EFFECT OF CROP ROTATION AND FERTILIZATION ON THE INVERTEBRATE COMPLEX FROM THE SOIL OF AN IRRIGATED MAIZE CROP

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ABSTRACT

This report exposes the first results concerning the effect of two soil management practices – rotation and fertilization- on the invertebrate communities from the soil of the irrigated maize crops. Crop rotation insted 1 – 4 years in two plots, with and without perennial lucerne crops + ryegrass. Each plot differed by NP fertilization + dung manure and unfertilized. In variants with perennial crops in rotation, the invertebrate population were greater and included a broader range of species, compared to variants without perennial crops. It was demonstrated that the invertebrate associations in the two variants had medium level of similarity from the standpoint of their component species (92.9%), being however of level from organisation and structure point of view (57.2% of combinations). In the functional structure, irrespective of crop rotation, the phytophagous components ranked in the first place in May, and the zoophagou ones in July. In variants with NP + dung manure the invertebrate communities had a very good numerical equilibrium, while in those fertilized only with NP this can be considered as good, by the values of diversity and equitability indices. When examining by the criterion of species biomass, the biological balance of invertebrates was not important, due to biomass input by the group of *Lumbricidae*, *Scarabaeidae* and *Elateridae*.

Key words: crop rotation, fertilization, invertebrates, maize

INTRODUCTION

Relationship between soil and crop management and communities of harmful and beneficial invertebrates is one of the main principles of the integrated control concept. In this field, many researches have been performed both abroad and in this country, having as a principal target the control means of some pests, important by damages induced to agricultural crops (Paulian and Mihăilă, 1963; Pașol, 1964; Manolache et al., 1969; Baicu et al., 1986, 1987; Henze and Sengonca, 1992; Hondru et al., 1994). However, investigations on the influence of crop rotation or fertilization on the invertebrates occurring in the soils of various agroecosystems were more reduced, world literature quoting results from Russia (Kulikova et al., 1980; Antonaș, 1990), France (Chambon, 1982), Germany (Buchner, 1991), Poland (Trojanowski and Baluk, 1993), India (Gupta and Ran, 1989). In Romania, such researches were also fewer, having to mention those by Radu et al., (1962, 1967). These investigations have been resumed in 1993, after a long period of discontinuity, being considered of a great actuality and significance, through their contribution to the development of an overall concept of sustainable agriculture.

This report offers the results derived from investigations on the effect of some crop and soil management measures – crop rotation and fertilization – on the invertebrate communities in the soil of an irrigated maize crop.

MATERIALS AND METHODS

Research was performed at the Research Institute for Cereals and Industrial Crops of Fundulea, within a long-term trial with 2 x 4 x 3 replications, in which the influence of crop rotation and fertilization on maize cropping under irrigation was investigated.

The types of rotation and the variants regarding the influence of plot with and without perennial crops are presented in table 1.

Each variant included 3 subvariants differing by fertilization: unfertilized, fertilized with N_{200} and P_{80}, fertilized with NP + dung at 10 t/ha/year, and culture without rotation, this always being applied to maize plots, and cumulated in dependence of returning this crop on the same plot. Thus, in variants 3 and 4, 20 t/ha have been administered, in variants 5, 6 and 1, 30 t/ha, and 40 t/ha in variants 7, 8 and 2. Dung used as fertilizer originated from cattle barns, after 1 – 2 years of fermentation.

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Each variant was tested in 4 replications, an experimental plot covering 50 m^2.

Table 1. Crop rotation in which the invertebrate communities have been analysed

Variant	Annual crops	Variant	Annual and perennial crops (duration in years)	Years from following
1	M – 28 years monoculture	2	M4 –Aa4	4
3	M – W	4	M – W, 6 – Aa3	1
5	M – W - SO	6	M – W – So, 12 – Aa4	4
7	M – Sf – W - Sb	8	M – Sf – W – Sb, 12 – Aa3	10

M = maize, W = wheat, So = soybeans, Sf = sunflower, Sb = sugarbeet, Aa = alphalpha

Maize seed was treated with Furadan 35 ST at the regular rate of 30 l/t, and to control weeds both preemergent Diizocab (80% buthylate) at 7 l/ha applications were made, as well as mechanical and hand hoeings. Sprinkling irrigation was applied, keeping soil humidity above 50% of the active humidity range throughout the season.

Depending on the group of organisms under study, methods used were faunal collections by soil samplings 25 x 25 x 30 cms, and Barber trap captures within 48 hrs.

Seasonal collections, 3 samples from each variant, have been kept in medicinal alcohol or ethanol 74%, then separated by taxonomic groups and identified up to genus and species.

Data have been processed by the current ecological statistical techniques datailed below.

RESULTS AND DISCUSSIONS

Samplings carried out in May, July and September provided data on invertebrate qualitative and quantitative structure, and its changes under the influence of rotation and fertilization in an irrigated maize crop.

Interpretation of data obtained on invertebrate statics and dynamics in the arable layer can give both a gross view of relationships existing at communities levels, and functional (ecological) links established between various components, and also between these ones and the two abiotic environmental factors considered

a. Peculiarities of range and structure of invertebrate communities

Some static structural features are rather obvious from analysis of data exposed in tables 2, 3 and 4. The arable layer of maize crop in the variants examined appeared as a fauna-rich environment, however the range and structure of component groups are marked by the influence of conditions created within the agrobiocenose by rotation and fertilization.

Table 2. Abundance and spectrum of invertebrate groups in the experimental variants (1993)

No.	Systematic invertebrate groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
I. Ord. ***PLESIOPHORA***									
1.	Fam. *Enchitraeidae*	3	24	9	27	3	31	67	23
II. Ord. ***OPISTHOPORA***									
2.	Fam. *Lumbricidae*	6	5	6	8	2	3	8	0
III. Ord. ***ARANEA***									
3.	Fam. *Thomisidae*	3	3	5	1	-	2	2	3
4.	Fam. *Lycosidae*	1	2	3	1	-	-	4	3
IV. Ord ***ACARI***									
5.	Fam. *Trombidiidae*	-	-	-	-	-	2	-	2
V. Ord. ***PROTEROSPERMOPHORA***									
6.	Fam. *Polydesmidae*	1	20	7	9	3	6	5	1
VI. Ord. ***OPISTOSPERMOPHORA***									
7.	Fam. *Iulidae*	2	6	11	8	6	2	12	5
VII. Ord. ***CHILOPODA***									
8.	Fam. *Goophilidae*	-	1	1	1	-	-	-	-
9.	Fam. *Lithobiidae*	-	-	6	2	-	1	-	1
VIII. Ord. ***COMEKBOLA***									
10.	Fam. *Isotonidae*	-	5	5	-	-	-	6	-
IX. Ord. ***ORTHOPTERA***									
11.	Fam. *Gryllidae*	-	-	1	-	1	2	2	1
X. Ord. *HYMENOPTERA*									
12.	Fam. *Formicidae*	2	-	-	-	-	2	2	1
XI. Ord. *COLEOPTERA*									
13.	Fam. *Carabidae*	5	27	8	7	34	27	4	26
14.	Fam. *Staphylinidae*	-	-	1	2	-	2	-	-
15.	Fam. *Scarabeidae*	-	2	-	8	-	41	1	4
16.	Fam. *Elateridae*	-	-	-	1	2	2	-	3
17.	Fam. *Anthicidae*	7	13	3	8	7	7	9	12
18.	Fam. *Chrysomelidae*	-	3	-	-	-	6	-	1
19.	Fam. *Curculionidae*	1	3	-	1	5	7	1	-
XII. Ord. ***DIPTERA***									
20.	Fam. *Chironomidae*	-	-	-	-	-	-	-	1
21.	Fam. *Sciaridae*	-	2	-	-	-	-	-	-
22.	Fam. *Cecidomyiidae*	1	-	-	-	-	-	-	-
23.	Fam. *Rhagionidae*	-	-	-	-	-	3	-	1
	Total ind. variant	32	116	66	84	63	146	123	88
	% by variant	4.5	16.2	9.2	11.7	8.8	20.2	17.1	12.3
	Total ind./crop groups	298 ind. = 41.54%				420 ind. = 58.5%			
	Ratio FCA/FCAP	1 : 1.4							

FCA = Fauna from annual crops
FCAP = Fauna from annual and perennial crops

The total population of invertebrate fauna collected reached the abundance values very close in May and July, dropping to half in September. An other general feature calling for attention is the ratio between invertebrate population in the two variant groups, with and without perennial plants.

The ratio obvioualy favourable to invertebrates in variants with perennial plants recorded successive increases from May through September (1:1.4; 1:1.5; 1:1.9). In the experimental variants, abundances of invertebrate communities did not maintain their structural position along the season, except for variant 7 which, by abundance values positioned the invertebrate communities populating it in a dominant place.

Table 3. Abundance and spectrum of invertebrate group in the experimental variants

No.	Systematic invertebrate groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
I. Ord. ***PLESIOPHORA***									
1.	Fam. *Enchitraeidae*	4	-	8	5	5	3	-	-
II. Ord. *OPISTHOPORA*									
2.	Fam. *Lumbricidae*	3	3	10	1	5	6	11	2
III. Ord. *ISOPODA*									
3.	Fam. *Porcollionidae*	1	1	1	1	1	1	1	2
IV. Ord. *ARANEA*									
4.	Fam. *Thomisidae*	2	6	3	1	3	8	9	8
5.	Fam. *Lycosidae*	2	4	2	3	4	6	9	10
V. Ord. *ACARI*									
6.	Fam. *Trombidiidae*	3	2	2	1	3	3	3	1
7.	Fam. *Oribatidae*	1	-	-	-	3	-	2	-
VI. Ord. *PROTEROSPERMOPHORA*									
8.	Fam. *Polydesmidae*	2	6	-	14	11	-	2	9
VII. Ord. *OPISTOSPERMOPHORA*									
9.	Fam. *Iulidae*	-	3	1	2	5	-	1	2
VIII. Ord. *CHILOPODA*									
10.	Fam. *Goophilidae*	-	-	1	-	1	-	-	-
11.	Fam. *Lithobiidae*	4	-	3	2	4	3	4	-
IX. Ord. *COMEKBOLA*									
12.	Fam. *Isotonidae*	-	8	-	-	9	5	11	8
X. Ord. *ISOCOPTERA*									
13.	Fam. *Isocidae*	-	-	-	-	1	1	-	-
XI. Ord. *ORTHOPTERA*									
14.	Fam. *Gryllidae*	3	4	1	1	2	1	8	1
15.	Fam. *Gryllotalpidae*	-	-	-	2	-	1	-	-
XII. Ord. *HETEROPTERA*									
16.	Fam. *Pentatomidae*	-	-	-	-	-	-	-	1
17.	Fam. *Nabidae*	-	-	-	-	-	-	-	1
XIII. Ord. *HYMENOPTERA*									
18.	Fam. *Formicidae*	-	-	5	4	2	12	1	-
19.	Fam. *Carabidae*	47	18	27	32	33	30	76	39
20.	Fam. *Staphylinidae*	2	4	1	1	6	3	1	2
21.	Fam. *Scarabeidae*	-	-	-	1	1	-	-	-
22.	Fam. *Cantharidae*	-	-	-	1	1	-	2	1
23.	Fam. *Nitidulidae*	-	-	-	-	-	2	-	-
24.	Fam. *Coccinellidae*	1	1	-	3	3	-	1	-
25.	Fam. *Elateridae*	-	-	-	2	-	2	-	1
26.	Fam. *Lathridiidae*	-	1	-	-	1	-	1	-
27.	Fam. *Chrysomelidae*	2	3	2	4	-	-	4	6
28.	Fam. *Curculionidae*	3	-	-	-	-	3	1	3
29.	Fam. *Anthicidae*	1	-	-	1	1	4	1	-
XIV. Ord. *DIPTERA*									
30.	Fam. *Chironomidae*	1	-	2	-	-	-	-	
31.	Fam. *Cecidomyiidae*	-	1	-	-	-	-	-	-
	Total ind. variant	82	65	70	72	105	95	149	96
	% by variant	11.2	8.9	9.5	9.8	14.3	12.9	20.3	13.1
	Total ind./crop groups	289 ind = 59.4%				445 ind = 60.6%			
	Ratio FCA/FCAP	1 : 1.54							

FCA = Fauna from annual crops
FCAP = Fauna from annual and perennial crops

Family and species spectra in each variant fluctuated within the year, being the richest in May and July. It is worth mentioning that in the check (V_1 = 28 – years monoculture, and V_5 = 4 – years monoculture) the invertebrate range declined from May through September. In the other variants the spectrum of species and systematic groups oscillated in size along the year.

Table 4. Abundance and spectrum of invertebrate group in the experimental variants

No.	Systematic invertebrate groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
I. Ord. *PLESIOPHORA*									
1.	Fam. *Enchitraeidae*	-	-	-	-	-	2	3	1
II. Ord. *OPISTHOPORA*									
2.	Fam. *Lumbricidae*	1	2	4	-	-	2	3	1
III. Ord. *ISOPODA*									
3.	Fam. *Porcollionidae*	-	1	1	1	1	-	-	-
IV. Ord. *ARANEA*									
4.	Fam. *Thomisidae*	6	5	2	4	4	5	7	8
5.	Fam. *Lycosidae*	2	4	3	2	3	4	8	5
V. Ord *ACARI*									
6.	Fam. *Trombidiidae*	3	2	2	-	-	2	3	-
7.	Fam. *Oribatidae*	1	-	-	2	3	-	2	2
VI. Ord. *PROTEROSPERMOPHORA*									
8.	Fam. *Polydesmidae*	-	1	2	2	5	1	12	23
VII. Ord. *OPISTOSPERMOPHORA*									
9.	Fam. *Iulidae*	-	-	-	1	1	3	5	-
VIII. Ord. *CHILOPODA*									
10.	Fam. *Goophilidae*	-	-	-	-	-	-	1	-
11.	Fam. *Lithobiidae*	4	1	-	2	1	3	6	3
IX. Ord. *COMEKBOLA*									
12.	Fam. *Isotonidae*	-	1	-	1	-	-	2	1
X. Ord. *ORTHOPTERA*									
13.	Fam. *Gryllidae*	4	1	1	-	2	-	4	1
XI. Ord. *PSOCOPTERA*									
14.	Fam. *Psolidae*	-	-	2	-	-	-	1	-
XII. Ord. *HETEROPTERA*									
15.	Fam. *Pentatomidae*	-	1	1	-	-	-	-	-
16.	Fam. *Nabidae*	-	1	-	1	-	-	-	-
XIII. Ord. *HYMENOPTERA*									
17.	Fam. *Formicidae*	-	-	2	8	4	8	2	-
XIV. Ord. *COLEOPTERA*									
18.	Fam. *Carabidae*	7	5	5	3	6	11	19	7
19.	Fam. *Staphylinidae*	-	-	-	-	2	-	1	-
20.	Fam. *Scarabeidae*	-	1	-	-	1	1	-	1
21.	Fam. *Cantharidae*	-	-	-	2	-	-	1	-
22.	Fam. *Nitidulidae*	-	-	-	-	-	2	-	-
23.	Fam. *Coccinellidae*	1	1	1	-	-	3	-	1
24.	Fam. *Elateridae*	-	1	-	-	-	-	-	1
25.	Fam. *Anthicidae*	2	1	-	-	-	6	1	2
26.	Fam. *Tenebrionidae*	-	-	-	-	-	-	1	-
27.	Fam. *Chrysomelidae*	2	4	3	-	2	-	3	4
28.	Fam. *Curculionidae*	1	-	-	-	-	-	2	-
XIV. Ord. *DIPTERA*									
29.	Fam. *Chironomidae*	-	1	-	-	-	3	-	-
	Total ind. variant	34	34	29	29	35	56	87	60
	% by variant	9.3	9.3	8.0	8.0	9.6	15.4	23.9	16.5
	Total ind./crop groups	126 ind. = 34.6%				238 ind.= 65.4%			
	Ratio FCA/FCAP	1 : 1.9							

FCA = Fauna from annual crops
FCAP = Fauna from annual and perennial crops

At the same time, data recorded in the 3 tables revealed that the most abundant invertebrate groups were, in decreasing order, Carabids with the species *Harpalus pubescens*, *H. distinguendus* Dftsch., *Pterostichus niger* Schall., *P. cupreus* L.; *Enchytreids* with *Fridericia bulbosa* L.; *Anthicids* (*Anthicus hispidus* Ross., *Notoxus cornutus* F.; *Lumbricids* with *Allobophors caliginosa* L., *A. rosea* L., *Lumbricus terrestries* Michall; Polydesmids with *Polydesmus complanatus* L.; *Aranea* with some species from *Thomisidae* and *Lycosidae*, *Iliuds* with *Iulus* spp.; it is also to note that, even among these 8 principal invertebrate groups, some of them had gradually reduced their abundance from spring to autumn (*Enchytreids*, *Anthicids*).

b. Ecological plasticity

Presence or absence of invertebrate families in the 8 experimental variants allowed to infer about their ecological plasticity size.

Table 5. Response of invertebrate families to ecological conditions in the variants and their ecological plasticity

Type of crop	Variant	Response of invertebrate fauna by variants					
		May		July		September	
		(+)	(-)	(+)	(-)	(+)	(-)
	V_1	11	26	11	26	13	24
Annual crops	V_2	12	25	15	22	18	15
	V_3	13	24	14	23	13	24
	V_4	12	25	20	17	13	24
	V_1	9	29	22	15	13	24
Annual and	V_2	17	20	17	20	16	21
perennial	V_3	12	25	20	17	21	26
crops	V_4	12	25	16	23	14	22

(+) = Faunistic occurrence in variant
(-) = Faunistically absent from variant

Ecological plasticity of systematic groups		
High	Medium	Slight
Enchytraeidae	*Porcellionidae*	*Trobidiidae*
Lumbricidae	*Lithobiidae*	*Oribatidae*
Thomisidae	*Gryllidae*	*Geophilidae*
Lycosidae	*Formicidae*	*Isotomidae*
Polydesmidae	*Scarabeidae*	*Psocidae*
Iulidae	*Elateridae*	*Pentatomidae*
Carabidae		*Nabidae*
Staphylinidae		*Cantharidae*
Anthicidae		*Nitidulidae*
Chrysomalidae		*Lathridiidae*
Curculionidae		*Coccinellidae*
		Tenebrionidae
		Chironomidae
		Sciaridae
		Cecidomyiidae
		Rhagionidae
		Dolichopodidae
32.35%	17.65%	50.00%

By this method, families populating the arable layer were divided into three categories – the first one, in which occurrence in variants ranged within the limits 75 – 100%; the second one, with medium plasticity, having 50 and 74% as occurrence limits; the third category with low plasticity, which included families whose occurrence dropped below 50%. Data obtained from the whole season showed that the first category with fair ecological plasticity included species from 11 families, followed by 6 families with medium plasticity, and 20 with reduced plasticity (Table 5).

Likewise, it was noticed that in the group of variants including perennial plants (V_5 – V^8), besides high populations, the invertebrate communities also had a broader range of species, compared to invertebrates in variants devold of perennial plants (V_1 - V_4). The extremes were the variant 1 (28 – years monoculture) with 11 families and the most reduced spectrum, and the variant 7 with a maximum spectrum of 26 families.

c. Ecological affinity of invertebrates

In order to determine the size of influences incured by application of rotation and fertilization in maize crop on the organization of invertebrate communities, two methods have been used, based on the criterion of comparison by couples of variants between themselves. One of these methods hives a qualitative measure of organization in these invertebrate communities and merely refers to the presence or absence of species in variants. As a result of these comparisons, the indices of similarity have been revealed, the most common of the in being Jaccard (1912), Kulcinski (1928) and Sorensen (1948) indices.

Choice from these three indices is dependent of data having to be processed. The Sorensen indix was the most adequate for us, being less affected by the number of samples, and also overtaxes rare species, against dominance of others.

Calculation of Sorensen index is made with the formula:

$$QS = \frac{2j}{a+b} \times 100 \text{ where,}$$

j = species com to the two communities compared,

a = species from biotype a,

b = species from biotypes b.

However, for a more realistic evaluation of invertebrate communities, organization occurring in soiles of testing, besides the qualitative facet (presence or absence od species) of their numerical position in the community structure, was also considered.

Measurement of these qualitative – quantitative similarities is made through the coefficient of rank correlation, either from Kendall (1962), or Spearman (1965). In our investigations the coefficient of rank correlation by Spearman (r_s) has been used, as in the rows of ranks compared, several linked values occurred.

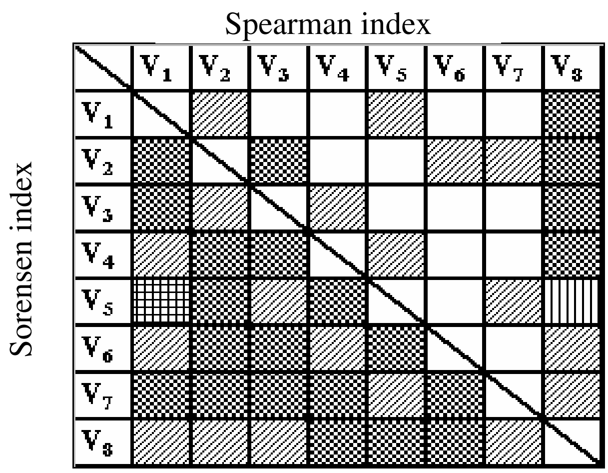
The formula of Spearman coefficient is:

$$r_s = 1 - \frac{6\sum d^2}{n^3 - n} = 1 - \frac{6\sum d^2}{n(n^2 - 1)}$$ where:

d^2 = square of difference between ranks;

n = total number of species in the two variants compared;

By comparing between thenselves the invertebrate communities from the variants studied, using calculation techniques by the index of Sorensen and the coefficient of Spearman, the diagram of Trellis has been drawn up (Figure 1).



Sorensen index	Spearman index
0 – 20%	0,06 – 0,20
21 – 40%	0, 21– 0,40
41 – 60%	0,41 – 0,60
61 – 80%	0,61 – 0,80
81 – 100%	0,81 – 1,00

Figure 1. The Trellis diagram with Sorensen and Spearman affinity index

For a better understanding of values inscribed in diagram, we give thein synthesis in table 6, thus allowing to see more clearly that for the most part (92.9%), the invertebrate communities have a medium-level qualitative similarity.

Table 6. Synthesis of values of similarity indices May, 19 – 21 1993, Fundulea

Classification of affinities	Indices	Values limits	Indices of affinity: QS No. of combinations	QS %	r_s No. of combinations	r_s %
Slifght	QS	1.0-39.0	0	0.0	-	-
	r_s	0.01-0.39	-	-	16	57.2
Medium	QS	40.0-60.0	26	92.9	-	-
	r_s	0.40-0.60	-	-	12	42.8
Good	QS	61.0-100.0	2	7.1	-	-
	r_s	0.61-1.00	-	-	0	0.0

As for the structure and quantitative organization, more than half of these communities (57.2%) had the Spearman's coeficient (rs) with values located in the slight zone of affinities, and the remainder (42.8%) in the medium zone.

The similarity degree of invertebrate communities in the different variants examined also had been interpreted by the index of Mountfort (1962), a multilateral index, derived from comparisons of communities from several variants, with a certain variant considered as basic, in which the values od similarity indices were the highest (communities with the best structures and specific qualities). The general formula of this type of comparison is:

$$M = \frac{1}{m \cdot n} \cdot \sum_{i=1}^{m} \cdot \sum_{j=1}^{n} (A\,ï\,B\,ï)$$

where:

Aï and Bï represent groups of invertebrate communities compared on the basis of Sorensen or Spearman indices while m and n the numbers of situations compared within these groups.

By this method, the similarity QS and r_s indices have been compared, starting in the former case from groups with 64% values, and with 0.59 values in the latter. When comparing the best groups with QS index = 64% (variants 2 and 7) with the other groups, values of Mountfort index are obtained, these oscillating between 51-56%, i.e. a medium similarity level.

When using the Mountfort formula for the values of rank correlation (rs), comparison has been made at the highest level 0.59 (variants 5 – 8) with the other couples, thus stating that for most cases the Mountfort indices were comprised between 0.18 and 0.46. Thus, we also demonstrated by this method that the environment factors considered, rotation and fertilization, substantially influenced the organization of invertebrate communities occurring in maize crop, this fact being more important when the experimental variants were spatially close enough.

d. Ecological structure of invertebrate communities

Analysis of functional (ecological) structures presented in table 7 revealed that in all variants including annual and perennial crops, abundance of invertebrate communities were superior to those of variants with only annual crops.

Table 7. Ecological structure of invertebrate communities in dependence of rotation and fertilization

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Month	Ecological groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
May	Phytophages	15	42	24	36	31	74	29	35
	Zoophages	6	33	22	14	29	34	10	25
	Detritivores	10	35	20	33	3	36	82	27
	Pantophages	1	6	0	1	0	2	2	1
July	Phytophages	38	19	17	20	34	29	47	35
	Zoophages	32	28	23	37	36	35	67	45
	Detritivores	9	12	19	7	24	14	29	11
	Pantophages	3	6	11	8	11	17	6	5
September	Phytophages	13	13	13	4	18	17	33	34
	Zoophages	15	14	7	14	11	18	37	18
	Detritivores	2	6	2	3	5	10	14	7
	Pantophages	4	1	7	8	1	11	3	1
Total season	Phytophages	66	74	54	60	83	120	109	104
	Zoophages	53	75	52	65	76	87	114	88
	Detritivores	21	53	41	43	32	60	125	45
	Pantophages	8	13	18	17	12	30	11	7
Total per croptype	Phytophages	257 = 35.0%				416 = 38.1%			
	Zoophages	245 = 34.4%				364 = 33.2%			
	Detritivores	158 = 22.2%				262 = 23.4%			
	Pantophages	56 = 7.8%				60 = 5.4%			

Likewise, it was noted that the functional structures have fluctuations of values, depending on rotation, fertilization or season. From the multitude of situations exposed in table 7, some general aspects resulted, referring to: a. dominance of phytophages in May and September, and of zoophages in July, in most communities examined; b. annual values of numerical and relative abundances revealed functional (ecological) structures identical for the two types of annual and perennial crops. Though the values of numerical abundances differ, the relative ones are very close for all 4 ecological categories compounding the invertebrate communities. Finally, crop rotation, influences only the populations of organisms, and not the position of the functional (ecological) categories of invertebrate communities.

To examine the effects of rotation and fertilization on faunal categories levels, as structural components of invertebrates, the method χ^2 has been used, applying the r x 2 and 2 x 2, as depending on the analysis modality – gross or by ecological categories (table 8).

To calculate χ^2, the following formula Has been used:

$$\chi^2 = \sum_{i=1}^{m} (\frac{A_0^{\ 2}}{Ac}) - N \text{ where:}$$

A_0 – abundance observed (from 3 collections);

A_c – theoretical abundances (calculated);

N – Sum of observed abundances.

By this method one can demonstrate weather all functional (ecological) categories are inscribed with the ratio 1:1.5 existing between the total invertebrate abundance in variants with annual crops (FCA) and those with annual and perennial crops (FCAP).

The χ^2 theoretical clossest to 5.17 for a number of freedom degrees corresponds to a probability of α = 10-30%, therefore the ratio between the functional categories of invertebrate communities in the two groups of variants FCA/FCAP deviated from this ratio only for phytophages group, in witch the probability is ± 5%, thus statistically significant. For

Table 8. Influence of rotation and fertilization on the ecological categories in the invertebrate structure on the 2 maize crop groups

Ecological category	Annual crops		Annual and perennial crops		Total	%	Probability	Significance
	Abundance		Abundance					
	Observed	Calculated	Observed	Calculated				
Phytophage	254	263.6	416	406.4	670	0.56	30 - 50	unsignificant
Zoophages	245	239.2	364	369.8	609	0.23	50 - 70	unsignificant
Detritivores	158	165.0	262	255.0	420	0.48	30 - 50	unsignificant
Pantophages	56	45.6	60	70.4	116	3.90	2.5 - 5	significant
TOTAL	713	713.4	1102	1101.6	1815	5.17	10 - 30	unsignificant

all the other categories χ^2 values corresponded to probabilities within the sphere of unsignificant deviations, ratios between these categories being around 1:1.54.

e. Concordance of structures and ecological balance of invertebrates in experimental variants

In order to know the similarity degree of structures of invertebrate communities we used the coefficient of concordance Kendall (w) given by the formula:

$$w = \frac{s}{\frac{1}{12}k^2(N^3 - N)} \text{ where:}$$

S = Sum of squares of differences between ranks (R_j) and their mean $\left(\frac{R_j}{N}\right)$, i. e. $\left(R_j = \frac{R_j^2}{N}\right)$;

K = number of compared variants;

$\frac{1}{12}K^2(N^3 - N)$ represents the maximum sums of square differences between ranks, i. e. S = K.

From table 8 results that unfertilized variants and those fertilized with NP + barn dung, the structural similarity degree of invertebrate communities is expressed by very low values, particularly during May, those being severely marked by the environment influence (rotation, fertilizers) and so diversifying and particularizing them. At the same date, a better situation is presented by the variants with chemical NP fertilization where invertebrate communities had higher concordance values, those with perennial cycles having structure concordance superior to variants with annual crops. In July and September these particularities maintain in variants with annual crops, but the values of concordance Kendall (w) are extremely reduced. In variants with perennial crops values of this index (w) differ, in July in those with NP fertilization + barn dung, while in September in the unfertilized ones.

This table also includes values of indices of diversity and equitability obtained by Mc Arthur (1958) and Lloyd and Ghelard (1964) methods. According to Mc Arthur method, the Schannon and Wiener expression from information theory was used, where:

$$H(S) = -\sum_{i=1}^{S} pr_i \log_2 pr_i$$

in which:

H(S) = information amount transmitted by the invertebrate community at a given moment;

pr_i = proportion of a certain species and groups in the invertebrate community.

The unit of expression for information content is a “bit” the most spread unit, which corresponds to the arithmetic type used in computers.

For equitability the following ratio has been used:

$$E = \frac{S^1}{S} \text{ where:}$$

S^1 = theoretical number of species corresponding to the observed value of index of diversity;

S = number of species in the invertebrate community.

For a more accurate estimation of ecological equilibrium state in invertebrate communities, indices of diversity and equitability have been calculated taking into account both numerical abundance of species and their biomass abundance. Our data demonstrate that from standpoint of number of species and their representation through specimens invertabrate communities are well balanced in unfertilized variants, and thouse fertilized with NP + barn dung (V5-V8) in both groups with and without perennial crops. It is explainable, as in thos variants invertebrates have the most reduced spectrum and abundance values. In variants with chemical fertilization the higher number species differenciated by their representation with specimens, results in a reduced degree of ecological balance, as shown by the indices of diversity (HS) and equitability (E) as average values.

As to the ecological balance of invertebrate communities, as shown by the biomass of component organisms, a disturbance of homogenity is noted, particulary in variants where Scarabeid are present (*Anisoplia austriaca, A. segetum)* or *Elaterides* or *Lumbricides (A. rosea, A. caliginosa, L. terrestria),* with dominant structural shares.

CONCLUSIONS

The results of investigations conducted in 1993 allowed to draw the following general conclusions:

Invertebrate communities in all variants covered a range of 37 families, including in 57 species. Among these 8 were the most frequent and abundant: *Lumbricidae, Enchytreidae, Iulidae, Polydesmidae, Carabidae, Anthicidae, Chrysomelidae* and *Curculionidae.*

The annual population in variants 1-4 without perennial crops accounted for 712 specimens in a 0.625m2 sampling area, whereas in variants 5-8 with perennial crops, was 1.022 specimens.

The ratio between populations in variants without perennial crops and those with perennial crops was steadily increasing from spring through autumn (1:4; 1:1.5 and 1:1.9).

According to ecological plasticity, the invertebrate groups fell into 3 categories: good ecological plasticity with 11 families, the anelid worms (*Lumbricides* and *Enchytreidae)* prevaling myriapodes (*Polydesmidae* and *Iulidae)* and some insect families (*Carabidae, Anthicidae)*; medium plasticity, including 6 families and reduced plasticity, encompassing 20 families.

Ecological affinity of invertebrate communities has been studies qualitatively (by OS index = Sorensen) and qualitatively – quantitatively) (rank correlation coefficient Spearman r_s).

It was demonstrated that most of the invertebrate associations (92.9%) had medium level similarity as for their componence by species, howeven slight as organization or structure (57% of combinations). The index of Mountfort has been applied, whose values support the above statement on quality and organization of invertebrate communities, as depending on rotation and fertilization.

Data are exposed on the functional (ecological) structure of communities which outline the fact that phytophagous components are in the first place of the trophic chain in May and zoophages in July, irrespective of crop rotation. As to codominant components there are some differenciations: in variants with perennial plants, detritivores, have a secondary place, while in those without perennial plants this place is hold by zoophages. The factor rotation with perennial plants (lucerne + orchard grass) influenced positively the abundance or density of invertebrates in the arable soil layer of irrigated maize crop.

Ratio between invertebrate populations in both variant groups, without or with perennial plants is 1:1.54. It is noted that size difference of density did not change the structure of invertebrate communities by ecological (functional) categories, which had structural percentages nearly equal, in both situations.

The last aspect outlined was concordance of invertebrate communities structures (Kandall's index w) and the ecological equilibrium as revealed by values of diversity (HS) and equitability (E) calculated from numbers of components species and from their biomass.

The concordance Kendall (W) indices reached very low values in invertebrate communities in all variants and particularity in July and September. Likewise the state of ecological equilibrium rated by numerical species representation was very good in invertebrate communities in variants not fertilized with barn dung; this is due to low number of individuals (species which reflects occurence of some more hemogenous life conditions in biotops they populate. In variants with chemical fertilization, values of indices of diversity and equitability attained medium levels; thus, a good ecological equilibrum state.

Using the criterion of species biomass, our results demonstrated that the ecological equilibrum state of invertebrate communities is reduced, below the theoretical average values. This imbalance is ascribed to occurrence in the soil of irrigated maize crop, of some invertebrate groups with very high biomass share, such as: *Lumbricidae, Julidae, Scarabeidae* and *Elateridae.*

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Table 1. Crop rotation in which the invertebrate communities have been analysed

Variant	Annual crops	Variant	Annual and perennial crops (duration in years)	Years from fallowing
1	M – 28 years monoculture	2	P4 – L4	4
3	M – W	4	P – G, 6 – L3	1
5	M – W - SO	6	P – G – SO, 12 – L4	4
7	M – Sf – W - Sb	8	P – Fls – G – Sf, 12 – L3	10

Table 2. Abundance and spectrum of invertebrate groups in the experimental variants (1993)

No.	Systematic invertebrate groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
I.	**Ord. *PLESIOPHORA***								
1.	Fam. *Enchitraeidae*	3	24	9	27	3	31	67	23
II.	**Ord. *OPISTHOPORA***								
2.	Fam. *Lumbricidae*	6	5	6	8	2	3	8	0
III.	**Ord. *ARANEA***								
3.	Fam. *Thomicidae*	3	3	5	1	-	2	2	3
4.	Fam. *Lycosidae*	1	2	3	1	-	-	4	3
IV.	**Ord *ACARI***								
5.	Fam. *Trombidiidae*	-	-	-	-	-	2	-	2
V.	**Ord. *PROTEROSPERMOPHORA***								
6.	Fam. *Polydesmidae*	1	20	7	9	3	6	5	1
VI.	**Ord. *OPISTOSPERMOPHORA***								
7.	Fam. *Iulidae*	2	6	11	8	6	2	12	5
VII.	**Ord. *CHILOPODA***								
8.	Fam. *Goophilidae*	-	1	1	1	-	-	-	-
9.	Fam. *LITHOBIIDAE*	-	-	6	2	-	1	-	1
VIII	**Ord. *COMEKBOLA***								
10.	Fam. *Isotonidae*	-	5	5	-	-	-	6	-
IX.	**Ord. *ORTHOPTERA***								
11.	Fam. *Gryllidae*	-	-	1	-	1	2	2	1
X.	**Ord. *HYMENOPTERA***								
12.	Fam. *Formicidae*	2	-	-	-	-	2	2	1
XI.	**Ord. *COLEOPTERA***								
13.	Fam. Carabidae	5	27	8	7	34	27	4	26
14.	Fam. *Staphylinidae*	-	-	1	2	-	2	-	-
15.	Fam. *Scarabeidae*	-	2	-	8	-	41	1	4
16.	Fam. *Elateridae*	-	-	-	1	2	2	-	3
17.	Fam. *Anthicidae*	7	13	3	8	7	7	9	12
18.	Fam. *Chrysomelidae*	-	3	-	-	-	6	-	1
19.	Fam. *Curculionidae*	1	3	-	1	5	7	1	-

XII.	**Ord. *DIPTERA***								
20.	Fam. *Chironomidae*	-	-	-	-	-	-	-	1
21.	Fam. *Soiaridae*	-	2	-	-	-	-	-	-
22.	Fam. *Cocidomyiidae*	1	-	-	-	-	-	-	-
23.	Fam. *Rhagionidae*	-	-	-	-	-	3	-	1
	Total ind. variant	32	116	66	84	63	146	123	88
	% by variant	4.5	16.2	9.2	11.7	8.8	20.2	17.1	12.3
	Total ind./crop groups	298 ind. = 41.54%				420 ind. = 58.5%			
	Ratio FCA/FCAP	1 : 1.4							

Table 3. Abundance and spectrum of invertebrate group in the experimental variants

No.	Systematic invertebrate groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
I.	**Ord. *PLESIOPHORA***								
1.	Fam. *Enchitraeidae*	4	-	8	5	5	3	-	-
II.	**Ord. *OPISTHOPORA***								
2.	Fam. *Lumbricidae*	3	3	10	1	5	6	11	2
III.	**Ord. *ISOPODA***								
3.	Fam. *Porcollionidae*	1	1	1	1	1	1	1	2
IV.	**Ord. *ARANEA***								
4.	Fam. *Thomicidae*	2	6	3	1	3	8	9	8
5.	Fam. *Lycosidae*	2	4	2	3	4	6	9	10
V.	**Ord *ACARI***								
6.	Fam. *Trombidiidae*	3	2	2	1	3	3	3	1
7.	Fam. *Oribatidae*	1	-	-	-	3	-	2	-
VI.	**Ord. *PROTEROSPERMOPHORA***								
8.	Fam. *Polydesmidae*	2	6	-	14	11	-	2	9
VII.	**Ord. *OPISTOSPERMOPHORA***								
9.	Fam. *Iulidae*	-	3	1	2	5	-	1	2
VIII.	**Ord. *CHILOPODA***								
10.	Fam. *Goophilidae*	-	-	1	-	1	-	-	-
11.	Fam. *Lithobiidae*	4	-	3	2	4	3	4	-
IX.	**Ord. *COMEKBOLA***								
12.	Fam. *Isotonidae*	-	8	-	-	9	5	11	8
X.	**Ord. *ISOCOPTERA***								
13.	Fam. *Isocidae*	-	-	-	-	1	1	-	-
XI.	**Ord. *ORTHOPTERA***								
14.	Fam. *Gryllidae*	3	4	1	1	2	1	8	1
15.	Fam. *Gryllotalpidae*	-	-	-	2	-	1	-	-
XII.	**Ord. *HETEROPTERA***								
16.	Fam. *Pentatomidae*	-	-	-	-	-	-	-	1
17.	Fam. *Nabidae*	-	-	-	-	-	-	-	1
XIII.	**Ord. *HYMENOPTERA***								
18.	Fam. *Formicidae*	-	-	5	4	2	12	1	-
19.	Fam. *Carabidae*	47	18	27	32	33	30	76	39
20.	Fam. *Staphylinidae*	2	4	1	1	6	3	1	2
21.	Fam. *Scarabeidae*	-	-	-	1	1	-	-	-
22.	Fam. *Cantharidae*	-	-	-	1	1	-	2	1
23.	Fam. *Nitidulidae*	-	-	-	-	-	2	-	-
24.	Fam. *Coccinellidae*	1	1	-	3	3	-	1	-
25.	Fam. *Elateridae*	-	-	-	2	-	2	-	1
26.	Fam. *Lathridiidae*	-	1	-	-	1	-	1	-
27.	Fam. *Chrysomelidae*	2	3	2	4	-	-	4	6
28.	Fam. *Curculionidae*	3	-	-	-	-	3	1	3
29.	Fam. *Anthicidae*	1	-	-	1	1	4	1	-
XIV.	**Ord. *DIPTERA***								
30.	Fam. *Chironomidae*	1	-	2	-	-	-	-	
31.	Fam. *Cocidomyiidae*	-	1	-	-	-	-	-	-
	Total ind. variant	82	65	70	72	105	95	149	96
	% by variant	11.2	8.9	9.5	9.8	14.3	12.9	20.3	13.1
	Total ind./crop groups	289 ind = 59.4%				445 ind = 60.6%			
	Ratio FCA/FCAP	1 : 1.54							

FCA = Fauna from annual crops

FCAP = Fauna from annual and perennial crops

Table 4. Abundance and spectrum of invertebrate group in the experimental variants

No.	Systematic invertebrate groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
I.	**Ord. *PLESIOPHORA***								
1.	Fam. *Enchitraeidae*	-	-	-	-	-	2	3	1
II.	**Ord. *OPISTHOPORA***								
2.	Fam. *Lumbricidae*	1	2	4	-	-	2	3	1
III.	**Ord. *ISOPODA***								
3.	Fam. *Porcollionidae*	-	1	1	1	1	-	-	-
IV.	**Ord. *ARANEA***								
4.	Fam. *Thomisidae*	6	5	2	4	4	5	7	8
5.	Fam. *Lycosidae*	2	4	3	2	3	4	8	5
V.	**Ord *ACARI***								
6.	Fam. *Trombidiidae*	3	2	2	-	-	2	3	-
7.	Fam. *Oribatidae*	1	-	-	2	3	-	2	2
VI.	**Ord. *PROTEROSPERMOPHORA***								
8.	Fam. *Polydesmidae*	-	1	2	2	5	1	12	23
VII.	**Ord. *OPISTOSPERMOPHORA***								
9.	Fam. *Iulidae*	-	-	-	1	1	3	5	-
VIII.	**Ord. *CHILOPODA***								
10.	Fam. *Goophilidae*	-	-	-	-	-	-	1	-
11.	Fam. *Lithobiidae*	4	1	-	2	1	3	6	3
IX.	**Ord. *COMEKBOLA***								
12.	Fam. *Isotonidae*	-	1	-	1	-	-	2	1
X.	**Ord. *ORTHOPTERA***								
13.	Fam. *Gryllidae*	4	1	1	-	2	-	4	1
XI.	**Ord. *PSOCOPTERA***								
14.	Fam. *Psolidae*	-	-	2	-	-	-	1	-
XII.	**Ord. *HETEROPTERA***								
15.	Fam. *Pentatomidae*	-	1	1	-	-	-	-	-
16.	Fam. *Nabidae*	-	1	-	1	-	-	-	-
XIII.	**Ord. *HYMENOPTERA***								
17.	Fam. *Formicidae*	-	-	2	8	4	8	2	-
XIV.	**Ord. *COLEOPTERA***								
18.	Fam. *Carabidae*	7	5	5	3	6	11	19	7
19.	Fam. *Staphylinidae*	-	-	-	-	2	-	1	-

20.	Fam. *Scarabeidae*	-	1	-	-	1	1	-	1
21.	Fam. *Cantharidae*	-	-	-	2	-	-	1	-
22.	Fam. *Nitidulidae*	-	-	-	-	-	2	-	-
23.	Fam. *Coccinellidae*	1	1	1	-	-	3	-	1
24.	Fam. *Elateridae*	-	1	-	-	-	-	-	1
25.	Fam. *Anthicidae*	2	1	-	-	-	6	1	2
26.	Fam. *Tenebrionidae*	-	-	-	-	-	-	1	-
27.	Fam. *Chrysomelidae*	2	4	3	-	2	-	3	4
28.	Fam. *Curculionidae*	1	-	-	-	-	-	2	-
XIV.	**Ord.** ***DIPTERA***								
29.	Fam. *Chironomidae*	-	1	-	-	-	3	-	-
	Total ind. variant	34	34	29	29	35	56	87	60
	% by variant	9.3	9.3	8.0	8.0	9.6	15.4	23.9	16.5
	Total ind./crop groups	126 ind. = 34.6%				238 ind.= 65.4%			
	Ratio FCA/FCAP	1 : 1.9							

FCA = Fauna from annual crops
FCAP = Fauna from annual and perennial crops

Table 5. Response of invertebrate families to ecological conditions in the variants and their ecological plasticity

Type of crop	Variant	Response of invertebrate fauna by variants					
		May		July		September	
		(+)	(-)	(+)	(-)	(+)	(-)
Annual crops	V_1	11	26	11	26	13	24
	V_2	12	25	15	22	18	15
	V_3	13	24	14	23	13	24
	V_4	12	25	20	17	13	24
Annual and perennial crops	V_1	9	29	22	15	13	24
	V_2	17	20	17	20	16	21
	V_3	12	25	20	17	21	26
	V_4	12	25	16	23	14	22

(+) = Faunistic occurrence in variant
(-) = Faunistically absent from variant

Ecological plasticity of systematic groups

High	Medium	Slight
1. Enchytraeidae	1. Porcellionidae	1. Trobidiidae
2. Lumbricidae	2. Lithobiidae	2. Oribatidae
3. Thomisidae	3. Cryllidae	3. Geophilidae
4. Lycosidae	4. Formicidae	4. Isotomidae
5. Polydesmidae	5. Scarabeidae	5. Psocidae
6. Iulidae	6. Elateridae	6. Pentatomidae
7. Carabidae		7. Nabidae
8. Staphylinidae		8. Cantharidae
9. Anthicidae		9. Nitidulidae
10. Chrysomalidae		10. Lathridiidae
11. Curculionidae		11.Coccinellidae
		12.Tenebrionidae
		13.Chironomidae
		14. Solaridae
		15.Cecidomyiidae
		16. Rhagionidae
		17.Dolichopodidae
32.35%	17.65%	50.00%

Table 6. Synthesis of values of similarity indexes
19 – 21 ay 1993 Fundulea

Classification of affinities	Indices	Values limits	Indices of affinity			
			QS		r_s	
			No. of combinations	%	No. of combinations	%
Slifght	QS	1.0-39.0	0	0.0	-	-
	r_s	0.01-0.39	-	-	16	57.2
Medium	QS	40.0-60.0	26	92.9	-	-

	r_s	0.40-0.60	-	-	12	42.8
Good	QS	61.0-100.0	2	7.1	-	-
	r_s	0.61-1.00	-	-	0	0.0

Table 7

Ecological structure of invertebrate communities in dependence of rotation and fertilization
1993 – ICCPT Fundulea

Month	Ecological groups	Annual crops				Annual and perennial crops			
		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
May	Phytophages	15	42	24	36	31	74	29	35
	Zoophages	6	33	22	14	29	34	10	25
	Detritivores	10	35	20	33	3	36	82	27
	Pantophages	1	6	0	1	0	2	2	1
July	Phytophages	38	19	17	20	34	29	47	35
	Zoophages	32	28	23	37	36	35	67	45
	Detritivores	9	12	19	7	24	14	29	11
	Pantophages	3	6	11	8	11	17	6	5
September	Phytophages	13	13	13	4	18	17	33	34
	Zoophages	15	14	7	14	11	18	37	18
	Detritivores	2	6	2	3	5	10	14	7
	Pantophages	4	1	7	8	1	11	3	1
Total season	Phytophages	66	74	54	60	83	120	109	104
	Zoophages	53	75	52	65	76	87	114	88
	Detritivores	21	53	41	43	32	60	125	45
	Pantophages	8	13	18	17	12	30	11	7
Total per croptype	Phytophages	257 = 35.0%				416 = 38.1%			
	Zoophages	245 = 34.4%				364 = 33.2%			
	Detritivores	158 = 22.2%				262 = 23.4%			
	Pantophages	56 = 7.8%				60 = 5.4%			

Table 8. Influence of rotation and fertilization on the ecological categories in the invertebrate structure on he 2 maize crop groups.

Ecological category	Annual crops		Annual and perennial crops		Total	Value of probability		Significance
	Abundance		Abundance				%	
	Observed	Calculated	Observed	Calculated				
Phytophage	254	263.6	416	406.4	670	0.56	30 - 50	unsignificant
Zoophages	245	239.2	364	369.8	609	0.23	50 - 70	unsignificant
Detritivores	158	165.0	262	255.0	420	0.48	30 - 50	unsignificant
Pantophages	56	45.6	60	70.4	116	3.90	2.5 - 5	significant
	713	713.4	1102	1101.6	1815	5.17	10 - 30	significant
	Ratio 1: 1.54		Total DF = (4 - 1) (2 - 1) = 3 Method R x 2					
			By DF groups = (2 - 1) (2 - 1) = 1 Method 2 x 2					