STUDIES IN THE ECOLOGICAL LIFE HISTORY OF *EUPHORBIA THYMIFOLIA* LINN.*

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ABSTRACT

Euphorbia thymifolia Linn. is a small prostrate herbaceous annual weed frequently met with along roadsides, gravel walks, grasslands, etc. Two ecotypes of the species, (i) the red form and (ii) the green form, have been recognized. In the case of the green form, the seed output is shown to be correlated directly with increase in the amount of exchangeable calcium within a range of 3·5 to 8·4 m.e. per cent. The associates of *E. thymifolia* in calcareous and non-calcareous soils are enumerated. Though the red form has a higher percentage germination of seeds than the green form, a better seed output of the latter compensates for it and thus gives a higher reproductive capacity for the green form. Stomatal frequency and stomatal index for the red and the green forms and also for the 'sun' and the 'shade' leaves of the red form have been studied. The osmotic pressure of the plant sap is well within the range of a typical mesophyte and is seen to fluctuate with changes in moisture level of the soil. The dispersal mechanism of seeds and its effectiveness has been studied and the seedling morphology is given.

Euphorbia thymifolia Linn. is a small prostrate herbaceous annual weed. The plant is frequently found to grow along roadsides, gravel walks, grasslands, abandoned fields, etc. The plant occurs throughout India and Ceylon in the plains and lower hills, ascending in Kashmir to 5,500 ft (Hooker 1872–1897). Distribution of the plant is pan-tropical.†

In *E. thymifolia* two ecotypes, the red form and the green form, have been recognized. These two forms interbreed and give rise to three intermediates. Thus in F_2 generation a ratio of $\frac{RR}{RR} : \frac{Rr}{RR} : \frac{Rr}{rR} : \frac{Rr}{rr} : \frac{rr}{rr} = 1 : 4 : 6 : 4 : 1$ is recognized, starting with the red form and ending into the green form with three intermediate types. It has been found that the first two forms can grow in calcareous as well as non-calcareous soils while the latter three forms are strictly confined to non-calcareous soils only. $\frac{RR}{RR}$ and $\frac{Rr}{RR}$ have been termed as facultative calcicoles and the other three forms as obligate calcifuges. It has been found that the obligate calcifuges are confined to non-calcareous soils due to their germination behaviour, performance and root

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† This information was obtained from the Director, Royal Botanic Gardens, Kew, Richmond, Surrey.

competition with facultative calcicoles in non-calcareous and calcareous soils (Ramakrishnan 1959, 1961).

Environmental Factors

Climatic :

The climate of Varanasi is typical of the Upper Gangetic Plains and has been mentioned elsewhere (Ramakrishnan 1960*a*). *E. thymifolia* thrives all the year round being able to withstand cold during the winter and drought during hot and dry months of summer. The plant continues to flower and fruit in all the seasons.

Edaphic :

The edaphic factors concerning the distribution of calcicolous and calcifugous forms in this plant have been discussed in another paper (Ramakrishnan 1961). The soil analysis data for the red form and the green form are set in Table I. The methods of soil analysis are given elsewhere (Ramakrishnan 1960*a*).

Table I

Soil analysis data for the red and the green forms of E. thymifolia

	Locality	Moisture content (%)	*p*H	Carbonate content (%)	Exchangeable calcium (m.e. %)	Nitrate content (mg/100 g of soil)	Organic matter (%)	Incidence of different forms
Red Form	Sarnath ..	14·00	7·4	0·018	4·75	1·30	3·50	Red and green forms grow together.
	Akhari ..	17·20	7·5	0·138	5·30	3·83	2·72	do.
	Lanka ..	1·21	7·4	0·130	7·00	2·00	1·02	do.
	University area ..	15·10	6·5	0·125	18·00	2·50	5·10	Only red form grows.
	Rajghat ..	19·30	8·0	0·236	18·50	5·50	4·22	do.
	Latifshaw ..	15·80	7·9	3·625	30·10	3·75	1·56	do.
	Rajatalab ..	21·20	8·3	1·690	35·85	2·75	4·30	do.
	Ramnagar ..	20·60	7·9	5·250	84·35	3·75	5·20	do.
Green Form	University area ..	14·60	5·6	0·118	4·50	2·75	4·60	Red and green forms grow together.
	Sarnath ..	14·00	7·4	0·018	4·75	1·30	3·50	do.
	Akhari ..	17·20	7·5	0·138	5·30	3·83	2·72	do.
	Lanka ..	1·21	7·4	0·130	7·00	2·50	5·10	do.
	Latifshaw ..	17·80	7·7	0·755	8·40	4·00	2·80	do.

Moisture content.—The plant has a wide range of tolerance with regard to moisture in the substratum. However, it does not withstand water-logged conditions.

*p*H.—The red form and the green form are found to grow mostly in alkaline soils irrespective of whether the soil is calcareous or not.

Carbonate content.—The red form shows a range of 0·018 to 5·250 per cent and the green form of 0·018 to 0·755 per cent with regard to this factor.

Exchangeable calcium.—It has already been mentioned that the red form grows in calcareous as well as non-calcareous soils and the green form in non-calcareous soils only.

Nitrate content.—Nitrate nitrogen in soil varies from 1·3 to 5·5 mg/100 g of soil.

Organic matter.—This factor has a range from 1·02 to 5·20 per cent in soil.

Performance of the Plant in Various Localities

The average seed output of the plant is indicative of its success in different localities (Table II).

Table II

Seed output of E. thymifolia *in various localities*

	Locality	Average No. of capsules/plant	Average seed output
Red Form	Sarnath ..	680	2,040
	Akhari ..	142	426
	Lanka ..	171	513
	University area	222	666
	Rajghat ..	228	684
	Latifshaw ..	524	1,572
	Rajatalab ..	321	963
	Ramnagar ..	180	540
Green Form	University area	421	1,263
	Sarnath ..	423	1,269
	Akhari ..	429	1,287
	Lanka ..	484	1,452
	Latifshaw ..	2,042	6,126

A comparison of Tables I and II shows no definite correlation between the soil analysis data and seed output in the case of the red form. It is interesting to note that calcareous or non-calcareous nature of the substratum is of little consequence in the performance of the red form.

In the case of the green form, however, a correlation could be established between the performance of the plant and exchangeable calcium in the soil as is revealed by a comparative study of Tables I and II. Within a range

of 4·5 to 8·4 m.e. per cent of exchangeable calcium (Table I), the seed output increases with an increase in the former. Nevertheless, as pointed out elsewhere, the plant has stunted growth and exhibits chlorosis in calcareous soils under cultural conditions (Ramakrishnan 1960*a*).

Associates

The common associates of *E. thymifolia* in calcareous soils are given in Table III.

Table III

Associates of E. thymifolia *in calcareous soils*

Species	Localities*				
	1	2	3	4	5
Euphorbia thymifolia ..	a	f	a	f	f
Amarantus spinosus ..	—	—	—	—	r
Coldenia procumbens ..	—	—	—	—	a
Croton sparsiflorus ..	—	—	—	—	d
Cynodon dactylon ..	—	—	—	—	f
Cyperus compressus ..	r	—	—	—	—
Desmodium triflorum ..	f	—	—	—	—
Eclipta alba	—	r	—	—	—
Euphorbia hirta ..	a	o.f	f	f	—
E. microphylla ..	—	—	o.f	—	—
Evolvulus alsinoides ..	—	—	f	f	—
Fimbristylis diphylla ..	—	—	—	a	—
Heliotropium strigosum	—	—	—	—	f
Lippia nodiflora ..	—	—	—	—	a
Mollugo hirta ..	—	a	—	—	—
Nepeta ruderalis ..	—	v.r	—	—	—
Sphaeranthus indicus ..	—	—	o.f	—	—
Sporobolus diander ..	—	—	o.f	—	—
Xanthium strumarium ..	—	f	—	—	—

* Localities: 1. University area, 2. Rajghat, 3. Latifshaw, 4. Rajatalab, 5. Ramnagar.

In Table IV are given the common associates of this species in calcium poor soils.

Root System

The root system penetrates up to a depth of 13 to 20 cm. From the main root a number of laterals arise. The root habit of the red form in calcareous and non-calcareous soils and the green form in non-calcareous soils appears not to be much different (Table V).

However, the root system of the green form, under cultural conditions, is much affected in calcareous soils (Ramakrishnan 1960*a*).

TABLE IV

Associates of E. thymifolia *in calcium poor soils*

Species	Localities*				
	1	2	3	4	5
Euphorbia thymifolia ..	f	v.f	f	a	v.f
Boerhaavia diffusa ..	f	—	—	—	—
Cassia tora ..	—	—	—	—	o.f
Crotalaria medicagenia ..	o.f	—	—	—	—
Cynodon dactylon ..	—	—	a	—	—
Dactyloctenium aegyptium	—	—	—	—	f
Desmodium triflorum ..	—	—	—	—	a
Euphorbia hirta ..	—	o.f	f	f	a
Evolvulus alsinoides ..	a	f	f	f	f
Fimbristylis diphylla ..	f	—	—	—	f
Heliotropium strigosum	f	—	—	—	—
Indigofera linifolia ..	f	—	—	o.f	—
Mollugo hirta ..	—	r	—	o.f	—
Tephrosia purpurea ..	—	—	r	—	—
Trichodesma decussata ..	—	—	—	r	—

* Localities: 1. University area, 2. Sarnath, 3. Akbari, 4. Lanka, 5. Latifshaw.

TABLE V

Root system of E. thymifolia *in calcareous and non-calcareous soils*

Observations	Calcareous soil, red form	Non-calcareous soil	
		Red form	Green form
Av. depth of the root system (cm)	17·0	14·9	13·2
Av. fresh weight of shoot (g) ..	2·270	1·382	2·331
Av. fresh weight of root (g) ..	0·107	0·061	0·083
Av. dry weight of shoot (g) ..	0·545	0·311	0·529
Av. dry weight of root (g) ..	0·027	0·018	0·023
Root/shoot ratio (fresh wt. basis) ..	0·047	0·044	0·036
Root/shoot ratio (dry wt. basis) ..	0·050	0·058	0·043

BIOTIC FACTORS

It has been discussed (Ramakrishnan 1961) that the obligate calcifuges from calcareous soils are eliminated by means of root competition with the facultative calcicoles. The plants can withstand grazing by cattle and scraping by man. Fungal parasites are not reported on this species from India.*

* This information was obtained from the Head of the Division of Mycology and Plant Pathology, Indian Agricultural Research Institute, New Delhi.

Phenology

The plants thrive throughout the year, flowering and fruiting freely. The seeds can germinate immediately after dispersal from the plant, if the conditions are favourable. Flowering starts when the plants are about 1 to 1½ months old and continues for about 5 to 7 weeks.

Size and Weight of Seeds

The seeds are minute, quadrangular bluntly pointed with 5 to 6 shallow transverse furrows. The length varies from 887 to 920μ and the breadth from 434 to 532μ. The shape index as indicated by the ratio length/breadth varies from 1·7 to 2·1. The average weight of the seeds is 0·13 mg. There is found to be no appreciable difference in the weight of the seeds of the various forms recognized in this plant.

Germination of Seeds

The seeds of *E. thymifolia* have no dormancy period. The germination of the red form and the green form of *E. thymifolia* was tried in petri dishes in between moist filter papers. The seeds collected in July, 1957, were put for germination on 10th October, 1957 (Table VI).

Table VI

Germination of seeds of the red and the green forms

Date	Number of seeds germinated out of 50	
	Red form	Green form
12-10-57	8	6
13-10-57	20	8
14-10-57	3	4
15-10-57	2	2
16-10-57	1	4
Percentage of germination	68	48

The red form has a germination of 68 per cent and the green form of 48 per cent only.

The germination of the seeds of *E. thymifolia* (green form) has been tried under different light conditions on 6th February, 1958 (Table VII). They were kept in (i) diffused daylight and darkness at night by the side of a window, (ii) continuous light of an electric bulb and (iii) continuous darkness inside a chamber.

TABLE VII

Germination of seeds of the green form of Euphorbia thymifolia *under different light conditions*

Date	Number of seeds germinated out of 50		
	Diffused daylight	Continuous light	Continuous darkness
8-2-58	0	0	13
9-2-58	10	1	5
10-2-58	7	0	1
11-2-58	5	0	0
12-2-58	1	0	0
13-2-58	1	0	0
Percentage of germination	48	2	38

Maximum germination of 48 per cent is obtained in diffused daylight. In continuous darkness germination percentage is low and in continuous light it is very poor.

REPRODUCTIVE CAPACITY

The reproductive capacity for the red and the green forms of *E. thymifolia* is set in Table VIII.

TABLE VIII

Reproductive capacity of E. thymifolia

Ecotype	Percentage of germination	Average seed output	Reproductive capacity
Red form ..	68	926	639
Green form ..	48	2,277	1,030

It is seen that the green form has a higher reproductive capacity though the germination percentage is low because of the higher seed ouput value for this ecotype.

EPIDERMAL STRUCTURE AND STOMATAL FREQUENCY OF LEAVES

The epidermal cells of the leaves of *E. thymifolia* differ in their configuration on the upper and lower surfaces. The epidermal cell walls of the upper side are more or less straight, while those on the lower surface are wavy in surface view. The stomata are found on both the surfaces, but their number per unit area is more on the upper side than on the lower side as seen from

Table IX unlike those of *Eclipta alba* and *Euphorbia hirta* (Ramakrishnan 1960*a*, *b*). The frequency of stomata of the red form and the green form of *E. thymifolia* was studied in plants growing side by side in the open and the results are shown in Table IX.

TABLE IX

Stomatal frequency and stomatal index in the red and the green forms of E. thymifolia

	Sl. No.	Upper epidermis		Lower epidermis		Stomatal index	
		Stomata per sq. mm	Epidermal cells per sq. mm	Stomata per sq. mm	Epidermal cells per sq. mm	Upper surface	Lower surface
RED FORM	I	411	1,411	314	1,275	22·6	19·8
	II	471	1,284	265	961	26·8	21·6
	III	431	1,284	245	922	25·1	21·0
GREEN FORM	I	411	1,392	216	990	22·8	17·9
	II	373	1,225	176	667	23·3	20·9
	III	392	1,333	167	824	22·7	16·9

It is seen that there is no appreciable difference in the stomatal frequency and stomatal index in the red and the green forms.

The frequency of stomata in the open and in the shade varies considerably being more in the 'sun leaves' than in the 'shade leaves'. The data regarding this for the red form are set in Table X. The leaves were examined from the 7th node.

TABLE X

Stomatal frequency and stomatal index in 'sun' and 'shade' leaves of E. thymifolia *(red form)*

	Sl. No.	Upper epidermis		Lower epidermis		Stomatal index	
		Stomata per sq. mm	Epidermal cells per sq. mm	Stomata per sq. mm	Epidermal cells per sq. mm	Upper surface	Lower surface
OPEN	I	411	1,411	314	1,275	22·6	19·8
	II	471	1,284	265	961	26·8	21·6
	III	431	1,284	245	922	25·1	21·0
SHADE	I	333	1,235	216	853	21·2	20·2
	II	304	1,235	206	824	19·8	20·2
	III	304	1,157	206	804	20·8	20·4

Osmotic Pressure of the Plant Sap

The osmotic pressure of the plant sap of *E. thymifolia* fluctuates with variation in the moisture content of the substratum. In locality II it is interesting to note that after heavy rains the osmotic pressure of the plant sap falls down due to a temporary increase in moisture level of the soil. The osmotic pressure values are well within the range of a typical mesophyte (Table XI).

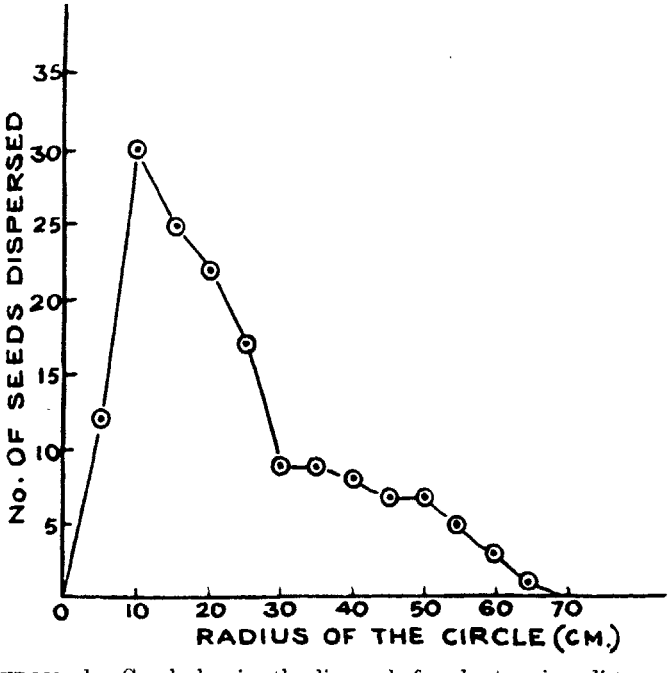
Table XI

Osmotic pressure of the plant sap of E. thymifolia

Locality	Moisture content of the substratum (%)	Osmotic pressure of plant sap (atmos.)	Remarks
I	5·5	12·3	—
II	19·2	8·3	—
III	25·4	6·8	After rains

Dispersal of Seeds

In *E. thymifolia* dispersal of the seeds occurs by an explosive mechanism of the capsule. Ridley (1930) describes this mechanism as follows for the



Text-fig. 1. Graph showing the dispersal of seeds at various distances.

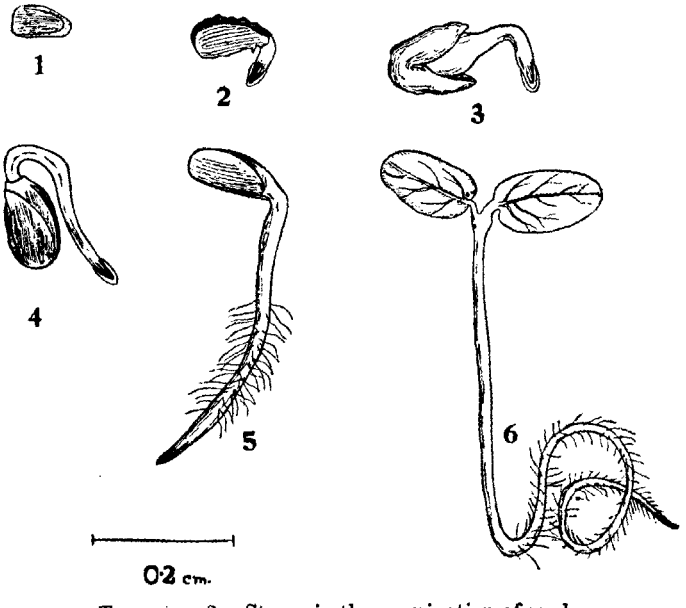
Euphorbiaceous plants with capsular fruits. 'The outer layer of the pericarp is thin and soft and soon becomes dry, the inner endocarp is hard and woody, composed of transverse fibres which are straight when wet but recurve on themselves when dry, so suddenly as to cause an explosion and eject the seeds.'

The effectiveness of this type of dispersal has been studied. On a large sheet of paper, circles with radii of 5, 10, 15 cm, etc., were drawn. Mature undehisced capsules were put in the centre of the innermost circle and were allowed to dry. The observations made after about 5 hours for the dispersal of seeds at various distances are shown in Text-f.g. 1.

It is observed that maximum number of seeds are dispersed to a distance of about 5 to 25 cm around the plant. In nature, the seeds dispersed by the bursting of the capsules may further be carried away by wind currents.

Seedling Morphology

The germination of seeds in *E. thymifolia* is epigeal. The radicle appears as a protuberance from the pointed end of the seed by a narrow split in the testa. When the radicle is a few mm long, the hypocotyl elongates in the form of a bend. The two cotyledons are raised above the soil due to this elongation and in this process are withdrawn from the testa. In the red form the cotyledons are red in colour even from the very beginning and in the green form they are green in colour. Thus in the 2-leaved stage itself



Text-fig. 2. Stages in the germination of seeds.

the difference in pigmentation is marked. The next pair of leaves are also similar to the cotyledonary leaves in size and shape and persist until several of the true leaves are developed (Text-fig. 2).

The germination of seeds and seedling morphology of this species are very similar to that of *Euphorbia hirta* Linn. It is often difficult to distinguish the seedlings of these two species up to the 4-leaved stage. The differences are marked only in the leaves that develop later.

Discussion

It has been discussed elsewhere (Ramakrishnan 1961) that the two ecotypes, the red form and the green form, interbreed and give rise to three intermediates and the five forms thus obtained fall into two ecological groups: (1) the facultative calcicoles, and (2) the obligate calcifuges. These two groups have been differentiated on the basis of germination behaviour, growth performance, competition and calcium content in calcareous and non-calcareous soils.

It has also been found that the red form is indifferent to calcium in the soil with regard to its seed output and this observation goes to prove again that the red form is calcicolous not by preference but just because of its capacity to thrive in calcareous soils; in other words, it is a facultative calcicole.

It has been observed, in the case of *Echinochloa colonum* Link., that the tall form has a higher seed weight compared to the short form (Ramakrishnan 1960*c*). This is understandable in *Echinochloa colonum* Link. because of the difference in size of the two ecotypes. But in *Euphorbia thymifolia* Linn. no difference in seed weight has been observed for the two ecotypes. This is evident as there is no marked difference in the growth form of the red and green forms.

The germination of seeds in *Euphorbia thymifolia* Linn. is markedly inhibited in continuous light, while in darkness the percentage germination tends to fall down. In diffused daylight optimum germination is obtained. In *Eclipta alba*, on the other hand, germination is markedly increased in continuous light but inhibited in darkness (Ramakrishnan 1960*a*). Most of the theories that have been advanced to account for this phenomenon have assumed that the effect of light is on the living tissues of either the endosperm or the embryo, while others have postulated its effect on the non-living seed coats also (Crocker and Barton 1953).

The frequency of stomata of the red form and the green form of *Euphorbia thymifolia* shows no difference. The difference in the stomatal frequency of the erect type and the prostrate type of *Euphorbia hirta* is understandable as these two ecotypes are confined to moist and drier habitats respectively. The higher stomatal frequency in the case of 'sun' leaves compared to 'shade'

leaves is accounted for as due to the drier conditions available in the open than in shade (Salisbury 1932).

Differences have also been recognized in the germination behaviour, seed output and reproductive capacity of the two ecotypes besides the factors that control the distribution of the two ecotypes in calcareous and non-calcareous soils.

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