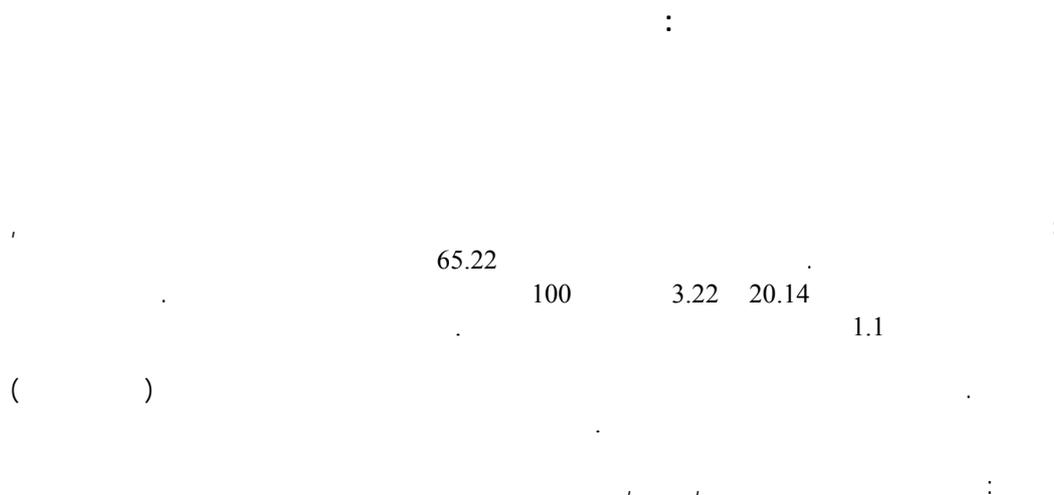


Desert Nitrogen Cycles: Fecal Nitrogen From a Population of the Sahelian Tree Locust in Oman

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ABSTRACT: This research quantifies the amount of nitrogen deposited by the tree locust, *Anacridium melanorhodon*, during an irregular population outbreak in an *Acacia tortilis* woodland in Oman. The average standing crop of feces was 65.28 g m⁻². The mean fecal crude protein and nitrogen were respectively, 20.14 and 3.22 g/100 g ash-free dry weight. A hectare of this woodland would contain approximately 1.1 kg of fecal nitrogen beneath the trees. This single contribution by the locusts equals about one-third of the total standing crop of detrital nitrogen under perennial vegetation in a hectare of the Mohave Desert of North America. This, and the fact that grasshoppers are diverse and seasonally abundant in deserts, suggests they may be important organisms in nitrogen cycles.

KEYWORDS: Nitrogen Cycles; Fecal Nitrogen; Deserts; Tree Locust; Grasshoppers; Oman.

1. Introduction

Phytophagous insects are important regulators of nutrient cycles in temperate forests (Mattson and Addy, 1975), but our knowledge of how they interact in desert ecosystems is still elementary. During the past two decades desert nutrient cycle research has focused on nitrogen, particularly on the concentration in plant tissues, leaf litter and soil (West and Skujins, 1978; Skujins, 1981; West, 1981; Whitford, 1986; Rundel and Gibson, 1996). Less attention has been given to the roles of animals in desert nitrogen cycles. Garner and Steinberger (1989) provide an insightful model of possible nitrogen pathways, and they emphasize that zoo-transport concentrates nitrogen around perennial vegetation. Field research by Dean *et al.* (1999) documents various ways vertebrate animals interact with trees in the arid woodland of the Kalahari Desert. It appears that the input of fecal nitrogen by tree locusts during one of their irregular population surges has not been quantified.

Tree locusts (genus *Anacridium*) are widely distributed in the arid and semi-arid regions of Africa and western Asia. During population outbreaks their swarms may cover several square kilometers and cause localized damage to trees (gum arabic, date and fruit trees) and other crops

(Popov and Ratcliffe, 1968; Marais and Wittneben 1977; Showler, 1995); however, tree locusts are generally not a major pest. The Sahelian Tree Locust, *Anacridium melanorhodon*, is distributed in the Sahelian region of Africa (*A. m. melanorhodon*) and the coastal zone of the Arabian Peninsula (*A. m. arabafrum*). Normally, they roost and feed in native trees of the xeric woodlands (eg., *Acacia spp.*, *Ziziphys spp.*, *Balanities aegyptiaca*). *A. m. arabafrum* breeds erratically in response to winter and spring rains and may produce several generations in a year (Popov and Ratcliffe, 1968).

The objectives of this study were to estimate the amount of fecal nitrogen deposited by the Sahelian tree locust during a population outbreak, and to point out the potential importance of acridid orthopterans in desert nitrogen cycles.

2. Methods

The study site was located in the Sultanate of Oman, approximately 40 km west of Muscat and 3 km southeast of Sultan Qaboos University (23°34.85'N, 58°11.14'E). Rainfall near the study area averages 81.3 mm/year (Fisher, 1994). The dominant perennial vegetation of this gravel plain includes *Acacia tortilis*, *Lycium shawi*, *Acridocarpus orientalis*, *Jaubertia aucheri*, *Pulicaria glutinosa*, and *Tephrosia apollinea* (nomenclature follows Ghazanfar, 1992). The locusts' primary roost was in samr trees (*A. tortilis*).

Adult tree locusts appeared on the study area sometime in late March 1998, and by April 2, approximately 10 to 30 individuals were seen in the larger trees. At the time of sampling (May 6-9), a clearly defined circular shadow of pellets was evident beneath most trees, representing the fecal accumulation of approximately 35-40 days. By May 25 the locust population was greatly reduced, but scattered individuals were still sighted in early autumn.

The standing crop of feces was quantified by collecting all fecal pellets inside four, 12.5cm square quadrats that were placed randomly beneath the canopy of 16 trees, a total of 64 sample units. *Anacridium* feces were easily distinguished from other grasshopper species by their large size. The fecal pellets were of various ages and degrees of desiccation, which possibly affected their protein content. Eleven sample units had sufficient mass for the ash and crude protein analyses. These samples represented 8 different trees (Table 1). All the samples were cleaned and oven-dried (60°C) to a constant mass. Crude protein was determined by the Kjeldahl method. The nitrogen content was assumed to be 16% of the crude protein (Cullison and Lowery, 1987). Samples were burned in a muffle furnace (550°C) to determine the ash content.

Table 1: Ash, crude protein (CP) and nitrogen (N) in 11 samples of tree locust (*Anacridium melanorhodon*) feces. Values are g/100 g dry weight. Crude protein and nitrogen are corrected for mineral contamination (AFDW).

Sample	Ash	CP	(AFDW)	Nitrogen	(AFDW)
T1-4	9.53	20.24	22.37	3.24	3.56
T2-2	10.95	17.53	19.68	2.80	3.15
T2-3	10.28	16.59	18.49	2.65	2.96
T3-4	9.95	17.22	19.12	2.76	3.06
T4-1	11.03	17.36	19.52	2.78	3.12
T4-4	11.00	17.02	19.12	2.72	3.06
T9-3	11.76	19.01	21.54	3.04	3.45
T9-4	10.18	18.81	20.94	3.01	3.35
T15-1	10.11	18.45	20.52	2.96	3.28
T7-3	11.57	17.81	20.13	2.85	3.22
T5-2	11.61	17.80	20.14	2.85	3.22

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3. Results

The mean fecal dry weight biomass in a quadrat was 1.02g, or 65.28g/m². Average density was 78.13 or 5000.32 pellets/m² (Table 2). This represents the fecal accumulation of slightly more than one month. The mean (\pm one standard deviation) dry mass and length of the pellets was 12.7 mg (\pm 1.52) and 8.4 mm (\pm 1.36), respectively (n=30). The mean crude protein and nitrogen content of the feces was, respectively, 20.14 (\pm 1.145) and 3.22 (\pm 0.180) g/100g ash-free dry weight (Table 1). Table 3 estimates the area beneath samr trees with various canopy diameters and the ash-free dry weight of feces, crude protein and nitrogen deposited by *A. melanorhodon*. One square meter would contain about 11.75 g of crude fecal protein and 1.88 g of fecal nitrogen.

Table 2: Mean dry weight biomass (g) and density of tree locust (*Anacridium melanorhodon arabafrum*, fecal pellets in 64, 12.5cm square quadrats beneath *Acacia tortilis* trees).

	Biomass	Density
Mean	1.02	78.13
SD	0.441	32.88
Minimum	0.41	30.0
Maximum	2.58	171.0

Table 3 : Ash-free dry weight estimates of fecal mass, crude protein and nitrogen (g) deposited by *Anacridium melanorhodon arabafrum* in surface litter under *Acacia tortilis* trees of various canopy diameters.

	Diameter (m)			
	2	4	6	8
Area (m ²)	3.14	12.57	28.27	50.27
Fecal Mass	182.82	731.85	1645.93	2926.82
Crude protein	36.82	147.42	331.54	589.55
Nitrogen	5.90	23.58	53.05	934.33

4. Discussion

Animal consumption and excretion are important pathways in nutrient cycles of desert and arid savanna (West, 1981; Garner and Steinberger, 1989; Belsky *et al.* 1989). Grazing animals increase the amount of plant material returned to the soil and in particular the turnover rate of nitrogen. Mammalian feces decompose more rapidly than non-ingested plant material, accelerating the flow of materials. Vertebrate herbivores deposit dung while resting beneath trees (Dean *et al.* 1999). The feces of a Chihuahuan Desert jackrabbit (*Lepus californicus*) comprise 10% of the total litter mass beneath creosote shrubs and 13.8% in open areas (Whitford *et al.*, 1982). Cowling (1977) estimates that 50-70% of the ingested nitrogen is returned as urine and a further 20% in dung.

While feeding, arthropods drop frass, partially eaten leaves, herbaceous stems and feces, into the surface litter, but estimates of this contribution by desert insect herbivores are very few. In a preliminary report, Boshoff (1988) estimates that immature Brown Locust (hoppers), at assumed swarm densities of 5000 individuals/m², could deposit 110 kg of frass/day. The average nitrogen concentration of the frass is 0.617gN/100g dry weight. At the roost sites 1 m² would contain about

0.093gN. I assume his data are without ash corrections; no methods are given. Fecal nitrogen of adult tree locusts is 4.6 times more concentrated than the frass of the Brown Locust (2.85gN/100gdw, not corrected for ash; Table 2). Locusts and other folivores capture nitrogen that would otherwise be translocated from the leaf prior to abscission. Nitrogen in tree locusts' feces is about 14% more concentrated than in the living leaflets of *A. tortilis* and 40% greater than the abscised leaflets in the litter (M. Robinson, unpublished).

Some of the fecal nitrogen of acridids is derived endogenously from the peritrophic membrane, which surrounds the egesta. For example, the creosote bush grasshopper, *Boottettix argentatus*, invests 10% of the ingested protein in the peritrophic membrane. When fed a tannin-rich diet, *Anacridium melanorhodon* produces a membrane that is 0.89% of the body weight (Bernays and Simpson, 1990). The main forms of fecal nitrogen excreted by Desert Locust (*Schistocerca gregaria*) are uric acid (30-35% of total egested nitrogen) and other undetermined nitrogenous waste products (55%), such as ammonia, allantoin and allantoinic acid. The feces contain relatively little protein or free amino acids (Zanotto *et al.* 1993).

The time required to decompose tree locust feces and mineralize the nitrogen is unknown. Estimates of turnover times of desert litter vary widely from 14 years (Holmgren and Brewster, 1972) to around two years (Cormanor and Prusso, 1973). Binet (1981) concludes that feces decompose slowly and mineralized nitrogen could remain a long time. Most of the nitrogen returned via feces and urine is lost in the gaseous form, with only 1% of the nitrogen becoming incorporated into the soil (Rixon, 1970). O'Brien's research (1978) in the Chihuahuan Desert also suggests that most of the nitrogen is volatilized during mineralization.

Considering their species richness and great seasonal abundance, orthopterans are probably important components in desert nutrient cycles. Wisdom (1991) reports 10 genera and 13 species of grasshoppers (Acrididae) occur on the Sonoran Desert tree *Prosopis glandulosa*. Mohave Desert grasshoppers comprise as much as 8% of the total invertebrate biomass, and their bodies contribute 13 g N/ha to the nitrogen pool (Rundel and Gibson, 1996). Grasshoppers are also abundant in the deserts of western Asia and Africa. Popov (1980) reports 70 taxa from eastern Arabia. Locusts (*Schistocerca*, *Locusta*) are legendary for their phenomenal sporadic population surges and the economic loss they inflict on agriculture (Popov *et al.*, 1984). However, the functional role of locusts and other acridids as concentrators of plant nitrogen and as a direct link to the decomposers has not been appreciated by ecologists.

The nitrogen budget of this community is unknown, but the potential input of fecal nitrogen by *A. melanorhodon* can be estimated. At a nearby site the density of *A. tortilis* averages 37 trees/ha. Most of these trees have canopy diameters between 3 and 6 m (Martin Fisher, personal communication). Assuming an average canopy diameter of 4.5 m, then approximately 30 g of fecal nitrogen would have been deposited under each tree, or 1.1 kg/ha (Table 3). Rundel and Gibson (1996) estimate that surface litter beneath perennial vegetation of the Mohave Desert contains 3kg nitrogen/ha, only about two-thirds more than that contributed by tree locusts. Without knowing how much fecal nitrogen is mineralized and eventually becomes available to the plants, the true impact of these irregular nitrogen inputs is impossible to assess. Locusts cause great economic losses to crops, but they probably also benefit agricultural and natural ecosystems by the nitrogen they contribute through death and defecation. It remains for future research to more clearly define their role in desert nutrient cycles.

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