Pedobiologia 31, 147—155 (1988)
VEB Gustav Fischer Verlag Jena

Department of Biology, New Mexico State University, Las Cruces, U.S.A.

Effects of rainfall supplementation on microarthropods on decomposing roots in the Chihuahuan Desert

W. G. WHITFORD, K. STINNET and Y. STEINBERGER

With 5 figures

(Accepted: 87-09-02)

1. Introduction

A number of studies have examined spatial and temporal variation in desert soil microarthropod populations (KAMILL *et al.* 1985, WALLWORK *et al.* 1985, 1986, STEINBERGER & WHITFORD 1984, 1985). Other studies have examined the responses of microarthropods to simulated rainfall (STEINBERGER *et al.* 1984, WHITFORD *et al.* 1981) and in relation to the stage of decomposition of the organic matter substrate (SANTOS & WHITFORD 1981, PARKER *et al.* 1984). PARKER *et al.* 1984 found that small fungus feeding mites and collembolans were important in nitrogen mineralization in decomposing roots of a desert annual. The study of STEINBERGER *et al.* (1984) demonstrated that microarthropod populations responded more to litter quantity than to added rainfall or enhanced soil moisture. There have been no studies of changes in soil microarthropod populations in response to changes in quantity or quality of dead roots nor in response to long term variation in soil moisture. As part of a study designed to test the hypothesis that single large quantity rainfall events would result in higher rates of root decomposition than small frequent rainfall events or no supplemental water, we sampled the microarthropods associated with the decomposing roots. We hypothesized that supplemental water would not only affect the rates of decomposition but would also affect the species composition and biomass of the microfauna feeding on the microflora on the roots. We further hypothesized that the successional trends in microarthropod populations observed on buried litter by SANTOS & WHITFORD (1981) would be similar on decomposing roots.

2. Methods

This study was conducted in the northern Chihuahuan desert on the Jornada Long Term Ecological Research Site 40 km NNE of Las Cruces, N.M. The average annual precipitation is 230 mm; average annual evaporation is 2,290 mm and 60% of the annual precipitation occurs between July and October. Maximum temperatures in summer range from 36 °C to 40 °C and winter minimum temperatures regularly drop below 0 °C.

We buried roots of a common small shrub, *Zinnia acerosa* GRAY, an evergreen shrub. *Larrea tridentata* (DC) COVILLE, an herbaceous spring annual, *Dithyrea wislizenii* ENGELM. and a spring-summer herbaceous annual, *Baileya multiradiata* HARV. et GRAY. The roots were tethered with wire connected to a tag on the surface at the edge of shrub canopies in 5 m × 15 m plots that received varying patterns of supplemental rainfall. Three plots received 6 mm × week^{-1}, 3 plots received 25 mm × month^{-1} and 3 plots received no supplemental moisture. Three sets of roots were removed from each plot at 30 day intervals for the first 4 months, at 9 months and at 12 months. The roots were excavated with a variable amount of the soil around the roots. We placed 500 cc of this soil into high gradient Tullgren funnels for extraction for 72 hours. The Tullgren funnels were fitted with vials of water which provided both a thermal and moisture gradient (SANTOS & WHITFORD 1981). The microarthropods were identified and counted immediately after extraction.

3. Results

Prostigmatid mites were the most numerous microarthropods in the soil around the decomposing roots (fig. 1). With the exception of *Baileya multiradiata* roots there was an overwhelming abundance of the pygmephorid, *Siteroptes sp;* in the soil around the unwatered roots (tables 1 & 2) at the end of the first month. Individual taxa of prostigmatids responded independently to the water amendments hence there was no discernible pattern of response by prostigmatids (fig. 1; tables 1 & 2). This was true for most of the other large groups of soil microarthropods as well (fig. 2—4). Mesostigmatids were abundant only in the September samples (fig. 3).

There were no important differences in taxa and or relative abundance of taxa associated with the different species of roots. Interestingly, although there was more than 50% of the original mass of the woody roots of *Larrea tridentata* and *Zinnia acerosa* and only 15% of the mass of *Baileya multiradiata* and *Dithyrea wislizenii* roots remaining at the end of the year, the patterns of abundance of the most numerous species of mites, collembolans and psocopterans were similar (tables 1 & 2). Despite the large numbers of small fungus feeding mites, *Siteroptes sp.* and *Tarsonemus sp.* in July, there were essentially no predatory mites in the soils around the roots i.e. cunaxids, raphignathids and mesostigmatids at that time.

In addition to the microarthropods listed in tables 1 and 2, there were a variety of other acari and other microarthropods in the soil around the roots on some of the sampling dates. These included species in the prostigmatid families Stigmaeidae, Bdlellidae, Scutacaridae, Teneriffidae; the cryptostigmatids *Joshuella striata*, *Aphelacarus sp.*, *Oppia sp.* and *Jornadia larraea;* insect larvae; thrips and pseudoscorpions. The occasional occurrence and inconsistent pattern of occurrence suggest that these taxa are inconsistent and minor components of microarthropod assemblages associated with decomposing roots in this desert.

At the end of the first month in the field there were extremely high population densities of mites in the soil around the roots (fig. 5). The species dominating these populations

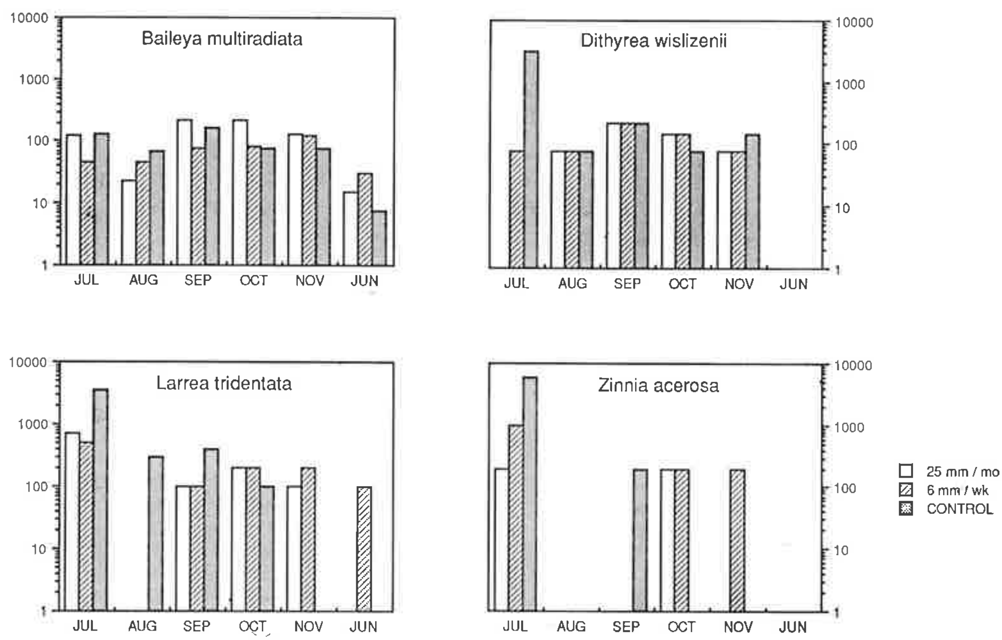

Fig. 1. Numbers of prostigmatid mites in 500 cm^3 of soil surrounding decomposing roots of woody shrubs *Larrea tridentata*, *Zinnia acerosa* and herbaceous plants, *Baileya multiradiata; Dithyrea wislizenii*. Supplemental rain all treatments are: 25 mm × mo^{-1}, 6 mm × wk^{-1} and no added water.

Table 1. Numbers of microarthropods in 500 cm³ of soil surrounding decomposing herbaceous plant roots of *Dithyrea wislizeni* (a) and *Baileya multiradiata* (b)

Taxa		1 mo July			2 mos August			3 mos September			4 mos October			9 mos March			12 mos June		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Tydeidae	(a)	6	4	4	2	7	20	26	43	43	46	26	18	7	2	48	7	14	0
Tydeus spp.	(b)	4	16	4	6	6	4	60	22	34	32	12	20	5	5	20	15	18	2
Nanorchestidae	(a)	1.0	0	7	0.7	1.4	0	0	0	0	1.5	4.2	0.3	0.3	0	0	4.2	4.5	0
Speleorchestes sp.	(b)	0.4	0	0	1.8	0	0	0	0	4	6	1.5	0	0	0	7	2	1	1
Tarsonemidae	(a)	20	16	100	20	24	20	140	120	200	60	60	35	35	60	20	5	0	0
Tarsonemus sp.	(b)	105	25	75	10	20	40	100	45	120	110	25	10	40	60	20	0	10	0
Raphignathidae	(a)	0	0	0	30	34	25	0	0	2	37	30	26	29	30	0	0	2	0
	(b)	0	0	0	7	15	12	0	0	0	40	44	40	64	20	15	0	7	0
Cunaxidae	(a)	0	0	0	0	0	0	44	38	5	14	10	16	4	2	46	2	2	0
	(b)	0	0	0	0	0	3	21	9	7	30	4	9	3	9	4	0	0	0
Passalozetes spp.	(a)	0	0	0	.3	.3	.3	0	0	1.8	0	0	0	.5	1.5	0	4.2	a.5	0
	(b)	0	0	0	0	0	0	0	0	1.0	1.5	0	0	0	0	0	2.3	2.1	0
Cosmocthonius spp.	(a)	0	0	0	0	0	0	2	2	1	5	0	0	6	4	5	1	20	0
	(b)	0	0	0	0.3	0	0	1	0	2	2	.3	0	1.8	0	1.5	0	2	0
Pygmephoridae	(a)	0	50	3000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siteroptes sp.	(b)	8	3	50	0	2	15	0	0	2	2	2	2	6	6	0	0	0	0
Psocoptera	(a)	0	0	1	0	0	2	0	0	0	1	0	0	0	1	0	6	6	30
Liposcelidae	(b)	0	0	0	1	0	2	1	0	3	2	0	0	1	2	2	10	5	20

Note: Supplemental rainfall treatments are: I = 25 mm × mo^{-1}, II = 6 mm × wk^{-1}, III = no added water.

Table 2. Numbers of microarthropods in 500 cm³ of soil surround decomposing plant roots of *Larrea tridentata* (a) and *Zinnia acorosa* (b)

Taxa		1 mo July			2 mos August			3 mos September			4 mos October			9 mos March			12 mos June		
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Tydeidae	(a)	20	8	8	5	2	7	50	32	43	19	18	22	10	14	10	10	21	2
Tydeus sp.	(b)	27	7	7	7	5	5	30	25	45	32	38	22	18	12	18	10	20	10
Nanorchestidae	(a)	0	.5	.7	0	0	1.8	0	0	0	0	.4	.6	4	2	2.5	4.5	6.5	2.0
Speleorchestes sp.	(b)	0	0	0	.5	0	1.5	0	0	0	3	5	3	2.5	2.2	1.0	4	7.5	0
Pygmephoridae	(a)	470	470	3500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siteroptes spp.	(b)	0	800	5500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tarsonemidae	(a)	226	56	226	8	8	195	64	96	375	62	66	24	36	210	8	0	9	0
Tarsonemus sp.	(b)	140	100	600	0	0	0	30	20	30	20	20	20	0	100	20	0	0	0
Raphignathidae	(a)	0	0	0	9	31	12	0	0	0	97	82	33	80	27	16	0	5	
	(b)	0	0	0	10	12	4	2	2	0	25	40	18	14	25	12	2	0	0
Cunaxidae	(a)	0	0	0	0	1	1	37	19	14	23	6	11	17	6	9	1	1	0
	(b)	0	1	0	0	0	0	25	30	35	30	10	20	12	10	2	0	2	0
Passalozetes sp.	(a)	0	0	0	0	0	.3	0	.6	.6	.6	.6	0	0	.6	0	2.5	2	0
	(b)	0	0	0	0	.3	0	0	0	1	.7	.5	0	.5	1	0	3	2	.7
Cosmocthonius sp.	(a)	0	0	0	1	0	0	0	2	0	3	.6	0	2.5	1	0	2	4.5	
	(b)	0	0	0	2	2	0	1	2	0	6	0	0	4	3	3	3	15	0
Psocoptera	(a)	0	80	0	.5	0	2.0	.5	.5	0	2	0	0	4	0	0	14	.5	10
Liposcelidae	(b)	1	0	1	0	0	0	1	0	0	2.3	3.5	0	3.5	.5	0	6	4	3.5

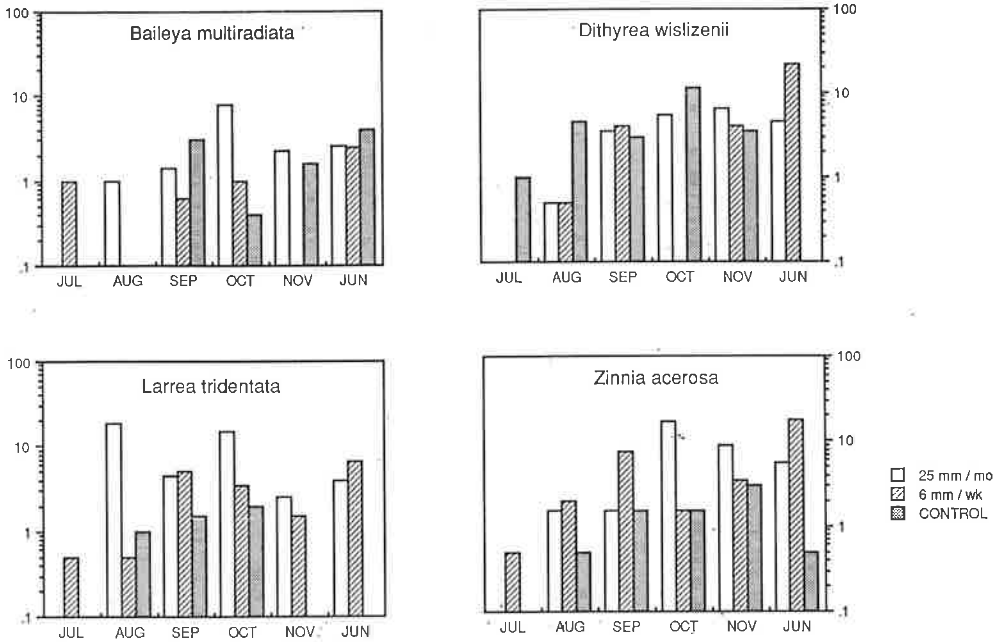

Fig. 2. Numbers of cryptostigmatid mites in 500 cm³ of soil surrounding decomposing roots of woody shrubs *Larrea tridentata*, *Zinnia acerosa* and herbaceous plants, *Baileya multiradiata; Dithyrea wislizenii*. Supplemental rainfall treatments are: 25 mm $\times$ mo^{-1}, 6 mm $\times$ wk^{-1} and no added water.

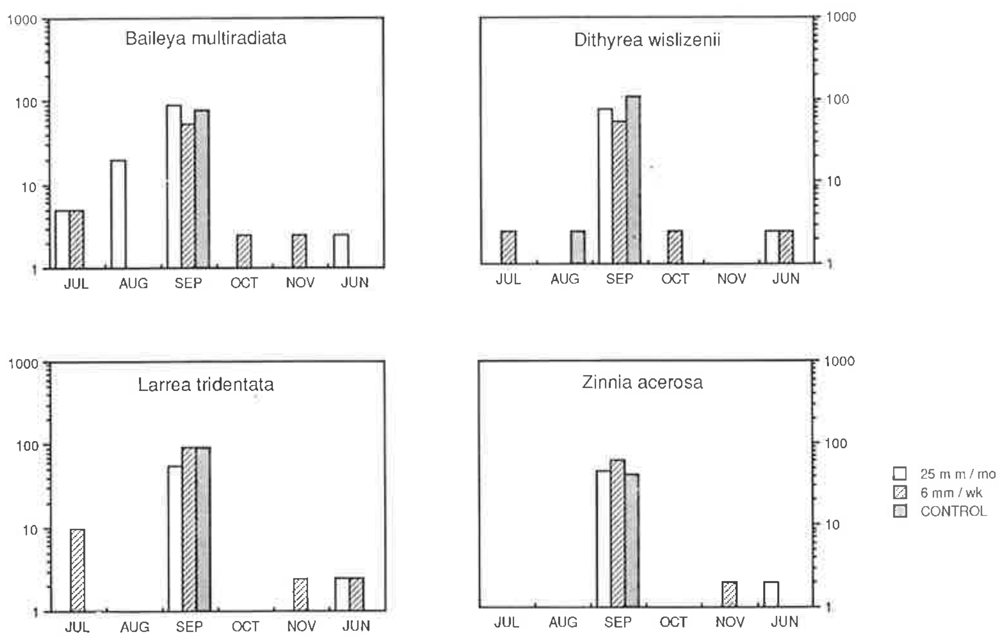

Fig. 3. Numbers of mesostigmatid mites in 500 cm³ of soil surrounding decomposing roots of woody shrubs *Larrea tridentata*, *Zinnia acerosa* and herbaceous plants, *Baileya multiradiata; Dithyrea wislizenii*. Supplemental rainfall treatments are: 25 mm $\times$ mo^{-1}, 6 mm $\times$ wk^{-1} and no added water.

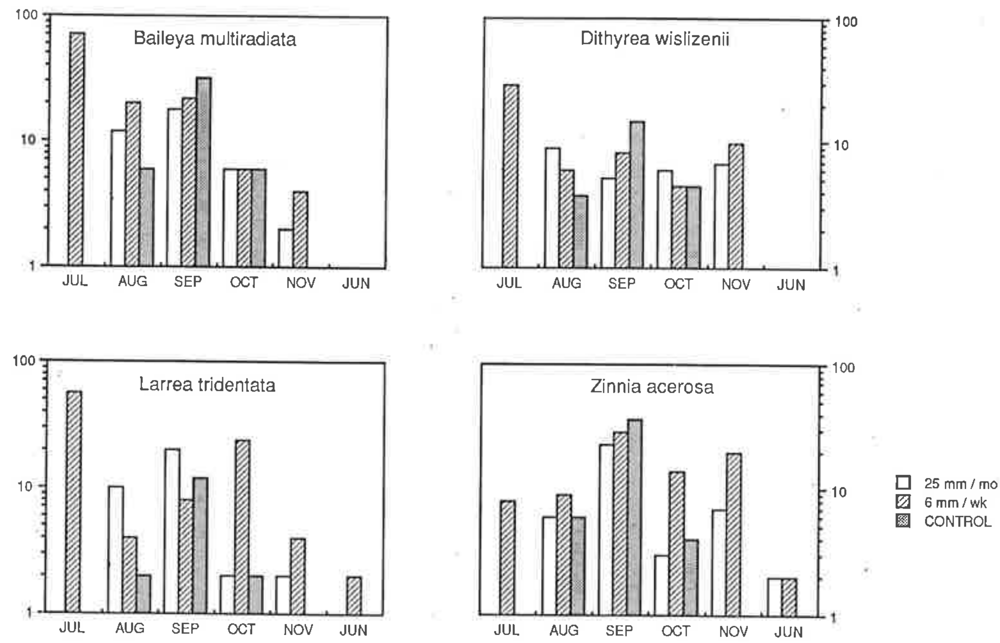

Fig. 4. Numbers of collembolans in 500 cm³ of soil surrounding decomposing roots of woody shrubs *Larrea tridentata*, *Zinnia acerosa* and herbaceous plants, *Baileya multiradiata; Dithyrea wislizenii*. Supplemental rainfall treatments are: 25 mm × mo^{-1}, 6 mm × wk^{-1} and no added water.

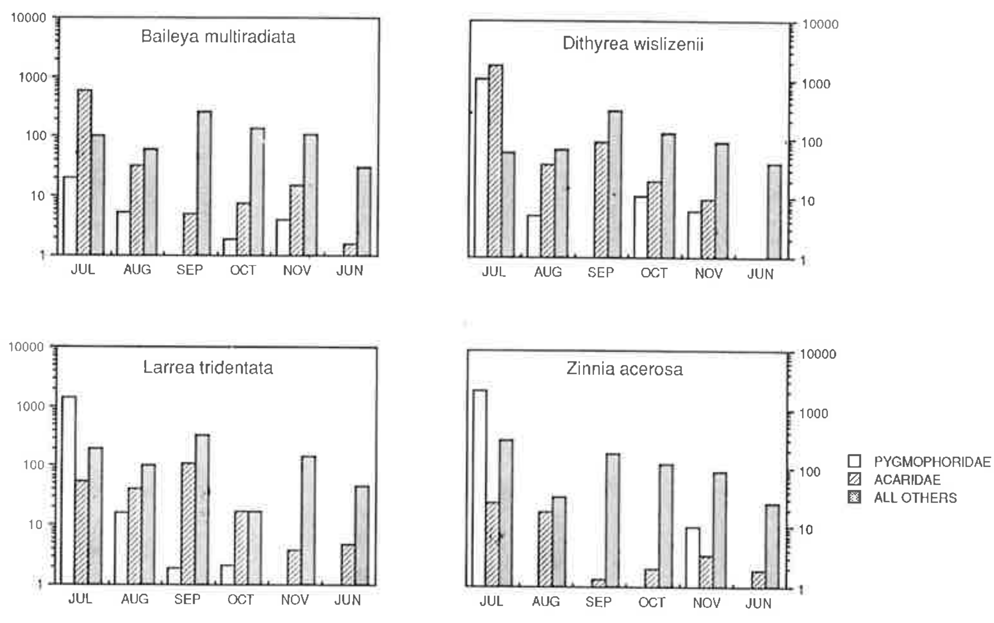

Fig. 5. Numbers of microarthropods in 500 cm³ of soil surrounding decomposing roots of woody shrubs *Larrea tridentata*, *Zinnia acerosa* and herbaceous plants, *Baileya multiradiata; Dithyrea wislizenii*. Data are averaged for all treatments.

Table 3. Monthly rainfall recorded at the study site during the period of the root decomposition study

1982	mm	1983	mm
June	4.5		
July	27.8	January	24.1
August	30.8	February	13.7
September	58.3	March	3.6
October	0.8	April	22.3
November	17.0	May	6.9
December	62.0		

differed with root type (woody or herbaceous) and with water amendment. Acarid mites, *Typhlophagus sp.* occurred at extremely high population densities around the roots of the herbaceous annuals in the monthly large event, 25 mm $\times$ month^{-1} irrigated plots and pygmephorid mites, *Siteroptes sp.* occurred at high population densities around *Dithyröa* roots in the unwatered plots (fig. 5). The acarids occurred around the woody roots in the 25 mm $\times$ month^{-1} plots but the pygmephorid, *Siteroptes sp.* dominated the microarthropod populations associated with the woody roots. For the remainder of the study, months 2 through 12, total numbers of microarthropods ranged between 200—600 Ind. $\times$ 500 cm^{-3} of soil and the taxonomic composition was made up of several species of nearly equal abundance (tables 1 & 2; figs. 2—5).

Collembolans responded to the frequent, small quantity 6 mm $\times$ week^{-2} irrigations during July and August, during which there were scattered rain events (table 3, fig. 4) but showed no pattern or slight inhibition by irrigation in the September and October samples when soils were wet due to natural rain events (table 3). Collembolans were virtually absent at the end of the study, possibly because of a lack of suitable food.

Cryptostigmatid mites were more abundant from the third month to the end of the study (fig. 2). Cryptostigmatid mites were more numerous in soils around woody roots in the water amended plots but that pattern did not hold for cryptostigmatids in soil around the herbaceous roots. These patterns were the same in the more abundant genera, *Passolozetes spp.* and *Cosmocthonius spp.* (tables 1 & 2), and in the tydeids, and tarsonemids, two groups of prostigmatid mites that maintained relatively high population densities throughout the study associated with both types of roots.

4. Discussion

The effects of supplemental water on microarthropod population associated with decomposing roots were most pronounced in the first month of the experiment where the single large event amendment resulted in huge populations of the Acarid, *Typhlophagus spp.* around the woody roots and no added water resulted in huge populations of the pygmephorid, *Siteroptes* around the herbaceous roots. The lack of any other detectable effect of supplemental water on the microarthropods associated with decomposing roots is strong evidence that soil moisture is not a critical factor for populations of soil microarthropods utilizing resources associated with decomposing roots. The pygmephorid and acarid mites that developed such large populations at the end of one month undoubtly immigrated to the vicinity of the recently placed dead roots to utilize some particularly attractive resource available in the vicinity of freshly decaying roots. The marked reduction in numbers or complete disappearance of these taxa at subsequent dates, suggests that the attractive resource(s) were available but for a brief time.

The mites that maintained consistent populations around the decomposing roots were the small fungivorous tarsonemids and the fungivorous nematode predator, tydeids (Santos *et al.* 1981). Both of these groups of prostigmatids are probably generalists and capable of feeding on a wide variety of fungi and/or the nematodes (Walter 1987). The absence of a distinct temporal or successional sequence in microarthropod taxa associated with decomposing roots is probably due to differences in the microflora in decaying leaf litter in comparison to decaying roots. Decomposing roots are colonized by fungi initially (SANTOS *et al.* 1981; ZAK unpublished data). While buried leaves are processed initially by bacterial and yeasts with filamentous fungi increasing slowly over the first three to four months (PARKER *et al.* 1984, SANTOS *et al.* 1981).

Although the substrates were different, woody vs. herbaceous roots, the diversity, population density and taxonomic composition of the microarthropods associated with the decomposing roots were very similar. This is similar to the findings of CURRY & GANLEY (1977) who found no identifiable root-arthropod association in a study of a variety of pasture plants in Ireland. This also suggests that the fungiphagous microarthropods are generalists. The predatory taxa thus had essentially the same food resource in each treatment of this experiment, hence there were few differences in the taxa of predators in the various treatments. The dominance of the fungiphagous microarthropods provides indirect support for the conclusions of PARKER *et al.* (1984) that these organisms are important agents of nitrogen mineralization from decaying roots. Thus, one important conclusion that can be drawn from this study is that desert soil microarthropods are probably limited by food availability not by soil moisture and that the most abundant taxa are generalist-fungivores.

5. Acknowledgements

This research was funded by grants BSR 821539 and BSR 8114466 from the U.S. National Science Foundation and is a contribution of the Jornada Long Term Ecological Research Program.

6. References

CURRY, J. P., & J. GANLEY, 1977. The arthropods associated with the roots of some common grass and weed species of pasture. Ecol. Bull. (Stockholm) **25**, 330—339.

KAMILL, B. W., Y. STEINBERGER & W. G. WHITFORD, 1985. Soil microarthropods from the Chihuahuan Desert of New Mexico. J. Zool. Lond. **205**, 273—286.

PARKER, L. W., P. F. SANTOS, J. PHILLIPS & W. G. WHITFORD, 1984. Carbon and nitrogen dynamics during the decomposition of litter and roots of a Chihuahuan desert annual, *Lepidium lasiocarpum*. Ecological Monographs **54**, 339—360.

SANTOS, P. F., & W. G. WHITFORD, 1983. The effets of microarthropods on litter decomposition in a Chihuahuan desert ecosystem. Ecology **62**, 654—663.

— — 1983. Seasonal and spatial variation in the soil microarthropod fauna of the White Sands National Monument. Southwest. Nat. **28**, 417—421.

STEINBERGER, Y., & W. G. WHITFORD, 1984. Spatial and temporal relationships of soil microarthropods on a desert watershed. Pedobiologia **26**, 275—284.

— D. W. FRECKMAN, L. W. PARKER, & W. G. WHITFORD, 1984. Effects of simulated rainfall and litter quantities on desert soil biota: nematodes and microarthropods. Pedobiologia **26**, 267—274.

— & W. G. WHITFORD, 1985. Microarthropods of a desert tabosa grass (Hilaria mutica) swale. Amer. Midl. Nat. **114**, 225—234.

WALTER, D. E., 1987. Trophic behavior of "mycophagous" microarthropods. Ecology **68**, 226—229.

WALLWORK, J. A., B. W. KAMILL, & W. G. WHITFORD, 1984. Life styles of desert litter-dwelling microarthropods: a reappraisal based on the reproductive behavior of cryptostigmatid mites. Suid-Afrikaanse Tydskrif vir Wetenskap **80**, 163—169.

— — — 1985. Distribution and diversity patterns of soil mites and other microarthropods in a Chihuahuan desert site. J. Arid Environ. **9**, 215—231.

— M. MACQUITTY, S. SILVA & W. G. WHITFORD, 1986. Seasonality of some Chihuahuan Desert soil oribatid mites (Acari: Cryptostigmata). J. Zool. Lond. **208**, 403—416.

WHITFORD, W. G., D. W. FRECKMAN, N. Z. ELKINS, I. W. PARKER, R. PARMALEE, J. PHILLIPS & S. TUCKER, 1981. Diurnal migration and responses to simulated rainfall in desert soil microarthropods and nematodes. Soil Biol. Biochem. **8**, 417—425.

— Y. STEINBERGER, W. MACKAY, L. W. PARKER, D. FRECKMAN, J. A. WALLWORK & D. WEEMS, 1986. Rainfall and decomposition in the Chihuahuan Desert. Oecologia (Berlin) **68**, 512—515.

Adress of the authors: W. G. WHITFORD (corresponding author). K. STINNET and Y. STEINBERGER, Department of Biology, New Mexico State University, Las Cruces, NM 88003, USA.

Synopsis: *Original scientific paper*

WHITFORD, W. G., K. STINNET & Y. STEINBERGER, 1988. Effects of rainfall supplementation on microarthropods on decomposing roots in the Chihuahuan Desert. Pedobiologia **31**, 147—155.

We tested the hypothesis that supplemental water would affect the species composition and population densities of microarthropods feeding on microflora on decomposing roots in a desert and that species composition would change through time in a predictable sequence. Prostigmatid mites were the most numerous microarthropods in the rhizosphere of decomposing roots. There were no consistent differences in species or abundances due to water supplementation or related to species of roots. After one month the microarthropod population densities in the rhizosphere exceeded 1,000 ind. × 500 cm^{-3} of soil mostly acarids and pygmephorids. Small fungivorous mites were the most abundant in the rhizosphere of decomposing roots for the remainder of the study. We conclude that desert soil microarthropod populations are limited by food availability, not by soil moisture. Further, generalist-fungivores are the most abundant taxa of soil microarthropods associated with decaying roots and may be important in nutrient mineralization from decaying roots.

Key words: Chihuahuan desert, root decomposition, rainfall supplementation, food availability, Prostigmatid mites.