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RESEARCH REPORT

Establishment of Forbs in Cattle Dungpats Deposited in Vegetation Gaps in a Degraded Sagebrush Community

by Matthew J. Shinderman and Christopher A. Call

Fecal seeding may be a viable option for restoring some species in overgrazed rangelands.

Sagebrush (*Artemisia* spp.) communities in many semi-arid and arid rangelands of the western United States have lost most of their herbaceous understory due to overgrazing and fire suppression (Young, 1994), which in turn has led to increases in sagebrush and exotic annual plant species and a decline in habitat for wildlife, such as the sage grouse (*Centrocercus urophasianus*) (Blaisdell and others, 1982; Allen, 1995; Monsen and Arthur, 1995). Increasing the diversity of herbaceous understory, especially forbs, in these communities has the potential to increase site productivity for wildlife by providing valuable forage during the spring and summer months (Roundy, 1996). But, how best to go about replanting these fragile understories in a way that fits with the economics of the range?

Recent research suggests that livestock, especially cattle, can be used to spread seeds—a technique known as fecal seeding (Janzen, 1984; Archer and Brown, 1987; Herrara, 1989; Archer and Pyke, 1991; Ocumpaugh, 1996). For example, Ocumpaugh (1996) fed switchgrass (*Panicum virgatum*) to cattle and found that fecal seeding resulted in greater seedling emergence and establishment than broadcast seeding. Likewise, Archer and Pyke (1991) demonstrated that fecal seeding can be a less disruptive, less costly, and more "natural" form of seed dispersal in rangelands than traditional, mechanical seeding methods.

An important, but typically overlooked, aspect of fecal seeding is the effect vegetation gaps and competition from neighboring vegetation have on the establishment of forb seedlings. We know that cattle dungpats create important gaps in canopies by suppressing underlying vegetation (Janzen, 1984; Hook and others, 1994; Auman, 1998), but there is a legitimate concern that roots from nearby vegetation may outcompete new seedlings for the flush of nutrients and water released from the dungpats (Welch, 1985; Hook and others, 1994; Auman and others 1998). Researchers have also pointed out that the survival and growth of seedlings under low moisture conditions are negatively affected by competition from other seedlings and adults (Reichenberger and Pyke, 1990; Leishman and Westoby, 1994).

In this article, we report on a study that we conducted to evaluate the effectiveness of fecal seeding two forb species, small burnet (*Sanguisorba minor*) and Lewis blue flax (*Linum lewisii*). The specific objectives of our experiment were to: 1) identify the potential of using cattle to disperse seeds of rangeland forbs for increasing community diversity in degraded sagebrush ecosystems; 2) identify differences in emergence, development, and survival of small burnet and Lewis blue flax seedlings in dung and soil substrates; and 3) determine the effect that competition from roots of neighboring plants has in different sized vegetation gaps on

the survival of small burnet and Lewis blue flax seedling in dung and soil substrates.

Materials and Methods

Study Site Description and Gap Definition

Our study site was located at the Utah State University (USU) Richmond Farm, 14 miles north of Logan, Utah. A 50-m^2 livestock exclosure (electric fence) was built on a gently sloping (NW aspect) grade at an elevation of 4800 feet. Annual precipitation is 20 inches, most of which falls as snow from late fall (mid-November) to mid-spring (late April). Average annual temperatures range from 32° to 61°F, with potential daily highs of 104°F and lows of -27°F. Soils are in the Sterling series (loamy-skeletal, mixed mesic, typic calcixerolls), are somewhat excessively drained, and have a pH range of 7.4-8.9 (USDA, 1974). Vegetation at the site is dominated by big sagebrush (*Artemisia tridentata*), snakeweed (*Gutierezia sarothrae*), Japanese brome (*Bromus japonicus*), cheatgrass (*Bromus tectorum*), bindweed (*Convolvulus arvensis*), and arrowleaf balsamroot (*Balsamorhiza sagittata*).

We characterized vegetation gaps as areas among existing vegetation where there was a break in the sagebrush canopy with few perennial grass shoots. We measured gap sizes as the diameter of open space (average of length+width) between neighboring sagebrush plants, and categorized them as large (diameter plant-to-plant greater than 2 m), medium (diameter plant-to-plant less than 2 m, but greater than 1m), and small (diameter plant-to-plant less than or equal to 1 m).

To get an idea of potential competition within vegetation gaps, we sampled the three gap sizes for root biomass using a 6 cm by 8 cm soil core taken from the center of gaps, periphery of gaps, and midway between center and periphery at depths 0-5 cm, 5-10 cm, and 10-15 cm.

Fecal Seeding and Broadcast Seeding in Vegetation Gaps

We selected small burnet and Lewis blue flax for this study because of their desirability as revegetation species, importance for wildlife habitat, and ability to pass through the digestive tract of cattle and successfully germinate. Small burnet is a relatively long-lived, aggressive, evergreen perennial. It has a branched caudex and a prominent taproot, and is weakly rhizomatous. Small burnet is adapted to sunny hill slopes and well-drained, infertile to disturbed soils (NRCS, 1997a). Lewis blue flax is a short-lived, semi-evergreen perennial that is native to northern Utah. Flax also thrives on well-drained, infertile to disturbed soils, and is tolerant of semi-shaded conditions (NRCS 1997b).

Prior to the field study, we tested the fecal seeding potential of eight Holstein heifers (same age and approximate weight) that were kept in open feeding stalls at the USU Caine Dairy Farm[1]. The animals were fed a standard grass hay diet (brome [*Bromus inermis*], orchard grass [*Dactylis glomerata*], fescue [*Festuca arundinacea*], timothy [*Phleum pratense*], and rushes [*Juncus* spp.]; 69 percent dry matter digestibility, 7.8 percent crude protein, 63.6 percent neutral detergent fiber, 39.2 percent acid detergent fiber) with continual access to the feed and water. We fed four of the cows seeds of small burnet and the other four seeds of blue flax, in a mixture of two parts calf feed (active drug ingredient: chlortetracycline-50g/ton; soybean, meat, cottonseed, linseed, and alfalfa meal, whey, ground corn and wheat, ground and rolled oats and barley, cane and beet molasses, dicalcium phosphate, animal fat, vitamins and minerals; 6 percent crude fiber, 21 percent crude protein, 3 percent crude fat) to one part seed. To standardize the mass of seeds fed and to ensure that seed masses were adequately consumed by each animal, we fed the larger-seeded species (small burnet) at a rate of 15,000 seeds per animal, while the smaller-seeded species (flax) was fed at 60,000 seeds per animal.

Once a day for four days, we collected 1 kg samples of feces from each of the animals. We washed and screened the samples until the remaining material consisted of fiber and seeds, which we then placed in plastic bags for transport to a laboratory. In the lab, samples were broken up and placed on newspaper to dry at room temperature for several days. Seeds were separated from the fiber, and then analyzed under a 10x lens. We recorded the number of damaged and undamaged seeds per kg sample.

We also measured the total fecal output per animal during a 24-hour period. This gave us the opportunity to determine the recovery of seeds from each collection as a percentage of seed input by multiplying the number of seeds per gram of fecal sample by the total fecal output per 24-hour collection period and dividing by the number of seeds ingested (Table 1).

We took four replicates of 25 undamaged (no visible damage to seed coat), recovered seeds for each species collection date and placed them on moistened (distilled water) filter paper in petri dishes. Petri dishes were placed in a germination chamber with a night/day temperature of 18°/36°F and a 12-hour photoperiod. Filter paper moisture was maintained by adding distilled water as needed. Germinating seeds were counted every day for a period of one month. Four replicates of 25 unpassed seeds were also analyzed for germinability. Seeds were considered germinated when the radicle had emerged

Table 1. Passage of small burnet and blue flax seeds over four day collection period.

Species	Day 1	Day 2	Day 3	Day 4
small burnet	1050	1030	290	65
blue flax	1820	1780	315	55

Figures represent the average number of seeds counted for each collection date.

Seed numbers represent both damaged and undamaged seeds recovered after passage. Approximately 10 percent of all passed seeds recovered were damaged during digestion.

5 mm and at least one cotyledon had emerged from the seed coat (Table 2).

Field Experiment

We designed our field experiment as a four-way factorial (gap size, forb species, fecal/broadcast seeding, presence/absence of belowground competition), which we arranged in a completely randomized manner. There were a total of 96 plots with 16 treatment combinations and six replications per treatment combination.

During March 1997, we fed six Holstein heifers 15,000 seeds of small burnet and another six heifers 60,000 seeds of blue flax at the USU Caine Dairy Farm (the 12 animals used for this study were some of the same animals used for the seed passage experiment). Animals were fed the same diet as in the seed passage experiment, and seeds were fed to the animals in a molasses-based mixture. We collected their dungpats in 2-kg samples, placed them in a 33-gallon plastic container, and mixed the samples to create a homogeneous sample. We took two 1-kg samples and, from chest height (4.5 ft) above the surface, dropped them into an open-ended bucket that we placed in the center of each specified gap site. The resulting, uniform dungpats were similar in size (20-cm in diameter, 4-cm depth) to natural cattle dungpats (Akbar and others, 1995). We also broadcast unpassed seeds onto the soil surface of similar-sized gap sites to serve as a comparison treatment. To simulate the soil disturbance that often accompanies conventional broadcast seeding techniques, we lightly raked bare soil plots before and after seeding. We broadcast flax seeds at a rate of 98 seeds/m^2 and small burnet at a rate of 66 seeds/m^2 based on recommendations provided by Granite Seed, a seed supply company specializing in revegetation species. Seeds were broadcast into 20-cm diameter circular plots (same size as dungpats).

Prior to dungpat deposition and broadcast seeding, we placed root exclusion tubes in half of the dungpat and broadcast seed treatments for each gap size to eliminate interspecific root competition from neighboring vegetation. Steel tubes (10-inch diameter, 10-inch length) were driven into the soil until the top of the tube lay just above the soil surface. We also enclosed all individual plots with poultry wire cages staked with 6-inch turf staples to reduce herbivory.

Table 2. Mean percent germination of passed seeds (collected 1 and 2 days after ingestion) and unpassed seeds of small burnet and blue flax.

Treatment and species	Day after ingestion	% germination (mean±SD)
Passed Seeds		
flax	1	51±5.6%
flax	2	31±5.6%
small burnet	1	38±5.6%
small burnet	2	5±4.5%
Upassed Seeds		
flax		81±2.3%
small burnet		81±6.8%

Seeds recovered from the third and fourth collection dates did not germinate in sufficient numbers for analysis.

Throughout the growing seasons (April through late July) of 1997 and 1998, we monitored seedling emergence and survival on a weekly basis. We calculated emergence percentage values by dividing the number of emerging seedlings per plot by the known (bare soil) or expected (dung) number of seeds per plot. We determined the expected number of seeds per dungpat using data gathered from the seed passage experiment. Survival data were expressed as the number of surviving seedlings in proportion to the number of seedlings that emerged from a particular treatment. We also recorded the number of stems per plant and number of leaves per stem during each growing season. We analyzed seedling emergence, survival, and performance data as a 2^4 factorial using a General Linear Model (SAS, 1985). Results were considered significant at $P<0.05$.

Results and Discussion

Seedling Emergence and Survival in 1997

Of the 96 original plots, 91 contained seedlings when we surveyed them in 1997. Both species had relatively low emergence from dung—a result of the seedlings' inability to penetrate the crust that forms on dungpats almost immediately after the deposition (Akbar, 1994). Cotyledons of seeds planted in bare soil treatments, on the other hand, had little or no substrate to penetrate through because we raked the soil surface before and after broadcast seeding.

We found the greatest emergence in small gap, broadcast treatments containing flax. In general, flax had greater emergence than small burnet in broadcast treatments, and broadcast treatments had greater emergence for both species than did dung treatments. In all treatments where dung was the substrate, gap size and species were not significant, although the effect of gap size in broadcast treatment became apparent with small burnet showing greater emergence in large gaps, and flax having greater emergence in small gaps (Figure 1). However, the low level of small burnet emergence in small gaps may have been due to seed predation by Great Basin pocket mice (*Perognathus parvus*), several of which we trapped after small burnet dung treatments began to show signs of disturbance. (Their small size allowed these mice to get through the chicken wire gages we had set up around the plots.) We speculate that predation may have been higher in small gap plots because those plots provide more protection for small foragers. We found no evidence of seed predation in the flax plots, so the difference in emergence between large and small gap plots of flax is probably the result of other factors such as light levels, soil moisture, air temperature, and relative humidity, although we did not measure any of them.

We found that small burnet had a greater level of emergence in dung than

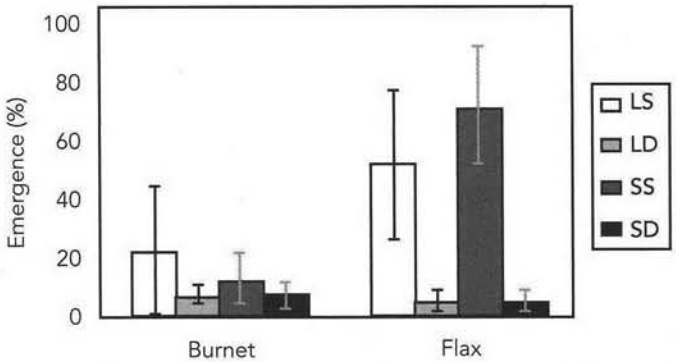

Figure 1. Percent mean emergence of small burnet and flax seeds sown in plots either in dung or broadcast from a species x gap x substrate interaction for the 1997 growing season. LS = large gap broadcast, LD = large gap dung, SS = small gap broadcast, and SD = small gap dung. Error bars indicate standard deviation.

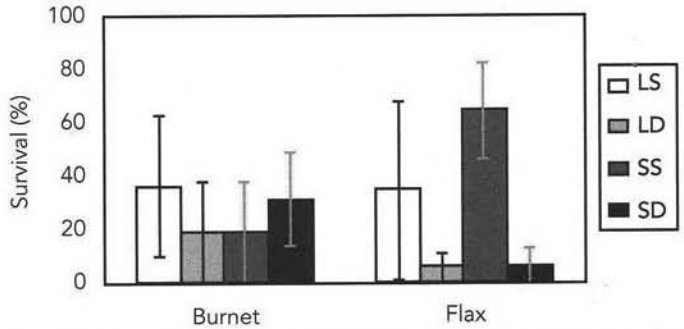

Figure 2. Percent mean survival of emerged small burnet and flax seedlings from the species x gap x substrate interaction for the 1997 growing season. LS = large gap broadcast, LD = large gap dung, SS = small gap broadcast, and SD = small gap dung. Error bars indicate standard deviation.

did flax. This is most likely due the greater carbohydrate reserve of its large-sized seed. However, it may also be the case that the disturbance created by seed predators may have decreased the suppressive impact of crust formation by breaking up the top crusted layer and decreasing the volume of crusted material through which small burnet seedlings had to penetrate.

In late July 1997, we counted 63 plots that contained surviving seedlings. As with emergence, substrate played a significant role in determining the survival of both species. Although species as a main effect was not significant, the species x substrate and species x gap x substrate interactions were significant ($P<0.05$).

In general, seedlings of both species exhibited higher survival in bare soil than dung. This is likely the result of several stresses dungpats place on young seedlings. These stresses arise because of crust formation, high internal and surface temperatures of dungpats, and invasion of the dungpats by macroinvertebrates (Greenham, 1972; Akbar, 1994; Auman, 1998). For example, while the surface crust may provide an insulating layer for moisture within the dungpat shortly after deposition, the dungpats typically become totally encrusted and contain little moisture after a few months of warm weather. As a result, seedlings that have not extended their roots into the underlying soil may no longer have access to dungpat moisture and may, therefore, be exposed to higher temperatures and dessication. Furthermore, dungpats often become hosts to numerous macroinvertebrates, the activities of which may result in the eventual decomposition of the pat. In our study, there were obvious signs of invasion and physical decomposition on several dungpats, which included the hollowing out of the underside of the pat and subsequent formation of small piles of loose organic material under the center of the pat. This disturbance could have impacted the root systems of developing seedlings and had a deleterious effect on their survival.

Fecal seeding may be a less disruptive, less costly, and more "natural" form of seed dispersal in rangelands than traditional, mechanical seeding methods.

Although broadcast seeding on bare soil resulted in higher total survival for both species, small burnet had much higher survival in dung than did flax. The highest survival for small burnet occurred in large gap, broadcast treatments, but survival in small gap, dung treatments was also relatively high (Figure 2). This may have been the result of the aforementioned disturbance of small gap, small burnet dung treatments, which resulted in destruction of the uppermost crusted layer. This disturbance allowed more moisture to infiltrate the dungpat, thereby enhancing the survival of the small burnet seedlings. Large gap treatments were exposed to more direct solar radiation and wind so that detrimental crust formation may have been more rapid in these plots, although we do not have specific data to support this hypothesis.

Survival patterns for the 1997 field season are more difficult to explain for dung and bare soil treatments in small gaps. The data indicate that small burnet survival in small gaps was higher in dung plots than in broadcast seed treatments when survival is expressed as the number of surviving seedlings in proportion to the number of seedlings that emerged in each plot. If a seedling developing in a dungpat can extend its roots into the underlying soil, the dung material may then be of benefit to that seedling because it probably reduces evaporative losses from the underlying soil. Therefore, moisture content of the underlying soil may be greater than in adjacent bare soil patches.

Survival data for flax were very similar to emergence data, with survival highest in small gap, broadcast treatments and negligible in all dung treatments. The reason for the difference between large and small gap, broadcast treatments is not clear, but the data for both emergence and survival suggest that some factor or group of factors within the small gap microenvironment are more favorable for flax establishment. Flax survival in dung was generally lower than that of small burnet in both gap sizes, and significantly lower in small gaps. Disturbance of pats containing small burnet had an effect on these differences, but seed biology may also have played a role. We found that flax germinated as well as small burnet in dung, but the individual flax seedlings typically did not survive more than two weeks. This suggests that the flax seedlings were unable to access the underlying soil with their roots and were subject to dessication.

We found that root exclusion tubes were not significant ($P<0.05$) as a main effect or in conjunction with other factors. This suggests that competition was not a significant factor limiting survival, although it may impact plant performance. However, determining the effect of exclusion tubes is problematic because the role of intraspecific competition among plants establishing within the tube is ignored. In many cases, excluded treatments contained high densities of seedlings (more than 25 seedlings per tube), such that intraspecific competition may have been at least as important, if not more important than interspecific competition in non-excluded treatments. Additionally, small burnet may not have been affected by the exclusion treatment because its deep taproot can extend for several yards into the soil (NRCS 1997a). As a result, any competitive interactions involving small burnet in excluded treatments would likely occur beyond the depth of the tube.

Plant Performance in 1997

Our analysis of stem count data revealed significant ($P<0.05$) species x substrate, species x exclusion, and substrate x exclusion interactions, as well as significant ($P<0.05$) species, substrate, and exclusion main effects. In general, seedlings of both species had higher stem counts in excluded and broadcast treatments. In excluded treatments, broadcast seeds may have an advantage over seeds in dung because they can establish root systems in the soil more rapidly. Conversely, competition in non-excluded treatments may limit broadcast seed treatments more than dung treatments (Figure 3). We think this occurs because broadcast seeds in non-excluded plots must compete for resources with the surrounding vegetation almost immediately after extending their roots into the soil, while seeds in dungpats have not yet extended their roots into the underlying soil and, at least initially, may experience an environment that has not yet been invaded by roots of neighboring plants. Therefore, although stem production is still slightly higher in broadcast seed treatments, the difference between the two substrates may be attenuated by competition.

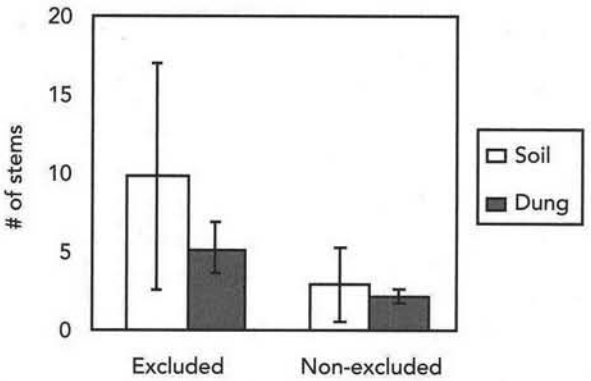

Figure 3. Mean number of stems per plant for the exclusion x substrate interaction for the 1997 growing season. Error bars indicate standard deviation.

Leaf data followed similar trends with significant ($P<0.05$) effects due to substrate and exclusion. We found that seedlings produced more leaves per stem in excluded and broadcast treatments than in non-excluded and dung treatments, respectively. While gap size did not significantly ($P<0.05$) affect the number of leaves produced per stem, the gap x substrate x exclusion interaction was significant ($P<0.05$) with the greatest leaf production in excluded, bare soil, small gap plots. Seedlings emerging from non-excluded dungpats in large gaps had the lowest leaf production. These results are consistent with the main effects of substrate and exclusion, except for the difference between large and small gap, dung, and excluded treatments, where plants in large gap treatments had greater leaf production than those in small gap treatments (approximately three leaves per stem). This may be the result of greater photosynthetic capacity and carbon allocation to leaf production in large, unshaded gaps. All of the other treatment combinations did not exhibit differences in leaf production. The lack of a gap main effect and restriction of this pattern to dungpat treatments weakens this argument, which leaves us with a statistical explanation. The effects of both substrate and exclusion were both highly significant ($p=0.0004$, 0.0001, respectively), and most likely influenced the significant three-way interaction.

We found that exclusion tubes can affect plant performance in several ways, including immediate reduction of interspecific competition for resources, altering nutrient and water exchange within the soil profile, and enhancing water availability within the area of the tube by causing slight ponding during precipitation events, and creating zones of increased infiltration at the tube soil interface. Our data indicate that exclusion enhanced plant performance for both species. The difficulty is in discerning which effects are responsible for the improved performance. As described above, root exclusion using steel tubes does not allow for distinctions between the effects of intraspecific and interspecific competition. Additionally, tube installation potentially alters several soil-water and soil nutrient characteristics that are difficult to quantify. These factors complicate explanations of variance in plant performance between excluded and non-excluded treatments.

Emergence and Survival 1998

Thirty-two of the 63 plots with surviving plants in 1997 resprouted in 1998. Four

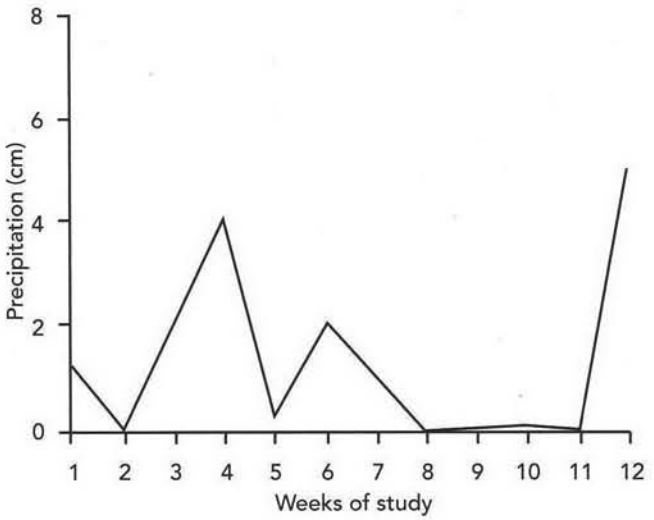

Figure 4. Weekly precipitation from April (week 1) to late July (week 12). Note the peak in rainfall in late April and the dry conditions throughout June.

plots contained new seedlings that had not germinated the previous year, although they all died within the first four weeks of the 1998 study period. Thus we measured and analyzed 1998 seedling survival in proportion to the number of seedlings that survived the 1997 field season. The effect of substrate was significant ($P<0.05$) with higher survival in broadcast seed plots (46 percent) than dung plots (36 percent). The effect of species was also significant ($P<0.05$) with small burnet accounting for all but six of the plots containing surviving plants. Survival for flax decreased dramatically (approximately 80 percent) between the two growing seasons. At the end of the 1997 field study, flax densities were fairly high in broadcast seed plots (greater than 20 plants per plot). A late summer drought coupled with heavy intraspecific competition may have caused high mortality for this species.

New seedling emergence during the 1998 field season was limited to small burnet in bare soil plots, with the exception of one seedling arising from a dungpat that had been disturbed by mice the previous year. Any developing seedlings in dungpats were probably suppressed by crust formation. Granivory may have had an impact on the number of seeds remaining in broadcast seed treatments, especially with small burnet.

Small burnet seedlings seemed to survive the 1997 late summer dry period (Figure 4) and winter conditions quite well. This species apparently has adaptations for both temporal and spatial resource acquisition. As an evergreen, small burnet can continue to explore soil strata with its root system long after most of its annual and perennial neighbors have senesced. As suggested earlier, a deep taproot allows this plant to access moisture and nutrients at depths that may be unavailable to flax and other more shallow rooted herbs. This may represent an example of habitat partitioning, where small burnet may not be in direct competition with neighboring vegetation because it is accessing different nutrients and/or water, while flax is most likely in direct competition for shared resources with its neighbors.

The difference in plant survival for small burnet on the two substrates was expected, based upon survival rates from the previous year. A general pattern emerged for small burnet where seedlings that had grown to a diameter (aerial cover) of 10 cm or more during the 1997 season all survived and set seed in 1998, regardless of substrate. There was no mortality for plants that had established in either substrate, suggesting that the negative effects related to dung (crust formation, extreme heat, macroinvertebrates) were overcome once seedlings had established roots in the underlying soil. At that point, dungpats may be of some benefit to developing plants through the gradual input of organic matter and nutrients as the pat decomposes. This organic material further increases soil moisture holding capacity and can increase cation exchange capacity, although these potential benefits may not result in noticeable changes in plant productivity within one year.

Fecal seeding has potential as a non-intrusive method of planting tap-rooted, evergreen, perennial species, such as small burnet.

Plant Performance in 1998

Plant performance results for 1998 represent data from small burnet plots only because there were not enough plots containing flax for statistical analysis. We found that the number of stems per plant and number of leaves per stem were not significantly affected by gap, substrate, or exclusion (Table 1). By the end of the study period (late July), surviving small burnet plants were approximately equal in all plant performance categories. The decreased performance of small burnet plants establishing in dung during 1997 may represent a delay in establishment compared to bare soil plots. However, this delay seems to have been ameliorated by the 1998 growing season. The beneficial influence of dungpats, as described above, may help to 'equalize' the performance levels of plants in dung once they become established in the underlying soil.

Management Implications

Fecal seeding has potential as a non-intrusive method of planting tap-rooted, evergreen, perennial species, such as small burnet. However, this potential depends upon management goals. If the goal is to rapidly stabilize soil or increase vegetation density, fecal seeding may be inappropriate because the response can be slow and sporadic. If the goal is to increase species diversity for livestock forage or wildlife habitat within a relatively stable plant community, fecal seeding may be a viable option, pro-

vided that land managers are willing to purchase seed, feed the seed to livestock, and accept that the process will be gradual.

Cook and his colleagues (1967) suggested that a 50-75 percent establishment rate would be acceptable for revegetation efforts in the Intermountain region. By these criteria, both fecal seeding and broadcast seeding produced acceptable levels of establishment at our study site. Nevertheless, we would like to point out several caveats. First, the success of our broadcast seeding treatments may have been artificially enhanced by seedbed preparation, and thus may not represent a realistic broadcast seeding treatment. This point is significant because trying to scale up from the methods used in our experiment to that needed for planting much larger sites will involve costs associated with equipment and labor needed to disturb the soil surface, in addition to the costs of equipment for seed dispersal. Second, the costs of fecal seeding are dependent upon availability of livestock, availability and cost of seed, costs associated with animal containment or herding, and the time and facilities needed for feeding animals the seed. Small burnet is relatively abundant and inexpensive ($0.80 per pound at the time of study), but the availability and cost of seeds of other species can be highly variable. Third, the dispersal of dungpats in this experiment is actually an underestimate of natural dungpat deposition. For example, we collected only 24 dungpats from the four animals fed small burnet. In reality these same four animals could produce up to 56 dungpats during a 24-hour period. In our experiment, we obtained a roughly 60 percent establishment rate for small burnet (15 plants from 24 plots), so with more dungpats and a similar rate of establishment the same area could have more plants following natural dispersal. Finally, there have been few similar studies conducted with other forb species, which suggests to us that continued studies on the potential for fecal seeding and the suitability of various species for this technique are obviously needed.

There are other questions that researchers in this area should consider, including the interaction between the amount of seed fed and seed predation, and the effect of greater rainfall or moisture from irrigation on the effectiveness of fecal seeding. For instance, several authors (Simao Neto and Jones, 1987; Auman, 1998) suggest that seeds be fed to livestock in smaller quantities more frequently, or to a greater number of animals to increase the dispersal area and decrease the effects of seed predation and intraspecific competition. Likewise, Janzen (1970) suggested that it may be necessary to decrease the number of seeds fed to dispersal agents if seed predation is correlated with concentration of seeds in a particular medium. Meanwhile, little or no research has taken place in areas that have access to irrigation or that have greater rainfall. We suspect that experiments in such areas may demonstrate a greater success with fecal seeding because increased moisture will alter the rate and degree of crust formation on dungpats, allowing greater emergence and establishment of the plant species being used. The need to develop low-impact, cost-effective revegetation techniques warrants further study of fecal seeding methods.

Table 3. Mean number (+/-) of stems and flowering heads per plant for small burnet during the 1998 growing season (April-.

Treatment	# stems	#flowering heads
Substrate		
Dung	18.3±3.6	11.2±2.3
Bare soil	19.1±2.1	12.8±2.9
Gap		
Large	18.3±2.2	10±3.2
Small	19.1±3.3	14±2.8
Exclusion		
Excluded	19.1±3.3	12±1.9
N-excluded	18.3±2.7	12.5±2.1

Acknowledgments

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References

Aquilera, M.O. and W.K. Lauenroth. 1993. Seedling establishment in adult neighborhoods-intraspecific constraints in the regeneration of the bunchgrass *Bouteloua gracilis*. *Journal of Ecology* 81:253-261.

Akbar, G. 1994. Dungpat microenvironmental effects on germination and establishment of crested wheatgrass. Ph.D. Dissertation, Utah State University, Logan.

Akbar, G., C.A. Call, and R.D. Wiedmeier. 1995. Cattle dungpat microenvironmental effects on germination and establishment of crested wheatgrass. *Arid Soil Research and Rehabilitation* 9:409-422.

Allen, E. 1995. Restoration ecology: Limits and possibilities in arid and semi-arid lands. Pages 7-15 in Roundy, B.A., D.E. MacArthur, J.S. Haley and D.K. Mann, eds. Proceedings of the symposium on wildland shrub and arid land restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR 315, Las Vegas. 384 pp.

Archer, S. and J.R. Brown. 1987. Woody plant seed dispersal and gap formation in a North American subtropical savanna woodland: The role of domestic herbivores. *Vegetatio* 73-74:73-80.

Archer, S. and D.A. Pyke. 1991. Plant-animal interaction affecting plant establishment and persistence on revegetated rangeland. *Journal of Range Management* 44:558-562.

Auman, B. 1998. Crested wheatgrass establishment in livestock dung deposited on degraded rangeland vegetation types in the Intermountain West. *Arid Soil Research and Rehabilitation* 12:317-333.

Blaisdell, J.P., R.B. Murray, and E.D. McArthur. 1982. Managing Intermountain rangelands-sagebrush grass ranges. USDA Forest Service Intermountain Forest and Range Experiment Station General Technical Report INT-GTR 134, Ogden. 41 pp.

Connell, J. 1990. Apparent versus "real" competition in plants. Pages 9-26 *in* Tilman, D, ed. Perspectives on plant competition. San Diego: Academic Press. 484 pp.

Cook, C.W., L.A. Stoddart and P.L. Sims. 1967. Effects of season, spacing and intensity of seeding on the development of foothill range grass stands. Utah Agricultural Experiment Station Bulletin 467. 73 pp.

Drut, M.S., W.H. Pyle, and J.A. Crawford. 1994. Technical note: diets and food selection of sage grouse chicks in Oregon. *Journal of Range Management* 47:90-93.

Goldberg, D.E. and P.A. Werner. 1983. The effects of size of opening in vegetation and

litter cover on establishment of goldenrods (*Solidago* spp.). *Oecologia* 60:149-155.

Greenham, P.M. 1972. The effect of temperature of cattle dung on the rate of development of the larvae of the Australian bushfly, *Musca vetustissima* Walker (*Diptera: Muscidae*). *Journal of Animal Ecology* 41:429-437.

Gross, K. 1984. Effects of seed size and growth on seedling establishment of six monocarpic perennial plants. *Journal of Ecology* 72:369-387.

Herrara, C.M. 1989. Seed dispersal by animals: A role in angiosperm diversification. *American Naturalist* 133:309-322.

Hook, P., W.K. Lauenroth, and I.C. Burke. 1994. Spatial patterns of roots in a semi-arid grassland: Abundance of canopy openings and regeneration gaps. *Journal of Ecology* 82:485-494.

Janzen, D.H. 1970. Herbivores and the number of tree species in tropical forests. *American Naturalist* 104:501-528.

__. 1984. Dispersal of small seed by herbivores: Foliage is the fruit. *American Naturalist* 133:338-53.

Leishman, M. and M. Westoby. 1994. The role of seed size in seedling establishment in dry soil conditions: Experimental evidence from semi-arid species. *Journal of Ecology* 82:249-58.

Monsen, S.B. and E.D. McArthur. 1995. Implications of early Intermountain range and watershed restoration practices. Pages 16-25 in Roundy, B.A., D.E. MacArthur, J.S. Haley and D.K. Mann, eds. Proceedings of the symposium on wildland shrub and arid land restoration. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR 315, Las Vegas. 384 pp.

Natural Resource Conservation Service (NRCS). 1997a. Plant guide: Management and use of small burnet. Boise Plant Materials Center, Boise, Idaho. 2 pp.

__. 1997b. Plant guide: Management and use of Lewis blue flax. Boise Plant Materials Center, Boise, Idaho. 2 pp.

Ocumpaugh, B. 1996. Switchgrass recruitment from broadcast seed vs. seed fed to cattle. *Journal of Range Management* 49:368-71.

Pyke, D.A. and M.M. Borman. 1993. Problem analysis for the vegetation diversity project. U.S. Department of the Interior, Bureau of Land Management Publication, T/N:OR-936-01, Corvallis. 45 pp.

Reichenberger, G. and D. Pyke. 1990. Root competition between important Great Basin species. *Oecologia* 85:159-66.

Roundy, B.A. 1996. Revegetation of rangelands for wildlife. Pages 355-368 *in* Krausman, P.R., ed. Rangeland wildlife. Denver: Society for Range Management.

SAS Institute Inc. 1985. *SAS User's Guide: Statistics*, Version 5 Edition. Cary, North Carolina. 956 pp.

Silvertown, J. and B. Smith. 1988. Gaps in the canopy: The missing dimension in vegetation dynamics. *Vegetatio* 77:57-60.

Simao Neto, M. and R.M. Jones. 1987. Recovery of pasture seed ingested by ruminants. 2. Digestion of seed *in sacco* and *in vitro*. *Australian Journal of Experimental Agriculture* 27:247-51.

United States Department of Agriculture (USDA). 1974. Soil Survey of Cache Valley Area, Utah. USDA Soil Conservation Service and Forest Service in Cooperation with the Utah Agricultural Experiment Station, Ogden. 192 pp.

Walker, A.E. 1991. *Mammals of the world*. Pages 629-630. Baltimore: Johns Hopkins University Press.

Welch, D. 1985. Studies in the grazing of heather moorland in North-East Scotland. *Journal of Applied Ecology* 22:461-472.

Young, J.A. 1994. History and use of semi-arid plant communities-changes in vegetation. Pages 5-8 in Monsen, S.B., and S.G. Kitchen, eds. Proceedings of the symposium on ecology and management of annual rangelands. USDA Forest Service Intermountain Research Station General Technical Report INT-GTR 313, Ogden. 416 pp.

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