J. Range Manage.
49:368-371

Switchgrass recruitment from broadcast seed vs. seed fed to cattle

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Abstract

Fecal seeding by livestock may be an effective, low-cost means of rangeland restoration. We compared recruitment of switchgrass (*Panicum virgatum* L.) from seed fed to cattle and deposited in dung to that of broadcast-seeded plots receiving a comparable number of unfed seed. Although germinability of seed passed through livestock (52 to 62%) was reduced relative to that of broadcast seed (85 to 91%), recruitment of switchgrass from seed in cattle feces was equal to or superior to that of broadcast seed in terms of establishment (frequency of occurrence and density), plant growth and final plant size. The frequency of plots with emerging switchgrass plants ranged from 62 to 100% when seeds were delivered in feces, but only 2 to 40% when seeds were broadcast. After 1 year, the frequency of occurrence of switchgrass plants in fecal vs. broadcast-seeded plots was comparable for autumn trials. However, evaluations 1 year after the spring trials continue to result in higher frequency of plots with switchgrass plants from seed delivered in feces than of broadcast seedings (56 vs. 4% for May 1990, $P<0.05$; and 90 vs. 51% for May 1991, $P \leq 0.01$). Enhanced plant recruitment on fecal-seeded plots occurred even though broadcast-seeded plots received 1.5 to 1.7 times more pure live seed (PLS). Plants on fecal-seeded plots had a greater plant size score (based on visual ratings of height, culm density, and biomass) than plants on broadcast-seeded plots ($P < 0.05$ for May seedings; $P < 0.05$ for October 1990; $P > 0.10$ for October 1991). Results suggest significant advantages of fecal seeding over conventional broadcast seeding in terms of seedling emergence, establishment and growth.

Key Words: (*Panicum virgatum* L.), seed dispersal, revegetation/restoration, plant establishment, seed germination, seed-feeding

Seed dispersal by domestic animals and wildlife is known to contribute to the spread of desirable and undesirable plants (Janzen 1984). The potential to utilize this knowledge to direct and enhance pasture and rangeland species composition has been variously explored (Burton and Andrews 1948, Dore and Raymond 1942, Glendening and Paulsen 1950), with a renewed interest in more recent literature (Wilson and Hennessy 1977, Wicklow and Zak 1983, Simao Neto et al. 1987, Barrow and Havstad 1992, Gardener 1993, Gardener et al. 1993, and Ocumpaugh et al. 1993). Most of the above cited research was restricted to seed viability measurements determined in germination cabinets or greenhouse studies. Viability of seeds recovered from feces varied from zero for some grass species to relatively high for other grass species. For those grass species with good survival through the digestive system, there is a near linear decline in seed viability with increased retention time (Burton and Andrews 1948, Simao Neto et al. 1987, and Ocumpaugh et al. 1993). Potential benefits for using livestock in rangeland restoration efforts have been reviewed (Archer and Pyke 1991). The benefits of delivering seed in dung include: enhanced microsite fertility, increased organic matter, increased water-holding capacity, short-term reduction in competition with extant vegetation, and short-term rejection of grazing near dung. A major disadvantage to delivering seed via feces is the poor distribution of feces across the landscape. However, if this technology was employed with a well-adapted plant, fecal-dispersed seeds could become the localized sources of seed for long-term rangeland improvement. To enhance our success with fecal seeding, an understanding of germination kinetics in the dung pat and subsequent seedling establishment will be required. In a previous study, 26% of switchgrass (*Panicum virgatum* L.) seed fed to cattle was found to escape mastication and digestion and be excreted in a viable form (Ocumpaugh et al. 1991). In this study, field recruitment of fed switchgrass seed in cattle dung was compared to that of unfed seed broadcast in the spring and autumn of each of 2 years.

This research was partially funded by USDA-CSRS grant 89-38300-4505 and Texas Agricultural Experiment Station Projects 6249, 6717 and 8148. The authors wish to thank Jeff Rahmes, Domingo Martinez, Jr., and Fred Bryn for assistance with field work and data processing.
Manuscript accepted 20 Sep 1995.

Materials and Methods

On each of 4 dates (May 1990, October 1990, May 1991, and October 1991), seeds of 'Alamo' switchgrass were fed to 2 cows and 2 steers which had been maintained on bermudagrass [*Cynodon dactylon* (L.) Pers.] hay for several days. About 200 g (200,000 seed) of switchgrass seed were mixed with a small amount of ground corn, soybean meal, and cane molasses and fed to each animal once a day for 2 days. Feces excreted 12 to 60 hours after the initial feeding of switchgrass seed were collected, composited and thoroughly mixed. Three subsamples (about 250 g fresh wt) were taken for dry matter calculations. The number of seeds per gram of feces was determined on 10 subsamples (about 100 g fresh wt each). Seed were recovered from feces within 24 hours following the mixing by placing the sample in a 400-ml beaker, filling it with water and stirring with a glass rod. The resulting suspension was allowed to settle momentarily and the forage residue decanted over a screen-covered bucket. Additional water was added and the process was repeated 10 to 15 times until what remained in the beaker was mainly seed. The remaining sample was vacuum filtered to aid water removal, and then air dried. Seed that were inadvertently poured off were recovered from the screen. After seed were dry, samples were sieved to aid in removal of forage residue and counted. All recovered seed were germinated (>100 per subsample). Four samples of 150 seed each of unfed seed were germinated for each seeding date. Seed were germinated in glass petri dishes (10 × 100 mm) with one piece of germinating paper below and one above the seed.

Seed were moistened with distilled water, dusted with captan (cis-N-trichloromethyl thio-4-cyclohexene-1,2-dicarboximide) and placed in germinator cabinets set at 32/18°C (day/night) with 9 hours of light associated with the day temperature. Seed were examined for germination daily for the first 7 days then on days 10, 14, 21, and 28. Additional distilled water was added as needed. A seed was considered to have germinated when the radicle protruded through the seed coat. The 28-day total germination results were used to calculate total viable seed placed in field plots.

Fecal samples were immediately transported to the Texas A&M University, La Copita Research Area near Alice, Texas, for placement in field plots which were fenced to exclude large herbivores. A total of 4 enclosures were used for this research, one for each seeding date. The enclosures were located in a hay pasture consisting of fertilized native and naturalized annual and perennial grasses which had been treated with glyphosate herbicide 3 weeks previously. Killed herbage was not removed. Soils were Clareville clay loam (fine, montmorillonitic, hyperthermic Pachic Argiustolls) with a high pH (8.2 to 8.4) and moderate to high fertility. These soils contain suitable concentrations of all macronutrients except nitrogen (10 to 15 kg/ha of N). Long-term average rainfall for the area is 68 cm, with rainfall for 1988, 1989, 1990, 1991, and 1992 totaling 39, 37, 57, 83, and 91 cm, respectively. Rainfall distribution is typically bimodal, with peaks in May–June and September.

Eight plots of 25 subplots (0.5 × 0.5 m) were situated within each 8 × 30 m enclosure. A calibrated container was used to apportion out seed-rich feces (about 600 g fresh wt) to 4 of the 8 plots to generate 100 subplots with seed-rich feces at each date. About 1 week later, seeds totaling the number dispensed in feces were broadcast on the other 4 plots of 25 subplots. The broadcast seed was concentrated over approximately the same area as those in feces so as to standardize differences in recruitment that might otherwise result from density dependent mortality. The calculated PLS per hectare assumed an effective seeding area of about 900 cm^2. Because the experiment was initiated during a period of extended drought, an automated sprinkler system was installed to provide supplemental water (1 to 2 cm) 2 nights per week in all of the 4 seeding trials in 1990 and 1991. Irrigation was not done during the mid-winter period, and all irrigation was terminated at a site within 1 year of seeding. The 1991 trials were not irrigated in 1992, the year post-seeding, as rainfall was above normal.

Switchgrass recruitment was evaluated periodically. Because of difficulties in counting large numbers of emerging seedlings or identifying the number or size of individual plants at later stages of development, plant size (visual estimate of seedling density, standing crop, basal diameter and height) was rated on a 0 to 9 scale. A score of 1 was assigned if small plant(s) dominated the plot, while a 9 was assigned when large plant(s) were present within a plot. The score presented for each treatment is a mean of plots with a score of at least 1. Zero scores were deleted from the analysis of plant size data so as to be able to compare relative plant size of the plots with at least 1 switchgrass plant. The value associated with the scale at any particular sampling date was not comparable with other sampling or seeding dates. Hence, a score of 5 represented the mid-sized seedlings (5 to 10 cm tall) in the plot of a new planting and could have represented a 1-m tall plant with 12 to 15 culms from an earlier planting date on the same evaluation date. In addition to the specific scores that were assigned to each subplot, the evaluators recorded other notes and comments about each site and plot at each evaluation date. These notes and comments could not be analyzed, but will be used in the discussion when appropriate.

Analysis of variance was conducted using general linear model procedures (SAS 1985) for each planting date and sampling date. Frequency of occurrence (proportion of subplots within a block of 25 subplots with at least one switchgrass plant) was handled as a completely random design with 4 replications and 2 treatments. Plant size scores on plots with switchgrass plants were treated as nested values within seeding treatment (feces vs. no feces). Statistical differences (P-values) reported are the F-tests for seeding treatment from the above described analysis of variance. Standard errors were calculated and reported for each set of means.

Results and Discussion

Total seed per site varied with seeding date (Table 1). Calculated seeding rates were 10 to 20 times higher than recommended rates for switchgrass (Vassey et al. 1985, USDA/SCS 1988). Germinability of broadcast seed (85 to 91%) exceeded that of seed recovered from feces (52 to 62%) for each trial date. As a result, the calculated pure live seed (PLS, kg/ha) delivered to broadcast plots was 1.5 to 1.7 times that of fecal-seeded plots.

Table 1. Seeding rate and laboratory germination data on fecal and broadcast seeding trials initiated in May and October of 1990 and 1991.

	Seeding Date			
Variable	May 1990	Oct. 1990	May 1991	Oct. 1991
Fecal Plots				
Germination, %	61±1[1]	62±1	52±1	55±1
Viable seed (number)	1108±73	756±22	1282±81	798±94
PLS kg/ha	155±10	97±3	140±9	106±12
Broadcast Plots				
Germination, %	85±2	91±2	85±3	87±2
Viable seed (number)	1544±39	1106±21	2087±64	1268±31
PLS kg/ha	216±5	145±3	223±7	165±4

[1]Mean and standard error based on 10 subsamples for fecal plots and 4 subsamples for broadcast plots.

Establishment of switchgrass plants from seed in feces was superior to that from broadcast seed for May seedings (Tables 2 and 3). The frequency of occurrence of switchgrass plants declined over 2 growing seasons for both fecal- and broadcast-

Table 2. Percentage of plots ($\bar{X}$±SE) with at least one Alamo switchgrass plant at 4 evaluation dates from fecal and broadcast seeding made in May of 1990 or 1991.

	Evaluation Date							
	Seeded in May of 1990				Seeded in May of 1991			
Seeding Method	27 June 1990	24 Aug. 1990	26 June 1991	8 Aug. 1991	26 June 1991	8 Aug. 1991	19 June 1992	3 Sept. 1992
	(%)							
Fecal	100±0	99±1	56±18	42±17	62±10	61±9	90±5	92±4
Broadcast	40±10	24±10	4±2	2±1	2±1	1±1	51±6	55±5
P-value	0.001	0.001	0.03	0.05	0.001	0.001	0.003	0.001

seeded plots initiated in May 1990, but increased over 2 growing seasons for plots seeded in May 1991. These contrasting trends in switchgrass recruitment between years may reflect differences in amount and seasonal patterns of annual rainfall and differences in interspecific competition experienced by seedlings of the 2 plantings. For example, general notes indicated that common buffelgrass (*Cenchrus cilliaris* L.) quickly re-established dominance on the plots initiated in 1990, but did not do so on plots initiated in 1991. When evaluated in April 1991, the May 1990 planting had only a few plots in the broadcast-seeded treatments with switchgrass plants 20 to 30 cm tall. However, switchgrass plants in fecal-seeded plots were typically 25 to 60 cm tall. General notes recorded 1 month after planting in May of 1991 revealed 10 to 30 switchgrass seedlings per plot at the 3 to 4 leaf stage in fecal-seeded plots, whereas only an occasional single seedling was present in broadcast-seeded plots.

Plants produced from seed dispersed in feces had a greater plant size score (3.8 to 7.2 of 9.0 possible) than plants emerging from broadcast seed (1.0 to 3.0) (Table 3). For the May 1990 seeding, initial differences in plant growth ratings became similar by the end of the second growing season (fecal = 4.8; broadcast = 3.0). However, for the May 1991 seedings, differences after 2 growing seasons remained significant (fecal = 5.8; broadcast = 2.7). By mid-June 1992, switchgrass plants in the fecal-seeded plots were 1 to 1.5 m tall and were estimated to have 100 times more standing crop than the broadcast-seeded plots. At the final evaluation in September 1992, switchgrass plants arising from seed in dung were approaching 2 m in height with 15 to 50 culms/plot. In contrast, switchgrass plants arising from broadcast seed were typically <1 m tall with only 2 to 5 culms/plot.

Table 3. Mean plant size score ($\bar{X}$±SE) of Alamo switchgrass plants at 4 evaluation dates from fecal and broadcast seedings made in May of 1990 or 1991.

	Evaluation Date							
	Seeded in May of 1990				Seeded in May of 1991			
Seeding Method	27 June 1990	24 Aug. 1990	26 June 1991	8 Aug. 1991	26 June 1991	8 Aug. 1991	19 June 1992	3 Sept. 1992
	(score[1])							
Fecal	4.5±0.2	4.1±0.2	4.2±0.3	4.8±0.4	ND[2]	3.8±0.2	7.2±0.2	5.8±0.2
Broadcast	1.9±0.1	1.8±0.1	2.5±0.5	3.0±2.0	ND	1.0±0.0	2.8±0.2	2.7±0.1
P-value	0.001	0.001	0.05	0.23		0.09	0.001	0.02

[1]Score scale, 0 = no plant, 9 = plot with largest plant(s). Mean score calculated on plots with a minimum score of 1.
[2]ND = Not Determined.

With trials initiated in October, frequency of switchgrass seedlings from seed in feces was initially higher than that of plants produced from broadcast seed (Tables 4 and 5). However, these statistical differences generally disappeared by the following spring or summer. Overwinter reductions in frequency of occurrence of plants in the October 1990 seeding were followed by recruitment of new individuals and an increase in frequency of occurrence the subsequent growing season. This was in contrast

Table 4. Percentage of plots ($\bar{X}$±SE) with at least 1 Alamo switchgrass plant at several evaluation dates from fecal and broadcast seedings made in October of 1990 or 1991.

	Evaluation Date							
	Seeded in October of 1990					Seeded in October of 1991		
Seeding Method	13 Nov. 1990	26 June 1991	8 Aug. 1991	19 June 1992	3 Sept. 1992	7 Nov. 1991	19 June 1992	3 Sept 1992
	(%)							
Fecal	89±6	39±5	48±10	65±9	68±8	62±10	82±10	92±8
Broadcast	28±5	28±10	32±9	53±12	65±14	6±6	71±10	81±8
P-value	0.001	0.35	0.28	0.45	0.86	0.003	0.48	0.42

Table 5. Mean plant size score ($\bar{X}$±SE) of Alamo switchgrass plants at several evaluation dates from fecal and broadcast seeding made in October of 1990 and 1991.

	Evaluation Date							
	Seeded in October of 1990					Seeded in October of 1991		
Seeding Method	13 Nov. 1990	26 June 1991	8 Aug. 1991	19 June 1992	3 Sept. 1992	7 Nov. 1991	19 June 1992	3 Sept. 1992
	score[1]							
Fecal	ND[2]	2.3±0.3	4.2±0.2	6.0±0.2	5.2±0.3	ND	3.2±0.2	4.4±0.2
Broadcast	ND	2.2±0.3	3.4±0.3	5.3±0.3	4.3±0.3	ND	3.3±0.2	4.3±0.2
P-value		0.34	0.02	0.06	0.08		0.83	0.83

[1]Score scale, 0 = no plant, 9 = plot with largest plant(s). Mean score calculated on plots with a minimum score of 1.
[2]ND = Not Determined

to the May 1990 seedings, where there was no net recouping of overwinter losses. Jones et al. (1991) evaluated seedlings germinating from naturally-collected fecal samples. They conducted their germination trials in a greenhouse using wet-dry cycling and found that 64% of all seedlings germinated during the first (of 4) 8-week wet cycle, suggesting that all viable seed may not germinate even under ideal growing conditions.

The good success (65 to 92%) from autumn seeding observed here regardless of seeding technique is in agreement with the generally accepted practice of late-summer seeding of switchgrass or kleingrass (*Panicum coloratum* L.) in this sub-tropical region (USDA/SCS 1988). Seeding recommendations imply that excellent stands can be expected from only 2 to 3 kg PLS ha^{-1} when planted between mid-August and late-October in cultivated pastures (USDA/SCS 1988). Recruitment of switchgrass from seed in cattle feces was equal to or better than that of broadcast seed with respect to frequency of occurrence and plant size, particularly for the spring (May) trials (Tables 2–5). Advantages of fecal seeding were realized even though broadcast-seeded plots received 1.5 to 1.7 times more PLS (Table 1). Over the longer term (2 growing seasons), benefits apparently associated with fecal enhancement of microsite fertility were manifested in greater switchgrass growth and survival. Data from the May 1991 and both October trials further indicate that recruitment of switchgrass from broadcast seed and seed in dung can occur for at least 2 growing seasons following dissemination. The reader should be cautioned that these responses were obtained utilizing supplemental water and complete chemical control of existing vegetation at seeding. This approach likely enhanced the percent success of both seeding techniques. However, the enhanced plant size from fecal seeding likely is a true treatment affect.

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