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ROLE OF SOIL SEED BANK IN PATTERN OF SPECIES DISTRIBUTION ALONG THE ARIDITY GRADIENT BY USING THE TECHNIQUE OF MULTIVARIATE ANALYSIS

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ABSTRACT

Floristic composition and diversity of weed infestation depend at least in part on the soil seed bank in agro-ecosystems. The results in this investigation of soil seed bank density m^{-2}, a total 1269 seedlings from 34 species emerged from the 180 soil samples cores of varying depths ranges from 0-30cm. The application of the classification to ordination suggested that up ground weed vegetation depends under the preservation of soil seed bank and some extent to crop specific. This study provides a protocol that both classification and ordination are able to delimit the seed bank density m^{-2} of weed communities according to their habitats. Such analysis should improve the way of complex data analysis and distribution patterns are interpreted. The distribution pattern soil seed bank of the species along the DCA axes 1 and 2 showed a very complex pattern and is hardly interpreted. However, on the first axis, species communities in rain-fed fields, such as *Alhagi maurorum, Suaeda fruticosa, Chrozophora tinctoria* and *Rhazya stricta* are clustered at lower score end of DCA axis-1. High score end is occupied by the species occur in canal-fed fields, these canals originated from rivers Sind and Chenab.

Keywords: soil core samples, seed bank, plant communities, diversity of species, cluster analysis, DCA.

INTRODUCTION

Seed banks are important in the dynamics of many plant communities (Leck *et al.*, 1989); including those of Mediterranean type ecosystems (Ferrandis *et al.*, 1996, 1999; Trabaud *et al.*, 1997; Ne'eman and Izhaki, 1998), as they provide an immediate source of propagules for recruitment after disturbance. Soil seed bank are reserves of viable seeds present on the surface and in the soil. The seed bank consists of new seeds recently shed by a weed plant or older seed that have persisted in the soil for several years. The seed bank is an indicator of past and present weed populations. There are enormous numbers of variable weed seed in the soil. Although a great number of the buried seeds die with in a few years, seeds of some species can remain viable for decades. It has been estimated that only 1-9% of the viable seeds produced in a given years develop into seedlings, the rest remain viable and will germinate in subsequent years depending on depth of its burial (Swanton and Shrestha, 2000).

The weed seed bank is the main source of weeds in agricultural fields. Most weeds start their life cycle from a single seed in the soil. If these weeds escape control, they grow and produce thousands of seeds, depending on the species. These seeds are returned to the soil seed bank and become the source of future weed populations. Therefore, knowledge of seed return and seed bank dynamics can help in future weed management. A weed field may contain millions of viable seeds. These seeds do not remain for long on the soil surface. Some seeds have special burying mechanisms such as awns and reflexed hairs of *Avena* spp. Seeds of other species may fall down cracks extending several feet into the subsoil. Harrowing and discing incorporate seeds in the soil throughout the cultivation depth, but ploughing buries the recently shed-seeds deeply and brings previously deeply buried seeds back to the surface. Besides, earthworms and large burrowing animals also affect the burying of seeds.

The greenhouse emergence method is a common and efficient approach for quantifying the abundance and diversity of viable seed in the soil (Gross, 1990; Brown 1992; Thompson *et al*., 1997). Yet caution is necessary in drawing inferences about the seed bank from the density and composition of germinants. In particular, greenhouse conditions may not stimulate emergence of species with specific germination requirements (e.g. heating above a threshold temperature; Clark and Wilson, 1994). Physical extraction can provide a more accurate estimate of seed density and diversity, but has notable limitations: it is labor intensive which limits the number of samples that can be processed, seeds must be tested for viability, and a reference collection is required for seed identification. Greenhouse emergence provides a reasonable basis for comparing the abundance of species with readily germinable seeds, which are the reflection of below ground soil seed bank of various species. The weed seed bank is the main source of weeds in agricultural fields. In agriculture, the identification and classification of weeds is technically and economically important because these would be helpful to identify the seed bank in soil of expected competitor weeds.

Many researchers in world reported that the similarity between vegetation and seed bank density m^{-2} decreases with increasing soil core layer depth (Leck and Simpson, 1987; Skoglund, 1990; Zhang and Maun, 1994).

However the study of soil seed bank and their distribution with increasing the soil core depth and arranged into dynamics models of plant communities was first time reported in the study area of Pakistan. The present aim of the study was to investigate the role of soil seed bank density m^{-2} in determining the pattern of species distribution along the aridity gradient of habitats.

MATERIALS AND METHODS

Field Methodology

Seed bank sampling

Seed bank was investigated in the soil of study area. Soil samples for the analysis of the viable seed bank were collected from the different sites. At each site 4-m^2 quadrat had been taken in 5 replicates from the 0-30cm depth of each sampling unit. The samples were taken from 5 places to make joint soil samples of every trail units.

Soil core sample collection

Total 180 soil cores sample were collected at random in the crop field prior to disturbance. In order to analyze the viable seed bank vertical distribution, each soil sample was divided into three fractions: the soil shallow layer (soil surface to 10cm depth), the mid-layer (10-20cm depth) and the deepest layer (20-30cm depth). Analysis of the large number of soil samples needed to determine accurately the density of individual species in the seed bank becomes impractical, when whole seed banks are to be documented. This procedure is followed by (Thompson, 1986). In this study methods were adopted to observe the possible composition of the viable seed bank in the selected area, enabling estimations of the density of seeds per unit volume of soil core/per unit area of soil surface, and of the relative abundance of different species in the seed bank. We followed the recommendation of (Thompson and Grime, 1979; Roberts, 1981; Graham and Hutchings, 1988a, b).

Experimental design

Soil core samples were spread into the 20x30cm plastic trays and trays were laid out into 3 separate blocks according to each depth. Each of these blocks included 60 trays filled with different depths soil core samples. Totally 180 trays were prepared with containing soil sampling units. The location of each tray was randomized and all the trays were wrapped with polythene sheet to avoid the contamination of air borne seed. Trays were watered from above once or twice a day depending upon weather conditions.

Seedling emergence counts

Seedlings were identified, counted and removed at approximately 4- week intervals. At each assessment, any unidentified plants were either left until the next assessment or transferred to pots to grow on for later identification. The soil layer with in each tray was disturbed after each count by scratching with forceps in order to help stimulate further germination (Roberts, 1981), taking care to avoid damage to any retained seedlings.

Data analysis

The differences between the samples of soil containing viable seed bank were detected by using analysis of variance. The pattern of distribution of weed vegetation and the under lying gradient was analyzed by using DCA of MVSP ver.3.2. of computing software. The relationship between ordination scores for the first two DCA axes and environmental variables were examined by using Pearson's correlations.

RESULTS

Viable seed bank

There were significant differences in soil seed bank density m^{-2} among the species regarding their viable seed bank (Table-2 and P<0.000***). Among the weed vegetation *Melilotus albus*, *Medicago denticulata* and *Lathrus aphaca* showed higher value of seed bank density m^{-2} than the remaining species, which did not differ between themselves. Seed bank density was also highly significant with the soil cores depths. The highest values were observed in upper strata (0-10cm), consequently the lowest values of seed bank were observed at the depth 20-30cm (Table-1). All the species showed similar pattern of vertical distribution, a species × depth interaction was not significant in the over all analysis of variance (Table-2).

Normal cluster analysis

Four plant associations were recognized on the basis of the Normal cluster analysis. The lists of stands in each association are represented in the Figures 2, 3. These associations were delineated based on specifying two hierarchical levels. The most noticeable feature indicated by this analysis was the separation of weed communities belonging to rain-fed from the rest. As a result of two hierarchical levels four clusters were created. These clusters (groups) delineated four types of weed vegetation along the aridity gradient.

a) Rain-fed fields (Association A)
b) Irrigated plains of Indus river (Association B)
c) Northern plains of Chenab river (Association C)
d) Southern plains of Chenab river (Association D)

Gradient analysis

Site ordination in the plane of first two axes is presented in Figure-2. The first DCA axis of the normal data set had an Eigenvalue of 0.63. The Eigen value for the second axis was 0.35. The remaining axes showed lower eigenvalue and then lowest were discarded (Table-4). The ordination diagram reflects the distribution of soil seed bank along the regional factors i.e., from reverine alluvial plains to rain-fed areas.

The distribution of the seed bank density over the landscape was not arbitrary but was significantly

influenced by habitats and edaphic factors. The species like *Alhagi maurorum, Suaeda fruticosa, Chrozophora tinctoria* and *Rhazya stricta* having the lowest score along DCA axis 1 was belonged to the rain-fed fields along with minimum soil seed bank density m^{-2} and presented on the right side of the ordination diagram (Figure-4), while the species like *Bracharia ramosa, Portulaca oleracea, Melilotus albus, Rumex dentatus* and *Vicia sativa* etc having the highest scores are distributed over the canal-fed fields along maximum soil seed bank density and presented on the far left side of the ordination diagram (Figure-4). The stands located in the middle of the ordination Figure-4 are distributed over the Indus plain. However there are few stands did not follow this sequence suggesting some species specific factors. Although the distribution of stands along DCA axis 2 is difficult to interpret, it seems the soil salt concentration (EC) played a significant role in this distribution. The stands with highest score along the DCA axis 2 as one move from south to the north of Chenab valley the concentration of salts (EC) is increased (Table-3).

DISCUSSIONS

Distribution pattern of soil seed bank

The soil seed bank density m^{-2} decreased with the increases in soil depth. The pattern of depth distribution of seed bank is similar for all the species (Table-1). This phenomenon might be partly attributed to the fact that it takes some time for seed produced by the weed species to penetrate the lower soil layer and this agrees with findings of (Milberg, 1995; Grandin and Rydin, 1998; Wagner *et al*., 2003).

The results showed that the canal-fed fields (association B-D) generally have higher soil seed bank density m^{-2} than the rain-fed (barani) at association A (Table-5, Figure 1, 2). This spatial pattern of distribution of soil seed bank density might be partly attributed, to that the most severe drought damaged the reproductive tillers and consequently the number of spikelets reduced dramatically. Xeric condition of rain-fed (barani) areas increases the abortive seed number that caused reduction in viable seed bank (Wang *et al*., 2005). This distribution might be a result of accumulation of wind blown seeds in sparsely distributed micro-depressions in the soil surface, with seeds comparatively rare elsewhere. Small surface irregularities create depositional microenvironments in rain-fed fields also appear to be important accumulation sites for seeds of some species (Inglis, 2000). Moreover the low soil seed bank in rain-fed (barani) areas reflect the fact that in xeric habitat various environmental stresses including, periodic aridity, high temperature, and physical removal by erosion caused lowering of seed bank density (DeBerry and Perry, 2000).

This study reveals that spatial patterns of soil seed bank (Table-1) is generally mirrored the distribution pattern of its associated standing vegetation (Figures 1, 2). This reflects the adaptive and several strategies of weed species in risky environment of agro-ecosystem. In such environment plant species ensure their survival by sustaining persistent seed bank. The persistent seed bank ensure the weed species to restore, when the condition are favourable for their establishment.

The results of this study indicate that the Indus valley plains and northern plains of chenab river has a large and diverse soil seed bank density m^{-2} which is composed predominantly of seeds belonging to the monocot and dicot forbs plant groups. Seed bank is comparable to the most abundant species germinating from the soil seed bank in this study included the annual dicots herbaceous species such as *Boerhaavia coccinea, Chenopodium spp, Lathyrus aphaca, Medicago denticulata* and *Melilotus albus*. *Cyperus rotundus* (Cyperaceae) and Members of the Poaceae family like *Avena fatua, Brachiaria ramosa, Lolium temulentum, Phalaris minor* and *Sorgham halepense* belonging to the monocot plant groups are sub-dominating species germinating from the soil seed bank in this investigation. This agrees with the findings of (La Deau and Ellison, 1999; Rossell and Wells, 1999).

Ordination diagram (Figure- 2 and 4) also confirmed the associations which was obtained by Normal cluster analyis. The species belonging to association D were grouped and existed at far left side of the ordination diagram and the species belonging to associatoion A were grouped and existed at far left side of the ordination diagram with low score. These suggested that the habitats as well as edaphic factors like organic matter, Exchangeable sodium and pH played a role in distribution of soil seed bank density.

Table-1. Mean values of seedlings emergence observed during germination experiment from different soil sampling units.

S. No.	Species Name	Seedlings emergence at different depths of soil			Mean
		1 (0-0cm)	**2** (10-0cm)	**3** (20-30cm)	
1	Alhagi maurorum	5.60	1.80	2.00	3.13
2	*Amaranthus viridus*	0.60	0.60	0.40	0.53
3	*Anagallis arvensis*	2.40	1.40	1.80	1.87
4	*Avena fatua*	6.80	0.80	0.60	2.73
5	*Boerhaavia coccinia*	7.80	0.60	0.40	2.93
6	*Brachiaria ramosa*	5.60	0.80	0.20	2.20
7	*Chenopodium album*	9.20	2.40	0.60	4.07
8	*Chenopodium murale*	9.20	3.20	1.00	4.47
9	*Chrozophora tinctoria*	2.60	0.40	0.00	1.00
10	*Convolvulus arvensis*	1.80	1.00	0.20	1.00
11	*Conyza bonariensis*	1.40	0.40	0.00	0.60
12	*Coronopus didymus*	1.00	0.80	0.00	0.60
13	*Cyperus rotundus*	5.20	1.00	0.60	2.27
14	*Euphorbia helioscopia*	4.80	1.20	0.40	2.13
15	*Euphorbia prostrata*	4.80	1.00	0.60	2.13
16	*Fumaria indica*	2.40	1.40	0.20	1.33
17	*Galium aparine*	3.20	1.40	0.60	1.73
18	*Lathyrus aphaca*	12.00	3.20	1.80	5.67
19	*Lolium temulentum*	0.60	0.40	0.20	0.40
20	*Malva neglecta*	2.80	4.40	0.80	2.67
21	*Medicago denticulata*	14.40	2.20	1.00	5.87
22	*Melilotus albus*	8.80	7.80	3.20	6.60
23	*Oxalis corniculata*	2.00	0.60	0.00	0.87
24	*Phalaris minor*	3.20	3.20	0.20	2.20
25	*Portulaca oleracea*	2.60	0.60	0.60	1.27
26	*Rhazya stricta*	1.80	0.60	0.00	0.80
27	*Rumex dentatus*	1.40	0.40	0.20	0.67
28	*Rumex obustifolius*	3.80	2.80	1.00	2.53
29	*Solanum nigrum*	2.40	1.00	0.20	1.20
30	*Sonchus asper*	1.40	0.40	0.20	0.67
31	*Sorgham halepense*	2.00	1.00	0.60	1.20
32	*Suaeda fruticosa*	4.00	0.20	0.00	1.40
33	*Trifolium alaxandrianum*	2.20	1.00	0.40	1.20
34	*Vicia sativa*	4.40	2.40	0.80	2.53
Mean		1.99	0.99	0.59	

Table-2. Two-way analysis of variance between samples collected for seed banks at various depths.

Source	df	MS	F. Value	P. Value
Seed bank of species	33	83.2	3.11	0.000***
Depth	2	591.3	22.12	0.000***
Interaction	68	33.5	1.25	0.099
Error	420	26.7		
Total	509			

Table-3. Pearson's correlations coefficient among axes of (DCA) stand scores of seed bank, region and different soil chemistry variables. (***= significant NS = non significant)

Environmental variables	Axis 1	Axis 2
Ex. Potassium (K^+) ppm	-0.021 NS 0.872	0.132 NS 0.316
Phosphorus (P) ppm	-0.213 NS 0.102	0.035 NS 0.793
Nitrogen (N) %	0.110 NS 0.403	-0.018 NS 0.537
Organic matter (O.M.)%	0.429 0.001***	0.144 NS 0.272
Exchangeable sodium (Ex. Na^+) mmole/100gm	-0.284 0.028**	-0.192 NS 0.141
Electrical conductivity (EC) ds/m	-0.208 NS 0.110	-0.285 0.027**
pH	0.245 0.060*	-0.022 NS 0.868
Habitat	-0.563 0.000***	0.008 NS 0.951

Table-4. Eigenvalues and cumulative percentage of DCA axes 1-4.

Axis	Eigenvalue	Percent of total	Cumulative percent
1	0.631	13.10	13.10
2	0.359	7.45	20.55
3	0.220	4.57	25.12
4	0.158	3.28	28.40

Table-5. Distribution of seed bank among plant associations (A-D) identified by Normal Cluster Analysis. Values are the mean across five replicates.

	Associations			
Species	**A**	**B**	**C**	**D**
Abutilon indicum	-	-	-	-
Achyranthes aspera	-	-	-	-
Aerua persica	-	-	-	-
Alhagi maurorum	3.00	-	-	-
Alternanthera sessilis	-	-	-	-
Amaranthus viridis	-	-	-	1.00
Anagallis arvensis	-	-	2.00	-
Avena fatua	-	-	3.00	-
Boerhaavia coccinea	-	-	3.00	-
Brachiaria ramosa	-	-	-	3.00
Calotropis procera	-	-	-	-
Cenchrus ciliaris	-	-	-	-
Chenopodium album	-	4.00	-	-
Chenopodium murale	-	-	-	5.00
Chrozophora tintoria	1.00	-	-	-
Citrullus colocynthis	-	-	-	-
Convolvulus arvensis	-	-	-	1.00
Conyza bonariensis	-	-	1.00	-
Coronopus didymus	-	-	1.00	-
Cressa cretica	-	-	-	-
Cucumus trigonus	-	-	-	-
Cynodon dactylon	-	-	-	-
Cyperus rotundus	-	-	3.00	-
Datura stramonium	-	-	-	-
Desmostachya bipinnata	-	-	-	-
Digera muricata	-	-	-	-
Diplachne fusca	-	-	-	-
Echinochlova crus-galli	-	-	-	-
Eclipta prostrata	-	-	-	-
Eleusine verticillata	-	-	-	-
Euphorbia helioscopia	-	5.00	-	-
Euphorbia prostrata	-	-	3.00	-
Fagonia indica	-	-	-	-
Fumaria indica	-	-	-	2.00
Galium aparine	-	2.00	-	-
Gnaphalium luteo-album	-	-	-	-
Heliotropium strigosum	-	-	-	-

Ipomoea eriocarpa	-	-	-	-
Kochia indica	-	-	-	-
Lathyrus aphaca	-	6.00	-	-
Launaea procumbens	-	-	-	-
Lolium temulentum	-	1.00	-	-
Malva neglecta	-	-	-	3.00
Medicago denticulata	-	-	-	6.00
Melilotus albus	-	-	-	7.00
Oxalis corniculata	-	-	-	1.00
Phalaris minor	-	-	3.00	-
Phyllanthus fraternus	-	-	-	-
Phyla nodiflora	-	-	-	-
Physalis pubescens	-	-	-	-
Polygonum plebejum	-	-	-	-
Portulaca oleracea	-	-	-	2.00
Rhazya stricta	1.00	-	-	-
Rumex dentatus	-	-	-	1.00
Rumex obustifolius	-	-	3.00	-
Salsola baryosma	-	-	-	-
Solanum nigrum	-	2.00	-	-
Solanum surrattense	-	-	-	-
Sonchus asper	-	-	1.00	-
Sorgham halepense	-	-	2.00	-
Suaeda fruticosa	2.00	-	-	-
Tribulus terrestris	-	-	-	-
Trifolium alaxandrianum	-	-	-	2.00
Typha elephantina	-	-	-	-
Withania somnifera	-	-	-	-
Xanthium strumarium	-	-	-	-
Vicia sativa	-	-	-	3.00

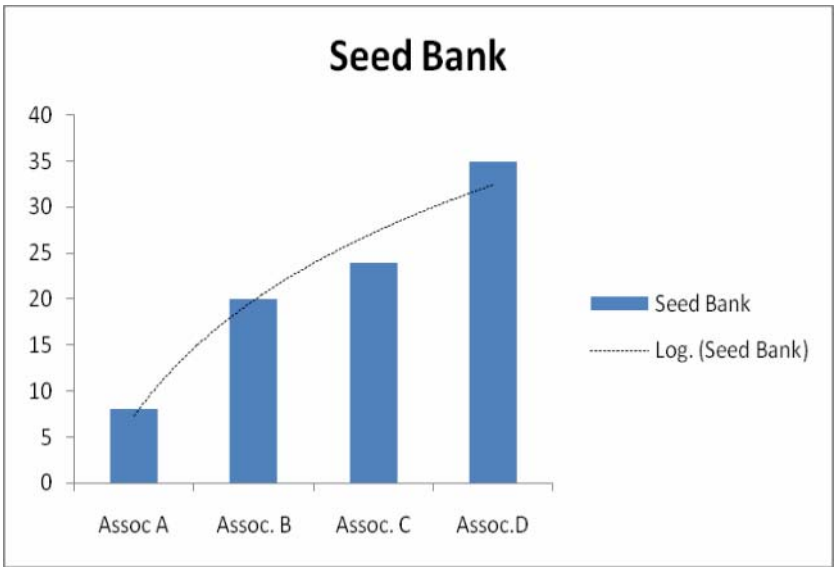

Figure-1. Distribution of seed bank among plant associations (A-D) identified by Normal Cluster Analysis.

1. Association A. Rain-fed fields
2. Association B. Irrigated plains of Indus River
3. Association C. Northern plains of Chenab River
4. Association D. Southern plains of Chenab River

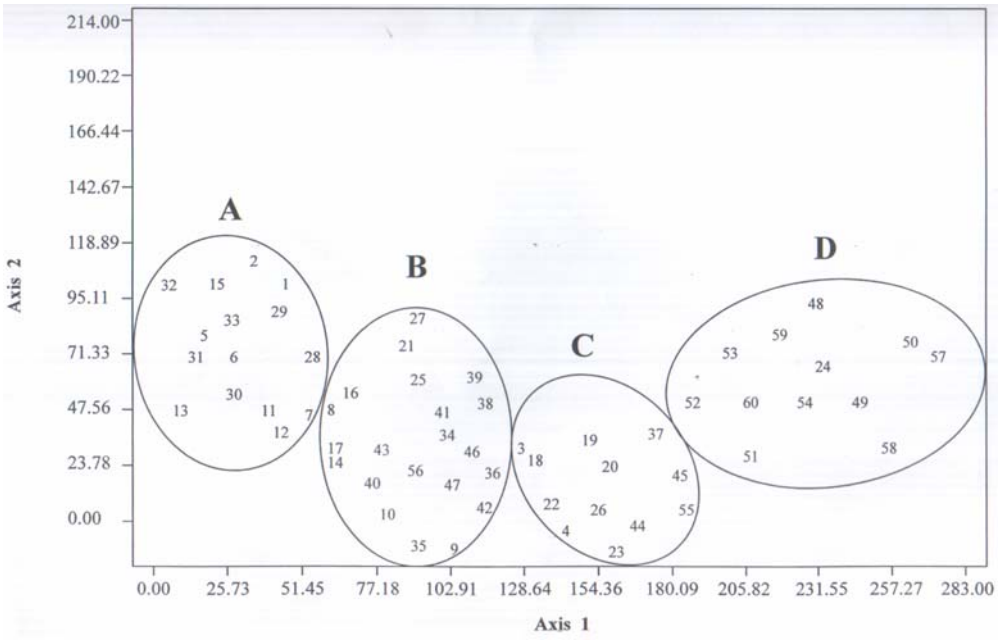

Figure-2. The DECORANA (Axis 1 and Axis 2) plot of the 60 samples (sites) the circle indicates the four associations segregated through normal cluster analysis.

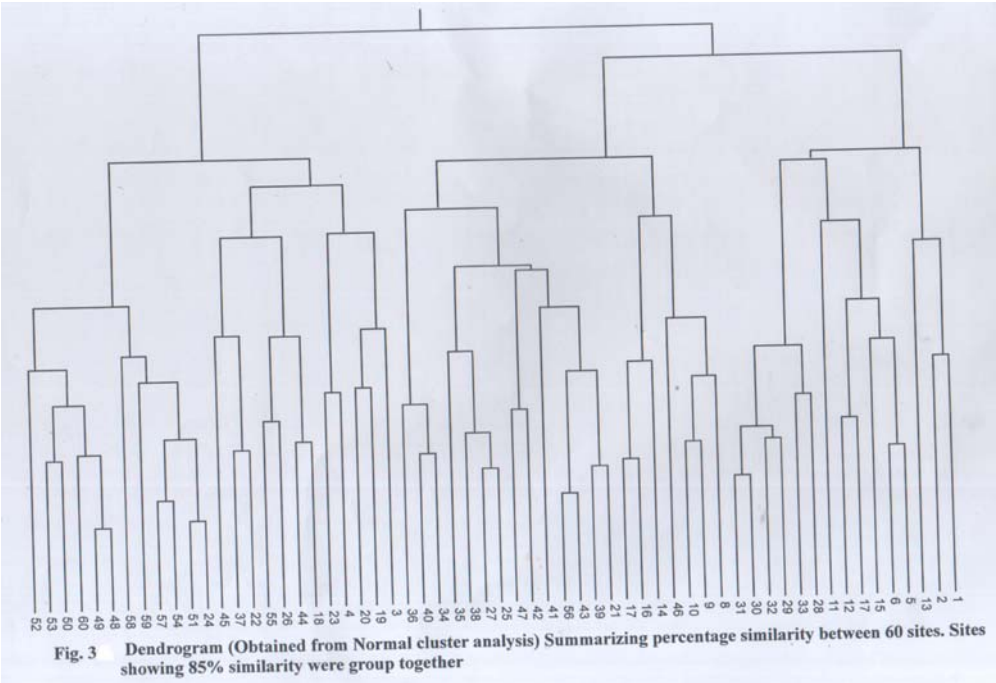

Figure-3. Normal cluster analysis of 60 stands of sites.

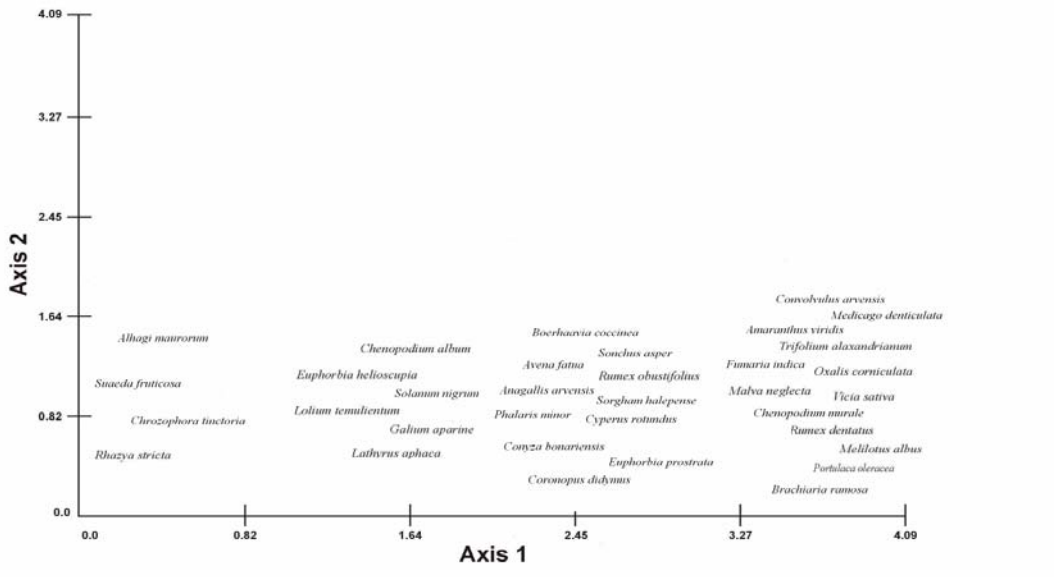

Figure-4. The DCA (Axis-1 and Axis-2) plot of the 34 species (seed bank density m^{-2}**)** observed during study

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