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The regeneration pattern and population structure of *Boerhaavia diffusa* L. in relation to disturbance in grasslands of north-eastern U.P.

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Boerhaavia diffusa L. is a wild perennial herb which may be encountered in different terrestrial habitats, ranging from managed grasslands, wastelands, agro-ecosystems to large forest gaps. The species of *Boerhaavia* ('Punernava') have been in use for medicinal purpose in different parts of India (ICMR 1976). The whole plant, preferably the root, is effectively used to cure several diseases including jaundice (Bajpay 1993; Srivastava & Padhya 1995). The present report refers to the regeneration strategy and the pattern of regrowth of the species after different degree of disturbance. Repeated clipping and trampling often results into an intricate shoot complex, borne by rather simpler root system. The effect of intense grazing, fire and water stress on the survival pattern (Chandrasekhara & Swamy 1995), the growth behaviour and architectural pattern (Escos *et al.* 1997) and population structure (William 1970; Ehrlen 1995) have been observed for several grassland species of common occurrence. Although the general biology and ecology of a few common species of *Boerhaavia* is well known (Bajpay 1993), the pattern of regeneration and population structure in relation to the level of disturbance is still least understood. The present study reports to the community relation, population status and survival strategy of *B. diffusa* as manifested in its sprouting behaviour, growth pattern and architectural plasticity in presence of disturbance of different degree.

The architectural development and growth strategy of *B. diffusa* was adjudged by repeated observations on a number of individuals of different age with description based on the terms and concepts of growth pattern propounded by Hallé *et al.* (1978). The architecture of *B. diffusa* is governed by mixed axes which are orthrotropic and superimposed. Each relay axis generally becomes pendulous and the renewable shoots arise on the upper surface of this axis. The part distal to this shoot becomes main axis. A dominant leader is seldom present in the construction of its overall architecture. Despite orthrotropic shoot construction, the habit of *Boerhaavia* is almost prostrate because of the rapid proliferation of relay axis over a length of main axis which develops mechanical tissue only after considerable interval. All the branches are sylleptic and emerge at every node in alternate fashion. The subtending leaf of these branches is about 3-times smaller than the opposite counterpart, devoid of any axillary branch. The primary opposite decussate orientation of leaves and branches is limited only to the most terminal shoots. The subsequent twisting of internodes brings leaves and branches in a single dorsi-ventral plane. The distal part of shoot which bears the composite inflorescence stalk, usually dies out after fruiting and thus triggers the emergence of proleptic branches during subsequent growing season. The cluster of monochasial cymes borne on peduncles is terminal in position and limits the growth of axial shoots. The species, therefore, conforms to Champgnat's model of architecture (Fig. 1a).

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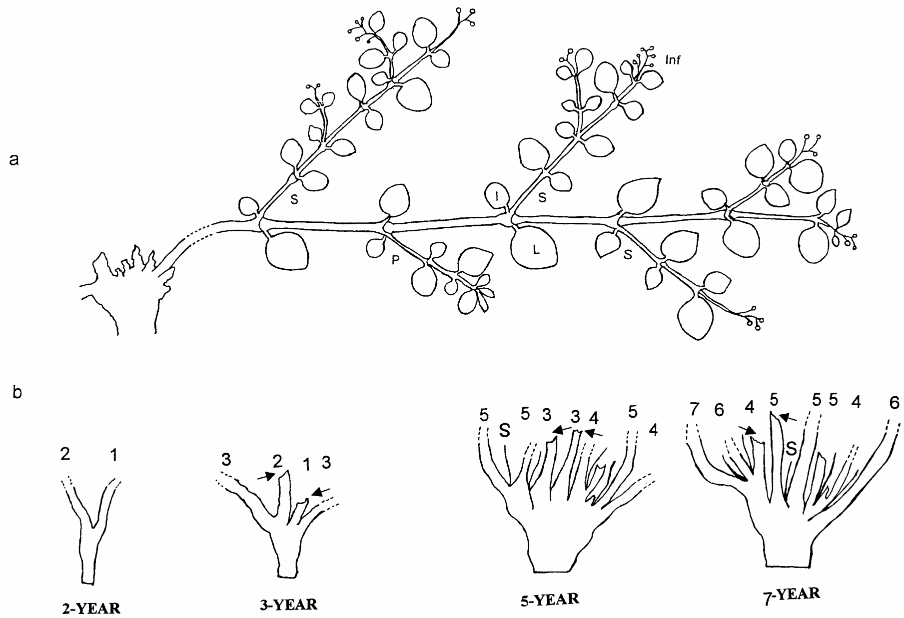

Fig. 1. Architectural development and growth pattern in *B. diffusa*. (a) Architectural plan of a diffuse axis (basal sprout) of a 4-year old individual with branching (S, sylleptic and P, Proleptic) upto II order. Each leaf pair had one small leaf, l destined to be axillant leaf for emerging axillary branch, and the other large leaf, L without any axillary branch. The inflorescence, Inf was terminal in position. (b) The pattern of emergence of shoots from the transition zone of young (2-yr) to old (7 yr) in the field conditions. The numbers denote the sequence of emerging shoots and the repetition of the same number equals the number of shoots emerging during any single annual growth period. S, is the short shoots which bore only a few leaves but no flower. Arrow indicates the points at which the shoot axes got severed due to disturbance.

The practices like harvesting of whole plant, trampling and grazing results in stumps of different shapes and sizes. The main sprout arising from stumps often repeats the characteristic architectural model of parent plant. The distal part of shoot may die even in undisturbed condition during the period of moisture stress. Substitution growth may occur within the same growing season if moisture condition becomes favourable. Initially the sequence of sprouts emerging from parent stump remains quite clear but gradually the position and sequence of emerging shoot gets obliterated due to formation of cavities, notches, scars and mounds at the base of shoot system. The age determination, on the basis of number of emerging shoots, may be quite authentic for younger stumps. In old ones, however, the position and number of emerging shoots gradually become uncertain. Nevertheless, on the basis of branches, basal thickness of shoot and length of main root, the age of parent plant may be easily approximated (Fig. 1b).

The base of old stump usually becomes irregularly thick and bears several small notches which provide microsites for the emergence of short shoots. They are about 5 ± 2 cm long bearing 2-4 pairs of small leaves which provide considerable effective leaf area. These shoots are always proleptic, bear no inflorescence and are ephemeral (life-span ~2 months). The number of short shoots per stump depends primarily upon stump thickness which, in turn, determines the amount of reserve nutrients. Such short shoots are known to channelize organic matter right into the base of the shoot rendering the transition point grow more thicker with age (Day & Gould 1994). While short shoots produced a few leaves but no inflorescence, the diffuse axes showed continuous extension growth and bore inflorescence. It may be argued that the production of long and short shoots enables the species to survive at sites facing disturbance of different intensities. The diffuse axes grow and capitalize upon through extensive shoot growth during most of the favourable growth period, depicting the exploitative strategy of the species. On the other hand, the emergence of short shoots during unfavourable period is indicative of the conservative strategy of species.

The significance of association of *B. diffusa* with its neighbour was tested through χ^2 using 2 x 2 contingency table. Due to the limitations that χ^2-test can detect only the presence and absence of association between any two species, the association of the species with its neighbour was measured through Cole's Association Index (Cole 1949). The association of *B. diffusa* with several neighbours was statistically significant. The degree and type of association could be correlated with architectural forms of neighbour species. The spatial features like branching pattern, leader growth and plant forms have been observed to have profound implication in regulation of community structure (Ricklefs 1993; Tiwari & Shukla 1995). The abundance of a species in an area is regulated also from the ability to withstand interference from other plants (Harper 1967). Species like *Euphorbia hirta, Tridax procumbens, Evolvulus nummularius* and *Vernonia cinerea* formed sparse vegetation especially at recurrently disturbed site causing little hindrance to the advancing shoots of *Boerhaavia*. As a result, it flourished quite often in the vicinity of these species and, therefore, showed positive association. On the other hand, *B. diffusa* showed negative association with *Desmodium triflorum, Anielema nudiflorum, Setaria glauca* and *Rungia pectinata*. These species formed dense vegetation near soil surface, thus causing hindrance to the free lateral spread of the shoots of *B. diffusa*. The occurrence of the latter species, however, was quite independent to that of *Croton bonplandianum, Triumfetta pentandra, Sida acuta, Dichanthium annulatum, Paspalum scorbiculatum* and *Gomphrena globosa* probably because these species showed least aggregation in these grasslands (Table 1). It is an established fact that the response of a plant species to the physical environment is largely conditioned by its interaction with other species (McIntosh 1970).

On the basis of the degree and type of disturbance, the grassland communities of the locality were marked as site I, II, and III. Occasional grazing and rare clipping was taken as low disturbance (Site I-at university campus), rare grazing but recurrent clipping and trampling as moderate disturbance (Site II- at golf course) and the trampling and frequent excavation of valuable roots as high disturbance (Site III - at public play-ground). A set of 20 individuals of each age class ranging from 1 yr to more than 6 yr were excavated with their roots intact from each of the three sites at the end of active growth period. The age of the parent plant was determined on the basis of annual growth pattern in terms of the number of regenerating shoots, short internodes, branches and leaf scars on the main axis and thickness at root: shoot transition point (Shukla & Ramakrishnan 1986). The age of all other individuals of *B. diffusa*, was determined by tallying with measured individuals. The population structure of *B. diffusa* was markedly different for different sites. The percent number of mature individuals belonging to higher age group (3-5 yr) was maximum at moderate disturbance but that of over- mature individuals (>6

Table 1. The degree of association between *B. diffusa* and its common neighbours in grassland vegetation, shown in terms of χ^2-values and Cole's Index (based on 2 x 2 contingency table).

Neighbour species	χ^2-values	Cole's Index
Positive associations:		
Euphorbia hirta L.	6.76*	+0.72
Evolvulus nummularius L.	0.82	+0.95
Tridax procumbens L.	9.59*	+0.35
Vernonia cinerea (L.) Less	4.68*	+0.73
Zornia gibbosa Span.	1.45*	+0.59
Negative associations:		
Anielema nudiflorum R. Br.	3.88*	-0.06
Desmodium triflorum L.	3.14	-0.07
Rungia pectinata L.	1.87	-0.10
Setaria glauca (L.) Beauv.	5.04*	-0.05
Independent occurrence:		
Croton bonplandianum Baill	0.01	-0.02
Dichanthium annulatum Forsk	0.001	-0.02
Gomphrena globosa L.	0.20	+0.22
Paspalum scrobiculatum L.	0.10	+0.01
Sida acuta Burm. f.	0.13	-0.005
Triumfetta pentandra A. Rich.	0.12	-0.009

* Significant at 5% probability level.

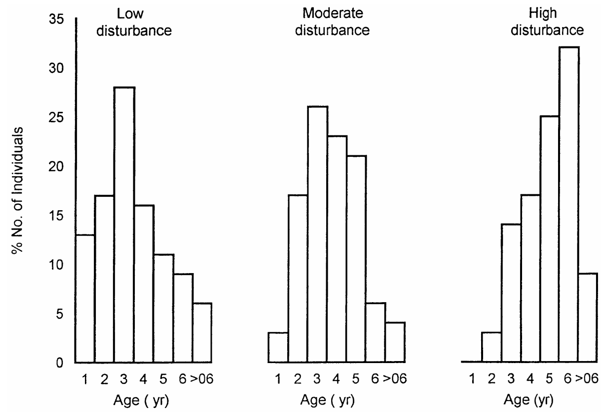

Fig. 2. The population structure of *B. diffusa* under low, moderate- and high disturbance levels, represented in the form of age structure.

yrs) was <10 at all the three sites, irrespective of disturbance level. At low to moderate disturbance this number increased but only up to 3rd year. The individuals of older age group (5-6 yr) were maximum in number at sites facing high disturbance. Very old (>6 yr) or very young (<2 yr) individuals were least in number (Fig. 2). The selective harvesting of old roots of *B. diffusa* may threaten the stability of the population unless there is high seedling survival which may be possible only under the condition of low stress and disturbance.

The grassland of northern plains now restricted only to waste and vacant lands have ever been a reservoir of weeds of great medicinal value. Since the cover of such lands is shrinking due to fast urban and agricultural expansion, some sort of reservoir may be needed in future to ensure the sustained supply of these plants. Also *ex-situ* conservation of such species assumes greater significance especially in a scenario when potential of wild plant harvesting falls short of the demand for commercial exploitation. In this regard it will be pertinent to know the effect of different level of disturbance on the growth pattern and survival strategy of such species before developing improved agro-technology for cultivation of medicinally valuable grassland species.

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