*Journal of Arid Environments* (1992) 22: 395–399

# Recovery and germination of gelatin-encapsulated seeds fed to cattle

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(*Received 22 May 1991, accepted 17 September 1991*)

Artificial reseeding of marginal farmlands, wildlands, or rangelands by mechanical means is expensive and often unsuccessful. This study was conducted to determine the recovery and germinability of seeds of south-western U.S.A. rangeland forages fed to cattle. Seed of fourwing saltbush (*Atriplex canescens*), alkali sacaton (*Sporobolus airoides*), blue panicgrass (*Panicum antidotale*), and sideoats grama (*Bouteloua curtipendula*) were administered in gelatin capsules to steers maintained on a moderate-quality alfalfa (*Medicago sativa*) diet. Approximately 95% of the recovered seed passed through the steers within 72 h after dosing, but recovery varied among species. Total recovery was 9·5, 46·4, 61·8, and 0% for fourwing saltbush, alkali sacaton, blue panicgrass and sideoats grama, respectively. Fourwing saltbush, blue panicgrass, and alkali sacaton retained viability and germinated in the fecal material. Germination of seeds recovered 48 h post ingestion was 14·8, 50·1, and 41·4% for fourwing saltbush, alkali sacaton, and blue panicgrass, respectively, and was similar to germinability of noningested seeds. The use of gelatin capsules would be an effective method for easily feeding known quantities of seeds to livestock in small herds and could be incorporated with other common and necessary livestock handling practices.

## Introduction

Rangelands are a valuable natural resource. The deterioration of these lands through the loss of grasses and other desirable vegetation has resulted in a loss of productivity, wildlife habitat, soil, water, and other valuable resources. Revegetation of most arid and semi-arid lands by mechanical means is prohibitive because of the expense and the high probability of stand failure. Development of alternative low-input methods of plant re-establishment is desirable. To be successful, these methods must require lower capital, labor, and mechanical inputs, and should be integrated with other livestock and land management practices that have potential for long term improvement of vegetation resources. These methods should be applicable to rangelands, irrigated pastures, and marginal or abandoned farmland.

Some plants produce seed in attractive packages such as fruits, nuts, or pods that are utilized as food by animals. Animals, in turn, can be effective dispersal agents for seeds (Lanner, 1982; Hall & Shay, 1981). Cavanagh (1980) verified the important role of birds

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and mammals in the dispersal and germination of *Acacia* species. Ahmed (1986) summarized several trials where goats and sheep effectively transported *Acacia tortilis* and *Prosopis chilensis* over long distances. Passage through the digestive tract protected seeds from insect herbivory and increased germination and establishment. Pelleting in the dung and preparation of the site before dispersal also enhanced establishment, and Ahmed (1986) recommended that animals be used for seeding semi-arid areas. Janzen (1986) has suggested that megafauna were evolutionarily important in the seed dispersal of numerous plant species, especially cacti, within the Chihuahuan Desert. In more recent periods, it is commonly accepted that domestic livestock played a major role in the widespread establishment of mesquite (*Prosopis glandulosa*) in the south-western U.S.A. (Buffington & Herbel, 1966). Hunziker *et al.* (1977) proposed that birds were responsible for the transport and introduction of creosote bush (*Larrea tridenta*) into North America from South America. This species has widely colonized much of the south-western U.S.A.

Seeds of different species respond differentially to animal digestion largely because of variability in seed coat and maturity characteristics. Yermachenko (1972) found that animal species also affected germinability. Germination percentages of undigested *D. caespitosa* seed recovered from control (not ingested), cow, horse, sheep, and pig treatments were 91, 91, 64, 40, and 11, respectively. Any species which retains germinability after passage could be dispersed by animals and subsequently established (Gersa & Martinez, 1985; Idani, 1986; Nobel & Whalley, 1978; Simao Neto *et al.*, 1987).

Prior studies have not quantified recovery of ingested seeds of native southwestern U.S.A. plant species nor has the ingestion of seed been experimentally controlled with a high degree of accuracy. The objective of this study was to determine the recovery and germinability of seeds of native range forages fed to livestock in gelatin capsules and subsequent seedling emergence from feces.

## Materials and methods

Three grass species, alkali sacaton (*Sporobolus airoides*), blue panicgrass (*Panicum antidotale*), and sideoats grama (*Bouteloua curtipendula*), and a shrub species, fourwing saltbush (*Atriplex canescens*), were selected to determine their potential for seed distribution by cattle. These species are adapted to arid range conditions and are considered to be valuable forages and ground cover for arid lands. Four yearling steers were selected based on age and body weight criteria (15- to 18-months-old and 250–300 kg). They were gentled, and fitted with fecal bags. Throughout the experimental period animals were fed alfalfa hay (66% *in vitro* digestible organic matter disappearance) at approximately 2·0% (dry matter basis) of body weight per day. This intake level paralleled average range livestock daily forage intake estimates from a variety of studies as summarized by Van Dyne *et al.* (1980). Steers were bolused with seed of each forage species, using 24 × 85 mm gelatin capsules. Each capsule contained approximately either 5300 sideoats grama, 21,000 blue panicgrass, 60,000 alkali sacaton, or 800 fourwing saltbush seed. These capsules dissolve within 45 min following rumen placement. The experimental design was a four × four latin square. In each of the four trials, a different steer received the seed of a different plant species. Trials lasted 96 h and were separated by 72 h periods. Steers were bolused at the start of each trial with either one capsule containing blue panicgrass or alkali sacaton seed, 2 capsules of sideoats grama seed, or 8 capsules containing fourwing saltbush seed. Fecal bags were fitted to each steer and total fecal output was collected at 24, 48, 72, and 96 h, weighed and mixed. Two samples averaging 400 g were taken each day. Seeds were separated from one sample by washing through appropriate sized screens. The seed fractions were dried at ambient temperature of about 31°C in 3 h. Seeds were then separated from the residue, counted and germinated in vermiculite in a growth chamber at 20°C to determine recovery and germinability. Germination percentages were established for noningested seed from each seed sample, using the same conditions applied to seed in the test. The second fecal sample was used for organic matter and dry matter determinations (AOAC, 1980) to correct fecal recovery weights for moisture and ash contents. Total seed passage was calculated as a product of dry fecal matter output (24 h basis) and g of seed per g of feces as determined from the first sample. Recovery was expressed as a percentage of total seed passed/number of seed fed in capsules. The residual fecal material was placed on a fenced nursery exclosure and formed into pats approximately 5 to 10 cm thick and 30 to 60 cm in diameter for observing seedling emergence under natural rainfall. The nursery was located in a grassland/mesquite vegetation type dominated by sandy loam soils of the Dona Ana and Regan series.

Data were analysed using General Linear Model procedures (SAS, 1985). Recoveries of seed during the four intervals (0 to 24, 24 to 48, 48 to 72, and 72–96 h) were analysed as a four × four latin square with seed species, animal, and trial as model effects. Treatment effects were tested with residual error, and means were separated by the least significant difference method (Snedecor & Cochran, 1980) protected by a preliminary $F$-test.

## Results

Considerable variation was observed among the four species in the recovery of the ingested seeds. Sideoats grama was not recovered and was apparently digested. Recovery of fourwing saltbush was lower than for the smaller-seeded grasses (Table 1). This may have resulted from increased exposure to chewing and digestion in the ruminating steers. Approximately 80% of all seed recovered was obtained by 48 h after ingestion (Table 1), and germinated similar to noningested seeds (Table 2). Germination was inhibited when fourwing saltbush remained for more than 72 h in the digestive tract. However, when these seeds were dried and rehydrated they were capable of germination, indicating the potential for germination at a later time. Blue panicgrass had the highest recovery and germination percentages. Microscopic observation after digestion indicated that alkali sacaton suffered more seed coat damage than blue panicgrass. Neither animal nor trial were significant sources of variation for any of the analyses.

The 16 fecal patties (four per steer) placed in the nursery from one of the four collection periods yielded 49 fourwing saltbush, 106 blue panicgrass, and 124 alkali sacaton seedlings. Because of sporadic and minimal rainfall (only 117 mm during the summer growing season) none of the placed patties of the other three periods produced any seedlings. Therefore, it was impossible to obtain a meaningful analysis of the field-placed patties, yet the emergence of seedlings was interpreted as biologically important. The fourwing saltbush seedlings were subsequently harvested by rodents native to the area, but

**Table 1.** *Recovery (% of seeds ingested) of gelatin-encapsulated seeds of fourwing saltbush, alkali sacaton, blue panicgrass, and sideoats grama at four 24-h intervals (24, 48, 72 and 96) post ingestion from steers fed a moderate quality alfalfa diet†*

| | Post-ingestion recovery (%) | | | | Total |
|---|---|---|---|---|---|
| Species | 24 h | 48 h | 72 h | 96 h | |
| Fourwing saltbush | 1·7*a*‡ | 5·8*a* | 1·6*a* | 0·5*a* | 9·5*a* |
| Alkali sacaton | 5·2*a* | 33·5*b* | 5·2*a* | 2·7*a* | 46·4*b* |
| Blue panicgrass | 15·5*a* | 40·3*b* | 5·3*a* | 0·6*a* | 61·8*b* |
| Sideoats grama | 0·0*a* | 0·0*a* | 0·0*a* | 0·0*a* | 0·0*a* |
| SE§ | 3·6 | 5·3 | 2·1 | 0·6 | 7·0 |

† Least-square Means. ‡ Means within a column followed by a different letter differ ($p < 0{\cdot}05$).
§ Standard error.

**Table 2.** *Germination (% of seeds recovered) of seeds of fourwing saltbush, alkali sacaton, and blue panicgrass following recovery at 24 h intervals (24, 48 and 72 h) post ingestion from steers fed a moderate quality roughage diet†*

| | Germination (%) | | | |
|---|---|---|---|---|
| | Post ingestion recovery interval | | | Noningested |
| Species | 24 h | 48 h | 72 h | |
| Fourwing saltbush | 0·0*a*‡ | 14·8*a* | 0·0*a* | 8·0 |
| Alkali sacaton | 44·9*b* | 50·1*b* | 5·5*a* | 45·1 |
| Blue panicgrass | 74·6*b* | 41·4*b* | 7·8*a* | 57·1 |
| SE§ | 11·1 | 5·2 | 3·3 | |

† Least-square Means. ‡ Means in a column followed by a different letter differ ($p < 0{\cdot}05$). § Standard error.

the blue panicgrass and alkali sacaton plants flowered and set seed before the season ended. However, grass seelings emerged in patties 15 months after collection following 14 mm of precipitation over a 96 h period.

## Discussion

Bolusing animals with gelatin capsules allowed insertion of known quantities of seed directly into the rumen. This provided a more accurate method for quantification of seed passage than previously utilized in other seed recovery studies. It is an easy method for administering seed to research animals and resulted in no known seed losses or damage from mastication. The bolusing method is inexpensive and rapid, requiring only a few seconds per animal. However, this is not a practical method of introducing seed to large herds of livestock. Other technologies could be developed with application to management practices characteristic of large range livestock operations or which could be used in the management of wildlife. For example, seed could be mixed into livestock supplements or simply provided free-choice to wildlife in feeding devices placed adjacent to water sources.

Recovery times and rates of passage were similar to those found by other researchers for other plant species. Yamada & Kawaguchi (1972) obtained near normal germination of five pasture grasses recovered in cattle feces 12 to 60 h after ingestion. However, seeds were recovered after the fourth day. Simao Neto *et al.* (1987) recovered the majority of seeds 48 to 72 h after feeding to cattle, sheep, and goats, and passage rates ranged from 8 to 39% for 2 grass and 4 legume species. However, in a related study (Simao Neto & Jones, 1987) subsequent germination and viability of passed seed was increased by feeding hard rather than soft seed.

In the Chihuahuan Desert, as in other arid environments, dung and other organic matter is rapidly decomposed during the rainy season by termites and microarthropods (Whitford *et al.*, 1982). Thus, further research on characteristics of seed germination within dung may not be important. Seedling emergence in an arid environment will likely continue to be primarily related to patterns of soil water availability (Winkel & Roundy, 1991). Unfortunately, seed dispersal in dung does not provide seed-soil contact that is important for subsequent seedling emergence and which is characteristic of seed burial techniques. Small seeded grass species which would not require seed burial for coarse soils would likely be well-suited to animal dispersal. It would be crucial to select seeds with durable seed coats and dormancy factors that would enable them to survive passage through the digestive tract and possibly retain viability even during sporadic rainfall until conditions that would allow for germination and establishment of the plants. If seeds can be obtained for native species that meet these requirements, then livestock could indeed be used to disperse these seeds, particularly in remote and inaccessible areas.

## References

Ahmed, A. el H. (1986). Some aspects of dry land afforestation in the Sudan with special reference to *Acacia tortilis* (Forsk.) Hayne, *A. senegal* Willd., and *Prosopis chilensis* (Molina) Stuntz. *Forest Ecology and Management*, **16**: 209–221.

Association of Official Agriculture Chemists (AOAC). (1980). *Official Methods of Analysis*. (13th Edn.) Washington, D.C.: Association of Official Agriculture Chemists. 1018 pp.

Buffington, L. C. & Herbel, C. H. (1966). Vegetational changes on a semidesert grassland from 1858 to 1963. *Ecological Monographs*, **35**: 139–164.

Cavanagh, A. K. (1980). A review of some aspects of the germination of *Acacias*. *Australia Range Society*, Victoria Proceedings, **91**: 1–2.

Hall, I. V. & Shay, J. M. (1981). Biological flora of Canada 3. *Vaccinium vitis* var *minus*. Supplementary account. *Canadian Field National*, **95**: 434–464.

Hunziker, J. H., Palacios, R. A., Poggio, L., Naranjo, C. A. & Yang, T. W. (1977). Geographic distribution, morphology, hybridization, cytogenetics and evolution. In Mabry, T. J., Hunziker, J. H. & DiFoe, D. R. Jr (Eds), *Creosote Bush: Biology and Chemistry of Larrea in New World Deserts*, pp. 10–47. Stroudsburg, Pennsylvania: Dowden, Hutchinson & Ross. 284 pp.

Gersa, C. M. & Martinez, M. A. (1985). The effect of cattle on johnsongrass seed dispersal. *Malezas*, **13**: 31–51.

Idani, G. (1986). Seed dispersal by pygmy chimpanzees *Pan paniscus*. A preliminary report. *Primates*, **27**: 441–448.

Janzen, D. H. (1986). Chihuahuan Desert nopaleras: defaunated big mammal vegetation. *Annual Reviews of Ecological Systems*, **17**: 595–636.

Lanner, R. M. (1982). Adaptations of whitebark pine *Pinus albicaulis* for seed dispersal by Clark's Nutcracker *Nucifraga columbiana*. *Canadian Journal of Forage Research*, **12**: 391–402.

Nobel, J. C. & Whalley, R. D. B. (1978). The biology and autcology of *Nitraria* in Australia. II. Seed germination, seedling establishment and response to salinity. *Australian Journal of Ecology*, **3**: 165–178.

Simao Neto, M. & Jones, R. M. (1987). Recovery of pasture seed ingested by ruminants. 2. Digestion of seed *in sacco* and *in vitro*. *Australian Journal of Experimental Agriculture*, **27**: 247–251.

Simao Neto, M., Jones, R. M. & Ratcliff, D. (1987). Recovery of pasture seed ingested by ruminants. 1. Seed of six tropical pasture species fed to cattle, sheep and goats. *Australian Journal of Experimental Agriculture*, **27**: 239–246.

Statistical Analysis Systems. (1985). *SAS® User's Guide: Statistics*. Cary, North Carolina: SAS Institute, 956 pp.

Snedecor, G. W. & Cochran, W. G. (1980). *Statistical Methods*, (7th Edn) Ames, Iowa: The Iowa State University Press. 507 pp.

Van Dyne, G. M., Brockington, N. R., Szocs, Z., Duek, J. & Ribic, C. A. (1980). Large herbivore subsystem. In: Breymeyer, A. I. & Van Dyne, G. M. (Eds), *Grasslands, System Analysis and Management*, pp. 269–537. Cambridge: Cambridge University Press. 950 pp.

Whitford, W. G., Steinberger, Y. & Ettershank, G. (1982). Contributions of subterranean termites to the 'economy' of Chihuahuan Desert ecosystems. *Oecologia*, **55**: 298–302.

Winkel, V. K. & Roundy, B. A. (1991). Effects of cattle trampling and mechanical seedbed preparation on grass seedling emergency. *Journal of Range Management*, **44**: 176–180.

Yamada, T. & Kawaguchi, T. (1972). Dissemination of pasture plants by livestock. 2. Recovery, viability and emergence of some pasture plant seeds passed through the digestive tract of the dairy cow. *Journal of Japanese Society Grassland Science*, **18**: 8–15.

Yermachenko, G. Y. (1972). Germination of *Deschampsia caespitosa* seeds after passing through the gastro-intestinal tract of animals. *Referativnyi Zhurnal*, **8**: 51–55.