SECTION V

CHAPTER 13

IMPORTANT FINDINGS AND GENERAL DISCUSSION

Autecological studies on three weeds - *Abutilon ramosum* Guill. & Perr., *Euphorbia geniculata* Orteg. and *Rivinia humilis* Linn. are presented in the thesis.

Out of these three species, *A. ramosum* is an indigenous weed having peculiar restricted distribution in Baroda, *E. geniculata* is an introduced agricultural weed which is rapidly spreading in this country, and *R. humilis* is an introduced garden plant which now grows as an escape in a particular locality in Baroda.

A. ramosum is a perennial shrub, *E. geniculata* is an annual herb, and *R. humilis* is a perennial herb. The three species have one feature in common, that they grow in more or less moist and shaded localities.

An account of the important climatic and edaphic factors of the study sites is given, and associates of the three species are listed.

An account of the distribution, habit and habitat of the species is given.

The morphology of root, stem, leaf, inflorescence, flower, fruit and seed of the three species is briefly described.

The important anatomical features of root, stem, petiole and leaf of the three species are briefly given.

The stomatal frequency and index in *A. ramosum* leaf range from 43.86 to 61.40 and 2.40 to 4.06 respectively in upper epidermis, and from 331.58 to 370.18 and 1849.12 to 1901.75 respectively in lower epidermis. The stomatal frequency and index in shade leaf of *E. geniculata* range from 252.63 to 294.74 and 12.48 to 13.15 respectively in upper epidermis, and from 335.09 to 408.77 and 20.97 to 22.73 respectively in lower epidermis. The values of stomatal frequency and index in sun leaf (from the plant growing in partly exposed locality) of *E. geniculata* are comparatively higher and range from 268.42 to 343.86 and 14.43 to 16.33 respectively in upper epidermis, and from 387.72 to 417.54 and 22.28 to 23.71 respectively in lower epidermis. In *R. humilis*, stomata are confined to the lower epidermis, and the stomatal frequency and index here range from 89.47 to 121.05 and 12.69 to 16.51 respectively.

The diploid chromosome number for *A. ramosum* worked out to be 2n = 16. That for *E. geniculata* (2n = 28) and *R. humilis* (2n = 108) as reported in the literature by various authors was confirmed.

The size, weight and moisture content of the seeds of the three species were determined.

The seed coat in seeds of *A. ramosum* is impermeable or only slightly permeable to water and so the seeds imbibe water at a considerably slow rate, the per cent imbibition being markedly lower. However, high temperature pre-treatment is effective in making the seed coat permeable. It could greatly improve imbibition capacity of the seeds and also the imbibition rate. The seed coat in *E. geniculata* seeds contains mucilaginous substances which form a sticky, swollen layer around the seed on coming in contact with water. This layer probably increases the imbibition capacity and the imbibition rate of the seeds to a considerable extent. The seeds of *R. humilis* imbibe water at a very slow rate, the per cent imbibition gradually increases with the increase in duration of soaking.

The average seed output and the reproductive capacity of - (i) *A. ramosum* are 2315 and 1852 respectively, (ii) *E. geniculata* are 165 and 134 respectively and (iii) *R. humilis* are 1586 and 1205 respectively.

The dispersal of seeds of *A. ramosum* seems to be very poor, since fruit or seed morphology does not show any specialised mechanism for wide dispersal by wind, animals or other agency. The seeds of *E. geniculata* are dispersed upto a distance of 4 m or more by an explosive dehiscence of the capsular fruits. The fruits or seeds of *R. humilis* are devoid of any special device for dispersal by wind, but the dispersing agencies in this species appear to be - (i) the water current in the irrigation channel by the side of which the plants are growing and (ii) ants.

Seed Germination

Dormancy - Seed coat of seeds of *A. ramosum* is impermeable to water and the seeds exhibit hard seed coat type dormancy. Some of the common methods, viz. mechanical scarification (rubbing the seeds between two sand papers for a few min), chemical scarification (con. H_2SO_4 treatment for 30 min), high temperature treatment (60°C for 6 h) and wet heating (in hot water for a few min) were found highly effective in making the seed coat permeable and thereby breaking dormancy of the seeds. However, pretreatment with organic solvents (absolute alcohol, acetone and chloroform) had no effect, while dry heating (on a hot plate for a few min) and wet heating (in boiling water for a few min) softened the seed coat, but were found to be severely harmful to the embryo.

A.ramosum seeds can endure comparatively longer duration (upto 3-4 h) of acid treatment without harm to the embryo. Further, it was observed that with increase in dry storage period the effective duration of acid treatment decreased. There seems to be probably a complicated interaction among the duration of dry storage of seeds, duration of acid treatment and temperatures prevailing during the course of the germination experiment.

Burial of the seeds in soil at the depths of 6 to 24 cm for 3 to 12 months was not effective in breaking their dormancy. Dry storage of the seeds at room conditions upto a period of 29 months was also not effective in breaking their dormancy. The experimental observations lead to assume that in nature *A. ramosum* seeds have dormancy period of probably more than one year.

Seeds of *E. geniculata* and *R. humilis* do not have any dormancy period and can readily germinate, if favourable conditions are available.

Hard seed coat type of dormancy and its ecological significance

Results of dormancy studies in *A. ramosum* are quite in accordance with those obtained by many other workers in various seeds possessing hard seed coat type of dormancy. The maturation of seeds of many species results not only in reduced water content but also in deposition of particular substances in the seed coverings to produce impermeability to water (Crocker, 1948). This is a genetic characteristic of certain plant families, but it can also be modified by particular environmental conditions and methods of handling. A. hard impervious seed coat has value in prolonging storage life, since the internal parts of such seeds, once dry, are held in sealed storage until the seed coverings become modified. The effective seed covering may be only the hardened outer seed coat, or it may include various parts of the pericarp which either are attached to the seed or surround it. A number of plant families contain species whose seeds have hard coats; these include the Leguminoseae, Malvaceae, Cannaceae, Geraniaceae, Chenopodiaceae, Convolvulaceae, Solanaceae (Harrington, 1916), Anacardiaceae (Stone and Juhren, 1951), and Rhamnaceae (Gratkowski, 1962). The plant group most commonly associated with hard seed coats is the legumes. Of 260 legume species examined, 85% had some or all impermeable seeds (Guppy, 1912). The water impermeability of the testa of hard seed is a physical exogenous dormancy (Nikolaeva, 1969), which may or may not be combined with other dormancy mechanisms.

nformation on water impermeable seeds has been catalogued by Barton (1967). Reviews and textbooks often give only brief atten ion to the dormancy of impermeable seeds (Crocker, 1948; Crock r and Barton, 1953; Eames, 1961; Salisbury and Rose, 1969; Nikolaeva, 1969; Viliers, 1972; Mayer and Poljakoff-Mayber, 1975; Copeland, 1976), while detailed reviews on seed impermeability have been presented by Porter (1949), Barton (1965 , Quinlivan (1971) and Ballard (1973). Although it is just over 100 years since Nobbe (1876) introduced the term "hard seed", our knowledge of the anatomy and physiology of this process is still incomplete (Rolston, 1978).

A number of investigators have endeavoured to establish a relation between impermeability and the structure of the seed coat. White (1908) has reported that the cuticular layer of the seed coat of small leguminous seeds, and the cuticle and a layer of palisade cells in the larger ones are impervious to water. On the other hand, Watson (1948) could not get any positive correlation between seed coat structure and impermeability.

Impermeable seed coats permit extension of life to many seeds so that they are distributed in time as well as space (Crocker and Barton, 1953). Not only do impermeable seeds remain viable for a long time, but under natural conditions increments of a seed population become permeable to water and germinate in successive intervals (Williams and Elliott, 1960).

Various treatments that will induce hard seeds to germinate have been known for many years, and the early methods have been reviewed by Porter (1949). Mechanical scarification in making the seed coat permeable has been successfully employed in a number of legumes (Hamly, 1932; Watson, 1948). Con. H_2SO_4 has been used experimentally for many years (Hiltner, 1902; Hopkins, 1923) with considerable success on many species. Even apparently acid resistant species such as Lupinus cosentini become permeable after 4 to 7 h soaking in con. H_2SO_4 (Horn and Hill, 1974). Various concentrations and durations of the acid treatment affect the germination in different ways (Prillwitz, 1930). Coe and Martin (1920) observed that the action of sulphuric acid destroyed the cuticle, subcuticular layer and caps in seed coat in five minutes in sweet clover seeds.

Alcohol and other organic solvents reduced hard seed in *Nelumbo lutea* (Shaw, 1929), but results in other species have been variable (Cavazza, 1951). In a detailed study of the legume sub-families, Barton (1947) found that seeds of species in Caesalpinoideae were made permeable by absolute ethyl alcohol, while those in Mimosoideae and Papilionoideae were generally unaffected or showed only slight increase in permeability. Acetone and petroleum ether caused small but significant reduction in the hardness of seeds of *Coronilla varia*, while the membrane penetrant dimethyl sulfoxide in combination with water or ethyl alcohol had little effect (Brant *et al.*, 1971).

Heating of the seeds for short durations has been acclaimed as a very convenient method for infusing permeability of the seed coat. In certain Acacias it has been observed that pre-soaking of seeds in boiling water was found very satisfactory (Anonymous, 1936), as also in *Medicago arabica* (Mc Nairn, 1917). Pre-soaking of seeds in boiling water for 30 sec has also been found successful in *Cornilla varia* (Brant *et al.*, 1971). Chatterji and Baxi (1966) reported beneficial effects of dry heating on the germination percentage of certain annual as well as perennial legumes of Western Rajasthan. A brief high temperature pretreatment increased the percentage germination in *Trianthema portulacastrum* (Ravel and Chatterji, 1968), but a longer heat treatment had deleterious effect due to desiccation.

Seed dormancy has been viewed as an important adaptation which provides insurance against germination under unfavourable period (Cooper, 1965). Impermeability of the seed coat is considered to be beneficial in increasing the longevity of seeds and thus prolonging the germination period. Ewart (1908) observed 22% germination in eighteen years old seeds of *Melilotus alba*.

In nature seeds get scarified presumably by the decomposing action of soil microbes, chemical action of organic and inorganic acids, mechanical action of soil particles, fluctuating temperatures, or other factors such as soil moisture, gaseous concentration, working singly or together (Mayer and Poljakoff-Mayber, 1963).

Type of soil - Garden soil, clay and wasteland soil were found equally favourable, and sand somewhat less favourable for germination of *A. ramosum* seeds. *E. geniculata* and *R. humilis* seeds seem to be well adapted to germinate in the aforesaid different types of soil.

Depth of sowing - The depths ranging from 0.5 to 3 cm were most favourable for germination of *A. ramosum* seeds, greater depths (from 4 to 10 cm) being unfavourable. *E. geniculata* and *R. humilis* seeds seem to be well adapted to germinate at the depths ranging from 1 to 6 cm. Quite a good number of seeds of *E. geniculata* can germinate on sowing even at the depth of 8 to 10 cm, while in case of *R. humilis* 8 and 10 cm depths seem to be very unfavourable.

Soil moisture content - 40 and 50% soil moisture levels were found to be most favourable for germination of *A. ramosum* seeds and 30 and 60% soil moisture levels also gave fairly good germination, but 20% level was very less favourable. *E. geniculata* seeds gave maximum germination at 50% soil moisture level, and fairly good germination at 60% level, while considerable reduction in germination was observed at 20 to 40% levels. In case of *R. humilis* 30, 40 and 50% soil moisture levels were found most favourable, 20% level also gave fairly good germination, but at 60% level germination was considerably reduced.

A high degree of ecological adaptibility or in other words wide ecological amplitude of a weed is intimately connected with its success. Ability to germinate well in variety of soil conditions, at greater depths and under wide range of soil moisture are also among the features contributing to the success of weeds.

The decrease in percentage germination with the increase in depth of sowing as observed in the species under investigation is probably due to reduced activity of soil microbes, presence ofsome gaseous inhibitors in soil atmosphere (Wess n and Wareing, 1969) or lack of light at lower depths.

Presence of adequate moisture in soil is an important factor affecting germination. The findings of the present investigation are quite in accordance with the field observations that all of the three species are adapted to grow in more or less moist soil. The experimental observation, that maximum or fairly good germination was obtained at 30 to 50% soil moisture in these species, explains their abundant occurrence in more or less moist situations.

Temperature - Germination was maximum at 30°C, fairly good at low temperature as obtained in refrigerator, and negligible at 40°C in case of *A. ramosum* seeds. *E. geniculata* seeds seem to be adapted to germinate under a fairly wide range of temperature, but 30°C seems to be the optimum, and 40°C seems to be harmful to the embryo. Germination of seeds of *R. humilis* was completely or almost completely suppressed at the constant temperatures tried, probably alternating temperatures as are obtained in nature are necessary for it.

Temperature too, must be in a favourable range for seed germination (Toole, 1955). In certain seeds it has been found that temperature at which they germinate is determined by genetic set up of the species. The response of seeds to temperature has significant ecological implication and has been extensively studied by various investigators (Asakawa, 1956; Toole *et al*., 1956; Vegis, 1964; Mayer and Poljakoff-Mayber, 1963). Thompson (1970) has also emphasized this fact and has correlated the germination responses of seeds to temperature with plant distribution.

Light - Seeds of *A. ramosum* are photoblastically neutral and germinate equally well in alternate diffuse light and darkness, continuous light and continuous darkness. Seeds of *E. geniculata* do not require presence of light for germination, however, alternate diffuse light and darkness was found to be the most favourable condition, and continuous light the least favourable one. Similarly, presence of light is not necessary for germination of *R. humilis* seeds, but continuous darkness was less favourable than the remaining two conditions (alternate diffuse light and darkness and continuous ~~darkness~~ light), which were the most favourable conditions, both being equally effective.

Colour (wavelength) of light - All the colours (wavelengths) were effective in giving considerably good germination in case of *A. ramosum* seeds, however, red, yellow, blue and green were equally effective and more favourable as compared to white and far-red. In case of *E. geniculata* seeds, best results were obtained under white and yellow light, while red, blue, green and far-red light showed more or less inhibitory effect on germination. The germination of *R. humilis* seeds was favoured by white, red and yellow light, and was more or less inhibited by blue, green and far-red light.

The importance of light as a factor in the germination of seeds has long been recognized. Species have been found to vary greatly in their response to light conditions during germination. Seeds, on the basis of their germination response to light, can be divided into groups, viz. (i) those which require light or are promoted by light, (ii) those which are inhibited by light and (iii) those which are indifferent to light.

Photoresponsive mechanisms are, however, intriguing and complex. The role of light in influencing seed germination has been discussed by various workers (Crocker, 1948; Crocker and Barton, 1953; Evenary, 1956; Borthwick *et al*., 1954; Toole, *et al* , 1956; Wareing, 1956; Toole, 1959; Koller *et al*., 1962; Fujii 1962; Isikawa and Yokohama, 1962; Downs, 1964; Borthwick, 1965).

The question of light requirement has been the subject of detailed studies under laboratory conditions. These studies have shown that different spectral zones affect germination quite differently. Flint and McAllister (1935 & 1937) ~~et al~~. ~~(1935-39~~) and Beadle (1953) cf. Singhal (1967) found that red and orange wavelengths are stimulatory and green and blue inhibitory to germination in lettuce. Wareing (1959) and Toole (1959) demonstrated that blue light is generally not promotive to germination, while Evenari *et al*. (1957 reported that blue light requires more time for effective exposure than red or far-red.

Hatano and Asakawa (1964) also reported that the effect of light on seed germination depends on its wavelength. Generally speaking, red light (around 660 mμ) stimulates and far-red light (around 730 mμ) inhibits germination. An important finding was the reversibility of both germination stimulation and germination inhibition by alternating red and far-red illuminations (Borthwick _et_ _al_., 1952).

Inorganic salts - The chlorides and nitrates of calcium, potassium and sodium at 0.5 to 2.0% concentrations inhibited germination of _A_. _ramosum_ seeds, the inhibition increasing with the increase in concentration of the salt, so much so that 1.0, 1.5 and 2.0% of NaCl; 1.5 and 2.0% of KCl; KNO_3 and $NaNO_3$; and 2.0% of $CaCl_2$ and $Ca(NO_3)_2$ suppressed germination totally or almost totally. The seeds could withstand lower concentrations (0.1 to 0.5%) of $Ca(NO_3)_2$ and 0.1% of KCl without showing significantly adverse effect on germination, but there was a significant reduction in germination under the effect of 0.1 to 0.5% of $CaCl_2$, KNO_3, NaCl and $NaNO_3$; and 0.2 to 0.5% of KCl.

The germination of _E_. _geniculata_ seeds was stimulated by 0. and 1.0% of $Ca(NO_3)_2$ and KNO_3; and 0.5% of $CaCl_2$ and KCl. It was not affected at all by 1.0% $CaCl_2$, 1.5% $Ca(NO_3)_2$ and 0.5% $NaNO_3$. However, 1.5 and 2.0% of $CaCl_2$ and KNO_3; 1.0 and 1.5% of KCl and $NaNO_3$; 0.5 and 1.0% of NaCl; and 2.0% of $Ca(NO_3)_2$ more or less inhibited germination; while it was totally suppressed in 2.0% of KCl and $NaNO_3$; and 1.5 and 2.0% of NaCl.

The chlorides and nitrates of calcium, potassium and sodium at comparatively higher concentrations (0.5 to 2.0%) inhibited germination either considerably or completely in case of *R. humilis* seeds. The lower concentrations (0.1 to 0.5%) of the same salts also showed inhibitory effect (except 0.1% $Ca(NO_3)_2$), but the inhibition caused by them was less pronounced. $Ca(NO_3)_2$ at 0.1% concentration had neither stimulatory nor inhibitory effect.

As reviewed by Bernstein and Hayward (1958), studies carried out on the effects of different salts on plants constitute mostly the effects of salinity on plants at their different stages, and those pertaining to germination relate mostly to the extent of retardation and reduction in the process due to different levels of salts and to the limits of tolerance of different species to salinity during germination.

Even low levels of salinity retard germination and higher levels reduce the total germination also (Ayers and Hayward cf. Bernstein and Hayward, 1958). In halophytes unlike in non-halophytes, germination does not drop with the increase in salinity but the process gets markedly impeded only when the limits of their tolerance or osmotic tension are reached.

The observed failure of the emergence of seedlings in saline soils which can apparently support the growth of established plants, have been attributed to the fact that in such habitats the seeds will be in more saline environment than the established plants (Wadleigh and Fireman cf. Bernstein and Hayward, 1958). The reduction in the soil moisture of the upper layers due evaporation aggravates the effects of salinity further (Ayers cf. Bernstein and Hayward, 1958). Inspite of this fact, it is interesting to note that species like corn and sugar beet have been found to show greater tolerance to salinity during their germination than during the subsequent phase of their life (Bernstein and Hayward, 1958). The inhibitory factor in salinity operating on the process of germination is chiefly osmotic (Ungar, 1962).

Borthwick (1937) found that the retarding effect of tap water on the germination of the seeds of Hypericum perforatum was due to calcium present in tap water.

Nitrates and germination in darkness - The nitrates of calcium, potassium, sodium and ammonium at 0.1 to 0.5% concentrations (except 0.5% KNO_3 and 0.5% $NaNO_3$) had neither stimulatory nor inhibitory effect on germination of **A.** ramosum seeds in darkness. 0.5% KNO_3 showed stimulatory effect and 0.5% $NaNO_3$ showed inhibitory effect on germination of these seeds in darkness.

The nitrates of calcium, potassium and sodium at certain concentrations (0.1 to 0.5% $Ca(NO_3)_2$; 0.2 and 0.3% KNO_3; 0.1

to 0.5% $NaNO_3$) had promoting effect on germination of *E. ge iculata* seeds in darkness. The germination was not affected in any way by 0.1 and 0.3% KNO_3, 0.5% $NaNO_3$, and 0.1 and 0.2% NH_4NO_3, while NH_4NO_3 at 0.3 and 0.5% concentrations had inhibitory effect.

The dark germination of *R. humilis* seeds was stimulated by 0. % $Ca(NO_3)_2$, and 0.1 and 0.2% $NaNO_3$, while it was inhibited by 0.5% concentration of $Ca(NO_3)_2$, KNO_3, $NaNO_3$ and NH_4NO . The remaining concentrations of the nitrates (0.1, 0.2 and 0.3% of KNO_3 and NH_4NO_3; 0.1 and 0.3% of $Ca(NO_3)_2$; and 0.3% aNO_3 had no effect on germination of these seeds.

Nitrates have been found to be effective promoters of germination in darkness especially of the light requiring seeds (Toole, *et al*., 1956; Kooler *et al*., 1962). They have also been found to break the dormancy of non-after-ripened seeds at the same time widening the temperature range for their germination (Vegis, 1964). In inducing the germination of tobacco, nitrates are known to act synergistically with GA_3 and kinetin. But whether the nitrates act on the embryo or the coat or get metabolised in the tissue is not known definitely (Koller *et al*., 1962).

Thiourea

It was observed that 50, 100, 200 and 1000 ppm of thiourea had no effect on germination of *A. ramosum* seeds, but 500 ppm thiourea had stimulatory effect. The germination of E. geniculata seeds was inhibited by 50 to 1000 ppm of thiourea, the inhibition increasing progressively with the increase in concentration. Thiourea at all concentrations ranging from 50 to 1000 ppm showed stimulatory effect on germination of R. humilis seeds, certain of the concentrations being equally effective.

Thiourea is known to substitute for light in breaking dormancy. Dark germination of many seeds is stimulated by thiourea (Mayer and Poljakoff-Mayber, 1975). In oak, as well as in other tree species such as Larix and Picea, thiourea substituted for cold temperature treatment (Deubner, 1932; Johnson, 1946). Thiourea substitutes for the natural germination stimulator which develops in Fraxinus seeds during chilling (Villiers and Wareing, 1960). Instances of interactions between the effect of thiourea and that of other factors affecting germination, such as light and temperature, are also known (Mayer and Poljakoff-Mayber, 1975).

GA_3

GA_3 at concentrations ranging from 50 to 2500 ppm had no effect either stimulatory or inhibitory on germination of A. ramosum seeds, but at 3000 ppm it showed inhibitory effect. In case of E. geniculata seeds stimulatory effect was observed at 50 to 3000 ppm of GA_3, certain of the concentrations being equally effective. GA_3 at concentrations ranging from 50 to 1500 ppm had neither stimulatory nor inhibitory effect on germination of R. humilis seeds, however, at concentrations beyond 1500 ppm there was a considerable inhibition of germination.

The possible significance of GA_3 as a natural factor in germination has been indicated by the detection of gibberellin like substances in a number of seeds (Phinney and West, 1960; Wellington, 1966). Lona (1956) and Kahn *et al*. (1956) were among the first to show that GA_3 stimulates the germination of *Lactuca scariola* and *Lactuca sativa* in the dark. In these cases GA_3 substituted for light in promoting germination. Other cases of substitution of GA_3 for red light are known, e.g. in the seeds of *Arabidopsis*, *Kalanchoe* and *Salsola volkensii* (Mayer and Poljakoff-Mayber, 1975). However, in a number of seeds whose germination is either promoted or inhibited by light, e.g. *Juncus maritimus*, *Oryzopsis miliacea* and others, treatment with GA_3 was not effective in promoting germination (Leizorowitz, 1959). Recently the germination of a number of species whose germination is not affected by light has been shown to be promoted by GA_3 (Kallio and Piiroinen, 1959; Corns, 1960).

Kinetin

It was observed that 10 ppm of kinetin showed stimulatory effect on germination of *A. ramosum* seeds; while 1, 5, 20 and 50 ppm concentrations had no effect; and concentrations beyond 50 ppm had progressively inhibiting effect so much so that

500 ppm gave only negligible germination. In case of germination of E. geniculata seeds it was found that 10 and 20 ppm of kinetin had stimulatory effect, while at concentrations ranging from 200 to 500 ppm it had inhibitory effect, and at 1, 5, 50 and 100 ppm concentrations it had no effect. The germination of seeds of R. humilis was promoted by 1 ppm of kinetin, while 5 ppm of kinetin had no effect, and concentrations from 10 ppm onwards had inhibitory effect.

There are contradictory reports in the literature regarding the role of kinetin in germination. Thus Mayer and Poljakoff-Mayber (1975) state, "While originally it was thought that kinetin substitutes red light in germination, it was later shown that in fact the seeds were sensitized by kinetin so that a smaller dose of light would induce their germination .... That kinetin does not substitute for light is also indicated by the fact that light-inhibited seeds such as Oryzopsis miliacea are stimulated by kinetin, while other light sensitive seeds such as Amaranthus are not affected by kinetin at all".

2,4-D

It was found that 0.5 and 5 ppm of 2,4-D stimulated germination of A. ramosum seeds, and that concentrations ranging from 10 to 1000 ppm had no effect, while 2000 ppm had inhibitory effect. In case of E. geniculata seeds all concentrations ranging from 0.5 to 2000 ppm of 2,4-D had inhibitory effect on germination. The germination of *R. humilis* seeds was stimulated by 0.5 ppm of 2,4-D, and was not affected by the concentrations ranging from 1 to 500 ppm, however, at 1000 and 2000 ppm concentrations germination was inhibited.

Thus *A. ramosum* and *R. humilis* seeds can tolerate comparatively higher concentrations (upto 1000 and 500 ppm respectively) of 2,4-D, whereas germination of *E. geniculata* seeds was inhibited by it even at concentration as low as 0.5 ppm.

As stated by Mayer and Poljakoff-Mayber (1975), "Herbicides of various kinds inhibit germination to a greater or lesser extent. Many of the commonly used substances, such as 2,4-D, affect germination of various seeds at comparatively low concentrations. The more effective of such herbicides can and have been used in order to prevent the germination of weed seeds in agricultural crops. No selective compound that will satisfactorily distinguish between crop and weed seeds appears to have been developed yet. A very frequent use of herbicides is as pre-emergence weed killers. In these cases the herbicide is applied in order to kill the seedling immediately after germination and before the main crop has germinated".

Growth performance in culture experiments

Light intensity

Light intensity has a profound influence on growth performance of *A. ramosum*, *E. geniculata* and *R. humilis*. Various growth parameters respond differently to different light intensities. The overall growth is, however, best in more or less shaded condition, while it is suppressed or stunted under open sunlight. With respect to most of the parameters studied, best performance, in all the three species, was obtained under 75% sunlight, in some cases 50% sunlight also being equally effective. In general, 25% sunlight favoured growth with respect to shoot length and leaf size. Root : shoot ratio both on fresh and dry weight basis was, however, adversely affected with the decrease in light intensity, maximum values of the ratio being obtained under open sunlight. This indicates that the deleterious effect of high light intensity is more pronounced on shoot than on root, and that the adverse effect of low light intensity was more pronounced on root than on shoot.

The varying light intensity had no significant effect on root circumference in *A. ramosum*, and on root length in *E. geniculata*.

The results of the experiments are in accordance with the field observations that all of the three species are adapted to grow in more or less shaded localities and that they have no tolerance to high light intensities as obtained under fully exposed situations. Further, the present findings are also supported by those of several other workers. Thus Black (1957) showed that reduction in light intensity leads to a very marked reduction in root growth and in the root : top ratio. Blackman and Templeman (1940) have also observed that root : top ratios under shade are lower than in full daylight. Shirley (1936) has also demonstrated that the development of roots of forest trees are always poor under low light intensity. Holch (1931) has reported that total depth and extent of roots depend upon the environment under which seedlings develop and he has observed that root systems in shade are miniature in comparison with the plants grown in open prairie. Popp (1926), Thut and Loomis (1944) have also reported that light intensity favours root elongation, which may be due to the fact that more of the photosynthates are translocated into the root.

Anderson (1955) reported larger leaf area as a result of shade in *Cornus florida* and *Viburnum prunifolium*. This finding is also supported by Blackmann and Rutter (1948) who found that the reduction in the light intensity increased the leaf area. Tolbert and Holch (1967) have reported that plants growing under high light intensities produce shorter leaves with smaller blades. The reduction in leaf area under high light intensities was also observed by Cline (1966) in *Schrophularia mariiandica* and Knecht and O'leary (1972) in *Phaseolus vulgaris*.

It was observed in the present investigation that floral initiation and maturity took place earlier in plants grown in 75% and 100% sunlight than in those grown in 50% and 25% sunlight in case of *A. ramosum* and *E. geniculata*. However, in *R. humilis* it was earlier in plants grown in 75% and 50% sunlight than in those grown in 25% and 100% sunlight. Hagan, Vaadia and Russel (1959) state, "In deep shade the delay in maturity probably resulted from two factors : cooler temperature in the shade which retarded the rate of growth and less photosynthesis which reduced the dry matter accumulation". Fritsch and Salisbury (1965) have also recognised that in the formation of flower buds, a higher light intensity is necessary.

It was further observed in case of all the three species, that among the plants grown in the artificial shades, the fresh and dry matter yield as well as the reproductive growth increased with the increase in light intensity. Hughes and Evans (1963) have reported that flowering and fruiting in *Impatiens parviflora* which is a day neutral plant, occurs equally well in dense shade as well as in full sun, though, seed production is much less in the former case. Many plants grown in strong light are capable of greater photosynthesis than the same plant grown in weak light (Wassink *et al*., 1956; Hiesey *et al*., 1967). Black

(19 7) observed that the total dry matter production decreases significantly with the decrease in light intensity in many tropical plants. Friend *et al*. (1962) have observed an increase in the dry matter of wheat with the increase in light intensity.

Soil moisture regime

It was observed that all of the three species investigated were highly susceptible to waterlogged condition, and that the plants grown under this condition could not survive for more than a few weeks. It was also observed that under once a week watering treatment the plants started showing signs of temporary wilting on the last dry day of each watering cycle i.e. on the day just before each succeeding irrigation day. This indicates that individuals of all the three species could not have tolerated further delay in watering.

Further, the differential watering treatment did not show significant effect on growth performance with respect to (i) length of root and longest axillary branch in *A. amosum*, (ii) root length, diameter of shoot and root, number of leaves and axillary branches in *E. geniculata*, and (iii) diameter of shoot and root, length and breadth of the largest leaf, number of inflorescence axes per plant, length of the longest fruiting inflorescence and the number of fruits on it, fresh weight of root and dry weight of root and dry weight of shoot and root in *R. humilis*.

The growth performance was significantly better under daily watering treatment than under once a week watering treatment with respect to - (i) most of the parameters studied in *A. ramosum*, (ii) shoot length, length of the longest axillary branch, length and breadth of the largest leaf, number of fruits per plant, fresh weight of shoot, dry weight of shoot and root in *E. geniculata* and (iii) shoot length, number of leaves and fresh weight of shoot in *R. humilis*.

Daily watering helped to maintain favourable level of soil moisture, so the plants could show better performance under that treatment; while once a week watering treatment could not maintain favourable level of soil moisture, so the plants under that treatment showed poorer performance. In general, the plants could withstand a gap of 2 or 3 dry days between two succeeding irrigation days without much harm, but when the gap is extended upto 6 days, significantly adverse effect is manifested in several characters. Further, the results indicate that though all of the three species can survive the water stress condition under once a week watering treatment, comparatively higher levels of soil moisture are needed for favourable effect on growth.

In *R. humilis*, it was observed that water stress condition under once a week watering treatment significantly stimulated root penetration.

The results of the experiments are in accordance with the field observations that all of the three species are adapted to grow in more or less moist soil, and are never found growing in extremely dry soil or in waterlogged condition. Further, the present findings are also supported by those of several other workers. Durell (1941) reported that most of the plants show either poor growth or die early in submerged soil. It may not be the excess of water which is harmful, but the lack of aeration resulting from submersion seems to be more important factor for plant growth. It has also been shown in many plants that their production is lowered when grown in excessively wet soils (Richards and Wadleigh, 1952; Kramer, 1963). Gardner (1960) attributed it to the poor aeration which hampers the development of deep and healthy roots and their functioning (Russel, 1959).

Stanhill (1957) has defined 'soil moisture regime' as an irrigation treatment in which the soil is allowed to dry until a definite measured point is reached within the available water range before sufficient water is supplied to restore the entire root zone to field capacity.

"The water as it affects the growth process is primarily an internal factor, but one which is influenced by number of environmental conditions. Any internal or external factor influencing the rate of intake of water or the utilization of water in metabolic processes will, therefore, play a part in determining the rate of growth" (Ch nz Tsui, 1948).

There has been some disagreement about the degree of availability of water to plants in drying soil over the range from field capacity to wilting percentage. Hagan *et al.* (1959) interpreting plant responses to soil moisture regimes, state that one group of investigators maintains that soil moisture is available for plant growth equally over the range from field capacity to permanent wilting percentage, whereas another group maintains that plant growth shows differential response as soil moisture varies between field capacity and permanent wilting percentage. Several experimental evidences have been advanced supporting the two views. There are many observations which indicate that plant processes are markedly influenced by decreasing soil moisture, and that real effects on metabolism and growth are manifested sometime before the soil actually approaches the wilting percentage (Beckett and Dunshee, 19[illegible]; Aldrich *et al.*, 1942; Ayers *et al.*, 1943; and Koz owski, 1949). The three species under the present investigation also exhibit more or less graded growth response from daily watering to delayed watering treatments, thus supporting the view that plant growth shows differential response as soil moisture varies between field capacity and permanent wilting percentage.

Stanhill (1958) has remarked that soil moisture status during the life cycle of the crop has a greater effect on the yield and that the dry matter production is highest in the wettest regime. Maurer *et al*. (1968) have reported that the moisture stress decreases both the branching and the number of leaves in beans. Daubenmire (1959), Lahiri and Kharabanda (1968) have observed that the size of leaves decreased with the decrease in soil moisture.

Davidson (1969) has reported that the root growth is stimulated by stress due to less moisture.

Organic matter content in soil

The presence of organic manure in the soil has a profound influence on the growth performance of *A. ramosum*, *E. geniculata* and *R. humilis*. In general, growth performance of all of the three species with respect to almost all the parameters studied was significantly higher in the soil where more or less manure was added as compared to that in the soil where no manure was added. The overall growth was best either in the soil with higher proportion of manure or in pure manure, whereas it was poorest in the soil where no manure was added. However, root : shoot ratio both on fresh and dry weight basis especially in case of *R. humilis* and to some extent in *A. ramosum* was maximum in the soil where no manure was added, and a progressive decline in its value was observed with the increase in the proportion of the manure added. This indicates that the favourable effect of manuring on growth is more pronounced in shoot than in root.

The differential manuring treatments had no significant effect on growth with respect to root length in *A. ramosum* and *R. humilis*.

The results of the experiments are in accordance with the field observations that all of the three species prefer soil more or less rich in organic matter content, the condition which is fulfilled by the presence of decaying litter in their natural habitat. Further, the present findings are also supported by those of several other workers.

The organic matter helps in the better growth of plants in various ways - by adding nutrients in the soil and by improving soil properties such as structure, porosity, tilth, water-holding capacity etc. It is known that the fertility of the soil increases to a large extent with the application of organic matter (Daubenmire, 1959; Buckman, *et al.*, 1952). Fritsch and Salisbury (1965) also state that humus present on the soil provides valuable nutrients to it. Vitamins and various growth promoting substances have been isolated from compost and cowdung manure (Starkey, 194 ; Steward and Anderson, 1942 and Carpenter, 1943). Khristeva (1958) is of the opinion that the humic acids entering plant at an early stage of development are supplementary sources of respiratory catalysts which cause an increase in living activity of plants and thus resulting in intensified enzyme systems, accelerated cell division, greater development of root system and high dry matter yield. Kononova (1961) stated systematic fertilizing with farmyard manure one of the measures favouring soil improvement.

Intraspecific competition

It was observed that growth of *A. ramosum*, *E. geniculata* and *R. humilis* with respect to all the parameters studied suffered heavily under the stress of intraspecific competition with increasing population density. The best performance was obtained in the set where there was no competition, but thereafter a progressive decline in the values of all the parameters was observed with the increase in population density. The fresh and dry matter yield of shoot and root and the reproductive potential as evidenced by the number of fruits or inflorescence axes per plant are the characters which suffered more heavily than the remaining ones. Further the deleterious effect of increasing stress of intraspecific competition on growth was more pronounced on shoot as compared to root, as indicated by the progressive rise in the value of root : shoot ratio both on fresh and dry weight basis with the increase in population density, especially in case of *A. ramosum* and *R. humilis*.

The present findings are supported by those of many other workers. Plants show extreme plasticity, responding remarkably in size and form to environmental conditions. One of the most potent of these external forces is the presence of competing neighbours, which may reduce a plant to diminutive size (Donald, 1963). Clements, Weaver and Han on's (1929) early experiments with *Helianthus annuus* planted at different densities provided dramatic proof of the individual species' plastic response to competitive stress. Plastic responses of this type have attracted the agronomists' attention for many years as the interaction of such responses with density is reflected in crop yield.

Plant growth progresses through the interaction between physiological functions and environmental factors (Kuroiwa, 196), and it integrates the situation when plants compete for these factors. Such integrating procedure has led to a better understanding of density effects (Iwaki, 1958; Hogetsu *et al.*, 1960). Accordingly the dry matter production or plant weight is taken as a good index of the outcome of the competition (Bleasdale, 1960).

Spacing in a crop is an important criterion which decides the economic return from a cultivated field. Heavier densities of crop beyond the optimum sustaining capacity of soil and climate may adversely affect the growth of crop through lodging, rapid spread of disease and weak growth of individual plant (Simpson and Beck, 1965).

Interspecific competition

The interspecific competition had markedly deleterious effect on growth performance of A. ramosum, E. geniculata and R. humilis. All the parameters studied suffered heavily under the stress of interspecific competition. The fresh and dry matter accumulation in shoot and root and the reproductive growth manifested by the number of inflorescence axes or fruits per plant are the characters which were more severely affected as compared to the remaining ones. The higher value of root : shoot ratio under the stress of interspecific competition indicates the more pronounced deleterious effect on shoot than on root. Results obtained by several workers lend support to the present findings.

Varma (1938) reported from the study of mortality rates that the intensity of competition is usually greater in mixed cultures than in cultures of individuals of single species. Competition appears to work through the direct suppression of the shoots of one species by those of the other as a result of the more vigorous growth of the species which is growing on its preferred soil. Shoot competition acting in this way appears to be adequate as the case of the suppression of one species by the other (Tansley, 1917).

Kenneth Mather (1961) reported that competition is an agency - indeed one of the principal agencies - of natural selection. It is equally true that the outcome of competition will vary not only with the intensity of competition but with the environments in which it takes place, as Sakai (1961) has demonstrated with reference to rice plants.

During the process of competition two or more organisms make a common endeavour to gain one or more requisites in excess from the available supply. The effect of different association in minimising the production of the plants by sharing nutrients, light and water supplied are in substantial agreement with the earlier works done on the subject (Bleasdale, 1960). Thus they depress the growth of one another. The extent of the depression depends upon the competition ability of a plant. Because of this competitor will always have a reciprocal depressive effect as well as on its own intrinsic characteristics. Varma (1938) reported the depressing effect of one species upon another to be, in part, at least, due to soluble toxic substances probably formed by the roots. Grummer and Bever (1960) reported that some plants produce gaseous substances, which are given off from the leaves and these are mostly essential oils. Neighbouring plants may be severely damaged by these gaseous excretions.

Scope for further work

The present investigation was undertaken as an attempt to understand and disclose the causes of the peculiar restricted distribution especially of Abutilon ramosum in Baroda, and the occurrence of A. ramosum, Euphorbia geniculata and Rivinia humilis in peculiar shaded localities.

As far as the latter part of the aforesaid problem is concerned, the experimental data gathered through the various aspects of autecological studies covered in the present work provide fairly adequate explanation regarding the occurrence and abundance of the three species in peculiar habitat and localities.

However, regarding the former part of the problem a complete and satisfactory answer is not yet reached. As it has been already pointed out in Chapter 5, the lack of any special device for effective dispersal of the propagules (seeds) by wind, water or animals or any other agency seems to be the main cause for the restricted distribution of the species. The L. V. Palace area where the species in question is growing is fully protected and undisturbed. It is situated in the heart of the city and is surrounded by thickly populated city complex. Under these circumstances, it is quite natural that the species like A. ramosum will not get any chance for being dispersed and spread to other parts of the city. But this is far from a complete answer. So the present data need to be supplemented by some additional information for a true picture to emerge.

Thus at the present stage, inspite of the extensive experimental work covering the different aspects of autecological studies carried out during the period of three years, many questions especially regarding the restricted distribution of *A. ramosum* have remained unanswered, and some new questions regarding it and also pertaining to the peculiar behaviour, in certain respects, of the three species have arisen. To understand and solve these questions it is necessary to probe deeper into the problem covering some more aspects of these studies.

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