Chapter III

RESULTS AND DISCUSSION

3.1 Geographical Distribution of E. geniculata :

In family Euphorbiaceae, the genus Euphorbia is the largest one, represented by more than 1600 species (Lawrence, 1973). Vasishta (1984) has also mentioned about 1600 or more species of Euphorbia. All the species are cosmopolitan in distribution and confined to the tropics (Kerner 1904, Good 1964). Two major centers of distribution are tropical America and Africa.

Euphorbia geniculata Orteg. is a plant, native of Tropical America and is naturalised and well established in many countries including India as a weed of cultivation in fallow fields, waste lands and gardens etc. (Singh, 1988, Personal communication).

Maharashtra is one of the regions from Western Ghat region of India. E. geniculata is very common weed of cultivated fields and gardens in this region. At the centre of present study the weed is much frequent in the botanical garden, located in the campus of Yashwantrao Chavan College of Science, Karad (L 21^{o}, 10'N, L 72^{o}, 50'E).

3.2 Field Studies :

Euphorbia geniculata Orteg. is an annual herb. The nomenclature of this species is as follows :

Euphorbia geniculata Orteg. Nov. Rar. Pl. Matr. Decad. 18. 1797 Hook. f. Fl. Brit. India 5: 239. 1886 and 266. 1887; Cooke, Fl. Pres. Bombay 3 : 66. 1958 (Repr. ed.); Sant. in Bull. Bot. Soc. Bengal 8:5 (1954) 1955. (Singh, 1988; Personal Communication).

The weed E. geniculata was collected frequently from the botanical garden of the college campus. The garden is rain fed during mansoon while irigated in other seasons. The well matured plants of flowering stage in the field were used for experimental purpose.

3.2.1 Habitat :

Genus Euphorbia is cosmopolitan in distribution, grows well in different habitats. Climatic and Edaphic conditions of Karad locality where sps. of Euphorbia grows are as follows,

- Average Annual rain fall ranges from 900 mm to 950 mm.
- Average relative humidity % varies from 32% to 84%.
- Mean temperature throughout the year ranges from 20.7°C to 29.5°C.
- Soil generally deep black with high clay content and moisture, neutral to slightly basic in nature, having high water holding capacity.

As far as occurrence of the species E. geniculata at the present study site is concerned it grows in different habitats. It is common both in moist as well as dry habitats. However frequency is more in moist places. In garden it was showing laxurient growth, when it was getting the effulient of sewage. Further it was observed that the weed was flourishing under tree shades and moist conditions.

Rao (1983) and Rao (1983) have recorded that E. geniculata is a common weed of cotton and maize fields. During present investigation we have recorded the weed from the fields of Sugarcane, Jawar and Rice also.

3.2.2 Morphology :

Habit : *E. geniculata* is an annual errect herb, growing upto 1 m. height (fig. 1)

Root : Tap root type of root system observed. Average root length varies from 7 cm. The root diameter varies from 0.8 cm to 3 cm.

Stem : Errect, cylindrical, branched or unbranched, with 9 to 12 internodes, green in shade or redish brown in exposed condition, 25-60 cm. long, and 1-2 cm in diameter, slightly succulent under shade, contains milky latex.

Leaves : Simple, petiolate, exstipulate, ovate, with reticulate venation, entire margin and acute apex, dark green, infected on lower surface by *Melampsora*, alternate on lower part but opposite on upper part of the stem, alternate leaves are 3-8 cms long and 1-4 cms broad, while opposite leaves are 5-10 cms long and 1-5 cms broad.

Inflorescence : It is a Cyathium type. Several such cyathia (45 $\pm$ 18) are arranged in terminal condensed dichasia of 3.5-4.0 cm in diameter. Cyathium is glabrous without and consists of an ovid involucre with the margin lined with a fringe of fleshy, finger-like lobes. A conspicuous, fleshy, terete, stipulate gland with slightly flared round opening is situated on the involucre to a side.

Each cyathium is normally bisexual, but occasionally the female part is suppressed. Out of the 50 cyathia examined, 90% were found to be bisexual, whereas 10% were unisexual male.

FIG. 1

Photograph of Euphorbia geniculata

1) Showing natural habitat.

2) Entire plant showing morphological details.

a

FIG. 1

b

Staminate flowers : Many male flowers are located around the female within the involucre. Male flowers lack perianth and each one is monandrous with subglobose, bicelled anther, born on a pedicel of 2-3 mm long. Another dehisces by the horizontal fissure. Pollen grains are subspheroidal, tricolporate, 40-50 µm. in diameter and with reticulate exine.

Pistillate flowers : Each cyathium bears solitary and centrally located female flower lacking perianth. A three celled ovary with a single ovule in each cell. It is supported on a rather prominent stalk. Styles are 3, connate at the base, each stigma is bifid.

Fruit : It is three chambered Schizocarpic capsule, splits into three one-seeded cocci.

Seed : Black to gray, slightly angular, 2-2.5 mm long and 1-2 mm broad, rough, endospermic.

3.2.3 Pollination mechanism :

Pollination is a one of the important process in the life cycle of weed, because multiplication and genetic variability in accordance with environment, depends upon it. Hence we have collected literature about pollination mechanism in E. geniculata and also observed pollinators, visiting the same plant.

Euphorbia geniculata is monoecious plant, reproduces both by geitonogamy and xenogamy. The cyathium of E. geniculata, though consists of many male flowers and one terminal female, is ecologically equivalent to a flat simple blossom (Knuth 1906-9). Such a floral device is very economical both to the plant and the animal visitor (Grant 1976). The cyathia of E. geniculata are protogynous, maturing one after the other, and are well equiped with nectór (glucose + fructose) secreting glands. Gland secreats nector in quantity by day and night. Thus cyathia are well adapted to achieve self as well as cross pollination.

The stigmas are fully receptive by the 3rd day of anthesis, and the male phase is evident from the 5th day of female anthesis, with the anthers dehiscing between 0800-1000 h. At the same time gland secretes the nector throughout day and night. Pollination is effected by a broad spectrum of diurnal insects and is of mess and soil type. The principal pollinators are ants (camponotus), wasps (Ropalidia, Polistes, Vespa) and beetles (coccinella), (Reddi and Reddi, 1982).

The dehiscent side of the anthers is directed upwards, and when the insects concerned land is the cyathia and walk about, pollen is deposited sterno tribically. Pollen pick-up by the insect is unhindered by the floral device involving the change in position of the pistil in the cyathia. When the pollen laden insects land and move in the female cyathia they contact the stigmas and effect pollination which may be geitons or xeno-gamous because the plants are well adapted for both modes of reproduction. The cyathia have no closely evolved relationship with any of the pollinating insects and thus functions as a promiscuous floral device in attracting insects (Grant 1949). As such, any insect with sufficient body size to permit contact with the anthers or the stigmas is capable of promoting pollination at least within the plant by its movement.

The major groups of insects associated with the cyathia of E. geniculata are similar to those encountered in related species of Euphorbia (Proctor and

Yeo 1975, Ehrenfld 1979). Flowering plant of E. geniculata when observed in the field of Jawar, Maize, and sugarcane, Black ants, bettles moving on the entire plant were noted. Thus a weed, E. geniculata is found to be well adapted to cross pollination with the help of insects.

3.2.4 Multiplication :

The propagatioin of the weed E. geniculata is through the seeds. The seeds are almost without any dormancy period. The dormancy was checked by using fresh seeds and the time period ranges from 0 to 14 days. The results of the germination percentage which finally leads to conclude the dormancy are shown in table-1. The resdults show the germination percentage ranging from 30 to 91%. Freshly threshed seeds show 30% germination while seeds stored above twelve days sdhows the uniform i.e. 91% germination.

From the resdults it is very clear that the seeds of E. geniculata are without any dormancy period. This is an efficient mean of multiplication.

Dormancy in the seeds of Parthenium hysterophorus was studied by Patil (1980). It is concluded that the seeds of Parthenium are without any dormancy period, however the maximum germination percentage was 70%. Germination percentage of seeds of different species of Euphorbia are given in a comprehensive treatise by Sen (1981). In Euphorbia thymifolia the maximum germinatioon percentage is 68 while in case of E. hirta the value is 66 and the seeds are without dormancy period.

From our results of table 1 we can say that the seeds of E. geniculata have no apparent dormancy however seed storage upto ten days gives better performance.

Table 1 : Effect of dry storage on germination percentage of seeds in *E.geniculata*

	Storage period in days														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
% Germination	30	40	45	50.5	53	59	60	65	70	74	80	90	90.5	90.5	90.5

Alongwith dormancy, the number of seeds per plant also determines the capacity of multiplication. Our observation of seed output per plant shows the number 168 (Table 4). The seed output of other species of Euphorbia are as, E. thymifolia- 926, E. hirta - 481 (Sen, 1981).

Considring and comparing seed output and dormancy of E. geniculata with the reference cited it can be said that to achieve better multiplication the seed output is compensated by enhanced germination percentage without the dormancy period.

3.2.5 Dehiscence and dispersal mechanism :

In E. geniculata the seeds are formed inside a capsule type of fruit. To achieve better dispersal of seeds, the plant is having its own natural mechanism. Mature capsule, in dry air dehisces both ventrally and dorsally to liberate the seeds. The liberation of seeds takes place by explosive mechanism of the capsule. Thus the seeds are dispersed upto 20 cm around the parent plant. Further dispersal of seeds takes place either by water, or by wind or through the agency of some arthropods.

The explosive mechanism of bursting of the capsule was recorded in the laboratory by keeping the unbroken ripe fruits in a closed periplate under table lamp. After 20 to 30 minutes exposure to light it was observed that capsule burst open to liberate the seeds with some force or gerk, which is the result of explosive mechanism of fruit.

Such type of explosive mechanism of seed dispersal is already mentioned in Euphorbia sps (Singh and Jain, 1987), Euphorbia thymifolia (Sen 1981). Our results are on similar line. However, the dispersal through the agency of arthro

-pods is predicated because there is a presence of mucilage in the seed coat. Thus by sticking to the body of animals which also helps in pollination, the seeds are taken from one place to another.

3.2.6 Phenology and life cycle :

Euphorbia geniculata is an annual errect herb. In nature generally the seeds germinate throughout the year depending upon the availability of favourable climatic conditions, and hence the plant is available throughout the year.

Generally the weed E. geniculata completes its life cycle withing $2\frac{1}{2}$ to 3 months. After the first rain the seedgerminates and continues its vegetative growth for a month. After this it flowers. The blooming lasts for $1\frac{1}{2}$ to 2 months. The density of the plants was observed maximum in July/August i.e. after the commencement of monsoon. Similar phenological observations are reported in Euphorbia thymifolia and Euphorbia hirta by Sen (1981) and in Parthenium hysterophorus by Patil (1980).

3.2.7 Growth performance :

Growth performance of E. geniculata has been analysed in terms of various attributes of its individuals like length and basal diameter of root and stem, root/shoot ratio, No. of branches and internodes, leaf measurements, No. of capsules, total seed output etc., and the results are tabulated in table No.2. The individuals under study were from the botanical garden of College campus. The habitat was considered under two heads : (1) Dry and full sunlight, (2) moist and shade habitat.

Table 2 : Growth performance of E.geniculata under natural drought/full light and moist/shade habitats.

Sr.No.	Morphological Characters	Drought/ full light	Moist/ Shade
A)	Vegetative Characters :		
1.	Length of the root in cm.	8.7	15.75
2.	Basal diameter of the root in cm.	0.85	2.45
3.	Length of the main stem in cm.	26.75	53.5
4.	Basal diameter of the stem in cm.	0.95	2.00
5.	No. of branches from main stem	5.00	8.00
6.	No. of internodes	9.00	11.00
7.	No. of alternate leaves	11	17
8.	Length of alternate leaf in cm.	3.9	7.85
9.	Width of alternate leaf in cm.	1.55	4.7
10.	Area of alternate leaf in cm^2	4.75	26.5
11.	No. of opposite leaves	6	39
12.	Length of opposite leaf in cm.	4.85	9.45
13.	Width of opposite leaf in cm.	1.6	4.75
14.	Area of opposite leaf in cm^2	5.75	36
15.	Root : Shoot ratio	0.31	0.3
16.	Number of leaves perp plant	17	56
B)	Reproductive Characters :		
1.	No. of capsule per plant	9	70
2.	No. of seeds per capsule	3	3
3.	Seed output per plant	27	210
4.	Reproductive capacity	24.3	190

From the results of various parameters listed in table 2, it is clear that E. geniculata is showing better performance in moist and shade habitat. We have not measured the degree of moisture stress, but considering the habitat which is fully exposed to sunlight and is dry, it is very clear that, the moisture stress retards the growth performance of E. geniculata. The fact is clear from the sixteen vegetative parameters and four reproductive parameters listed in table - 2.

Stout et al.,(1978) have shown this in Sorghum bicolour. The length of main stem was decreased due to moisture stress. Similar observatiions are of Yedappam and Paton (1982) in Helianthus annus L. Yadav (1983) have studied three species of medicinal plants namely Psoralea corylifolia, Tephrosia puuea and Withania somnifera for their performance in different habitats more correctly under moisture stress. The results are also on similar line.

Portulaca oleracea is a weed of the same habitats where E. geniculata thrives well. Portulaca oleracea also flourish more in moist and shady habitats (Sen, 1981). The shape and size of Portulaca plants are greatly influenced by environmental conditions. In high humidity and shade the plants show long inter nodes and big leaves.

Now comparing our results of table 2 with the observations of various workers cited above it is clear that E. geniculata is a moist and shade loving plant. It can be justified by the parameter which show two fold average length of stem, three times more number of leaves and about ten time more seed output in moist and shade plants in comparison with plants of moisture stress.

3.2.8 Phytosociological studies :

Phytosociological sltudy of E. geniculata was done by using list quadrats (Fig. 2). The comparative account of natural associates of E. geniculata under two habitats and their status in terms of percentage frequency, average abvundance and density are depicted in table 3. E. geniculata being basically a member of grass land community was associated with grasses and herbaceous member of other families at both the habitats.

Data of table 3 shows that excluding the common plant species at both the habitats E. geniculata is associated with some additional plant species at full light locality. The associate species at full light locality are Indigofera enneaphylla, Desmodium gyrans, Corchorus acutangulus, Phyllanthus niruri and Sonchus arvensis.

Kellman (1978) have studied the phytosociology of various weeds from corn field and a pasture and compared their density and frequency. Bansal (1975) have studied the periodical fluctuation in the weed flora at different time intervals in Kharif crops at Jodhpur. In this study, he concentrate mainly on variation in seed output in different season. However, the analysis of our phytosociological study reveals that at both the habitats Parthenium hysterophorus a noxious Mexican weed was found to be dominating along with a Grass sps. The 100% frequency of Parthenium and grass sps. was followed by E. geniculata, E. hirta, and Cyperus rotundus. The phytosociological parameters e.g. abundance, density, and % frequency show that E. geniculata is establishing well in shade habitat. These observations are in co-ordination with the fact that it is a moisture and shade loving weed.

FIG. 2

Quadrat showing E. geniculata along with associate plants.

FIG. 2

Table 3 : Phytosociological observations on E.geniculata, under two different habitats - i) Full light ii) Under tree shade.

Sr. No.	Plant Species	Full light			Under tree shade		
		Abundance	Density	% Frequency	Abundance	Density	% Frequency
1.	Euphorbia geniculata	17.72	12.4	70	32.	29.6	90
2.	Tridax procumbens	10.13	8.1	80	7.13	5.7	80
3.	Cynodon dactylon	10.78	9.7	90	4.17	2.5	60
4.	Parthenium hysterophorus	12.1	12.1	100	13	13	100
5.	Indigofera enneaphylla	2.0	1.00	50	-	-	-
6.	Sida acuta	6.63	5.3	80	3.25	2.6	80
7.	Desmodium gyrans	3.73	2.6	70	-	-	-
8.	Corchorus acutangulus	2.67	0.8	30	-	-	-
9.	Grass sps.	11.8	11.8	100	8.2	8.2	100
10.	Oxalis corniculata	6.71	4.7	70	4.57	3.2	70
11.	Cyperus rotundus	6.2	6.2	100	3.67	3.3	90
12.	Euphorbia hirta	5.00	4.00	80	3.44	3.1	90
13.	Phyllanthus niruri	4.14	2.9	70	-	-	-
14.	Ageratum conyzoides	3.33	3.00	90	4.83	2.9	60
15.	Sonchus arvensis	1.80	0.90	50	-	-	-

3.3 Seed Attributes :

Seed is a chief mean of multiplication in Euphorbia geniculata and hence the varioius seed attributes are worked out deeply to some extent. We have started from colour of the seed and have tested the percentage viability of the seed upto two and half year through various parameters like diamensions, viability and reproductive capacity etc. Table 4 shows the seed attributes of E. geniculata in natural population.

In general the seeds are slightly angular and black to gray in colour. Average length and breadth of seed is 2.12 and 1.8 mm respectively. The value of seed index in case of E. geniculata is 3.8.

The average air and oven dry weight per hundred seeds is 0.62 and 0.57 g respectively. Further the average moisture percentage per hundred seeds is 8.65. These results indicate that possibly there is no any ecotype of E. geniculata at present. Very less moisture content of the seeds may be useful to the seed to remain viable for a long period without any damage. The values of percentage of viable and nonviable seeds per plant directly show that almost all (98%) seeds produced are viable and hence it is the chief mean of multiplication. The values of seed output per plant (168) and reproductive capacity (152) show that through seeds only the weed E. geniculata maintains its potentiality to colonize and establish in the nature. The seeds are without any dormancy period and can remain viable when stored upto the period of $2\frac{1}{2}$ years.

The study of seed attributes is of some definite importance to plant taxonomists. Navachoo and Buth (1986) have studied seed and fruit characteristics of some weeds of Kashmir. In their study they have worked out the

Table 4 : Seed attributes in natural populations of *E.geniculata*.

Sr. No.	Observations		Nature and values
1.	Colour of the seed		Black to grey
2.	Shapte of the seed		Slightly angular
3.	Length of the seed	mm	2.12
4.	Breadth of the seed	mm	1.80
5.	Seed index		3.8
6.	Air dry weight per 100 seeds	gms	0.62
7.	Oven dry weight per 100 seeds	gms	0.57
8.	% of moisture per 100 gms of seeds		9%
9.	% of non viable seeds per plant		2.5
10.	% of viable seeds per plant		97.5
11.	% of germination		90.5
12.	Average seed output per plant		168
13.	Reproductive capacity		152.04
14.	Dormancy period		No
15.	% viability at 80 ^{o}C temperature		54
16.	Longevity or viable period of the seed		More than $2\frac{1}{2}$ years
17.	% viability after $2\frac{1}{2}$ years of dry storage		70 %

identification clues of seeds and fruits of hundred sps. of weeds. They have studied sdurface, shape, size, colour, texture wings, spines, and awns of various seeds.

Puchet and Yanes (1987) have worked out Cryptic heteromorphism of recalcitrant seeds of three plant species from wet tropical forest of Veracruz Mexico. They have studied length, width and thickness, and moisture content of individual seeds and they have co-related the results with the germination data.

Other weed scientists who have studied the seed attributes are as follows

Bhandari et al., (1977) in two forms of Indigofera cordifolia.

Bansal and Sen (1978) in Cucumis callosus

Bhati et al., (1979) in Chenopodium album and Chenopodium murale

Seed attributes of three medicinal plant species is worked out by Yadav (1983).

Kozlowski (1972) have given the critical analysis of moisture percentage of seeds. The moisture percentage above 14% leads to the destruction of seeds by storage fungi, while below 5% the aging of seeds increases. E. geniculata is having moisture percentage value 9%. Its significance in light of interpretation of Kozlowski is that due to optimum moisture percentage the E. geniculata seeds can remain viable upto considerable long period.

3.3.1 Effect of moisture on seed coat :

We have already discussed in dispersal mechanism of seeds of E. geniculata that the dispersal is achieved through the agency of some arthropods. This is basically due to the mucilage of seed coat.

FIG. 3

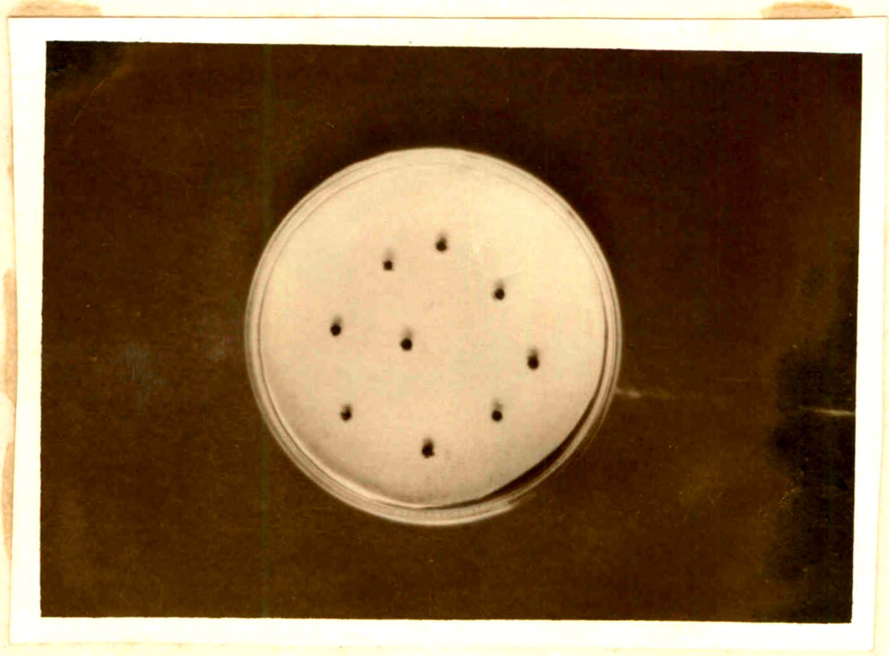
Effect of moisture on seed coat of *Euphorbia geniculata*

a) Dry seeds

b) Seeds treated with water

a

FIG.3



b

Kozlowski (1972) have discussed the importance of mucilage of seed coat. One of the importance is the adherence to the body of animals. The production of mucilage on testa is also discussed in detail. According to him epidermis of seed testa consists of mucilagenous cell structure. From outer wall of each epidermal cell, a threadlike outgrowth protrudes into the cell. This outgrowth consists of a wall with folds forming a dense helix and is filled with a substance that swells when moistened. Upon wetting of the seed a small round section of the outer wall above the thickening opens on one side like a lid, and the inner substance of the threadlike outgrowth swells. Later, the outgrowth is pushed out like a finger of a glove and acquires a hairlike structure. The inversion of the thread is a result of the swelling of substance present in the lumen of the epidermal cell.

Jordan <u>et al.</u>, (1985) have studied the changes induced by water on <u>Euphorbia supina</u> seed coat structure. They have found that when moisture is applied to the dry seeds of <u>Euphorbia supina</u> the helices of seed coat are elongated. The elongation of helices is because, initially they are tightly coiled and after getting the moisture they become loose and then elongates. To find out the exact nature of these helices Jordan <u>et al.</u>, (1985) have conducted Acid Schiff test and have concluded that the helices contain polysaccharide possibly the mucilage.

In light of this information we have also worked out the same aspect in <u>Euphorbia gniculata</u>. The dry seeds when treated with moisture or water produces helices on seed coat. The helices were observed under microscope and further tested by Acid Schiff reagent and I_2KI solution. These tests indicates the presence of polysaccharide which is considered as mucilage in light of above literature (The experimental data - Fig.3)

3.3.2 Seed vigor :

The capacity of the seed to germinate is called as seed vigor. Seed should maintain their qualities under proper storage conditions. They should germinate rapidly and uniformly when planted. The seed vigor can be estimated by measuring the germination rates (Kozlowski 1972).

Speed of germination of seeds of E. geniculata is measured from zero (0) to 56 hours. (Table 5). From the results it is clear that upto 24 hours there is no germination. The fact can be discussed under the light of results discussed by Leopold and Kriedemann (1981). It is stated that in case of non-dormant seed during initial 20 hrs. there is imbibition of water and formation of enzyme systems. This finally leads to the germination of seed.

not in list

Our res ults of E. geniculata showing no germination upto 24 hrs. can be attributed to the time required for imbibition and getting the enzyme machi nery on. However already while discussing the dormancy we have stated that there is no seed dormancy and these things coincides with one another. Further it can be added that with the speed the maximum germination is achieved with in 28 hrs. Thus we can interpret that the seeds are without dormancy and having high seed vigor. Speed of germination of seeds is taken as one of the parameters to estimate the seed vigor by Wanjura et ali (1969) in case of cotton seed variety and by Larson (1961) in case of Pinus ponderosa.

The literature on seed vigor of weeds is scanty because generally the weed seeds are assumed to have these gifts. However the present work is the primary attempt and hence can be supported by the literature cited above.

Table 5 : Estimation of seed vigor of *E. geniculata*.

	Hours after keeping the seeds for germination									
	0	24	28	32	36	40	44	48	52	56
Germination percentage	00	00	10	30	60	70	80	90	90	90

3.3.3 Effect of dry storage on germination :

This is nothing but to extend the investigation for seed dormancy in detail to some extent. While discussing the multiplication of E. geniculata we have assumed that seeds are without dormancy (Table 1). The same study is continued upto fifteen days and the dormancy was checked. From Table 1 it is clear that about 90% germination is observed after 10 days of dry storage. It seems that to complete all the pre-requisites of seed germination in all seeds it is the optimum period of dry storage.

Similar study is already carried out by Bansal (1978) in seeds of a weed Bureria articulata. He has found out the maximum germination percentage after eight days. Tripathi (1968) has stated that germination of seeds of a weed Asphodelus tenuifolius increases with seed storage. Our results are on similar line.

3.3.4 Ecological amplitude :

The extreme range that the taxa can tolerate is called as ecological amplitude. Parthenium hysterophorus is having the best ecological amplitude and have the adaptability.

During present study we have screened the seeds for temperature effect and maximum storage period. The results are interpreted uner ecological amplitude but may not fit properly. However, from the information added in table 4 it is clear that seeds of E. geniculata can tolerate the maximum temperature upto 80^{o}C where viability percentage is 54. This is in accordance with statement of Noggle and Fritz (1986) who state that dry seeds are frequently able to withstand a broad range of temperature. Sen (1981) has reported that the seeds of Crotolaria medicaginea are resistant to fire and profuse germination takes place in rains after firing these weed-infested fields.

For longevity seeds have screened at the end of M.Phil. dissertation work and it was found that even after a long period of two and half years the viability percentage was 70%. Thus we can say that the seeds of E. geniculata are temperature resistant and with considerable longevity. Similar results are interpreted by Sen (1981). He has shown that the seeds of weeds of family Gramineae, Leguminosae, Boraginaceae, Cucurbitaceae, can remain viable for a long period varing from one to fifteen years. Kozlowaski (1972) has reported that Euphorbia helioscopia and Euphorbia peplus are having longer viable period i.e. 10 years and 57 years respectively.

3.4 Leaf Study :

Euphorbia geniculata is characterised by alternate phyllotaxy in lower part while opposite leaves in the upper part of the stem. The leaves are with reticulate venation (Cooke, 1906). It was interesting to study the leaves with respect to leaf architecture, their organic constituents and stomatal behaviour.

3.4.1 Leaf architecture :

In order to study water use efficiency and 'Kranz' syndrome transverse sections of leaves of E. geniculata were taken (Fig. 4). It is clear from the microphotograph that E. geniculata shows typical dorsiventral leaf anatomy without any bundle sheath cells.

Crookston and Moss (1970) have screened a large number of plants for their leaf anatomical peculiarities and have classified the studied dicotyledonary taxa into three groups as follows,

i) In Crotalaria retusa and Cardiospermum helicacabum veins which are embedded in green mesophyll do not have a clearly distinguished sheath.

ii) In Genista tinctoria and Farsetia macrantha a prominent green sheath is present, but it is composed of parenchyma cells not specialized for starch formation.

iii) In Tribulus terrestris, Boerhaavia paniculata and Trienthema poutulacastrum distinct thick walled cells containing specialized plastids are seen.

Williams et al. (1977) reported that Verbascum thapsus with normal type of leaf anatomy operates C_3 path of photosynthesis. While Jones and Milburn (1978) and Takeda et al. (1980) have demionstrated the operation of C_4 path of photosynthesis in plants like Cyperus papyrus and Rhynchospora rubra respectively having 'Kranz Anatomy'.

In genus Euphorbia there are some species with bundle sheath and C_4 path (e.g. E. hirta, E. thymifolia) while other show normal leaf anatomy e.g. E. pulcherima, E. heterophylla.

Occurrence of 'Kranz' syndrome is one of the advanced character and can be acquired in due course of time. It is well known fact that Parthenium hysterophorus is having wide ecological adaptability. To adopt with various environments it has developed better assets.

Patil (1980) have studied the leaf anatomy of Parthenium hysterophorus. The most striking feature observed in this plant was the presence of prominent chlorenchymatous Kranz sheath with centripetally located chloroplasts in the mature leaves. However, it was incipint in medium mature leaf while not differentiated in young leaf. A typical dorsiventral arrangement of mesophyll

FIG. 4

Microphotograph of transverse section of leaf of E. geniculata

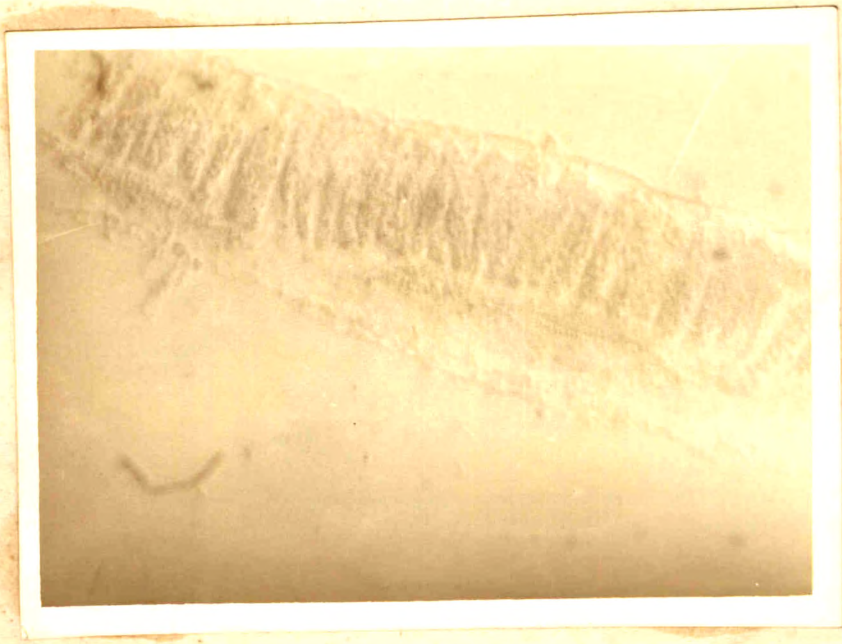


FIG. 4

differentiated into palisade and spongy chlorenchyma was evident in all the leaves. The chloroplasts are more or less evenly distributed among all the mesophyll cells. Thus from the results of Patil (1980) it can be said that Kranz architecture can appear in C_3 plants also, because Parthenium is basically a C_3 plant.

In general C_4 plants are with 'Kranz syndrome' Rathnam and Chollet (1980). However there are some plants which show C_4 path without Kranz leaf architecture.

Joshi (1976) has shown that the mangroves are aspartate former type of C_4 plants without 'Kranz' leaf anatomy.

Ceriops tagal and Luminitzera racemosa are the mangroves which show C_4 path without presence of bundle sheath (Waghmode 1982).

Suaeda monoica a salt marsh halophyte is shown to be C_4 plant without Kranz leaf anatomy (Shomer-Ilan et al., 1975). Further Shomer-Ilan et al.,(1979) have shown that S. monoica is a C_4 plant with three photosynthesising cell layers.

Joshi et al.,(1982) have shown that Ipomoea-pes-caprae (Linn.) a creeper of sea coast is a C_4 plant without 'Kranz' leaf anatomy.

In C_3 - C_4 intermediate species the leaf anatomy is also of intermediate type. (Monson, et al., 1984). In these plants bundle sheath is not much prominent as in C_4 plants. The same fact is also previously discussed by Raghvendra (1980) in his valuable review article.

E. geniculata shows normal dorsiventral leaf anatomy. There is no any prominent bundle sheath. In the light of the various reference cited above, it

Table 6 : Diamension of leaf section of *E. geniculata*.

Leaf type	Cuticle thickness		Epidermis nature & thickness		Hypodermis	Mesophyll tissue nature and thickness		Kranz Anatomy
	Upp.	Low.	Upp.	Low.		Pallisade tissue	Spongy tissue	
Opposite leaf	5 u	3 u	16 u	11.77u		66.2 u	29.42 u	
			Unilayered		Absent	Unilayered	2-4 layered	Absent
Alternate leaf	3 u	2 u	16.18u	8.81 u		36.78 u	22.7 u	
			Unilayered		Absent	Unilayered	2-3 layered	Absent

can be concluded that there is no 'Kranz' anatomy in E. geniculata. It shows only normal type of dorsiventral leaf anatomy which shows upper pallisade and lower spongy tissue. Thus from leaf architecture E. geniculata seems to be basically a C_3 plant.

Monson et al., (1984) while studying the C_3-C_4 intermediate sps. of Flavaria have studied the leaf sections in detail. They have concentrated mainly on presence and diamensions of bundle sheath. We have extended our study of leaf anatomy and have measured the diamensions of cuticle, epidermis, pallisade and spongy cells. The measurements were done in opposite and alternate leaves of E. geniculata (Table 6).

Such diamension measurement study was done by Pathan (1982) in Alternanthera ficoidea and A. paronychioides. He has found that in C_4 sps. the epidermis is multilayered and thickening of cuticle is less as compared to C_3 sps. i.e. A. ficoidea.

Our results show that in both opposite and alternate leaves the epidermis is unilayered. However the opposite leaves in upper part of plant body are much thick than the alternate leaves. At present what we can say is that opposite leaves are relatively thick in comparison with alternate leaves. However, in them basic C_3 path is guissed on the basis of normal leaf anatomy. Further probe into the biochemical aspects will throw some light definitely.

3.4.2 Organic constituents :

Various organic constituents i.e. moisture percentage, TAN, chlorophylls, total nitrogen are estimated from the leaves of E. geniculata. The results are tabulated in table 7a. These estimates can add towards the predictions based on the leaf architecture.

Table 7 a : Organic constituents in the leaves of *E. geniculata*.

Moisture	TAN*	Chlorophylls** 'a'	'b'	'a + b'	a/b	Mesophyll succulence (Sm)	Total*** Nitrogen	Total*** Protein
88.55	79.40	138.2	64.2	202.4	2.15	0.44	6.5	37.05

* ml of decinormal NaOH required to neutralize the acid content in 100 gm of leaves.

** mg per 100 g of fresh wt.

*** g per 100 g of dry wt.

Table 7 b : Diurnal variation in acidity status (TAN) of leaves of *E. geniculata*.

	Time							
	6 a.m.	8 a.m.	10 a.m.	12 p.m.	2 p.m.	4 p.m.	6 p.m.	12 mid night
TAN*	57.02	57.02	73.31	73.2	73.1	61.08	52.95	79.40

* ml of 0.1 N NaOH required to neutralize the acid present in 100 g of fresh tissue.

TAN was estimated from 6 to 24 hrs. of the 'day (Table 7b). From the table it is clear that there is no diurnal variation in TAN values like that of CAM plants. Hence in E. geniculata there is no CAM. Joshi (1976) have also carried out similar studies of TAN in mangrove leaves and have concluded that the mangroves are not CAM plants.

From the chlorophyll values shown in table 6 the chl.a/b ratio is 2.15. This ratio is one of the parameters of C_3 and C_4 plants. Holden (1973) studied the pigments in C_3 and C_4 plant speices. According to him chlorophyll a/b ratio ranges from 3.1 to 5.6 for C_4 dicotyledonous plants, while it ranges from 2.5 to 3.7 for C_3 dicotyledons. Thus the chl a/b ratio of E. geniculata signifies its C_3 nature.

Mesophyll succulence (Sm) is calculated from moisture percentage and total chlorophyll value. The magnitude of leaf succulence is 0.44. Kluge and Ting (1978) have taken the value of mesophyll succulence to judge whether the plant species is CAM or non CAM. For CAM the Sm values ranges from 1.34 to 13, while for non CAM it is found 0.3 to 0.8. Comparing our results it clearly indicates non-CAM nature of E. geniculata.

Considering the value of nitrogen content and total proteins we can say that in spite of CAM, E. geniculata indicates its nitrophilous nature.

Thus the overall indication of the estimate of organic constituents is that E. geniculata is basically a C_3 plant. This supports our prediction based on leaf architecture.

3.4.3 Stomatal studies :

Stomatal physiology has been receiving increasing attention in recent years. Stomatal activities regulate gas exchange and control the transpiration.

Table 8 : Stomatal frequency in the leaves of <u>E.geniculata</u>.

Leaf type	No. of stomata mm^{-2}			Stomatal frequency ratio (Lower/Upper)
	Upper epidermis	Lower epidermis	Total	
Opposite leaf	86	161	247	1.86
Alternate leaf	199	269	468	1.39

There is a correlation between the stomatal behaviour and the path of photosynthesis (Das and Santakumari 1977; Wardley and Simpkins 1980; Solarova et al. 1981).

Stomatal frequency of both the surface and frequency ratio (L. /upp. surface) is depicted in table 8. From the values it is clear that more stomata are situated on lower sdurface of both alternate and opposite leaves. The ratio of stomatal frequency of both alternate and opposite leaves is 1.4 and 1.9 respectively.

Stomatal frequency (number of stomata/mm^2) can be used as a guide in determining the pattern of photosynthesis. According to Das and Santakumari (1977) stomatal frequency ratio (L/upp. surface) is always high (2.22 to 4.10) in C_3 plants while it is low (0.6 to 1.60) in C_4 plants.

Our values of stomatal frequency ratio of opposite leaves clearly indicate its C_3 nature. In case of alternate leaves the value is 1.4 and it inclinds more towasrds C_3 than C_4. Thus distribution of stomata signifies basic C_3 nature of E. geniculata.

Now a days the pattern of opening and closing of stomata is taken to judge the photosynthetic path. Das and Santakumari (1977) have shown that in C_3 plants maximum stomatal width is at 10 a.m. while in C_4 it is at 12 noon. C_4 nature of Aeluropus lagopoides is proved by such studies by Waghmode and Joshi (1979). In Parthenium hysterophorus maximum stomatal width is at 10 a.m and hence it is basically C_3 (Patil,1980). C_3-C_4 intermediate nature of Ceriops and Luminitzera is predicated by Waghmode (1982) as the maximum stomatal opening is at 11 a.m.

Table 9 : Diurnal variation in stomatal behaviour of opposite and alternate leaves of *E. geniculata*.

		Opposite Leaf							Alternate Leaf						
Time	Leaf surface	R.H. %	Quantum $\mu E\ m^{-2} s^{-1}$	Scm^{-1} Diff. Resistance	Transpirate $\mu g\ cm^{-2} s^{-1}$	Leaf temp. ^oC	Cuvette temp. ^oC	Flow rate $cm^{-3} s^{-1}$	R. H. %	Quantum $\mu E\ m^{-2} s^{-1}$	Diff. Resistance $S\ cm^{-1}$	Transpiration Rate $\mu g\ cm^{-2} s^{-1}$	Leaf temp. ^oC	Cuvette temp. ^oC	Flow rate $cm^{-3} s^{-1}$
6.00	Upper	16.40	00	3.27	4.54	21.40	22	1.64	25.20	00	5.22	2.43	20.50	21.00	0.575
a.m.	Lower	12.00	00	3.15	5.28	22.40	23	2.58	16.80	00	5.00	2.91	21.10	21.60	1.03
7.00	Upper	27.60	37	15.70	0.803	20.40	20.60	0.175	41.60	14	10.40	0.927	19.60	19.80	0.137
a.m.	Lower	28.00	29	3.34	3.65	20.70	21.00	0.769	40.40	41	6.07	1.61	19.90	20.20	0.24
8.00	Upper	30.80	410	2.58	4.73	21.50	21.40	0.87	31.20	500	2.63	4.70	21.7	21.6	0.848
a.m.	Lower	30.80	610	1.07	10.41	21.20	21.20	1.966	32.00	470	1.21	9.33	21.4	21.4	1.664
9.00	Upper	11.60	809	18.60	1.05	24.40	24.00	0.502	14.00	330	21.40	0.9	24.60	24.40	0.388
a.m.	Lower	12.00	800	3.51	5.17	23.80	23.60	2.428	14.40	740	6.43	2.89	24.4	24.2	1.06
10.00	Upper	17.60	1520	3.15	6.25	26.5	26.00	1.65	20.80	1680	2.8	6.66	26.9	26.4	1.42
a.m.	Lower	17.60	1570	1.85	9.95	25.80	25.60	2.681	20.80	1640	1.54	11.69	26.50	26.20	2.52
11.00	Upper	13.60	1770	2.9	7.23	27.2	26.8	2.454	13.60	1780	3.46	6.29	27.4	27.4	2.063
a.m.	Lower	14.00	1840	1.5	13.6	26.6	26.5	4.45	13.60	1590	2.5	8.6	27.6	27.2	2.854
12.00	Upper	48.40	1820	1.59	9.77	30.4	29.2	0.726	47.6	1780	1.81	9.091	31.10	29.60	0.671
p.m.	Lower	48.40	1810	0.75	19.20	30.20	28.40	1.48	50.4	1710	0.75	17.12	30.10	29.60	1.191
1.00	Upper	35.20	1850	2.12	9.298	30.70	29.2	0.966	36.00	1730	5.35	3.87	31.10	29.60	0.384
p.m.	Lower	34.40	1740	0.91	20.02	30.5	29.00	2.153	36.4	1740	0.91	19.87	30.90	29.40	1.96
2.00	Upper	33.20	1870	2.63	8.08	31.3	29.80	0.864	36.4	1710	2.73	7.68	31.9	30.4	0.721
p.m.	Lower	33.20	1770	1.00	19.05	30.90	29.40	2.07	36.4	1620	0.85	21.98	31.7	30.2	2.08
3.00	Upper	25.20	1170	1.49	15.93	32.30	30.88	2.166	26.80	998	1.8	13.43	32.70	31.20	1.67
p.m.	Lower	25.20	1320	0.84	26.20	32.10	30.60	3.608	26.80	980	0.92	24.53	32.70	31.20	3.05
4.00	Upper	28.40	490	2.05	11.53	32.50	31.0	1.36	31.20	410	1.74	13.15	32.70	31.20	1.39
p.m.	Lower	27.60	669	0.91	23.77	32.10	30.60	2.96	31.60	689	0.92	22.81	32.50	31.00	2.40
5.00	Upper	11.60	400	2.78	8.44	28.7	29.20	3.03	11.20	360	8.11	3.11	29.30	29.40	1.15
p.m.	Lower	10.80	400	2.74	8.75	28.80	29.20	3.43	12.00	580	1.56	14.56	28.80	29.40	4.95
6.00	Upper	4.40	16	28.40	0.861	27.1	27.2	1.38	18.80	7	41.7	0.516	26.9	27.00	0.159
p.m.	Lower	4.40	20	16.40	1.48	27.1	27.2	2.378	10.00	7	24.90	0.912	26.9	27.00	0.444

During present study it was not possibl to study the stomatal behaviour by nail paint method. We have measured the diffusive resistance and transpiration rate with the help of steady state Autoporometer (Table 9). Noggle and Fritz (1986) have given the correlation between diffusive resistance and stomatal aperture. According to him diffusive resistance is inversely proportional to stomatal aperture and hence the transpiration rate. The values of diffusive resistance are manipulated in terms of stomatal aperture. It is obvious that maximum stomatal aperture and the transpiration rate is showing two peaks - one at 8 a.m. and other at 3 p.m. The significance of peak at 8 p.m. is that it is guiding towards the C_3 nature of the plant. However, interpretation of second peak remains undiscussed. This is because of scanty literature on this aspect. However, we can say that the stomatal opening is governed by other factors such as leaf temperature, relative humidity, light quantum etc. because these values are more or less high at 3 p.m.

From our results in table 9 it is further clear in general transpiration rate is more in lower epidermis of both type of leaves and this can be well attributed to the maximum stomatal frequency on lower surface.

3.5 Nitrogen Metabolism :

3.5.1 Total nitrogen, proteins and key enzymes :

While discussing the organic constituents of leaves we have predicted E. geniculata to be a nitrophilous weed. However, literature on weeds also indicates the demand and competition of weed for nitrogen. The weed generally uses twice the amount of nitrogen in comparison to normal crop plant (Sen, 1982). Vaidya et al. (1978) have mentioned the loss of nitrogen through weeds is as high as 150 kg/ha. With this background the investigation was continued for study of marker steps of nitrogen metabolism in E. geniculata.

Table 10 shows the nitrogen metabolism in E. geniculata. It is having the values of total nitrogen, total proteins and activities of enzymes nitrate and nitrite reductase. The value of available soil nitrogen is also mentioned in the table. To manipulate the results more correctly, moisture percentage is also worked out.

It is evident from table 10, that the activities of enzymes nitrate reductase and nitrite reductase is maximum in leaves. It is followed by stem and least is found in root. The trend of enzyme activities is in co-ordination with the amount of total nitrogen and total proteins. The maximum values are recorded in leaves and minimum in root while in stem values are intermediate. So thus the enzyme activities and amount of total nitrogen are proportionate to each other. Water potential of the tissue plays a vital role in the activity of nitrate reductase (Morilla et al., 1973, Plaut 1973, Rhodes and Matsuda 1976 Shinde 1981). Considering the value of moisture percentage of leaf, root and stem they can be easily co-related with the activities of nitrate reductase, which are already proportionate to the total nitrogen.

Nitrogen metabolism of groundnut is worked out by Chavan (1987). He has given the activity of nitrate reductase from leaves, stem and root of mature groundnut plant. The values are 4.395, 1.954 and 1.205 μ mole $NO_2^{-1}h^{-1}g^{-1}$ f.wt. respectively. Comparing our values with this leguminous plant we understand that the activity is rather high. This high enzyme activity can be interpreted on the basis of nitrophilous nature of the E. geniculata. Further as

Table 10 : Nitrogen metabolism in *E. geniculata*.

Material	Moisture percentage	Nitrate reductase activity μ moles $No_2 h^{-1} g^{-1}$ fresh wt.	Nitrate reductase activity μ moles $No_2 h^{-1} g^{-1}$ fresh wt.	Total nitrogen g $100 g^{-1}$ dry wt.	Total crude proteins g $100^{-1} g$ dry wt.
Root	74.63	6.82	0.15	1.6	9.12
Stem	83.73	8.82	0.19	4.0	22.8
Leaf	80.04	97.99	0.66	5.1	29.07
Soil	-	-	-	3.17	-

stated by Sen (1981) the weed demand more nitrogen for their growth. The high enzyme activity may be the result of the same. The soil where E. geniculata thrives well is rich in nitrogen. The soil is having nitrogen content 3.17 g 100^{-1}g dry wt. of soil. This nitrogen rich soil can be one more factor to add towards the enhanced enzyme activity. The increased activity of nitrate reductase due to soil rich in nitrogen content is previously shown by Hageman and Flesher (1960), and Stewart et al. (1972).

Upadhye (1986) have weorked out the enzyme activity of nitrate reductase and nitrite reductase from weeds namely Pennisetum purpureum and Trianthema monogyna. The estimate of enzyme activity NR from leaves are 55.34 and 75.32 μ moles. $NO_2 h^{-1}$ g^{-1} f.wt. respectively. With these values we can say our results are in range of values of other weeds.

The trend of enzyme activity i.e. maximum in leaves, followed by stem and root from table 10, is attributed to the proportion of total nitrogen content and moisture percentage in early paragraph of discussion. Maximum enzyme activity of leaf can also be justified. Since the leaves are the major contributors to the biomass of the plant, the enzyme activity in these organs can have a lion's share in the nitrate reduction process of the entire plant. Further the higher level of enzyme in this plant part correlates well with the fact that the nitrate reduction process depends on a constant supply of reductants which are produced during the process of photosynthesis. Our observations agree with the findings of Srivastava (1965) in case of bean. He found that leaves always had higher level of enzyme activity than the root or stem. Chavan (1987) have also shown the similar trend of enzyme activity in grounnut. In a wetland plant, Typha sps. the decreasing order of activity of NR from leaf to stem to root is shown by Waghmode and Patil (1988).

It is evident from table 10 that the stem tissue also has appreciable nitrate reductase activity. These observations support the work of Andrews et al. (1984) which indicated that stem tissue can contribute significantly to over all nitrate metabolism. These workers observed that more than 20% of total plant nitrate reductase activity can occur in the stem of legminous plant like Pisum sativum. Our observations also indicate more or less similar trend because in stem tissue appreciable nitrate reductase activity as well as total nitrogen and proteins are detected.

Besides stem tissue, the roots also show enzyme activity but activity of nitrate reductase is about two fold less in root than the stem (Table 10). Bowerman and Goodman (1971) in case of Lolium perenne, have shown that the shoot material has ten fold more nitrate reductase activity than root material. Hatam (1978) found that in case of soybean the root tissue had lower nitrate reductase activity as compared to leaf tissue. Our results can be well explained in light of these results.

The nitrate reductase activity is discussed in light of results of various workers. However the interpretation of nitrite reductase (NiR) activity is limited because of the scarcity of literature on the same aspect.

3.5.2 Salt stress and enzymes of nitrogen metabolism :

Effect of NaCl in vitro on activity of nitrate reductase and nitrite reductase from leaves of E. geniculata is shown in Fig. 5. From the graph it is evident that Nitrate reductase is inhibited by NaCl while nitrite reductase is showing stimulation of the activity.

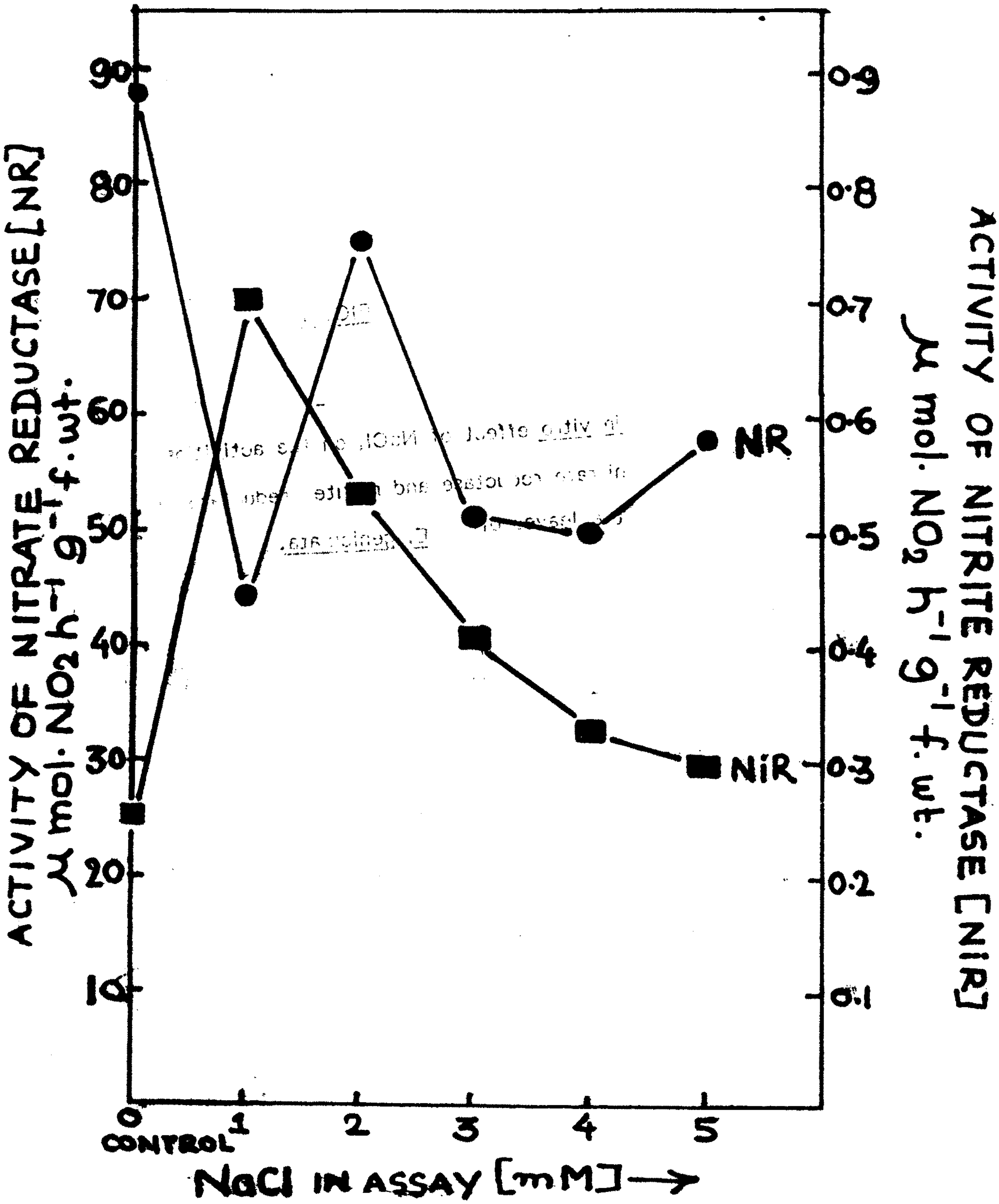

ACTIVITY OF NITRATE REDUCTASE [NR]
μ mol. NO2 h⁻¹ g⁻¹ f. wt.
90
80
70
60
50
40
30
20
10
ACTIVITY OF NITRITE REDUCTASE [NiR]
μ mol. NO2 h⁻¹ g⁻¹ f. wt.
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
NR
NiR
0
CONTROL
1
2
3
4
5
NaCl IN ASSAY [mM] →

FIG. 5

Nitrate reductase in general is salt sensitive enzyme because it is inhibited due to the presence of salt. Considering the activity at 2 and 5 mM concentrations, the values are elevated but less than the control one. Similar observations are reported by Toro (1987). She has studied NaCl effect on nitrate reductase of two cultivars of Setaria italica. The concentrations checked are 50, 100 and 200 mM NaCl. At 200 mM the activity is elevated little bit, but less than the control one. Our resdults are on similar line.

Billard and Boucaud (1982) observed a decrease in NR activity in a halophyte Suaeda macrocarpa. They considered that in vitro the salt induces non-competitive inhibition and NaCl stabilizes the NR substrate complex. Dissociation of a molybdofactor from the enzyme apoprotein takes place which is responsible for decrease in NR activity (Kabisheva et al., 1981). Decrease in NR activity is associated with leaf relative water content (Sairam and Dube, 1984) in rice genotypes subjected to water stress. Safaralliev et al. (1984) studied the causes of decrease in NR activity in legumes under salt stress and found that it may be due to dissociation of FAD (in leaves) and Mo (in roots). Aslam et al. (1984) observed a severe inhibition of NR when salt was added in vitro while in vivo it was only slightly affected. This indicates that in situ NR activity is protected from salt injury. Decrease in NR is also reported by Patil (1984) in Sesbania, Rajmane (1984) in winged bean, Bottacin et al. (1985) in Pennisetum and Murumkar (1986) in chickpea which is considered by them to be due to the nonavailability of substrate. While studying the nitrogen nutrition of wetland plants we (Waghmode and Patil, 1988) have studied NaCl effect on NR activity of Typha and Hydrilla. The results show the stimulation of enzyme activity due to presence of NaCl. Presence of NaCl seems to be essential for expression of full NR activity in these fresh water plants.

not listed in refs

Thus the NR from the leaves of E. geniculata is inhibited by the NaCl. This can be attributed either to unavailability of the substrate or dissociation of the molybdofactor from the enzyme apoprotein.

Activity of nitrite reductase is stimulated due to the presence of NaCl. Similar results are obtained by Toro (1987) in Setaria italica. The activity of NiR in leaves increases several folds at concentrations of 50, 100 and 200 mM NaCl. Our results are on similar line.

3.6 Seasonal Variations in Physico-Chemical Constituents :

Karad city is located in the Satara district of Maharashtra in Western Ghat region of India. As it is situated in sub-tropical zone, there are three distinct seasons namely monsoon, winter and summer. Monsoon sets in more or less in the middle of June and it is intense in July and lasts upto the middle of August. During this period more than 900 mm rainfall is recorded. From mid-August onwards sunshine is interrupted by showers. This later condition prevails upto the end of September and this period is considered as post-monsoon period. Winter is from November to February. While summer is from March to June. The minimum and maximum temperature ranges between 23 to 29^{o}C during monsoon, 18 to 26^{o}C during winter and 28 to 36^{o}C during summer.

The weed E. geniculata under present investigation found to be growing more or less well in all seasons of the year. The way in which E. geniculata responds to this varying environmental conditions is judged by working out, the seasonal variations in its physico-chemical constituents throughout the year.

Table 11 : Seasonal variations in moisture % and the dry matter from E.geniculata.

	1987									1988		
	Monsoon				Winter					Summer		
	zJuly	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
Root	77.85	73.75	58.89	74.63	82.35	44.44	77.78	87.14	79.79	71.36	63.23	81.96
Stem	88.53	87.97	74.61	83.73	87.75	74.50	73.65	89.34	88.54	90.08	82.78	91.87
Leaf	80.20	87.86	75.24	80.04	77.30	64.50	79.92	79.20	80.31	85.33	77.80	88.55
% Dry matter per plant	15.72	12.84	26.57	18.75	17.53	31.58	22.92	15.68	15.81	13.63	21.47	11.26

3.6.1 Organic constituents :

Seasonal variations in organic constituents like moisture content, dry matter, pH, TAN, total chlorophylls, total nitrogen and proteins of E. geniculata is recorded in table 11 and table 12.

a) Moisture percentage and dry matter :

The values of moisture percentage recorded in table 11 indicates that different plant parts of E. geniculata i.e. root, stem and leaf are showing appreciable quantity of moisture percentage. Collectively the maximum value of moisture percentage is 90 per cent while minimum is 44 per cent irrespective of root, stem and leaf.

The analysis of moisture % with respect to three seasons of the year signified that E. geniculata maintain its moisture % level little bit uniformly. This is possibly because of maintaining the rate of all enzymatic machinery constant throughout the year, which finally is related to multiplication. The role of moisture % we have already discussed in nitrogen metabolism and have correlated to the enzyme activities.

Considering the values of dry matter production it is evident that in winter maximum while in summer it is minimum. Attributing these results to the different seasons it can be said that due to the comparatively less availability of water in summer the dry matter production is lowered. However, how the plant restores its internal moisture % is unsolved question.

In winter the soil is having optimum water and hence the dry matter values and moisture percentage can be easily co-related and explained.

Seasonal variations of different plants is worked out by different persons. Shinde (1981) have studied the seasonal variations in moisture % and dry

Table 12 : Seasonal variations in Physico-Organic constituents of leaves of *E.geniculata*.

	1987						1988					
	Monsoon				Winter					Summer		
	July	Agu.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June
pH	5.5	5.65	5.7	6.3	6.2	6.4	6.06	5.98	6.4	6.6	5.75	5.32
TAN*	50.91	-	51.2	31.11	-	28.28	33.93	33.94	28.28	16.97	37.89	56.56
Total chlorophylls mg 100^{-1}g of fresh tissue	294.00	258.00	261.40	280.6	311.00	331.00	301.58	299.60	256.00	244.20	199.20	202.40
Total nitrogen g 100^{-1}g of dry wt.	6.2	4.3	5.1	4.	8.3	6.2	8.5	4.	6.1	7.4	6.6	6.5
Total proteins g 100^{-1}_{g} of dry wt.	35.34	24.51	29.07	22.8	47.31	35.34	48.45	22.8	34.77	42.18	37.62	37.05

* ml of decinormal NaOH required to neutralize acid present in 100 g of fresh tissue.

matter production in leaves of Aegiceras corniculatum and Sesuvium poutulacastrum. He has also recorded the minimum dry matter in summer season while maximum was in monsoon season. Our results show maximum values in winter. This difference can be explained on the basis of halophytic and glycophytic nature of the plants.

Gracillaria corticata a marine red alga is studied for its seasonal variations of moisture % by Kulkarni and Nimbalkar (1981). They also have recorded maximum moisture % in summer season.

Thus our results are in coordination of other workers however the literature on the same aspect of other weeds is not available.

b) pH and TAN :

The values of pH and TAN from table 12 show that the pH value of cell sap of E. geniculata is maintained within the range of pH 4.34 to 6.6. Thus all the metabolism of E. geniculata is conducted under the acidic condition of the cell sap.

Values of TAN we have already referred to indicate the non CAM nature of E. geniculata. From pH value it is very clear that acidic pH is maintained throughout the year. TAN and pH value are inversely proportional to each other. However, to maintain the acidic condition of cell sap the TAN values are also fluctuating in a limited range so that the nature of cell sap remains unaltered.

c) Chlorophylls :

Chlorophylls play vital role, in light harvesting process of plant. From the value of total chlorophylls it is evident that maximum chlorophyll is recorded in winter season and the value is 331 mg 100 g^{-1} f.wt. The minimum chlorophyll content is in month of May i.e. summer season. Chlorophyll content through photosynthesis are finally related to dry matter production. Now correlating the values of chlorophylls with the dry matter percentage already discussed it is exactly in accordance with chlorophyll values.

Shetty (1971) have recorded maximum chlorophyll content in winter season in the leaves of fern. Shinde (1981) have found maximum chlorophylls in leaves of Aegiceras corniculatum and Sesuvium portulacastrum in winter season. These plants are the weeds but halophytes. However, atleast the trend of our results is confirmed at least with their results.

d) Total nitrogen and crude proteins :

The values of total nitrogen are fluctuating between 4 to 8.5 g 100 g^{-1} dry wt. throughout the year. The magnitude of crude proteins is from 23 to 40 g 100 g^{-1} dry wt. Considering the general values of nitrogen content it is obvious that E. geniculata is rich in nitrogen contents. The nitrogen contents of various halophytes ranges from 1.5 to 2.5% (Waghmode and Joshi 1982). Sabale (1983) have worked out the seasonal variations in nitrogen and protein contents of Cymbopogon martinni and have found the range between 1.28 to 3.84% for nitrogen. The range of E. geniculata is 4 to 8%. This fact further confirms the nitrophilous nature of the weed.

The value of crude protein show the variation from 23 to 49%. This value is also high when compared to other plants.

In Cynodon dactylon - 14.75 to 21.94%

Sorghum vulgare - 5.21 %

Cymbopogon martinni - 8.00 to 24%.

Thus the crude protein content which is manipulated from total nitrogen content is also in accordance with the nitrophilous nature of E. geniculata.

3.6.2 Inorganic constituents :

Seasonal variations in inorganic nutrients from the root, stem and leaves of E. geniculata are depicted in table 13. The data compiles the values of Na, K, Ca, Mg, Fe, Mn, Cu, Zn, Si, Ni and Co estimated in various plant parts of E. geniculata throughout the year.

Sodium is one of the major inorganic elements required by plants. In E. geniculata the values of Na with respect to various parts are as,

root - 0.3 to 1.3 g 100^{-1} dry wt.

stem - 0.1 to 0.35 ,,

leaf - 0.1 to 0.25 ,,

Thus collectively the magnitude of Na ranges from 0.1 to 1.3 in E. geniculata throughout the year. In glycophytes the sodium content ranges from 0.6 to 1.4% of dry wt. as cited by Chirputkar (1969). Our values are falling in general range.

Analysis of sodium content with respect to various seasons of the year is given in the table 13. From table 13, it is evident that the maximum sodium content of E. geniculata is found in summer while in winter and monsoon the sodium content is more or less uniform. Clerodendrum inerme a hedge plant of family verbinaceae is analysed by Mishra (1987) for the seasonal variations of inorganic elements. He has found that in summer months Na content is high and minimum in monsoon season. Our results run parallel to it.

The average value for potassium (K) in terrestrial plants varies from 0.3 g to 6.0 g per 100 g of dry tissue (Ferry and Ward, 1959). However, Epstein (1972) mentioned that in terrestrial plants the optimum values for K are 1.0% of dry weight. Potassium content of E. geniculata can be summarised as,

root - 1.4 to 5.6

stem - 1.6 to 4.6

leaf - 2.2 to 4.5

Thus the value of K ranges from 1.4 to 5.6% dry wt. The values when compared to Ferry and Ward are in normal range however in comparison with Epstein they are high.

Seasonwise values of K content signify that maximum potassium is restored in E. geniculata during winter and summer while in monsoon the amount of K is minimum. Mishra (1967) has studied seasonal variations in Clerodendrum inerme and found that K values are high in summer. Bhosale (1974) recorded maximum values during winter and summer while minimum in monsoon in case of Acanthus ilicifolius and Avicennia officinalis. Our results are on similar line.

Potassium content in light of the references of Ferry and Ward (1959) and Epstein (1972) is somewhat high in E. geniculata. Laetach (1971) have suggested that K level could be a factor in the regulation of nitrogen metabolism in the plants. High K level favours the mobilization of soluble nitrogen. Thus the potassium level also supports the nitrophilous nature of E. geniculata.

Calcium is another indispensible macroelement for the growth of plants as it functions both as a structural component as well as a cofactor for certain enzymes. The root, stem and leaves of E. geniculata shows the value of calcium, 1.04 to 3.86, 1.08 to 4.42, and 5.98 to 8.42 g 100 g^{-1} dry wt. respectively. The overall range is thus from 1.04 to 8.42. Literature value of calcium content of plants in general is 100 mg to 3.5 g 100 g^{-1} dry wt. according to Ferry and Ward (1959). However Epstein (1972) quotes 0.5 % Ca content. Comparing our results with these it is evident that calcium content is high in E. geniculata. In Jatropha curcas, a member of Euphorbiaceae the recorded calcium content is 5.03% (Torne and Joshi, 1964). Our values are comparable with it.

Considering the seasonal variation of calcium it is clear that the values are maximum during summer and followed in winter and monsoon. Mishra (1967 in Clerodendrum inerme have found low calcium during monsoon and high in summer. Our results show the same pattern.

Epstein (1961) state that calcium is essential for maintaining the integrity of the selective ion transport mechanism and essential for full growth. Comparatively high values of calcium may be one of the additional means towards achieving the healthy growth of Euphorbia geniculata throughout the year.

Magnesium (Mg) is a constituent of chlorophyll molecule and acts as a cofactor in many enzymatic transfers. Though it participates in a number of enzymatic reactions its requirement for plant is relatively low and hence treated as one of the microelements. The optimum value of Mg recorded by Ferry and Ward (1959) is 0.05 to 0.7 g 110 g^{-1} dry wt. While that of Epstein is 0.2% dry wt. The pattern of Mg value from E. geniculata is as follows,

root - 0.266 to 1.03 g 100^{-1} g dry wt.

stem - 0.138 to 0.808 ,, ,,

leaf - 0.790 to 1.98 ,, ,,

The maximum Mg content of leaves can be attributed to the chlorophyll content of leaf tissues.

Maximum Mg content is observed during summer and these values are followed in monsoon and winter. The lower Mg content during winter can be correlated with the maximum dry wt. of winter season in light of results of Jamale (1975). He has stated that in mangroves the low values of Mg accelerates the photosynthetic efficiency which ends with dry matter production. Our results can be explained in the same line.

Adequate value of iron in plants ranges from 0.01% of dry wt. (Epstein 1972) In E. geniculata iron values are as follows,

root - 0.004 to 0.145

stem - 0.09 to 0.107

leaf - 0.02 to 0.088

Values of root and stem are in normal range. However, in leaves the Fe values are little high and can be explained on the basis of requirement of iron in various enzymatic reactions carried out in the leaf. Maximum iron is found during winter in case of root while in leaf tissue it is maximum during summer These haphazard variations can be due to the fact that iron is an immobile element.

Manganese (Mn) is the activator of enzymes mediating reactions of the Kreb's cycle and is prominent component of chloroplast. It participates in the reactions leading to the evolution of oxygen. Inspite of its importance plant require Mn in trace quantities. Optimum value of Mn recorded by Epstein (1972 is 0.005% dry wt. Our values of Manganese from root, stem and leaf are in the range. However, maximum 0.025 g 100 g^{-1} dry wt. is recorded in leaf tissues. Karadge (1981) in Portulaca oleracea have recorded Mn content of leaf from our results is within the range as compared to Portulaca.

Table 13 : Seasonal variations in inorganic constituents* of root, stem, leaf of *Euphorbia geniculata*.

		1987								1988			
		Monsoon				Winter				Summer			
		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Na	Root	0.5	0.4	0.5	0.4	0.4	0.7	1.1	0.7	1.3	0.6	0.3	0.4
	Stem	0.2	0.15	0.2	0.15	0.15	0.15	0.15	0.25	0.35	0.15	0.1	0.25
	Leaf	0.2	0.2	0.25	0.15	0.15	0.15	0.2	0.25	0.15	0.10	0.15	0.15
K	Root	1.9	1.4	1.4	2.4	1.8	2.2	3.4	5.00	4.2	5.6	2.00	2.4
	Stem	1.65	1.6	1.6	1.8	1.9	2.4	3.5	4.3	4.00	4.6	3.1	2.25
	Leaf	2.9	3.5	2.6	2.8	2.2	3.0	4.	3.6	4.5	3.7	2.7	4.5
Ca	Root	1.84	-	2.42	2.18	1.04	0.98	3.2	2.6	2.48	3.86	1.86	1.7
	Stem	1.58	1.12	3.16	1.77	1.08	1.12	3.31	2.74	2.64	4.16	4.42	1.81
	Leaf	5.98	6.02	6.1	6.44	6.66	7.76	7.02	7.10	7.36	8.42	6.76	6.5
Mg	Root	0.404	0.776	0.47	0.31	0.254	0.266	0.89	0.79	0.66	1.03	0.414	0.272
	Stem	0.322	0.138	0.796	0.340	0.257	0.358	0.385	0.705	0.609	0.840	0.808	0.365
	Leaf	1.55	1.50	1.47	1.19	0.79	0.97	0.98	1.30	1.78	1.98	1.39	0.68
Fe	Root	0.0133	0.059	0.030	0.057	0.145	0.101	0.102	0.082	0.045	0.004	0.059	0.049
	Stem	0.03	0.014	0.022	0.014	0.02	0.021	0.012	0.018	0.019	0.017	0.107	0.009
	Leaf	0.02	0.03	0.034	0.051	0.31	0.029	0.028	0.033	0.088	0.051	0.055	0.024
Mn	Root	0.005	0.002	0.006	0.003	0.008	0.007	0.011	0.006	0.008	0.006	0.004	0.006
	Stem	0.001	0.001	0.004	0.003	0.002	0.003	0.003	0.003	0.003	0.003	0.004	0.001
	Leaf	0.008	0.025	0.016	0.012	0.01	0.009	0.026	0.009	0.015	0.013	0.014	0.009
Cu	Root	0.008	0.003	0.004	0.003	0.004	0.002	0.006	0.004	0.002	-	0.002	0.002
	Stem	0.001	0.0015	0.004	0.002	0.0015	0.001	0.0055	0.0015	0.0005	0.0025	0.002	0.001
	Leaf	0.004	0.005	-	0.005	0.002	0.002	0.003	0.004	0.005	0.003	0.003	0.004
Zn	Root	0.005	0.005	0.007	0.008	0.007	0.005	0.009	0.031	0.067	0.013	0.005	0.005
	Stem	0.003	0.0055	0.0055	0.0045	0.0045	0.004	0.0125	0.0775	0.0115	0.012	0.004	0.002
	Leaf	0.006	0.01	0.01	0.011	0.007	0.01	0.01	0.042	0.017	0.01	0.006	0.009
Si	Root	5	1	5	4	4	3	6	7	5	5	3	3
	Stem	1	1.5	2	3	1	0.5	2	1.5	1.5	3	1.5	0.5
	Leaf	1	5	1.5	1.5	0.5	1	5	3	5	4	2	1
Ni	Root	-	-	0.003	-	0.002	0.001	0.004	0.002	0.003	0.002	0.001	0.001
	Stem	0.0005	-	0.0015	-	0.0005	0.001	0.0015	0.001	0.0015	0.001	0.0015	0.0015
	Leaf	0.001	0.001	0.002	-	0.0005	0.001	0.001	0.001	0.0005	0.002	0.002	0.002
Co	Root	0.002	0.001	0.002	-	-	-	-	-	0.001	0.001	0.001	0.003
	Stem	0.001	0.0005	0.0005	0.001	0.001	0.001	0.0005	0.001	0.0005	0.001	0.001	0.001
	Leaf	0.001	0.002	0.002	0.001	-	0.0015	0.001	0.001	0.0005	0.0015	0.0015	0.0015

* $g\ 100\ g^{-1}$ of dry wt.

Silicon content of E. geniculata from root is 0.5 to 3.0% stem - 1 to 7% and from leaves 0.5 to 5%. The range of Si in plant tissue is very wide and as high as 18% has been recorded in graminaceous plants. In many forage species the Si compound accumulated practically in all plant tissues respectively 3 to 5 per cent of dry matter content (Smith et al. 1971). Si content of Maize and Cymbopogon is 9.8 and 8.40 % respectively. Generally due to high Si content the plant nature is sturdy. E. geniculata shows maximum 7%Si in stem tissues which can justify its soft herbaceous nature and moderate disease resting capacity.

Other trace elements like Zn, Cu, Ni and Co are also worked out and recorded in table 13.The literature on the trace elements is not readily available. Bhosale (1978) have given the distribution of trace elements from the mangrove leaves. From our results what we can say only is that possibly due to the availability of all the macro and micro elements listed in table 13, E. geniculata thrives well during all the seasons of the year.

3.7 Pathophysiology :

Pathophysiology is a specialized branch of phytopathology, which deals with the study of physiological and biochemical activities of pathogen and response of host plant tissues. Thus pathophysiology covers both the aspects i.e. physiology of pathogen and physiological response shown by the host to attack of pathogen. However, in present investigation we have concentrated our study only on effect of pathogen on physiology of host plant.

Pathogen observed during present study is a rust Melampsora sps. belongs to a order Uredinales of class Basidiomycetes. It is characterized by its sessile

FIG. 6

a) Healthy leaf of E. geniculata

b) E. geniculata leaf infected with Melampsora sps.

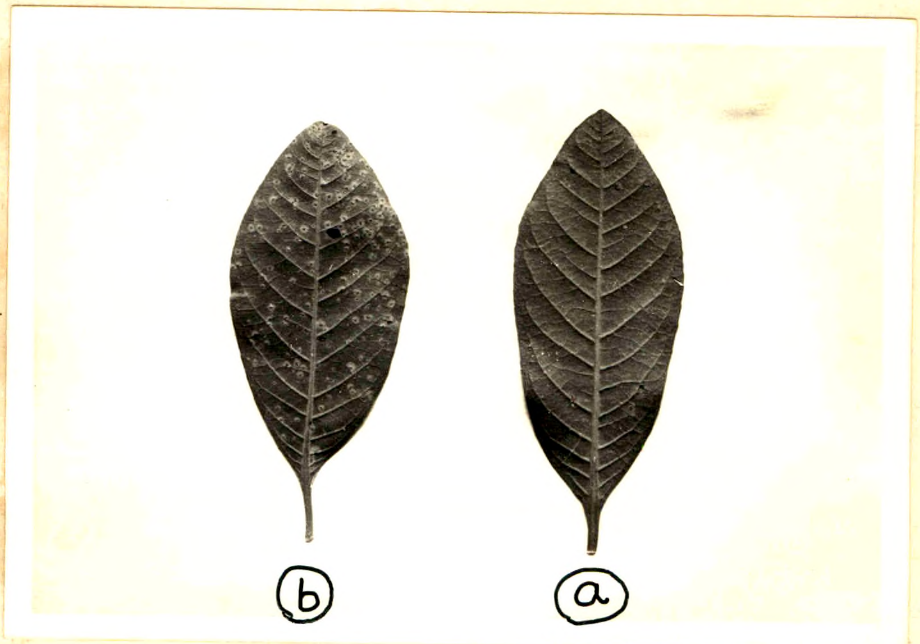


FIG. 6

teliospores which unite laterally to form a palisade layer below the epidermis. While uredospores are yellowish orange in colour.

During present study the weed Euphorbia geniculata Orteg. was found to be infected with Melampsora sps. throughout the winter season. Infection was observed on undersurface of leaf, and was identified by many yellowish orange spots or lesions of Urediospores (Fig. 6).

It is a generalized fact that pathogen, during pathogenesis affects the normal metabolism of host plant. However to cope with the attack of pathogen host plant develops certain defence mechanisms (Mehrotra 1987).

The weed E. geniculata though infected by rust Melampsora sps. grows more or less well in winter season. So it was interesting to study effect of Melampsora infection on physiology of host E. geniculata which will throw some light on its defence mechanisms.

3.7.1 Effect of Melampsora infection on organic constituents :

Comparative valuesd of organic constituents like TAN, chlorophylls, NR, NiR, totalnitrogen and crude proteins in healthy and rust (Melampsora) infected leaves of E. geniculata are given in table 14.

From table 14, it is evident that TAN value is decreased due to the infection by Melampsora sps. This indicates that there is an inhibition of acid production due to the infection. This fact can be attributed to disease resistance capacity of E. geniculata. Marutyan et al. (1979) studied the metabolism of leaves of new varieties of allied forms of grapes under infection with mildews (Plasmopara viticola). In their study they reported that resistant varieties had leaves with higher total acidity than the non resistant varieties.

Table 14 : Effect of *Melampsora* infection on organic constituents of leaves of *E.geniculata*.

Material	TAN*	Chlorophylls **				*** Nitrate reductase	*** Nitrite reductase	**** Total nitrogen	**** Total proteins
		'a'	'b'	'a + b'	a/b				
Healthy Leaf	31.11	193	97.6	290.6	1.98	97.99	0.66	4	22.8
Infected leaf	28.28	98.9	85.70	184.6	1.15	29.82	0.47	3.25	18.5

* ml of decinormal NaOH required to neutralize acid present in 100 g fresh tissue.

** mg $100 g^{-1}$ fresh tissue.

*** u moles of $No_2 h^{-1} g^{-1}$ fresh wt.

**** g 100 g^{-1} dry wt.

Upon the infection acidity of the leaves of non-resistant varieties increased and that of resistant ones decreased. Similarly Thite et al. (1980) have reported that TAN value in teak leaves decreases due to the powdery mildew infection. In case of Ricinus communis, a member of Euphorbiaceae decrease in TAN value due to the infection of Melampsora ricini was recorded by Gharge (1984). Our results in E. geniculata follows similar pattern.

The chlorophylls are the green pigments universally present in all photosynthetic tissues. Chlorophyll 'a' and 'b' occur almost in all higher plants. The disease development affects not only the total chlorophyll content but also alters the ratio between chl. 'a' to chl. 'b'. A measurement of green pigments may indirectly denote the severity of disease especially in systemic diseases. Chlorophyll estimate may also be required to relate other biochemical changes in plant tissue. In present investigation therefore an attempt has been made to analyse the healthy and infected leaves with respect to chlorophylls and to relat this to the mechanism of disease resistance in the E. geniculata.

The results showing the amount of Chl.'a', Chl.'b', total chlorophylls and chl. a:b ratio are depicted in table 14. It is clear that total chlorophyll content of leaf tissue is depleted due to fungal infection. Chl. 'a' is affected more as compared to chl. 'b' which further decreases Chl. a:b ratio. Many workers have suggested that there is a decrease in chlorophylls due to infection of fungi as well as bacteria and viruses.

Montalbini et al. (1975) have shown 50% decrease in chlorophyll content in the leaves of peach infected by Taphrina deformans. They have also shown that the chlorophyll 'a' to 'b' ratio is lower in infected leaves than in healthy ones. Srinivasan and Jeyarajan (1976) observed a great decrease in chlorophyll and anthocyanins in the grape leaves infected by Plasmopara vitiola. Tungwat (1977) has studied the chl. a:b ratio as influenced by plant pathogens in some plants. In Dichanthium annulatum the chl. a:b ratio was 5:1 in healthy plant, while in diseased plants it was 4:0. The decrease in ratio in deseased plant is thought to be advantageous to the plants and decrease being due to decompo sition of chl. 'a' or 'b'. Gharge (1984) have recorded similar results in leaves of Ricinus communis infected by Melampsora ricini. Our observations with Euphorbia geniculata also show the same trend.

Nitrogen is one of the most prevalent elements in the living organisms and is found in essential compounds such as proteins, nucleic acids, growth regulators and in many of the vitamins. It is well known that amino acids are good nutritional source for parasitic fungi. Fungi decomposes proteins in nature to their component amino acids. Because of parasitic pathogens plant shows changes in growth to normal pattern.

Several workers have reported that there is reduction in total nitrogen and proteins due to the infection. Izawa (1974) reported that there is decrease in protein content in Italian rye grass when infection with Puccinia coronata. Arjunan (1976) found that in leaves of jawar infected by Helminthosporium turcicum, there is slight increase in 10 days old plant but after 60 days there is significant decrease of nitrogen in infected leaves. Decrease in total nitrogen and proteins in Melampsora ricini infected leaves of Ricinus communis have been recorded by Gharge (1984). Our results about total nitrogen and total proteins content in infected leaves of E. geniculata are on similar line. This decreased levels of nitrogen and protein may be due to the susceptibility of plants or because of utilization of it by fungal pathogen. This fact is further confirmed by reduced activity of enzyme nitrate reductase and nitrite reductase in Melampsora infected leaves of E. geniculata because there is a positive correlation between protein metabolism and NR activity (Pate, 1968).

Nitrate reductase and nitrite reductase are key enzymes of nitrogen metabolism. From table 14, it is evident that activity of NR and NiR is significantly decreased in leaves of E. geniculata due to infection of Melampsora sps. The literature about effect of pathogen on activity of NR and NiR is scanty. We have already discussed the reduced chlorophyll content in leaves due to infection. It is a fact that NR and NiR are chloroplastic enzymes (Miflin, 1974; Losada et al., 1981). The reduced chlorophyll value due to infection finally will result in less photosynthetic efficiency and disturbed protein metabolism. The inhibited activities of enzymes of nitrogen metabolism can be one of the effects reflected by reduced chlorophyll level.

3.7.2 Effect of Melampsora infection on inorganic constituents :

Plants need number of inorganic elements for their normal growth. A majority of them are derived from the supporting substratum. Similarly fungi also need inorganic elements for their normal growth. Amongst the inorganic elements, phosphorus, sulfur and magnesium are major ones. In addition to this they also need atleast five microelements. The known essential micronutrients are iron, zinc, copper, manganese and molybdenum (Cochrane, 1963). Parasitic fungi obtain these mineral nutrients from host. Due to which the nutrient level of the host plant alters.

The effect of Melampsora infection on inorganic constituents in leaves of E. geniculata is shown in table 15. From table it is clear that due to rust

Table 15 : Effect of *Melampsora* infection on inorganic constituents* of leaves of *E. geniculata*

	Na	K	Ca	Fe	Mg	Si	Cu	Zn	Mn	Co
Healthy leaf	0.14	4	6.04	0.05	1.19	1.5	0.004	0.011	0.012	.001
Infected leaf	0.19	3.5	4.76	0.052	0.47	2.5	0.003	0.007	0.010	.0015

* $g\ 100\ g^{-1}$ dry wt.

infection inorganic metabolism is disturbed. Rust infected leaves of E. geniculata contain more Na, Fe, and Si and reduced level of K, Ca, Mg, Cu, Zn, Mn, while cobalt remains unaffected.

Accumulation of sodium in the infected leaves of E. geniculata may be due to the stimulatory effect of pathogen in uptake of Na. Hegade and Karande (1978) have recorded accumulation of Na in leaves of bajara infected by green ear disease. Similarly increase in Na content in leaves of Arachis hypogaea and Ricinus communis due to the infection of Puccinia arachidis and Melampsora ricini respectively was reported by Gharge (1984). Our results are on similar line.

Very little information is available regarding the role of potassium in fungal physiology as well as on the effect of fungal infection on K metabolism. However Sivaprakasan et al (1974) have shown that there is reduction in potassium content in the leaves of brinjal infected by Verticillium dahliae. While Steinberg (1946) in case of Aspergillus niger reported that an increase in potassium content in culture medium, decreases the rate of mycelium production. In light of above literature we can say that though potassium content in leaves of E. geniculata is reduced due to Melampsora infection, over all K content of leaves is high, table 15. This high level of K may inhibit the production of fungal mycellium and hence moderate resistance to pathogen. Gharge (1984) have observed similar results in leaves of castor infected by Melampsora ricini.

Calcium is a macroelement which gives mechanical strength to the tissue Kiraly and Gilly (1976) state that calcium increases resistance of pectic substances and cell wall against enzymatic degradation. Patil and Kulkarni (1977) have reported that there is an accumulation of calcium in the leaves of sunflower infected by rust Puccinia helianthi. However, our present results show slight decrease in 'Ca' content due to infection. Such results are already reported in Ricinus communis infected by Melampsora by Gharge (1984).

From table 15 it is evident that iron level in infected leaves of Euphorbia geniculata is slightly increased. Kulkarni and Kulkarni (1978) have noted that there is an accumulation of iron in the leaves of sunflower and mango plants infected by Puccinia helianthi and Capnodium ramosum respectively. Chaudhri et al. (1978) state that reduction in the iron content leads to the severe chloro sis, which occurs as a primary effect of infection. Gharge (1984) have shown that there is a significant increase in iron content in the infected leaves of Ricinus communis. Our results are in co-ordination with literature cited above. Further according to the view of Chaudhri et al. (1978) we can say that incr- eased level of Fe may be one of the defence mechanisms of E. geniculata, with the help of which E. geniculata may resist against the chlorosis effect of pathogen.

The value of Mg in infected leaves of E. geniculata is significantly low as compared to healthy leaves (Table 15). This fact is well attributed with reduction in chlorophyll content of infected leaves of E. geniculata. Gharge (1984) have reported similar results in leaves of Ricinus communis infected by Melampsora ricini.

From table 15, it is clear that level of silicon (Si) is significantly high in leaves of E. geniculata infected by Melampsora sps. Benoit et al. (1978) have suggested that silicon affords resistance against the attack of pathogens. Considering the opinion of Benoit et al.,(1978) we can say that E. geniculata may resist the attack of pathogen, Melampsora to a some extent by increasing the level of silicon in the leaves.

The information about the role of trace elements like Cu, Zn, Mn, and Co in physiology of diseased plant is not available. However, we can say that this reduced level of trace elements in infected leaves is possibly due to utilization of these elements in growth of the fungal pathogen.