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EFFECTS OF PLAINS POCKET GOPHERS ON ROOT BIOMASS AND SOIL NITROGEN

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Abstract. Total nitrogen and root biomass in 60 cm soil cores from plains pocket gopher den and food cache sites were compared to cores from control sites. Locations of den sites and food caches were determined from monitoring radio-tagged gophers. Control sites were located 5 m north of gopher sites and were assumed to have minimal gopher activity other than feeding. Gopher activities at den sites and food caches appeared to reduce total nitrogen in the top 10 cm of soil, but increased total nitrogen from 11-60 cm, especially at the level of primary tunnels (21-40 cm) and dens (51-60 cm). The decrease in total nitrogen in the top 10 cm soil zone probably resulted from gophers moving soil from lower levels to the surface when building mounds. Increases in total nitrogen in zones below 11 cm could have resulted from urine, feces, and decomposing plant parts left in food caches, tunnels, and dens.

INTRODUCTION

Plains pocket gophers, *Geomys bursarius* (Shaw), live in a three-dimensional subterranean habitat with burrows located from a few cm below the surface for feeding, to more than 50 cm deep for nest chambers (Scheffer 1940). Pocket gophers have the potential to markedly affect plant communities because digging and filling burrows changes the location of soil resources (Huntly and Inouye 1988, Reichman et al. 1982). Several studies have documented changes in surface soil characteristics as a result of mound building activity. Grant et al. (1980) found a short-term decrease in plant production proportional to the area covered by mounds. This created a mosaic of patches in various stages of secondary succession. Grant and McBrayer (1981) examined the nutrient status of soil in pocket gopher mounds and found an increase in the availability of cations from the decay of buried plant material. Tilman (1983) concluded that food preferences of gophers and the rapid growth of annual forbs on gopher mounds tended to confound the direct effects of experimental manipulation of nutrients. Addition of nutrients increased plant production, but consumption by gophers masked the increase. Inouye et al. (1987b) found that gophers reduced average soil nitrogen near the surface and increased point-to-point heterogeneity of surface soil nitrogen by moving nitrogen-poor subsurface soil to the surface when building mounds.

Our study site, Old Field 42, was located at the Cedar Creek Natural History Area, 55 km north of Minneapolis, Minnesota. The Sartell soil association, formed in fine, sand-textured glacial outwash and aeolian sediments, was light colored, undulating to hilly, and excessively drained (Grigal et al. 1974). Old Field 42 was clear-cut and farmed about 1910. The last known crop, in 1951, was clover. After 34 years of lying fallow, vegetation in Old Field 42 consisted primarily of Kentucky bluegrass (*Poa praetensis* L.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), big bluestem (*Andropogon gerardi* Vitman), and prairie forbs. We presume gopher presence in this field coincided with the advent of agriculture.

Locations of 22 den sites and 8 food caches were known from a radio-telemetry study of gopher behavior conducted from October 1983 through September 1985 (Zinnel 1992). Runways 25-35 cm deep, which connect den sites and foraging areas, remain in permanent use (Scheffer 1940). In this paper, den site refers to a discrete location at the confluence of several permanent tunnels and contains the primary nest chamber. Topology over den sites consisted of a tussock or hillock slightly raised above an otherwise uniform surface. Den sites and food caches were small distinct locations where gophers spent more than 50% of their time (referred to as gopher use areas).

We compared total nitrogen and root biomass in the top 60 cm of the soil profile at these sites with nearby control sites. Our basic premise was that available nitrogen was correlated with total nitrogen. Thus, an increase or decrease in total nitrogen should be reflected in a corresponding increase or decrease in root biomass. This relationship is based on data showing that total above-ground biomass in Cedar Creek old fields increased significantly with soil nitrogen (Inouye et al. 1987a).

METHODS

Soil cores were taken from 22 presumed den sites and 8 presumed food caches in October 1985. Soil cores taken 5 m north of each of the first sample sites were used as controls. Because of the sandy nature of the soil, compaction did not occur while taking the core. If a tunnel was encountered when taking the soil core, an alternate sample site was selected. Paired soil cores were known to be from the same gopher home range, but the 5 m separation was believed adequate to ensure that the control was not part of the den site or food cache.

Telemetry data were accurate to 1 m and allowed the den sites and food caches to be very precisely located. For example, the 4 m^2 area surrounding the den typically contained 40-50% of all locations. An area of 9 m^2 contained 66-76% of all locations. However, expanding this area to 25 m^2 added only an additional 1-4% of the locations (Zinnel 1992). Food caches were also identified as concentrations of telemetry locations. However, because the surface relief was not typical of gopher dens, these sites were inferred to be food caches.

Each sample site was further classified on the basis of telemetry data as to whether it had been used by a gopher either more or less than 50% of the time since the location was first known. Sites used more than 50% were classified as usually occupied; those used less than 50% of the time were classified as usually vacant. A further criterion for selection of sample sites was lack of disturbance caused by trapping or badger digging.

The 3.4 cm diameter soil cores were cut into six 10 cm samples, as measured from the surface. Volume of each 10 cm sample was 90.79 cm^3. Each sample was oven dried at 40C to constant mass. Root material was separated with a 1 mm mesh sieve, weighed to 0.001 g, and expressed as root biomass per 1000 cm^3 of soil. Total nitrogen, expressed as ppm/g of soil after roots were removed, was determined colorimetrically using an alkaline persulfate digestion technique (Tilman 1983) with a Technicon Auto-Analyzer. Accuracy was within 3%, as determined by analysis of 32 duplicate samples. Analysis of differences in root biomass and total nitrogen between den sites or food caches and corresponding controls was performed using the SPSS paired t-test procedure and a 2-tailed probability test (Nie et al. 1975).

RESULTS

Food Cache Sites

At food caches total nitrogen was reduced 33% in the 1-10 cm zone compared to controls ($P < .031$) (Figure 1B). Total nitrogen was significantly higher compared to control sites at 11-20 cm ($P < .037$), 21-30 cm ($P < .001$), 31-40 cm ($P < .027$), 41-50 cm ($P < .020$), and 51-60 cm ($P < .050$). Thus, total nitrogen was reduced at the surface but was significantly higher at every zone below 10 cm at the food cache sites. This pattern could result from release of nutrients during decomposition of uneaten food caches.

No significant differences in root biomass could be detected at any depth at food cache sites (Figure 1A). The high average root biomass in the 21-30 cm zone is the result of sampling through food caches. Some of the stored plant material became part of the root biomass sample. There is also a large standard error at this depth because half of the caches were vacant at the time of sampling. This resulted in a non-significant t-test, despite the high average root biomass for food caches as compared to control sites.

Occupied Den Sites

Total nitrogen was not significantly reduced in the 1-10 cm zone at usually occupied den sites compared to control sites (Figure 2B). Average root biomass was higher compared to control sites, although not significantly (Figure 2A). Root biomass was significantly higher in the 11-20 cm zone ($P < .005$) at usually occupied den sites compared to control sites, but no significant effect was found for total nitrogen at this depth. Conversely, we found a significant increase in total nitrogen but not in root biomass at 21-30 cm ($P < .013$), 31-40 cm ($P < .004$), and 51-60 cm ($P < .041$) at usually occupied den sites compared to control sites. As indicated above, these depths are characteristic of primary tunnels and nest chambers. The intervening layer, 41-50 cm, between tunnel and den site depths, showed no significant difference compared to control sites for either total nitrogen or root biomass.

Vacant Den Sites

In the 1-10 cm zone at usually vacant den sites, a significant decrease in total nitrogen ($P < .042$) occurred with a corresponding significant decrease in root biomass ($P < .008$) (Figure 3). No significant differences were seen for total nitrogen or root biomass from 11-20 cm, 41-50 cm, or 51-60 cm. However, both total nitrogen and root biomass showed a significant increase ($P < .028$ and $P < .001$, respectively) in the 21-30 cm zone. Total nitrogen was also significantly higher ($P < .0001$) at 31-40 cm near usually vacant den sites. Root biomass was not different from paired controls at this depth.

DISCUSSION

Because the study site was in glacial outwash sand plain of uniform deposition, initial conditions for the paired soil cores were assumed to be equal. Therefore, measured differences in total nitrogen and root biomass were assumed to reflect modification by gophers.

Reichman and Smith (1985) found 33% lower plant biomass over active gopher burrows compared to control sites. However, they concluded it might take decades for this effect to create significant differences in vegetation between areas with gophers compared to areas without gophers. They found the greatest above-ground plant biomass adjacent to active burrow systems and concluded that gophers chose to burrow in the most productive areas.

Figure 3A shows a significant decrease in root biomass in the 1-10 cm zone near usually vacant den sites compared to control sites. This decrease may be due to over-grazing by gophers, leading to temporary abandonment of the den sites. Comparing average root biomass from the 1-10 cm zone at usually occupied den sites (Figure 2A) to biomass from usually vacant den sites (Figure 3A) also suggests that gophers occupied the most productive areas. Average root biomass values for usually occupied den sites were higher than those of usually vacant den sites.

Owens and Wiegert (1976) proposed that consumers, like pollinators, have a mutualistic relationship with plants. Increased root biomass around den sites would support this hypothesis. Significant increases in root biomass and total nitrogen at den sites, as compared to less frequently used areas, occurred at 25-35 cm, the depth of main tunnels connecting other parts of the gopher home range with the actual nesting chamber (Scheffer 1940).

Soil movement by gophers may change soil compaction, thus allowing roots to penetrate deeper. Evidence supporting this was the significant increase in root biomass at 11-20 cm and 21-30 cm at den sites compared to controls.

We suspect that gophers harvest roots in the vicinity of den sites. This may explain why the significant increases in total nitrogen did not always have corresponding increases in root biomass. Because gophers spend more than 50% of their time in the den site area, and den sites are used repeatedly by a succession of gophers, this effect could be considerable.

Grant and McBrayer (1981) reported that freshly buried plant parts in gopher mounds increased the availability of cations and appeared to have a green-manure effect. Nitrogen concentration in new mounds averaged 650 ppm, with a range of 500 to 980 ppm. These values are comparable to our data. Their October sampling recorded new mounds as having more, freshly buried plant parts than old mounds and control sites combined. All of our food cache samples were also taken in October. Thus, nutrient influx phenomena should be comparable. Significantly higher total nitrogen at all depths below 11 cm in the vicinity of food caches (Figure 1B) may result from decay of plants stored by gophers.

If increases in total nitrogen at den sites were due solely to gophers redistributing the high-nitrogen surface soil to lower depths when filling abandoned burrows and to gophers moving low-nitrogen soil to the surface when building mounds, the sum of all the nitrogen samples for all depths should be similar for den versus control sites. This is not the case. The sum of nitrogen measurements at all zones for den sites is 11% higher than for control sites situated 5 m away. We propose that gopher urine, feces, and decomposing uneaten food could account for the increase in total nitrogen in the 21-30 cm, 31-40 cm, and 51-60 cm zones at den sites.

Increased total nitrogen at nest chamber depth (51-60 cm) was associated with usually occupied den sites, but not with usually vacant den sites. Concentrations of feces, urine, and plant parts near the den may have been the source of this nitrogen. Telemetry data indicated that non-resident gophers investigated unoccupied den sites. These transient gophers may have deposited feces and urine near the den, perhaps as scent marks. Because of historical use by generations of gophers, den sites appear to be a valuable resource.

Gopher activities in the 1-10 cm zone at or near den sites and food caches appeared to reduce total nitrogen when compared to control sites, which were used less frequently. We concluded that this was caused by gophers moving soil with low nitrogen content from deeper levels to the surface when building mounds and by gophers removing surface vegetation while foraging.

Gophers may benefit by maintaining conditions favorable for early successional species. Tilman (1983) found significant positive correlation between above-ground plant biomass and gopher activity. This supports the mutualism hypothesis of Owens and Wiegart (1976) in that mounds characterized by low nitrogen and high light would be dominated by early successional species. Some of these species, such as annual forbs, are favored by gophers as food items (Behrend and Tester 1988).

It is apparent that pocket gophers may have a large impact on soil fertility and, consequently, on the plant community. Impacts of mounds and castings have been well documented. Data presented here provide new information on the impact of den sites and food caches on soil fertility and root biomass.

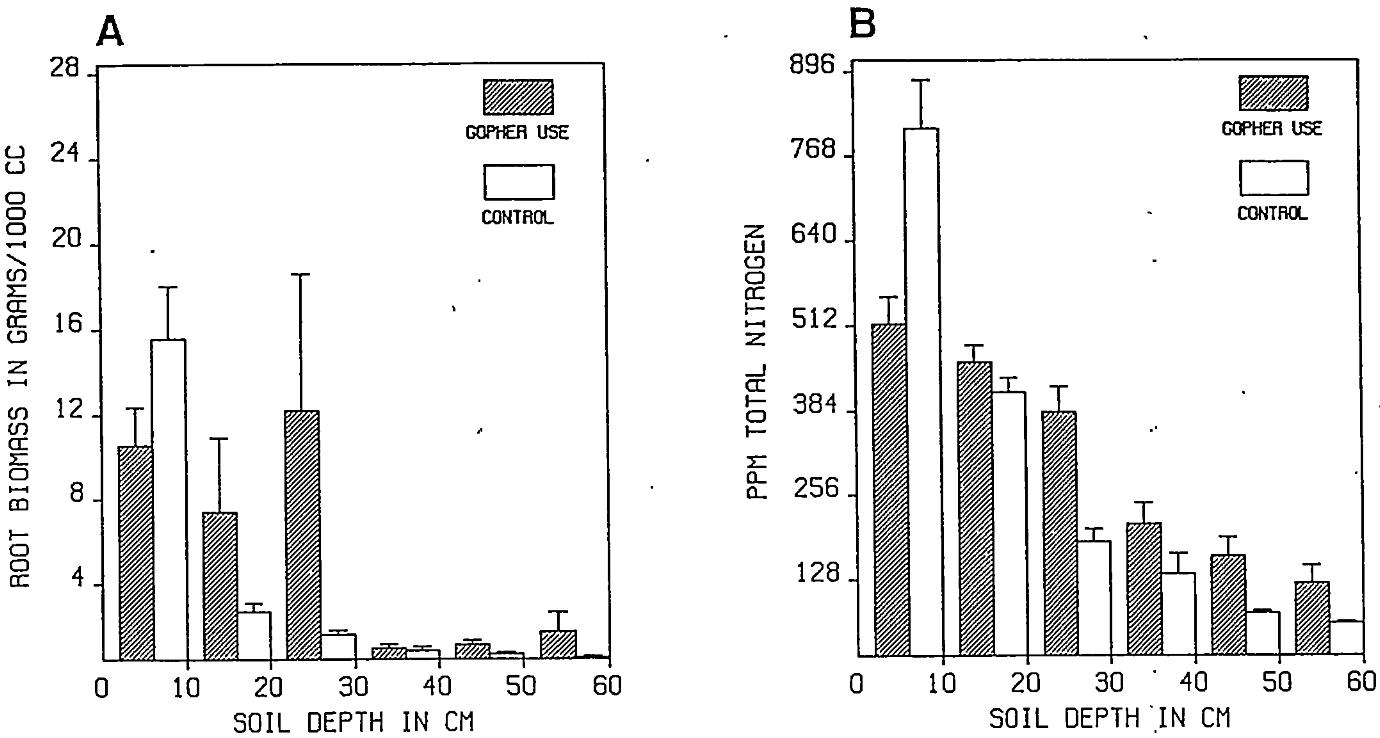

Figure 1. Root biomass (A) and total nitrogen (B) at various soil depths at eight pocket gopher food caches and paired control sites.

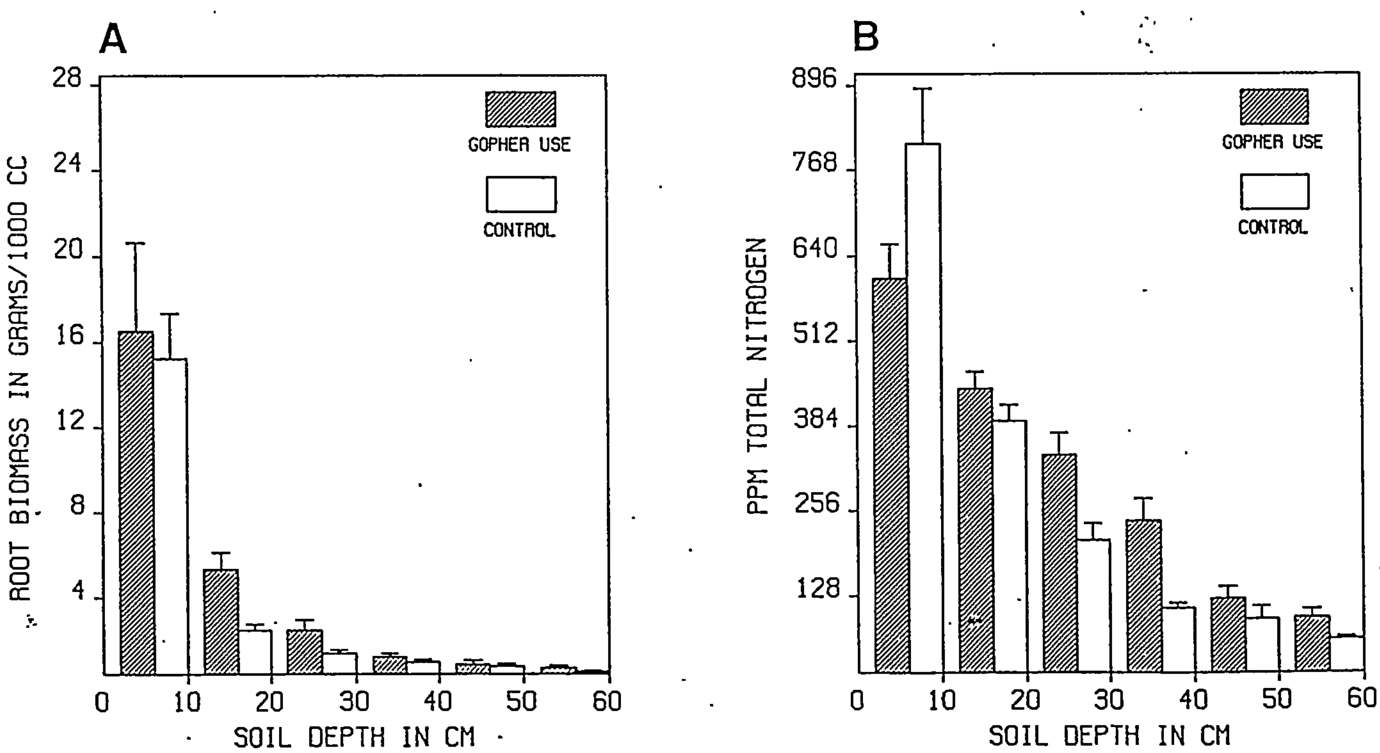

Figure 2. Root biomass (A) and total nitrogen (B) at various soil depths at 11 usually occupied pocket gopher den sites and paired control sites.

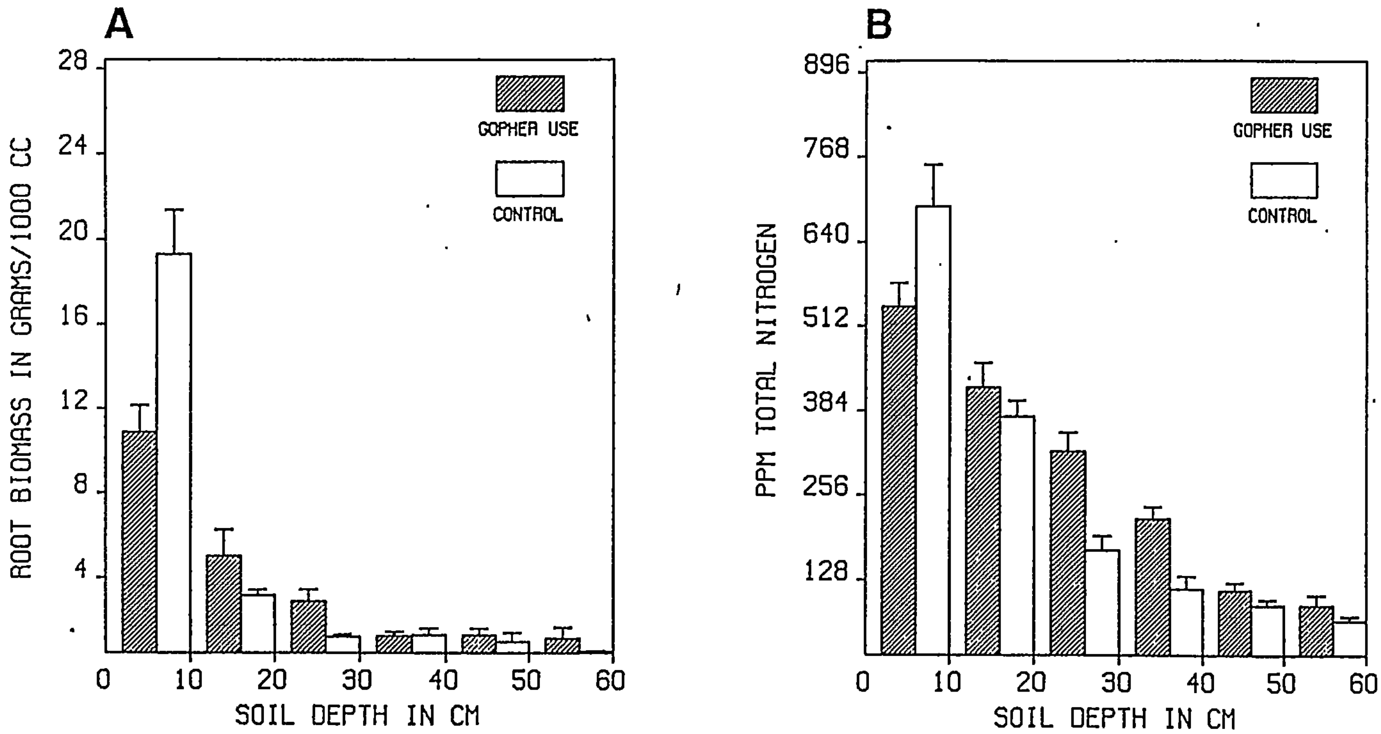

Figure 3. Root biomass (A) and total nitrogen (B) at various soil depths at 11 usually vacant pocket gopher den sites and paired control sites.

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LITERATURE CITED

Andersen, D. C. 1982. Below ground herbivory: the adaptive geometry of geomyid burrows. American Naturalist 119(1):18-28.

Behrend, A., and J. R. Tester. 1988. Feeding ecology of the plains pocket gopher in east central Minnesota. Prairie Naturalist 20:99-107.

Grant, W. E., N. R. French, and L. J. Folse. 1980. Effects of pocket gopher mounds on plant production in shortgrass prairie ecosystems. Southwestern Naturalist 25(2):215-224.

Grant, W. E., and J. F. McBrayer. 1981. Effects of mound formation by pocket gophers (*Geomys bursarius*) on old field ecosystems. Pedobiologia 22:21-28.

Grigal, D. F., L. M. Chamberlin, H. R. Finney, D. V. Wroblewski, and E. R. Gross. 1974. Soils of the Cedar Creek Natural History Area. University of Minnesota Agricultural Experiment Station Miscellaneous Report 123:1-47.

Huntly, N., and R. Inouye. 1988. Pocket gophers in ecosystems: patterns and mechanisms. BioScience 38(11):786-793.

Inouye, R. S., N. J. Huntly, D. Tilman, and J. R. Tester. 1987a. Pocket gophers, vegetation and soil nitrogen along a succession sere in east central Minnesota. Oecologia 72: 178-184.

Inouye, R. S., N. J. Huntly, D. Tilman, J. R. Tester, M. A. Stillwell. and K. C. Zinnel. 1987b. Old-field succession on a Minnesota sand plain. Ecology 68(1):12-26.

Nie. N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Brent. 1975. Statistical package for the social sciences. McGraw Hill Inc., New York.

Owens, D. F., and R. G. Wiegert. 1976. Do consumers maximize plant fitness? Oikos 27:488-492.

Reichman, O. J., and S. C. Smith. 1985. Impact of pocket gopher burrows on overlying vegetation. Journal of Mammalogy 66(4):720-725.

Reichman, O. J., T. G. Whitham, and G. A. Ruffner. 1982. Adaptive geometry of burrow spacing in two pocket gopher populations. Ecology 63(3):687-695.

Scheffer, T. H. 1940. Excavation of a runway of the pocket gopher (*Geomys bursarius*). Transactions Kansas Academy Science 43:473-478.

Tilman, D. 1983. Plant succession and gopher disturbance along an experimental gradient. Oecologia 60:285-292.

Zinnel, K.C. 1992. Behavior of free-ranging plains pocket gophers. Doctor of Philosophy Thesis. University of Minnesota, Minneapolis.