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ASSESSMENT OF HANDICAPS OWING TO HIGH INPUT (HIP) FARMING ON THE SOIL MACRO-INVERTEBRATES DIVERSITY IN SUGARCANE FIELD

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The modern and intensified agriculture can cause significant reduction in diversity of soil macro-invertebrates resulting in negative impacts on soil organisms, aeration, and decomposition of organic matter and functional roles of component populations. Keeping in view these facts, the present study was conducted to evaluate the effects of high input farming on soil macro-invertebrates diversity in comparison to low input farming system. Soil samples were taken by core sampler from three micro-habitats from a randomly selected field (open edge, sub-shadow and within field) for two consecutive years, for the session 2008 & 2009. Soil samples were sorted out in the laboratory for the collection of macro-invertebrates by direct hand picking, preserved in the 70% ethanol solution with few drops of glycerin and identified up to species level. A total of 2138 specimens belonging to various order and families were recorded from both low input and high input. Out of 2138 specimens, 1400 were recorded from low input belonging to 79 species as well just 738 specimens belonging to 61 species from high input crop fields of sugarcane. The abundance of macro-invertebrates in the low input fields was significantly higher ($p<0.001$) than in the high input fields and species diversity was also higher in the low input fields (H^{l} = 3.630), than the high input fields (H^{l} = 2.932). T-test analysis between them was highly significant ($t = 10.24$). Order Pulmonata, Hymenoptera, Oligochaeta and Coleoptera were the most abundant from both the low input and high input fields. The data showed that organically managed low input fields of sugarcane are supporting the diversity of macro-invertebrates, which is essential for appropriate functioning of ecosystem.
Keywords: Soil biota, diversity, organic farming, conventional farming, macro-invertebrates, sugarcane

INTRODUCTION

The soil not only houses a huge proportion of the soil's invertebrate biodiversity, which is essential for the soil health but also provides the physical substrate for most human activities. Although soils have been extensively studied and classified on the basis of physical and chemical characteristics, knowledge of soil invertebrate biodiversity and function is far from complete (Swift, 1997; Wall and Virginia, 2000; Swift *et al.,* 2004, Brussaard *et al*., 2004). This gap in the knowledge is partially due to the limited recognition that soil organisms plays a significant role which are useful to determine the physical and chemical properties and productivity of soils, as well as partially due to the enormous diversity of soil micro and macro invertebrates and the difficulties faced for their identification as well as for the study of their direct linkages to soil function (Brussaard *et al*., 1997; Lavelle and Spain, 2001; Coleman *et al*., 2004).

Recent knowledge reveals that soil micro and macro invertebrates are an integral component of agricultural ecosystems. The presence of a range of soil invertebrates is essential for the maintenance of healthy productive soils. An excessive reduction in soil biodiversity, for example the loss of species with unique functions, may have disastrous effects, leading to the irreparable degradation of soil and the loss of agricultural productive capacity. As a result, more land would be needed to increase the agricultural production to fulfill the demands of growing population (Ruiz and Lavelle, 2008).

The depletion of the beneficial functions carried out by soil macro and micro invertebrates in agricultural ecosystems as a consequence of inappropriate soil biological management is contributing to increased rates of land deterioration, nutrient reduction, and decline in fertility, water scarcity, and reduction in yield. All these factors have a negative impact on the livelihoods of human population who depend directly on agricultural products for their survival (Ruiz and Lavelle, 2008).

Especially the role of soil invertebrates in high input agricultural ecosystem has received little attention because in the high input field's natural and biologically mediated processes like those regulating soil structure, nutrient supply, and pest and disease control have been mainly replaced by human inputs (soil tillage, fertilizer and pesticide applications) that ultimately depend on non-renewable energy sources. In natural ecosystems, the internal regulation of function is largely a result of plant biodiversity that influences the magnitude and temporal distribution of carbon and nutrient flows; however, this form of control is increasingly lost through agricultural intensification (conventional farming) (Swift and Anderson, 1993). Therefore, in recent decade organic farming gaining popularity, characterized by prohibition of majority of synthetic chemicals, so purportedly sustainable farming systems such as organic farming are now seen by many as a potential solution to loss in the soil characteristics as well as loss of functional biodiversity (Hole *et al.,* 2005).

In view of this the present study was planed to determine the deleterious effects of HIP (conventional) farming on the soil macro-invertebrates, which plays a vital role for the fertility as well as other important function of soil in turn increasing the productivity of soil. The objectives of the study were quantitative assessment of decline of soil-macro-invertebrates in sugarcane crops owing to high input (conventional farming) vs low input farming (organic farming) and to determine the intensity of reduction of soil-macro-invertebrates among high input fields over low input along the micro-habitat *viz.* open edge, sub-shadow and inside the field.

MATERIALS AND METHODS

Study area: A preliminary survey was made to select the sugarcane fields under chemically low input “LIP”. The area from Gatti (Name of locality)- was selected, situated in north-east about 24km away from main city in district Faisalabad and chemically high input “HIP” cultivation with intensive farming using pesticides and synthetic fertilizers was selected from Ayub Agriculture Research Institute, Faisalabad. A block of 10 acres was randomly selected from each locality. Low input farming system was taken as control whereas, those of high input farming system was taken as treated.

Soil sampling: For the extraction of invertebrates, soil’s samples were taken from randomly selected three fields each of one acre from each 10 acre block in each month. Three different microhabitats from each acre field were sampled for the extraction of macro-fauna from the soil. These sites are defined as follows:

Open edge: It is an elevated ridge making the boundary of sugarcane field. Samples were taken from any place on this ridge without any shade of shrub/ scrub/ tree plant on it.

Sub-shadow: Samples were taken from the above said boundary ridge under the shade of a shrub/ scrub/ tree plant.

Inside field: Samples were taken from inside positions in the crop field

Procedure: An iron square quadrangle measuring one cubic ft. was used to collect the samples of soil from open edge and under tree in each crop field. Core sampler measuring 7.6 cm diameter was used to collect the samples of soil from third micro habitat *i.e.* inside the crop field. Three core samples were taken diagonally as the triplets of three, one ft deep inside the field (Dangerfield, 1990; Magurran, 1988). Samples of the soil were brought to the laboratory for sorting the various invertebrate. They were sorted through hand sorting and after it through burlese funnel, and preserved in 70% ethanol. Identification of the specimens was done with the help of reference material (Triplehorn and Johnson, 2005; Blanford, 1898.) in the Biodiversity Laboratory, Department of Zoology and Fisheries, University of Agriculture, Faisalabad.

High input/low input: The assessment of low and high input was made on the basis of the following standards approved by the Govt. of Punjab, Pakistan to get 2400-2600 kg ideal yield of sugarcane. Govt. of Punjab recommended the below mentioned doses of fertilizers along with sprays of different pesticides at the hours of need. Cultivation accordingly was high input and cultivation other than this was low input farming (Govt. of Punjab, 2008). Sampling was done for two consecutive sessions from January to June for six months (each month for new field from 10 acre block) for the session 2007/08-2008/09. Ratios of different fertilizers used for standard cultivation as described by Govt. of Punjab (2008) are: nitrogen (70 kg/acre), phosphorus (50 kg/acre), potassium (70-80 kg/acre), calcium (7 kg/acre), sulfur (12 kg/acre), magnesium (12 kg/acre) and organic fertilizers (2400-3200 kg/acre).

Statistical Analysis: Correspondence analysis (CA) is a weighted-average technique that reciprocally double-transforms community data (by species and SUs) and then employs Correspondence analysis to produce “corresponding” species and SU ordinations by using the programme CA.BAS and Minitab 13 (Ludwig and James, 1988) as well as calculate the diversity according to Shahnon’s Diversity Index, 1948 (Magurran, 1988; Ludwig and James, 1988) through GW-BASIC Microsoft (www.daniweb.com). All statistical tests were conducted at the level of significance α=5% using *t* distribution (Microsoft Excel). The richness, diversity and evenness indices were computed by using the Programme SPDIVERS.BAS.

RESULTS AND DISCUSSION

A total of 2138 specimens of macro-invertebrates were captured out of which 1400 from the low input farming system representing 10 orders, 32 families, and 79 species as well as 738 specimens from the high input farming system representing again 10 orders 32 families and 61 species. The dominant orders were Coleoptera, Hymenoptera and Pulmonata (Table 1). The data shows that LIP farms were highly abundant as well as species rich. Three species were found highly dominant in the low input and restricted only to this habitat viz *Punctum spp* (127), *Cryptaustenia spp.* (80) and *Caecilloides spp.* (40). No species was found which is dominant as well as restricted to HIP fields of sugarcane while a number of species were collected which were almost equally abundant in both LIP and HIP farming systems like *Trachelipus rathkei* (441), *Formica spp.* (109), *Hawaiia minuscule* (102), *Solenopsis invicta* (100), *Pheretima posthuma* (88), *Forficula auricularia* (66), and *Planorbis planorbis* (49) were commonly occurring on both the farming system showing that they are resistant to synthetic chemicals which are used to eliminate the pests from the HIP farms. According to Matson *et al*. (1997) pesticide and insecticides resistance has become a ubiquitous problem as well as stated that soil fauna are generally dominated by a single or small number of species, highly adapted to the changed environment.

Table 1. Population Dynamics of macro-fauna in the microhabitat of LIP and HIP farming

Order	Family	Species	LOE	LUT	LIF	Total	HOE	HUT	HIF	Total	GT
Haplotaxida	Megascolecidae	*Pheretima posthuma*	+	+	+	+	+	+	+	+	+
		Pheretima morrisi	+	+	+	+	+	+	-	+	+
		Pheretima hawayana	+	+	+	+	+	+	-	+	+
		Pheretima houlleti	+	-	+	+	+	-	+	+	+
		Pheretima elongata	+	+	+	+	+	+	+	+	+
		Pheretima suctoria	+	+	-	+	+	+	+	+	+
Orthoptera	Gryllidae	*Nemobius fasciatus*	+	-	-	+	+	+	-	+	+
	Gryllotalpidae	*Gryllotalpa orientallis*	+	-	+	+	+	+	+	+	+
Dermaptera	Forficulidae	*Forficula auricularia*	+	+	+	+	+	+	+	+	+
		*Forfi. spp.**	+	+	+	+	+	-	+	+	+
Hemiptera	Cydnidae	*Pangaeus bilineatus*	+	+	+	+	-	-	+	+	+
		Tritomegas sexmaculatus	-	+	+	+	+	+	+	+	+
		*Cydn . spp.**	+	-	-	+	+	+	+	+	+
	Pentatomidae	*Thynata custator*	+	-	+	+	+	+	+	+	+
		*Penta. spp.**	+	-	-	+	-	-	+	+	+
Coleoptera	Carabidae	*Scaphinotus angulatus*	+	+	-	+	-	-	-	-	+
		Oryctes rhinoceros	-	-	-	-	+	-	-	+	+
		Carabus auratus	-	-	-	-	+	-	-	+	+
	Staphylinidae	*Paedurus littoralis*	-	-	-	-	-	-	+	+	+
	Coccinellidae	*Adalia decempunctata*	+	+	-	+	-	-	-	-	+
	Tenebrionidae	*Gonocephalum stocklieni*	+	+	-	+	+	-	-	+	+
		Gonocephalum vagum	+	-	-	+	+	-	+	+	+
		Gonocephalum depressum	-	-	-	-	+	-	+	+	+
		Gonocephalum elderi	-	-	-	-	+	-	-	+	+
		Gonocephalum misellum	-	-	-	-	+	-	-	+	+
		Gonocephalum terminale	+	-	-	+	-	-	-	-	+
		Eleodes hirtipennis	-	+	-	+	+	+	-	+	+
		Balps muronota	-	-	-	-	+	-	-	+	+
		Heleus waitei	+	-	+	+	-	-	-	-	+
		Blastinus spp.	+	-	+	+	-	-	-	-	+
		Tribolium confusum	-	-	+	+	+	-	-	+	+
		Platydema subcostatum	+	+	-	+	+	+	-	+	+
		Promethis nigra	+	-	-	+	-	-	-	-	+
	Scarabaeidae	*Pentodon bispinosus*	+	-	-	+	+	-	-	+	+
		Pentodon idiota	+	+	+	+	+	+	+	+	+
		Pentodon punctatus	-	-	-	-	+	-	-	+	+
		Gymnopleurus miliaris	-	-	-	-	+	-	-	+	+
	Chrysomelidae	*Hispellinus moestus*	-	-	-	-	+	-	-	+	+
		Chrysochus auratus	-	-	+	+	-	-	-	-	+
	Curculionidae	*Hypolixus truncatulatus*	+	+	-	+	+	-	-	+	+
		Esamus princeps	-	+	-	+	-	-	-	-	+

		Cleonus jaunus	-	-	-	-	+	-	-	+	+
		Liophoeus tessulatus	-	+	-	+	-	-	-	-	+
		Cleonus riger	-	-	-	-	+	-	-	+	+
Hymenoptera	Formicidae	*Formica sanguinea*	+	-	+	+	+	+	+	+	+
		Formica exsectoides	+	+	+	+	+	+	+	+	+
		Formica rufa	+	+	+	+	-	-	-	-	+
		Formica spp.	+	+	+	+	+	+	+	+	+
		Solenopsis invicta	+	+	+	+	+	+	+	+	+
		Manuel antonio	+	+	+	+	+	+	+	+	+
		Camponotus pensylvanicus	+	+	+	+	+	+	+	+	+
		Camponotus herculeanus	+	+	+	+	-	-	-	-	+
		Camponotous spp.	+	+	+	+	+	+	+	+	+
		Dolichoderus taschenbergi	+	+	+	+	+	+	+	+	+
		*Formi. spp. 1**	+	-	+	+	+	+	+	+	+
		*Formi. spp. 2**	-	+	-	+	+	-	+	+	+
Araneae	Anyphaenidae	*Hibana spp.*	-	+	-	+	-	-	-	-	+
	Lycosidae	*Hippasa madhuae*	+	+	+	+	+	+	+	+	+
		Hippasa partita	+	+	+	+	+	+	+	+	+
	Salticidae	*Phintella piatensis*	-	+	+	+	-	-	-	-	+
		Spartaeus uplandicus	-	-	-	-	+	+	-	+	+
	Oxyopidae	*Oxyopes javanus)*	+	-	-	+	-	-	-	-	+
	Clubionidae	*Cheiracanthium tigbauanensis*	-	+	-	+	-	-	-	-	+
	Tetragnathidae	*Dyschiriognatha hawigtenera*	-	+	-	+	-	-	-	-	+
Isopoda	Trachelipodidae	*Trachelipus rathkei*	+	+	+	+	+	+	+	+	+
	Armadillidae	*Armadillium nastum*	-	+	+	+	-	-	-	-	+
		*Aramd. spp.1**	+	+	-	+	-	+	-	+	+
		*Aramd. spp.2**	+	+	-	+	+	+	-	+	+
		*Aramd. spp.3**	+	-	-	+	+	+	-	+	+
Geophilomorpha	Schendylidae	*Schendyla nemorensis*	+	+	-	+	-	-	-	-	+
Pulmonata	Lymnaeidae	*Lymnaea stagnalis*	-	-	-	-	-	+	-	+	+
	Planorbidae	*Planorbis planorbis*	+	+	+	+	+	+	-	+	+
		Planorbis convexiusculus	+	-	-	+	-	-	-	-	+
		Planorbis merguiensis	+	+	+	+	+	+	+	+	+
		Planorbis nanus	+	+	+	+	+	-	+	+	+
		Biomphalaria havanensis	+	-	-	+	+	-	-	+	+
		Hawaiia minuscula	+	+	+	+	+	+	+	+	+
		*Plano. spp.**	+	+	-	+	-	+	-	+	+
	Ferrussaciidae	*Caecilloides spp.*	+	+	+	+	-	-	-	-	+
		Glessula spp.	+	+	+	+	-	-	-	-	+
	Pupillidae	*Pupoides spp*	+	+	+	+	-	-	-	-	+
	Endontidae	*Punctum spp.*	+	+	+	+	-	-	-	-	+
		*Endon. spp. 1**	+	-	-	+	-	-	-	-	+
		*Endon spp. 2**	-	-	+	+	-	-	-	-	+
		*Endon spp. 3**	-	+	-	+	-	-	-	-	+
	Achatinidae	*Zootecus spp.*	+	-	-	+	-	-	-	-	+
		Curvella spp.	+	+	+	+	-	-	-	-	+
		Achatina fulica	-	-	-	-	+	-	-	+	+
	Subulinidae	*Subulina octona*	+	-	+	+	+	-	-	+	+
		Opeas hannese	-	+	-	+	-	-	-	-	+
	Succineidae	*Succinea spp.*	-	+	-	+	-	-	-	-	+
	Zontidae	*Vitrina spp.*	+	+	-	+	-	-	-	-	+
		Cryptaustenia spp.	+	+	-	+	-	-	-	-	+
		Bensonia spp	+	+	-	+	-	-	-	-	+

Diversity, species richness and evenness (Table 2) were calculated by Shannon diversity index (1948) and the largest value of $H^{/}$ and evenness when every individual belongs to different species, is the relative measure of diversity (Kikkawa, 1996). The comparison of LIP& HIP fields have showed significantly differences ($p<0.001$). But, the comparison of LIP and HIP microhabitat viz., open edge, under tree and inside the fields have also showed significant differences ($p<0.001$). In previous field studies (Siddiqui *et al.,* 2005; Rana *et al*., 2006; Kapagianni *et al.,* 2010) have reported negative association between low (organic) and high input (conventional) farming with sever deterioration in high input system. But, in the present

Table 2. Shannon diversity indices among low input and high input in sugarcane fields

Crop	Locality	Open Edge					Under Tree					t- test	d*f*	*p*- value
		N_0	H'	N1	N2	E5	N_0	H'	N1	N2	E5			
Sugarcane 1, 2		Open Edge					Under Tree							
	LIP	63	3.566	35.38	24.03	0.670	55	3.256	25.94	16.22	0.610	4.958	>120	0.000***
		Open Edge					Inside Field							
	LIP	63	3.566	35.38	24.03	0.670	43	3.145	23.21	13.94	0.583	4.972	>120	0.000***
		Under Tree					Inside Field							
	LIP	55	3.256	25.94	16.22	0.610	43	3.145	23.21	13.94	0.583	1.275	>120	0.203ns
		Open Edge					Under Tree							
	HIP	55	3.058	21.27	8.88	0.38	35	2.469	11.80	5.23	0.39	4.723	>120	0.000***
		Open Edge					Inside Field							
	HIP	55	3.058	21.27	8.88	0.38	32	2.488	12.03	5.35	0.39	3.996	>120	0.000***
		Under Tree					Inside Field							
	HIP	35	2.469	11.80	5.23	0.39	32	2.488	12.03	5.35	0.39	-0.126	>120	0.899ns
		LIP					**HIP**							
	Open Edge	63	3.566	35.38	24.03	0.670	55	3.058	21.27	8.88	0.38	5.553	>120	0.000***
	Under Tree	55	3.256	25.94	16.22	0.610	35	2.469	11.80	5.23	0.39	8.310	>120	0.000***
	Inside Field	43	3.145	23.21	13.94	0.582	32	2.488	12.03	5.35	0.39	5.105	>120	0.000***
	Total	79	3.630	37.71	22.84	0.59	61	2.932	18.77	6.67	0.31	10.24	111	0.000***

**Shannon diversity indices of sub-habitat of low input and high input of sugarcane fields. P-value for the factor are given (ns: p>0.05, *: p<0.05, * *: p<0.01, * * *: p<0.001). N_0 = S where S is the total number of species in the sample, H' is the Shannon's index of diversity, and where E is the index of evenness, and N1 and N2 are the number of abundant very abundant species respectively in the sample.*

study main focus was on the below ground-soil fauna, to investigate the impacts of low input and high input among three micro-habitats.

The correspondence analysis was performed on the 1% reduced data to determine the ordination of dominant species. Table 3 and 4 depicted the ordination of three microhabitats of (LIP) and (HIP) on the species of orders Oligochaeta, Orthoptera, Dermaptera, Hemiptera, Hymenoptera and Araneae, Isopoda and Pulmonata respectively.

The axis one, two and three of the analysis extracted 43.44%, 23.56% and 17.18% the proportion, respectively (Table 3), while the species *Solenopsis invicta* and *Camponotous spp.* were the major contributors to the first axis which contribute 19.2% (r = 0.821) and 16.6% (r = 0.781) as well as the species *Gryllotalpa orientallis, Pangaeus bilineatus* and *Tritomegas sexmaculatus* contribute 34.7% (r=0.477), 16.1% (r=0.521) and 18.5% (r=0.454) respectively to the second axis (Fig.1). The axis one, two and three of the analysis extracted 61.57%, 33.26% and 04.13% the proportion respectively (Table 4), the species *Trachelipus rathkei* and *Punctum spp.* contribute 52.0% (r=0.989) and 15.3% (r=0.651) respectively to the first axis. While the major contributor of the second axis were *Planorbis convexiusculus* and *Hawaiia minuscula* contributed 21.0% (r=0.653) and 20.2% (r=0.656) (Fig.2).

CONCLUSION

It has been concluded from the whole investigation that the introduction of intensive agriculture farming to fill the gap between supply and demands for massively boosting human population, has many paramount handicaps and it can cause unmanageable losses to soil macro-faunal diversity. Therefore, organic farming is recommended for sustainable future that is self regulatory, self perpetuating and a better option to avoid from these handicaps.

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Table 3. The correspondence analysis (CA) of the relative abundance in total counts of Oligochaeta, Orthoptera, Dermaptera, Hemiptera and Hymenoptera from July to December in two consecutive years on the three microhabitat of each low and high input sugarcane fields.

Axis	Inertia	Proportion	Cumulative
1	0.1905	0.4344	0.4344
2	0.1033	0.2356	0.6700
3	0.0753	0.1718	0.8418
4	0.0516	0.1177	0.9595
5	0.0178	0.0405	1.0000
Total	0.4385		

Table 4. The correspondence analysis (CA) of the relative abundance in total counts of Araneae, Isopoda and Pulmonata from July to December in two consecutive years on the three microhabitat of each low and high input sugarcane fields

Axis	Inertia	Proportion	Cumulative
1	0.4358	0.6157	0.6157
2	0.2355	0.3326	0.9483
3	0.0292	0.0413	0.9896
4	0.0072	0.0102	0.9998
5	0.0002	0.0002	1.0000
Total	0.7079		

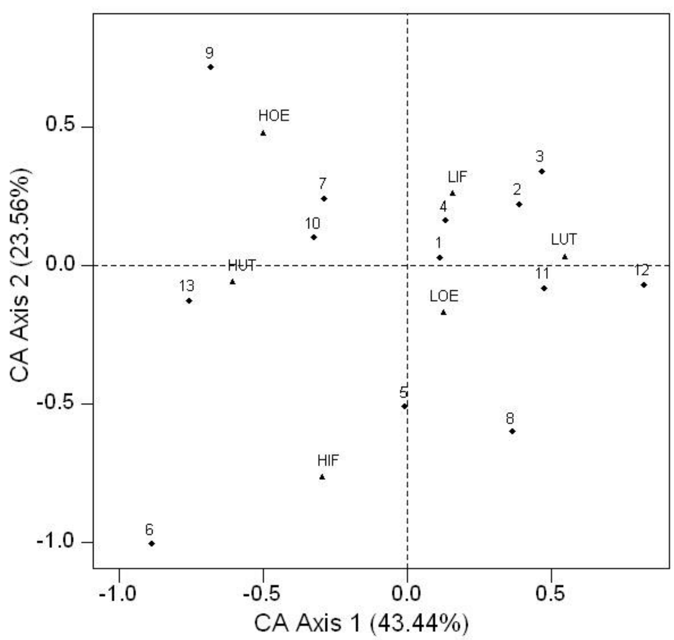

Figure 1. Ordination on axis 1 and 2 of six microhabitat (three microhabitat from each LIP and HIP) and 13 species recorded belonging to Oligochaeta, Orthoptera, Dermaptera, Hemiptera and Hymenoptera from July to December in two consecutive years on the three microhabitat of each low and high input sugarcane fields) in high and low input sugarcane fields.

Species identity: 1.*Pheretima posthuma,* 2. *Pheretima morrisi,* 3. *Pheretima hawayana,* 4. *Pheretima elongate,* 5. *Pheretima suctoria,* 6. *Gryllotalpa orientallis,* 7. *Forficula auricularia,* 8. *Pangaeus bilineatus.* 9. *Tritomegas sexmaculatus,* 10. *Formica spp.,* 11. *Solenopsis invicta,* 12. *Camponotus herculeanus,* 13. *Camponotous spp.*

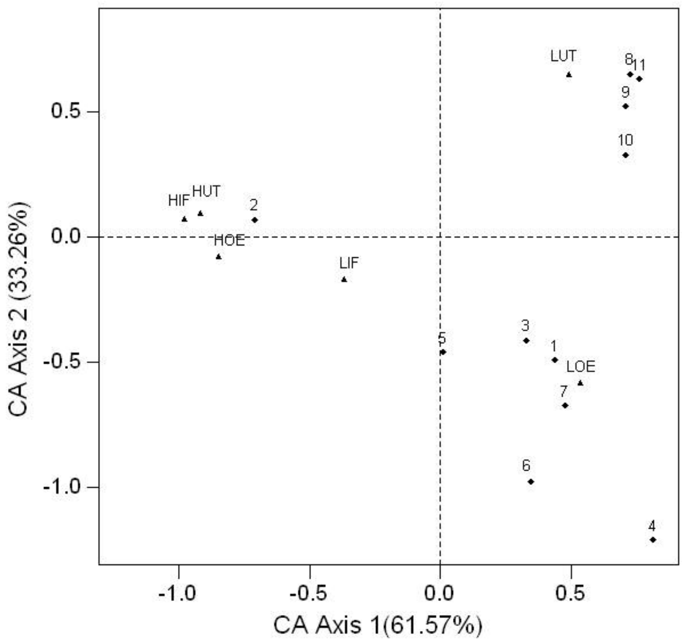

Figure 2. Ordination on axis 1 and 2 of six microhabitat (three microhabitat from each LIP and HIP) and 11 species recorded belonging to Araneae, Isopoda and Pulmonata from July to December in two consecutive years on the three microhabitat of each low and high input sugarcane fields in high and low input sugarcane fields

Species identity: 1. *Hippasa madhuae,* 2. *Trachelipus rathkei,* 3. *Planorbis planorbis,* 4. *Planorbis convexiusculus,* 5. *Planorbis merguiensis,* 6. *Biomphalaria havanensis,* 7. *Hawaiia minuscule,* 8. *Caecilloides spp.* 9. *Punctum spp.,* 10. *Curvella spp.,* 11. *Cryptaustenia spp.*

* LOE = Low input open edge, LUT = Low input under tree, LIF = Low input inside field.
HOE = High input open edge, HUT = High input under tree, HIF = High input inside field

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