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CONTRIBUTION TO THE ECOLOGY OF TEN NOXIOUS WEEDS

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I. Introduction

The improved communications through the last 200 years have facilitated the migration of weeds from America to India and *vice versa*. The Terminology Committee of the Weed Society of America have prepared in 1962 a list of annual and perennial herbaceous weeds of the U.S.A. of which at least 95 species are common in the Upper Gangetic Plain. Out of these, the following ten which range from xeric to hydric character, have been selected for detailed investigation of their ecological life-history:

Cassia tora L., *Eleusine indica* (L.) Gaertn., *Portulaca oleracea* L., *Anagallis arvensis* L., *Amaranthus spinosus* L., *Chenopodium album* L., *Cyperus rotundus* L., *Eleocharis palustris* R.Br., *Echhornia crassipes* Solms. and *Spirodela polyrhiza* (L.) Schleid.

The work on this project entitled "Ecological Studies of Noxious Weeds, Common to India and America, which are becoming an increasing problem in the Upper Gangetic Plains" has been undertaken since 1st September 1964 with Prof. R. Misra as the Principal Investigator and Dr. K. C. Misra as the Research Officer. The scheme is financed by the U.S.A. Government through their P.L. 480 Funds.

These studies will help in explaining the mechanisms of acclimatization and speciation in the concerned weeds and may ultimately be helpful in selecting suitable measures for their control. In the present communication, results obtained during the period September 1964 to June 1967 have been briefly reviewed. During this period, studies were mostly directed towards understanding the germination behaviour of seeds, sprouting behaviour of vegetative propagules, influence of various environmental factors on the growth performance, and population differentiation.

II. Seed Germination

1. *Dormancy*

(i) *Due to seed coat.*—Mature seeds of *Cassia tora* have impermeable seed coats, which become increasingly permeable during storage, and upon mechanical or chemical scarification (Singh, J. S., 1965 *a*). The

seed coat impermeability develops towards the end of seed maturation, green immature seeds being permeable (Singh, J. S., 1966 *a*).

(ii) *Due to inhibitor.*—Seeds of *Anagallis arvensis* show post harvest, dormancy varying from four months to more than a year (Singh, K. P., 1966 *a*). Its seeds contain a water-soluble inhibitor which controls dormancy ; higher amount of inhibitor being associated with deeper dormancy. Higher storage temperature and/or washing of seeds artificially or by natural rainfall, decreases the amount of inhibitor, thereby making the seeds non-dormant (Singh, K. P., 1965 *a*, 1966 *a*).

2. *Temperature*

Winter annuals, namely, *Anagallis arvensis* (Singh, K. P., 1966 *a*) and *Chenopodium album* (Mukherjie, 1965*a*) germinate at low temperature (10–20° C). Prechilling increases percentage germination in *Eleusine indica* (Singh, J. S., 1965*b*), and *Chenopodium album*, brown seeds of which germinate even at sub-freezing temperature (Mukherjie, 1965*a*, 1967*a*). Fresh seeds of *Amaranthus spinosus* (Mukherjie, 1965*b*) and aged seeds of *Portulaca oleracea* (Singh, K. P., 1965 *b*) show maximum germination at 40° C, while those of *Cassia tora* (Singh, J. S., 1965*a*) and *Cyperus rotundus* (Tripathi, 1966*a*) do so at 30° C. On the other hand, freshly collected seeds of *Eleusine indica* (Singh, J. S., 1965*b*) and *Portulaca oleracea* (Singh, K. P., 1966 *b*) exhibit distinct thermoperiodicity, germinating better at alternating low and high temperatures (20–40° C and 20–30° C respectively). However, with the passage of time, the seeds of these species are able to germinate at constant temperatures.

3. *Light*

Seeds of *Anagallis arvensis* (Singh, K. P., 1966*a*), *Portulaca oleracea* (Singh, K. P., 1966*b*), *Eleusine indica* (Singh, J. S., 1966*g*) and *Chenopodium album* (Mukherjie, 1965*a*) are light sensitive. In the case of *Portulaca oleracea* freshly collected seeds require photoperiodic (alternate light and dark) conditions for maximum germination, but during storage their specific light requirement decreases and they germinate considerably in darkness. Light distinctly improves germination of freshly collected seeds of *Eleusine indica* at 30° C. Presence of light is essential for germination of seeds of *Anagallis arvensis*, because even 4-year old seeds show very little germination ($\geqslant$ 5%) in darkness (Singh, K. P., 1967*a*).

4. *Storage Conditions*

(1) *Dry storage at different temperatures.*—Germinability of seeds of *Cassia tora* (Singh, J.S., 1966*a*) and *Anagallis arvensis* (Singh, K.P., 1966*a*) increases with increase in storage temperature, the maximum being obtained at storage temperatures of 30 and 40° C, respectively. In *Cyperus rotundus* seed germinability increases during storage at 30–35° C

(Tripathi, 1966*a*). Storage of seeds of *Chenopodium album* at different temperatures decreases the germinability and the capacity of plumule emergence (Mukherjie, 1966*a*, 1967*b*). Freshly collected seeds of this species can tolerate more seed coat damage than the stored ones (Mukherjie, 1966*b*). Seeds of *Portulaca oleracea* show no differential response to storage temperatures ranging between 10–40° C for 50 days (Singh, K. P., 1965 *b*).

(ii) *Storage in soil.*—Seeds of *Anagallis arvensis* were enclosed in perforated nylon bags and sealed glass tubes, which were buried at different depths in the soil in the month of June. After few heavy showers in July, the seeds contained in the nylon bags gave 100% germination, while those in the sealed tubes showed significantly lower germination. However, after the rainy season, percentage germination of seeds from nylon bags slightly decreased (Singh, K. P., 1966 *a*).

5. *Growth-regulating Substances*

Gibberellic acid replaces the light requirement of seeds of *Anagallis arvensis* at 18–20° C. When limited light is provided increasing concentrations of gibberellic acid promote germination. However, when light requirement is satisfied higher concentrations of gibberellic acid tend to depress the germination (Singh, K. P., 1967 *a*). In the case of *Chenopodium album* gibberellic acid has been found to be better germination promoter than indole acetic acid (Mukherjie, 1967 *b*). Various concentrations of gibberellic acid, indole-acetic acid and coumarin failed to show any marked effect on the germinability of aged seeds of *Amaranthus spinosus* at 40° C (Mukherjie, 1966 *c*).

III. Vegetative Propagation

Tuber population of *Cyperus rotundus* in soil is considerable (187–288/900 sq cm) and majority of them occur in the top 10 cm horizon (Tripathi, 1966 *b*). Clipping of aerial shoots considerably decreases tuber production (Tipathi, 1966 *c*). Upon air drying, the tubers quickly lose moisture and their sprouting percentage decreases and completely stops if their moisture content falls below 13% (Tripathi, 1966 *b*). Sprouting of tubers increases with the increase in temperature up to 40° C (Tripathi, 1965 *a*). In *Eichhornia crassipes*, when the rhizomes are air-dried upto a moisture content of 8·23% or dried in mud upto 7·92%, they lose sprouting capacity (Das, 1955 *a*). Turions of *Spirodela polyrhiza* are capable of sprouting only when stored under water (Das, 1965 *a*). In this species the transversely cut fronds produce new fronds exactly as the intact ones, but longitudinally cut ones lose this capacity (Das, 1967 *a*). Apical dominance in sprouting of rhizomes has been demonstrated in *Eliocharis palustris* (Tripathi, 1965 *b*) and *Eichhornia crassipes* (Das, 1966 *b*).

IV. Effect of Environmental Factors on Growth Performance

1. *Temperature*

(i) *Effect of exposure to sub-freezing temperature.*—Influence of repeated daily exposures to sub-freezing temperature (−10 to −15° C) on seedlings of *Eleusine indica* (Singh, J. S., 1965 *c*) and *Anagallis arvensis* (Singh, K. P., 1966 *c*), and fresh sprouts from tubers of *Cyperus rotundus* (Tripathi, 1965 *c*) have been studied. In *Eleusine indica* heavy mortality occurs (upto 80%), if the seedlings are exposed for 2 hours/day for 6 days. This treatment results in decrease in height (upto 92%) and early flowering. Single 4 hours exposure results in 44% mortality of *Anagallis arvensis* seedlings, while repeated exposures (1·5–2·0 hours/day) for 6 days can cause 100% mortality. In this respect *Cyperus rotundus* is more resistant, where even 3 hours of daily exposure for 8 days results only in 40% mortality, shorter exposures being ineffective.

(ii) *Growth at different temperature.*—Growth of plants maintained at 15° C in the phytotron and in an adjoining glasshouse (30–40° C) has been studied in the following species: *Cassia tora* (Singh, J. S., 1967 *g*), *Eleusine indica* (Singh, J. S., 1966 *b*), *Portulaca oleracea* (Singh, K. P., 1966*d*, 1967*b*), *Cyperus rotundus*, (Tripathi, 1966*d*), *Spirodela polyrhiza* (Das, 1966 *c*) and *Eichhornia crassipes* (Das, 1967 *b*). *Cassia tora* shows an increase in total leaf dry weight, total leaf area, optical density of leaf chlorophyll extract, height of plants, stem diameter and dry matter yield at 30-40° C than 15° C *Eleusine indica* grows better and flowers earlier at higher temperature. Similarly, high temperature favours the growth and production of tubers in *Cyperus rotundus*. However, Pandey (1967*e*) recorded that in this species the growth of aerial parts increases and that of the underground part is suppressed on treatment to low temperature for three months after five months growth under atmospheric conditions. Growth of both the varieties of *Portulaca oleracea* is favoured by higher temperature, and at 15° C the vegetative growth of broad leaf variety is only slightly depressed, whereas that of narrow leaf variety is significantly decreased. On the other hand low temperature adversely affects the seed production, which is reduced to about 50% and 25% (of that at higher temperature) in the broad leaf and the narrow leaf varieties, respectively. Maximum growth in *Spirodela polyrhiza* takes place at 25° C, although there is no direct relationship between growth rate and the temperature. In the case of *Eichhornia crassipes*, growth completely stops at 15° C, while the plants are considerably more vigorous when grown at higher temperature.

2. *Light*

(i) *Day length.*—*Eleusine indica* flowers between 6–16 hours day length and its vegetative growth increases with increase in day length up to 14 hours, beyond which the values decline sharply (Singh, J. S., 1966 *c*). Both the varieties of *Portulaca oleracea* are day-neutral;

although they show a quantitative response in flowering, which increases with increasing day length attaining the maximum at 10 and 12 hours in narrow leaf and broad leaf varieties, respectively. The vegetative growth of broad leaf variety is not affected by day length varying between 6–16 hours, while the same increases up to 16 hours in the case of narrow leaf variety (Singh, K. P., 1966 *e*, 1967 *c*). *Anagallis arvensis* is a long-day plant having a critical day length of about 10 hours. Although this species is sensitive to photoperiodic stimulus at cotyledonary leaf stage, maximum sensitivity occurs at 6–18 leaf stage (Singh, K. P., 1967 *d*). When growing under non-inductive day length this species can be induced to flower by foliar spray of gibberellic acid (Singh, K. P., 1967 *e*). *Cyperus rotundus* is a quantitative intermediate day plant giving floral response between 8–14 hours day length (Pandey, 1967 *a*). Maximum dry matter production occurs in *Spirodela polyrhiza* under continuous light, while the minimum is found at 8 hour day length (Das, 1967 *c*).

(ii) *Light intensity*.—Growth of some of the species was studied under artificial shades, constructed with the help of 1, 2 or 3 layers of muslin cloth, which transmit approximately 70, 50 and 40% of sunlight, respectively. Controls were kept under full sunlight. Growth of *Eleusine indica*, as reflected by number of tillers, lateral spread, dry matter yield and number of inflorescence rays, is influenced favourably by increase in the intensity of sunlight. The plants are taller under shade (Singh, J. S., 1967 *b*). In *Cassia tora* seedling mortality increases with reduction of light intensity and growth performance is best at full sunlight, although dry matter production with certain limitations is maximum at 70% sunlight (Singh, J. S., 1967 *c*). The narrow leaf variety of *Portulaca oleracea* is an obligate heliophyte and its seed formation stops at 40% sunlight ; on the other hand broad leaf variety is a facultative sciophyte showing maximum growth at 70% sunlight (Singh, K. P., 1967 *f*). *Spirodela polyrhiza* is a sciophyte showing better growth under low light intensities (Das, 1967 *d*).

3. *Moisture*

Eleusine indica shows best growth when watered daily, and lesser irrigation frequencies reduce the growth performance and increase the mortality percentage (Singh, J. S., 1965 *d*). Vegetative multiplication in *Eleocharis palustris* is more rapid in saturated soil than under inundated or comparatively drier conditions (Pandey, 1967 *b*). Plants grown in tanks with varying depths of standing water exhibit maximum dry matter production by shoots in 25 cm. water depth, while the maximum height is recorded in 55 cm. deep water ; further increase in depth retards its growth (Pandey, 1967 *c*).

4. *Competition*

The existence of intraspecific competition within *Cassia tora* populations in field is demonstrated through the effect of increasing population density on morphological features, flower and fruit production and dry matter yield. Generally beyond a density of 10 plants/900 sq cm area growth performance decreases, although plants become considerably taller (Singh, J. S., 1967 *d*). Observations on plants of different localities indicate linear positive correlation between stem diameter and dry matter yield (Singh, J. S., 1967 *e*). Marked reduction in number of leaves, tuber production and sprouts, and above-ground dry matter yield is registered in *Cyperus rotundus* beyond a density of 6 plants per pot of 30 cm. diameter (Pandey, 1967 *d*). Mutual interaction between *Chenopodium album* and *Brassica campestris* is exhibited by their growth in mixed species cultures. The degree of interference increases with an increase in the population density (Mukherjie, 1967 *c*).

5. *Direction of Slope*

Being a heliophyte, *Eleusine indica* shows maximum growth on south facing slope and minimum on north; further the plants of north facing slope are erect while those of south facing slope and level ground are prostrate and spreading (Singh, J. S., 1967 *f*).

V. Population Differentiation

Provenance trial technique has been applied with a view to determine whether the wide distribution of *Cassia tora* and *Anagallis arvensis* althrough India is due to the wide ecological amplitude of the species or to the occurrence of distinct local populations. Plants were raised from seeds of seven localities distributed between 23–28° N. latitudes in the case of *Cassia tora* (Singh, J. S., 1966 *d*), and from eight localities between 24–27° N. latitudes in the case of *Anagallis arvensis* (Singh, K. P., 1967 *g*), under uniform culture conditions. Analysis of data on growth performance of the above cultures indicates the presence of latitudinally differentiated populations in both the taxa.

VI. Endogenous Rhythm

A study of the curvature behaviour of the inflorescence axis in *Eichhornia crassipes* suggests the presence of a free running endogenous rhythm (with a period of 25–40 hours), because the curvature is not associated with auxin action or the opening of the last flower as pointed out by other workers or any environmental stimulus (Das, 1965 *b*, 1966 *d*, 1967 *e*). *Spirodela polyrhiza* imported from the U.S.A. failed to grow under the normal light cycles at Varanasi, but when the cycle was reversed it started growing. This indicates that the populations from different longitudes have their distinct light and dark cycles which are endogenously controlled and can be modified by gradual changes in the phase (Das, 1967 *f*).

VII. Distribution

Because of the confusion about the taxonomic status of *Cassia tora*, which has often been treated as synonymous to *Cassia obtusifolia* L., it is difficult to trace the exact distribution of the former species, However, due to differences in the germination behaviour and the growth performance under uniform culture conditions, the above-mentioned species have been proved to be distinct (Singh, J. S., 1966 *a*), and the distribution of *Cassia tora* in India has been traced (Singh, J. S., 1966 *d*). Distribution maps of *Anagallis arvensis* (Singh, K. P., 1967*g*), *Eichhornia crassipes* (Das, 1967 *g*), *Spirodela polyrhiza* (Das, 1967 *f*), *Amaranthus spinosus* (Mukherjie, 1967 *d*), *Chenopodium album* (Mukherjie, 1967 *e*) and *Eleusine indica* (Singh, J. S., 1966 *f*) have also been prepared.

VIII. General Discussion

The aforementioned studies reveal interesting correlations between the range of optimal temperature for germination and the time at which various species occur in nature. Thus winter annuals, *viz.*, *Anagallis arvensis* and *Chenopodium album*, germinate best at low temperature, and are favoured by exposures to still lower temperatures. On the other hand, being a rainy season annual, *Cassia tora* germinates best at 30° C. Species like *Eleusine indica* and *Portulaca oleracea*, seedlings of which emerge from the ground almost all the year round, exhibit favourable response towards alternating low and high temperatures. Germination of freshly collected seeds of *Amaranthus spinosus*, which occurs abundantly on manure heaps, is favoured by high temperature (40° C). Temperature of such manure heaps remains higher and stable all the year round on account of the microbial activity, and the species thus appears to be acclimatized to such conditions. *Portulaca oleracea*, which produces abundant seedlings during summer months, provided moisture is adequate, possesses strongly heat-resistant seeds, the germination of which is considerable at 40° C.

The studies have revealed interesting aspects of dormancy, which seem to be adjusted to the environmental conditions to which the seeds are exposed after dispersal. As relatively moderate and stable temperature, and sufficient soil moisture are required for *Cassia tora*, conditions which do not exist at the time of seed dispersal (October-November), the germination has to be deferred till such conditions exist in rainy season. Even if few seedlings are able to emerge at the time of seed dispersal on account of favourable conditions, further growth is greatly hampered because of low temperature obtaining in winter season. A study of the growth at low temperature (15° C) supports this contention. Moreover, there is no special mechanism for seed dispersal in this species. As the seeds are heavy, wind is also not much effective, and the species has to ensure sufficient longevity for its seeds. The seed coat dormancy present in this case is an effective measure in this regard. These coats undergo mechanical and microbial scarification in the field and a good proportion of seeds becomes capable of germination at the advent of monsoon. Retention of seed coat impermeability in the rest of seeds ensures another crop if adverse conditions like flooding and drought are obtained. Similarly in the case of *Anagallis arvensis* the seeds contain an inhibitor which restricts its germination during summer. If the seedlings were to emerge in this season, further growth would be impossible as the plant cannot tolerate high temperatures. The inhibitor, however, is leached out by torrential downpours, during rainy season and the seeds become germinable when temperature falls to optimal range in winter. By virtue of this fact, after irrigations during winter season repeated fresh crops of seedlings appear.

In *Cyperus rotundus*, *Eleocharis palustris* and *Eichhornia crassipes* cut tubers/rhizomes are found to be capable of sprouting. This mechanism helps the dispersal and sustentation of the species even under heavy biotic disturbance. However, the fact that the propagules are susceptible to air-drying and the tubers are mostly concentrated in the upper 10 cm. soil horizon, is suggestive of a possible method of control through frequent ploughings without irrigation.

Experiments on the effect of environmental factors on growth performance of these weeds help in explaining their distribution in nature. Being a heliophytic herb, demanding exposed and lighter environments, *Eleusine indica* does not occur amongst tall crop plants and is restricted towards comparatively open margins of crop fields. Being a partial shade—tolerant as well as capable of growing in full sunlight, *Cassia tora* occurs in open as well as in sparsely populated crop fields, specially of *Cajanus indicus*, and open canopied forests. The narrow leaf variety of *Portulaca oleracea* which is a heliophyte, avoids dense crops while, being a facultative sciophyte, the broad leaf variety is capable of growing in comparatively denser crops as well as open situations. A careful consideration of these facts with respect to crop management may provide suitable means for suppression of these weeds.

Almost all the species, except the winter season annuals, grow better and produce greater amounts of dry matter at temperatures ranging from 30–40° C. This shows the acclimatization of these species to tropical conditions available here. At least two species, *viz.*, *Eleusine indica* and *Anagallis arvensis* are susceptible to exposures to sub-freezing temperatures. This indicates that populations of these species occurring in temperate American conditions may be altogether different ecological races.

The experiments on photoperiodic response of species so far studied, indicate that they are well adjusted to tropical conditions specially with regard to day length.

At least two species, *Cassia tora* and *Cyperus rotundus* appear to be susceptible to intraspecific competition. In *Cassia tora* this effect appears to be similar to that of artificial shade indicating light as a causative factor.

The species under investigation appear to be highly plastic. Provenance trials in the case of *Cassia tora* and *Anagallis arvensis* indicate the occurrence of distinct local populations which are differentiated latitudinally. The wide distribution of these two species in India appears to be due to this fact. In *Spirodela polyrhiza* there are two distinct seasonal populations, *viz.*, summer and the winter forms. These forms alternate with each other within a year, hence the species is available throughout.

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