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# INFLUENCE OF BIOTIC DISTURBANCE ON THE PREPONDERANCE AND INTERSPECIFIC ASSOCIATION OF TWO COMMON FORBS IN THE GRASSLANDS AT VARANASI, INDIA

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## INTRODUCTION

The influence of biotic operations like grazing, mowing and scraping, on the preponderance of various grassland species has been the subject of ecological investigations since long (Weaver and Hansen 1941, Voigt and Weaver 1951, Kucera 1956, Ellison 1960). Attempts have been made to classify various species as 'decreasers,' 'increasers,' or 'indifferent' depending upon their response to grazing. Such studies have been competently reviewed by Ellison (1960). Dix (1959) endeavoured to give a quantitative expression to the species response towards grazing and evolved a formula for computing 'grazing susceptibility number' taking into account the density of species in ungrazed and grazed plots. This method was followed by Sant (1961) to indicate the relative changes in the densities of a few species on account of grazing. In spite of such a large number of studies made on this subject, only a few investigators attempted to base their conclusions on statistical grounds (Cook and Hurst 1962).

Since, "the vegetation is not a random assemblage of individuals of many species, but that plants are associated in communities, which have a definite structure and often a regular specific composition" (Poore 1962), plants growing in such communities may exhibit interspecific association or may be distributed independently. The importance of interspecific associations in understanding biological relationships among different species has been emphasized by Forbes (1907), Cole (1949), and Goodall (1952, 1953). In the statistical sense association is regarded as the amount of co-occurrence in excess or otherwise of that to be expected if two species are independently distributed. Positive association of this type is to be anticipated in the case of two species which exhibit overlapping habitat requirements or which favour mutual presence. Negative association, on the other hand, is exhibited when

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habitat requirements are distinct or where, through disoperative phenomena, one species tends to exclude the other (Cole 1949).

Keeping in view the above observations, it seemed interesting to investigate whether an increase in the intensity of herbage removal can influence the association between any two species. For the present study, two annual species, viz., *Murdannia malabarica* (L) Brueck. (=*Ancilema nudiflorum* R. Br.) and *Fimbristylis schoenoides* Vahl., which are fairly abundant in the grasslands at Varanasi (Singh 1967) were selected.

## MATERIAL AND METHODS

The study sites are located within the campus of the Banaras Hindu University situated about 5 kilometres south of Varanasi (25° 18′ North latitude and 83° 1′ East longitude) approximately 76.19 m above the sea level. This area forms a part of upper Gangetic plain, the latter being a distinct botanical region of India (Chatterjee 1939). The area is situated on 'western uplands' which is a natural division of Varanasi based on topography and land system (Agarwal and Mehrotra 1951-'52) and is covered with alluvial soil. According to the classification of Agarwal and Mehrotra (1952), the soils come under Banaras Soil Type III. Details of physico-chemical characters of soil are given by Ramam (1959) and Sant (1961) from the area of the present study. The climatic conditions have been described in detail by Misra (1958) and Singh (1968a).

From the site referred to as 'disturbed' in this paper, herbage is removed through cutting in November. In February the regrowth is grazed by cattle, thereafter grazing becomes rare. In the case of 'overdisturbed' site, after the herbage is removed through cutting in November, the field is scraped (herbage removed through cutting with a sharp flat instrument 'Khurpi' very close to the ground) frequently till the advent of next monsoon. Thus, although both the sites are disturbed, they differ in the scale of disturbance. Further details of biotic disturbance and its implication on the net primary production are given elsewhere (Singh 1968a).

The preponderance of the two test species on these sites has been studied through tiller analysis from June to October, 1964. In the present work each annual erect plant is considered as a plant unit and the terms 'tiller' and 'plant' have been considered as synonyms. On each site, during the last week of each month, a number of one square meter quadrats were laid at random. Each such quadrat was sub-divided into 10×10 cm segments. Four such segments were analysed from each quadrat at random. These segments (turves) were cut from the field upto 5 cm depth and brought to the laboratory. Each of them was then sub-divided into four 5×5 cm segments and individuals of the two species were counted separately. The data were then mixed and values for each 10×10 cm segment were recorded. In the present study density represents, "the average number of individuals of a species per quadrat, obtained by dividing the total number of individuals of that species in all quadrats by the total number of quadrats examined," and abundance represents, "the average number of individuals of a species per quadrat of occurrence, obtained by dividing the total number of individuals of that species by the number of quadrats in which it occurred" (Curtis 1956). Both these attributes are represented on square metre basis in the present communication. Frequency refers to the percentage of quadrats occupied by the species. According to Whitford (1949), "the ratio of abundance to frequency is a relative measure of the degree of contagiousness of the distribution of any species," and therefore A/F ratio has also been calculated.

For the test of the interspecific association and association of the two taxa with site condition, presence and absence of the species in quadrats (5×5 cm) have been recorded during September, 1964. The data are analysed through 2×2×2 and 2×2 contingency tables. The procedures for the same are indicated at appropriate places.

## RESULTS

### Phytosociologic values

The phytosociologic values are set in table 1 and are briefly discussed below for both the species separately.

*M. malabarica*:—Starting its life cycle after the first few showers of monsoon rainfall in June, the species attains maximum density in August on both the sites and declines slightly in September and considerably in October. The peak density is greater on the disturbed site (690 plants/sq. m) than that on the overdisturbed site (373 plants/sq. m). The higher frequency value for the disturbed site indicates greater dispersion on that site. The abundance is greater on overdisturbed site during June and July, and on disturbed site during August and September.

*F. schoenoides*:—Seedlings of this species also emerge in June. Its maximum density has been recorded in August on overdisturbed site (9,680 plants/sq. m) and in September on the disturbed site (8,562 plants/sq. m). The species is distributed over a larger area on overdisturbed site as compared to the other site, as indicated by the higher frequency values for overdisturbed site. On the overdisturbed site the abundance declines during August which reflects mortality of young plants in particularly crowded areas. Density, on the other hand, exhibits an increase in the same period reflecting the addition of new plants through seed germination. The decline in density during October on both the sites indicates mortality in the population as many plants complete their life cycle by that time and are obliterated.

### Test for species vs. species, and species vs. site condition association

The data for presence and absence of the species in sampling units are arranged in table 2 which is essentially a 2×2×2 table (Cook and Hurst 1962).

TABLE 1. *Phytosociologic Values for* M. malabarica *and* F. schoenoides *on the study sites*
F=frequency, D[1]=density, A[1]=abundance,
A/F=abundance/frequency ratio

(60 quadrats of 10 × 10 cm were examined in each month except September when only 29·5[2] and 30[3] quadrats on disturbed and overdisturbed sites respectively, were examined.)

| Month | M. malabarica | | | | | | | | F. schoenoides | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Disturbed site | | | | Overdisturbed site | | | | Disturbed site | | | | Overdisturbed site | | | |
| | F | D | A | A/F | F | D | A | A/F | F | D | A | A/F | F | D | A | A/F |
| June .. | 38·3 | 115 | 300 | 7·8 | 23·3 | 105 | 450 | 19·3 | 45·0 | 2565 | 5700 | 126·6 | 46·6 | 3033 | 6500 | 139·4 |
| July .. | 71·6 | 357 | 500 | 6·9 | 48·3 | 313 | 648 | 13·4 | 66·6 | 6210 | 9315 | 139·8 | 70·0 | 8400 | 12000 | 171·4 |
| August .. | 76·6 | 690 | 900 | 11·7 | 53·3 | 373 | 700 | 13·1 | 86·6 | 8246 | 9515 | 109·8 | 95·0 | 9680 | 10180 | 107·1 |
| September .. | 74·5 | 633 | 850 | 11·4 | 43·0 | 260 | 600 | 13·9 | 84·7 | 8562 | 10104 | 119·2 | 93·3 | 9353 | 10021 | 107·4 |
| October .. | 56·6 | 170 | 300 | 5·3 | 55·0 | 105 | 300 | 8·5 | 73·3 | 7408 | 10102 | 137·8 | 80·0 | 7208 | 9010 | 112·7 |

1. Expressed as number of plants/sq. m.
2. A total of 118 quadrats of 5×5 cm were examined.
3. A total of 120 quadrats of 5×5 cm were examined.

TABLE 2. *Expected and Observed Frequency values for* M. malabarica *and* F. schoenoides *arranged in a* $2\times2\times2$ *table*

| Species | | Site condition | Observed frequency (O) | Expected frequency (E) | $(O-E)^2/E$ $(\chi^2)$ |
|---|---|---|---|---|---|
| *F. schoenoides* | *M. malabarica* | | | | |
| − | − | Overdisturbed | 7 | 6·89 | 0·0017 |
| − | − | Disturbed | 11 | 6·87 | 2·4700 |
| − | + | Overdisturbed | 8 | 10·15 | 0·4550 |
| − | + | Disturbed | 8 | 9·98 | 0·3900 |
| + | − | Overdisturbed | 61 | 41·92 | 8·7000 |
| + | − | Disturbed | 18 | 41·22 | 13·0500 |
| + | + | Overdisturbed | 44 | 60·92 | 4·6900 |
| + | + | Disturbed | 81 | 59·91 | 7·4200 |
| Total | | | 238 | 237·86 | 37·1767 |

− represents absence and + represents presence of the species under which the signs are placed.

Expected frequency values were obtained by calculating the probability of presence (P) and absence (Q) as follows:—

$$P = \frac{\text{Species occurrence in quadrats}}{\text{total number of quadrats}}$$

$$Q = 1 - P$$

These values for different species and total values for the two site conditions have been arrived at as follows:

$P_1$ (*Fimbristylis*) $= 61 + 18 + 44 + 81 = 204/238$ (refer table 2) $= 0.8571$
$P_2$ (*Murdannia*) $= 8 + 8 + 44 + 81 = 141/238$ (refer table 2) $= 0·5924$
$Q_1$ (*Fimbristylis*) $= 1 - 0.8571 = 0.1429$
$Q_2$ (*Murdannia*) $= 1 - 0.5924 = 0·4076$
Pd (disturbed site condition) $= 118/238 = 0·4958$
Po (overdisturbed site condition) $= 120/238 = 0.5042$

Various expected values (E) set in table 2 have been calculated as below (n=238) :—

E − − overdisturbed = $(Q_1)(Q_2)(Po)\,n$ = 6·89
E − − disturbed = $(Q_1)(Q_2)(Pd)\,n$ = 6·87
E − + overdisturbed = $(Q_1)(P_2)(Po)\,n$ = 10·15
E − + disturbed = $(Q_1)(P_2)(Pd)\,n$ = 9·98
E + − overdisturbed = $(P_1)(Q_2)(Po)\,n$ = 41·92
E + − disturbed = $(P_1)(Q_2)(Pd)\,n$ = 41·22
E + + overdisturbed = $(P_1)(P_2)(Po)\,n$ = 60·92
E + + disturbed = $(P_1)(P_2)(Pd)\,n$ = 59·91

From table 2 the total chi-square value for species vs. species vs. site condition association comes to 37.18 with 4 degrees of freedom. This value is a composite value representing three chi-square values; one for species vs. species association, another for *F. schoenoides* vs. site condition and the third for *M. malabarica* vs. site condition. Since this value is statistically significant, it indicates association between the two species and site condition. This complex relation has been further investigated through the aid of individual 2×2 contingency tables so as to arrive at definite conclusions as regards to both the taxa separately.

The association between *M. malabarica* and *F. schoenoides* on the two sites has been tested through tables 3 and 4.

The chi-square ($x^2$) values have been calculated through the following formula and their significance was seen at 1 degree of freedom.

$$x^2 = \frac{(ad - bc)^2 n}{(a+b)\ (a+c)\ (b+d)\ (c+d)}$$

It is indicated from table 3 and the respective chi-square value which is significant at 0.01 level of probability that both the test species are significantly associated on the disturbed site.

TABLE 3. *Test for association between* M. malabarica *and* F. schoenoides *on the disturbed site*

| | | F. schoenoides | | |
|---|---|---|---|---|
| | | Number of quadrats in which present | Number of quadrats in which absent | Total |
| | | a | b | a+b |
| M. malabarica | Number of quadrats in which present | 81 | 8 | 89 |
| | | c | d | c+d |
| | Number of quadrats in which absent | 18 | 11 | 29 |
| | | a+c | b+d | n |
| | Total | 99 | 19 | 118 |

$\chi^2 = 11{\cdot}05$

Table 4 and the respective chi-square value (which is statistically insignificant) show, on the other hand, that both the species are distributed independently on the overdisturbed site.

TABLE 4. *Test for association between* M. malabarica *and* F. schoenoides *on the overdisturbed site*

| | | F. schoenoides | | |
|---|---|---|---|---|
| | | Number of quadrats in which present | Number of quadrats in which absent | Total |
| M. malabarica | Number of quadrats in which present | a<br>44 | b<br>8 | a+b<br>52 |
| | Number of quadrats in which absent | e<br>61 | d<br>7 | c+d<br>68 |
| | Total | a+c<br>105 | b+d<br>15 | n<br>120 |

$\chi^2 = 0 \cdot 698$

When the data for both the site conditions are bulked and then chi-square value for association between *M. malabarica* and *F. schoenoides* is calculated (Table 5) it is seen that their association is not statistically significant.

TABLE 5. *Test for association between* M. malabarica *and* F. schoenoides *taking into consideration both sites*

| | | F. schoenoides | | |
|---|---|---|---|---|
| | | Number of quadrats in which present | Number of quadrats in which absent | Total |
| M. malabarica | Number of quadrats in which present | a<br>125 | b<br>16 | a+b<br>141 |
| | Number of quadrats in which absent | c<br>79 | d<br>18 | c+d<br>97 |
| | Total | a+c<br>204 | b+d<br>34 | n<br>238 |

$\chi^2 = 3 \cdot 09$

The association between *F. schoenoides* and site condition has been tested through table 6. The chi-square value thus obtained indicates that the intensity of biotic disturbance has no influence on the presence of this species.

TABLE 6. *Test for association between* M. malabarica *and site condition*

| | | M. malabarica | | |
|---|---|---|---|---|
| | | Number of quadrats in which present | Number of quadrats in which absent | Total |
| Site condition | | a | b | a + b |
| | Overdisturbed | 52 | 68 | 120 |
| | | c | d | c + d |
| | Disturbed | 89 | 29 | 118 |
| | Total | a + c | b + d | n |
| | | 141 | 97 | 238 |

$\chi^2 = 25{\cdot}5$

On the other hand, the association between *M. malabarica* and site condition (Table 7) is statistically significant (chi-square value being significant at 0.01 level of probability). This indicates, therefore, that the magnitude of herbage removal has a profound influence on the occurrence of this species.

TABLE 7. *Test for association between* F. schoenoides *and site condition*

| | | F. schoenoides | | |
|---|---|---|---|---|
| | | Number of quadrats in which present | Number of quadrats in which absent | Total |
| Site condition | | a | b | a + b |
| | Overdisturbed | 105 | 15 | 120 |
| | | c | d | c + d |
| | Disturbed | 99 | 19 | 118 |
| | | a + c | b + d | n |
| | Total | 204 | 34 | 238 |

$\chi^2 = 0{\cdot}63$

From the various tests described so far it has been elucidated whether a species is associated with the other species and whether these species are associated with the site conditions. It now remains to investigate whether the species show positive association or they are associated negatively among themselves and the site condition. For this purpose expected values for each of the attributes in tables 3–7 have been calculated as follows, assuming that the species are independently distributed with regard to each other as well as with the site conditions :—

$$a_1 = \frac{(a + c) \times (a + b)}{n}$$

$$b_1 = \frac{(b + d) \times (a + b)}{n}$$

$$c_1 = \frac{(a + c) \times (c + d)}{n}$$

$$d_1 = \frac{(c + d) \times (b + d)}{n}$$

where $a_1$, $b_1$, $c_1$, $d_1$ are the expected values; a, b, c, d are the observed values and n is the total (refer Tables 3–7).

The values so obtained are compiled in table 8. A comparison of these values with the observed ones (Tables 3–7) indicates the following:

TABLE 8. *Expected values for different attributes (a, b, c, d) in tables 3–7*

| Table | Attribute | Expected value |
|---|---|---|
| III | a | 74·66 |
| | b | 14·33 |
| | c | 24·33 |
| | d | 4·66 |
| IV | a | 45·5 |
| | b | 6·5 |
| | c | 59·5 |
| | d | 8·5 |
| V | a | 120·8 |
| | b | 20·1 |
| | c | 82·7 |
| | d | 13·4 |
| VI | a | 71·1 |
| | b | 48·9 |
| | c | 69·9 |
| | d | 48·1 |
| VII | a | 102·8 |
| | b | 17·1 |
| | c | 101·1 |
| | d | 16·8 |

1. Both the test species co-occur in greater number of quadrats than would be expected if the species were independently distributed. Similarly the observed values for their occurrence in absence of each other are lower than the expected ones. This indicates that both the species are positively associated although the association becomes significant only on the disturbed site.
2. *M. malabarica* is present in lesser number of quadrats on overdisturbed site than would be expected if the species was indifferent to the biotic disturbance. On disturbed site it is recorded in more number of quadrats than expected. These observations indicate that an increase in biotic disturbance (through an increase in the intensity of herbage removal) is deleterious for its occurrence.
3. Occurrence of *F. schoenoides* is not influenced by the increase in biotic disturbance as the differences between expected and observed values are meagre. Moreover the chi-square value for its association with site condition is not significant statistically.

## DISCUSSION

As argued by Whitford (1949) and Curtis (1956) if the A/F ratio is taken as a relative measure of contagiousness of the species, it becomes apparent that *Fimbristylis schoenoides* exhibits more aggregation on both the disturbed and overdisturbed sites as compared to *Murdannia malabarica*. Since both the species do not possess any special mechanism for seed dispersal, this differential behaviour may be attributed to the following reasons. The seed output, reproductive capacity and the aggressive capacity of *F. schoenoides* may be considerably greater than that of *M. malabarica* so as to yield higher number of plants irrespective of distribution space. This situation is indicated by greater density of this taxon on both the sites as compared to *M. malabarica*. However, another and more important factor involved is the capability to withstand intra-specific competition. If greater number of individuals of the same species are to grow within a limited space they have to be least susceptible to competitive effects from each other. Pielou (1960, 1962) has explained the distribution of trees in forest stands on the basis of their capacity to withstand intra– and interspecific competition; and has argued that the species which show aggregated distribution are more tolerant of intra-specific competition.

The data reported here further indicate the profound effect of site condition (biotic disturbance) on the nature of species distribution. Although there is no consistent difference in the relative contagiousness of *F. schoenoides* on the two sites except for minor fluctuations, *M. malabarica* evidently is distributed more contagiously on the overdisturbed site as compared to the disturbed one. It will be interesting here to recall that an increase in the intensity of herbage removal (i.e., on overdisturbed site) decreases the frequency of occurrence of this species and increases the abundance during the earlier and hence more crucial period of growth (i.e., June and July). It may, therefore, be argued that overdisturbance, somehow, reduces the effective distribution space for this species. By the term 'effective distribution space' is meant the space available for this species to colonise and grow. The limitation in the effective distribution space may be brought about by a number of factors. Apart from the physico-chemical factors, which have been shown by Sant (1961) to be greatly modified by overgrazing, the total vegetal density and botanical composition during its period of occurrence may have profound influence. Singh (1967) has recorded that in overdisturbed grassfields in the present area, total vegetal density, particularly of annual species, is considerably greater during the rainy season, and that the floristic composition is altered. While the increase in the total vegetal density may reduce physically the distribution space it may also influence the plants by reducing the light intensity at particularly dense spots. That various species differ in the capacity to grow under reduced light intensities is a well-known fact (Donald 1961, Singh 1968b) and as such differential response of various species towards this factor could be expected. The change in the floristic composition, due to overdisturbance, may also introduce species which have similar habitat requirements as *M. malabarica* and as such may intensify the competitive effects. *F. schoenoides* on the other hand, exhibits no association with site condition, that means that the species is indifferent to the scale of disturbance as far as occurrence is concerned.

Apart from the habitat condition, the march of the season also appears to influence the contagiousness of the species. The values of A/F ratio fluctuate throughout the growing period and fairly indicate the pattern of addition of new plants through seed germination as well as mortality. In *M. malabarica* the A/F ratio declines considerably in October. This reflects that there is relatively greater early mortality of plants from the more crowded areas resulting in greater reduction in abundance than frequency. In *F. schoenoides* the situation is different as the A/F ratio in October shows an increase over that in the preceding month. This indicates greater early mortality in widely scattered plants as compared to those growing in crowded positions. Thus *F. schoenoides* appears to be more tolerant of intraspecific competition than *M. malabarica*.

The tendency of the two species to be positively associated indicates their overlapping habitat requirements as argued by Cole (1949), and Cook and Hurst (1962). The data, however, indicate statistically significant positive association only on the disturbed site. On the overdisturbed site the species seem to be independently distributed. In seeking an explanation for their behaviour, the value of density and A/F ratio have to be reconsidered. It is evident that on the overdisturbed site, although there is not much difference in the occurrence, the density of *F. schoenoides* has increased. That means that the individuals of *M. malabarica* will be subjected to intenser competition from *F. schoenoides* by virtue of the increased density of latter species on this site. It has been earlier indicated that owing to the reduction in the effective distribution space, the individuals of *M. malabarica* become more aggregated on overdisturbed site. Thus the relative increase in the population of both the species within the effective distribution space of one species may impose certain limitation to the area in which both the species can co-occur. Hence, the two species may tend to be distributed independently on such habitats.

The study clearly illustrates that the influence of site condition is profound on the interspecific association of this pair of species and it is advisable to take into consideration the habitat condition before any generalised statements are made on their mutual association.


## SUMMARY

Investigation on the influence of biotic disturbance (herbage removal) on the preponderance of *Murdannia malabarica* and *Fimbristylis schoenoides*, which are common forbs in the grasslands at Varanasi (India), was conducted through tiller analysis. The data indicate that an increase in the intensity of herbage removal results in greater preponderance of *F. schoenoides* while the same reduces the occurrence of *M. malabarica.* Statistical analyses reveal that *M. malabarica* and *F. schoenoides* are positively associated on disturbed site while they tend to be independently distributed on the overdisturbed site. The implication of biotic disturbance on the interspecific association has been discussed in detail.



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