGR) are not regularly applied.

In other regions of the USA, applications of foliar fungicide to winter wheat have been shown to be beneficial. Kelley (1993) in Kansas found yield increases due to fungicide applications when disease was present and varieties were susceptible. Cox et al. (1989) observed limited response to fungicide application in New York. Guy et al. (1989) showed economic benefits from fungicide application were possible in most of the tested environments in Wisconsin when cultivars were susceptible to disease and yields were high. In Pennsylvania, Roth and

Abbreviations: ICM, intensive cereal management; MT, management treatment; PGR, plant growth regulator.

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