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Summary

Response of the soil microarthropod community was monitored across different soil management treatments with annual and perennial crops in semi-arid tropical Alfisols. Annual crop management treatments included zero, shallow and deep tillage either bare, or with application of 15 t ha^{-1} farm-yard manure or 5 t ha^{-1} rice-straw. Perennial crop treatments were *Stylosanthes hamata*, *Cenchrus ciliaris* and pigeonpea either alone or in combination. Microarthropods, across all the treatments, included Collembola, Acarina, Araneae, Pseudoscorpiones, Pauropods, Symphyla, Diplura, Dermaptera, Psocoptera, Isoptera, Thysanoptera, Homoptera, Hymenoptera and Coleoptera adults and larvae. The number of Collembola and Acarina together constituted > 62% of the total microarthropods. The population densities of all microarthropods showed a more or less similar pattern of temporal variations under all treatments. They were higher during the rainy season of 1990 and 1991 in bare plots under zero-tillage treatment followed by plots under rice-straw treatment. However, densities during rainy months of 1989 were low compared to those of 1990 because of the high dose of carbofuran treatment. Population densities showed significant treatment differences during some months indicating significant impact of soil management practices on microarthropod community structure.

Introduction

Soil microarthropods play an indispensable role in litter decomposition and mineral cycling (Seastedt, 1984). They decompose litter and crop-residue and increase the soil fertility. Their role in arable soils has received attention only recently (Edwards et al., 1988; Mueller et al., 1990). With the popularisation of low-input and conservation tillage agriculture, studies on soil invertebrates of arable soils have increased (Crossley et al., 1989).

These microarthropods are adversely affected when soil is disturbed with various soil management practices such as tillage, which leads to sudden changes in the soil physico-chemical environment (Wallwork, 1976). On the other hand, conservation tillage or no-tillage and organic manure treatments increase the soil biotic interactions providing shelter for these soil arthropods by altering the soil environment (Crossley et al., 1984, Hendrix et al., 1986 and House et al., 1989) and enhancing the soil organic matter. Although considerable research work has been done on the effects of various soil management practices on soil arthropods in temperate agroecosystems, little is known of these aspects in tropical and subtropical agroecosystems. This paper reports the impact of soil management practices such as tillage, application of farm-yard manure or rice-straw mulch, and cultivation of different cover crops on the community structure of soil micrarthropods inhabiting the Alfisols of semi-arid tropics in India.

Materials and Methods

Experimental site and treatments:

This experiment was conducted using plots 28 m long (2% slope) and 5 m wide on a shallow to medium depth Alfisol (Patancheru Series, Udic Rhodustalf) at ICRISAT farm (Long. 78° 17' 0'E, Lat. 17° 28' 58N") near Hyderabad in south India. The soil is hard setting and very prone to surface sealing and crusting. The experimental design was an incomplete randomised block with an embedded factorial. There were 15 treatments each with three replicates. Annual crops were grown on nine treatments which included three tillage options [no or zero-tillage, shallow-tillage (10 cm deep) and deep-tillage (20 cm deep)] and three amendments (no amendment or bare, 15 t ha^{-1} farm-yard manure, and 5 t ha^{-1} rice straw), in the factorial. The remaining tratments were with perennial pigeonpea, Cenchrus ciliaris and Stylosanthes hamata alone or in combination. Full details of the experimental design are given in Smith et al. (1992).

The experiment was established in 1988 and the treatments were maintained in the same plot each year. The tillage treatments and amendments were imposed after initial rains every year. In June 1989, carbofuran insecticide granules (40 kg ha^{-1}) were applied to the soil in the planting rows to control shoot fly (Atherigona soccata Rond.). Again, during August 1990, carbofuran granules (5 kg ha^{-1}) were applied to whorls of the seedlings for shoot fly control. No insecticide was applied during 1991 and 1992. Paraquat (4 l ha^{-1}) was applied to all plots on June 29 and July 20, 1989 and to no till mulch on July 5, 1990.

Tillage plots received a shallow cultivation to break the crust, and then, about a week later a tyne cultivation (50 cm spacing) to the treatment depth. Amendments were added in three equal increments after each tillage operation and after planting. Millet was grown with the treatments in July 1988. In 1989 and 1990, sorghum was sown in mid July after imposing the treatments in late June - early July. In 1991, maize was grown after applying the treatments in June.

Soil microarthropod sampling

Each plot was sampled for soil microarthropod population density with the help of an iron soil core sampler of 5 cm diameter and 10 cm depth. Sampling was carried out in the morning hours between 0730 and 0930 when the ambient temperature was low, monthly from July to October 1989, February to December 1990, May to December 1991, and February and March 1992. Three soil core samples were taken randomly in the central area of each plot leaving 2 m from each side in order to avoid edge effects. The soil samples were processed through Tullgren funnel apparatus for 72 hours and the soil microarthropods were extracted in 80% alcohol. They were identified into major taxa, enumerated and data were converted into densities m^{-2}.

Statistical analysis (analysis of variance) of the data was accomplished within the factorial to show the effect of tillage depth and mulch, or within the randomised block to compare all treatments, using GENSTAT package.

Results and Discussion

Because of difficulties in determining the genus and species of these microarthropods, they were identified to higher taxa only (e.g., Prostigmata, Mesostigmata, Cryptostigmata and Astigmata in Acarina, Isotomidae, Entomobryidae, Hypogastruridae, Onychiuridae and Sminthuridae in Collembola, and Araneae, Pseudoscorpiones, Pauropods, Symphyla, Diplura, Dermaptera, Psocoptera, Isoptera, Thysanoptera, Homoptera, Hymenoptera, and Coleoptera adults). Acarina on average comprised > 34%, Collembola comprised 28%, and the miscellaneous arthropods, which included all arthropods other than Collembola and Acarina, comprised of > 37% of the total number of microarthropods across the treatments over the study period.

Among the tillage treatments, higher numbers of soil microarthropods were associated with zero tillage bare treatment (mean $\pm$ S.E. density for the study-period: 2493.3 $\pm$ 722.4 m^{-2}) and with zero tillage rice-straw treatment (2396.7 $\pm$ 575.9 m^{-2}) compared to farm-yard manure treatment (1870.0 $\pm$ 421.7 m^{-2}) ($P < 0.05$) (Fig. 1a). In shallow and deep tillage treatments, the microarthropod densities were more in rice-straw treatment (2356.7 $\pm$ 514.4 m^{-2} in shallow tillage and 1933.3 $\pm$ 440.2 m^{-2} in deep tillage) than in farm-yard manure treatment (1943.3 $\pm$ 448.6 m^{-2} in shallow tillage and 1736.7 $\pm$ 410.8 m^{-2} in deep tillage) ($P < 0.05$) (Fig. 1b and 1c). This indicates that the zero-tillage bare, and rice straw mulch conditions are more favourable for soil microarthropods (Nakamura, 1988). House and Parmelee (1985) recorded higher numbers of soil arthropods in no-tillage treatment at the Horseshoe Bend research site in Clarke county near Athens in Georgia (USA). The present results are also in accordance with the findings of House et al. (1989) that tillage has a more consistent effect on soil arthropod community composition than no-tillage treatment. This is because tillage induced sudden changes in the soil environment, such as mechanical disturbances, changes in soil temperature and humidity, redistribution of plant residues, and disruption of access to their food resources (Wallwork, 1976; Andren and Lagerlof, 1980). In contrast, no-tillage practices minimise soil disturbance; plant residues are deposited on the soil surface where they serve to reduce moisture loss and offer a concentration of food resources. The direct detrimental effects of tillage are, in part, due to abrasive damage to these arthropods and in part, due to trapping of arthropods in the soil during inversion when the existing systems of cracks and animal-pores are damaged (Nakamura, 1988).

Under the perennial cover crops, higher densities of microarthropods were recorded in zero-tillage pigeonpea + *S. hamata* treatment (2516.7 $\pm$ 464.1 m^{-2}) and with pigeonpea + *S. hamata* + *C. ciliaris* treatment (2193.3 $\pm$ 477.1 m^{-2}) compared to that of only pigeonpea treatment (1496.7 $\pm$ 262.0 m^{-2}) ($P < 0.05$) (Fig. 2a). Higher numbers of microarthropods were also recorded in zero-tillage with *S. hamata* treatment (2936.7 $\pm$ 576.4 m^{-2}) followed by that with *C. ciliaris* + *S. hamata* treatment (2790.0 $\pm$ 540.7 m^{-2}) and with only *C. ciliaris* (2778.3 $\pm$ 526.5 m^{-2}) (Fig. 2b). This may be a result of the formation and subsequent arrangement of microhabitats available under a specific vegetational regime (Berg and Pawluk, 1984). It indicated that the microarthropod densities over the years, across all treatments, were much higher in zero-tillage particularly with *S. hamata* treatment followed by zero-tillage with *C. ciliaris* + *S. hamata* treatment and with *C. ciliaris* treatment.

The microarthropod population densities showed significant treatment differences during July and August (variance ratio: $P < 0.05$) and October 1989 (variance ratio: $P < 0.01$), February and July 1990 (variance ratio: $P < 0.05$), June (variance ratio: $P < 0.01$)

and July 1991 (variance ratio: $P < 0.05$) and February 1992 (variance ratio: $P < 0.01$). This indicated that the soil management practices had significant effects on the community structure of the microarthropods. However, during the other months, there was no significant effect of these management practices on the microarthropod population densities which was probably because of wide variations in the population densities among the replicate plots of each treatment. This is possibly because of the nature of non-randomised distribution of soil microarthropods; and the most likely cause of such non-randomness is the patchy distribution of either food resources or soil water (Usher, 1976; Farrar and Crossley, 1983). Thus, the microarthropod populations sampled may contain biased samples of clumped individuals. Farrar and Crossley (1983) found microarthropod aggregations higher in no-tillage soybean systems than those in conventionally tilled soybean systems.

The population densities of soil microarthropods showed temporal variations and fluctuated irregularly across the season. During 1990 and 1991, their abundance tended to follow a similar seasonal pattern and was higher during rainy season than the preceding and following dry summer and winter seasons. Most probably rainfall and soil moisture had a favourable influence on soil microarthropod population densities (Reddy, 1984). However, during 1989 the population densities were low, and were distinctly different from those of the year 1990, and 1991, except in July 1990 (Figs. 1 and 2). This is attributable to the ecotoxicological effects of higher dose of carbofuran granules, and herbicides applied from time to time. Application of carbofuran granules at a lower dose (5 kg ha^{-1}) to the whorls of the seedling had little effect on soil microarthropod densities during 1991. Many researchers have reported the reduced population structure of soil microarthropods because of higher doses of insecticide and herbicide treatments (Reddy, 1989). The population densities slowly recovered from the stress of the insecticide and herbicides by the rainy season in 1990. However, during the initial months of the rainy season in these two years the microarthropod densities were lower compared to the following months (Figs. 1 and 2) which may be because of disturbance caused by tillage operation practiced during that period. The development of an environmental mosaic (i.e., soil stabilization and undisturbedness, and favourable environment) in the following months probably induced reestablishment and recolonisation of the microarthropods leading to their increased population densities. Such an initial decrease in microarthropod population density followed by an increase towards the end of the growing season corroborates the findings of Stinner and Crossley (1988) and Loring et al. (1981).

Soil microarthropods have been reported as good bioindicators of impact of modern agricultural management practices (Paoletti et al. 1991). These arthropods ameliorate the soil structure and soil fertility (Lee and Foster, 1991). Therefore, it is beneficial to maintain a good number of soil microarthropods in crop fields by different soil management practices such as zero tillage, mulching with crop residue and sowing cover crops (Lal, 1991). The present findings indicated higher microarthropod densities under perennial crop covers, zero-tillage and rice-straw mulched conditions. Such management practices may be useful in sustainable agriculture and enhance the productivity.

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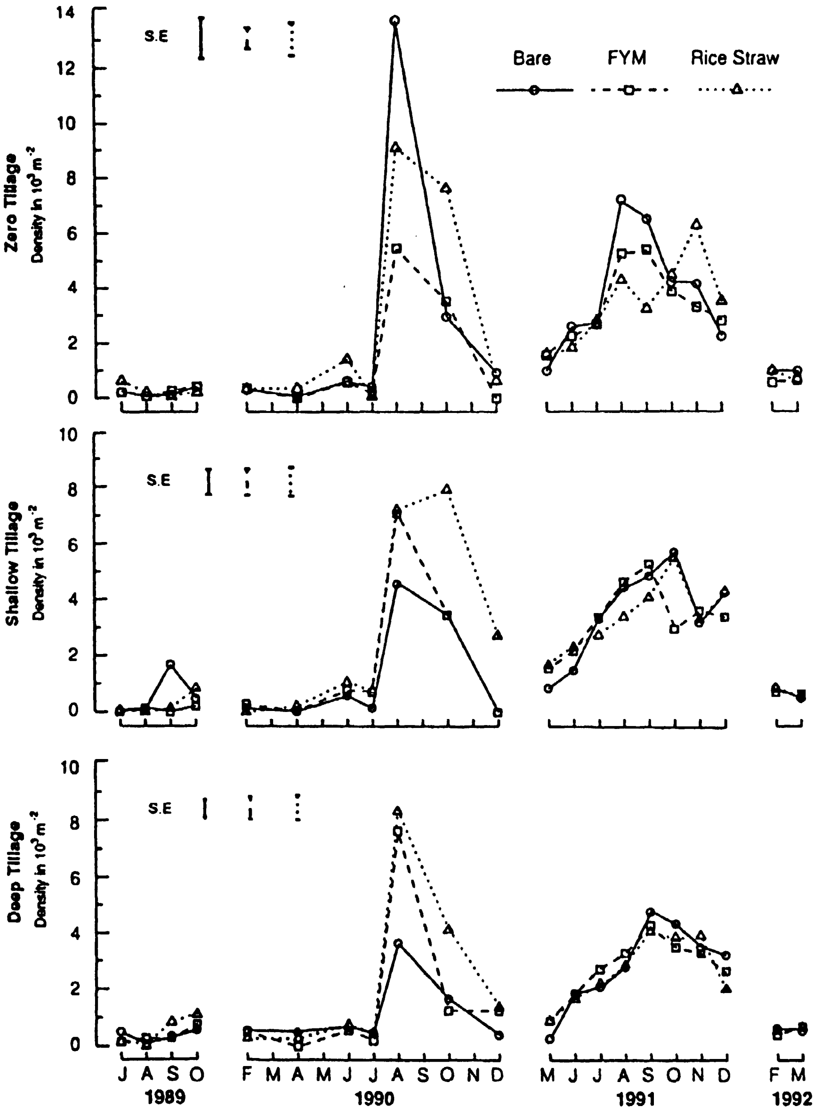

Fig. 1. Population densities of soil microarthropods across tillage treatments with different organic amendments.

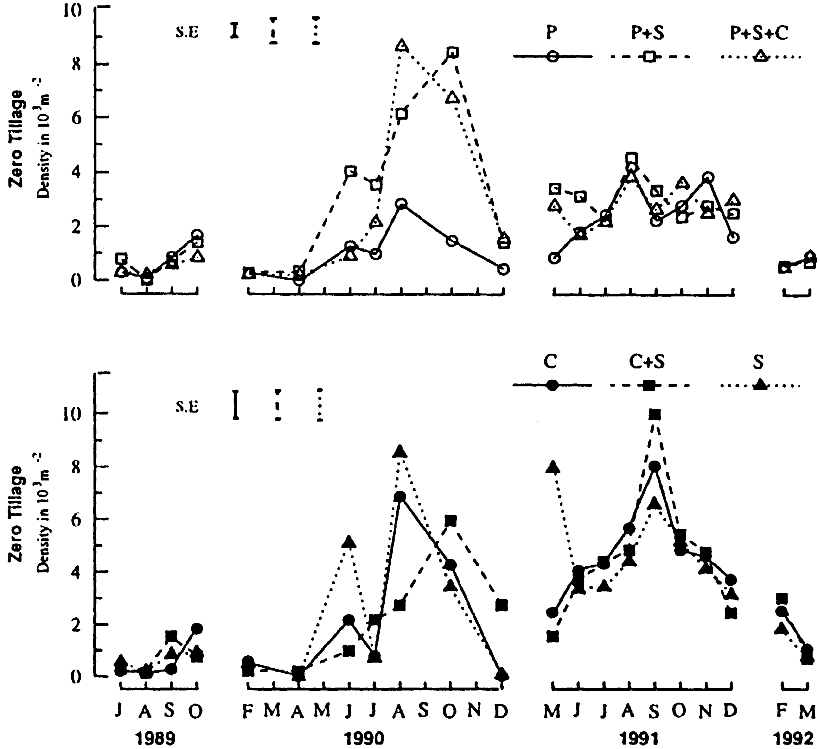

Fig. 2. Population densities of soil microarthropods across treatments of zero-tillage with pigeonpea (P), *Stylosanthes hamata* (S) and *Cenchrus ciliaris* (C) alone and in combination.