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Decomposition Rates of Native and Improved Cultivars of Grasses in the Northern Great Plains

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*Decomposition is a critical process that links the above- and below-ground portions of the nutrient cycle. A study was initiated in North Dakota, USA, to evaluate the decomposition rate between three genetically improved grass species monocultures, *Agropyron desertorum*, *Bromus inermis*, and *Pascopyrum smithii*, and two native perennial grass species occurring in area rangelands, *Nassella viridula* and *Bouteloua gracilis*. Standing litter of all five species was harvested in October 1996 and placed into litterbags. Litterbags were placed along transects in early November 1996 and randomly selected bags were sampled in June, July, August, September, and October, 1997. Carbon (C), nitrogen (N) and lignin were determined on all samples including the initial litter samples. The percent of dry matter decomposed across time ranged from 18.4% for *B. gracilis* to 26.8% for *A. desertorum*. The two native species, occurring in undisturbed rangeland, had significantly lower rates of decomposition than did the monocultures of the improved cultivars, including the monoculture of the improved native, *P. smithii*. Most decomposition occurred prior to the June 1997 sampling date, and from June to October 1997 decomposition was approximately the same for all species (7 to 8%). The N concentration of the initial samples had the strongest correlation ($r = 0.78$, $P < 0.01$) with decomposition rates. Lignin had a significant positive correlation ($r = 0.49$, $P = 0.03$) and the C:N ratio had a significant negative correlation*

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($r = -0.67$ $P < 0.01$) with decomposition. Traits, such as decomposition, that can affect ecosystem functioning need to be given greater emphasis in genetic selection of native and improved grass species.

Keywords carbon, lignin, nitrogen, monocultures, litter

Decomposition serves as a major pathway for return of nutrients to the soil, and changes in the amount and rate of decomposition may affect crucial ecosystem characteristics (O'Neill and Norby 1996). Factors that affect decomposition include temperature, moisture, and the chemical composition of the litter (Gillon, Joffre, and Ibrahima 1994; Schlesinger 1991). Litter quality factors, such as lignin, carbon (C), nitrogen (N) and the lignin : N and C : N ratios affect the rate litter decomposes and its net mineralization into the soil (Melillo, Aber, and Muratore 1982; Taylor, Parkinson, and Parsons 1989; Wedin 1999). High C : N ratios lead to greater immobilization of N in microbial biomass and may result in reduced N available to the plant (Wedin 1999). This can influence plant community composition (Wedin 1999; Wedin and Tilman 1996) and impact ecosystem functioning (Wedin and Tilman 1996).

Some introduced grasses have been shown to have negative impacts on soil quality (Dormarr et al. 1995) and nutrient cycling (Wedin and Tilman 1996). Therefore, many recent efforts in rehabilitation and reclamation of range and croplands have focused on the use of native species. For example in the Great Plains, 40% of the land placed in the original Conservation Reserve Program (CRP) was seeded to introduced grasses and 53% was seeded to native grasses (Newman 1987). Use of native grasses as a cover component increased the likelihood of acceptance in the CRP (USDA-FSA 1999). However, the focus of most grass breeding programs has been on plant traits such as seedling vigor, disease resistance, forage quality and others that have a direct benefit to the producer rather than traits that have potential environmental impacts.

Despite concerns about the impacts of improved grass cultivars on soil quality and nutrient cycling, relatively little is known about their rates of decomposition compared to naturally occurring native species. A study was conducted in North Dakota, USA to compare litter decomposition rates between monocultures of two introduced perennial grass cultivars, *Agropyron desertorum* (Fischer ex Link) Schultes, and *Bromus inermis* Leysser, an improved native perennial grass cultivar, *Pascopyrum smithii* (Rydb.) A. Löve, and two native perennial grass species occurring on rangelands, *Nassella viridula* (Trin.) Barkworth and *Bouteloua gracilis* (Willd. Ex Kunth) Lagasca ex Griffiths. Our hypothesis was that the introduced grasses would have a faster rate of decomposition than the native grass species, including the improved native cultivar of *P. smithii*.

Materials and Methods

This study was conducted at the Northern Great Plains Research Laboratory located approximately 6 km south of Mandan, North Dakota, USA (46°46'N and 100°50'W). The sixteen 5.7-ha pastures used in the study had predominately silt loam soils (fine-silty mixed Pachic Haploborolls). Pastures were seeded to either the improved grass cultivars of *Agropyron desertorum* (Fisch. ex. Link) Schult. (crested wheatgrass, cultivar 'Nordan'), *Bromus inermis* Leyss. (smooth brome grass, cultivar 'Lincoln'), *Pascopyrum smithii* (Rydb.) Love (western wheatgrass, cultivar 'Rodan') or left as native range in the fall of 1985 creating four replications of each species (Hofmann et al. 1993). *Agropyron desertorum* and *B. inermis* are introduced grasses while *P. smithii* is a native perennial grass. The cultivars for *A. desertorum* and *P. smithii* were developed at the Mandan USDA-ARS Laboratory. Standing dead plant material of each species was collected from within nongrazed exclosures

located in each of the pastures in October 1996. Standing dead plant material of the naturally occurring native species, *Bouteloua gracilis* (H.B.K.) Lag. ex Steud. (blue grama) and *Nassella viridula* (Trin.) Barkworth (green needlegrass) was collected at the same time from outside exclosures in the four native range pastures. *Bromus inermis* had invaded the exclosures in these pastures reducing the availability of the desired native species. None of the pastures was fertilized after 1982. Long-term (1913 to present) precipitation and temperature data as well as seasonal temperature data were recorded at a weather station 3.3 km from the experimental site. Precipitation received during the 1997 growing season (April to September) was recorded at a weather station located within one of the pastures.

Cold winters and warm summers with erratic precipitation characterize the Northern Great Plains. The average maximum temperature ranges from -6.9°C in January to 28.7°C in July. The average annual precipitation is 411 mm, 79% of which occurs from April through September. Because of the temperature and moisture regime, potential evaporation exceeds precipitation during most of the growing season. During the study period of November 1996 to October 1997, precipitation was 406 mm or 99% of average. Precipitation was augmented by 143 mm of precipitation in the form of snow from November 1, 1996 to April 6, 1997. Precipitation during the growing season of April through October was 270 mm or 83% of the long-term average of 327 mm. This precipitation amount includes the April snowfall. Growing season precipitation was negatively affected by limited precipitation during May (12mm) and June (46mm), which was 20 and 54% of the long-term average. Both April and July were wetter than average (174% and 131% of average respectively). April precipitation was increased by snow the first week of April.

Plant material was air-dried and broken to fit into 16×16 -cm nylon mesh litterbags. Twenty-four litterbags (six collection dates \times four replications), containing approximately 10 g of plant material, were made for each species. Only 8 g of *B. gracilis* litter was placed in the litterbags because 10 g would not fit into litterbags. Plant material remaining after the litter bags were filled was subsampled for determination of leaf: stem ratios. Each fraction was then double ground to pass through a 1 mm screen. In November 1996, litter bags were placed along transects in the ungrazed exclosures from which the litter was collected. Litter and plant material was removed from the immediate area under the litterbags and the bags were placed as flat as possible on the soil surface. Each corner of the bag was anchored with a 15 cm nail. A randomly selected litterbag was collected monthly, from June through October 1997, in each of the 16 pastures. In the native pastures, both *B. gracilis* and *N. viridula* litter bags were collected. Litterbags were then air-dried and remaining plant material was removed, weighed and double ground to pass through a 1-mm screen. The air-drying of the initial samples and of the decomposed samples followed the procedure of Abougendia and Whitman (1979). Lignin was determined using acid detergent lignin procedure (Goering and Van Soest 1970). Carbon and N were determined on each of the litter samples collected and the stem and leaf portions of the initial material using a Carlo Erba NA 1500 Series 2 analyzer (Carlo Erba/Fisons Instruments, Valencia, California, USA). Concentrations of N, C and lignin (g kg^{-1}) in the initial litter material was determined by weighting the N, C and lignin concentration in the leaf and stem components by the proportion of the stem and leaf material for each species. Content (g m^{-2}) was determined by multiplying the concentration by remaining biomass at the sampling date.

Dry matter loss was determined by subtracting the weight of the remaining biomass from the original weight and then dividing by the original weight. The C: N and lignin: N ratios were determined for the initial litter samples and for the litter samples collected across time. Data were analyzed as a split plot in time with species being the main plot factor and time being a subplot factor using PROC GLM (SAS 1990). Means were separated using the Student-Newman-Keul's test. The C, N, and lignin concentrations and the lignin: N and C: N ratios were correlated with

dry matter disappearance using the Pearson's correlation coefficient in the PROC CORR procedure (SAS 1990). All differences are at the $P < 0.05$ level unless otherwise noted.

Results

B. gracilis and *N. viridula* litter decomposed less than the other three grasses (Figure 1). Most decomposition occurred prior to the June sampling date ($> 65\%$) for all species. Percent decomposition occurring prior to June ranged from 65% for *B. gracilis* and *N. viridula* to 72% for *P. smithii*. Differences in percent decomposition among species in June persisted for the remainder of the growing season. Percent decomposition during the active growing season (June to October) was approximately the same for all species (7 to 8%).

The initial litter samples contained more stems than leaves for all species except *B. gracilis*, (Table 1). The initial litter samples had significant differences between species in the concentrations of lignin, C and the C:N ratios but not in N concentration or in the lignin:N ratio. *P. smithii* had a lower C:N ratio than did *N. viridula* (Figure 2A). Carbon concentration in *B. gracilis*, *B. inermis*, and *P. smithii* were significantly less than in *A. desertorum* and *N. viridula* (Figure 2C). *A. desertorum*

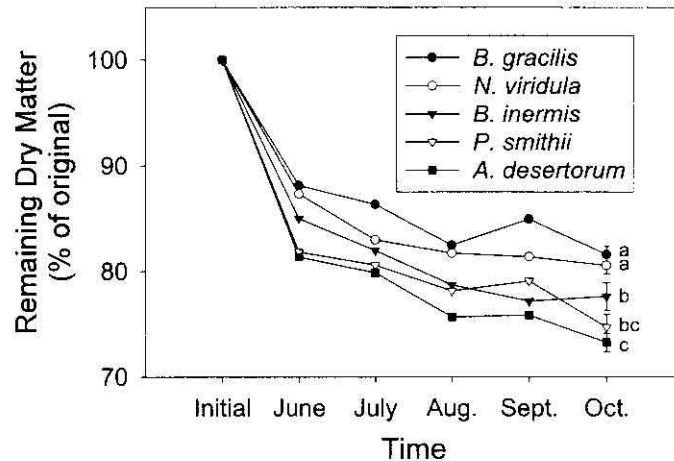


FIGURE 1 Decomposition expressed as percent of original dry matter remaining at each sampling date for each species. Letters at the end of the lines indicate significant differences in the decomposition rates between species over time.

TABLE 1 Proportions of leaves and stems in the initial litter samples by species. (Standard errors are in parenthesis).

Species	Stems	Leaves
<i>B. gracilis</i>	19.96 (1.61)	80.04 (1.61)
<i>N. viridula</i>	66.35 (3.96)	33.65 (3.96)
<i>P. smithii</i>	54.52 (2.94)	45.48 (2.94)
<i>B. inermis</i>	64.05 (4.71)	35.95 (4.71)
<i>A. cristatum</i>	92.46 (1.26)	7.54 (1.26)

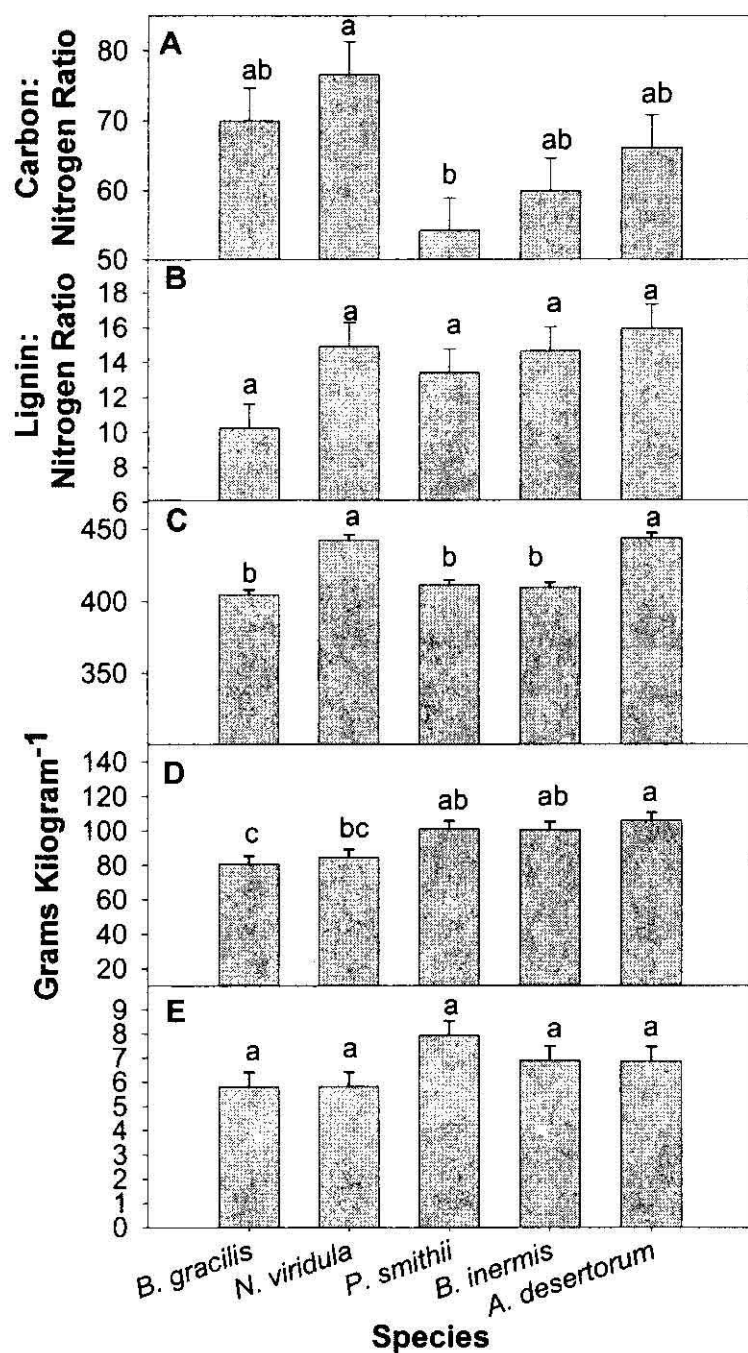


FIGURE 2 The carbon:nitrogen (A) and lignin:nitrogen (B) ratios and the concentration of carbon (C), lignin (D) and nitrogen (E) in the initial litter samples for each species. Different letters over bars indicate significant differences in these variables between species. Lines at the top of the bars indicate standard errors for each species.

had significantly greater lignin concentration than *N. viridula* and *B. gracilis* and the lignin concentration of *B. gracilis* was significantly less than *B. inermis* and *P. smithii* (Figure 2D).

Litter quality in the decomposed samples had significant differences between species and sampling periods, but there was not a species by time interaction. Carbon concentration (g kg^{-1}) was higher for *A. desertorum* than for the other species, and *N. viridula* had a higher C concentration than did the remaining three species (Figure 3A). The content of C (g m^{-2}) was higher for *N. viridula* than for the other species and *A. desertorum* had a higher C content than did the remaining three species (Figure 3B). *P. smithii* had a higher lignin concentration than did *N. viridula*, *A. desertorum*, and *B. gracilis*, and the lignin concentration of *B. inermis* and *A. desertorum* was greater than in *N. viridula* or *B. gracilis* (Figure 3C). The lignin concentration of *B. gracilis* was significantly less than any of the other species (Figure 3C). Lignin content was greater for *P. smithii* and *B. inermis* than for the other species and the lignin content of *B. gracilis* was significantly less than *A. desertorum* or *N. viridula* (Figure 3D). There were no significant differences in the N concentration between species (Figure 3E) but *P. smithii* had a significantly greater N content than did *B. gracilis* (Figure 3F). The C:N ratio for *P. smithii* was significantly lower than for *A. desertorum* or *N. viridula* (Figure 4A) and the lignin:N ratio was significantly lower for *B. gracilis* than for the other four species (Figure 4B).

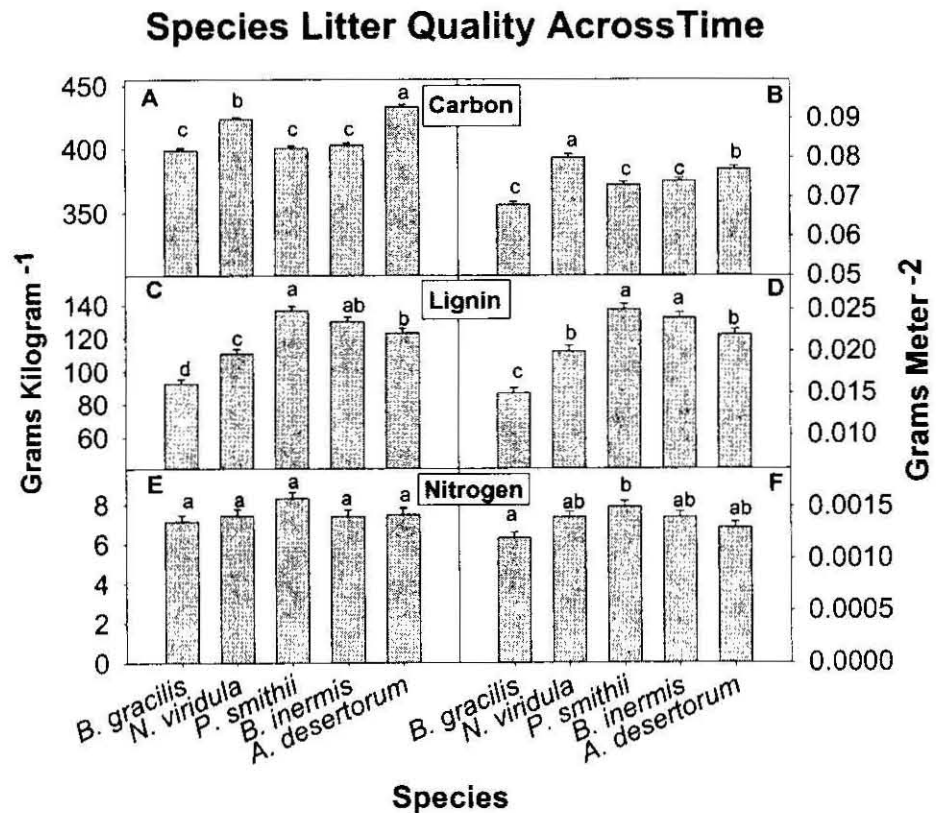


FIGURE 3 Nitrogen, lignin and carbon for each species pooled over all sampling dates expressed as concentration (g kg^{-1}) and content (g m^{-2}). Letters over bars indicate significant differences between species in these variables. Lines at the top of the bars indicate standard errors for each species.

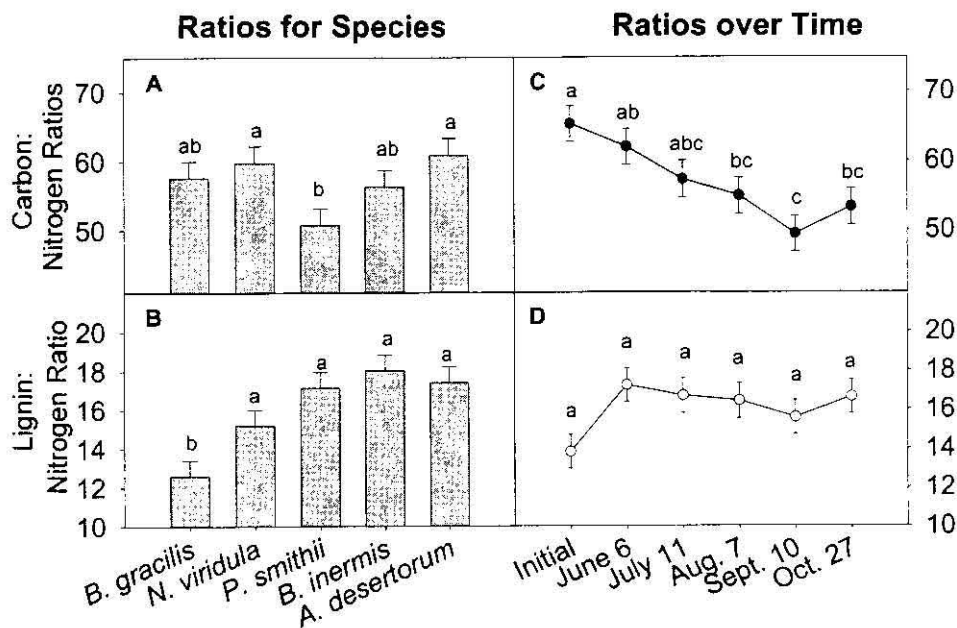


FIGURE 4 Lignin:nitrogen and carbon:nitrogen ratios for each species pooled over time (A and B) and over time pooled across species (C and D). Letters over symbols and bars indicate significant differences between time periods or species for that variable.

The C:N ratios in the September 1997 sampling period were significantly lower than the initial or the June sampling period, and the C:N ratio for the August and October sampling periods was significantly less than the initial litter samples (Figure 4C). There were no significant differences in the lignin:N ratios across time (Figure 4D).

Carbon concentration and content declined across time, but there were differences in significance between time periods. The C concentration and content of the initial sample was significantly greater than any of the other time periods (Figure 5A, B). Carbon content in the June time period was significantly greater than for the remaining time periods, and C content in the October sampling period was significantly less than in July (Figure 5B). Lignin concentration in the initial litter samples was significantly less than the other time periods, and the June litter samples contained less lignin than the September and October litter samples (Figure 5C). There were no significant differences between time periods in lignin content of the litter samples. Nitrogen concentration was lower in the initial litter samples and in the June litter samples than in the September litter samples (Figure 5E). Nitrogen content was greater in the initial and September litter samples than in the June litter samples (Figure 5F).

Dry matter loss was positively correlated ($P < 0.05$) with grams of N and lignin in the initial litter dry matter (Table 2). Dry matter loss was negatively correlated ($P < 0.05$) with the C:N ratio of the initial litter dry matter (Table 2).

Discussion

The two native grasses in the rangeland decomposed slower than the monocultures of the genetically improved species, including the genetically improved native *P. smithii*, which had a decomposition rate similar to that of the two introduced species.

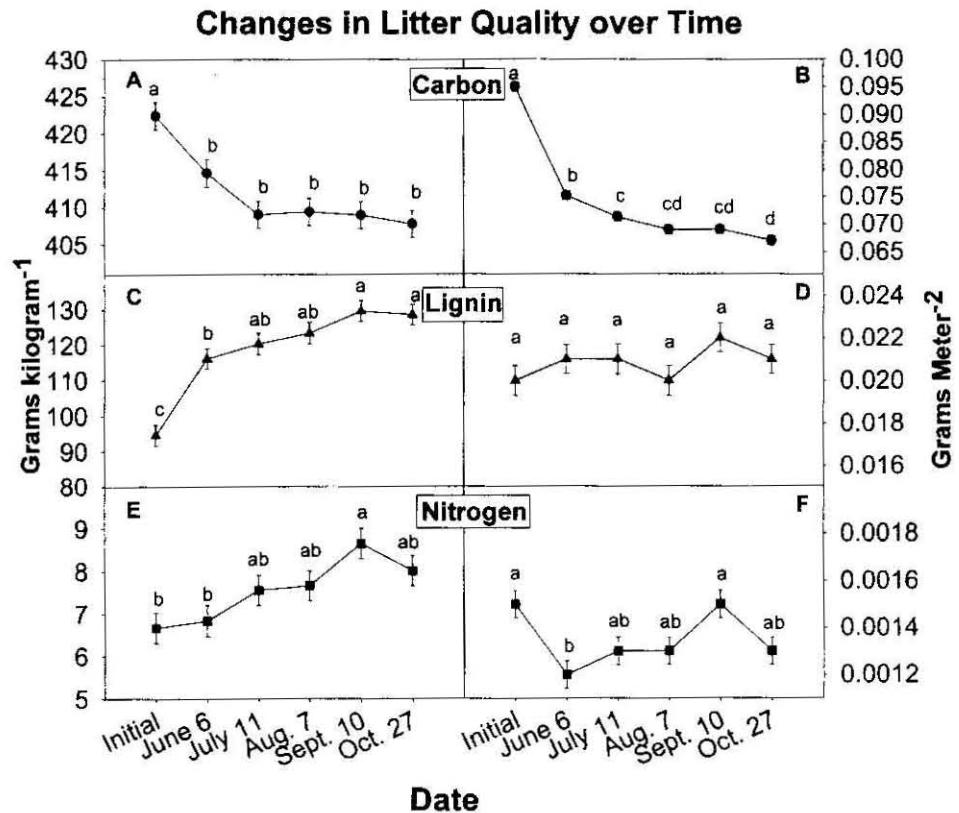


FIGURE 5 Changes in litter quality over time expressed as concentration (g kg^{-1}) or content (g m^{-2}). Letters over the symbols indicate significant differences between time periods for each variable.

TABLE 2 Percent dry matter loss over one year correlated with the grams lignin, carbon, nitrogen and carbon:nitrogen and lignin:nitrogen ratios in the initial samples

Variable	r^a	P value ^a
Nitrogen (N)	0.78	< 0.01
Carbon (C)	0.19	0.42
Lignin (Lig.)	0.49	0.03
C:N Ratio	-0.67	< 0.01
Lig:N Ratio	-0.07	0.78

^aPearson correlation coefficient.

Therefore, we rejected our hypothesis that native species have slower rates of decomposition than introduced species. Rather, the genetically improved species in monocultures had higher rates of decomposition than did the naturally occurring native species in rangelands. In a native community, *P. smithii* had decomposition rates similar to *B. gracilis* (Abouguendia and Whitman 1979); however, our results show

that an improved cultivar of *P. smithii* had a significantly higher decomposition rate than did *B. gracilis*.

Several factors may have contributed to the faster rates of decomposition in the genetically improved species. The genetically improved species are generally used in previously cultivated fields (Dormaer et al. 1995), and the pastures used in this study were tilled prior to seeding the pastures. Cultivation of native prairie has been shown to have lasting effects on soil properties (Dormaer, Adams, and Willms 1994), and even the type of tillage may affect the composition of the decomposer communities (Beare et al. 1992). Therefore, the faster decomposition of the genetically improved species may be linked to cultivation rather than to inherent factors in the grasses.

Alternatively, the differences in decomposition rates may be linked to differences in litter quality. Higher initial N concentrations have increased decomposition rates, particularly in species with lignin concentrations greater than 10% (Taylor et al. 1989). The native species tended to have the lowest ($P = 0.12$) initial N concentrations, and both *N. viridula* and *B. gracilis* had lower initial lignin concentration than the genetically improved species, although only *B. gracilis* was significantly different. Initial N concentration had the highest correlation with dry matter loss ($r = 0.78$, $P < 0.001$).

Carbon : nitrogen ratios have also been linked to litter dry matter loss (Taylor et al. 1989). The C : N ratios of the initial samples had a significant negative correlations ($r = -0.67$, $P < 0.01$) with dry matter loss from the litter samples but were correlated less strongly than the initial N content. The C : N ratios decreased across time as C concentration decreased and N concentration increased. Although C : N ratios are crude estimations of litter quality (Pregitzer et al. 2000), shifts in these ratios may have significant effects on ecosystem functioning (Wedin and Tilman 1996). In Minnesota, a shift in species composition decreased the C : N ratios which increased N mineralization, soil nitrate and N losses from the soil (Wedin and Tilman 1996). C : N ratios greater than 30 have been suggested to result in greater immobilization of N in grasslands (Wedin 1999). All of the species in this study had C : N ratios greater than 50, which should result in a net N immobilization. However, in more semiarid areas the linkages between litter quality and feedback are not as defined (Burke et al. 1998).

There have been mixed reports in the literature about the effect of lignin on decomposition rates. Initial lignin concentrations (Aber, Melillo, and McClaugherty 1990) and lignin : N ratios (Melillo et al. 1982) have been correlated with litter matter loss; however, low correlations with lignin have also been reported (Henriksen and Breland 1999). Lignin is a complex chemical fraction that has been shown to have differential digestibility to herbivores (Jung 1989). In our study, the slower decomposing native species had lower lignin concentration in the initial samples than *A. desertorum*, which decomposed the most rapidly, and the lignin : N ratio was poorly correlated with decomposition. The grams of lignin in the litter samples remained relatively constant across time for all species, which suggested that the lignin fraction in all species was relatively resistant to decomposition.

A majority of the decomposition occurred before the active growing season when warmer temperatures and increased moisture should help in the decomposition process. Lower precipitation during the growing season because of dry weather during late April, May, and part of June may have slowed decomposition. Alternatively, a late snowfall may have provided enough soil moisture for decomposition to occur in the earliest part of the growing season. The higher N concentrations of the genetically improved species may have increased their early season decomposition rates.

Conclusions

There has been increasing interest in the use of native cultivars in revegetation efforts. However, our study illustrates the lack of a basic understanding of many

ecological attributes, such as decomposition, for some genetically improved species. For example, a monoculture of the improved cultivar of a native species had a decomposition rate similar to the introduced cultivars used in the study. The initial N content of these grasses had the highest correlation with decomposition rates and may be a valuable screening mechanism in selecting cultivars in for use in revegetation projects where ecosystem functioning is a consideration. More explicit comparisons of decomposition rate and other ecological attributes need to be done between genetically improved and naturally occurring native species. Important attributes that affect ecosystem functioning could then be given greater emphasis in genetic selection programs to develop grasses that are suited for revegetation projects.

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