



Barley, Oat, and Cereal-Pea Mixtures as Dryland Forages in the Northern Great Plains

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Cereals are popular annual forages in the northern Great Plains and were harvested for forage from 0.25 million ha across Montana, North Dakota and South Dakota in 1997. Oat is the most popular cool-season cereal species grown for forage in the Great Plains region, particularly in northern tier states. Oat comprised approximately 80% of the cereal area devoted to hay production in 1997 in North Dakota, approximately 90% of cereal in South Dakota and almost 50% in Montana. The remaining area consisted of barley (14%) and rye and wheat cereal crops.

Previous work in subhumid regions indicates barley produces higher-quality forage than oat. Barley had greater nutritive value than oat, triticale and wheat in Minnesota. Barley forage was highest in digestible dry matter (DM) and lowest in acid detergent fiber (ADF) concentrations. Crude protein (CP) concentration was 16 g kg⁻¹ greater in barley forage than in oat forage.

The superior quality of barley forage compared with oat and other cereal forages may result from a greater proportion of DM occurring as inflorescence in barley. More than 25% of barley forage DM consisted of inflorescence compared with 20% for oat, triticale and wheat forage across six maturity stages in subhumid regions. The inflorescence was more digestible and nutritious than other plant components. The leaf blade and sheath of barley also had less lignified area than oat.

The CP concentrations of barley and barley-pea forage were superior to those of oat and oat-pea forage in a study at Dickinson, ND. Factors in addition to CP concentration are important in determining the nutritive and economic value of forage. Energy, digestibility and mineral concentrations are required for comparisons between barley and oat grown in the region.

Barley forage yield has been equal or superior to forage yield of oat in subhumid regions, whether grown alone or with pea as a companion crop for alfalfa establishment. Barley forage yield has been inconsistent compared with oat in the northern Great

Plains. Data suggest cultivar selection may impact barley forage yield in semiarid regions. Comparison of a diverse group of barley and oat cultivars may be justified to verify these results.

Intercropping pea with cereal crops is practiced to enhance forage CP concentration compared with cereal sole cropping.

The impact of intercropping pea with cereal crops on forage DM yield has been inconsistent. Results of a study in 1998 suggest that the cereal component should be seeded at a sole crop or heavier rate if the goal of intercropping is maintenance of forage DM yield compared with a cereal sole crop in the northern Great Plains.

Our objectives were to determine in a low-soil-N environment in the northern Great Plains: (1) if forage yield and quality of barley were superior to oat; (2) the effect of cultivar selection on forage yield and quality; (3) the relative contribution of stem, inflorescence, leaf blade and leaf sheath to yield; and (4) the effect of intercropping with field pea on forage yield and quality.

Field experiments were conducted under dryland management during 1999 and 2000 at Dickinson, ND. The experiments were located on a Farnuf loam in fields where foxtail millet was grown the previous year. Low amounts of less than 15 kg N ha⁻¹ as nitrate occurred in the 0- to 60-cm soil depth, but moderate amounts, or approximately 20 kg P ha⁻¹ occurred in the 0- to 15-cm soil depth before establishing the field experiments in both years. Nitrogen and P fertilizers were not applied to reflect the common practice of forgoing fertilizer applications when growing cool-season annual forages in the region. Nine barley, five oat and one pea cultivar, along with two barley-pea and two oat-pea intercrops, were included in the study.

RESULTS AND DISCUSSION

Forage Yield. Dry matter production averaged 3.84 Mg DM ha⁻¹ for oat cultivars compared with 2.91 Mg ha⁻¹ for barley cultivars included in this study. Dry matter production of barley cultivars developed for grain production was 1.05 Mg DM ha⁻¹ less than oat cultivars developed for grain production and 1.17 Mg ha⁻¹ less than oat cultivars grown for forage. Differences in DM production were not detected, but significance was approached between barley cultivars grown for forage and oat cultivars grown for forage or developed for grain production. Previous work in southwestern North Dakota indicated that DM production generally is lower for barley compared with oat in the northern Great Plains in high soil N environments. Conversely, DM production has been equal or superior for barley compared with oat in subhumid regions.



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The contributions of stem, inflorescence, leaf blade, and leaf sheath to DM yield were 20%, 44%, 14% and 22%, respectively, for barley and oat in this study. A similar composition of barley plant DM was reported in a study in 1995. Conversely, a greater proportion of barley DM consisted of stem and leaf sheath in other studies. Inconsistencies in the composition of barley forage DM reported among studies may result from differences in harvest timing. Small changes in crop development stages can alter plant fraction composition of forage DM significantly. Harvest timing as related to crop development stage can affect forage composition more than other management considerations.

Intercropping oat with pea increased DM production compared with an oat sole crop, regardless of cultivar selection. Intercropping barley with pea increased DM production compared with a barley sole crop when cultivars developed for grain production were grown in a sole crop but not when cultivars developed for forage production were grown. The pea component contributed from 40% to 50% of total DM of intercropped forage, depending on cereal crop species and cereal and pea cultivars comprising the mixture. Results of this research indicate that intercropping pea with barley and oat can enhance forage DM in low-soil-N environments. In contrast, previous research indicates that DM yield is not enhanced and may be reduced when pea is intercropped with cereals under high-soil-N conditions.

Forage DM yield was maintained by intercropping barley with pea compared with an oat sole crop. These results suggest that barley-pea intercrops may be substituted for a monoculture of oat without sacrificing DM yield in low-soil-N environments. The substitution of barley-pea intercrops for an oat sole crop may be advantageous when quality of intercropped forage is superior, if barley and pea are easier to obtain than oat, or if other factors favor use of the intercrop. Forage DM yield was greater for an oat-pea intercrop than barley-pea intercrops, indicating that oat-pea intercrops would be favored to barley-pea intercrops in low-soil-N environments if the goal of intercropping is to maximize forage DM yield. Similarly, previous research indicated that more DM was produced by oat-pea intercrops than barley-pea intercrops in high-soil-N environments in the northern Great Plains.

Differences in DM yield were not detected between barley cultivars developed for grain or forage production or between two- and six-rowed grain barley types. Differences in DM yield also were not detected between oat cultivars developed for grain production and cultivars grown for forage or between hull-less and hulled grain oat cultivars. These results suggest that cultivar selection within small-grain species may not be important in low-soil-N environments, possibly because lack of N eliminates the potential for differences in DM production between low- and high-yielding cultivars that can occur under high-soil-N conditions.

Forage Quality. CP concentration averaged 90 g kg⁻¹ in barley forage compared with 61 g kg⁻¹ in oat. Likewise, other studies concluded that CP concentration of forage generally is greater for barley compared with oat. However, the impact of growth stage differences on CP concentration of cereal forages often is greater than the impact of the crop species and cultivars compared.

Forage CP was 35 g kg⁻¹ more concentrated for barley-pea intercrops compared with a barley sole crop and for oat-pea intercrops compared with an oat sole crop. Forage CP was 74 g kg⁻¹ more concentrated for barley-pea intercrops compared with

a monoculture of oat and 10 g kg⁻¹ more concentrated for oat-pea intercrops compared with a monoculture of barley. Our results suggest that intercropping pea with barley or oat can enhance the CP concentration of forage compared with a sole crop of either cereal species. The results indicate that intercropping pea with barley may be preferred to an oat sole crop in low-soil-N environments since forage CP concentration is superior for the intercrop and DM yield is maintained. Similarly, intercropping pea with oat may be preferred to a barley sole crop since forage DM yield is superior for the intercrop and CP concentration can be maintained.

Nitrogen yield was similar between barley and oat in our study, indicating that the higher concentration of CP in barley forage compensated for the lower production of DM compared with oat. A study in 1970 found that CP yield was greater for oat when oat and barley were harvested at the milk growth stage, whereas CP yield was greater for barley when both crops were harvested at the dough stage. That study indicates the ranking of barley and oat for N yield is transitory and depends on the growth stage of crops when harvested, but additional research may be needed to justify those conclusions using modern production methods and germplasm.

Nitrogen yield was 32 kg ha⁻¹ greater for barley-pea intercrops compared with a barley sole crop and 37 kg ha⁻¹ greater for oat-pea intercrops compared with an oat sole crop in low-soil-N environments. Conversely, forage N yield was unaffected by intercropping in previous research under relatively high-soil-N conditions. Intercropping cereal crops with pea may be advantageous because of the biological N-fixing ability of pea under low-soil-N conditions.

Nitrogen yield was greater for barley-pea intercrops compared with an oat sole crop and for oat-pea intercrops compared with a sole crop of barley. Hence, intercropping pea with either barley or oat enhances forage N yield compared with growing either cereal species as a sole crop. No difference in N yield was detected between barley-pea and oat-pea intercrops, suggesting that the relatively high CP concentration of pea forage compensated for the relatively low yield of barley-pea intercrop compared with oat-pea intercrop.

ADF concentration averaged 35 g kg⁻¹ lower for barley forage compared with oat forage while NDF concentration averaged 34 g kg⁻¹ lower in barley forage. Forage ADF and NDF concentrations were lower for barley cultivars grown for forage compared with oat cultivars grown for forage and for barley cultivars developed for grain production compared with oat cultivars grown for forage. Differences in forage ADF concentration were not detected between barley cultivars grown for forage and oat cultivars developed for grain production, nor were differences in forage NDF concentration detected between barley cultivars grown for forage and oat cultivars grown for grain or for forage. Our results suggest that cultivar selection may impact relative ranking of barley and oat for forage NDF concentration.

Intercropping pea with barley did not affect forage ADF concentration compared with a barley sole crop while forage NDF concentration was reduced by intercropping. Likewise, intercropping pea with oat reduced the NDF concentration of forage compared with an oat sole crop. ADF concentration also was lower for forage produced by an oat-pea intercrop compared with a sole crop comprised of a forage cultivar but not an oat cultivar grown for grain. Differences in forage ADF concentra-



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tion were not detected between barley-pea and oat-pea intercrops while NDF concentration was lower in forage produced by barley-pea intercrops than oat-pea intercrops.

Average TDN concentration was 46 g kg⁻¹ higher for forage produced by barley compared with oat in this study. Forage TDN concentration was greater for barley compared with oat cultivars grown for forage and greater for barley cultivars developed for grain production compared with either group of oat cultivars. Differences in the TDN concentration of forage produced by barley cultivars grown for forage and oat cultivars grown for grain were not detected. Results of our study suggest that crop species and cultivar selection can impact TDN concentration of small-grain forage.

Total digestible nutrients were 17 g kg⁻¹ more concentrated in forage produced by barley-pea intercrops than a barley sole crop and 29 g kg⁻¹ more concentrated in forage produced by oat-pea intercrops than an oat sole crop. These data suggest intercropping may be a suitable strategy for enhancing TDN concentration of forage compared with managing the cereal component as a sole crop. No differences were found in TDN concentration between barley-pea and oat-pea forage.

Forage P was 0.77 g kg⁻¹ more concentrated for barley compared with oat. P was 0.70 g kg⁻¹ more concentrated in barley forage when oat and barley cultivars developed for grain production were compared, but differences were not detected in forage P concentration between barley cultivars grown for forage and oat cultivars grown for forage or developed for grain production. Differences also were not detected in forage P concentration between barley cultivars developed for grain production and oat cultivars grown for forage. Our results suggest cultivar selection may affect the ranking of barley and oat for forage P concentration in some environments.

Forage Ca concentration was 3.64 g kg⁻¹ for barley forage compared with 2.98 g kg⁻¹ for oat forage. Calcium was 2.78 g kg⁻¹ more concentrated in forage produced by a barley-pea intercrop than a monoculture of oat and 3.45 g kg⁻¹ more concentrated in forage produced by an oat-pea intercrop than a monoculture of barley. There was no difference in forage Ca concentration between barley-pea and oat-pea intercrops.

Intercropping increased Ca concentration of forage compared with a sole crop of either cereal species in this study. The relatively high concentrations of Ca in pea forage accounted for the elevated Ca concentration of forage produced by intercrops compared with a cereal sole crop. Conversely, intercropping generally failed to affect forage P concentration compared with a cereal sole crop.

Differences in CP, P, and N yield were not detected between barley cultivars developed for grain production and cultivars developed for forage. Forage was lower in ADF and NDF concentrations but higher in TDN concentration for barley cultivars developed for grain production compared with cultivars developed for forage. Similarly, differences in forage quality traits were not detected between oat cultivars grown for grain and cultivars developed for forage or between hull-less and hulled oat cultivars, except for forage NDF concentration.

CONCLUSIONS

Our objective was to determine if forage yield and quality were superior for a diverse group of adapted barley cultivars compared with a group of oat cultivars in the northern Great Plains. Research in other environments suggested forage DM produc-

tion would be superior for oat but barley would produce higher-quality forage. Forage DM production was greater for oat in this study while quality of barley forage was superior. Our field experiments were located in low-soil-N, unfertilized environments, but similar results were generated previously with relatively high-soil N. Results of these two studies indicate that forage DM yield is greater for oat than barley under a range of soil N conditions in the northern Great Plains, in contrast to sub-humid regions where barley has produced equal or greater amounts of forage compared with oat.

Forage CP concentration was superior for barley compared with oat in our study as well as previous studies in the northern Great Plains. However, past research did not compare barley and oat forage for other quality parameters in this region. Our research suggests that P, Ca and TDN are more concentrated in barley forage while ADF and NDF are less concentrated. Differences in forage N yield were not detected in our study or in other environments in previous research, suggesting barley may be preferred to oat if optimizing N yield while limiting DM production is important in forage selection.

Forage DM yield and CP concentrations were optimized when cultivars developed for forage rather than grain production were grown in previous research in the northern Great Plains. However, cultivar selection did not affect forage DM yield and CP concentration in our study. We speculate that differences in forage DM production, CP concentration, and N yield were narrowed between cultivars because of the low-soil-N, unfertilized environments that were encountered. Our results support the hypothesis that cultivar selection may not be an important criterion for maximizing forage DM yield or quality in N-stressed environments, but additional research may be needed.

Differences in the percentage of forage comprised of various plant fractions between barley and oat were not detected in our study. We are unable to explain the superior quality of barley forage compared with oat forage on the basis of plant fraction composition, as researchers did in subhumid regions. Additional work is needed in the northern Great Plains to determine if plant fraction composition of barley and oat forage is similar in environments that favor DM production. The impact of timing of harvest on plant fraction composition of forage across the range of growth development stages when barley and oat are harvested for forage should be included in the effort.

Forage DM and N yield were unaffected by intercropping under favorable soil N conditions in previous research in the northern Great Plains. Conversely, forage DM and N yield were enhanced by intercropping in this study. The ability of pea to fix N biologically may have been an advantage in the low-soil-N environments in our study while ability of pea to fix N biologically may have been limited in high-soil-N environments in previous research. Our results support the hypothesis that intercropping pea with barley and oat can enhance forage DM and N yield along with forage CP concentration compared with a monoculture of either cereal crop under low-soil-N conditions when N fertilizer is not applied in the northern Great Plains.

Editor's note: Content was adapted from the paper "Barley, Oat and Cereal-Pea Mixtures as Dryland Forages in the Northern Great Plains," which was published in *Agronomy Journal*, Vol. 96, May-June 2004, and is courtesy of the authors Patrick M. Carr, Richard D. Horsley and Woodrow W. Poland.



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Barley, Oat, and Cereal-Pea Mixtures as Dryland Forages in the Northern Great Plains

October Self-Study Examination

1. The most common annual forage crop in the northern Great Plains is

- a. oats.
- b. barley.
- c. wheat.
- d. rye.

2. Compared to oat forage, barley forage is higher in

- a. acid detergent fiber.
- b. neutral detergent fiber.
- c. crude protein concentration.
- d. dry matter yield.

3. A reason to intercrop cereal crops with field peas for forage is to

- a. increase the protein concentration in the forage.
- b. increase the crude fiber concentration.
- c. speed the rate of forage curing during rainy periods.
- d. decrease the rate of soil erosion.

4. Intercropping with field pea as compared to sole cropping resulted in

- a. increased forage calcium levels.
- b. decreased TDN.
- c. increased P levels.
- d. decreased nitrogen yields.

5. The most nutritious parts of barley harvested as forage are the

- a. leaf sheaths.
- b. inflorescences.
- c. leaf blades.
- d. stems.

6. A reason why nitrogen and phosphorus fertilizers were not applied in this study was to

- a. mirror the common practice of not using fertilizers for forages grown in the northern Great Plains.
- b. keep forage yields low to maximize the impact of management treatments.
- c. minimize the impact of fertilizer treatments on subsequent field plot studies.
- d. avoid late-season foliar diseases that are common with the over-application of fertilizers.

7. A factor contributing to the superior forage quality of barley as compared to oats is

- a. barley's superior drought tolerance.
- b. the proliferation of tillers in oat varieties used for forage.
- c. barley's resistance to most foliar diseases.
- d. the relatively larger inflorescence in barley.

8. Under the low soil nitrogen conditions of this study, the dry matter contribution of field peas when intercropped with either barley or oats was

- a. 10-20%.
- b. 20-30%.
- c. 30-40%.
- d. 40-50%.



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9. The results of this study contrast with previous research in forages in that

- a. cultivar selection did not affect forage dry matter yield.
- b. oats produced higher-quality forage than barley.
- c. intercropping had little impact on forage quality.
- d. higher rates of nitrogen and phosphorus caused lodging.

10. The relative contribution of the inflorescence to dry matter yield in either oat or barley in this study was

- a. 20-30%.
- b. 30-40%.
- c. 40-50%.
- d. 50-60%.



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