Using Cattle to Disperse Seeds for Winter Forage Plants

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ABSTRACT

The effectiveness of using cattle to disperse cool-season plant seeds was assessed in 4 trials. In Trial 1, 4 steers were fitted with total fecal collection bags and fed seeds from 6 different cool season forage species to determine seed recovery rate. The 6 species used were Illinois bundleflower (*Desmanthus illinoensis* (Michx.) MacM.), hairy vetch (*Vica villosa* Roth.), perennial ryegrass (*Lolium perenne* L.), western wheatgrass (*Elytrigia smithii* (Rydb.) Nevski), Maximilian sunflower (*Helianthus maximiliani* Shrade.), and Engelmann daisy (*Engelmannia pinnatifida* Nutt.). Seed recovery varied (P<0.05) among species with 75% of Illinois bundleflower seeds recovered to no seeds of western wheatgrass recovered. In Trial 2, *in situ* and *in vitro* digestion techniques were used to assess seed weight loss to digestion. Hairy vetch and Engelmann daisy both lost more than 16% of their weight while all other seeds lost 5% or less of their weight during rumen incubation. During *in vitro* digestion, hairy vetch and Engelmann daisy lost 29% and 15% of their weight, respectively. Trial 3 assessed the affect of digestion on germination of surviving seeds. Seeds were collected from feces and placed in petri dishes along with nonfed seeds to compare germination before and after ingestion. Passing through the digestive tract of cattle reduced germination of all species except Illinois bundleflower. In Trial 4, seedling emergence and establishment were compared among seeds deposited in dung pats and seeds planted using traditional agronomic techniques. Perennial ryegrass established in dung pats, while others did not. Collectively, these results indicate that perennial ryegrass and Illinois bundleflower may be suitable candidates for fecal seeding while others are not because they are unable to pass through the ruminant digestive system and germinate.

KEY WORDS: fecal, cool-season, improvements, seeding, digestion, germination

INTRODUCTION

Seeding of rangelands has become widely used for improvement of range sites since its emergence as a technology about 100 years ago (Call and Roundy, 1991). In the semiarid southwest, these efforts often are aimed at increasing warm-season grass production, but cool-season forages are also an important component of productive rangelands in the southwest.

Successful reseeding efforts are difficult because revegetation processes in the semiarid southwest are regulated by episodic environmental conditions rather than average conditions (Call and Roundy, 1991). Seedling germination, establishment, and persistence occur during infrequent years of well above-average precipitation (Westoby, 1980). Traditional seeding methods often fail to overcome environmental and climatic factors that limit

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seedling success and can be very expensive (Valentine, 1989). Seedling recruitment will fail if requirements for seed germination and seedling establishment are not met by the microsite (Grubb, 1977; Harper, 1977; Winkel et al., 1991). Thus, seedling establishment is often the result of the number of seeds that are deposited in favorable microsites rather than the total number of seeds dispersed (Harper et al., 1965; Young, 1988).

The number of favorable microsites may be increased by using livestock to disseminate seeds in feces (Akbar et al., 1995). Seeds delivered in dungpats should benefit from the microsite's high organic matter, high moisture content, short-term avoidance of grazing, and short-term reduction of competition with pre-existing vegetation. For instance, fecal delivery of switchgrass (*Panicum virgatum* L.) was advantageous over the traditional broadcast seeding (Ocumpaugh et al., 1996). On fecal-seeded plots, switchgrass recruitment was equal to or greater than the recruitment of switchgrass on broadcast-seeded plots, and fecal-seeded plants were larger than broadcasted-seed plants. Several other species of seeds survive the digestive system of livestock (Harmon and Keim, 1934; Dore and Raymond, 1942; Burton and Andrews, 1948; Janzen, 1981), and a large portion of seeds may remain viable (Heady, 1954; Lehrer and Tisdale, 1956; Peinetti et al., 1993; Wallander et al., 1995).

Using cattle to disseminate seeds is promising, but the approach has not been used extensively to establish cool-season forages in the semi-arid southwest. We conducted a series of trials to assess the effectiveness of using cattle to disperse seeds from cool-season forage plants and to identify differences in seed recovery, germination, and establishment among species after ingestion by cattle.

MATERIAL AND METHODS

Animals and Feeding

In Trials 1, 3, and 4, we used 4 crossbred steers weighing approximately 200 kg. Steers were kept at the Angelo State University (ASU) Management, Instruction, and Research (MIR) Center and housed in 3 m × 6 m pens. Steers were fed a basal ration (1.5% BW) (Table 1) and Sudan hay to meet maintenance requirements (NRC 1984). Water was provided ad libitum. In Trial 2, we relied on a ruminally cannulated steer for an *in situ* digestion trial and for rumen fluid collection for a two-stage *in vitro* digestion trial. The steer was fed the same basal ration (1.5% BW) and Sudan hay for 21 days prior to Trial 2.

Trial 1: Seed Recovery

To assess seed recovery rates from different cool season forage species, 4 steers were fitted with fecal collection bags. Seeds were intermixed with the basal ration and fed to the steers. Seeds from 6 different plant species were fed on separate occasions to individual steers (n = 4), with each seed fed to all steers once and feces collected until no seeds were found in samples. Two grasses were used along with 2 legumes and 2 composites. All selected plant species were cool-season plants, palatable forages, and adapted for survival in the semi-arid southwestern U.S. These included western wheatgrass (*Elytrigia smithii*

Table 1. Ingredients and nutrient content of ration fed to steers to meet maintenance requirements.

Ingredient	Percent (%) in Diet
Alfalfa, 17% dehy	25.0
Corn	48.8
Cottonseed meal	8.8
Gin Trash	15.0
Beef Premix[1]	2.5
Nutrient	
Crude Protein	14.5
Digestible Energy	2.8
Crude Fiber	13.2
Total Digestible Nutrients (TDN)	62.5

[1] Beef premix included Lasalocid (1158 g/907kg), 22.8% Ca, 22.8% Salt, 1.4% Mg, .21% Zn, .1% Mn, 3.9 ppm Se, and 18,182 IU/Kg Vitamin A.

(Rydb.)Nevski), and perennial ryegrass (*Lolium perenne* L.), Illinois bundleflower (*Desmanthus illinoensis* (Michx.) MacM.), hairy vetch (*Vicia villosa* Roth.), Engelmanndaisy (*Engelmannia pinnatifida* Nutt.), and Maximillian sunflower (*Helianthus Maximiliani* Shrade.). We fed 113 g of each seed to each steer because individual seed size and weight varied among species. Seeds were fed at a given weight rather than a set number to minimize the effect of feed-to-seed ratio on loss of seeds to mastication.

Each morning of the trial, each steer's feces was collected, weighed, thoroughly mixed, and a 200 g sample was collected. Feces were washed through a series of screens to recover seeds. The number of seeds recovered and the weight of the fecal sample was used to estimate the total number of seeds in the fecal collection for that day. After a minimum collection period of 4 d, seed recovery was terminated when no seeds were found in fecal samples. Each steer was monitored separately and the average percentage seed recovery was estimated for each day and across all days.

Trial 2: Seed Digestion

In Situ Digestion

A ruminally cannulated steer was used to estimate seed weight loss from rumen digestion. We assumed that seed weight loss would result from seed digestion or seed damage from digestion which would reduce seed viability. Seeds were sealed in porous nylon bags, weighed, and incubated in duplicate along with blanks in the rumen for 12 and 24 hours. Bags were extracted, thoroughly washed, dried at 105° C for 12 hrs, and re-weighed to determine percent seed weight loss to rumen fermentation. Weight gained by blanks was used as a correction factor when determining weight lost by seeds.

In Vitro Digestion

Each species seed was exposed to a two-stage *in vitro* digestion technique (Tilley and Terry, 1963) to quantify seed weight loss to rumen and abomasal digestion. Rumen fluid

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was collected from a ruminally cannulated steer fed the same basal ration and Sudan hay diet as in Trial 1. Samples in triplicate and blanks were incubated in rumen fluid for 48 hrs and a HCL-pepsin solution for 24 hrs. After incubation, residual material was dried at 105° C for 12 hrs and re-weighed to determine the average weight loss of seeds. Weight gained by blanks was used as a correction factor.

Trial 3: Seed Germination

An estimate of the difference in germination of fed and nonfed seeds was made for each species. Seeds from the fed treatment were obtained by washing dung through a series of screens. Fed and nonfed seeds were placed on moist filter paper in petri dishes. Eight replicate treatments were assigned to petri dishes completely at random. Treatments were a factorial combination of species and fed or nonfed. Each petri dish received 4 seeds. The dishes were placed under a bank of fluorescent and incandescent lights and maintained at a temperature of 25° C. Lights were on for 12 hours (day), and off for 12 hours (night) each day. Moisture was added as needed. Seeds were monitored and seedlings removed every 7 days for 21 days. On day 21, all remaining ungerminated seeds were collected and percentage germination calculated. Engelmann daisy and western wheatgrass were excluded from this experiment because low recovery rates made collection of adequate seed numbers impractical.

Trial 4: Seeding

A single site was selected for the seeding trial on a plowed field adjacent to the MIR Center. Each seed was hand-seeded on 4 randomly assigned 0.5 m × 8 m replicates with 100 seeds per replicate. Dung pats for each species were randomly assigned to 3- 0.5 m × 8 m replicates with 8 dung pats per replicate. Feces was collected 2 days after feeding seeds to steers. All fecal material was combined and throughly mixed. Fecal material was shaped by hand 30 cm-diameter dung pats. The number of seeds per dung pat was estimated based on seed recovery rate from Trial 1. Half of the hand-seeded and fecal-seeded plots were watered weekly to promote establishment. A sprinkler was used to simulate rainfall at the rate of approximately 3 cm per hour. When watering, the sprinkler was moved periodically to adjust for wind and droplet patterns. The number of emerging seedlings were marked and recorded every 7 days for 42 days.

Statistical Analysis

Differences in survival of seeds fed to steers was determined by analyzing data using repeated measures analysis of variance because data was collected over several days (Hicks, 1993). Species of seed served as the main effect and steers served as replications. In Trial 2, differences among species of seeds was compared using analysis of variance for the *in situ* and *in vitro* digestion trials. Differences in germination among fed and nonfed seeds and differences among species was assessed using repeated measures of analysis of variance in Trial 3. The least significant difference (LSD) test was used to

Table 2. Percentage (%) seed survival of 6 cool season forages fed to steers in a mixed ration. Total fecal collections were used to recover seeds in dung.

Species	Percent Seed Recovery
Engelmanndaisy	1.5[c]
Maximillian sunflower	29.1[bc]
hairy vetch	40.6[b]
Illinois bundleflower	75.0[a]
perennial ryegrass	37.3[b]
western wheatgrass	0.0[d]

[a-d]Means with different superscripts differ (P<0.05)

determine differences among means when P ≤ 0.05 (Gomez and Gomez ,1984). Data from Trial 4 was not analyzed because of limited emergence and establishment.

RESULTS

Trial 1: Seed Recovery

The first objective of this study was to determine the percentage of seeds remaining intact after passage through the digestive system of cattle. More (P<0.05) Illinois bundleflower seeds remained intact than the other species; 75% of Illinois bundleflower seeds were found whole in the feces (Table 2). Fewer hairy vetch, perennial ryegrass, and Maximillian sunflower seeds were recovered than Illinois bundleflower, while few seeds of Engelmanndaisy were recovered. No western wheatgrass seeds were found in fecal samples.

Daily recovery rate of seeds differed (P<0.05) across the 4 days of fecal collection (Figure 1). More seeds were deposited in dung on day 2 than on days 1, 3, and 4. No seeds were recovered after day 4.

Trial 2: Digestion of Seeds

Hairy vetch and Engelmanndaisy seeds showed significant (P<0.05) weight loss during *in situ* incubation (Table 3). Illinois bundleflower, Maximillian sunflower, perennial ryegrass, and western wheatgrass showed little weight loss to rumen digestion.

An *in vitro* digestion trial was used to quantify the combined effect of rumen and abomasal digestion. Hairy vetch lost more (P<0.05) weight during digestion than the remaining species (Table 4).

Trial 3: Seed Germination

The potential success of fecal seeding depends on the germinability of seeds after fecal deposition. Engelmanndaisy and western wheatgrass were excluded from the germination test because of their low recovery after digestion. Germination was reduced (P<0.05) for all species except Illinois bundleflower (Table 5). Hairy vetch seeds did not germinate after passage through the digestive tract of steers. Perennial ryegrass and

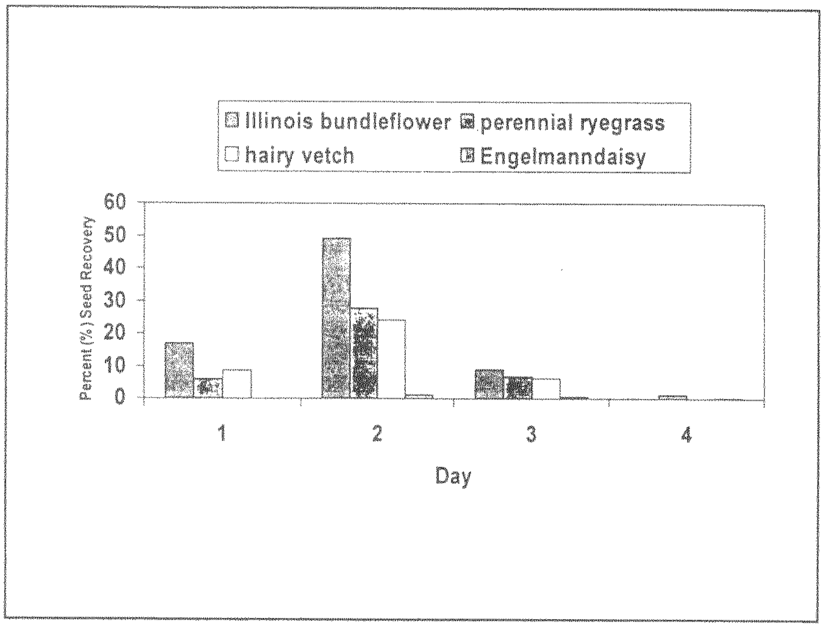

Figure 1. The percentage of seeds fed that was found whole in the feces each day for 4 days after ingestion. Means were averaged across all steers. Western wheatgrass seeds were not found in feces. No seeds were found after the fourth day after ingestion.

Table 3. Percentage (%) weight loss of seeds after 12 and 24 hours of *in situ* digestion

	Percent Weight Loss	
Species	12-hour	24-hour
Engelmanndaisy	14.0[a]	19.3[a]
Maximilian sunflower	3.9[d]	3.7[d]
hairy vetch	13.3[b]	19.1[a]
Illinois bundleflower	4.2[cd]	5.1[c]
perennial ryegrass	2.8[e]	3.1[e]
western wheatgrass	4.5[d]	5.8[b]

[a-e] Means within columns with different superscripts differ ($P<0.05$)

Table 4. Percentage (%) weight loss of seeds during *in vitro* digestion.

Species	Percent Weight Loss
Engelmanndaisy	15.3[b]
Maximilian sunflower	29.2[a]
hairy vetch	18.0[b]
Illinois bundleflower	18.0[b]
perennial ryegrass	14.0[b]
western wheatgrass	14.7[b]

[a-b] Means within columns with different superscripts differ ($P<0.05$)

Table 5. Percentage (%) germination for both fed and nonfed seeds.

Species	Percent Germination		Difference[1]
	Fed	Nonfed	
hairy vetch	0.0^{d}	72^{b}	S
Illinois bundleflower	27.5^{b}	27.5^{c}	NS
Maximillian sunflower	15.0^{c}	22.5^{c}	S
perennial ryegrass	75.0^{a}	97.5^{a}	S

[a-d] Means within columns with different superscripts differ ($P<0.05$).
[1]Differences ($P<0.05$) for before and after feeding seeds.

Table 6. Percentage (%) germination of seedlings emerging in Trial 4 from dungpats and the broadcast treatment.

Species	Percent Germination	
	Broadcast-seeded	Fecal-seeded
perennial ryegrass	3.0	3.7
hairy vetch	2.2	0.2

Maximillian sunflower showed some reduction in germination. More perennial ryegrass seeds germinated than any other species used (Table 5).

Trial 4: Seeding

Perennial ryegrass was the first species to emerge in dungpats and in broadcast-seeded plots. Weekly watering improved germination as 20 of the 22 perennial ryegrass seedlings that emerged were from watered dungpats (Table 6). Maximillian sunflower also emerged from dung pats. Hairy vetch and perennial ryegrass seedlings emerged in both the watered and unwatered broadcast treatments, but only 1 hairy vetch seed emerged from a dungpat.

DISCUSSION

Of the 6 cool season forage plants used in this study, Illinois bundleflower, perennial ryegrass, and Maximillian sunflower may be successfully established by fecal seeding. More seeds of perennial ryegrass germinated and established in dungpats, and it had the highest germination both before and after passage through the digestive tract of cattle. Only 1 seedling of Maximillian sunflower emerged from dungpats, but some seeds germinated in the laboratory.

No Illinois bundleflower emerged from dung pats. Nevertheless, more Illinois bundleflower seeds remained intact after ingestion and defecation by cattle, and it had a high germination rate in the laboratory after passage through cattle. Thus, data from Trials 1 and 3 suggest that Illinois bundleflower may be another potential candidate for fecal seeding.

Engelmann daisy, western wheatgrass, and hairy vetch are not viable choices for fecal seeding. Engelmann daisy and western wheatgrass did not survive the digestive system of cattle; both had significant weight losses during *in situ* digestion, and hairy vetch had significant weight losses during *in vitro* digestion.

The lack of germination of hairy vetch seeds recovered from feces in the laboratory may have resulted from damage during the collection and washing of seeds. When placed in petri dishes, hairy vetch seeds recovered from feces swelled and ruptured. By the end of the 21 days of the experiment, all fecal-collected hairy vetch seeds had molded and decayed. This supports the observation by Simao, Neto, and Jones (1987) that legume seeds disintegrate more readily than grass seeds when damaged. In addition, only 1 hairy vetch seedling emerged from dung while 9 seedlings emerged from the broadcast seedings.

During the planning of this study, 6 species were selected: 2 from the Fabaceae family, 2 from the Asteraceae family, and 2 from the Poaeceae family. Theoretically, species from the same family should be more likely to respond in a similar manner; species in the same family typically have similar types of seeds. For instance, both Illinois bundleflower and hairy vetch have hard seed coats that are typical of seeds produced in pods. However, 1 species will germinate after passage through the digestive tract, and the other did not. Similarly, Engelmann daisy and Maximilian sunflower are from the same family (Asteraceae), but responded differently to rumen digestion.

Perennial ryegrass and western wheatgrass also differed ($P<0.05$) in recovery from digestion. Survival of digestion and emergence of perennial ryegrass in dung pats could be due to evolutionary adaptations to grazing animals. The "foliage is the fruit" hypothesis suggests that some plants evolved with herbivores and are selected for traits that attract herbivores and lead to ingestion and passing of seeds (Janzen, 1984). Under this hypothesis, a plant would have increased reproductive success if its seeds were ingested and dispersed by herbivores. Studies with buffalograss (*Buchloe dactyloides*) and blue grama (*Bouteloua gracilis*), 2 species that evolved with bison herbivory, support this hypothesis (Quinn et al., 1994; Wicklow et al., 1984; Ortmann et al., 1999). Furthermore, perennial ryegrass is a short-lived perennial and should rely more on seed production and dispersal than longer-lived perennial grasses like western wheatgrass which rely heavily on vegetative reproduction (Booth and Haferkamp, 1995).

Passage through the digestive tract reduced germinability for all species of seeds tested except Illinois bundleflower. Reduction of germinability was also observed by Ocumpaugh et al. (1996) with switchgrass, and by Willms et al.(1995) with cicer milkvetch (*Astragalus cicer* L.). Germination may have been reduced further by the characteristics of the dungpat, especially when germination did not occur quickly after deposition. Akbar et al. (1995) reported that crust formation, and decreasing moisture content caused a lack of favorable conditions for gemination in dungpats 4 weeks after placement. However, in the watered treatment in this study, seedlings emerged up to 19 weeks post-dung pat placement. The moisture added to the dungpats from the simulated rainfall probably softened the crust enough for those seedlings to emerge. In addition, weathering of dungpats may create favorable conditions for establishment (Akbar et al., 1995).

Some seed damage and reduced germination in dung pats was probably due to the combined effect of digestion and seed decomposition in the dung pat (Atkeson et al., 1934). Passage through the digestive tract of cattle has been shown to remove all or part of a thin layer of seed coat which should increase decomposition of seeds in dung and explain why some species like Illinois bundleflower germinate in the laboratory but not in dung pats (Simao Neto et al., 1987).

Despite conflicting evidence, some argue that dung pats may provide an appropriate microsite for seedling survival (Ocumpaugh et al., 1996; Archer and Pyke, 1991). The potential benefits of the dung pat microsite include high fertility, high moisture retention capacity, short-term reduction of competition with pre-existing vegetation, and short-term grazing avoidance. The results of this study indicate that dung deposition may improve seedling establishment for some species. For instance, perennial ryegrass seedlings that emerged in dung pats appeared more robust with more tillers and greater biomass than seedlings of the broadcast seeded treatment as observed with switchgrass (Ocumpaugh et al., 1996). Nevertheless, the lack of germination of Illinois bundleflower which survived digestion and readily germinated in the laboratory but failed to emerge in dung suggest that the dung pat microenvironment may reduce the likelihood of emergence of some species.

IMPLICATIONS

From the observations of this study, fecal seeding perennial ryegrass in late fall or early winter in the semi-arid southwest should produce better results than any other species or time. Producers could feed seeds to cattle the morning of the day that they were to be moved into a pasture and have seeds being deposited in substantial amounts for 3 days given that seeds typically pass for 4 days after ingestion (Burton and Andrews, 1948; Yamada and Kawaguchi, 1972; Ozer, 1979; Willms et al., 1995).

Even though perennial ryegrass was the most likely candidate from this study for fecal-seeding, traditional broadcast-seeding may be more economically feasible. Thirty seven percent of perennial ryegrass seeds survived digestion with 75% of those germinating in the lab. Thus, only 28% of the perennial ryegrass seeds fed could be expected to survive and germinate. Conversely, 98% of nonfed seeds germinated in the laboratory. When traditional microsite preparation is applicable, broadcast-seeding may result in higher recruitment of cool-season forages in the semi-arid southwest.

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