Table VIII. Effect of crop residue management methods on some chemical properties from sorghum plots at Mokwa.

Chemical property	Sampling depth (cm)	Values at start of experiment	Crop residue management methods: Mulch	Remove	Burn	LSD (0.05)
Organic C (%)	0-15	0.59	0.60	0.58	0.57	0.04
	15-30	0.35	0.36	0.36	0.34	0.04
pH-H_2O	0-15	6.0	5.6	5.5	5.7	0.1
	15-30	5.6	5.4	5.4	5.4	0.1
Extr. P (mg kg^{-1})	0-15	11.9	45.0	50.7	48.0	5.8
	15-30	4.9	5.7	5.3	5.3	0.1
Extr. K (cmol kg^{-1})	0-15	0.13	0.14	0.13	0.16	0.02
	15-30	0.07	0.05	0.05	0.08	0.04
Extr. Ca (cmol kg^{-1})	0-15	1.24	1.92	0.83	0.97	0.25
	15-30	0.98	0.68	0.78	0.77	0.18
Extr. Mg (cmol kg^{-1})	0-15	0.24	0.23	0.20	0.19	0.05
	15-30	0.18	0.14	0.15	0.18	0.02

CP #68

EFFECTS OF SOIL MANAGEMENT ON POPULATION ABUNDANCE AND BIOMASS OF EARTHWORMS IN A SEMI-ARID TROPICAL ALFISOL

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INTRODUCTION

Conservation tillage, reduced tillage and no tillage systems for agriculture have been widely researched and adopted in temperate climates (Blevins, 1984). The key elements of these systems are a reduction in the number, depth and severity of the tillage operations and the retention of crop residues on the soil surface. These systems have lead to improved soil quality as evidenced by increased soil organic matter content (Blevins et al., 1983) and reduced runoff and soil erosion (Sallaway et al., 1990). In contrast, conventional tillage systems typically involve removal or burning of the crop residues and inverting tillage which incorporates crop residues.

No tillage agroecosystems were found to have higher densities of soil inhabiting animals than conventional tillage systems in U.S.A. (House and Parmelee, 1985). Earthworms comprise a large portion of animal biomass in soils and their activities have ameliorative effects on soil physico-chemical properties, soil fertility and plant growth (Atlavinyte and Zimkuviene, 1985; Lee, 1985; Reddy, 1988). Soil management practices, such as tillage and crop residue management, alter both soil physico-chemical properties and soil faunal activity (Andren and Lagerloef, 1983; House and Parmelee, 1985) but reduced tillage systems are generally less harmful (Robertson, 1989; Haukka, 1988; Rovira et al., 1987). Tillage damages earthworms and their burrows and reduces the food supply by burying plant residues while farm yard manure and organic mulches increase the food supply. Pastures both increase the food supply and decrease disturbance and mechanical damage due to lack of cultivation (Edwards and Lofty, 1977; Lee, 1985).

Many investigations have studied the effects of soil management on soil animals, particularly earthworms in temperate climates (House and Parmelee, 1985; Andersen, 1987; Haukka, 1988; Parmelee et al., 1990) but Lal and Vleeschauwer (1981) report one of the few similar studies in tropical soils. We know of no reports of studies of the effects of soil management on earthworms in Alfisols in semi-arid tropical climates. The earthworm study reported here was conducted within an experiment which aims to quantify the effects of management on soil physical properties and processes. A wide range of treatments had been established and large effects were measured on runoff (Yule et al., 1990). The treatments included tillage, amendments of farm yard manure or rice straw and perennial pastures. These soil managements should affect earthworm populations and biomass. The aim of the earthworm study was to measure the population dynamics and biomass of earthworms in response to soil management.

MATERIALS AND METHODS

The core experiment is conducted on a shallow to medium depth Alfisol (Patancheru Series, Udic Rhodustralf) in field RM19B at ICRISAT, near Hyderabad, India. The soil is hardsetting and very prone to surface sealing and crusting. The climate is monsoonal semi-arid tropical with average annual rainfall of 764 mm and 80% of rain occurring from June to early October. The core experiment combines two balanced incomplete block designs, one a 3 x 3 factorial arrangement of tillage x amendment with annual cropping, the other involving six treatments with perennial species. The fifteen treatment combinations are listed in Table 1. There are three replications and the plot size is 22m long x 5 m wide. The core experiment was established in 1988 and treatments are maintained in the same plot each year. The tillage X amendment treatments are imposed after initial rains in early June. Tilled plots initially receive a shallow tine with duckfoot tillage (0.05-0.07 m depth) to break the surface crust and to control weeds. After further rains, typically 10

Table 1. Treatments applied in soil management study on an Alfisol at ICRISAT, India. The annual crops have been millet (1988), sorghum (1989) and sorghum (1990). The perennial species are perennial pigeonpea (*Cajanus cajan*), *Stylosanthes hamata* and *Cenchrus ciliaris*

Annual crops	Tillage	X	Amendment
	Zero (T0)		Bare (B)
	10 cm depth (T10)		FYM[1] (F)
	20 cm depth (T20)		Straw[2] (S)
Perennial crops	Perennial pigeonpea (PP)		
	PP + *S. hamata* (PP+S)		
	PP + *S. hamata* + *C. ciliaris* (PP+S+C)		
	C. ciliaris (C)		
	C. ciliaris + *S. hamata* (C+S)		
	S. hamata (S)		

[1]FYM = farm yard manuare, 15 t ha^{-1} (air dry)
[2]Straw = rice straw, 5 t ha^{-1} (air dry)

to 14 days, a second tillage is imposed using narrow tines at 50 cm spacing to the treatment depth. Planting by hand follows 10 to 14 days later. The amendments are applied (15 t ha^{-1} farmyard manure (FYM), 5 t ha^{-1} rice straw) in three equal increments after each of these cultural operations. Rice straw is removed to facilitate tillage and then replaced. Herbicides (glyphosate, paraquat, diquat) are applied pre-planting as required. One or two hand weedings are carried out during crop growth. In 1989, carbofuran insecticide granules (40 kg ha^{-1}) were applied to the soil in the planting furrow to control shoot fly (*Atherigona soccata*). In 1990, about 5 kg ha^{-1} carbofuran granules were applied in the whorls of the seedlings for shoot fly control. Fertilizer applied was 100 kg ha^{-1} diammonium phosphate at planting and 200 kg ha^{-1} urea by side dressing. The annual crop is harvested in October.

The *S. hamata* and *C. ciliaris* plots are harvested twice per year and the cut material removed. The perennial pigeonpea (PP) was pruned for grain harvesting once or twice in each year and also pruned in 1989 to control growth. In 1990, the perennial pigeonpea (PP) were replanted because wilt (*Fusarium udum*), termites (*Odontotermes bellatiunisensis* and *Microtermes obesi*) and drought had decimated the population (Reddy et al., unpub.). Considerable leaf fall occurs from perennial pigeonpea. Much of this is retained in the PP + S and PP + S + C plots but it is blown away from PP plots which consequently have generally bare soil throughout the year. The *S. hamata* produces a thick cover up to 0.3 cm high during the rainy season while *C. ciliaris* plots have complete projected foliage cover but grass tufts are separated by bare soil areas.

Two observational plots of the same dimensions were established prior to the rainy season in 1990 in a 10 years old pasture area on a similar Alfisol about 800 m away. This pasture had a complete cover, was composed of mixed grasses and legumes and had been ungrazed but occasionally mown. Cuttings were left in place so that a thick organic mulch had developed.

The earthworms were sampled in each plot by the hand sorting method, every month during July to September, 1989 and June to October, 1990. The soil of an area measuring 0.25 m x 0.25 m was removed to a depth of 0.15 m, placed in an enamel tray and carefully searched for adult and juvenile earthworms. In 1989, two randomly selected areas and in 1990 three areas in each plot were sampled. The earthworms of each plot were collected in separate polythene bags with a little amount of moist soil and brought to the laboratory. They were counted and washed of the adhered soil particles, soaked with filter paper to remove the water attached to their outer body wall, and weighed.

Examination of the earthworm data showed that the populations were much higher in the perennial species treatments compared to the treatments with annual cropping. Consequently a least squares analysis of variance was done separately for each group to obtain adjusted treatment means which were compared statistically using Duncan's k-ratio t test.

RESULTS AND DISCUSSION

The species of earthworm found in plots of the core experiment were predominantly Ochochaetona philleti (67%), Lampito mauritti (31%) and occasionally Drawida sp (2%). These are relatively small sized species living mostly in the surface soil (0-0.15 m depth). In the long term pasture area the dominant species was Barogaster sp., a relatively larger and deeper burrowing species which deposits large castings on the soil surface. O. philleti and Drawida sp. were also recorded in small numbers.

Table 2. Adjusted treatment means and significant responses (k < 100) in juvenile earthworms, total number of earthworms and earthworm biomass to treatments in 1989 and 1990.

a) Annual crops

Earthworm measurement	Date	Treatment T_0	T_{10}	T_{20}	k-ratio LSD
Juveniles (counts m^{-2})	Jun 1990	11.3^{a}	0.6^{b}	4.7^{b}	5.9
Totals (counts m^{-2})	Jun 1990	16.9^{a}	0.9^{b}	7.1^{b}	8.8
Biomass (g m^{-2})	Jul 1989	9.1^{ab}	14.9^{a}	4.7^{b}	7.5
	Jun 1990	1.1^{a}	0.1^{b}	0.5^{ab}	0.7

b) Perennial crops

Earthworm measurement	Date	Treatment PP	PP+S	PP+C+S	C	C+S	S	k-ratio LSD
Juveniles (counts m^{-2})	Jun 1990	4.3^{bc}	20.0^{a}	6.7^{b}	0^{c}	5.3^{b}	6.4^{b}	4.7
Totals (counts m^{-2})	Jun 1990	6.4^{bc}	30.0^{a}	10.0^{b}	0^{c}	8.0^{b}	9.6^{b}	7.0
Biomass (g m^{-2})	Jul 1990	19.0^{b}	19.8^{b}	6.4^{c}	42.4^{a}	10.4^{c}	39.2^{a}	7.2
	Sep 1989	8.7^{c}	12.4^{bc}	3.2^{d}	12.2^{bc}	16.2^{ab}	18.9^{a}	4.9
	Jun 1990	0.4^{bc}	2.0^{a}	0.7^{b}	0^{c}	0.4^{bc}	0.8^{b}	0.6

Few significant responses in earthworm population or biomass were measured to the individual treatments (Table 2). A general response was measured in June, 1990 when tillage and perennial species produced significant responses for juvenilles and total biomass. The response to treatments for juveniles, total and biomass were the same with zero tillage having the most earthworms among the annually cropped treatments and treatments with S. hamata and having generally more earthworms than the plots which had less cover (PP) Also these responses were not generally similar to the responses in June, 1990. The effect of amendments on earthworms was not significant at all sampling dates and the tillage x amendment interaction was significant for biomass at one sampling date (August, 1989). We conclude that the response of earthworms to the individual treatments within either annual cropping or perennial cropping has been small and inconsistent.

The adjusted treatment means were combined for perennial crops and the mean values are compared in Figure 1 with the data from the long term pasture plots. Very large differences are apparent between the treatment groups in both values and trends during the season. Although the annual group and the perennial group had similar values at our initial sampling in July 1989 the changes during the season were in marked contrast. The plots with perennial species either maintained or increased population and biomass but in the plots with sorghum earthworm population rapidly declined to virtually zero.

In June 1990, small numbers of juveniles were present in the annually and perennially cropped plots of the core experiment but numbers in the annually cropped plots declined over time to near zero, compared to steady increases in numbers of both juveniles and adults in perennial plots. In the long term pasture plots earthworms numbers also increased through the season but the total numbers present were much larger and a relatively large number of adults were already present at the initial sampling at this site in June, 1990.

The earthworm populations in the long term pasture are generally within the ranges reported by Edwards and Lofty (1977) for temperate pastures and more than they report in tropical soils. The June, 1989 populations in the core experiment are also within the ranges reported for arable soils in Europe (Edwards and Lofty, 1977) and in sub-tropical Queensland, Australia (Robertson, 1989). While the pasture plots show the expected trends of higher populations with longer time under pasture and increasing populations during the wet season, the plots cropped to sorghum consistently show unexpected seasonal trends (decrease of earthworms to near zero) and little or no response to the applied treatments. The most likely explanation for these responses is that the carbofuran applications for insect pest control also killed the earthworms. Carbofuran is toxic to earthworms and takes some time to completely reduce the population (Parmelee et al., 1990). Figure 1 shows a population decline over two months to September 1989. The reappearance of juvenile earthworms in these plots in June 1990 was probably due to emergence from cocoons or migration from border areas. Negligible numbers of juveniles and adults were subsequently found indicating further toxic effects due to either residual carbofuran from 1989 or the small additional application of carbofuran in 1990. This decline in the population completely masked any possible tillage or amendment treatment effects although the few differences found did favour reduced tillage as expected (Table 2).

We plan to continue this experiment without applying soil insecticides to the annual crop to follow longer term effects on population and biomass. We will also remove the perennial pastures in the core experiment and study the population dynamics under subsequent annual cropping. The long term pasture area will be retained for comparative purposes. The data from the July, 1989 sampling suggest that cultivation systems without soil applied insecticides may maintain reasonable populations of earthworms. We therefore consider a survey of fields with known histories of both insecticide use and cultivation would clarify the effects of these managements on earthworms.

CONCLUSIONS

Semi-arid Alfisols under pasture support relatively high populations of earthworms and populations increase with time under a pasture phase.

Any response to soil management treatments for annual cropping in our experiment was masked by decimation of the population by insecticidal application.

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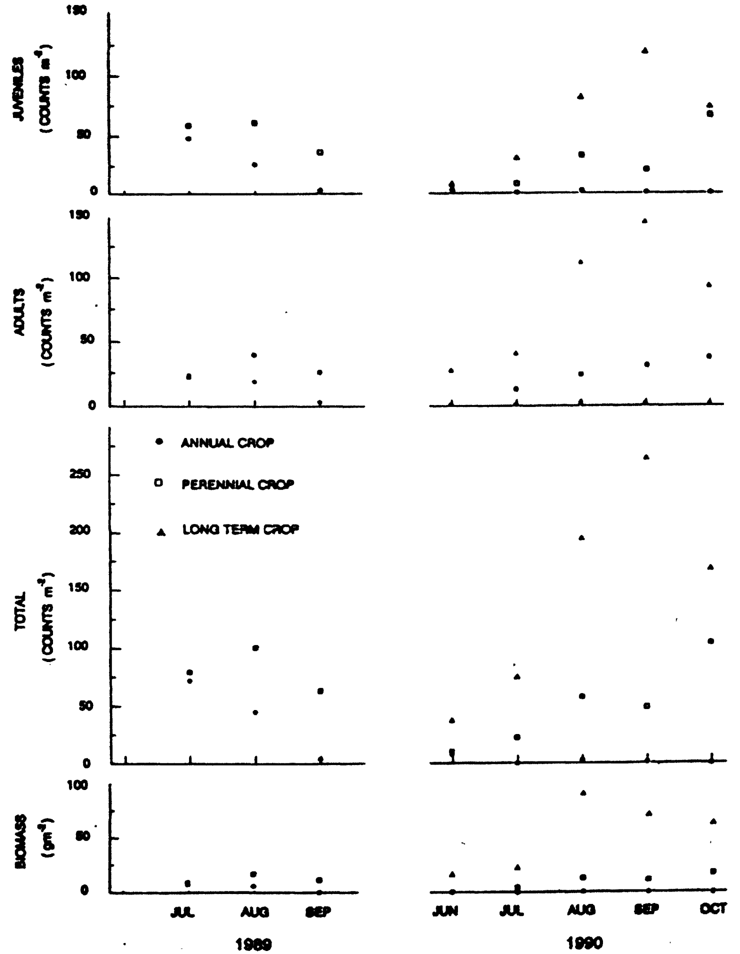

Figure 1. Temporal changes in earthworm population and biomass for three management on alfisols at ICRISAT during 1989 and 1990