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ABSTRACT

Soil surface arthropod populations in conventional tillage (CT) and no-tillage (NT) sorghum and adjacent old field (OF) were compared using pitfall trap captures. Total numbers of individuals and species, overall diversity ($\overline{H}$), richness (D), evenness (J'), dominance (C) and similarity quotients (QS) between systems were calculated for each of seven 24 hour sampling periods throughout the season. Although each system was distinct (any two of the systems had less than 30 percent of their species in common), NT was most similar to OF and least similar to CT during a period of stress (drought) and after heading of the sorghum. Percentages of individuals and species represented by spiders were similar in NT (30 and 15%) and OF (22 and 17%); percentages were substantially less in CT (11 and 8%). Yields (biomass of sorghum) in CT and NT were not significantly different despite the generally predicted higher pest populations in NT. Results suggest that insecticide stress may lower the stability of NT systems, thus allowing an increase in pest species.

As the crop acreage under no-tillage (NT) practices increases, research concerning the composition of the arthropod complex associated with these systems and the corresponding complex in analgous conventional tillage (CT) systems is being expanded (All 1978, Musick 1972, Musick and Collins 1971). Ecological dogma, though not resolved on cause and effect, couples the properties of stability and diversity, and diversity has been used as an indicator of relative stability (van Emden and Williams 1974). With regard to programs of pest management, there is considerable support for the concept that, through various practices, an increase in the complexity of agroecosystems would lead to greater stability (Rabb et al. 1974). Also the importance of adjacent, more floristically diverse systems has been recognized (Morrill 1978, van Emden and Williams 1974). These systems may act as "reservoirs" of faunal diversity, including both herbivores and predators.

Deliberate addition of diversity will not necessarily increase stability, and the manipulation of diversity through introduction of new species must be considered on the basis of knowledge of the entire complex present (Rabb et al. 1974, van Emden and Williams 1974). Most comparative studies of the arthropods in CT and NT have focused on one or a few pest species in insecticide-stressed systems (All 1978, Musick 1972, Musick and Collins 1971). Results from these studies indicate that specific pest species may be enhanced, deterred or not affected by NT practices (All 1978).

Classifying habitats according to increasing spatial heterogeneity (Southwood 1976) might be expected to parallel diversity measurements. If an increase in spatial diversity does allow for greater faunal diversity, and concurrently imparts an increase in stability, then NT systems should be more stable than CT, providing not only advantages such as reduced erosion and increased soil moisture but also a system less susceptible to pest outbreaks. Basic research concerning the composition of such systems and relevant comparisons is not presently available. In order to understand better the nature of these systems, the objective of the present research was to compare beta or between-habitat diversity (Whittaker 1975) of the ground arthropod populations in three systems - CT sorghum, NT sorghum and old-field (OF). Using a number of indices, the populations sampled (as limited to those arthropods captured in pitfall traps) were compared. In order to determine and define the complete arthropod complex, insecticides were not used in any of the systems. Research of this nature has not previously been conducted in the absence of insecticides.

Methods and Materials

The systems sampled are located at the Horseshoe Bend (HSB) Research Area in Athens, Georgia, which is part of the University of Georgia. The perimeter is forested, while the center is an old field except for the present cultivated area. Prior to acquisition by the Institute of Ecology in 1964 HSB was used for forage and pasture. The area used in the present study for CT and NT was the same in which Barrett (1968) cultivated a grain crop in 1966. Although not cultivated since 1966 the area has been naturally flooded and was experimentally burned in 1970 (Odum et al. 1974). In late spring 1978, the area to be cultivated was cleared of woody growth, rotary mowed, and divided into eight 929 m^2 (0.25 acre) plots. Plots were assigned either CT or NT treatment (four replicates each) at random. Following CT and NT agronomic practices standard for the region, grain sorghum was planted in June of 1978.

Conventional tillage plots were plowed and drag harrowed; NT plots were not cultivated. AAtrex® was applied to the entire area at a rate of 1.9 liters per 3716 m^2 (four pints per acre) which resulted in 0.9 kg active ingredient atrazine per 3716 m^2 (two pounds per acre). A two-row fluted coulter planter (John Deere®) was used to plant 4.5 kg per 3716 m^2 (two pounds per acre) Funk's 516 BR hybrid grain sorghum seed in 76 cm (30 in) rows. Upon completion of planting, Fowler's® 6-12-12 fertilizer was broadcast at the rate of 272 kg per 3716 m^2 (600 lb per acre) to plots 1,2,3,4,5 and 8; plots 6 and 7 were treated with fertilizer at half the rate of the other plots and were not used in the present study.

Ten pitfall traps consisting of plastic SOLO® cups (9.8 cm in diameter) and funnels (Morrill 1975) were installed in a regular pattern in each of three CT and three NT plots. Five traps were installed in an adjacent 464 m^2 (0.125 acre) section of OF. Traps were opened, fitted with a vial of alcohol beneath the funnel and left open for twenty-four periods throughout the season; when not set, traps were covered with McDonald's® plastic soft drink caps.

A number of indices were calculated for the comparison of systems. Total number of individuals captured and species captured were tabulated for each habitat. The Shannon index of diversity ($\overline{H}$) is given by:

$$H(s) = H = -\sum_{i=1}^{s} p_i \log_e p_i$$

where s is the total number of species in a sample and p_i is the observed proportion of individuals belonging to the i^{th} species (i = 1, 2,...,s) (Shannon 1948). Margarlef's index of species richness (D) is given by:

$$D = (s - 1)/\log_e N$$

where N is the total number of individuals in the sample (Margarlef 1957).

The apportionment of individuals within species was measured with Pielou's index of evenness (J'):

$$J' = \overline{H} / \overline{H}_{max}$$

where $\overline{H}$ is the observed diversity and $\overline{H}_{max}$ is numerically equivalent to $\log_e s$ (Pielou 1966). Simpson's index of dominance (C) is given by:

$$C = \Sigma \, (n_i/N)^2$$

where n_i is the number of individuals of a particular species and N is the total number of individuals in the sample (Simpson 1949). The degree of similarity of species captured in any two systems was estimated by Sørenson's quotient of similarity (QS):

$$QS = 2c/(a+b)$$

where a and b are the numbers of species in samples A and B and c is the number of species common to both samples A and B (Odum 1971).

Results

A brief evaluation of the trapping method is in order. Pitfall traps have been used to quantitate arthropod populations (Gist and Crossley 1973), although pitfalls are more often used for the comparison of the species occupying different habitats (Crossley et al. 1973, Fichter 1941, Greenslade 1964, Hagvar et al. 1978, Martin 1964). The efficacy of the method has been much discussed (Briggs 1961, Hagvar et al. 1978, Martin 1964, Uetz and Unzicker 1976). There are several specific methodological factors pertinent to the present study. Hagvar et al. (1978) found that catches from traps placed along the outer margins of a system did not differ significantly from those of traps in the center of the pattern when traps were five meters (sixteen feet) apart (in the present study traps were slightly less than five meters apart). In trapping Carabidae (Coleoptera) Greenslade (1964) found that baiting, odor (from alcohol or other preservatives), and trap color (black, white or clear) caused no significant variation in catch. The decision to use alcohol in the present trapping was made after observing predation of trap contents by birds and predation inside the traps by some of the larger predatory species. Mitchell (1963) made similar observations while trapping carabid beetles in cabbage fields.

Cumulative $\overline{H}$ was calculated by increasing the sample base by one trap increments in OF and randomly chosen plots of CT and NT (Figure 1). The resulting curves proved analogous to those of cumulative number of traps which provide an adequate sample (Phillips 1959). When the percentage increase in $\overline{H}$ fell below 10 percent, the sample was considered sufficient. Use of this criterion suggests samples of four traps from CT, three traps from NT and four traps from OF. This compared favorably with Uetz and Unzicker (1976) who, using species curves, determined that 3.8 traps of 15 cm diameter or 9.2 traps of 6.5 cm diameter were adequate for sampling wandering spiders (the present traps are 9.8 cm in diameter).

Comparison of CT, NT and OF; Five Traps Per System

Indices calculated for selected sampling periods are summarized in Table 1. After a period of drought which ended 9 July, NT consistently had a greater number of species present than either CT or OF, and, expeet for 6 September, also had the highest overall diversity and richness. On 10 August NT (29 species) had 75 percent more species than CT (17) and OF (16); $\overline{H}$ in NT was 2.91 while it was lower and nearly equal in CT (2.63) and OF (2.60); richness was considerably higher in NT (6.51) than in CT (4.91) or OF (4.60). The number of species in NT (29) on 6 September was only one more than OF (28) but nine more than CT (20); however, $\overline{H}$ in OF (3.22) exceeded that of NT (2.86) and was lowest in CT (2.49); richness was slightly higher in OF (7.37) than NT (6.78) and both OF and NT exceeded CT (4.47). On 20 October NT had the greatest number of species (18; 13 in CT and 14 in OF); greatest diversity (2.79; 2.51 in CT and 2.58 in OF), and the greatest richness (5.35; 4.24 and 4.42 in CT and OF, respectively). Note that on 10 August and 20 October NT had the highest indices while those of CT and OF were almost equal. The sorghum was ready for harvest at the time the 22 November sample was taken. Conventional tillage had only two species represented by one individual each; diversity was only 0.69 and richness 1.44. Again NT had more species (14) and greater diversity (2.19) and richness (3.99) than OF with eight species, an $\overline{H}$ of 2.04 and a richness of 3.19.

Similarity of species present between CT and NT (36 percent) was greatest shortly after planting (30 July) but fell to zero during the drought (4 and 7 July) and never recovered its previous high, ranging between 12 and 29 percent the remainder of the season. Similarity between NT and OF peaked during the drought (21 percent on 4 July), dropped toward the end of the drought (14 percent on 7 July) and varied between 18 and 21 percent through November. Trends during the drought indicate that the ground fauna in CT was most affected by the stress while NT and OF were equally affected and less dissimilar (Figure 2). NT and OF were both consistently more diverse than CT.

Previous comparisons of pitfalls in different habitats have reported greater catches in the more established systems. Martin (1964), trapping various stages of pine stands, recorded the largest catches in established stands (31 years) and the smallest catches in a stand under monocultural practices for 21 years. Crossley et al. (1973) used three methods to sample Coleoptera and Hymenoptera in a white pine plantation and coppice and concluded that trophic level interactions are perhaps more significant to community stability than species diversity alone. The low diversity ($\overline{H}$) of the herbivorous Coleoptera was not propagated through the food chain. Diversity was partially recovered at the highest trophic levels with the hymenopterous predators and parasites.

Comparisons of diversity in fields and adjacent hedgerows have suggested a generally lower diversity in fields (Peet 1974). Most of these studies, however, have analyzed only select groups from the catch. Smith and van den Bosch (1967) felt that the "unseen" faunal diversity existing in many crops was probably worth evaluation and preservation from destructive agricultural practices. They suggested that several crops appeared to have hundreds of species associated with them, only a small portion of which was phytophagous. It should be noted that in the present study, although there were nearly 50 percent more individuals captured in NT than in CT (samples pooled), yield (above-ground biomass of sorghum) was not significantly different in the two systems (at α = .05) (Kumara et al. personal comm.). The increase in individuals in NT concomitant with greater richness resulted in NT having the greatest diversity of the three systems. Thus, when not under insecticide stress, the increase in diversity/stability in NT due to the increase in spatial diversity provided by the litter may ameliorate any increase in pest numbers or species. This possibility has far-reaching implications concerning insecticide use. Insecticides may at times actually destabilize an agricultural system, temporarily reducing pest populations but eliminating the ability of the intact arthropod complex to effect stabilization within the system. As with the problem of resistance, insecticides in NT systems may in truth amplify pest problems, not ameliorate them.

Herbicides are frequently used as a supplement to tillage in the control of weeds. In reduced-tillage systems herbicides have become the major means of weed control. In corn grown continuously for seven years without tillage, Triplett and Lytle (1972) found that corn yields with no-tillage were equal to yields in tilled areas provided weed control was satisfactory. In the present study atrazine was applied to both CT and NT as a preemergence treatment. Atrazine is a residual herbicide which acts mainly through root absorbtion, its effectiveness dependent upon rainfall (or irrigation) to move it into the root zone. In the research reported here, the period of drought which followed planting drastically reduced the effectiveness of the atrazine treatment. Shallow cultivation or rotary hoeing is recommended in such conditions. In June, a decision was made neither to cultivate or herbicide again during the growing season. Consequently, more weeds were present in both CT and NT than would have been usually tolerated in agricultural systems. The factors controlling weed growth and distribution include the crop plant itself as well as the agronomic practices (Tripathi 1977). The biomass of weeds in NT consistently exceeded that in CT in the present study; the same is true for $\overline{H}$ based on weed biomass. Significantly, as the diversity of weeds increased, leaf area of sorghum grazed by insects decreased (r - 0.75) (Kumura et al., personal comm.). Tripathi (1977) has questioned the desirability of eliminating weeds from crop systems, and the present study suggests that an increase in both weed biomass and number of weed species does not necessarily result in increased damage to the crop. The increase in insect diversity and numbers coupled with the increase in weed diversity and biomass in NT resulted in a crop yield equal to that of CT. Thus the benefits of NT were accrued without a yield reduction. Whether this could have happened in the presence of insecticides is questionable since the complex relationships among crop, weeds and arthropods would have been disrupted. The roles of pesticides in agroecosystems and the long term effects have yet to be adequately defined.

Species composition

A total of 643 individuals in 146 species were recognized from pitfall traps. Insects were identified to family, but only morpho-species were identified within family. Spiders (with the exception of Microphantidae) were identified to genus and, when possible, to species. The overall distribution of both individuals and species and the low similarity quotients (Table 1) indicate the existence of three distinct ground arthropod communities. (Although pitalls are not the best means of sampling Diptera, Hymenoptera or some of the primarily leaf-feeding groups, precedent exists for their capture in pitfalls: Fenton and Howell (1957) were surprised to find both Diptera and Hymenoptera frequently represented by several small species in their catches and Martin (1964) reported differences noted among Diptera captured in pine stands of various ages. All groups captured in the present study have been included in indices calculations).

Spiders

Spiders have been shown to be common predators in orchards (Dondale 1958, Dondale et al. 1979, Muma 1973, Putman 1967, Sprecht and Dondale 1960). Whitcomb et al. (1963) reported the first comparison of ground spider populations in adjacent natural and cultivated communities. Of the 64 species captured in pitfall traps, only 26 were common to both communities. Of the 17 species captured in the present study, four were common to all three systems, four were common to CT and NT, five were common to CT and OF, and eight were common to NT and OF. Spiders comprised only eight percent of the species and 11 percent of the individuals in CT, while they were 15 and 17 percent of the species and 30 and 22 percent of the individuals of NT and OF, respectively. Doane and Dondale (1979) found individuals and species more numerous and greater diversity (Brillouin) and evenness in the grassy borders of a wheat field than in the field itself. Although the importance of spiders as general predators in agroecosystems is not clear (Whitcomb 1974), indications of the effects of cultural practices on their distribution warrants further study since habitat preference has been demonstrated.

DISCUSSION

Throughout the sampling period each of the three community types CT, NT or OF, had a distinctive ground-surface arthropod community. This community evidently has a rapid response to either CT or NT practices. Trapping efficiency doubtless became different between the treatments, but this would not explain our observed differences in species composition between treatments. Hagvar et. al (1978) suggested that only if the vegetation is more or less equally dense at the soil surface could catches in different habitats be taken as a measure of relative density. However, surface-activity may be restricted by vegetational obstructions at the soil surface. Therefore, if the catches are larger in a habitat with denser vegetation, such as NT or OF, then the density of animals is undoubtedly higher than that in a habitat which allows unrestricted movement (i.e., CT).

Immediately after plowing, the NT community was more similar to the CT, but under drought stress the NT community became more similar to the OF. The early similarity was probably due to a common response to clearing and mowing. The NT community clearly was better buffered against drought than was the CT community. The soil surface arthropods were numerous in NT owing to the combination of properties found in cropping and natural systems: the increased moisture regime and variety of plant species available paralleled conditions in a natural system while the crop, still an energy-subsidized system, provided an attractive nutrient-rich food source.

The complex of arthropods captured in NT was composed of relatively more individuals and species of predators and parasites than in CT; the threefold increase in wandering spiders in NT over CT once again raises the question of the role of spiders as general predators in agroecosystems. The overall increase in numbers in NT with no concurrent rise in herbivory over CT suggests that stability may parallel diversity in these systems. We assume that the greater complexity of the NT food web is indicative of higher relative stability, sensu Pimentel (1961). We do not infer resistence to or resilience following perturbation, however; further measurements of ecosystem-level phenomena will be required to identify these stability characteristics of NT systems.

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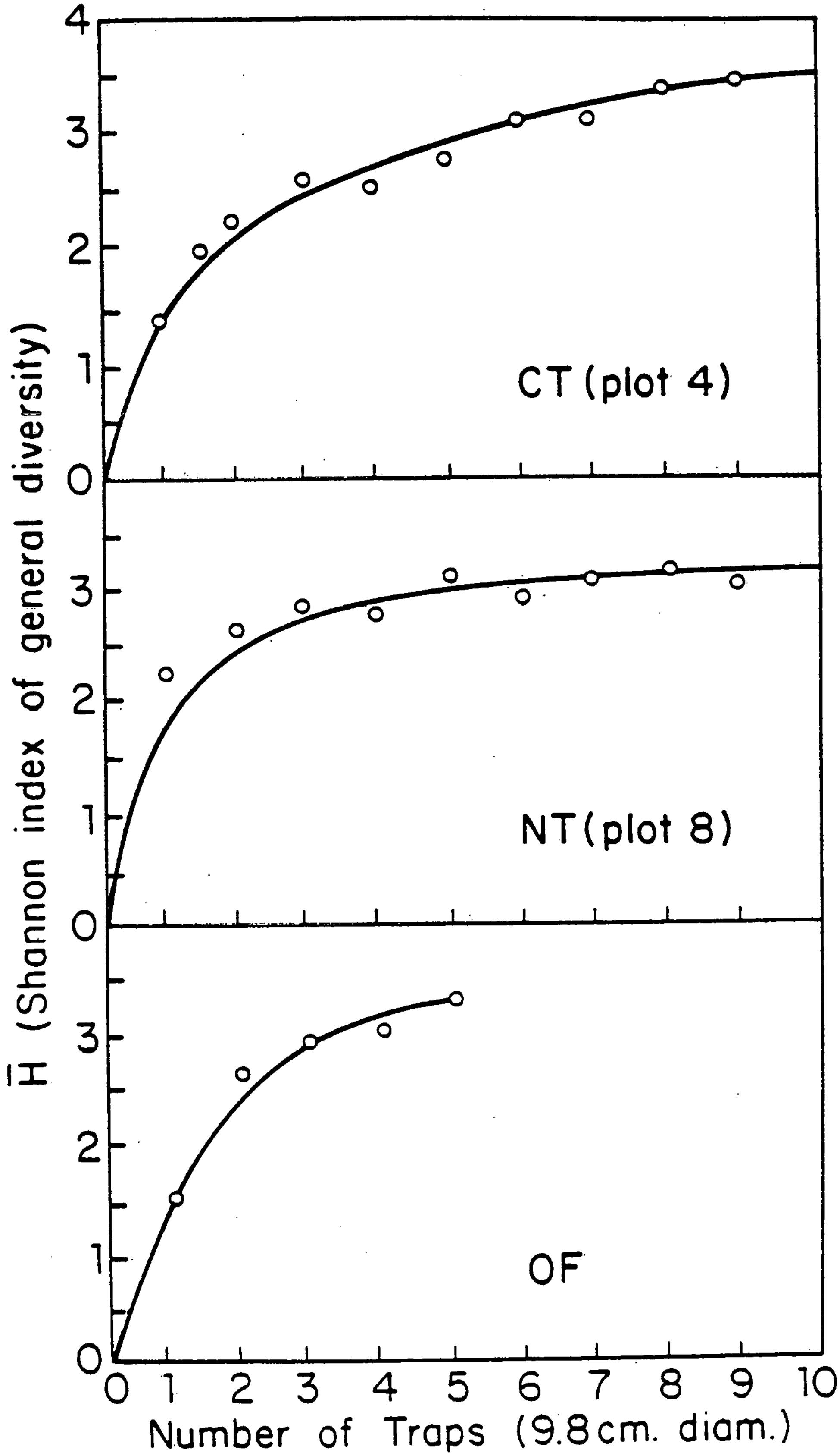
Table 1. Indices of arthropod community structure as measured by pitfall trap catches in conventional tillage (CT; traps from plot 4) and no-tillage (NT; traps from plot 1) sorghum and old field (OF). Each 464 m^2 (0.125 acre) plot containing five traps each was sampled for seven twenty-four hour periods.

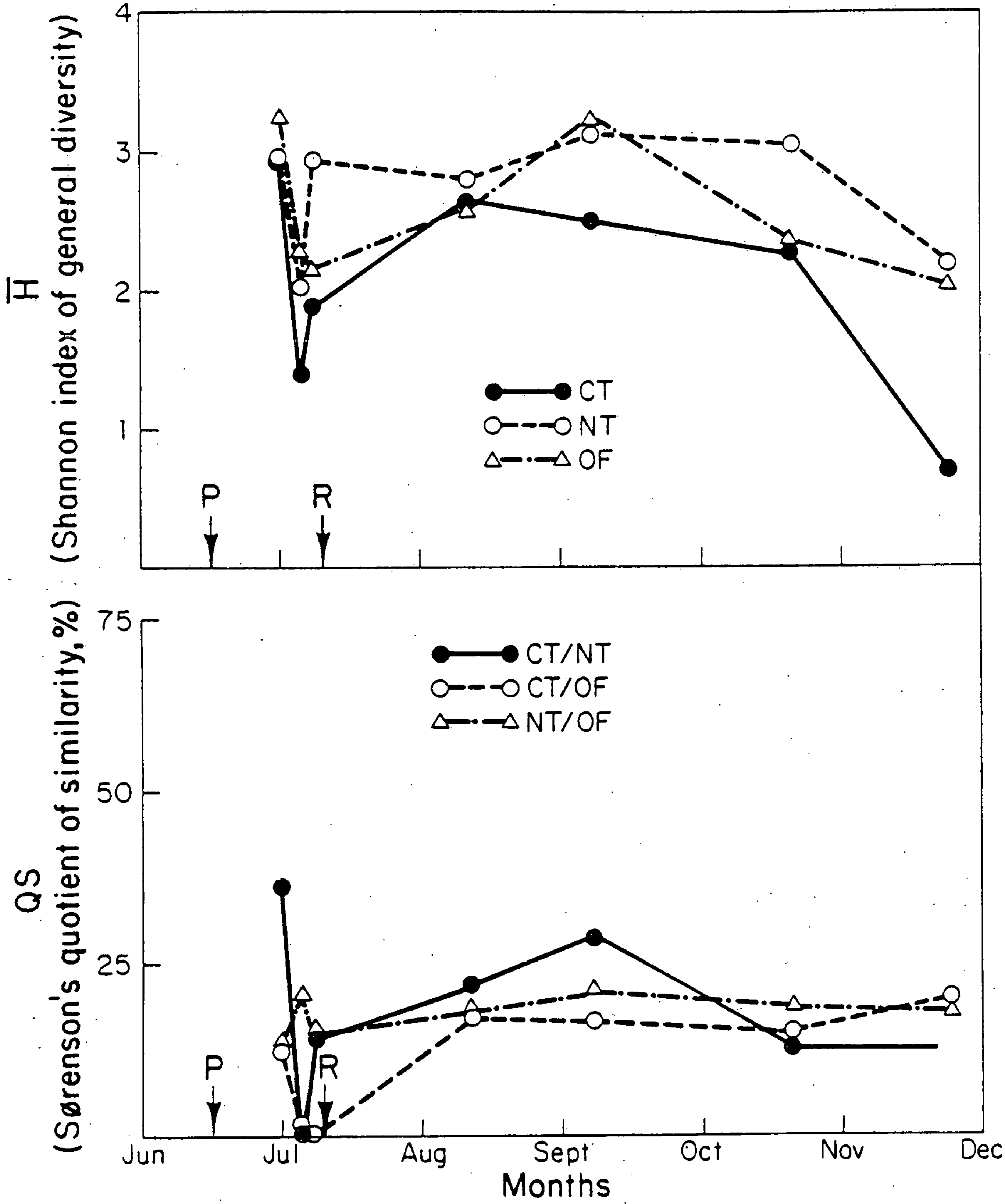
Date (1978)	30 June			4 July			7 July			10 Aug.			6 Sept.			20 Oct.			22 Nov.		
System	CT	NT	OF	CT	NT	OF	CT	NT	OF	CT	NT	OF	CT	NT	OF	CT	NT	OF	CT	NT	OF
Index																					
N (Total number of adults collected)	38.	38.	38.	17.	10.	22.	9.	32.	45.	26.	74.	26.	70.	62.	39.	17.	24.	19.	2.	26.	9.
S (Number of species)	21.	23.	28.	7.	8.	11.	7.	22.	19.	17.	29.	16.	20.	29	28.	13.	18.	14.	2.	14.	8.
H̄ (Shannon index of general diversity)	2.92	2.95	3.22	1.40	2.03	2.28	1.89	2.94	2.64	2.63	2.91	2.60	2.49	2.86	3.22	2.61	2.79	2.58	.69	2.19	2.0
D (Margarlef index of richness)	5.50	6.05	7.42	2.12	3.04	3.24	2.73	6.06	4.73	4.91	6.51	4.60	4.47	6.78	7.37	4.24	5.35	4.42	1.44	3.99	3.1
J' (Pielou index of evenness)	.96	.94	.97	.72	.97	.95	.97	.95	.90	.93	.86	.94	.83	.85	.97	.98	.96	.98	1.00	.83	.9
C (Simpson index of dominance)	.06	.06	.05	.38	.14	.12	.16	.06	.09	.09	.08	.09	.12	.10	.05	.09	.07	.08	.50	.18	.1
QS (Sørenson's quotient of similarity, %)	36.36		11.76	0		21.05	13.79		14.63	21.74		17.78	28.57		21.05	12.90		18.75	12.50		18.18
		12.24			0			0			18.18			16.67			14.81			20.00	

Figure 1. Shannon index of general diversity ($\overline{H}$) calculated cumulatively as sample is increased by one trap increments. Sampling took place concurrently in sorghum and old field (OF) over a twenty-four hour period in June, 1978.



H̄ (Shannon index of general diversity)
CT (plot 4)
NT (plot 8)
OF
Number of Traps (9.8 cm. diam.)

Figure 2. Shannon index of general diversity ($\overline{H}$) and Sørenson's quotient of similarity (QS, given as a percentage) for conventional tillage (CT; traps from plot 4) and no-tillage (NT; traps from plot 1) sorghum and old field (OF). Each point represents five traps in 464 m^2 (0.125 acre). (P - planting of sorghum; R - first rainfall after planting).


4
3
2
1
$\overline{H}$
(Shannon index of general diversity)
CT
NT
OF
P
R
75
50
25
QS
(Sørenson's quotient of similarity, %)
CT/NT
CT/OF
NT/OF
P
R
Jun
Jul
Aug
Sept
Oct
Nov
Dec
Months

RUNNING HEAD

BLUMBERG AND CROSSLEY: ARTHROPODS IN NO-TILL SORGHUM