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STRUCTURE, COMPOSITION AND PATTERN IN *PERISTROPHE PANICULATA* (FORSSK.) BRUMITT. DOMINATED RUDERAL VEGETATION EMERGING AFTER SUMMER RAINS IN KARACHI

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ABSTRACT

Forty two species were found to be present in *P. paniculata (Forssk) Brumitt.* - dominated stands in the campus of University of Karachi with mean number of species per stand, 12.45 ± 0.054. Poaceae was the dominant family (10 genera and 15 species) followed by Leguminosae (4 genera and 5 species). Species diversity of the stands was low and the Whittaker's diversity-dominance curves were linear indicating geometric distribution of abundance among the species. Species diversity was more related to equitability than species richness. *P. paniculata* was the leading dominant in all the stands with average importance value of 88.70. All stands associated with non-saline, sandy to sandy loam type of soil basic in reaction. The variation in IVI of *P. paniculata* was found to be explained around 75% by the linear combination of $CaCO_3$ and organic matter contents and pH of the soil. Diversity related with IVI of *P. paniculata* inversely. Population structure of *P. paniculata* and some of its associates suggested that pattern was contiguous and the primary pattern scale was of reproductive origin. Negative correlations were observed between *P. paniculata* and its associates in the pattern analysis. The larger patches of *P. paniculata* alternated with small patches of the associates. The survivorship curves of *P. paniculata* in its two populations resembled to Deevy type – I.

Key Words: *Peristrophe paniculata*, Population structure, Species diversity, Pattern, Survivorship curve.

INTRODUCTION

The herbaceous ruderal vegetation emerging after summer rains in arid regions is not only ecologically important and serves in multiple ways but also a hotspot of biota (Frenkel, 1977) i.e. huge reservoir of genetic resources of plant species and bears its own aesthetic appeal (Kuzimeirska *et al.,* 2009; Sharifi *et al.,* 2013). There is long-list of constituent species of such vegetation in Karachi – on road-side and in the derelict areas, plains and dry detached low hills. *Peristrophe paniculata* (Forssk) Brumitt. [syn. *P. bicalyculata* (Retz.) Nees] (Hindi: Kali Aghedi), also called "The goddess of mercy" (Ogunwande *et al.,* 2010), is a hispid herb reaching up to 1.5m; distributed in Sindh and Punjab. It is shown to be an element of wall flora of Varanasi city, India as therophytic colonizer on the top of walls (Singh, 2014). Jangid and Sharma (2011) have included this species amongst weeds of Modasa, District Sabarkantha (Gujrat), India and Udayakumar *et al.* (2014) have ranked it an invasive species in Tamilnadu, India. It is also an element of old field and scrub vegetation of Tarai landscape of Northeastern UP, India (Shukla, 2009).

P. paniculata is very important medicinal and biologically active herb (Rushmi *et al.*, 2010; Janakiraman *et al.*, 2012; Abdulazeez *et al.*, 2009; 2013; Ogunwande *et al.*, 2010). It forms populations of variable sizes at several ruderal sites in the campus of University of Karachi, Karachi, Pakistan in situations of partial shade of trees and sometimes in open derelict spaces (Fig. 1) after summer rains. It also grows among the hedge plants. This study involves the analysis of structure and composition of *P. paniculata* dominated stands. The pattern of *P. paniculata* in its stands and that of its important associates within the vegetation samples has also been undertaken.

Fig. 1. A partial view of the sward of *P. paniculata*.

MATERIALS AND METHODS

Field Methods: Eleven stands dominated by *P. paniculata* in the Campus of University of Karachi were each sampled by 20 randomly placed quadrats of 30 x 30 cm. All stands were exposed to some degree of disturbance. Sampling to study abundance of species was made in September-October after c two months of rains. These stands were located on roadsides or derelict open areas under differential degree of shade and light. Soil samples were collected at three different sites in a stand from 20 cm depth. The three sub-samples of a stand were pooled to obtain a composite sample.

To study thinning in *P. paniculata* populations, at two sites colonized by *P. paniculata* previous year, two permanent quatrats of $1m^2$ each were established. The number of *P. paniculata* live seedlings was counted on 2^{nd}, 9th, 23^{rd}, 39^{th}, 52^{nd} and 84^{th} day of emergence of seedlings after summer rain. The seedlings of *P. paniculata* were identified with the help of those obtained by germination of the seeds in laboratory. Density of *P. bicalyculata* was recorded and survival curves ($\log_{10}$ based) were plotted.

Soil Analysis: Soil samples were air-dried and passed through a 2mm sieve to separate gravel. Soil texture was determined by pipette method (Anon., 1951), maximum water holding capacity by the method of Keen (1920), total organic matter (OM) by the total loss on ignition method (Jackson, 1958), Calcium carbonate by the method of Qadir *et al.*, (1966) and pH by glass electrode pH meter after preparing sample according to Peech et al. (1947). Filtrate of the saturated soil paste was employed for the measurement of electrical conductivity (ECe) of the soil.

Vegetation Analysis: The quantitative vegetation parameters viz. relative density (D_3) and relative frequency (F_3) were computed from the raw quadrat data. The importance value index for each species was obtained by direct summation of D_3 and F_3.

A number of diversity measures have been proposed by several workers (Magurran, 2004) and there has been some discussion on the superiority of diversity indices (Shaukat and Khan, 1979; Shaukat et al., 1981; Dhanmoanonda and Sahunalu, 1988; Magurran, 2004). The dominance and diversity and its components (species richness and evenness) were calculated using the following formulae (Ludwig and Reynolds, 1988). Diversity was measured by the information theory function H' (Shannon and Weaver (1963) and also by McIntosh diversity measure Mc (McIntosh, 1967) as these indices have been reported to be suitable for desert vegetation (Shaukat and Khan, 1979; Shaukat *et al.,* 1981). The measure of species richness (d) was calculated by Menhinick (1964) index and equitability was measured by e (Pielou, 1975, 1977) and V (Hurlbert, 1971). These measures of diversity have been employed by many ecologists to ascertain diversity under various conditions (Johnson *et al.,* 1975; Shaukat *et al.,* 1981; Khan *et al.,* 1987, 1999; Atiqullah *et al.,* 1997; Niazi *et al.,* 2007; Nazim *et al.,* 2010; Sharifi *et al.,* 2013). The dominance concentration within stands was ascertained by Simpson's (1949) index (C). The formulae employed for diversity estimation were as follows:

Species Richness, $d = S / \sqrt{N}$ … (Menhinick, 1964)

Diversity = $H' = -\sum_{i=1}^{s} pi. \ln pi$ (Shannon-Wiener Index)

$$Mc = 1 - \frac{\sqrt{\Sigma ni^2}}{N}$$ (McIntosh, 1967) and

$$C = -\sum_{i=1}^{s} pi.^2$$ …….. (Simpson, 1949)

$$V = \frac{\{N - \sqrt{\Sigma ni^2}] - [N - \sqrt{[N - \{S-1)]^2 + (S+1)]}}{[N - N/\sqrt{S}] - [N - \sqrt{[N - \{S-1)]^2 + (S+1)]}}$$ (Hurlbert, 1971; Johnson *et al.,* 1975)

$e = H' / H'_{max} = H' / \log S$ (Pielou, 1975, 1977).

Where S is the number of species, N, the total individuals, pi is the proportion of total individual belonging to a species to the total number of individuals in the sample stand. The relationship of conspicuousness (IVI) *of P.*

paniculata in its stands with diversity measures was determined by correlation and regression techniques. IVI of *P. paniculata* was also related with edaphic variables. The dominance-diversity curves (Whittaker, 1965) were plotted to portray the underlying relative abundance pattern.

Analysis of Interspecific Association: The quadrat data was utilized for the analysis of interspecific associations. Between *P. paniculata* and its major associates by X^2 –test (with Yate's correction) using 2x2 contingency tables for each species pair (Mueller- Dombois and Ellenberg, 1974).

Population Structure: The technique of pattern analysis developed by Greig-Smith (1961) and Kershaw (1962) was used for the detection of pattern, determination of the scale and intensity of aggregation, and to elucidate the interactions between species populations. This technique has been successfully used for this purpose by Brereton (1971), Pemadasa *et al.* (1974), Shaukat *et al*. (1983), and Khan *et al*. (1987).
The data on small scale spatial pattern were collected from two sites, A and B, where P. paniculata was the leading dominant. Each site was systematically sampled by a grid of contiguous quadrats. The sample grid was 4.80 x 1.20m consisting of 64 square grid units of 30 cm side. Density data were collected from each grid unit in a sequence for all the species occurring in the grid units and analyzed by analysis of variance of successive block sizes (NS) (Greig-Smith, 1961). In the graph relating mean square to block size., different scales of pattern appear as "peaks" at block assizes corresponding to the mean area of "clump:. The interaction between species populations was evaluated by pattern correlation analysis given by Kershaw (1961).

$$r = C_{ab} \sqrt{V_a.V_b}$$

Where C_{ab} represents covariance of species a and b and V_a and V_b are the variances of species a and b, respectively.

RESULTS

Vegetation composition and Structure of *P. paniculata* dominated stands

Species from diverse families entered the composition of *Peristrophe* dominated vegetation (Fig.2). Floristically, 18 families, 35 genera and 42 species were recorded. Sixteen monocotyledonous and 26 dicotyledonous species were recorded. Genera with one species each were 29. There was only one genus (*Cenchrus*) with three species and five genera had two species each. Poaceae was the most dominant family with 10 genera and 15 species (occupying a proportion of 35.7%) followed by Leguminosae (4 genera and 5 species. There were three Amaranthaceous and three Asteraceous species. Tiliaceae, Malvaceae and Acanthaceae contributed two species each. Eleven families were merely represented by one species each. The predominance of Poaceae and Leguminosae has also previously been reported by Khan *et al.* (1999) with reference to the summer aspect of the herbaceous vegetation of Karachi and by Khan and Ahmad (1992) regarding the flora of Pakistan Coast.

The relative phytosociological data on species of 11 stands is summarized in Table 1. The mean number of species per stand was 12.00 ± 0.486. *P. paniculata* was the leading dominant in all the stands with average importance value of 88.70. Only eight species viz. *Aristida adscensionis, A. mutabilis, Tragus roxburghii, Cenchrus setigerus, Leucas urticifolia, Panicum antidotale, Sonchus asper* and *Sida pakistanicum* were those which attained a position of second or third dominant. *Rhynchosia minima*, though widely distributed, was not important in the sense that its % IVI was low. *A. adscensionis* and *T. roxburghii* occurred in 9 and 5 stands respectively with quite high IVI (34.66 and 44.35, respectively). *A. adscensionis* was second dominant in 5 and third dominant in 4 stands where as *T. roxburghii* was second dominant in 4 stands. Both, *Dichanthium annulatum* and *L. urticifolia* occurred in 8 stands but with relatively low IVI. The species occurring in 8 stands were two, in 7 stands were 3, and in five stands were three. Thirty three species were restricted in four or less than four stands only. A major proportion of 40.4% of the total number of species was occupied by those species which occurred in one stand only. *Launaea procumbens* though was encountered in 7 stands but never attained a status of dominant and its % IVI never exceeded the value of 3.76.

The edaphic characteristics of the stands are presented in Table 2. The soil was differentially basic, Low to moderate in calcareousness, non-saline, sandy to loamy sand (to sandy loam) in texture with low to moderate organic matter (Table 2).

Species diversity (H') of *P. paniculata* dominated stands was low (Table 3). It ranged from 0.31154 to 0.72201 (Table 3). The mean diversity of the stands amounted to 0.5668 ± 0.0354. McIntosh diversity index also gave low values averaging to 0.39211 ± 0.0333. There was, however, more variation in McIntosh's measure (26.87%) than the information theory function H' (19.76%). Equitability of these stands in terms of V varied from 0.15922 to 0.71375 (mean: 0.5233 ± 0.0515). Pielou's equitability (e) varied from 0.2887 to 0.6482 (mean: 0.5326). The magnitude of species richness averaged to 0.6977 ± 0.0555. The dominance index (C) was substantially high (mean: 0.41003 ± 0.0527 due to predominance of *P. paniculata* in these stands. The variability of C was 40.74%.

Whittaker's dominance-diversity curves of the stands in hand being linear on a semi-log plot indicated generally geometric distribution of abundance (Fig. 3).

Table 1. Summary of phytosociological data of *P. paniculata* dominated vegetation.

S. No.	Species	Presence*	Av. IVI	Max. IVI	Min. IVI	Dominants		
						I	II	III
1	*Peristrophe paniculata* (Forssk) Brumitt.	11	88.703	139.34	54.29	11	-	-
2	*Rhynchosia minima* (L.) DC.	10	6.7.10	18.29	1.40	-	-	-
3	*Aristida adscensionis* L.	9	34.66	45.05	14.07	-	5	4
4	*Launaea procumbens* (Roxb.) Ramayya & Rajgopal	7	2.77	3.76	1.60	-	-	-
5	*Dichanthium annulatum* (Forssk.) Stapf	8	4.46	8.65	1.94	-	-	-
6	*Leucas urticifolia* R. Br.	8	13.32	33.43	3.76	-	-	3
7	*Tragus roxburghii* Panigrahi	5	43.35	55.68	10.64	-	4	-
8	*Corchorus olitorius L.*	5	5.64	9.60	2.38	-	-	-
9	*Panicum antidotale* Retz.	5	11.89	20.60	1.40	-	-	2
10	*Convolvulus arvensis* L.	4	5.47	5.67	1.1.40	-	-	-
11	*Cenchrus pennisetiformis* Hochst. Steud.	4	5.72	11.02	2.68	-	-	-
12	*Sporobolus arabicus* Boiss.	4	6.84	11.99	3.08	-	-	-
13	*Chloris barbata* Sw.	4	8.45	12.53	5.02	-	-	-
14	*Tephrosia strigosa* (Delz.) Sant. & Maheshw.	4	8002	8.55	1.40	-	-	-
15	*Cyperus rotundus* L.	3	15.09	17.39	11.10	-	-	-
16	*Dactyloctenium scindicum* Boiss.	3	4.81	8.95	1.40	-	-	-
17	*Digera muricata* (L.) Mart.	3	3.29	4.41	2.78	-	-	-
18	*Tribulus terrestris* L.	2	2.22	2.24	2.20	-	1	-
19	*Sonchus asper* (L.) Hill	2	16.25	26.35	6.16	-	-	-
20	*Tephrosia uniflora* Pres.	2	2.73	3.08	2.38	-	-	-
21	*Sida ovata* Forssk.	3	7.45	16.33	2.44	-	-	-
22	*Withania somnifera* (L.) Dunal	2	2.21	2.38	1.88	-	-	-
23	*Eleusine compressa* (Forssk.) Aschers Schweif. Ex C. Christ.	1	5.00	8.16	3.10	-	-	-
24	*Corchorus trilocularis* L.	1	7.91	13.98	1.88	-	-	-
25	*Cenchrus setigerus* Vahl	1	10.58	16.03	5.13	-	1	-
26	*Abutilon pakistanicum* Jafri & Ali	1	6.91	6.91	6.91	-	-	1
27	*Heliotropium ophioglossum* Boiss.	1	1.31	1.31	1.31	-	-	-
28	*Commicarpus stellatus* (Wight & Arn. Berhault	1	1.31	1.31	1.31	-	-	-
29	*Zaleya petandra* (L.) Jeffrey	1	3.38	2.38	2.38	-	-	-
30	*Eragrostis pilose* (L.) P. Beauv.	1	2.51	2.51	2.51	-	-	-
31	*Ziziphus nummularia* (Burm.f.) Wight & Arn.	1	3.76	3.76	3.76	-	-	-
32	*Sporobolus helvolus* (Trin.) Dur. & Schinz.	1	3.66	3.37	3.37	-	-	-
33	*Alysicarpus monilifer* (L.) DC.	1	1.60	1.60	1.60	-	-	-
34	*Barleria acanthoides* Vahl.	1	1.89	1.89	1.89	-	-	-
35	Aerva javanica (Burm.f.) Juss. Ex. Schultes.	1	5.30	5.30	5.30	-	-	-
36	*Dactyloctenium aegypticum* (L.) P. Beauv.	1	3.78	3.78	3.78	-	-	-
37	*Achyranthes aspera* L.	1	2.55	2.55	2.55	-	-	-
38	*Erigeron Canadensis* L.	1	2.20	2.20	2.20	-	-	-
39	*Farsetia jacquemonti* H. & T.	1	5.24	5.24	5.24	-	-	-
40	*Cassia holosericea* Fresn.	1	2.20	2.20	2.20	-	-	-
41	Aristida mutabilis Trin. & Rupr.	1	9.75	9.74	9.74	-	-	1
42	*Cenchrus biflorus* Roxb.	2	2.86	2.86	2.86	-	-	-

*, number of stands.

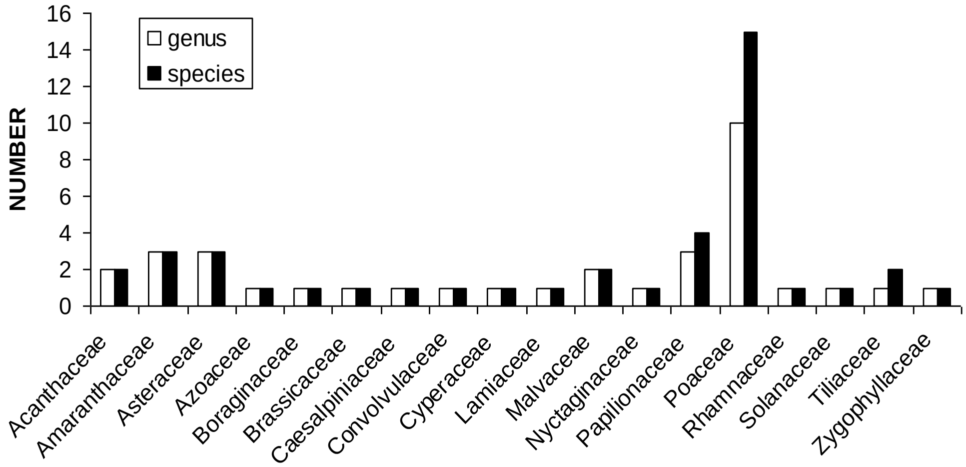


Fig. 2. Number of genera and species representing families that entered the vegetational composition of *P. paniculata* dominated stands.

Table 2. Edaphic characteristics of *P. paniculata* dominated stands.

Stand #	pH	$CaCO_3$ (%)	OM (%)	ECe (dS/m)	MWHC (%)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)
1	7.4	24.32	1.012	1.38	30.57	50.6	28.1	16.1	5.2
2	8.0	16.02	2.125	1.22	35.62	48.6	24.3	21.5	5.6
3	7.7	20.65	0.685	1.10	19.68	57.1	25.4	8.4	9.1
4	7.8	18.62	0.864	2.08	23.10	46.7	31.4	10.7	14.2
5	8.0	21.57	0.995	1.06	20.15	50.8	35.4	9.5	4.3
6	7.6	17.53	0.831	0.82	27.57	51.5	26.8	13.2	8.5
7	7.8	16.32	1.512	0.80	30.65	52.3	18.8	22.4	6.5
8	7.9	24.51	0.781	1.30	30.92	46.8	28.0	18.1	7.1
9	7.4	17.13	1.662	0.98	32.19	50.5	27.1	17.3	5.1
10	7.9	24.10	0.912	0.92	25.69	53.2	27.4	12.7	6.7
11	8.0	23.63	1.231	0.78	24.48	42.9	29.0	21.3	6.8

Interrelationships amongst diversity indices

The species diversity H was found to be closely positively correlated with Mc ($r = 0.885$; $p < 0.0001$) and also with e and V ($r = 0.916$ and $r = 0.894$, respectively – $p < 0.0001$ in each case). Species richness (S and d) exhibited insignificant association with H'. Dominance C related with H' negatively ($r = -0.733$, $p < 0.01$).

Interspecific association

As determined by 2 x 2 contingency table, *P. paniculata* was found to be negatively associated with a number of species viz. *C. biflorus* (-), *C. setigerus* (-) *T. roxburghii* (-), *P. antidotale* (--), *Digera muricata* (---), *S. asper* (--), *R. minima* (-), *W. somnifera* (---) and *S. helvolus* (-). *P. paniculata* was associated positively with none.

Relationship of IVI of *P. paniculata* with edaphic variables

The variation in IVI of *P. paniculata* was found to be explained around 75% by the linear combination of $CaCO_3$, organic matter and pH as given by the following equation.

$$IVI = 216.257 + 2.662\ CaCO_3 + 25.992\ OM - 32.948\ pH \pm 7.299$$

t = 2.70 t = 3.08 t = 3.96 t = -3.10

$p < 0.031$ $p < 0.018$ $p < 0.005$ $p < 0.017$

$R = 0.868$, $R^2 = 0.754$, $F = 7.14$ ($p < 0.016$)

Zero order correlation: $CaCO_3$: 0.095; OM: 0.458, pH: -0.421

Partial correlation: $CaCO_3$: 0.758; OM: 0.832, pH: -0.761

The relative density (D_3) of *P. paniculata* was found to be significantly negatively correlated with that of *A. adscensionis* (r = - 0.6068, p < 0.05), *T. roxburghii* (r = -0.6625), p < 0.05), *C. barbata* (r = -0.7337, p < 0.01) and *C. olitorius* (r = -0.5874, p < 0.10).

Table.3. Species richness, equitability, diversity and dominance of *P. paniculata* dominated stands.

Stand #	S	d = S / √ N	V	e	H'	Mc	C
1	12	0.7941	0.1592	0.2887	0.3115	0.1826	0.7180
2	13	0.9826	0.4186	0.5251	0.58497	0.3438	0.4306
3	14	0.6890	0.5270	0.5071	0.5812	0.4049	0.6890
4	13	0.5011	0.7138	0.6482	0.7220	0.5205	0.2299
5	12	0.4936	0.6817	0.6324	0.67786	0.4909	0.2592
6	13	0.5779	0.6198	0.4733	0.5272	0.4569	0.2949
7	10	0.6788	0.6320	0.6430	0.6430	0.4474	0.3054
8	9	0.4962	0.6213	0.6132	0.6030	0.4234	0.3325
9	10	0.6159	0.3908	0.4463	0.4463	0.2020	0.5012
10	13	0.8705	0.4178	0.5055	0.5631	0.3332	0.4447
11	13	0.9754	0.5745	0.5757	0.5744	0.4478	0.3050
Mean	12	0.6977	0.5233	0.5326	0.5668	0.3867	0.4100
SE	0.486	0.05558	0.0493	0.0324	0.0337	0.0335	0.0504

H' = 0.036 + 0.996 e ± 0.034287; r = 0.957; r^2 = 0.916, F = 97.67 (p < 0.0001)

H' = 0.222 + 0.893 Mc ± 0.05498, r = 0.885, r^2 = 0.783, F = 10.43 (p < 0.0001)

H' = 0.242 + 0.611 V ± 0.053613; r =0.894. r^2 = 0.794; F = 34.63 (p < 0.0001)

H' = 0.768 – 0.491C ± 0.080333; r = 0.733; r^2 = 0.537, F = 10.43 (p < 0.010)

H' vs. S …. r = 0.081; r^2 = 0.00656 (NS)

H' vs. d …..r = 0.317; r^2 = 0.01115 (NS)

MC = -0.078 + 0.873 e ± 0.06244; r = 0.846; r^2 = 0.715, F = 22.61 (p< 0.001)

MC= -0.111 + 0.877 H; ± 0.0545, r = 0.885, r^2 = 0.783, F = 32.48 (p < 0.0001)

MC = 0.051 + 0.641 V ± 0.03811; r =0.943. r^2 = 0.889; F = 72.43 (p < 0.0001)

MC = 0.594 – 0.503 C ± 0.0761; r = 0.760; r^2 = 0.577, F = 12.27 (p < 0.007)

MC vs. S …. r = 0.192; r^2 = 0.037 (NS)

MC vs. d …..r = 0.360; r^2 = 0.130 (NS)

Relationship of IVI of *P. paniculata* with diversity measures

The relationship of the conspicuousness of *Peristrophe* with diversity measures is given in Table 4. The IVI of *Peristrophe* related with species richness d positively and negatively with evenness component of diversity e or V i.e. higher is the magnitude of evenness, lesser is the conspicuousness of *P. paniculata* in the stand. IVI associated with diversity H; and Mc negatively and with C positively. There was positive correlation of % IVI of *P. paniculata* with species richness (d). It may, somehow, be related to the fertility status of the sites differentially dominated by *P. paniculata* – more species richness leading to better growth of *Peristrophe*. On the contrary, there was no correlation between IVI of *P. paniculata* in a stand and the number of species in a stand. Autoxicity is well known in *P. paniculata* in form of inhibition of germination and seedling growth more drastically by the shoot extract (Khan and Shaukat, 2007). Its stem and root contain a wide variety of biochemicals- alkaloids, Coumarin (both free and glycoside Coumarins), saponins, triterpenoids, KCl (Duke, 1977; Satyanarayana *et al.*, 1993), besides phenolics. Coumarin is a very strong inhibitor (Itoh, 1976, Hedge and Miller, 1992). Further research is needed to elucidate ecological implications of autotoxicity in *P. paniculata*, a short-lived ruderal species, with special reference to the chemistry of the soil under *P. paniculata* occupancy. The accumulation of toxins in arid soil during current season may influence the seedlings of the future generation arising from the seed bank. Autoxicity plays a crucial role in spatial and temporal dispersal of seed germination and seedling establishment (Edwards *et al.*, 1988). Plants having autotoxicity however, should better grow in association of other species.

Edaphic relations of diversity

The variance in diversity H' was accounted for by linear combination of soil chemical characteristics ($CaCO_3$, organic matter and pH) by 83 % as given by the following equation. These soil factors were the same which also related with conspicuousness (IVI) of *P. paniculata* in obviously opposite directions. It signified the role of *P. paniculata* exerted over the composition of this vegetation.

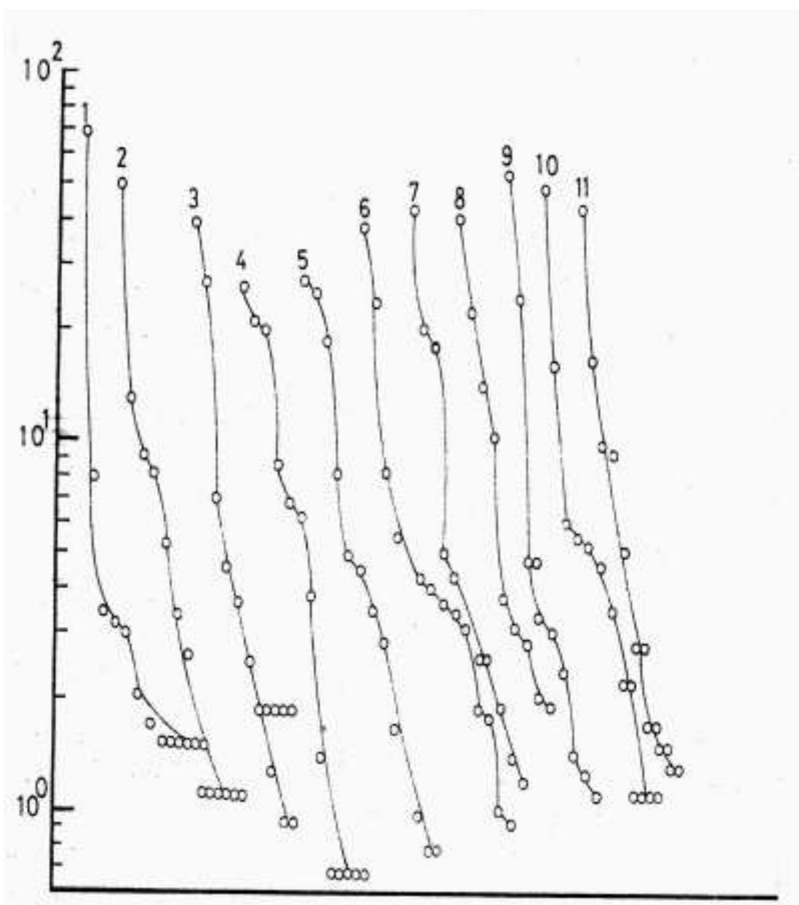
H’ = -2.261 + 0.446 pH – 0.023 $CaCO_3$ – 0.146 OM ± 0.04622
t = -4.454 t = 6.62 t = -4.18 t = -3.52
$p < 0.0032$ $p < 0.0001$ $p < 0.004$ $p < 0.010$
R = 0.938, $R^2 = 0.881$, Adj.$R^2 = 0.830$, F = 17.24 ($p < 0.001$)
Zero order correlation: pH: 0.747; $CaCO_3$: - 0.227; OM: -0.098
Partial correlation: pH: 0.929; $CaCO_3$: - 0.845; OM: - 0.798

Table 4. Relationship of *P. paniculata* conspicuousness (Y) with diversity measures (X).

Y Parameter	X parameter	Linear Relationship
% IVI *	S	r = 0.010 (NS)
% IVI	d	Y = 14.971 + 41.995 X ± 10.0823, r = 0.629, r^2 = 0.396; F = 5.90 ($p < 0.038$)
% IVI	V	Y = 81.895 – 71.872 V ± 3.87490; r = -0.954, r^2 = 0.911, F = 91.85 ($p < 0.0001$)
% IVI	e	Y = 93.862 – 93.109 e ± 7.53750, r = -0.814, r^2 = 0.663, F = 17.69 ($p < 0.002$)
% IVI	Mc	Y = 81.944 - 97.423 Mc ± 6.1852, r = -0.879, r^2 = 0.773. F = 30.58 (p , 0.0001)
% IVI	H’	Y = 95.833 – 90.972 H’ ± 7.2745, r = -0.828, r^2 = 0.695, F = 19.61 ($p < 0.0001$)
% IVI	C	Y = 22.94 + +52.03 C ± 9.183, r = 0.706, r^2 = 0.499, F = 8.95 ($p < 0.015$)

*, IVI (%) of *P. paniculata*.

% IVI (Log Scale)



SPEFCIES SEQUENCE

Fig.3. Relative abundance pattern of species in 11 stands dominated by *P. paniculata*.

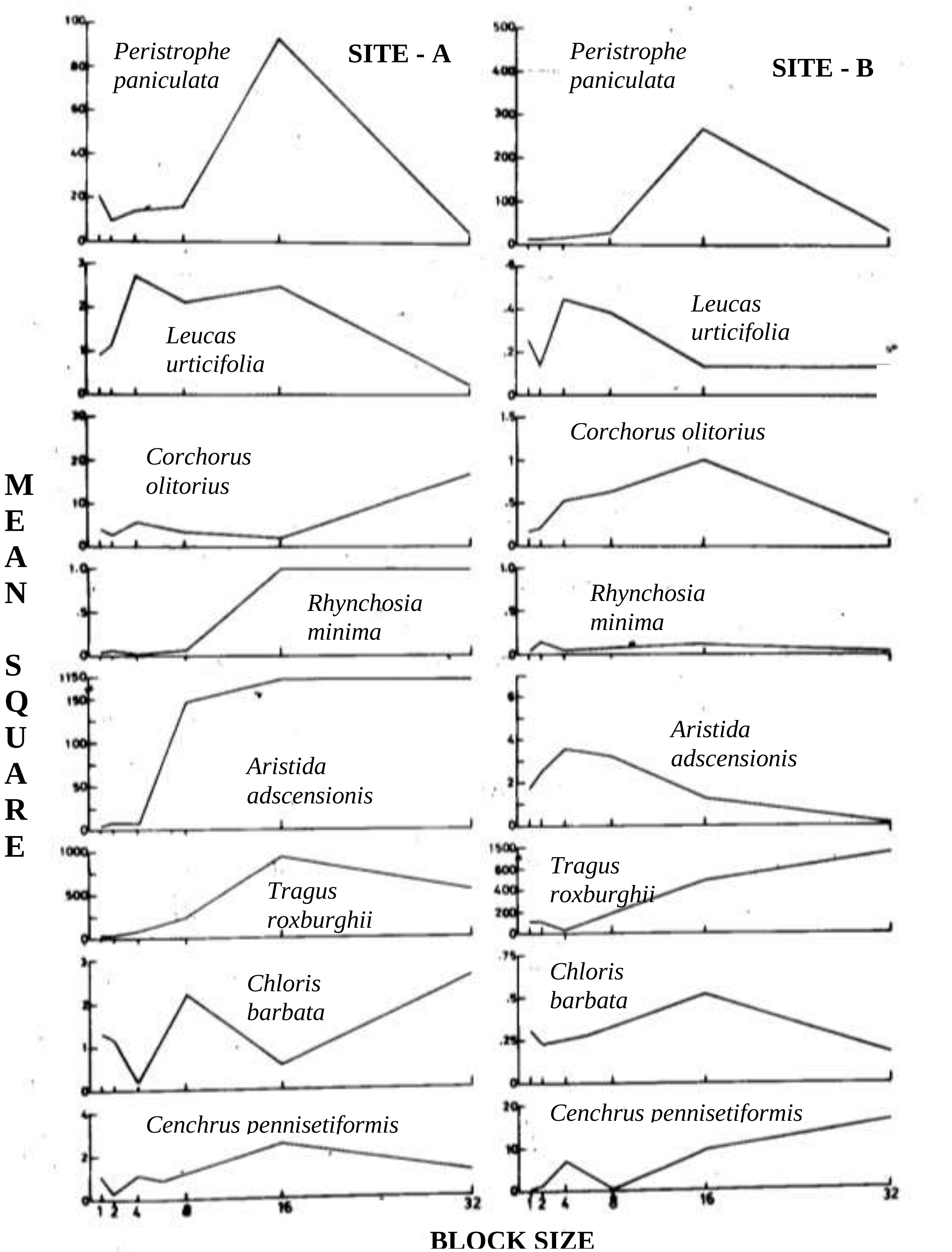


Fig. 4. A representative series of mean square / Block size graphs showing pattern of *P. paniculata* and its associates in two sites A and B.

Detection of pattern and inter-species correlation

The graphs of mean square against block size for some associates of *P. paniculata* in its two sites (Fig. 4) indicated that the primary pattern peak of *Peristrophe* was present at NS 1 in the site A and secondary peak at NS 8 in both the sites. *L. urticifolia* showed its primary pattern peak at NS 4 and 1 in the sites A and B, respectively and secondary pattern peak at NS 16 and 4, in the respective sites A and B. in the site A, *C. olitorius* exhibited its primary and secondary pattern peaks at NS 4 and 32 in the site A whereas at NS 4 and 16 in the site B. The primary peak of *R. minima* in the sites was located at NS 2 and the secondary peak at NS 16 in the sites A and B, both. *A. adscensionis* exhibited primary peak at NS 16 and 4 in the site A and B, respectively and secondary peaks were missing in both sites. The pattern peaks of *T. roxburghii* was present at NS 16 and 32, respectively in the site A and B. *C. barbata* showed its primary and secondary peaks at NS 8 and 32 in the site A and only one peak in site A at NS 16. Primary pattern peak of *C. pennisetiformis* was present at NS 4 in both sites where as secondary peaks at NS 16 and 32 in the site A and B, respectively.

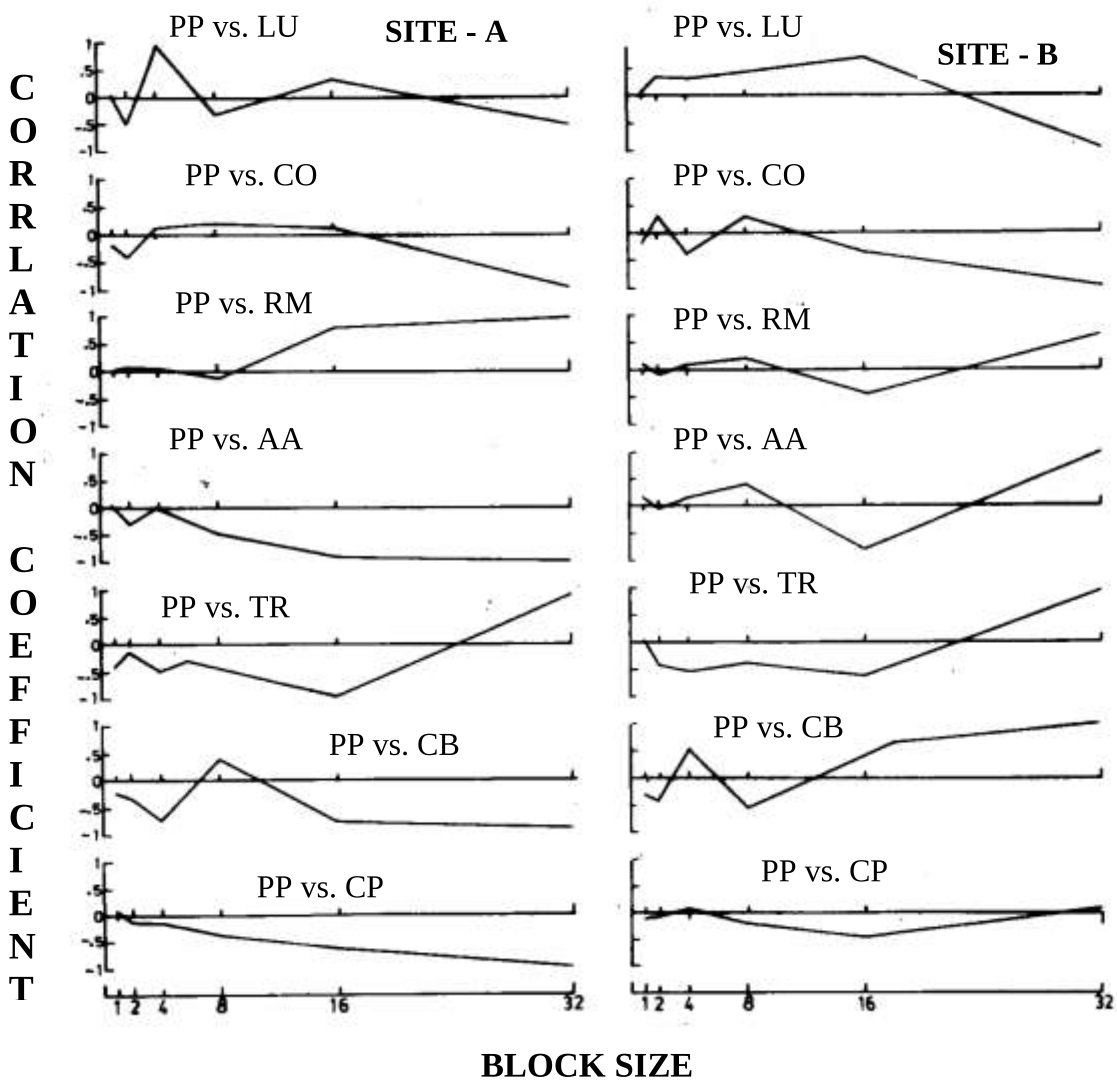


Fig. 5. A representative series of pattern correlation / block size graphs between *P. paniculata* and its associates for two sites A and B. Key top the acronyms: PP, *Peristrophe paniculata*; LU, *Leucas urticifolia* ; Co, *Corchorus olitorius*; RM, *Rhynchosia minima*; AA, *Aristida adscensionis*; TR, *Tragus roxburghii*; CB, *Chloris barbata* and CP, *Cenchrus pennisetiformis*.

The interaction of *P. paniculata* with seven species occurring in sites studied by pattern correlation analysis is presented in Fig. 5. *L. urticifolia* exhibited negative correlation with *P. paniculata* at NS 2 and 8 and positive correlation at NS 4 in the site A. In the site A, its positive peak was at NS 16. *C. olitorius* was negatively associated at NS 2 and 32 in the site A and at NS 4 and 32 in the site B. *R. minima* was positively associated at NS 32 in both the sites and it negatively associated at NS 16 in the site B. *A. adscensionis* exhibited negative correlation at all block size in the site A and at NS 16 in the site B and positive correlation at NS 8 and 32 in the site B. *T. roxburghii* in both the sites was consistently negatively associated with *Peristrophe* at each block size except 32 at which it was positively associated. *C. barbata* exhibited negative correlations at NS 4 and 8 and positive correlation at NS 8 and 4 in the site A and B, respectively. *C. pennisetiformis* was consistently negatively correlated at each block size in each site of study.

Seedling survival in field populations

Figure 6 and 7 represents data on thinning in the two natural populations of *P. paniculata* emerging after summer rain and recorded for 84 days. The sharpest decline of density.m^{-2} of *P. paniculata* seedlings was recorded within the first week of establishment of its seedlings after emergence. Density decline in subsequent weeks was low. After 52 days of emergence c. 14% of the seedlings could survive which also died in a span of next 30 days or so. The survivorships curves based on $\log_{10}$ scale accorded to third degree polynomial equations and were similar to that of Pearl type I (Pearl, 1928) and also described by Deevey (1947).

DISCUSSION

Ruderal vegetation represents a highly dynamic floristic / vegetational complex, which develops most often in human settlements, but also in other environments which are permanently or temporarily exposed to anthropogenic influences. Anthropogenic factors are of key significance in the formation, survival, distribution, diversity and dynamics of this type of vegetation. The specificity and diversity of ruderal habitats are conditioned by their location (Jarić *et al.,* 2011). The phytosociological structure of the ruderal sites dominated by *P. paniculata* in the Campus of University of Karachi, Pakistan was quite simple in organization and composition. In all, 42 angiospermic herbaceous species were encountered as associate of this species in field. Average number of species per site was as low 12.00 ± 0.486. *P. paniculata* was the leading dominant in all the stands with average % importance value of 88.70. Only eight species viz. *Aristida adscensionis, A. mutabilis, Tragus roxburghii, Cenchrus setigerus, Leucas urticifolia, Panicum antidotale, Sonchus asper* and *Sida pakistanicum* were those which attained a position of second or third dominant. The proportion of genera entering the composition of *P. paniculata* stands and each of them represented by a single species was quite high (82.86%). It indicated a great deal of floristic heterogeneity of the overall assemblage but which varied from site to site due to locally varying sub-ordinate species existing under the P. paniculata influence.

P. paniculata associated with differentially basic, lowly to moderately calcareous, non-saline and sandy to loamy sand (to sandy loam) soil with low to moderate organic matter content generally under situation of partial or substantial shade on roadsides or open spaces of the Campus of the University of Karachi. Sites rich in Nitrogen and partial shady are reported to be optimum for *P. paniculata*. Open areas of sunshine are colonized by this species are low in nitrogen contents (Misra and Ramakrishnan, 1959, 1960).

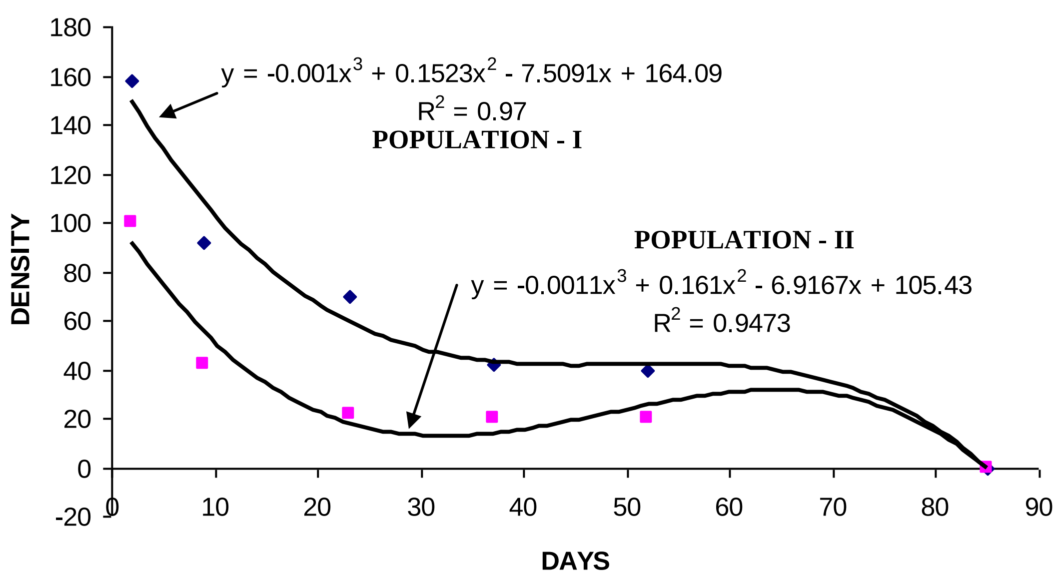


Fig. 6. Temporal variation in density.m^2 of live individuals in two populations of *P. paniculata* after 2, 9, 23, 37, 52 and 84 days after emergence. These sites were dominated by *P. paniculata* previous year.

The stands colonized by *P. paniculata* had low diversity and high dominance by one or two species. Whittaker (1965) has viewed a natural community as an admixture of differentially and unequally successful species. The dominant species in a community influence the community structure and the function of the subordinate species. The relative abundance pattern throughout the year was essentially linear on semi-log plot that indicated geometric distribution of resources amongst the species. The geometric distribution of abundance of species in the stands in hand implied that the most successful (dominant) species pre-empted a fraction 'k' of the resources, next a fraction of the remainder of the and so on (May, 1975; Tokeshi, 1990, 1996; Magurran, 2004). Such a distribution is attributed to species poor and stressful conditions of the environment (Whittaker, 1975) where the phenomenon of dominance is strongly developed. Our results indicated that two components of diversity were not equally important in determining the diversity of these stands vegetation. Here equitability appeared to more control diversity than species richness. Tramer (1969) suggested that communities from adverse rigorous environments very in diversity according to their relative abundance pattern whereas communities in non-rigorous environment (biologically controlled environment) is a function of species. Smith (1980) reiterated that there is no such entity as wholly physically controlled or wholly biologically controlled community. The community is rather influenced by the interaction of the two.

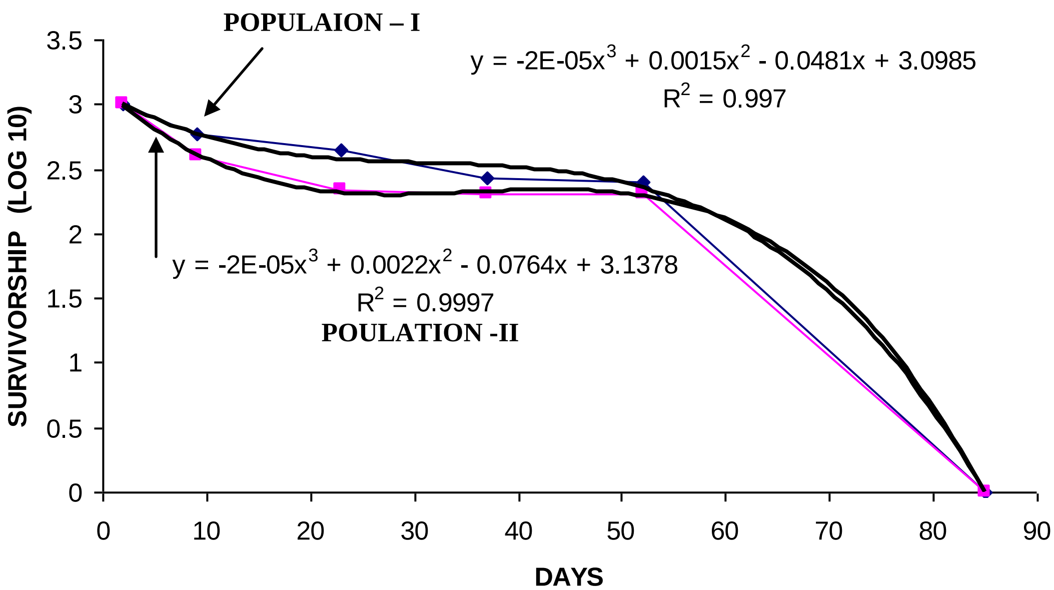


Fig. 7. Survivorship curve ($\log_{10}$) for two *P. paniculata* populations.

An examination of dispersion pattern revealed that several of the primary peaks appeared at block size 2 and 4 which indicated that the mean linear dimension of the mosaic unit at this scale ranges generally from 60 to 120 cm. None of the species chosen for pattern analysis possessed any special mechanism for seed dispersal. The most probable dispersal agency is wind. *A. adscensionis*, however, offers a special case. The seeds of this species are light and arrow-like which may be blown long distances by the winds. Furthermore, on sandy soils plants of A. adscensionis get uprooted and roll on the ground along with wind currents until intercepted by some plant or other obstacle. However, all of other plants being herbaceous in nature can only disperse their seeds to a small distance (≤ 1m). Even the seeds of *P. paniculata* were generally seen lying in the vicinity of the parent plant. The dense emergence of seeds of *P. paniculata* in clusters at the site which was occupied by parent population also supports the supposition that aggregation of individuals at smaller block sizes may be to a greater extent the result of the effect of the limited distance of seed dispersal and observed primary peak of pattern may, therefore, be presumably of reproductive origin. The pattern peak of *A. adscensionis* at higher block size may be attributed to its long-distance-dispersal capacity.

The negative correlation between *P. paniculata* and most of the associates studied at smaller block sizes (2 and 4 generally) indicated that inter-species interference operated between *P. paniculata* and other herbaceous species in the field. In the sites where *P. paniculata* is leading dominant, suppressive effect of it are also elucidated by the negative inter-specific associations between *Peristrophe* and other herbs such as *W. somnifera, S. asper, P. antidotale, S. helvolus, D. muricata, C. pennisetiformis, C. setigerus*, and *T. roxburghii*. Density dependent interactions between *Peristrophe* and its associates is manifested by significant negative correlations between relative density (D_3) of *Peristrophe* and that of *A. adscensionis, Chloris barbata, T. roxburghii* and *C. olitorius*.

P. paniculata is a semelparous plant. On reaching maturation, it's all meristems die as a result of which the plants dies completely leaving behind seeds as future generation stored in the soil. On advent of rains in summer, the seeds germinate in cohorts. The seedlings of a cohort undergo thinning. The survivorship curve of *P. paniculata* populations broadly resembled to Pearl (or Deevey) type-I, generally exhibited by annuals. Watkinson and Harper (1978) reported type I survivorship curve in an annual *Vulpia fasciculata*. This type of curve is also reported in *Ipomoea sindica*, an annual species (Aziz and Shaukat, 2011). A variety of survivorship curves ranging from type I to Type II (Mack and Pyke, 1983; Dolan and Sharitz, 1984; Reichenberger and Pyke, 1990; Shaukat and Siddiqui, 2007; or even type III curve exhibited by annual weeds such as *Galinsoga ciliata* and *G. parviflora* (Rai and Tripathi, 1984). *P. paniculata* is also shown to portray type I survivorship curve by Aziz and Rizvi (2014). It has been suggested by Sarukhan and Harper (1973) that great mortality risk involved at the seedling stage in sexually reproducing species may be due to the genetic load of unfit genotypes than the problems for making metabolic adjustment between food dependent seedlings and self sufficient established plants. In the arid environment since recruitment of seedlings of annuals is generally in the open space with no or little vegetation except a few biennials or perennials, the thinning due to genetic reasons could be, of course, important, although moisture deficit progressively intensifying with time subsequent to rain, seedling disparity due to differential seed size and keen inter-seedling competition could be equally important factors in desert environment. The seed weight variation in *P. paniculata* is known to be 12.91% (Khan *et al.*, 1984) but significance of seed size in respect of seedling performance or juvenile mortality is not known. There is a need to investigate inter-seedling competition in *P. paniculata* along with seed size – seedling growth relationship in this species. Under dry conditions, *P. paniculata* becomes highly stunted in growth with few leaves and capsules. It curtails vegetative growth and enters reproduction at early stages. Plasticity is expressed continuously in all plants but rapid curtailment of the vegetative growth under stressful environment and diversion of resources to seed production is characteristics of ruderal plants (Grime and Mackey, 2002). This may be significant in widening niche breadth of this species since plasticity is an integral part of the mechanism by which plants survive, capture resources and produce offspring

REFERENCES

Abdulazeez *M., I.A. Baba, E.Z. Yenusa, S.J. Omanibe and I.H. Oladimeji* (2013*).* Antitrypanosomal effect of *Peristrophe bicalyculata* extract on *Trypanosoma brucei* infected rats. *Asian Pacif. J. Trop. Biomed*. 3(7): 523-531.

Abdulazeez, A.M., A.J. Nok, and H. Gwani (2009). *Effect of Peristrophe bicalyculata on lipid profile of P-407 induced hyperlipidemic Wister rats.* Ph. D. thesis. Dept. Biochem. Ahmadu Bello University Zaria, Kaduna, State, Nigeria.

Anonymous (1951). *Soil Survey Manual*. USDA Handbook No. 18, Washington, D.C. 503 p.

Atiqullah, M., S.S. Shaukat and N. Qureshi (1997). Diversity of fish communities at Sandspit, Karachi Coast, Pakistan. *Oebalia* XXIII: 45-59.

Aziz, S. and A. Rizvi (2014). Population dynamics of *Peristrophe bicalyculata* (Retz.) Nees., A desert annual herb. *Int. J. Biol. Res*. 2(1): in press.

Aziz, S. and S.S. Shaukat (2011). Demographic studies of *Ipomoea sindica* Stapf. , a desert summer annual. *Pak. J. Bot.* 43(6): 3035-3040.

Brereton, A.J. (1971). The structure of the species populations in the initial stages of salt marsh succession. *J. Ecol*., 59: 321-338.

Deevey, E.S. Jr. (1947). Life tables for natural populations of animals. Quart. Rev. Biol. 22: 283-314.

Dhanmoanonda, P. and P. Sahunalu. (1988). Comparison of some indices of species diversity in the estimation of the actual diversity in three forest types at Namprom Basin, Chairaphum province. *Kasetsart J.* (Nat. Sci) 22: 77-82.

Dolan, R.W and R.R. Sharitz (1984). Population dynamics of *Ludwigia leptocarpa* (Onagraceae) and some factors affecting seed hierarchies in a natural population. *J. Ecol.*, 72: 1031-1041.

Duke. J.A. (1977). Phytotoxin Tables (1 and 2). *Critical Reviews in Toxicology*. CRC. Pp. 189-237.

Edwards, M.E., E.M. Harris, and F.H. Wagner (1988). Seed germination of American Pokeweed (*Phytolaca americana*) I. Laboratory Techniques and Autotoxicity. *Am. J. Bot.*, 75: 1794-1802.

Frenkel, R.E. (1977). *Ruderal Vegetation along Some California Road-sides.* Univ. Calif. Press. 163 pp.
Greig-Smith, P. (1961). Data on pattern within plant communities. I. The analysis of pattern. *J. Ecol*. 49: 695-702.
Grime, J.P. and M.L. Mackey (2002). The role of plasticity in resource capture by plants. *Evol. Ecol.* 16: 299-307.
Hedge, R.S. and D.A. Miller (1992). Concentration dependency and stage of crop growth in alfalfa autotoxicity. *Agron. J*., 84: 940-946.
Hurlbert, S.H. (1971). The non-concept of species diversity: a critique and alternate parameters. Ecology 52: 577-586.
Itoh, T. (1976). Microscopic and sub-microscopic observations of the effects of Coumarin and colchicines during elongation of pine seedlings. *Plant and Cell Physiol*., 17: 367-384.
Jackson, M.I. (1958). Soil Chemical Analysis. Prentice-Hall, Englewood Cliffs., N.J. 498 p.
Janakiraman, N., S. Saliya, S. Sathish and m. Johnson (2012) Antibacterial studies on P. paniculata (Retz.) Nees. *Asian Pacific J. Trop. Biomedicine*, S147-S150.
Jangid, M.S. and S.S. Sharma (2011). Weed plants of Modasa, District Sabarkantha (Gujrat). *Life Sciences Leaflets* 13: 435-442.
Jarić, Snežana Miroslava Mitrović, S. Vrbničanin, B. Karadžić, L. Djurdjević, Olga Kostić, Marina Mačuka nović-Jocić , Gorda na Gaji ć and P. Pavlović. (2011). A contribution to studies of the ruderal vegetation of Southern Srem, Serbia. *Arch. Biol. Sci., Belgrade*, 63 (4): 1181-1197.
Johnson, H.B., E.C. Vasek and T. Yonkers (1975). Productivity, diversity and stability relationships in Mojave Desert roadside vegetation. Bull. Torrey Bot. Club 102: 106- 115.
Keen, B.A. 1920. The relations existing between the soil and its water content. *J. Agr. Sci*. 10: 44-71.
Kershaw, K.A. (1961). Association and covariance analysis of plant communities. *J. Ecol* 49: 643-654.
Khan, D., S.S. Shaukat and M. Faheemuddin (1984). Germination studies of certain desert plants. *Pak. J. Bot.* 16(2): 231-254.
Khan, D, S.S. Shaukat and S. Ismail (1987). Structure, composition and pattern in *Achyranthes aspera* L. dominated ruderal vegetation in the suburbs of Karachi. *Pak. J. Bot.* 19(2): a57-a74.
Khan, D. and R. Ahmad (1992). Floristics, life-form, leaf-size and halo-physiotypic spectra of Coastal flora of Pakistan. Proc. National Confr. On Problems and Resources of Pakistan Coast and Plan of Action for its Development. Quetta Sept. 1991. PCST, Islamabad.
Khan, D. and S.S. Shaukat (2007). Preliminary observations on auto- and reciprocal toxicities in *Achyranthes aspera* L. and *Peristrophe bicalyculata* (Retz.) Nees. *Int. J. Biol. & Biotech*. 4(1): 65-70.
Khan, D., M.M. Alam and m. Faheemuddin (1999). Structure, composition and aboveground standing phytomass of some grass-dominated communities of Karachi: Summer Aspect. *Hamdard Medicus* XLII (2): 19-52.
Kuzimeirska, N., M. Szymura and K. Wolski (2009). Aesthetic aspects of plant communities of ruderal urban sites in Szczecin. Biodiver. Res. Conserv. 13: 43-48.
Ludwig, J.A. and J.F. Reynolds (1988). *Statistical Ecology: A Primer on Methods and Computing*. John Wiley & Sons Inc., xviii + 337 pp.
Mack, R.N. and D.A. Pyke (1983). The demography of *Bromus tectorum*: variation in time and space. *J. Ecol.* 71: 69-93.
Magurran, A.F. (2004). *Measuring Biological Diversity.* Blackwell Sci. Ltd., Blackwell Publishing Co. viii+ 256 pp.
May, R.M. (1975). Pattern of species abundance and diversity (pp. 83-120). In: *Ecology and Evolution of Communication* (Cody, M.L. and J.M. Diamond, Eds). Belknap Press, Cambridge.
McIntosh, R.P. (1967). An index of diversity and its relations to certain concepts of diversity. *Ecology* 48: 392-404.
Menhinick, E.F. (1964). AS comparison of some species-individuals diversity indices applied to samples of field insects. *Ecology* 45: 859-0 961.
Misra, R. and P.S. Ramakrishnan (1959). Distribution of *Peristrophe bicalyculata* Nees. In relation to soil nitrogen and light. Curr. Sci. Letter to the Editor, P340.
Misra, R. and P.S. Ramakrishnan (1960). Ecological distribution of Peristrophe bicalyculata Nees. *Proc. National Inst. Sci.* India B26: 51.-53.
Mueller-Dombois, D. and H. Ellenberg (1974). *Aims and Methods of Vegetation Ecology*. . John Wiley & Sons. New York, 547 pp.
Nazim, K, M. Ahmed, M.U. Khan, N. Khan and S.S. Shaukat (2010). The diversity of crabs in some mangrove forests of Karachi, Pakistan. *Int. J. Biol. & Biotech.* 7(3): 235-240.
Niazi, R.M., N.A. Qureshi and M. Ahmed (2007). Abundance, distribution and species diversity of invertebrates collected in commercial trawler from near shore coastal areas of Karachi, Pakistan (Northern Arabian Sea). *Int. J. Biol. & Biotech.* 4 (special issue): 65-71.

Ogunwande, I.A., T.M. walker, A. Bansal, W.N. Setzer and E.ER. Essein (2010). Essential oil constituents and biological activities of *Peristrophe bicalyculata* and *Borreria verticillata. Nat. Prod. Comm*. 5 (11): 1815-1818.
Pearl, R. (1928). *The rate of living*. Knopf. New York, 226 Pp.
Peech, M., L.T. Alexander, i. A. Dean and J.F. Read (1947). *Methods of Soil Analysis for Soil Fertility Investigations.* USDA cir. 757, 25 pp.
Peet, R.K. (1974). The measurement of species diversity. *Ann. Rev. Ecol. & Syst.* 5: 285-307.
Pemadasa, M.A., P. Greig-Smith and P.H. Lovell (1974). A quantitative description of the distribution of annuals in the dune system at Aberffraw, Anglesey. *J. Ecol*. 62: 379-402.
Pielou, E.C. (1975). *Ecological Diversity*. Wiley, New York.
Pielou, E.C. (1977). *Ecological Diversity*. Wiley, New York.
Qadir, S.A. , S.Z. Qureshi and M.A. Ahmed (1966). A phytosociological survey of Karachi University Campus. *Vegetatio* 13: 339-362.
Rai, J.P.N. and R.S. Tripathi (1984). Population dynamics of different seedling cohorts of two co-existing annual weeds, *Galinsoga ciliata* and *G. parviflora* on two contacting sites. *Acta Oecologia* 5: 357-368.
Reichenberger, G. and D.A. Pyke (1990). Impact of early root competition on fitness components of four semiarid species. *Oecologia* (Berlin) 85: 159 – 166.
Rushmi, G., P. Jaya, P. Hardik, M. Bhumi and A. Shivani (2010). Peristrophe bicalyculata – A Review. *Pharmacognosy Journal* 2(4): 39-45.
Sarukhan, J. and J.L. Harper (1973). Studies on plant demography: *Ranunculus repens* L., *R. bulbosus* L. and *R. acris* L. I. Population flux and survivorship. *J. Ecol.* 61: 675-716.
Satyanarayana, N.V., S.H. La Chake and M.G. Chauhan (1993). Pharmacological and phytochemical investigation of *Peristrophe bicalyculata*. *Ancient. Sci. of Life*. XII (3 & $): 420-427.
Shannon, C.E. and W. Weaver (1963). *The Mathematical Theory of Communication*. Univ. Illinois Press, Urbana, 367 pp.
Sharifi, A., A, Sapahry and H. Barani (2013). Investigation biodiversity of vegetation species in roadside (case study: Incheh-broun (Golestan Province). *Int. J. Agronomy and Plant Production* 4(5): 856 – 862.
Shaukat, S.S. and D. Khan (1979). A comparative study of the statistical behaviour of diversity and equitability indices with reference to desert vegetation. *Pak. J. Bot.* 11(2): 155-165.
Shaukat, S.S. and I.A. Siddiqui (2007). Comparative population ecology of *Senna occidentalis* (L.) Link, a monsoon desert annual, in two different habitats. *J. Arid Environs*. 68: 223-236
Shaukat, S.S., A. Khairi, D. Khan and m. Afzal (1981). On the applicability of McIntosh's diversity measures. *Tropical Ecology* 22 (1): 54 – 81.
Shaukat, S.S., D. Khan and S.T. Ali (1983). Suppression of herbs by Inula grantioides Boiss. In the Sind desert, Pakistan. Pak. J. Bot. 15: 43-67.
Shukla, R.P. (2009). Pattern of plant species diversity across Tarai landscape in Northeastern Uttar Preadesh, India. *Tropical Ecology* 50(1): 101-128.
Simpson, E.F. (1949). Measurement of species diversity. Nature 163: 688.
Singh, A. (2014). Observations on the vascular wall flora of Varanasi city, India. *Int. J. Modern Biology and Medicine* 5(2): 40-55.
Smith, B. and J.B. Wilson (1996). A consumer's guide to evenness measures. *Oikos* 76: 70-82.
Smith, R.L. (1980). *Ecology and Field Biology*. Harper & row Publishers. New York, 835: P.
Tokeshi, M. (1993). Species abundance pattern and community structure. *Adv. Ecol. Res*. 24:112-186.
Tokeshi, M. (1996). Power fraction: A new explanation for species abundance patterns in species rich assemblages. *Oikos* 75: 543-550.
Tramer, E.J. (1969). Bird species diversity; components of Shannon's formula. *Ecology* 50:927-929.
Udayakumar, M., E. Bharathdasan, and T. Sekar (2014). Invasive alien flora of Thiruvaller District, Tamilnadu, India. *Scholars Acad. Journal of Bioscience* (SAJB) 2(4): 295-306.
Watkinson, A.E and J.L. Harper (1978). The demography of sand dune annual, *Vulpia fasciculata*m.1: The natural regulation of population. *J. Ecol.* 66: 15-33.
Whittaker, R.H. (1965). Dominance and diversity in land plant communities. Science, New York, 147: 250-260.
Whittaker, R.H. (1975). *Communities and Ecosystems*, Macmillan Publ. Co., N.Y. 385 p.

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