Effects of some physical factors and agricultural practices on Collembola in a multiple cropping programme in West Bengal (India)

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EFFECTS OF SOME PHYSICAL FACTORS AND AGRICULTURAL PRACTICES ON COLLEMBOLA IN A MULTIPLE CROPPING PROGRAMME IN WEST BENGAL (INDIA)

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Running title: Collembolan fauna in a multiple cropping programme

Abstract:

Collembolan populations were followed monthly for three years in a long-term cultivated and fertilized agricultural field in East India (West Bengal), in which three crops (jute, paddy rice and wheat) were cultivated and subjected to various doses of NPK fertilizers, herbicides and organic manure. Each crop showed a rise followed by a decrease in Collembolan populations. Crossed with crop effects Collembolan populations showed a negative correlation with soil temperature and and a positive correlation with soil moisture. Application of organic manure induced the highest populations but the effects of fertilization and other treatments applied to the field were smaller than seasonal and crop influences.

Keywords: Collembola/physical factors/agricultural practices.

1.INTRODUCTION:

Soil animals promote the decomposition of organic matter by comminuting litter, interacting with microbes, recycling nutrients [6, 35, 1] and making them available for uptake by an autotrophic plant community [27]. Soil animals are directly associated with the soil structure through fecal deposition and drilling of pores [22]. Any human interference such as agricultural practices including conventional tillage, use of pesticides which interferes with the composition of soil communities and reduce the abundance of soil invertebrates [30, 23] may reduce process rates in the soil [33]. Considerable attention has been paid to the effects of agricultural practices on soil fauna, especially microarthropods, mainly represented by mites and collembola [13, 12, 25]. Research efforts concerning tropical countries are still in progress and more knowledge is needed before more conservative methods can be applied to the management of agricultural soils.

The present experiment was conducted to study the Collembolan population of agricultural fields in which three crops (jute, paddy rice and wheat) were cultivated and supplemented with graded doses of N, P, and K fertilizers. Treatments were also designed to estimate the effects of organic manure and herbicides.

2.MATERIALS AND METHODS:

Experimental plots were selected at the Jute Agricultural Research Institute (I.C.A.R.), Barrackpore, West Bengal, India (22°46'N, 88°24'E), in a long-term (15-yr) fertilizer experiment. In this experiment, three croppping systems using jute, paddy rice and wheat succeeded round the year. Nine different treatments (Table I) were replicated four times using a randomised block design. Soil samples were collected from experimental plots at monthly intervals for three consecutive years. Plot size was 20m x 10m.

The soil was alluvium from the Gangetic plain. Fertilizer sources for NPK treatment were urea, superphosphate and potassium chloride, respectively. The three crop rotations consisted of two cereals, paddy rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) and one fibre crop, jute (*Corchorus olitorius* L.). Jute was sown in April and harvested in July. Paddy rice was transplanted in August and harvested in November. Wheat was sown in December and harvested in March.

Hand weeding and hoeing were done at monthly intervals after sowing or transplanting. A herbicide was used for weed control in treatment 7. Soil samples were collected from all replicated plots at monthly intervals. Samplers were 9cm long and with a cross sectional area of 28cm^2. Three cores were taken from each plot, at each time. Tullgren funnel extractors were used for collecting soil microarthropods. The extraction time was five days. Soil temperature, surface humidity and soil moisture were recorded each month from all replicated plots under each treatment.

After extraction, animals were mounted in polyvinylalcohol and identified to the species or to the genus level under a phase contrast microscope. In the absence of a comprehensive account of Indian springtails, half of the species could only be identified at the genus level.

Data pooled over three years for each experimental plot were used for the calculation of Spearman rank correlation coefficients, a posteriori comparisons among means using t-tests or non-parametric Kolmogorov-Smirnov tests according to normality of residuals [32] and correspondence analysis [16]. For correspondence analysis, data were transformed using refocusing (mean fixed to 20) and reweighting (variance fixed to 1) and variables were doubled in higher and lower values according to Ponge and Delhaye [28]. The latter procedure allowed to display changes in population densities. Each variable was thus represented by two points (higher and lower values) which were symmetrical around the origin. The farther these points were from the origin in the direction of a given axis, the better the corresponding variable contributed to this axis. Main (active) variables were Collembolan taxa (densities) and additional (passive) variables were crops (wheat, paddy rice or wheat), total abundance of Collembola, temperature, moisture, relative humidity and months (January to December).

3.RESULTS:

Eleven Collembolan species (Table 2) were found in this experiment of which *Isotomurus balteatus* and *Cryptopygus thermophilus* were most common.

The first two axes of correspondence analysis explained 29% and 23% of the total variance, respectively (Figure 1). Axis 1 was interpreted as a global trend of decreasing abundance of the Collembolan population, depending mainly on temperature and, to a lesser extent, relative humidity and moisture, judging from the corresponding loadings (Table 3). Axis 2 expressed detail changes in species composition, but no proper explanation was found for this axis. Thus it will not be accounted for in the following. The position of months, projected as additional (passive) variables, in the plane of axes 1 and 2, but more especially along axis 1, showed that January, February, July, September, October and November exhibited an abundant Collembolan fauna, while these animals were scarce in March, April, May, June, August and December (Figures 1 and 2). Jute was the crop with the lowest Collembolan population, while paddy rice and wheat had more animals, as was indicated by the position of corresponding additional variables in the plane of axes 1 and 2 (Figure 1) and by monthly data (Figure 2). The population of Collembola was highest during February followed by October. Collembola were thus at a maximum during paddy rice cultivation when soil temperature was low and the moisture content of the soil was high (Figure 3). A Spearman rank correlation coefficient showed a significant negative correlation with temperature (r_s=-0.41) and a significant but weaker positive correlation with moisture (r_s=0.30). No significant correlation was found with relative humidity (r_s=0.12). Waves of increases and decreases of Collembolan populations followed the development of cultivated vegetation (Figure 2). Wheat cultivation started in December, with a low population which increased to a maximum during February, then collapsed in March (differences between February and March total densities significant according to Kolmogorov-Smirnov test). Jute also started with a low population in April and May, which increased until July, after that a collapse (differences in total densities not significant) was observed in August at the start of paddy cultivation. Under paddy rice the Collembolan population increased until October, then decreased in November (not significant) and more abruptly in December(significant).

In relation to the application of fertilizer and organic manure, it was observed that treatment T6, receiving organic manure (farmyard manure) during jute cultivation in addition to moderate doses of NPK fertilizer, encouraged the highest development of Collembolan population (Figure 4). The treatment T3, with moderate doses of NPK, could be considered as a control for T6 and exhibited a lower population, although a t-test exhibited a weak level of significance (P=0.06). The next highest population of Collembola was observed in the control (T8) plot. T1, receiving the lowest dose of NPK fertilizer, supported the same total population as T2 which received the highest dose of fertilizer. The lowest Collembolan population was observed in the treatment T9 (fallow) followed by T5 which received only N fertilizer and was devoid of P and

K.No effect of herbicide treatment was observed, if we compare T7 (with herbicide) with the control T8 (Figure 4).

4. DISCUSSION:

Low numbers of Collembola (Table 3) in this long term cultivated and fertilized field (15 years) agrees with the observations that, compared to cultivated land, uncultivated and undisturbed land had more Collembolan fauna [12, 7, 23]. Arable land has no vegetation during a period whereas uncultivated land ensures a continuous food supply through litter deposition and root exudates [5]. Conventional tillage, such as deep plowing and heavy machinery use, has an adverse effect on Collembola [20, 21].

The maximum population of Collembola was in February (Spring) followed by October (Autumn), as has been already observed in other studies done in India [7, 31]. The decrease in the density of soil animals after cultivation resulted from a drop in organic matter content following a period of intense biological activity [15]. Such reduction of soil animal populations has been observed immediately following cultivation [34]. Agricultural operations like plooughing and harrowing generally decrease the abundance of soil animals [15, 11, 2]. Crop rotation causes a decline in the number of soil animals compared with continuous cropping [12]. The present investigation was carried out under a high cropping intensity round the year and the soil was prepared three times in a year before planting the crops with power tillage implements. Conventional tillage utilizing a moldboard plow significantly reduces Collembola immediately following its use [24]. In the present experiment it was observed that after harvesting of one crop the next crop started with lower Collembolan fauna and then increased gradually (Figure 2).

A higher organic matter content is usually beneficial for most animal groups [2]. The same beneficial effect of organic matter was observed here under the influence of farmyard manure. The plot which received farmyard manure showed a higher population than the control plot as already observed by Curry and Purvis [9]. The organic matter is crucial for the stability of the soil structure and it serves as an energy source for microorganisms which mesofauna consume [12]. The beneficial effects of manure recorded here could be thought at first sight to be due to the fact that manure itself contains high numbers of soil microarthropods [8], but it should be noticed that some species abundant in manure such as *Xenylla welchi* were never found in our collections.

In the present experiment the abundance of Collembola did not seem to vary to a great extent according to the dose of NPK fertilizer applied to the soil. This result contradicts the observation that any sort of fertilizer tend to increase the number of soil Collembola [14]. The plot T5 receiving N-fertilizer only showed a lower Collembolan population. A similar depressive effect has been reported on earthworms by Deleporte and Tillier [10]. Urea was the source of nitrogen in the present experiment. The long-term use of urea was found to decrease soil pH, through increase in nitrate ions [4]. The acidity of soil exerts a profound influence on many Collembolan species [3, 19, 17, 18]. Nitrogen fertilizer alone was also thought to create a too high osmotic pressure in the soil solution which has a negative effect on the abundance of soil animals [2]. Herbicide (atrazine) exerted no adverse effect on Collembola as reported in other studies [26, 29].

Nevertheless we observed that, in the conditions of West Bengal agriculture (strong climate variations and multiple cropping within a year), the influence of crop changes and seasonal variations in temperature was much more pronounced than that of fertilizer and herbicide treatments.

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Legends of figures

Figure 1. Correspondence analysis. Projection of Collembolan species (three-letter codes) as active variables and additional variables in the plane of axes 1 and 2. Higher values of variables were indicated by bold type, lower values by italic type

Figure 2. Abundance of Collembola in relation to months and crops.

Figure 3. Changes in temperature and moisture in different months.

Figure 4. Abundance of Collembola in relation to different treatments.

Table 1. Treatments showing the different doses of fertilizers, farmyard manure (FYM), chemical weeding (CW) and hand weeding (HW) during three crops

	JUTE	PADDY	WHEAT
T1	N30P15K30+HW	N60P30K30+Hoeing	N60P30K30+Hoeing
T2	N90P45K90+HW	N180P90K90+Hoeing	N180P90K90+Hoeing
T3	N60P30K60+HW	N120P60K60+HW+Hoeing	N120P60K60+HW+Hoeing
T4	N60P30K0+HW	N120P60K0+Hoeing	N120P60K0+Hoeing
T5	N60P0K0+HW	N120P0K0+Hoeing	N120P0K0+Hoeing
T6	N60P30K60+FYM10ton/ha+HW	N120P60K60+Hoeing	N120P60K60+Hoeing
T7	N60P30K60+CW	N120P60K60+CW	N120P60K60+CW
T8	N0P0K0(control)+HW	N0P0K0(control)+Hoeing	N0P0K0(control)+Hoeing
T9	Fallow	Fallow	Fallow

Table 2. Collembolan species/genera found in the experiment, with their mean densities per unit surface

Code	Species name	Densities.m^{-2}
IBA	*Isotomurus balteatus*	86.73
CTH	*Cryptopygus thermophilus*	53.46
LSP	*Lepidocyrtus sp.*	22.37
CJA	*Cyphoderus javanus*	24.27
SIN	*Seira indica*	3.00
SAP	*Sminthurides appendiculatus*	1.09
BSP	*Brachystomella sp.*	6.00
SSP	*Sminthurus sp.*	4.91
SCO	*Sphaeridia cornuta*	0.55
ISP	*Isotomodes sp.*	1.09
ASP	*Acherontiella sp.*	0.55

Table 3. Correspondence analysis. Loadings of the variables according to the first two factorial axes. For doubled variables codes for higher values are in bold type while lower values are in italic type

Variables	Axis 1	Axis 2
IBA	-0.041	-0.011
CTH	-0.028	0.032
LSP	-0.039	-0.001
CJA	-0.007	-0.025
SIN	0.013	0.002
SAP	0.023	-0.026
BSP	-0.026	-0.024
SSP	0.017	0.028
SCO	0.023	-0.026
ISP	0.019	0.034
ASP	-0.026	0.015
IBA	0.041	0.011
CTH	0.028	-0.032
LSP	0.039	0.001
CJA	0.007	0.025
SIN	-0.013	-0.002
SAP	-0.023	0.026
BSP	0.026	0.024
SSP	-0.017	-0.028
SCO	-0.023	0.026
ISP	-0.019	-0.034
ASP	0.026	-0.015
Abundance	-0.044	-0.002
Relative humidity	0.008	-0.014
Temperature	0.030	0.011
Moisture	-0.006	-0.005
Abundance	0.044	0.002
Relative humidity	-0.008	0.014
Temperature	-0.030	-0.011
Moisture	0.006	0.005
Wheat	-0.009	-0.011
Jute	0.023	0.028
Paddy	-0.009	-0.003
January	-0.007	-0.006
February	-0.044	-0.020
March	0.017	0.000
April	0.028	0.045
May	0.017	0.028
June	0.019	-0.003
July	-0.010	-0.029
August	0.040	-0.041
September	-0.003	0.002
October	-0.046	0.023
November	-0.019	0.006
December	0.007	-0.005

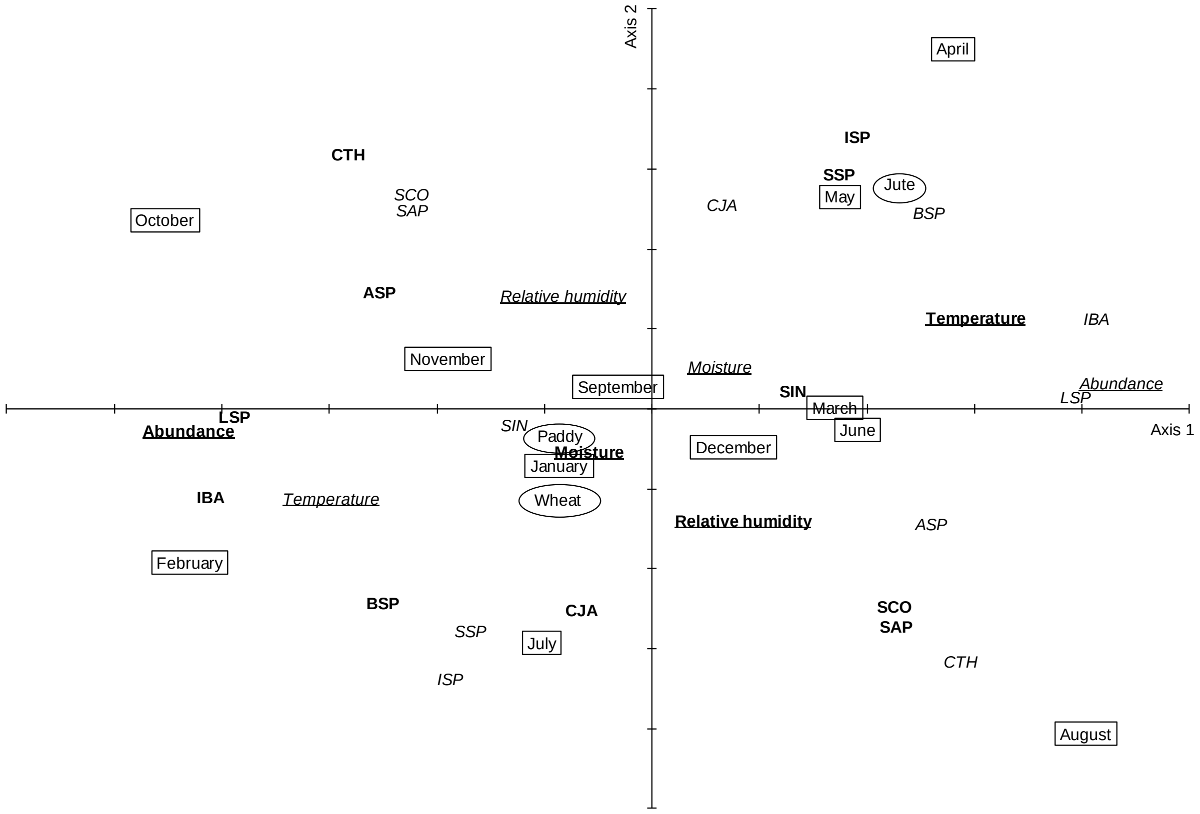
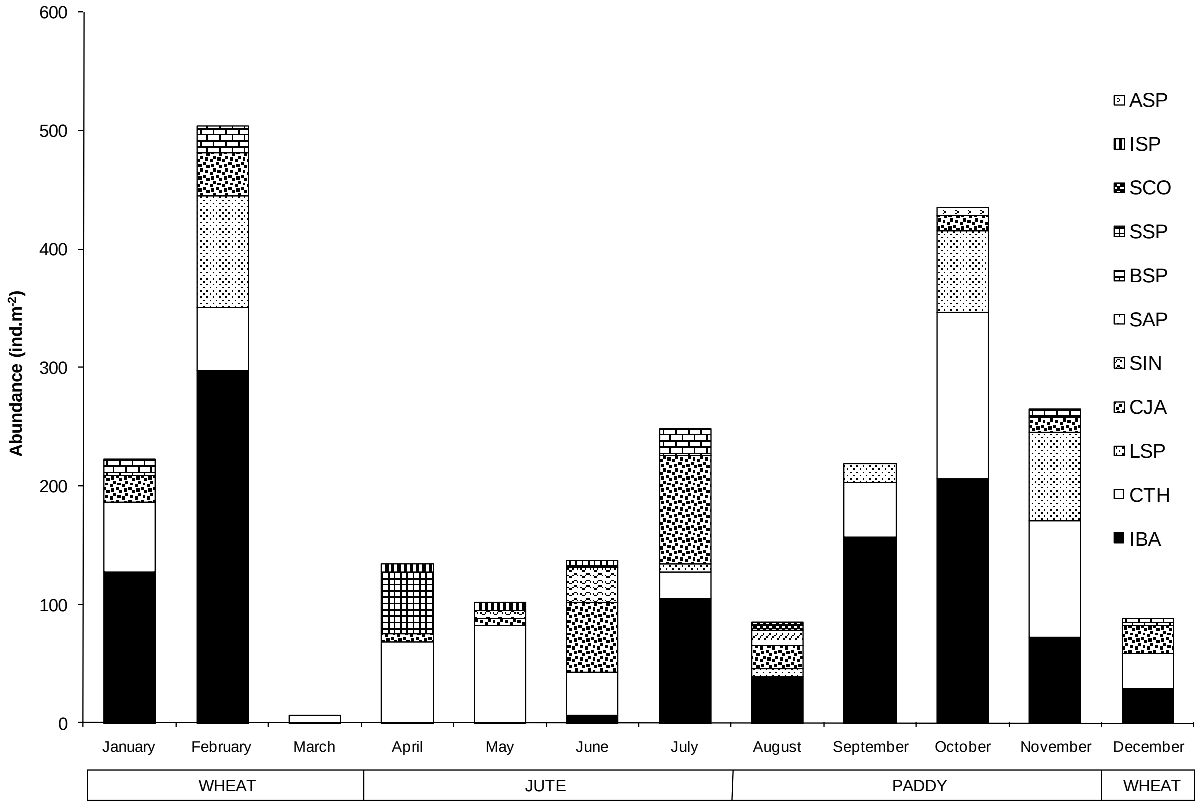

Axis 2
April
ISP
CTH
SSP
Jute
May
SCO
SAP
CJA
BSP
October
ASP
Relative humidity
Temperature
IBA
November
Moisture
September
SIN
Abundance
LSP
March
LSP
Abundance
SIN
Paddy
June
Axis 1
Moisture
December
January
IBA
Temperature
Wheat
Relative humidity
ASP
February
BSP
CJA
SCO
SAP
SSP
July
CTH
ISP
August

Fig. 1



600
500
400
300
200
100
0
Abundance (ind.m⁻²)
ASP
ISP
SCO
SSP
BSP
SAP
SIN
CJA
LSP
CTH
IBA
January
February
March
April
May
June
July
August
September
October
November
December
WHEAT
JUTE
PADDY
WHEAT

Fig. 2

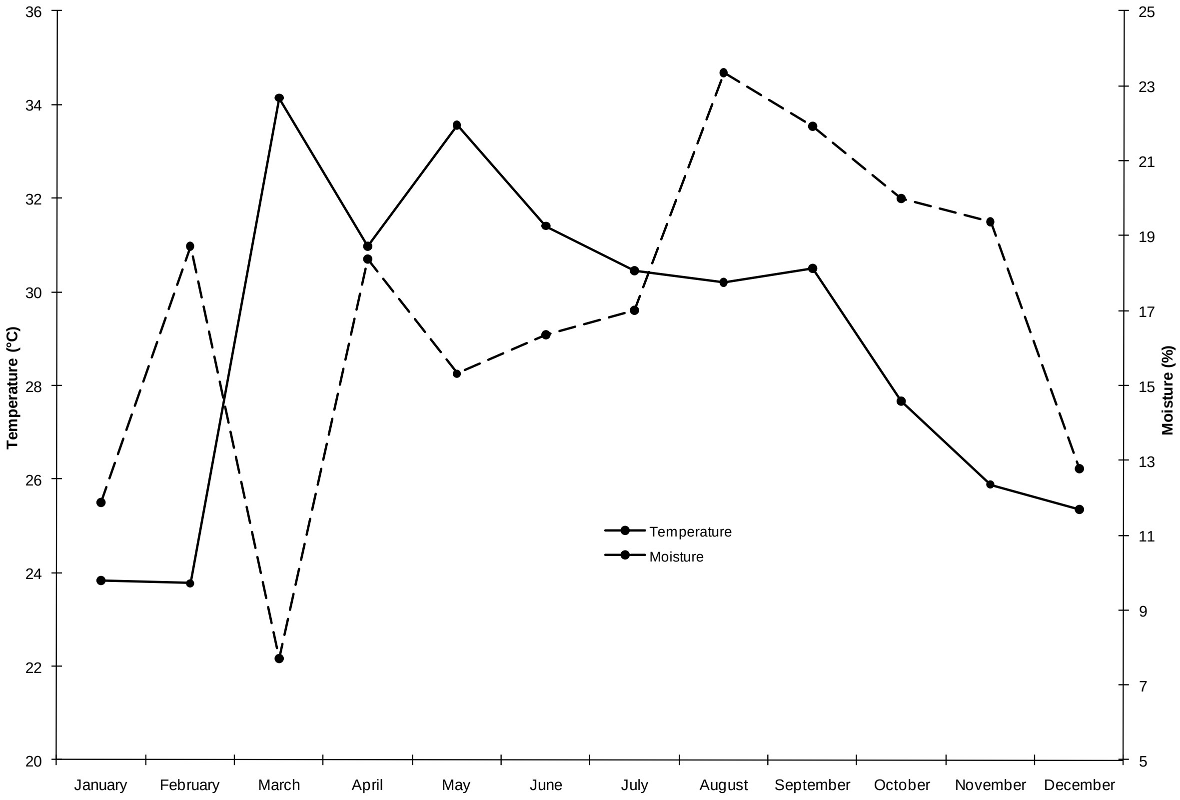
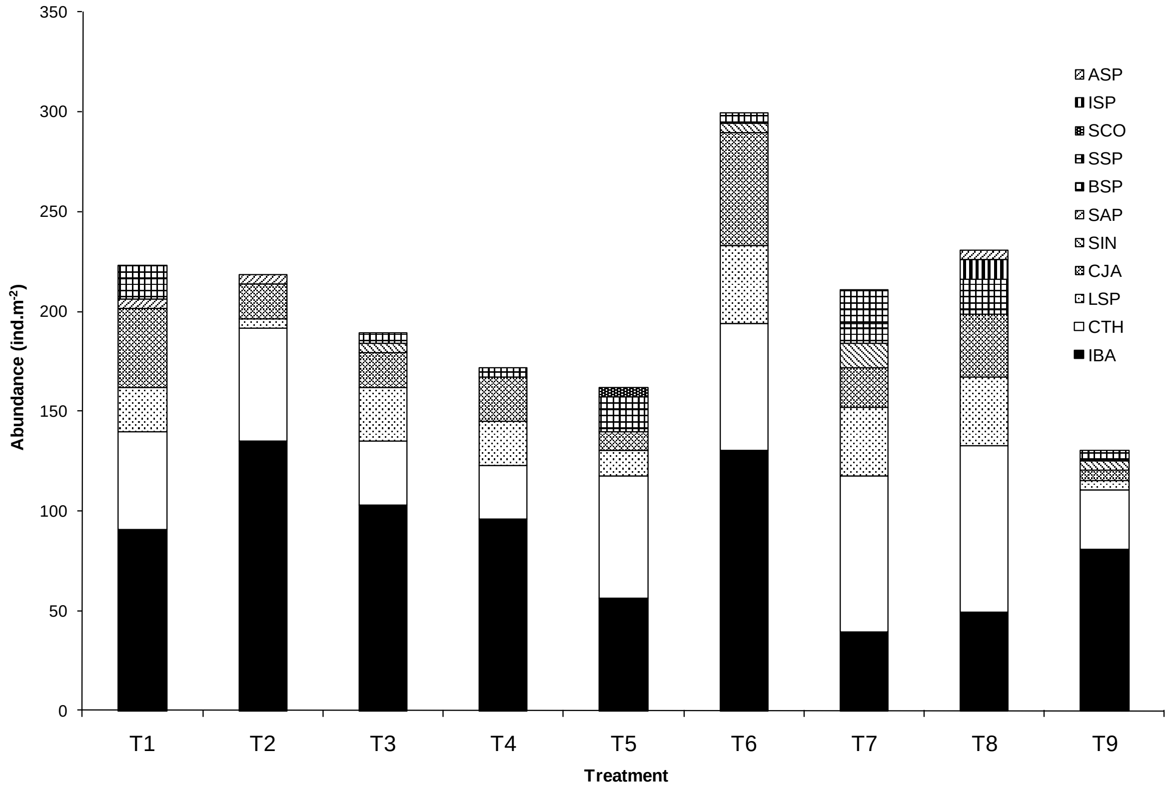

Temperature (°C)
Moisture (%)
36
34
32
30
28
26
24
22
20
25
23
21
19
17
15
13
11
9
7
5
Temperature
Moisture
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 3



350
300
250
200
150
100
50
0
Abundance (ind.m⁻²)
T1
T2
T3
T4
T5
T6
T7
T8
T9
Treatment
ASP
ISP
SCO
SSP
BSP
SAP
SIN
CJA
LSP
CTH
IBA

Fig. 4