© 2010 Plant Management Network.
Accepted for publication 21 December 2009. Published 16 March 2010.

Renovation and Management Effects on Pasture Productivity Under Rotational Grazing

Geoffrey E. Brink, USDA-ARS, United States Dairy Forage Research Center, 1925 Linden Drive West, Madison, WI 53706;
Randall D. Jackson, Department of Agronomy, University of Wisconsin, 1575 Linden Drive, Madison, WI 53706;
Jonathon S. Bleier, USDA-ARS, United States Dairy Forage Research Center, 1925 Linden Drive West, Madison, WI 53706;
Susan K. Chamberlain and **Andrew R. Jakubowski,** Nelson Institute for Environmental Studies, University of Wisconsin, 1575 Linden Drive, Madison, WI 53706

Corresponding author: Geoffrey E. Brink. geoffrey.brink@ars.usda.gov

Brink, G. E., Jackson, R. D., Bleier, J. S., Chamberlain, S. K., and Jakubowski, A. R. 2010. Renovation and management effects on pasture productivity under rotational grazing. Online. Forage and Grazinglands doi:10.1094/FG-2010-0316-01-RS.

Abstract
Renovating permanent pasture to replace existing cool-season perennial grasses with improved varieties has potential risk and reward. Improved grasses may increase long-term productivity, but these increases should offset costs associated with replacing an existing stand. We eliminated existing perennial grass stands with tillage and herbicides and sowed a mixture of improved orchardgrass and meadow fescue in 2006 on five Wisconsin farms that used a range of rotational grazing systems. Paddocks were also subject to either typical producer management or recommended agronomic management. Despite considerable farm-to-farm variation, annual forage yield of improved varieties was greater than that of existing grasses the next two years. The yield advantage of improved varieties was greater when managed according to recommended agronomic practices in 2007, but management had no effect in 2008. Forage nutritive value was not influenced by grasses or management at any time during the growing season. Our results suggest that renovation with improved grasses increases pasture productivity, but producers should also consider their management and pasture production goals before renovating.

Introduction
Cool-season perennial grass varieties with improved productivity (5), nutritive value (2), animal preference (4), and persistence (6) are available to grazing-based livestock producers. Graziers who decide to plant these improved varieties, however, must consider the cost and labor of renovating existing pasture, the risk of establishment failure due to unfavorable environmental conditions, and reduced productivity during the establishment period. In addition, the grazier must consider how productive and persistent an improved grass variety will be compared to grasses already growing on the farm under existing management conditions (13). New varieties are selected for superior agronomic performance under relatively controlled conditions, and the difference in productivity between an improved variety and existing grasses may not be apparent in pastures subject to a range of management systems.

Increasing forage intake and livestock production on pasture depends primarily on increasing the quantity of forage available for grazing (16). A major advantage of management-intensive rotational grazing (MIRG) is the low cost of production compared to other livestock production methods (11). If, in order to achieve its production potential and remain persistent, an improved perennial grass variety requires additional management inputs that partially or totally offset gains in forage production, the producer may realize little or no gain in animal performance or profitability. Our objective was to compare the productivity and nutritive value of improved perennial cool-season grass

varieties with existing pasture grasses on diverse, grazing-based farms. Our approach was to make this comparison under a wide but representative range of management, soil, and environmental conditions in order to draw broad inferences about renovation.

Farm Site Description, Renovation, and Management

We conducted this experiment on five Wisconsin farms located along a latitudinal gradient from the southwest to the north-central region of the state, an area that receives ca. 31 to 34 inches annual precipitation and is located in USDA plant hardiness zones 3 and 4. On each farm, a paddock included in the rotational grazing system was chosen for uniformity of soil type, slope, aspect, and vegetation (Table 1). Vegetation was quantified with ten random 30-ft line-point transects for species ground cover (8) (Table 2). Within each paddock, a single replicate of a strip-plot arrangement of treatments was imposed on a 300- by 300-ft area, where the vertical strip was either existing perennial grasses or seeded improved perennial grasses, and the horizontal strip was either management imposed by the producer according to his or her preferences, or recommended agronomic management (15) for rotationally-grazed pastures. The vertical strip intended for seeding of improved grass varieties was sprayed in September 2005 with Round-up herbicide [potassium salt of N-(phosphonomethyl)glycine] to kill all existing vegetation. Soil within the whole plot area was sampled (20 cores to a 6-inch depth) and analyzed by the University of Wisconsin soil and plant analysis laboratory to determine pH and nutrient status. It was not necessary to amend soil pH on any farm; P and K levels were high except on farms no. 4 and 5, where 150 lb K per acre were applied to the horizontal strip intended for recommended agronomic management.

Table 1. Characteristics of five Wisconsin farms and the paddocks on which the experiment was conducted.

	Farm no.				
	1	2	3	4	5
Location	Spring Green (43.18°N, 90.06°W)	Wonewoc (43.65°N, 90.22°W)	Black River Falls (44.30°N, 90.85°W)	Edgar (44.92° N, 89.96°W)	Medford (45.32°N, 90.21°W)
Wisconsin geographic province	Western Upland	Western Upland	Central Plain	Northern Highland	Northern Highland
Soil type	Orion silt loam (coarse-silty, mixed, superactive, non-acid, mesic Aquic Udifluvent)	Urne fine sandy loam (coarse-loamy, mixed, active, mesic Dystric Eutrudept)	Jackson silt loam (fine-silty, mixed, superactive, mesic Typic Hapludalf)	Loyal silt loam (fine-loamy, mixed, superactive, frigid Oxyaquic Glossudalf)	Freeon silt loam (coarse-loamy, mixed, superactive, frigid Oxyaquic Glossudalf)
Farm type	Beef	Beef	Dairy	Dairy	Dairy
Grazing (hr), rotation (days) period	48 – 96, 30 – 50	48 – 96, 30 – 50	12 – 24, 24 - 40	12 – 24, 24 - 40	12 – 24, 24 - 40
Initial, residual sward height (inches)	14 – 16, 6 – 8	14 – 16, 2 - 4	10 – 14, 4 - 6	10 – 14, 4 - 6	10 – 14, 2 - 4
Slope, aspect	1 - 2°, East	6 - 8°, South	1 - 2°, Southeast	1 - 2°, West	3 - 4°, South

In April, 2006, the sprayed strip was disked, harrowed, and a 50:50 mixture (by weight) of 'Bartura' meadow fescue and 'Bronc' orchardgrass was seeded with a Brillion seeder at 20 lb pure live seed per acre. In order to insure successful establishment, the seeded strip was sprayed with 2,4-D (2,4-dichlorophenoxyacetic acid) one month after seeding to control broadleaf weeds, fertilized with 50 lb N per acre as ammonium nitrate when grasses reached 4 inches of height, and fenced to prevent grazing until early July. After

establishment of the improved grasses, the fence was removed and the entire plot area was subject to rotational grazing as dictated by the producer (Table 1).

Producer management practiced each year consisted of the following: composted cattle manure was applied in early spring on farm nos. 3, 4, and 5 at approximately 1 ton (as is) per acre (25 to 50 lb N per acre), and ammonium sulfate was applied in late spring on farm no. 4 at 50 lb N per acre. In addition to the potassium applied before seeding described above, the recommended management consisted of 50 lb N per acre applied as urea in late April and August (15).

Measuring Forage Yield and Nutritive Value, and Statistical Analysis

Throughout the 2006, 2007, and 2008 growing seasons, herbage yield was measured on each farm by the producer with a rising plate meter (14) at nine random locations within each treatment immediately before and after the paddock was grazed. Yield of the renovated area was not measured while fenced during the establishment period. Before the paddock was grazed in the spring, summer, and fall of 2007 and 2008, plate meter measurements were also made at four random locations within each treatment by a project coordinator, who clipped the herbage beneath the plate to a 2-inch residual sward height. Herbage samples were dried in cloth bags at 150°F for 48 h. Dry weights of all herbage samples collected by the coordinators were regressed against the respective plate meter measurements to develop an equation that permitted prediction of yield from plate meter measurements made by each producer. The regression equation describing the relationship between plate meter height (inches) above the ground and actual forage yield (grams DM beneath the 0.20 m^2 plate) was $Y = 6.37x - 10.8$; $r^2 = 0.85$. Annual forage production was calculated by summing the yield measured before the first grazing event and yield measured before subsequent grazing events minus the post-grazing yield of the previous event. Annual utilization was calculated by summing the pre-grazing yield minus the post-grazing yield for all events.

Herbage samples collected by the coordinator were ground (1-mm Wiley mill screen) and analyzed for crude protein (CP), neutral detergent fiber (NDF), and *in vitro* dry matter digestibility (IVDMD) by calibrated near infrared reflectance spectroscopy. Herbage N (CP = N × 6.25) was measured by the Dumas method (1), NDF by the method of Mertens (10), and IVDMD by the method of Goering and Van Soest (7). Calibration statistics were the following: N, standard error of prediction corrected for bias [SEP(C)] = 0.14 and R^2 = 0.97; NDF, SEP(C) = 1.85 and R^2 = 0.94; IVDMD, SEP(C) = 2.78 and R^2 = 0.83.

Data were analyzed by the Mixed Models procedure of SAS (SAS Institute Inc., Cary, NC)with farm site (replicate) and year assumed to be a random effect, and grass (existing vs. improved) and agronomic management (producer vs. recommended) assumed to be fixed effects.

Renovation Success and Annual Yield

During the establishment year (2006), yellow foxtail (*Setaria glauca* L.) was present in portions of the improved grass strip on all farms. White clover germinated, presumably from hard seed produced by plants present before spraying (Table 2), in the improved grass treatment on all farms except no. 1. By the spring of 2007, however, improved orchardgrass and meadow fescue represented 75 to 90% of the ground cover in the improved grass strip on all farms.

Table 2. Species composition of the paddock on each Wisconsin farm before renovation and management treatments were applied.

Common name	Scientific name	Farm no. 1	2	3	4	5
		Cover (%)				
Meadow fescue	*Schedonorus pratensis* (Huds.) P. Beauv.	38	2	1		
Tall fescue	*Schedonorus phoenix* (Scop.) Holub	19	1	6		
Orchardgrass	*Dactylis glomerata* L.	17	10	5	34	1
Kentucky bluegrass	*Poa pratensis* L.	21	14	24	6	35
Timothy	*Phleum pratense* L.	2		13	3	19
Ryegrass	*Lolium perenne* L.				42	
Alfalfa	*Medicago sativa* L.		1	1		
White clover	*Trifolium repens* L.		9	19	7	15
Red clover	*Trifolium pratense* L.		9	1		1
Canada thistle	*Cirsium arvense* L.	1	3	2		
Quackgrass	*Elymus repens* (L.) Gould	3	32	22		28
Broadleaf plantain	*Plantago major* L.		1	1	1	
Buckhorn plantain	*Plantago lanceolata* L.		4			
Common ragweed	*Ambrosia artemisiifolia* L.		2		5	
Common lambsquarter	*Chenopodium alba* L.		3			
Dandelion	*Taraxacum officinale* L.		3	6	3	3
Barnyardgrass	*Echinochloa crusgalli* L.		1			
White cockle	*Silene latifolia* ssp. *alba* (P. Mill.) Greuter & Burdet		1			
Daisy fleabane	*Erigeron annuus* L.		2			
Common burdock	*Arctium minus* L.			1		
Wild radish	*Raphanus raphanistrum* L.			1		
Wild rose	*Rosa setigera* L.		1			
Wild carrot	*Daucus carota* L.		4			

Annual yield of the grass treatment (existing vs. improved) varied with year and agronomic management (producer vs. recommended). As expected, improved grasses produced less forage during the establishment year (2006) than the existing perennial grasses (Table 3). Because grass and weed competition was eliminated before and after seeding as much as practically possible by tillage and herbicides (12) and N fertilizer was applied after grass emergence (17), seedling growth of improved grasses was rapid. Without these practices, the 600 lb DM per acre loss in annual production measured during the establishment year for the improved grasses may have been greater. In each of the two years after the establishment year, improved grass varieties yielded more forage than existing grasses (Table 3). In 2007, this difference was influenced by agronomic management likely related to differences in N application; the yield advantage of improved grass varieties over existing grasses was two-fold greater under recommended management compared to producer management, suggesting that the additional N applied under recommended management exploited the greater production potential of improved grass varieties. In 2008, however, management had no effect on annual forage production (Table 3).

Table 3. Annual forage production of existing grasses and improved grass varieties (mean of five farm sites and two agronomic management systems in 2006 and 2008, and of five farm sites in 2007), and significance of main effects and their interactions.

Grass	2006	2007		2008
		Producer mgt	Recommended mgt	
	Annual forage production (lb DM per acre)			
Existing	4290	4630	4340	4360
Improved	3690	5300**	5710**	5280
	***P* > F**			
Grass (G)	0.086	0.014		0.062
Management (M)	0.217	0.830		0.743
G x M	0.988	0.006		0.431

** Significantly different at $P < 0.01$.

Although replacing existing perennial grasses with improved varieties increased average annual forage yield across all farms after the establishment year, site-specific characteristics and management were likely responsible for differential treatment response on some farms. For example, the greatest increase in annual yield in 2007 and 2008 achieved by planting improved grasses was measured on farm nos. 1 and 2 (Fig. 1). On both farms, weeds, less productive grass species (Kentucky bluegrass), and grasses that livestock may not readily graze (tall fescue) constituted a large proportion of the existing plants (45% on farm no. 1 and over 70% on farm no. 2; Table 2). In contrast, yield increases were relatively less on farm nos. 3, 4, and 5, dairy farms where N fertility inputs were greater than on farm nos. 1 and 2 (Fig. 1). In 2007, existing grasses managed by the producer on farm no. 4 were as productive as improved grass varieties managed by recommended practices, very likely because orchardgrass and ryegrass constituted 76% of the original pasture sward and producer N inputs were roughly equivalent to those applied under recommended management.

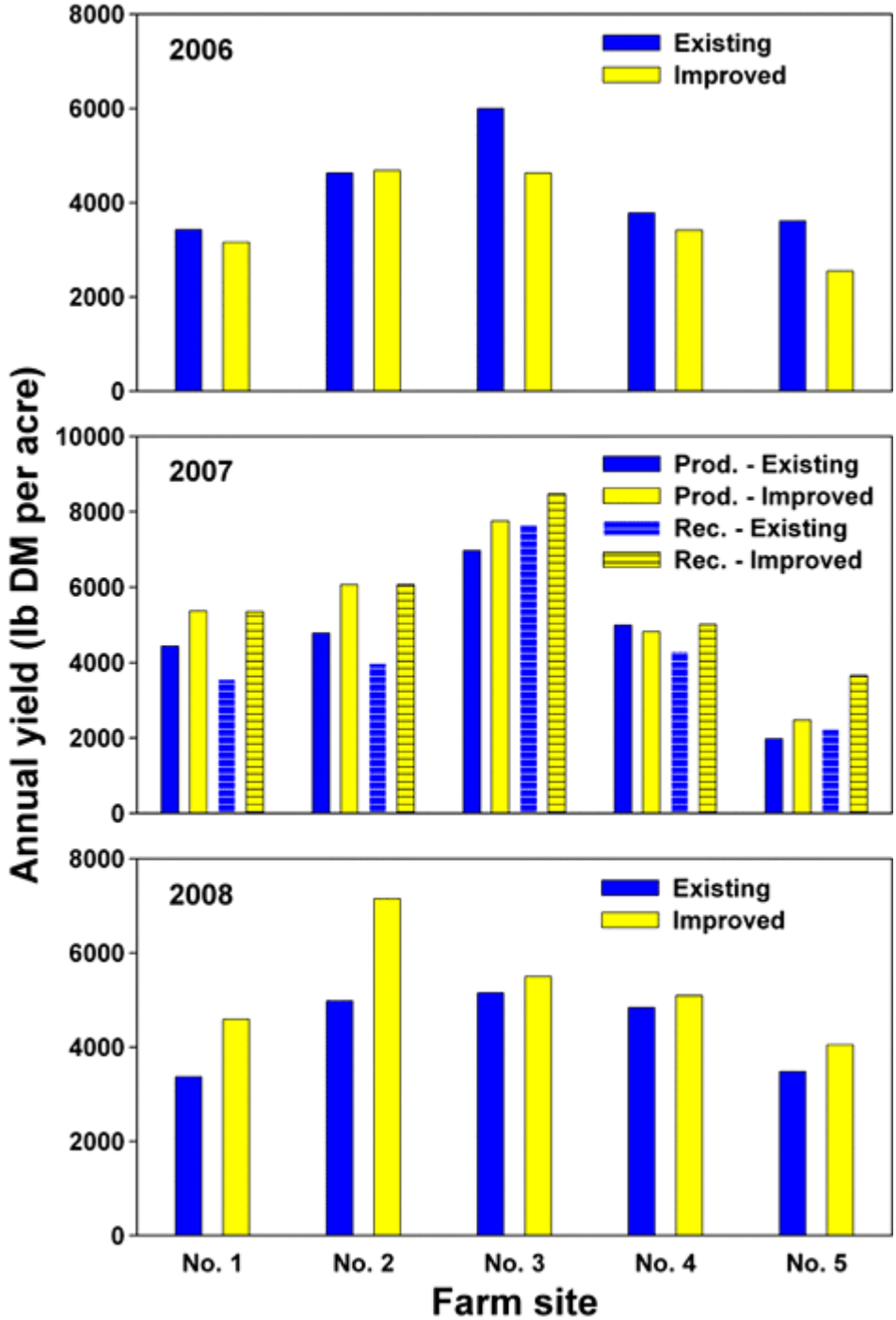

Fig. 1. Annual forage production of existing grasses and improved grass varieties on each of five Wisconsin farms in three years (values in 2006 and 2008 represent the mean of producer management and recommended agronomic management). Each farm served as a single replicate of the treatments; experiment-wise treatment means are presented in Table 3.

Utilization and Forage Nutritive Value

Measurements of forage yield remaining after each grazing event support the findings of Vazquez and Smith (16); estimated pasture utilization was positively associated with dry matter yield ($R^2 = 0.98$, $P < 0.001$). Unlike the significant differences measured among perennial grasses in small-plot experiments (3), no differences in forage nutritive value were found during the spring, summer, or fall between improved and existing grasses managed according to producer preferences or recommended practices. Mean CP, NDF,

and IVDMD was 18.6, 55.2, and 72.7%, respectively, in the spring, 17.8, 53.4, and 72.7%, respectively, in the summer, and 24.9, 48.2, and 76.4%, respectively, in the fall.

Conclusions

From both an economic and agronomic perspective, complete renovation of permanent pasture represents one of the most important decisions a pasture-based livestock producer might make. Costs associated with eliminating existing grasses, seeding new varieties, and reduced productivity during the establishment year, as well as the risk of establishment failure and lower-then-anticipated productivity from improved varieties after seeding must be taken into consideration. The results of this study, conducted on diverse but representative grazing-based farms, indicate that annual forage productivity is increased by replacing unimproved perennial grasses with improved varieties when aggressive renovation practices are employed. The results also suggest, however, that farm-specific characteristics such as existing pasture composition and management influence the annual yield increase a producer will achieve when improved grass varieties are seeded. Producers having pastures comprised of productive, adapted species and currently applying N at recommended rates as manure or inorganic fertilizer may not gain sufficiently more yield by seeding improved grass varieties to justify the risk or cost of renovation. Producers must therefore carefully consider their yield goals and their preferred level of management before pursuing renovation.

Despite documented differences in nutritive value between grass species grown in monoculture (2,3), forage nutritive value did not differ for any of the treatments (grass or management) in the spring, summer, or fall. The results underscore the potential difficulty for differences in forage nutritive value among cool-season grasses to be realized by producers given that farm pastures are seldom composed of a single grass species and often have wide variation in pasture composition. Introducing legumes such as white clover, red clover, or alfalfa into pastures will provide producers with the greatest opportunity to improve pasture nutritive value and animal performance (9).

Acknowledgements

This project was supported in part by grants from the University of Wisconsin-Madison Center for Integrated Agricultural Systems and the Grazing Lands Conservation Initiative. We wish to sincerely thank Dick Cates, Robert Pesz, Roger Kaufmann, Peter Arnold, and Mark Matyka for their commitment and willingness to provide pasture land and to make timely measurements of pasture growth that made this investigation possible.

Literature Cited

1. Bremner, J. M. 1996. Nitrogen - total. Pages 1085-1121 in: Methods of Soil Analysis: Part 3. Chemical Methods. D. L. Sparks, ed. SSSA and ASA, Madison, WI.
2. Brink, G. E., and Casler, M. D. 2009. Meadow fescue, tall fescue, and orchardgrass response to nitrogen application rate. Online. Forage and Grazinglands doi:10.1094/FG-2009-0130-01-RS.
3. Brink, G. E., Casler, M. D., and Hall, M. B. 2007. Canopy structure and neutral detergent fiber differences among temperate perennial grasses. Crop Sci. 47:2182-2189.
4. Casler, M. D., Undersander, D. J., Fredericks, C., Combs, D. K., and Reed, J. D. 1998. An on-farm test of perennial forage grass varieties under management intensive grazing. J. Prod. Agric. 11:92-99.
5. Casler, M. D., Pitts, P. G., Rose-Fricker, C., Bilkey, P. C., and Wipff, J. K. 2001. Registration of 'Spring Green' festulolium. Crop Sci. 41:1365-1366.
6. Conger, B. V. 2003. Registration of 'Persist' Orchardgrass. Crop Sci. 43:436-437.
7. Goering, H. K., and Van Soest, P. J. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). Agric. Handbook 379. USDA-ARS, Washington, DC.
8. Jonasson, S. 1983. The point intercept method for non-destructive estimation of biomass. Phytocoenologia 11:385-388.

9. Koch, D. W., Holter, J. B., Coates, D. M., and Mitchell, J. R. 1987. Animal evaluation of forages following several methods of field renovation. Agron. J. 79:1044-1048.
10. Mertens, D. R. 2002. Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: Collaborative study. J. AOAC Inter. 85:1217-1240.
11. Paine, L. K., Klemme, R. M., Undersander, D. J., and Welsh, M. 2000. Wisconsin's grazing networks: history, structure, and function. J. Natural Res. and Life Sci. Education 29:60-67.
12. Samson, J. F., and Moser, L. E. 1982. Sod-seeding perennial grasses into eastern Nebraska pastures. Agron. J. 74:1055-1060.
13. Sanderson, M. A., and Elwinger, G. F. 2002. Plant density and environment effects on orchardgrass-white clover mixtures. Crop Sci. 42:2055-2063.
14. Sanderson, M. A., Rotz, C. A., Fultz, S. W., and Rayburn, E. B. 2001. Estimating forage mass with a commercial capacitance meter, rising plate meter, and pasture ruler. Agron. J. 93:1281-1286.
15. Undersander, D. J., Albert, E. C., Cosgrove, D. R., Johnson, D. G., and Peterson, P. R. 2002. Pastures for profit: A guide to rotational grazing. Coop. Ext. Pub. A3529. Univ. of Wisconsin, Madison, WI.
16. Vazquez, O. P., and Smith, T. R. 2000. Factors affecting pasture intake and total dry matter intake in grazing dairy cows. J. Dairy Sci. 83:2301-2309.
17. Whalley, R. D. B., and McKell, C. M. 1976. Seedling vigor of some important range species as affected by nitrogen and phosphorus. Agron. J. 68:565-569.