CONTRIBUTION TO THE PHYSIOLOGICAL ECOLOGY OF *ZALEYA GOVINDIA* (BUCH-HAM. EX G DON.) N. C. NAIR, COMB. NOV. (SYN. *TRIANTHEMA GOVINDIA* BUCH.-HAM. EX G. DON. = *TRIANTHEMA PENTANDRA* AUCT. PLUR. NON. LINN.) - A COMMON MEDICINAL PLANT

A THESIS SUBMITTED IN PART FULFILMENT
ON THE REQUIREMENT FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
BOTANY

BY
BISHAN CHANDRA NIGAM, M. Sc.

DEPARTMENT OF BIOLOGICAL SCIENCES,
BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE,
PILANI, RAJASTHAN, INDIA
1970

DEDICATED

TO

MY

PARENTS

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE

PILANI

DEPARTMENT OF BIOLOGICAL SCIENCES

The thesis entitled "CONTRIBUTION TO THE PHYSIOLOGICAL ECOLOGY OF ZALEYA GOVINDIA (BUCH.-HAM. EX G.DON.) N.C.NAIR, COMB. NOV. (SYN. TRIANTHEMA GOVINDIA BUCH.-HAM. EX G.DON. = TRIANTHEMA PENTANDRA AUCT. PLUR. NON. LINN.) - A COMMON MEDICINAL PLANT", submitted by Shri B.C.Nigam, M.Sc., for the Degree of Doctor of Philosophy in Botany embodies the results of investigations done under my supervision, and I certify that the work is original.

September, 2 ,1970.

(Mohan Chandra Joshi)

Assistant Professor (Reader) of Botany

ACKNOWLEDGEMENTS

It is my foremost duty to offer my sincere gratitude to Dr.M.C.Joshi, Ph.D., F.B.S., F.R.A.Sc., F.I.T.E., Assistant Professor (Reader) of Botany for supervision and able guidance during the course of present investigation and the pains he has been taking most ungrudgingly in the preparation of this thesis. His words "Weeds, coming as visitors, appearing as companions and establishing as regulators, are subtle thieves", has put me on the right track and encouraged me to undertake this investigation.

I am grateful to Professor S.K.Pillai, former Head of the department of Botany and Professor A.K.Dattagupta, Head of the department of Biological Sciences, B.I.T.S., for providing laboratory facilities.

I also gratefully acknowledge the help rendered to me by Dr.B.D.Deshpande, Dr.K.R.Chandhoke, Dr.(Mrs.) A.Pillai, Dr.Bhambie and Dr.C.G.P.Rao.

I am highly obliged to Professor and Head, R.Misra and to Dr.K.C.Misra, Reader, department of Botany, Banaras Hindu University, Varanasi, for suggestions and improvements in the research programme and library facilities in the department. It is difficult to express my gratitude for the valuable suggestions of Dr.J.S.Singh, Kurukshetra University, which have been of immense value in my research work. I also feel obliged to Prof.B.V.Ratnam, Head of the department of Botany, Government College, Ajmer, for valuable criticism on Plant Water Relations, part of my thesis and to Dr.N.C.Nair, B.S.I. Calcutta, for going through the chapter on nomenclature problem of the plant investigated.

The required informations supplied by various departments, viz., Royal Botanic Gardens, England, New York and Sydney; Botanical Survey of India, Dehra Dun, Calcutta, Poona and Coimbatore; National Botanic Gardens, Lucknow; Central National Herbarium, Howrah; Forest Research Institute, Dehra Dun, and Nematology Section, I.A.R.I., New Delhi, are sincerely acknowledged.

My sincere thanks are due to Shri A.D.Taneja and his collegues of the Chemistry department, Shri M.G.Chandiramani of Mechanical Engineering department for helping in soil and plant analysis; Dr.Birbal Singh of Mathematics department for statistical analysis; Dr.M.K.Dheer of Physics department for programming and computation of the data and to Dr.V.N.Sharma of Zoology department for going through the manscript.

I am thankful to my collegues, Shri.V.Ramesh Babu, Arun Chaudhry and A.S.Reddy, who extended their whole hearted cooperation and help. I am also thankful to Dr.M.L.Trivedi, Dr.A.K.Kulshreshtha, Dr.S.C. Narula, Mrs.G.Banerji and K.T.Sebastian, M.P.G.Kutty, N.M.Gopinath and P.C.Khasgiwal for their timely help.

Had it not been for my parents, brothers and sisters I would not have been able to undertake and complete this project. I express my deep gratitude to them.

I am thankful to the U.G.C. for the scholarship awarded to me during the period of my research. I acknowledge gratefully the timely financial assistance given to me by the Director, B.I.T.S., Pilani.

B C Nigam

(BISHAN CHANDRA NIGAM)

September, 2. ,1970.

LIST OF PUBLICATION

KUMAR, A., M.C.JOSHI AND B.C.NIGAM. 1970. Structure of vegetation and primary productivity of grasses in relation to forbs and sedges in two different habitats of Pilani, Rajasthan. Productivity Symp. 57th.Indian Sci. Congr. Botany, Kharagpur. Abstract 17:9.

NIGAM, B.C. AND M.C.JOSHI. 1970. Effect of high temperature on moisture loss, inbibition and germination of seeds of <u>Trianthema govindia</u> Buch.-Ham. ex G.Don.Oster. Bot.Z. 118: 448-452.

NIGAM, B.C. AND M.C.JOSHI. 1970. Primary production and respiration in the leaves of two varieties of <u>Zaleya govindia</u> Buch.-Ham.ex G.Don.(<u>Trianthema pentandra</u> Linn.). Phyton (In Press).

C O N T E N T S

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CHAPTER 1

INTRODUCTION

together have contri... This reciprocal relationship of related complex sys... resolve into an understanding of organisms to its su... The form, function and factors interacting in time and space. ... in recent years has all the more found ... concept where an enquiry on the ... of organisms and their environment ... binding involving in the flow of energy and cycle of minerals ... the various components of the organism-habitat complex into a single whole, are concerned.

As opposed to population studies (Synecology) the study of individual (Autecology) has engaged the attention of workers from time to time. Salisbury (1928) formulated a scheme to work the ecological life histories of plants of British Isles. Elaborate schemes for such studies have been outlined by Pelton (1951) for herbs, shrubs and stem succulents; Penfound (1952) for herbaceous vascular hydrophytes and Stevens and Rock (1952) for herbaceous plants. Misra (1958) gave the biological flora concept in India. Daubenmire (1959) emphasised the plant behavioral study in relation to the natural or cultural environment of the plant.

Billings (1952), advocating the relationship between plant and environment, has stated that every plant species grows where it does to meet its genetic requirement. According to Misra (1958) a correct assessment of ecological nature of the plant can be gained by the study of its autecology.

Ecological life histories have much to contribute towards an understanding of the distribution of species as well as aiding in the solution of such general biological problems as environmental response, adaptation and speciation. Ecological physiology or physiological ecology is an ecotone branch between ecology and physiology which are closely inter-related. Eco-physiology thus embraces not only the study of the adaptive structural and functional features linking the individual to its specific environment, but also all the forms of transfer and transformation of energy connected with the dynamics of the ecosystem (Eckardt, 1965). Integral ecological life histories dealing with the plant population of the species, as it grows in nature (organisms in nature), are integral parts of ecosystems. Therefore, their ecological physiology must be considered as it involves the energy flow through the system explaining that ecology and physiology of ecosystems are the basic self sufficient units in nature. The ability of certain components (the primary producers) to introduce energy from solar radiation into the system by photosynthesis helps in laying the foundation of a complex biotic community.

Ecology of individual species has been investigated by Tansley (1917), Mukerjee (1936), Conway (1936, 1937, 1938), Gregor (1946, 1948), Montasir (1950), Montasir and Shafey (1951), Pelton (1953), Lodge (1962 a, b), and Tothill and Love (1964). In this field, Whitehead (1957) pleaded for experimental attention while [illegible] (1932) and Hiesey (1940) stressed on transplantation studies for ecotypic studies.

In India, [illegible] (19[illegible]) reported the species varieties and ecads in [illegible], [illegible] and Desai (1947) worked out the ecology of [illegible] [illegible] and Misra and Siva Rao (1948) reported the ecotypes of Lindenbergia. It was followed by autecological studies on [illegible] bispinosa (Srivastava and Iondon, 1951); Anisochilus eriocephalus (Bakshi, 1952), Cassia tora, C. obtusifolia, Polygonum glabrum, Heliotropium supinum, Trigonella occulata and Chrozophora rottleri (Mall, 195[illegible], 195[illegible], 1956); Crypis aculeata (Mall and Manilal, 1962); Dichanthium annulatum (Pandeya, 1953); Iseilandia latebrosa (Shrivastava, 1953); Sida acuta and Boswellia serrata (Sharma, 1954, 1955); Sesbania bispinosa (Trivedi, 1955); Casuarina equisetifolia (Puri, 1957); Xanthium strumarium (Kaul, 1959); Euphorbia hirta, Echinochloa colonum, Eclipta alba, Euphorbia thymifolia, and Setaria glauca (Ramakrishnan, 1960 a, b, c, d; 1961 a, b; 1963); Cynodon dactylon, Dactyloctenium aegyptium, Eragrostis tenella, E. viscosa and Evolvulus nummularius (Sant, 1961, 1965); Malvastrum tricuspidatum and Sida veroniceaefolia (Srivastava, 1963); Rouvolfia serpentina and Solanum xanthocarpum (Wakhloo, 1964 a, b, 1965); Arthroxon lancifolius and Bidens biternata (Varshney, 1964, 1966); Bacopa monnieri (Sah, 1965); Boerhaavia diffusa and Gompherena celosioides (Srivastava, 1966); Asphodelus tenuifolius, Cyperus rotundus and Eleocharis palustris (Tripathi, 1965); Solanum nigrum and S. surattense (Verma, 1966); Trichodesma amplixicaule (Shanker, 1967); Tribulus terrestris (Pathak, 1967), Biophytum sensitivum and Sphaeranthus indicus (Shetty, 1967 a, b) and Eichhornia crassipes and Spirodela polyrhiza (Das, 1968).

[illegible]cal studies on Rajasthan desert plants were made by [illegible] and Kapil (1952, 1954) on [illegible] and M. cerviana, Joshi and Kamohoj (1959) on Gisekia pharnaceoides, Joshi and Varghese (1967) on Anticharis linearis and Joshi et al. (1967) on Tribulus [illegible]. Recently, a survey on ecological life histories of Rajasthan desert plants has also been made by Joshi and Gupta (1970).

[illegible] regards the ecophysiology of Indian pentandrous species of Trianthema pentandra little work has been done. Joshi and Bhartiya (1957) worked out certain ecological aspects of this species. Deshpande et al. (1960) contributed to the ecological anatomy of the root of Trianthema found in Pilani. The floral anatomy of some members of Ficoideae including T. pentandra and T. decandra have been worked out by Sharma (1962). This author differentiated T. pentandra on the basis of two carpels and 5 alternitepalous stamens. Joshi and Mazumdar (1963) worked out anatomical features of certain members of Ficoideae including T. pentandra. Talbot (1956) has recorded Entorrhiza calospora to be associated with large galls on the roots of T. pentandra which is an African pentandrous species.

Since the plant T. pentandra is in plenty in tropical regions, its study in relation to environmental factors, concerning enquiry into its biological and ecological equipment, is of considerable importance.

The present investigation is an attempt to study the physiological ecology of the two varieties of Trianthema pentandra (Zaleya govindia N.C. Nair). The results of various aspects of physiological ecology have been recorded and discussed in detail in the succeeding pages under different chapters.

CHAPTER 2

SITE DESCRIPTION AND CLIMATE OF PILANI

LOCATION

The geographic location of Pilani is at 28°23' 15.07" N latitude and 75°36' 41.98" E longitude in the north - west of Jhunjhunu district of Jaipur division in Rajasthan. It is about 353.7 metres (1160.5 feet) above mean sea-level (Fig. 2.1).

PHYSIOGRAPHY

Pilani and its environs represent a typical semi-desert area with stretches of sand dunes and hard flats of varying stability. A general survey of the area reveals the various topographic zones like hillocks, low-lying areas, temporary ponds, sandy plains, mobile semi-stabilized and stabilized dunes of various shapes and sizes within the outskirt of Vidya Vihar Campus, Pilani, supporting discontinuous patches of plant associations with different dominant species from locality to locality (Ratnam and Joshi, 1952 and Joshi, 1958 a and b). During summer, when the velocity of wind is high, longitudinal and crescent shape (Barchan) dunes are well demarcated. Perennial water bodies are absent except a few permanent artificial reservoirs.

STUDY SITES

A few sites selected for the present study are located in or immediate vicinity of Vidya Vihar Campus. These sites

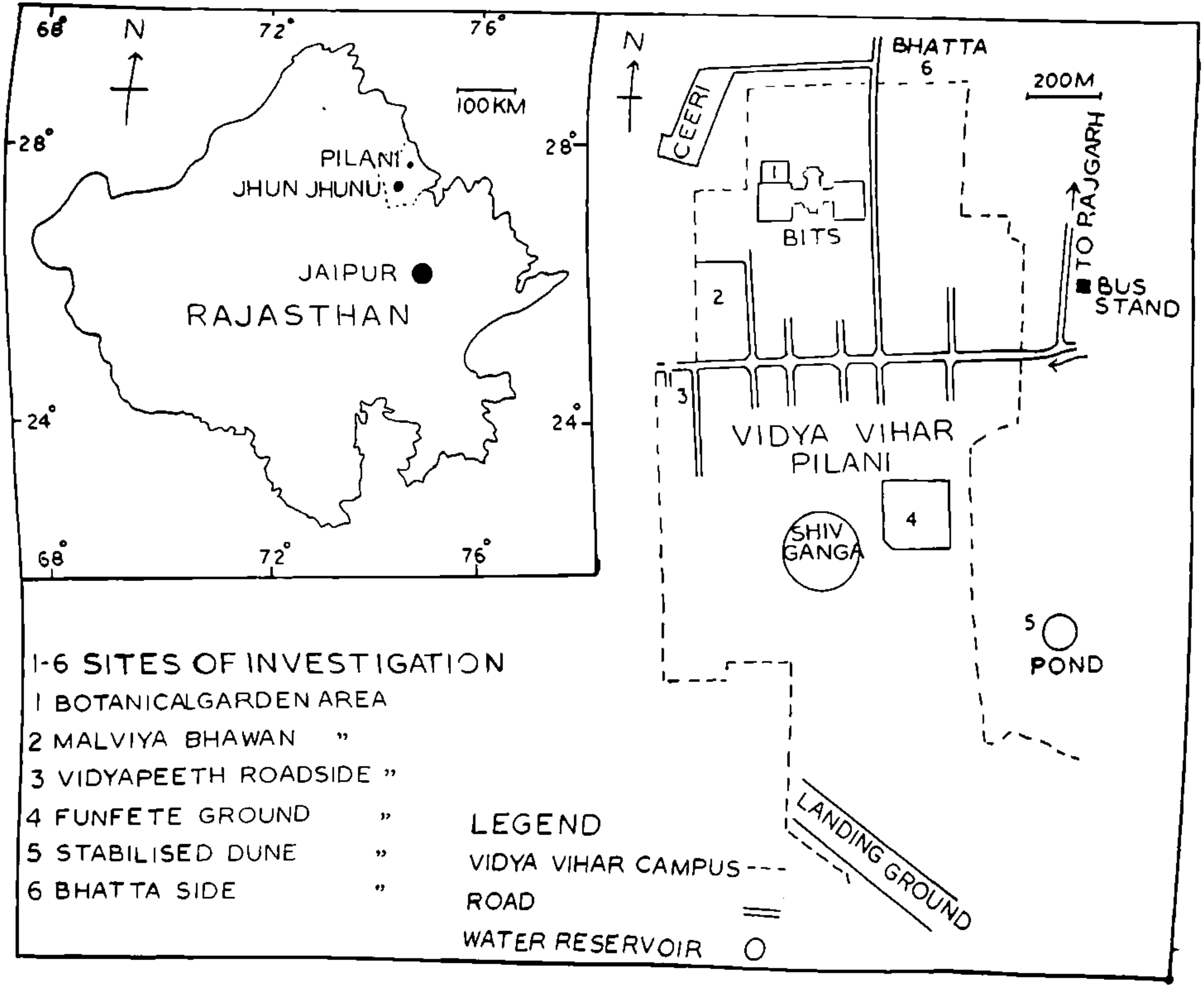
N
68°
72°
76°
100 KM
28°
24°
PILANI
JHUN JHUNU
JAIPUR
RAJASTHAN
BHATTA
6
200M
CEERI
1
BITS
2
3
TO RAJGARH
BUS STAND
VIDYA VIHAR PILANI
4
SHIV GANGA
5
POND
LANDING GROUND
1-6 SITES OF INVESTIGATION
1 BOTANICAL GARDEN AREA
2 MALVIYA BHAWAN "
3 VIDYAPEETH ROADSIDE "
4 FUNFETE GROUND "
5 STABILISED DUNE "
6 BHATTA SIDE "
LEGEND
VIDYA VIHAR CAMPUS
ROAD
WATER RESERVOIR

FIG. 2.1

differ from each other in their vegetation, soil composition, availability of water and biotic disturbances.

I. Botanical Garden area:

The area is protected by a high boundary wall and in part is shaded by the building wall and the trees like Albizzia lebbeck, Azadirachta indica, Butea frondosa, Cassia siamea, Millingtonia hortens, Moringa oleifera, Prosopis juliflora, P. cineraria, Salvadora oleoides, Tamarindus indica, etc. The area is free of grazing animals (Photo 2.1).

II. Malviya Bhawan area:

This is partially protected open area. The ground is plain and the top soil surface is found mixed with mortar and coke pieces in the sub-soil. Ground vegetation is composed of perennials like Aerva, Boerhaavia, Zaleya, Cyperus and Cynodon besides the annual species. The area is without any perennial tree complex. The vegetation is least disturbed but for rare manual scraping (Photo. 2.2).

III. Vidyapeeth Roadside area:

This is an unprotected open hard ground with herbaceous cover which comprises of Aerva, Boerhaavia and Zizyphus etc. with Prosopis juliflora planted along the road. The vegetation is heavily trampled by local people and domestic animals (Photo. 2.3).

IV. Fun-Fete Ground area:

It is also an unprotected area of flat plain and hard ground with a power station and an overhead water tank. It

I

2.1

II

2.2

III

2.3

has a single tree of *Prosopis cineraria*. The area is very much disturbed by the local and dairy animals (Photo. 2.4).

V. Stabilized Dune area:

The site is located outside the campus surrounding a temporary pond. The stabilized dunes are of varying height and size (Kumar *et al.*, 1970) and often leave a microrelief in between. The soil is loose in the inter-dune areas. The area supports a scrub of *Balanites roxburghii*, *Maytenus senegalensis*, *Prosopis cineraria*, *P. juliflora* and species of *Acacia*, *Capparis*, *Lycium* and *Zizyphus* (Ratnam and Joshi, 1952) besides the perennial and annual herbaceous vegetation in different seasons of the year. The area is heavily disturbed by the repeated sweeping of dunes for dried vegetation by local people. Besides, the ground vegetation is eaten by wild (rodents) and domestic animals (sheep, goat, cows, buffaloes and donkeys) (Photo 2.5).

VI. Bhatta Side area:

It is located to the north-east side of boundary wall of Campus. The ground is hard and the soil contains mortar and brick pieces. It supports a few herbaceous species like *Capparis*, *Zizyphus* and *Boerhaavia* (Photo. 2.6).

The corresponding number of sites has been referred throughout the text.

CLIMATE

The climate of Pilani can be roughly divided into four seasons, i.e., summer, rainy, pre-winter and winter, depending upon the change in temperature, rainfall and humidity (Fig. 2.2).

IV

2.4

V

2.5

VI

2.6

The data recorded (1967-69) has been obtained from Pilani observatory.

i. Temperature:

Summer starts from mid March and extends up to May and June. In March the monthly mean minimum and maximum temperatures range from 11°C to 14°C and 28°C to 34°C, respectively showing a difference of 20°C. In April, the temperature shows a rough increase of 10°C and the monthly mean minimum and maximum temperatures range from 16°C to 19°C and 35°C to 37°C respectively. The temperature further shoots up in May and June when the day temperatures go upto 48°C. The monthly mean maximum temperature during July, August and September varies within a narrow range of 32°C to 37°C while the monthly minimum temperature ranges between 23°C to 27°C, with a difference of 10°C between minimum and maximum. This is followed by pre-winter season which prevails for 30 to 40 days during October and November. During this short period the temperature is sufficiently lowered with a difference of 18°C to 20°C between minimum and maximum temperatures.

Winter starts from mid November and extends upto February. The monthly mean minimum and maximum temperatures range between 1.8°C to 10°C. In January, the temperature falls even to 0°C in night hours. Frost is rare while cold waves are common.

ii. Rainfall:

The monsoon usually starts in the end of June and extends up to September. The minimum and maximum rainfall in the months of June to September during 1967-69 ranges from 12.2 to 280.3 mm.

Maximum rain is recorded during July and August (Figs. 2.2, 2.3). During monsoon period approximately 200 to 260 mm. rain is received, which constitutes 70-80% of the total annual rainfall in a year. The month of the maximum rain is found to fluctuate from year to year. After September, no or little rain is received in the succeeding months.

iii. Humidity:

The mean humidity percentage is found to fluctuate from 65 to 80 in rainy months (July and August) and 21 to 23 in summer (April or May) depending upon the changes in rain and temperature.

According to Walter (1963), the ombrothermic diagrams made between the mean temperature in ^{o}C and total monthly rainfall in mm. in a ratio of 1:2 can explain and establish the climate type of a region. This author states that the arid period prevails when the rainfall curve goes below the temperature curve and a humid period when the rainfall curve passes above the temperature curve. 'The horizontal extension of the different areas on the diagrams shows the duration of the periods, the vertical extension, the intensity of humidity or aridity respectively' (Walter, 1963). This method, when applied to climate of Pilani to make ombrothermic diagrams (Fig. 2.3), reveals that the humid period lasts from July to September and a dry period from October to March. This, therefore, gives an idea of diphasic climatic conditions prevailing round the year, i.e., a humid period of short duration extending from July to September and a long dry period existing in the rest of the months.

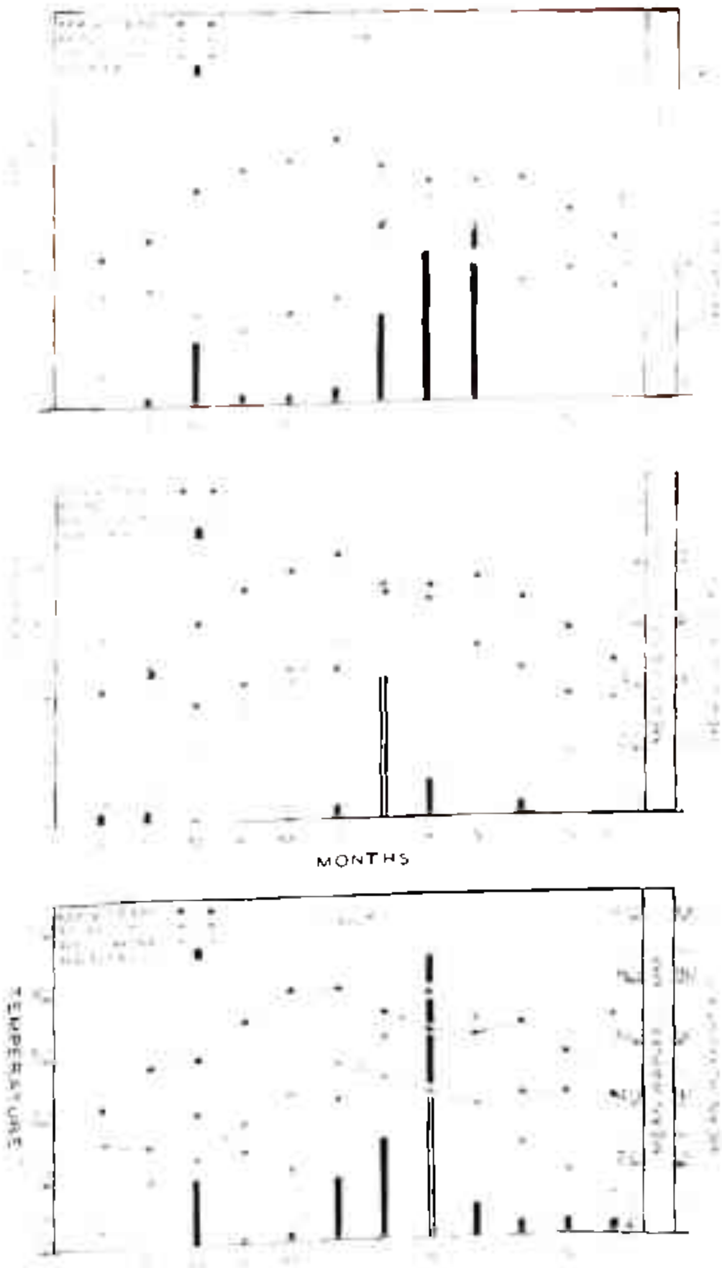

FIG. 2.2.

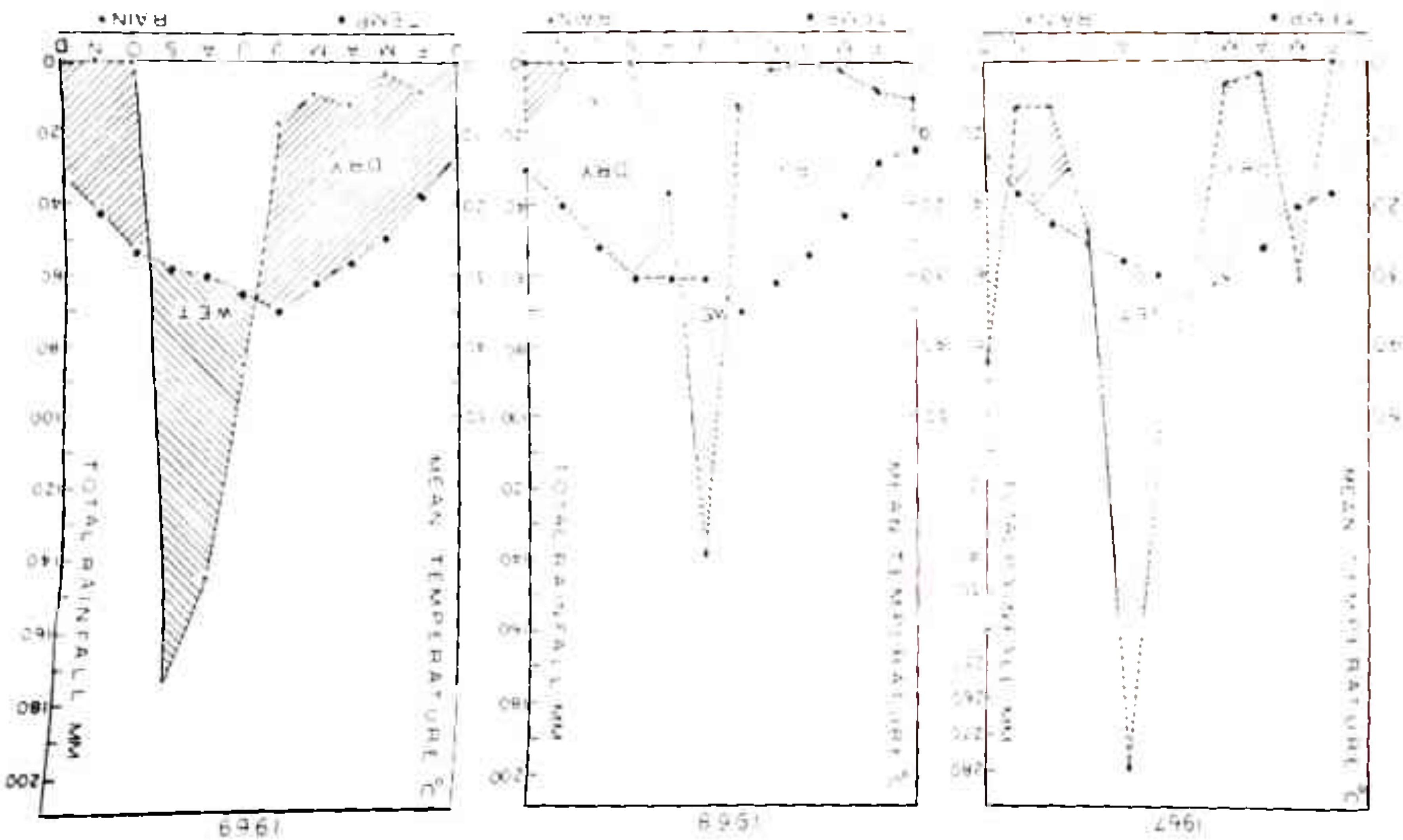
RAIN
TEMP
DRY
WET
TOTAL RAINFALL MM
MEAN TEMPERATURE °C
1969
1968
1967

FIG. 2.3

Comparing the ombrothermic diagrams for the three consecutive years, it is observed that during 1967-69 the duration of humid period prevails for 120, 39 and 90 days respectively, depending upon the horizontal extension of humid areas, and that of dry period continues for 240, 321 and 270 days respectively, depending upon the horizontal extension of dry period. Thus, the dry conditions exist for more than two times as compared to the humid conditions. Further, the high intensity of humid climate (vertical extension) prevails for a very short period (horizontal extension) as compared to the dry climate which suppresses the humid climate due to the vertical extension coupled with the horizontal extension in the dry period. Therefore, the course of humid and arid climate round the year and year after year fluctuates due to the intensity and duration of rains and dry periods. It may further be concluded that the year 1967 and 1969 form optimum years while 1968 constitutes a deficit year.

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CHAPTER 3

SYSTEMATIC POSITION, NOMENCLATURE AND ECONOMIC IMPORTANCE

In recent years the International Code of Botanical Nomenclature has been widely recognised. In this context, change in name of the plant, under present investigation, has been taken in detail. Besides, the information with regard to systematic position and economic importance of the plant has also been collected from different sources and incorporated in this chapter.

SYSTEMATIC POSITION AND NOMENCLATURE

Trianthema has about 15 species distributed in the tropics and sub-tropics of both the hemispheres, especially in Australia (Backer, 1951). According to our present knowledge, *T. pentandra* Linn. does not occur in India. The Indian plant and typical *T. pentandra* are different. Hooker (1879) has divided the family Ficoideae into two tribes, *viz.*, Aizoideae and Mollugineae, on the basis of calyx tube and position of stamens on it. Aizoideae includes *Aizoon*, *Sesuvium* and *Trianthema* while Mollugineae consists of *Corbichonia*, *Mollugo*, *Gisekia* and *Limeum*. The genus *Trianthema* consists of 5 species which are distinguished on the basis of the number of style, stamen and seed. These are:

T. monogyna Linn. Style 1; capsule in lower part has 3-5 seeds.

T. crystallina Vahl. syn. *T. triquetra* Rottl. Style 1; capsule superimposed.

T. *pentandra* Linn. Styles 2; stamens 5; lower part of fruit is 2-seeded.

T. *decandra* Linn. Styles 2; stamens 10; lower part of fruit is 2-seeded.

T. *hydaspica* Edgw. Styles 2; stamens 5-7; lower part of fruit 10-15 seed.

Duthie (1903) has included genus *Trianthema* in family Ficoideae and has distinguished 3 species on the basis of style and stamen number.

T. *monogyna* Linn. Style 1; stamens 15.

T. *crystallina* Vahl. Style 1; stamens 5.

T. *pentandra* Linn. Styles 2; stamens 5.

Gamble (1957) has also included *Trianthema* in family Aizoaceae and has distinguished 3 species on the basis of the number of style, stamen and seed:

T. *portulacastrum* Linn. (T. *monogyna* Linn.). Style 1; stamens 10-15; capsule top has 1 seed, lower part has 3-5 seeds.

T. *triquetra* Rottle. (T. *crystallina* Vahl). Style 1; stamens 5; capsule top has 1 seed, lower part has 3-5 seeds.

T. *decandra* Linn. Styles 2; stamens 10-15; capsule top has 2 seeds; lower part has 2 seeds.

Cooke (1958) has distinguished five species of genus *Trianthema* (stamens inserted on calyx tube; capsule circumscissilely dehiscent; ovary 1-2 celled) based on stamen, style and seed characters:

T. monogyna Linn. Stamens 10 or more; style 1.

T. decandra Linn. Stamens 10 or more; styles 2.

T. hydaspica Edgew. Stamens less than 10; lower half or capsule 8-10 seeded.

T. triquetra Rottl. and Willd. Stamens less than 10; lower half or capsule 1-2 seeded.

T. pentandra Linn. Stamens less than 10; lower half or capsule 1-2 seeded.

The foregoing account reflects the dual characters of *T. pentandra* and *T. decandra* due to the similarities in their characters. Both these species have been included by Hooker (1879) and Cooke (1958) in the genus *Trianthema* but the former has not been recorded by Gamble (1957) and the latter by Duthie (1903) from the list except *T. hydaspica*, which has not been recorded by either of these (Gamble, 1957; Duthie, 1903). It is also observed that *T. pentandra* Linn. with 2 styles and 5 stamens has been distinguished by Hooker (1879), Duthie (1903) and Cooke (1958). At the same time, plant with 2 styles, 10-15 stamens and 4 seeds has been distinguished as *T. decandra* Linn. by Hooker (1879) and also by Gamble (1957) and Cooke (1958).

Though *T. pentandra* and *T. decandra* having similar features (styles 2, lower part of fruit 2-seeded) but they can be distinguished on the basis of number of stamens as done by Hooker (1879). However, Cooke (1958) has not described any definite or clear number of stamens. Hooker (1879) further suggested *T. pentandra* Linn. as *T. govindia* Wall. and *T. decandra* as *Zaleya decandra* Brum. and again distinguished them on the basis of their fruit as below:

T. pentandra Linn. Beak of fruit mitriform and two seeded, separating into two one seeded part; lower part of fruit 2-seeded.

T. decandra Linn. Beak truncate consolidated with two included seeds indehiscent or only finally splitting.

Melville (1952) regards *T. pentandra* L. Mant. to be an African species (Distribution: Nigeria, France, Sudan, Egypt, Kenya, Uganda and Rhodesia etc.) while *T. govindia* Buch. - Ham. as an Indian species (Distribution: India, Persia and Arabia). He has distinguished them on the basis of structure and form of operculum as follows:

Operculum: Smooth, uniformly papillose with blunt rounded crest and the base generally expanded into a rounded solid rim.- *T. pentandra* L. Mant.

Operculum has nearly parallel sides rising laterally into one or two sharp pointed crest, appearing as a bishop's mitre. - *T. govindia* Buch.-Ham.

Since the number of stamens varies from 10 to 15 and no such constant correlation with other characters could be established in the plants having different number of stamens, Melville (1952) has established that pentandrous Indian species is quite distinct from *T. pentandra* Linn. which is African in distribution. To him pentandrous Indian species appeared to be *T. govindia* Buch.-Ham.

Santapau (1959), while designating the lectotypes of the species and varieties in *T. pentandra* Linn. as described by Blatter and Hallberg (1918-21) in the 'Flora of Indian Desert', has recommended the genus *T. decandra* Linn. as the lectotype of *T. pentandra* auct. non. Linn.

According to Jeffrey (1960) *Trianthema* is a digynous plant and all the species of *Trianthema* are not congeneric. He, therefore, has separated *Zaleya* and *Trianthema* as follows:

Zaleya: Operculum 2-valved; ovules 4 attached at one side to the interlocular septum; ovary 2-locular; stigma 2.

Trianthema: Operculum 2-valved; cap pyxidiate; ovary 1-locular; style 1.

Maheshwari (1963) has also included the genus *Trianthema* in Aizoaceae (Ficoideaceae) and distinguished it on the basis of stamen and flower colour as follows:

T. govindia Buch.-Ham. ex G. Don. Stamens 5; flowers rosy-pink; styles 2.

T. crystallina Vahl. Stamens 5; flowers greenish; style 1.

T. portulacastrum Linn. Stamens 10; flowers pinkish or white; style 1.

Nair (1966) while reviewing the findings of Melville (1952) and Jeffery (1960) on the nomenclatural changes of the genus *Trianthema*, has concluded that *T. pentandra* is not an Indian plant but is African. He has, therefore, emphasised to transfer *Trianthema govindia* (Buch.-Ham. ex G. Don.), which was treated conspecific with *T. pentandra* Linn. by earlier workers (Hooker, 1879; Duthie, 1903; Cooke, 1958), to *Zaleya* and has made the following three new combinations.

Zeleya govindia Buch.-Ham. ex G. Don. N.C. Nair, Trianthema govindia Buch.-Ham. ex G. Don, Gen. Syst, 3: 72, 1834: Melville in Kew Bull, 1952: 164, 1952. T. pentandra auct. plur. non. Linn.

Z. govindia var. Flava (Blatt. et Hallb.) N.C. Nair, Trianthema pentandra var. flava Blatt. et Hallb. in J. Bombay nat. Hist. Soc. 26: 531. T. decandra Linn. var. flava (Blatt. et Hallb.) Santapau in J. Bombay nat. Hist. Soc. 56: 280, 1959.

Z. govindia var. rubra (Blatt. et Hallb.) N.C. Nair. Trianthema pentandra var. rubra Blatt. et Hallb. in J. Bombay nat. Hist. Soc. 26: 530, 1919. T. decandra Linn. var. rubra (Blatt. et Hallb.) Santapau in J. Bombay nat. Hist. Soc. 56: 279, 1959.

According to Kirtikar and Basu (1935), Trianthema pentandra has been named differently in different languages, viz., Gadabani (Bengali), Gaijasoppu (Canarese), Charanai (Ceylon), Bhiskapra (Deccan), Gadabani (Hindi), Vellaisaruvelai (Madras), Punarnavi (Sanskrit), Mahsarana (Sinhalese), Vellaishurunnai (Tamil) and Galijeru or Tellagalijeru (Telugu). These names are based on the use of the plant, especially for medicinal purposes, in a particular state or site. However, in North India and Rajasthan the plant is called as Santhi or Sata.

ECONOMIC IMPORTANCE

The plant is used as an astringent in abdominal diseases and is believed to cause abortion. In Las Belar, the plant is also used as acure both for pain in bladder and for snake bite

(Kirtikar and Basu, 1935). Locally, the stem and leaves are used as cattle food and also as vegetables by inhabitants of the area. It is widely used in Pilani and round about areas as domestic medicine in diarrhoea, indigestion, liver swelling, jaundice and also in improving the eyesight. The plant, like other members of the family, is also rich in the alkaloidal contents. The roots are powdered and used in gum swelling and gum bleeding.

CONCLUSION

In the light of recent studies by various taxonomists and systematists, the genus occurring in India has been named as *Zaleya govindia* N.C. Nair, which has taxonomic features very close to that of African genus. Further, the genus *Zaleya*, based on colour differences for leaves, stem and fruit, has got two varietal forms known as 'rubra' and 'flava' as described by Blatter and Hallberg (1918-21) in the 'Flora of Indian Desert' for *Trianthema pentandra*. Hereafter, in the succeeding chapters, the plant under investigation is referred to as *Zaleya govindia* N.C. Nair variety 'rubra' and 'flava'.

The economic importance of *Trianthema pentandra*, as described by earlier workers (Kirtikar and Basu, 1935), can now be attributed to *Zaleya govindia* (Buch.-Ham. ex G. Don.) N.C.Nair as well after its name change.

+++:+++

CHAPTER 4

GEOGRAPHICAL AND ALTITUDINAL DISTRIBUTION

INTRODUCTION

Plant distribution is caused by the interaction of environmental factors (Schimper, 1903). Environment is a complex of climatic, edaphic and physiographic factors. In climatic factor, the range and fluctuation in temperature, humidity and water, affect the plants directly while soil and physiographic factors affect indirectly. The plant distribution is controlled primarily by climatic factor and secondarily by edaphic factor (Good, 1953). According to Hanson and Churchill (1961), 'the ecological success of a species depends upon its capacity to cope with the physical environment ....'. They have also opined that the ecological amplitude indicates the range of condition in which an organism can live and thrive while tolerance refers to that range within which it can survive. Thus, the ecological amplitude and tolerance range of a plant shows its potentiality for growth within a limited range of environmental conditions. It also determines whether or not a species will be present in a certain habitat.

The present chapter summarizes the distribution of *Zaleya govindia* (*Trianthema pentandra*) in the world, India and Rajasthan. Its distribution in India and Rajasthan has been discussed in detail in view of its wide occurrence in different parts. However, the distribution of *T. pentandra* has been described outside India but not discussed due to dispute in the nomenclature. Therefore, the distribution of the plant shown in figures 4.1; 4.4; 4.8; 4.10 outside India are for Trianthema pentandra while within Indian territory it is for Zaleya govindia (Trianthema pentandra).

METHODS OF STUDY

The distribution of Zaleya govindia (Trianthema pentandra) has been recorded from various sources like old records, books and journals besides personal communications and visits to different places. The distribution of the plant in India has been obtained from Botanical Survey of India, Poona, Dehra Dun, Coimbatore and Calcutta; Forest Research Institute, Dehra Dun; National Botanic Gardens, Lucknow and Central National Herbarium, Calcutta. Information with regard to its distribution outside India has been obtained from Royal Botanic Gardens, Kew (England) and Sydney (Australia). The places of occurrence have been shown on various maps made for specific factor.

GEOGRAPHICAL DISTRIBUTION

According to Bentham (1866) Genus Trianthema is dispersed over the tropical and subtropical regions of new as well as old world. He has recorded them from North Australia, Queensland and North-South Wales. It is also distributed in Tropical Africa, Western Asia and India (Hooker, 1879; Blatter and Hallberg, 1918-21). ~~He~~ Hooker has reported this plant as a weed also from Sind (now in Pakistan), Konkan and Poona (India). In Pakistan, the plant has been recorded from Karachi (Woodrow, 1897) and also from Rawalpindi, Multan and Lahore (Sabnis, 1934).

According to information available from Kew Gardens, the plant is also found in South Arabia, Jidda and Egypt. In Africa, it has been recorded from Sudan (Kassas, 1956).

In India, this plant has been recorded from many states, viz.,(1) Uttar Pradesh, (2) Delhi, (3) Punjab, (4) Haryana, (5) Rajasthan, (6) Gujarat, (7) Maharastra, (8) Mysore (Table 4.1). In Rajasthan, Blatter and Hallberg (1918-21) have reported it from Jodhpur, Jaisalmer, Phalodi, Bap, Pokaran, Bikaner and Loharki. In recent years, the plant has been again reported from many places of Western Rajasthan like Jaisalmer, Jodhpur, Barmer, Phalodi, Pokaran and Bikaner (Sarup, 1957, 1958; Seshagiri and Kanodia, 1962). From North-West Rajasthan, it has been reported from Pilani (Ratnam and Joshi, 1952; Joshi, 1958 a and b; Joshi and Bansal, 1968), Chirawa (Nair, 1956), Harshnath (Nair and Nathawat, 1957), Khetri (Nair and Kanodia, 1959), and Ajit Sagar Bundh (Nair *et al*., 1961).

Out of the 7 geographical regions in Rajasthan (Misra, 1967), *Zaleya govindia* (*T. pentandra*) has been reported from four regions as given in Table 4.2 (Fig. 4.1).

TH16

ALTITUDINAL DISTRIBUTION

Zaleya govindia (*Trianthema pentandra*) occurs in a wide range of altitude and latitude. Based on the physiographic divisions of India as delineated by Raychaudhuri (1966) the plant occurs (Fig. 4.2) in West Coastal Plains from 200 to 500 metres (m.s.l.) between 11°-22°N latitude and 69°-77°E longitude (Cambay, Godhra, Poona, Dwarka and Coimbatore); in South Deccan from 1000 metres (m.s.l.) between 14°-15°N latitude

Table 4.1: Showing the distribution of Zaleya
different parts of the world.

Country/State	Place of collection	Latitude	Longi
INDIA			
1. Uttar Pradesh	Agra	27.10 N	78.5
	Aligarh	27.54 N	78.6
	Etawah	26.47 N	79.2
	Hamirpur	25.58 N	80.1
	Lucknow	26.55 N	80.5
	Meerut	29.10 N	77.4
	Saharanpur	29.58 N	77.
2. Bihar	Aurangabad	24.45 N	84.
3. Delhi	Delhi	28.38 N	77.
4. Haryana	Hansi	29.60 N	76.
	Hissar	29.10 N	74.
	Jind	29.19 N	76.
	Kurukshetra	29.00 N	77.
	Narnaul	28.20 N	76.
	Panipat	29.23 N	77.
	Rohtak	28.54 N	76.
5. Punjab	Bhatinda	30.11 N	75.
	Fatehabad	29.31 N	75.
	Firozepur	30.55 N	74.
6. Rajasthan	Ajmer	26.27 N	74.
	Bap	27.22 N	72.
	Bharatpur	27.15 N	77.
	Bikaner	28.10 N	73.
	Harshnath Hills	27.37 N	75.
	Jaipur	26.55 N	75.
	Jaisalmer	26.55 N	70.
	Jodhpur	28.18 N	73.
	Pali	24.46 N	73.
	Phalodi	27.90 N	72.
	Pokaran	26.55 N	71.
	Ramgarh	28.10 N	75.
	Sirohi	25.00 N	73.
7. Gujarat	Cambay	21.00 N	72.
	Dwarka	22.14 N	69.
	Godhra	22.45 N	73.
8. Maharashtra	Daultabad		
	Poona	19.57 N	75.

Table 4.2 Showing occurrence of *Zaleya govindia* (*T. pentandra*) in different geographical regions of Rajasthan.

Geographical regions	Places of occurrence
1. Western arid region	*Churu, *Bikaner, *Nagaur, *Bap, *Phalodi, *Jaisalmer, *Pokaran, *Barmer, *Sheo.
2. Semi-arid region	*Jhunjhunu, *Sikar, Didwana, *Jodhpur, *Pali, *Jalore.
3. Canal region	Ganganagar.
4. Aravalli region	*Sirohi, Udaipur, Nathdwara.
5. Eastern Agro-Industrial region	Alwar, *Bharatpur, *Jaipur, *Ajmer, Tonk, Sawai Madhopur, Bundi, Bhilwara, Kota.
6. South-eastern Agricultural region	Jhalawar, Chitorgarh, Dungarpur, Banswara.
7. Chambal Ravine region	X

*Places from where *Z. govindia* (*T. pentandra*) has been reported.

Fig. 4.1 Distribution of Z. *govindia* (black solid circles- ●) in different physiographic divisions of India.

Fig. 4.2 Distribution of Z. *govindia* (black solid circles- ●) in different geographical regions of Rajasthan.


INDIA
PHYSIOGRAPHIC
DIVISIONS
1 WEST HIMALAYA
2 CENTRAL
3 NORTH EASTERN RANGES
4 EASTERN HIMALAYA
5 WESTERN PLAINS
6 NORTH CENTRAL HIGH
7 NORTHERN PLAINS
8 EASTERN
9 WEST COASTAL
10 SOUTH CENTRAL HIGHLANDS
11 EASTERN PLATEAUS
12 NORTH DECCAN
13 EASTERN HILLS
14 SOUTH DECCAN
15 EAST COASTAL PLAINS
16 WESTERN HILLS
17 CONTINENTAL SHELF
18 EASTERN

FIG. 4.1

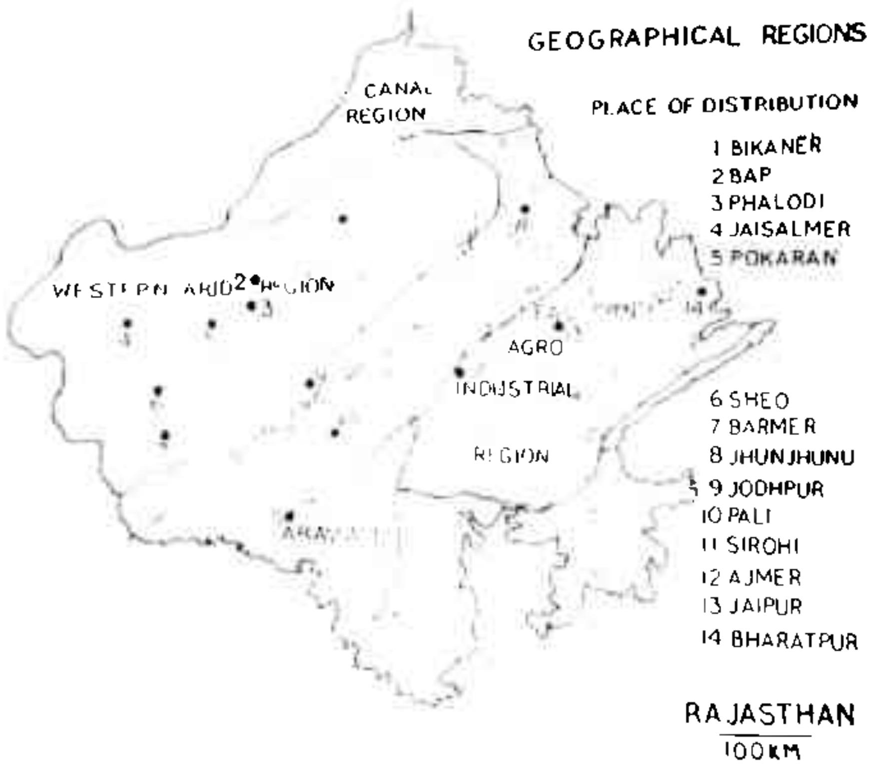

GEOGRAPHICAL REGIONS
PLACE OF DISTRIBUTION
1 BIKANER
2 BAP
3 PHALODI
4 JAISALMER
5 POKARAN
6 SHEO
7 BARMER
8 JHUNJHUNU
9 JODHPUR
10 PALI
11 SIROHI
12 AJMER
13 JAIPUR
14 BHARATPUR
CANAL REGION
AGRO INDUSTRIAL REGION
RAJASTHAN
100 KM

FIG. 4.2

and 75^{o}-78^{o} E longitude (Kolar, Badami); in North Deccan from 500 to 1000 m.s.l. between 18^{o}-19^{o} N latitudes and 73^{o}-75^{o} E longitudes (Poona, Aurangabad) and in North plain from 200 to 500 metres (m.s.l.) and between 25^{o} and 29^{o} N latitude and 77^{o} and 80^{o}E. longitude (Delhi, Uttar Pradesh, Haryana and Punjab). However, in Western plains, constituting the Western sandy plains (Sandy arid plains and Semi-arid Transitional plain), and North Central Highlands, constituting the Eastern plains (Aravalli Range, hilly and humid region of eastern Rajasthan) of Rajasthan, the plants occur from 500 to 1000 metres (m.s.l.) and between 24^{o} and 28^{o} N latitude and between 70^{o} and 75^{o} E longitude (Fig. 4.2).

ECOLOGICAL DISTRIBUTION

i. Physiography:

Considering the physiographic division of India, as described by Raychaudhuri (1966), *Z. govindia* (*T. pentandra*) is found in the following six zones (Fig. 4.2).

1. North plain, 2. Western plain, 3. North Central highland,
4. West Coastal plain , 5. North Deccan plain, and
6. South Deccan plain.

In Rajasthan, the plant occurs in all the physiographic divisions, except the South Eastern Rajasthan Pathar (Fig. 4.3). These divisions, where the plant occurs, are composed of vast expanses of sand, sand dunes and gritty substratum of exposed rocks and hilly areas. Such topography in these regions is a result of denudation and erosion for years (Misra, 1967). The plant is mostly distributed in sandy arid and semi-arid

Fig. 4. Distribution [illegible] (black solid circles- ●) in different [illegible] regions of Rajasthan.

Fig. 4.1 Distribution of Z. *coviridis* (black solid circles- ⊙) in different rainfall region of India.


PHYSIOGRAPHY
AND
DRAINAGE
2
3
4
ARID PLAINS
SEMI ARID TRAN
RANGE
EASTERN RAJASTHAN PATHAR
RAJASTHAN
100KM

FIG. 4.3

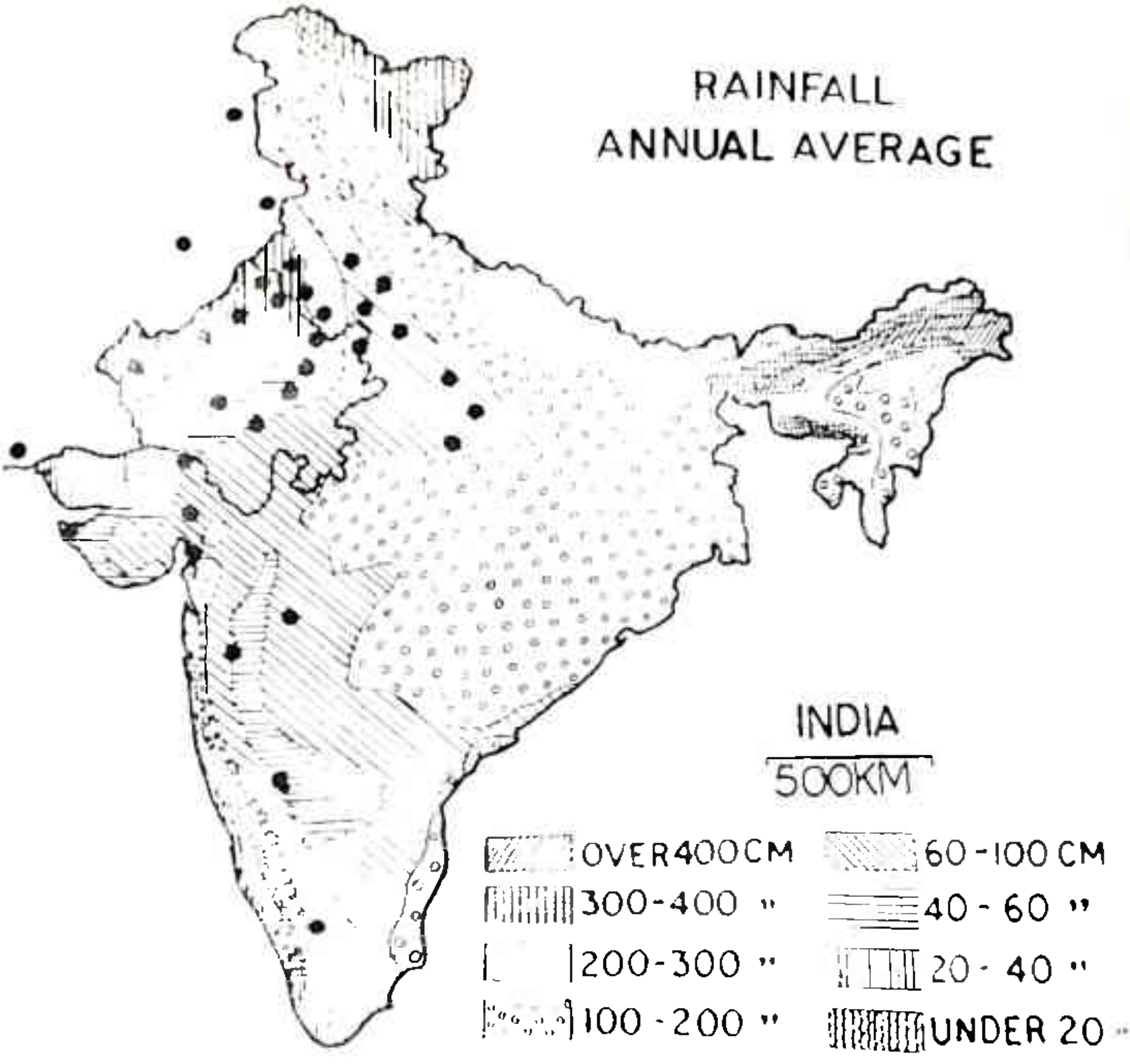

RAINFALL
ANNUAL AVERAGE
INDIA
500KM
OVER 400 CM
300-400 "
200-300 "
100-200 "
60-100 CM
40-60 "
20-40 "
UNDER 20 "

FIG. 4.4

transitional plains. Sandy Arid plain is covered with sand and rocks. According to Misra (1967), the rocks and elevated areas in Jaisalmer, Barmer, Bikaner, Churu and Ganganagar are Jurassic and Eocene rocks and as they protrude through the sandy surfaces, they confirm as the part of western extension of the Peninsular block. This part is covered with no or different extent and degree of sand dunes. Semi-arid transitional plain is covered with superficial sand deposit and the rocks are more frequent than sandy arid plain.

ii. Climate:

Climate has been considered as one of the important ecological factors influencing the distribution of plants. Based on rainfall, Z. govindia (T. pentandra) shows a wide range of distribution between 20 to 200 cm. rainfall (Fig. 4.4; Table 4.3). Other than Rajasthan, this species is rare in the range of 20 to 40 cm. (Ferozepur, Fatehabad and Dwarka) and 100 to 200 cm. (Coimbatore) but not uncommon within 40 to 60 cm. However, maximum occurrence of the plant is found between 60 to 100 cm. (Uttar Pradesh, Delhi, Gujarat, Maharashtra and Mysore).

The climatic conditions of Rajasthan for Z. govindia (T. pentandra) are not so severe as found in the other countries like North Arabia, part of Egypt and Liberia, Northern Sahara and part of Mexico, which are situated between the corresponding latitudes and longitudes of Rajasthan (23°3'N to 30°12'N latitudes and 69°30'E to 78°17'E longitudes). The climatic pattern of Rajasthan is affected by seasonal variation in temperature, rainfall and humidity throughout the year. In general, the climate of Western Rajasthan is characterised by extremes of

Table 4.3: Showing tolerance range of *Z. govindia* (*T. pentandra*) with regard to rainfall, temperature and soil types in different states of India other than Rajasthan.

State	Place	Average Annual rainfall (cm.)	January Temperature (°C)	Soil types
UTTAR PRADESH	Agra	60-100	15.6-21.1	Alluvial
	Aligarh	60-100	15.6-21.1	Alluvial and Alkaline
	Etawah	60-100	15.6-21.1	Alluvial and Alkaline
	Hamirpur	60-100	15.6-21.1	Red and Black
	Lucknow	60-100	15.6-21.1	Red and Black
	Meerut	60-100	15.6-21.1	Pedocal Sierozem
	Sanaranpur	60-100	15.6-21.1	Alluvial
DELHI	Delhi	60-100	15.6-21.1	Pedocal Sierozem
HARYANA	Hissar	40-60	15-21	Pedocal Sierozem
	Narnaul	40-60	15-21	Pedocal Sierozem
	Rohtak	40-60	15-21	Pedocal Sierozem
PUNJAB	Bhatinda	40-60	15-21	Pedocal Sierozem
	Fatehabad	20-40	15-21	Pedocal Sierozem
	Ferozepur	20-40	15-21	Pedocal Sierozem
GUJARAT	Cambay	60-100	15-21	Alluvial on coastal alluvium
	Dwarka	20-40	15-21	Alluvial on deltaic alluvium
	Godhra	60-100	15-21	Medium black
MAHARASHTRA	Aurangabad	60-100	21-27	Medium black
	Poona	40-60	21-27	Medium black
MYSORE	Badami	60-100	21-27	Ferruginous
	Kolar	60-100	21-27	Ferruginous
KERALA	Coimbatore	100-200	21-27	Ferruginous

temperatures, severe drought, high wind velocity and low relative humidity.

In the western part of Rajasthan, mainly at Bikaner, Phalodi, Jaisalmer, Barmer and west of Jodhpur, where the species occurs frequently, the maximum daily temperature in summer goes up to 40 to 45°C. The mean isotherms of 32, 34 and 36°C for May (Fig. 4.5) show a gradual increase in temperature towards the west. During May, the isotherms between 32 and 36°C cover Barmer, Sheo, Pali, east of Jodhpur, Ajmer, Jaipur and Bharatpur, and between 34 and 36°C cover Barmer, Sheo, west of Jodhpur, Jaisalmer, Pokaran, Bap, Phalodi and Bikaner.

The winter temperatures throughout Rajasthan are fairly uniform, the maximum ranging between 33.3 to 36.1°C and minimum from 17.7 to 21.1°C (Misra, 1967). Further, in January (Fig. 4.6) the temperature ranges between 12 to 14°C in north Rajasthan (Ganganagar, Jhunjhunu and north of Churu and Alwar) and above 16°C in south Rajasthan (Barmer, east of Jodhpur, Pali, Jalor, Sirohi, Udaipur, Dungarpur, Banswara, Chittorgarh, Bhilwara, Bundi, Kota, and Jhalawar). The winter temperature between 14 and 16°C prevails in Jaisalmer, Bikaner, Phalodi, Nagaur, Sikar, Bharatpur, Sawai Madhopur, Jaipur, Tonk, Ajmer and west of Jodhpur.

During monsoon (June to September), the rainfall at Ganganagar, Churu, Bikaner, Bap, Phalodi, Pokaran, Jaisalmer and Sheo is less than 25 cm; at Jhunjhunu, Sikar, Didwana, Nagaur, Ajmer, Jodhpur, Pali, Jalore and Barmer is 25 to 50 cm; Alwar, Bharatpur, Jaipur, Tonk, Sawai Madhopur, Bundi, Bhilwara, Kota, Chittorgarh, Udaipur, Dungarpur and Sirohi receive 50 to 70 cm.

Fig. 4.5 Distribution of Z. *govindia* (black solid circles-●) in different mean isothermic ranges in Rajasthan during May.

Fig. 4.6 Distribution of Z. *govindia* (black solid circles-●) in different mean isothermic ranges in Rajasthan during January.

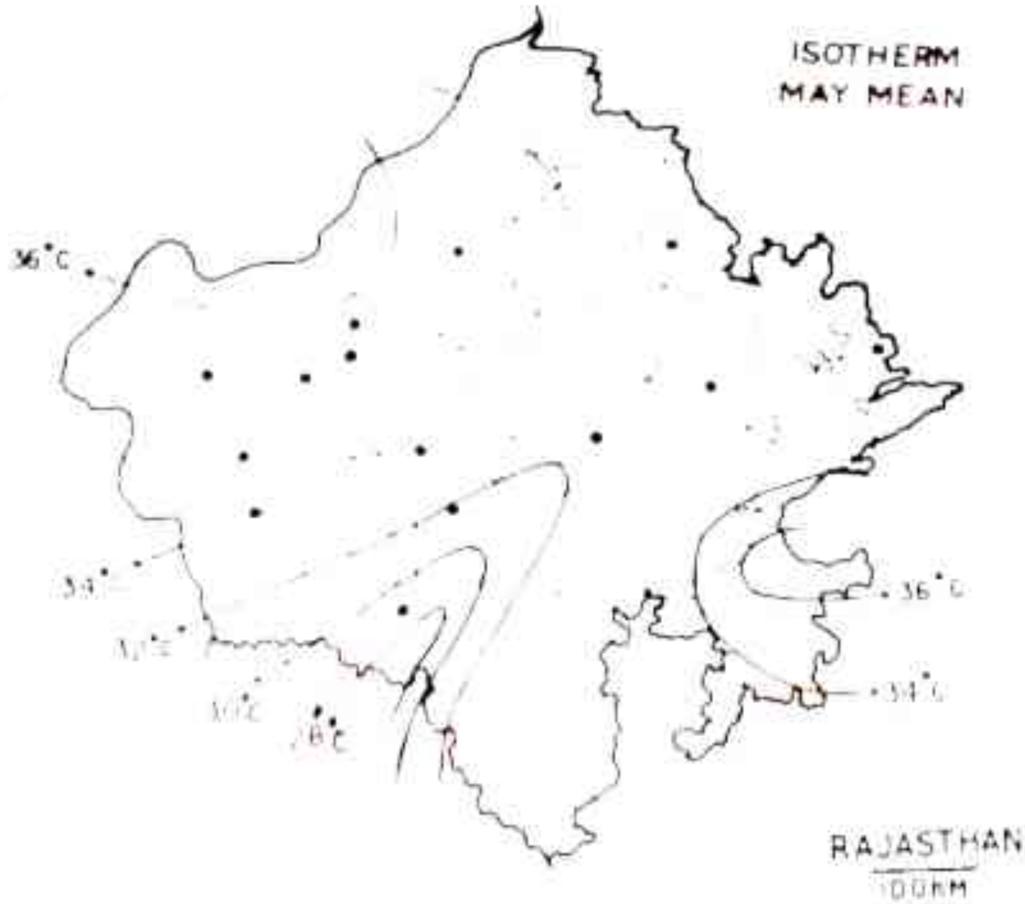
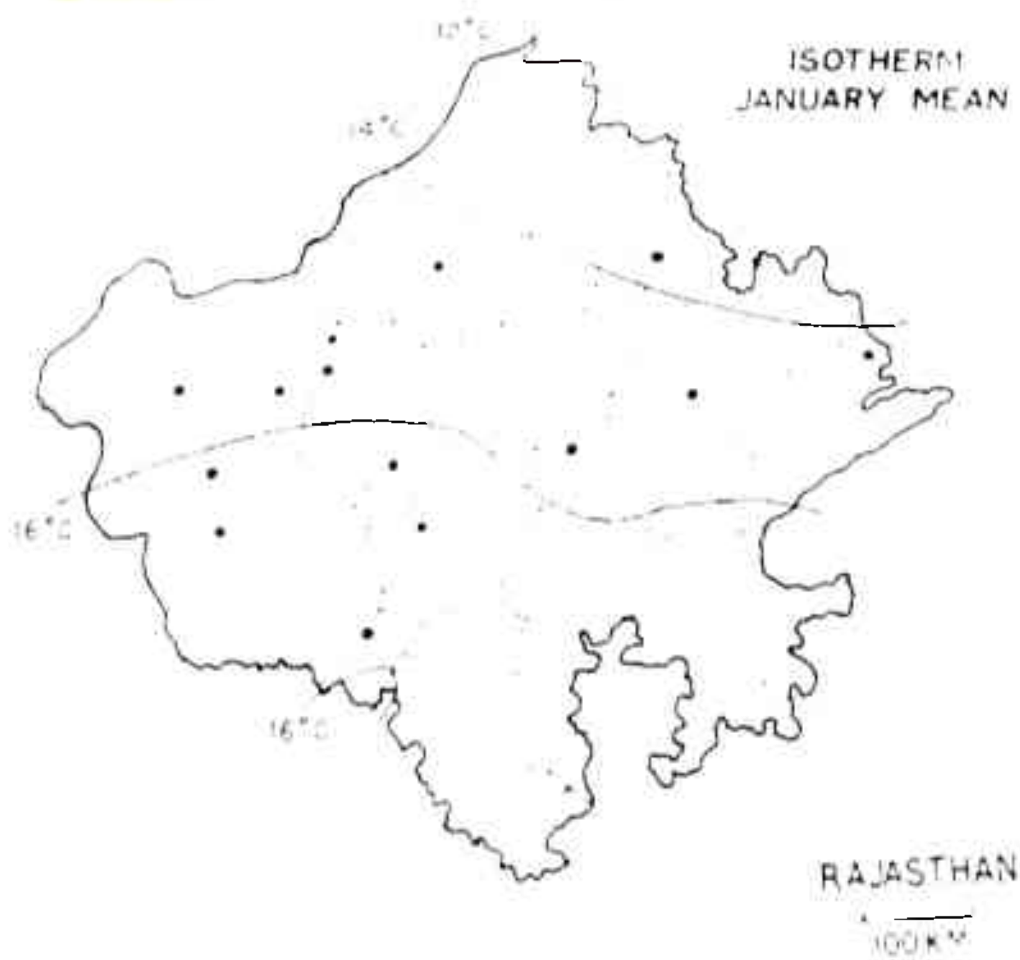

ISOTHERM
MAY MEAN
36°C
34°C
36°C
34°C
RAJASTHAN
100KM

FIG. 4.5


ISOTHERM
JANUARY MEAN
12°C
14°C
16°C
16°C
RAJASTHAN
100KM

rainfall; while Nathdwara gets 100 to 125 cm. and Jhalawar and Banswara receive below 75 cm. rainfall (Fig. 4.7).

iii. Soils:

The soils all over India vary in its character. *Z. govindia* (*T. pentandra*) has been recorded from different soil types like Pedocal Sierozem, Alluvial, Alluvial and Alkaline, Red and Black, Medium black, Ferruginous, Alluvial on deltaic alluvium and Alluvial on coastal alluvium (Table 4.3; Fig. 4.8).

According to Misra (1967), Rajasthan has seven types of soils (Table 4.4; Fig. 4.9), more or less all of them show the occurrence of *Z. govindia* (*T. pentandra*). The whole of western part (Bikaner, Jaisalmer, Phalodi, Bap, Sheo, Barmer, Jodhpur and Nagaur) is occupied by desert soil. It contains 90-95% sand, 6-7% clay; high percentage of soluble salt, high pH and is poor in organic matter. Calcium oxide varies from 1-1.5%. Next to desert soil is the grey brown soil which covers the area of Jhunjhunu, Sikar, Didwana, Sirohi, Jalor, and Nagaur in the west of Aravalli. These areas are mostly saline and alkaline with high pH values. Rest of Rajasthan is occupied by Red and Yellow soil (Ajmer, Pali, Sawai Madhopur), Ferruginous red (Udaipur, Dungarpur), mixed Red and Black (Tonk, Bhilwara, Chittorgarh, Banswara) and medium black (Bundi, Kota, Jhalawar) soils. Thus it is observed that *Z. govindia* (*T. pentandra*) does not occur on Ferruginous red mixed red and black and medium black soil of Rajasthan but has been reported from similar soils of other parts of India (Tables 4.3, 4.4).

Table 4.4: Showing tolerance range of *Z. govindia* (*T. pentandra*) with regard to rainfall, temperature and soil types in Rajasthan.

Place	Average annual rainfall (cm.)	Average summer (May) temperature (°C)	Average winter (January) temperature (°C)	Soil types
Jaisalmer	Under 20	34	16	Desert
Pokaran	Under 20	34	16	Desert
Bap	20-40	34	16	Desert
Phalodi	20-40	34	16	Desert
Sheo	20-40	34	16	Desert
Barmer	20-40	32-34	16	Desert
West of Jodhpur	20-40	34	16	Desert
Bikaner	20-40	34	16	Desert
East of Jodhpur	40-60	32	14	Desert
Churu	40-60	32	12	Desert
Nagaur	40-60	34	16	Desert
Jhunjhunu	40-60	32	12	Desert Grey and Brown
Sikar	40-60	32	16	Desert Grey and Brown
Didwana	40-60	32	16	Desert Grey and Brown
Sirohi	40-60	28 or less	14	Desert Grey and Brown
Jalor	40-60	30	14	Desert Grey and Brown
Jaipur	40-60	32	16	Alluvial
Ganganagar	40-60	32	12	Alluvial
Ajmer	40-60	32	16	Red and Yellow
Pali	60-100	30-32	14	Red and Yellow
Sawai Madhopur	60-100	32	16	Red and Yellow
Bharatpur	60-100	32	16	Alluvial
Alwar	60-100	32	12	Alluvial
Tonk	60-100	32	16	Mixed Red and Black
Bhilwara	60-100	34	14	Mixed Red and Black
Chittorgarh	60-100	32	14	Mixed Red and Black
Banswara	60-100	32	14	Mixed Red and Black
Bundi	60-100	32-34	14	Medium Black
Kota	60-100	32-36	14	Medium Black
Jhalawar	60-100	32-34	14	Medium Black
Udaipur	60-100	30-32	14	Ferruginous Red
Dungarpur	60-100	32	14	Ferruginous Red

Fig. 4.7 Distribution of Z. *govindia* (black solid circles-●) in different rainfall regions of India during June-September.

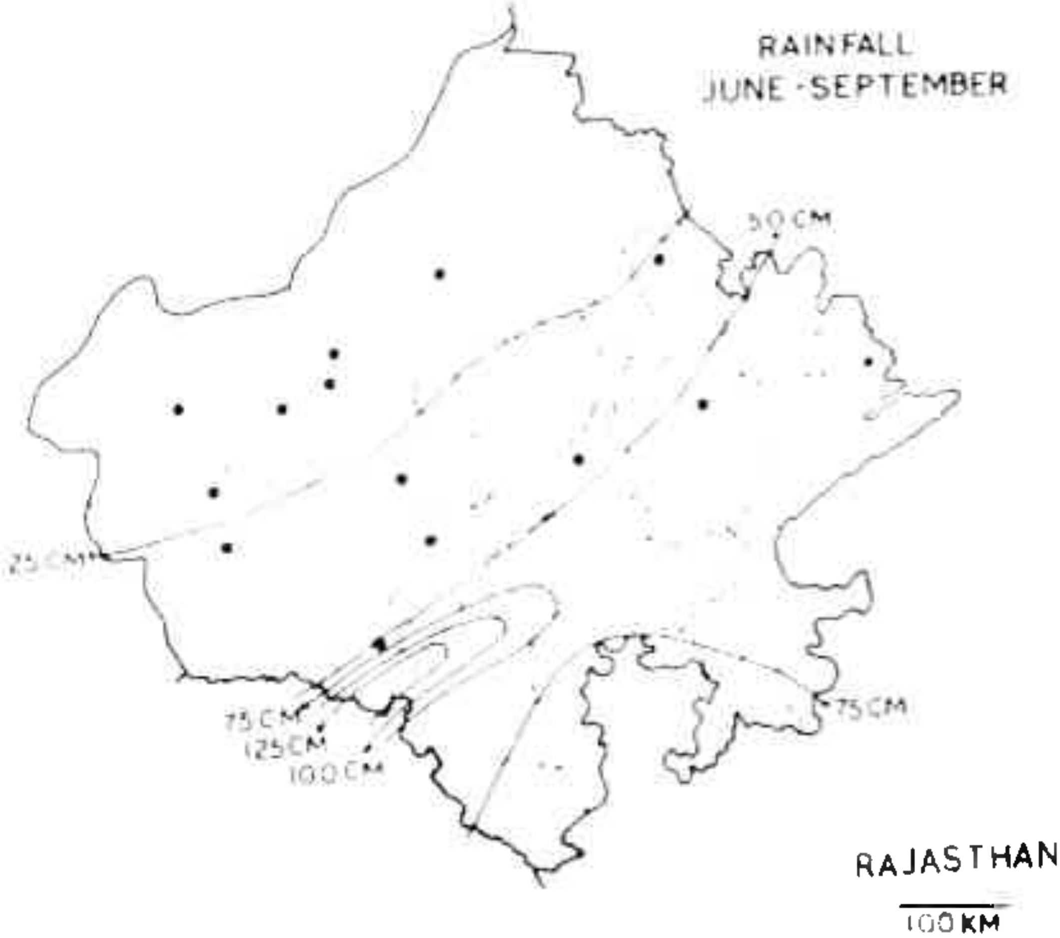

RAINFALL
JUNE - SEPTEMBER
50 CM
25 CM
75 CM
125 CM
100 CM
75 CM
RAJASTHAN
100 KM

FIG. 4.7

Fig. 4.8 [illegible]on of [illegible] (Black soils) [illegible] soil typ[illegible] India.

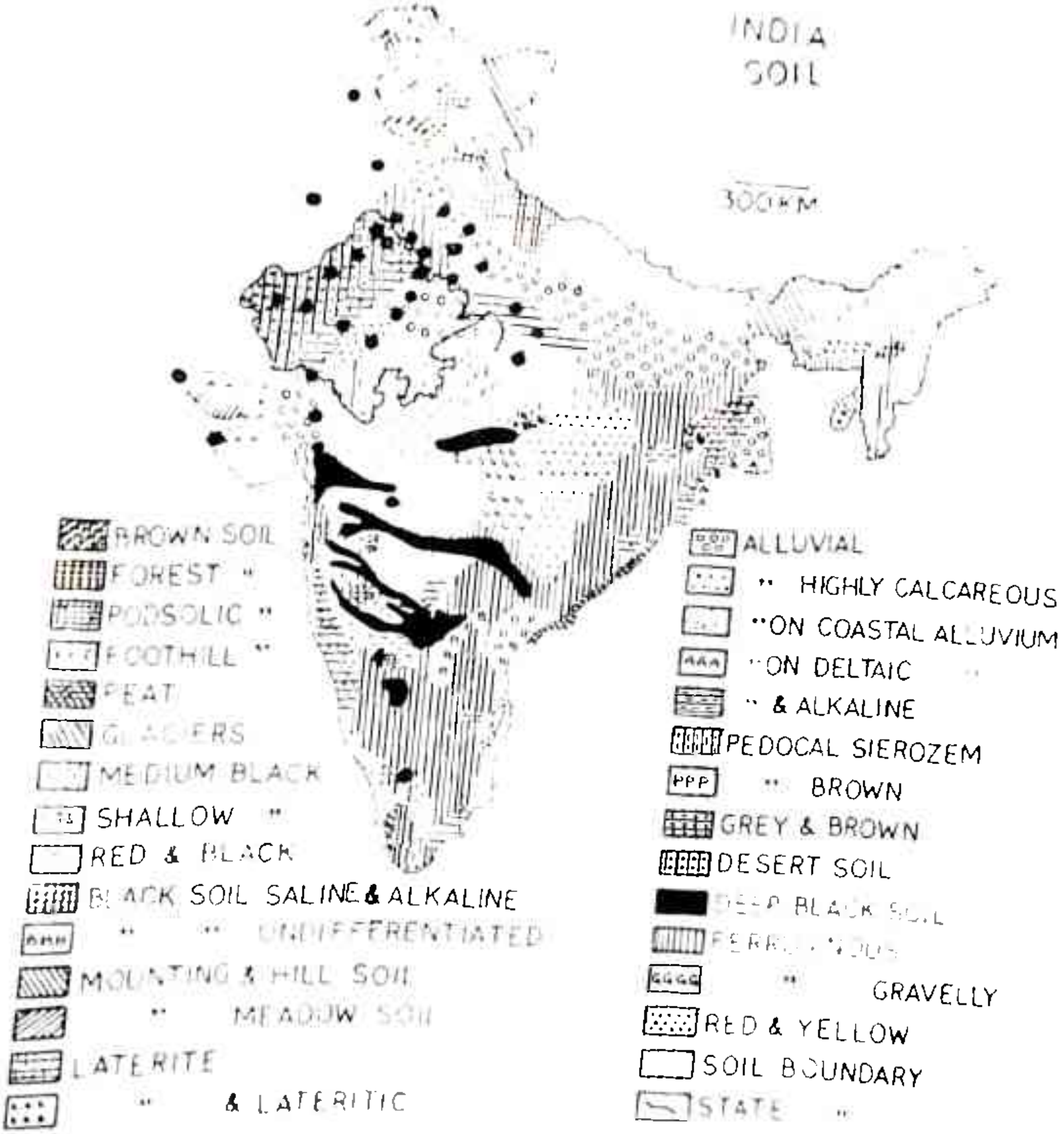

INDIA
SOIL
300 KM
BROWN SOIL
FOREST
PODSOLIC
FOOTHILL
PEAT
MEDIUM BLACK
SHALLOW
RED & BLACK
BLACK SOIL SALINE & ALKALINE
UNDIFFERENTIATED
MOUNTING & HILL SOIL
MEADOW SOIL
LATERITE
& LATERITIC
ALLUVIAL
HIGHLY CALCAREOUS
ON COASTAL ALLUVIUM
ON DELTAIC
& ALKALINE
PEDOCAL SIEROZEM
BROWN
GREY & BROWN
DESERT SOIL
GRAVELLY
RED & YELLOW
SOIL BOUNDARY
STATE

Fig. 4.9 Distribution of Z. *govindia* (black solid circles-●) in different soil types of Rajasthan.

Fig. 4.10 Distribution of Z. *govindia* (black solid circles-●) in arid and semi-arid zones of India.

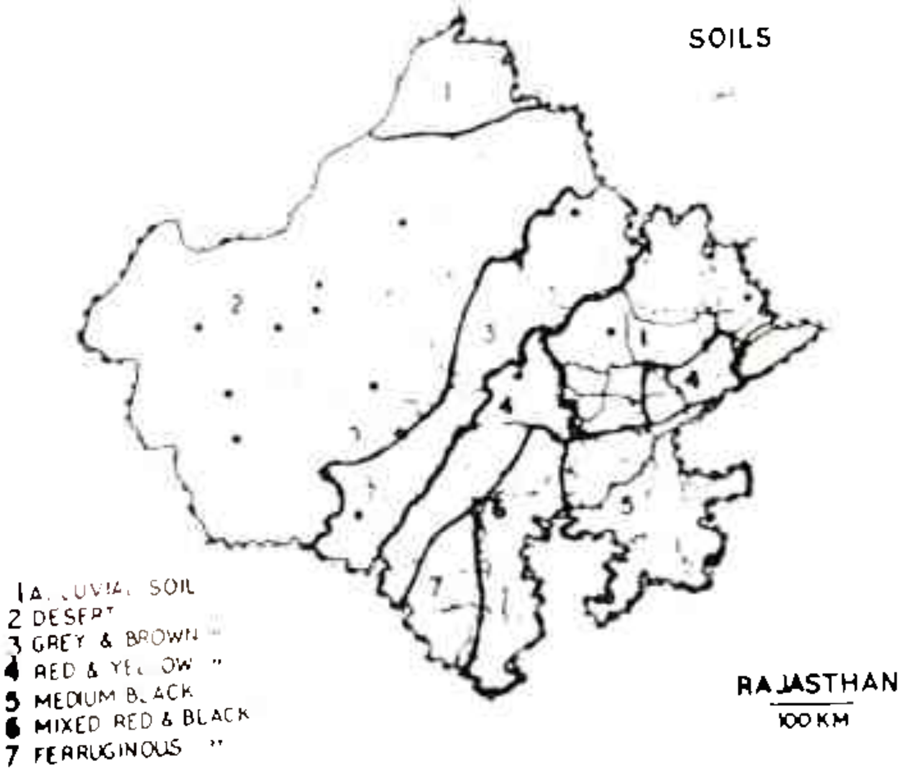


FIG. 4.9

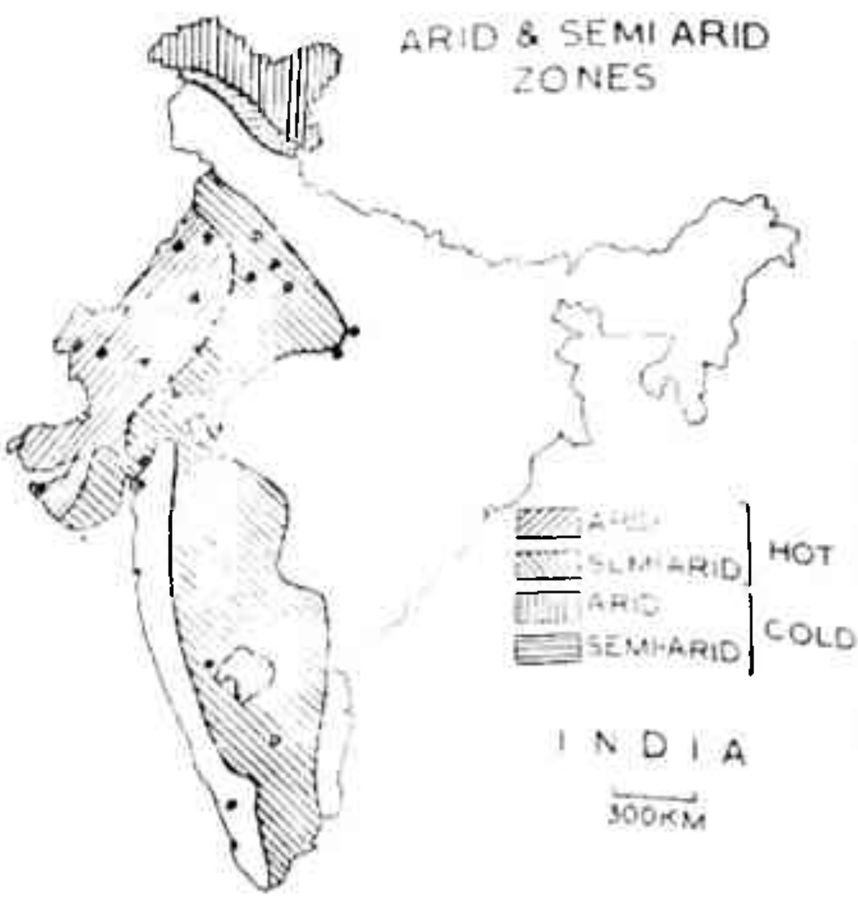


FIG. 4.10

CONCLUSION

The distribution of *Z. govindia* (*T. pentandra*) in different parts of India indicates its wide range of tolerance with regard to different environmental factors like temperature, rainfall and soil. The altitudinal and latitudinal distribution of the plant indicates its occurrence from latitude 11° (Coimbatore, 500 m.) to 33°.37 N (Rawalpindi, 1000 m.) and from longitude 67°.4 (Karachi, 200 m.) to 84°.25 E (Aurangabad, 1000 m.) as shown in Table 4.1 (Fig. 4.2). Though the plant has been recorded from six sub-physiographic zones of India which roughly fall between 11° to 30° N latitude and 69° to 81° E longitude, yet it is found in abundance from several places in Western plain, Northern plain and west part of north-central Highland, roughly falling between 25° to 30° N latitude and 70° to 78° E longitude, which cover more than 3/4th part of Western sandy arid and semi-arid transitional plain of Rajasthan. Thus, the species has a wide range of distribution but the maximum distribution of the plant ranges roughly from 24° to 30° N latitude and 73° to 75° E longitude. This clearly reflects its preference towards the arid environment prevailing in the arid and semi-arid regions of Rajasthan and part of Haryana and Punjab (Fig. 4.10).

The western sandy plain, where the plant has been frequently recorded, faces the extremes of temperatures and low rainfall (mean summer temperature from 32° to 36° C and rainfall from 12 to 50 cm. in the rainy season). The records support the tolerance range of this species for high temperature and low rain. The plant is also not uncommon in many places in the semi-arid region where the mean summer temperature ranges from 32° to 34° C receiving 25 to 50 cm. rains during rainy season. The plant is also found capable to grow in places getting mean rainfall ranging from 60 to 100 cm. in most of the regions other than Rajasthan (Table 4.3). This rainfall is much higher than that received in the western arid region of Rajasthan (2 to 40 cm.).

An increase in winter temperature from north to south is noted in Rajasthan. In arid region, the winter mean temperature has been found to be (i) minimum 12°C in the extreme north (Ganganagar), (ii) maximum 16°C in the middle part (Jaisalmer, Bap, Bikaner, Phalodi and west of Jodhpur) and (iii) intermediate 14°C in the south part (Barmer, Sheo and east of Jodhpur). Similarly, in the semi-arid region the winter temperature is (a) minimum (12°C) in the north part (Jhunjhunu), (b) maximum (16°C) in the middle part (Jaipur and Ajmer etc.) and (c) intermediate (14°C) in the south part (Sirohi, Pali and Udaipur). This range of winter temperature indicates that the plant is tolerant even to sufficiently low temperature ranging from 12° to 16°C.

The occurrence of Z. <u>govindia</u> (T. <u>pentandra</u>) in a wide range of soil types indicates its tolerance capacity towards different soil types (Tables 4.3, 4.4; Figs. 4.8, 4.9). In Rajasthan, the plant shows affinity towards desert soil (Western arid region) but is quite common in the grey and brown soils (Jhunjhunu, Sirohi), alluvial soils (Jaipur, Bharatput) and red and yellow (Ajmer and Pali) soils too. In other parts, like Punjab and Haryana, the plant tolerance for soil has been found towards Ped[illegible]

The foregoing account indicates that the plant is capable of withstanding a wide fluctuation in the geographical and ecological factors but mostly prefers arid environment of Rajasthan, Haryana and Punjab (Fig. 4.10). Since all the prevailing factors are not uniform throughout the places of its occurrence, the plant is subjected to a variety of climatic conditions from season to season in these places. Though all these factors affect the distribution as a whole, but no single factor acts as a critical factor. However, the plant has been most frequently recorded from the Western Sandy plain (which constitutes the arid and semi-arid part) of Rajasthan. It may, therefore, be concluded that the general temperature tolerance of *Z. govindia* falls between 32° and 36°C and winter temperatures of 12° and 16°C. Due to its frequent occurrence in the arid and semi-arid regions of Rajasthan, *Z. govindia* may be considered as a successful inhabitant of dry conditions.

CHAPTER 5

GENERAL MORPHOLOGY, PHENOLOGY AND PLANT PARASITES

INTRODUCTION

Since morphological characters of a plant are the measures of its functional habit, a detailed morphological study of *Zaleya govindia* cannot be ignored. A change in morphological character is the result of the change in the environmental factors. Thus, the habit of a plant is developed according to the habitat in which it grows. Further, such observed differences may be plastic or rigid based on the genetic set up of a particular species. This indicates the rigid and flexible nature of a species and thus can be differentiated into ecotypes and ecads.

Z. govindia is subjectec to various environmental factors, showing variations in normal form. Development of perennating habit, microphyllous nature of leaves and more or less complete loss of shoot system are some of the interesting and essential adaptations, which this species has developed to tide over the adverse situations for the continuity of its life. The present chapter includes the main morphological differences between the two varieties 'rubra' and 'flava' and also includes certain adaptations and modifications of the species. Its phenology and parasites have also been studied.

METHODS OF STUDY

The external morphological characters of both the varieties of *Z. govindia* were studied on conventional taxonomic features with the help of field studies and from flora available. A few morphological characters were measured on metric scale. Erect and prostrate plants from nature as well as from culture were also studied. Phenology was recorded from July 1968 to 1969 in nature and in August 1968 in culture. Phenological characters were recorded from culture pots up to fruit dispersal stage and the days taken by each phase were noted. Plant parasites like nematode galls in roots and Coleopteran larva from the fruit were also recorded during the laboratory and field studies. For soil nematodes, the root galls were smeared and sectioned following the traditional methods of staining for anatomical features. Study of ectoparasite was done from the root washings after centrifuging it.

OBSERVATIONS

i. General morphology:

Z. govindia is a branched and diffused herb with prostrate branches in open and hard ground areas (Photo. 5.1-A,B) and erect or semi-erect in shade (Photo. 5.2-A,B; 3-A,B). The primary tap root goes deep for a considerable depth and then develops laterals in all the directions. A plant, growing in open, was measured, following Dittmer's (1948) formula. The total root length was found to be 1836.68 cm. Young papillose stem becomes hard at maturity and consists of long internodes with broadened and sheathed nodes from where two opposite leaves, inflorescence and branch arise (Photo. 5.4-A,B). Leaves are simple, exstipulate, opposite; lamina elliptic-oblong, sometimes ovate, glabrous or papillose; 1.5 to 5.5 cm. long, rounded at the apex, narrowed

Photo. 5.1: Fresh plant of *Zaleya govindia* [illegible]
season showing prostrate branching in
open situations (5.1- [illegible] .'rubra'; 5.1- [illegible])

Photo. 5.2: Erect plant of *Z. govindia* [illegible] in shade
situations (5. [illegible] .'rubra'; [illegible])

Photo. 5.3: *Z. govindia* in association with other herbs,
grasses and sedges (A, B).

5.1-A

5.1-B

5.2 A

5.3 A

5.2-B

5.3-B

Photo. [illegible]: External morphology of Z. [illegible] [illegible]).

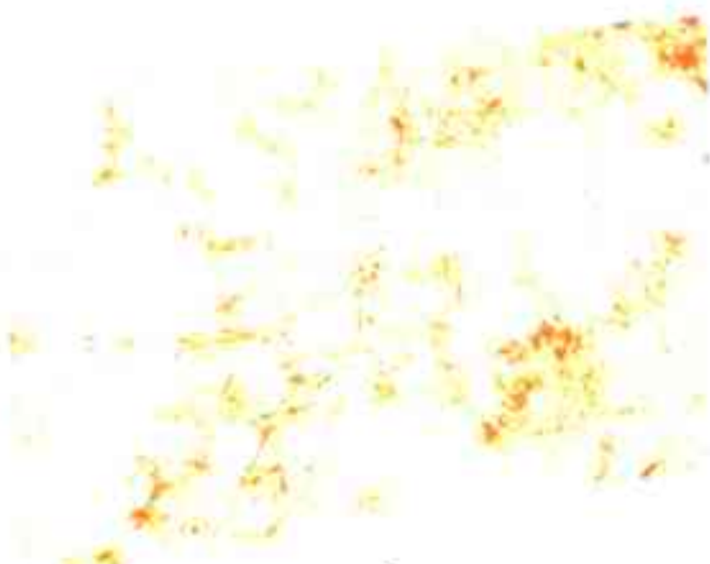
Photo. [illegible]: [illegible] of the branch in Z. [illegible] [illegible].

Photo. 5.6: Stunted growth [illegible] Z. [illegible] [illegible] open fields.

Photo. 5.7: Fresh branches [illegible] from a [illegible]nating plant at the [illegible] of [illegible] season.

5.4-A

5.4-B



5.5-A

5.5-B

at the base; petiole long, ensheathing the base by its dilated margins at the proximal end. Inflorescence sessile or sub-sessile (short pedicel). Flowers in clusters of dichasial cyme.

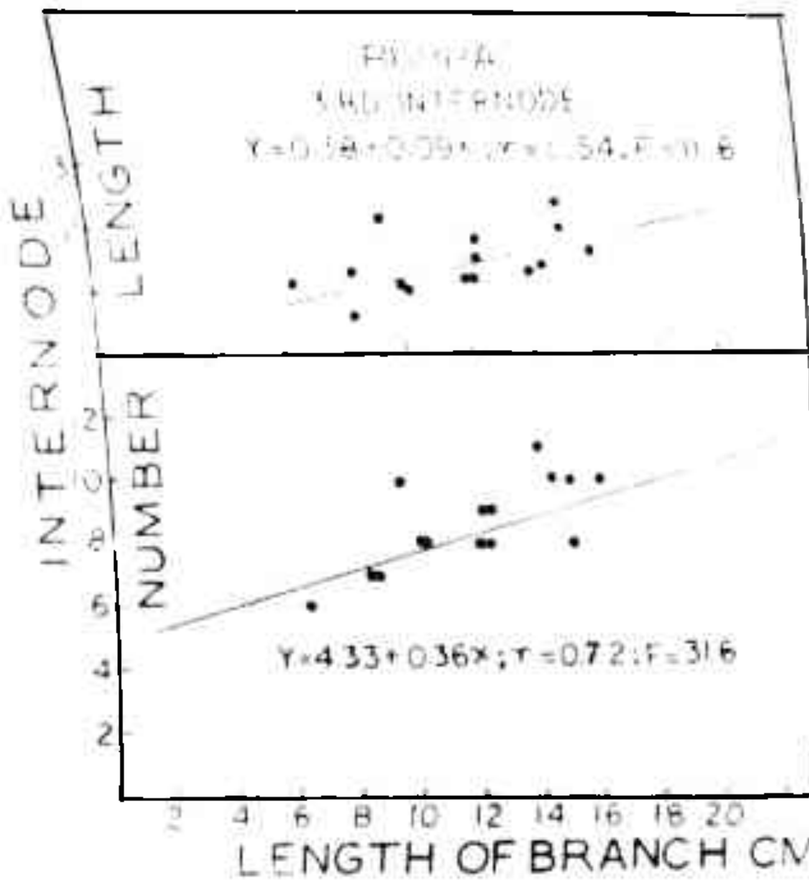
Flowers consists of 5 lobed calyx, scarious membranous bracts, calyx 2.5 to 3.0 mm. long, deeply lobed; lobes ovate-oblong with a short apiculation at the back below the apex. Stamens 5, inserted near the top of the tepal tube, introse and basifixed. Gynoecium bicarpellary, ovary bilocular with axile placentation; each carpel contains 2 ovules, one above the other and attached at one side to the interlocular septum (Jeffrey, 1960) (total 4 ovules); styles 2, stigma 2. Fruit is 4 mm. long capsule consisting of 2-valved operculum with broad deflexed horns, mitriform, dividing into two 1-seeded portions, the lower half of the capsule contains 2 seeds. Seeds small. (1.5 to 2.0 mm. diameter), black, remiform and slightly compressed.

Blatter and Hallberg (1918-21) have distinguished this species into variety 'rubra' having red stem, red petiole, red flower and red fruit with four seeds, and variety 'flava' having green stem, green petiole, yellowish green flower and yellow fruit with 4 seeds.

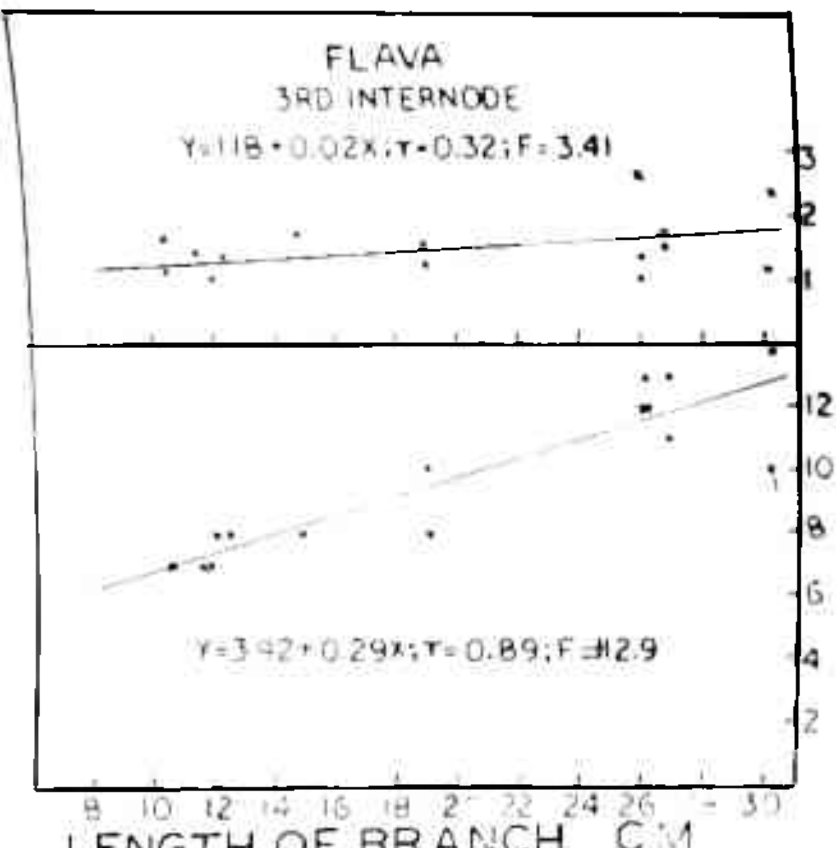
ii. Comparison of 'rubra' and 'flava':

Varieties 'rubra' and 'flava' differ significantly in their morphological features like length of the largest branch and number of internodes on the largest branch (Table 5.1; Fig. 5.1). Length of largest branch and number of internodes are found more in 'rubra'. In each variety, the performance of plants, growing in open and shade conditions, also differs

Fig. 5.[illegible] Correlation [illegible] of number of [illegible] nodes and length of third internode on the largest branch with the length of largest branch in 'rubra' and 'flava'.


INTERNODE
LENGTH
NUMBER
Y=4.33+0.36X; r=0.72; F=31.6
2
4
6
8
10
12
14
16
18
20
LENGTH OF BRANCH CM

FI


FLAVA
3RD INTERNODE
Y=1.18+0.02X;r=0.32;F=3.41
Y=3.42+0.29X;r=0.89;F=112.9
LENGTH OF BRANCH CM

G. 5.1

significantly both in nature and in culture (Table 5.2).

Table 5.1: Showing distinguishing characters in the two varieties, 'rubra' and 'flava' of *Zaleya govindia* (*T. pentandra*) growing in open field

(observation of 30 plants in each variety)

S.No.	Characters	'rubra'	'flava'
1.	Length of the largest branch (cm.)	11.77±2.82	9.62±1.68
2.	Length of 3rd.internode on the largest branch (cm.)	1.4 ±0.46	1.58±0.45
3.	Number of internodes on the largest branch	8.6 ±1.4	7.13±1.22

iii. Phenology:

In natural sites, where both the varieties of *Z. govindia* grow in open situation, the seedlings emerge in the second week of July after the first few showers of rain and continue up to fourth week of July. The mean maximum and minimum temperatures during this time ranged from 36.0°C to 36.7°C and from 24.7°C to 25.0°C, respectively.(Table 5.3). During August, the plants of two-leaf stage to vegetative stage were mostly observed. At this time a few perennial plants were also seen bearing flowers and fruits. New plants achieved maximum growth by September. During second and third week of October further growth was stopped and the plants of both the varieties started drying. The mean minimum and maximum temperature during this period were found to be 16.9°C and 34.8°C, respectively. Perennating plants were seen loosing old leaves but bearing a few leaves at the distal end of the branch (Photo. 5.5-A,B). The plants continued drying till fourth week of October to first week of November in all the places but for a few situations where they showed stunted

Table 5.2: *Showing morphological differences in erect* and prostrate** plants of 'rubra' and 'flava' studied in nature and culture (1968).*

(Observation of 15 plants in each variety)

S.No.	Character	'Rubra' Prostrate Mean+S.D.	'Rubra' Erect Mean+S.D.	'Rubra' 't' test	'Flava' Prostrate Mean+S.D.	'Flava' Erect Mean+S.D.	'Flava' 't' test
	NATURE						
1.	Length of largest branch (cm)	37.81±3.7	10.73±2.1	20.0	32.20±10.0	7.10±1.5	9.5
2.	Number of Internodes on the largest branch	10.10±1.1	4.50±1.0	3.6	14.39± 2.8	5.98±2.0	9.3
3.	Length of third Internode on the largest branch (cm)	3.24±0.5	2.31±0.4	1.3	2.27± 0.4	1.16±0.5	[illegible].1
4.	No. of fruit	137.40±89.8	4.80±2.1	3.2	117.60±45.7	4.60±2.3	5.5
	CULTURE						
1.	Length of largest branch (cm)	112.9 ±9.3	7.3 ±2.5	32.7	75.1 ±21.7	11.0 ±6.4	8.9
2.	Number of Internodes on the largest branch	15.5 ±0.3	4.4 ±1.4	21.1	12.3 ± 1.5	4.9 ±1.3	11.2
3.	Length of third Internode on the largest branch(cm)	6.5 ±1.2	2.5 ±1.5	18.4	6.8 ± 1.3	1.7 ±0.8	10.2
4.	No. of fruit	103.6 ±43.2	3.2 ±1.9	4.7	100.2 ±56.6	2.4 ±1.1	3.8

Table [illegible].3: Showing phenological observations on the two varieties ('rubra' and 'flava') of ?. govindia on a habitat with both the forms growing together. Observations were recorded from June 19[illegible] to July 19[illegible] in and around the Institute Campus.

Period	Climate data of the corresponding months				'Rubra'	'Flava'
	Av. Max. Temp. °C	Av. Min. Temp. °C	Av. relative	Total rainfall		

appearance (Photo. 5.6) due to slow growth. They remained stunted till winter rains in February (8.1 mm. rainfall) when they rejuvenated and showed an increase in growth. During this period, flowering and fruiting also took place. In summer months (May-June), the aerial parts of the plants were mostly lost. However, these plants usually perennate and survive by means of under-ground part. At certain favourable spots aerial shoots were given out whenever moisture was available. Soon after the rains in July (85.2 mm.), these perennating plants resumed their fresh growth (Photo. 5.7) besides the fresh seedlings which also appear as a new crop (Photo. 5.8). However, perennating ones start growing faster and fruit very early (Photo. 5.8). After attaining sufficient growth, new as well as perennating individuals show almost similar aerial look. Thus the plants exhibit flowering and fruiting almost round the year (Table 5.3).

Sometimes in brief drought condition, the plants in young stage were observed to drop their branches from the main stem and resumed the growth again in favourable conditions by developing new branches (Photo. 5.9). Besides, in situations like foot-path and also in extreme summer, the plants showed stunted growth with short branches and very minute leaves (Photo. 5.10-A,B).

The seedlings in culture take hardly 37 to 40 days from cotyledonary stage to fruit dispersal stage (Table 5.4). It is found that both the varieties take nearly equal time for each phase of the life cycle. The life processes seem to be accelerated due to the favourable conditions of available moisture supply in culture to insufficient supply of moisture in natural habitats where they show retarded and delayed growth.

Table [illegible] [illegible]
June 1968 to July 196[illegible] [illegible]

Period		Climate data of the corresponding months			
		Av. Max. Temp. °C	Av. Min. Temp. °C	Av. relative humidity	Total rainfall mm.
August	1968	36.7	24.7	70	37.2
September	1968	38.5	22.9	54	-
October	1968	34.8	16.9	47	10.8
November	1968	30.3	10.2	38	-
December	1968	24.6	5.6	37	-
January	1969	22.9	3.7	34	-
February	1969	26.0	11.1	36	8.1
March	1969	34.2	14.6	28	2.7
April	1969	36.9	19.6	23	11.8
May	1969	38.6	23.8	28	9.0
June	1969	41.8	28.9	33	16.8
July	1969	37.5	27.5	57	85.2

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Table 5.4: Showing number of days taken by each phase (Phenology) in the two varieties of Z. govindia in the culture pots starting from August 4, 1968.

Variety	Replicates	Cotyledons attain full size	Initiation of first pair of leaves	First pair of leaves	4-leaf stage	Vegetative phase	Flower bud initiation.	Flowering started	Fruiting started	Mature fruit	Fruit dispersal
	1	2	3	7	11	16	19	21	24	29	37
	2	3	4	7	12	17	21	23	26	30	39
'rubra'	3	3	4	7	11	15	18	20	23	29	40
	4	2	3	6	10	14	18	20	24	31	39
	5	3	4	7	11	17	21	23	25	29	38
	Mean	2.6	3.6	6.8	11	15.8	19.4	21.4	24.4	29.6	38.6
	1	2	3	6	10	15	19	21	25	30	38
	2	2	3	7	11	16	18	20	24	28	41
'flava'	3	2	3	8	13	16	19	22	25	30	40
	4	3	4	7	12	15	18	21	24	31	40
	5	3	4	6	11	16	19	21	24	31	39
	Mean	2.4	3.4	6.8	11.4	15.6	18.6	21.0	24.4	30.0	39.6

Photo. 5.8: Comparative growth in fresh and perennial plants of _Zaleya_

Photo. 5.9: Development of fresh branchings from the hypocotyl region when the old branches are shattered in dry conditions of drought.

Photo. 5.10: Prostrate plant on hard ground and road sides in the form of rosette.
(5.10-A,'rubra'; 5.10-B,'flava')

5.8

5.9

5.10-A

5.10-B

iv. Plant Parasites:

During the field studies, it was observed that a number of plant parasites affect the life cycle of the plant as given below:

a. Plant v. Cuscuta: Young to mature plants of Z. govindia are severely attacked by Cuscuta (Photo. 5.11). The parasite twines around the stem and leaves of the host, penetrating its haustoria for extracting nourishment. The host (Zaleya govindia) is thus, subjected to loss of leaves and fruits resulting in the reduction of its photosynthetic capacity and seed formation.

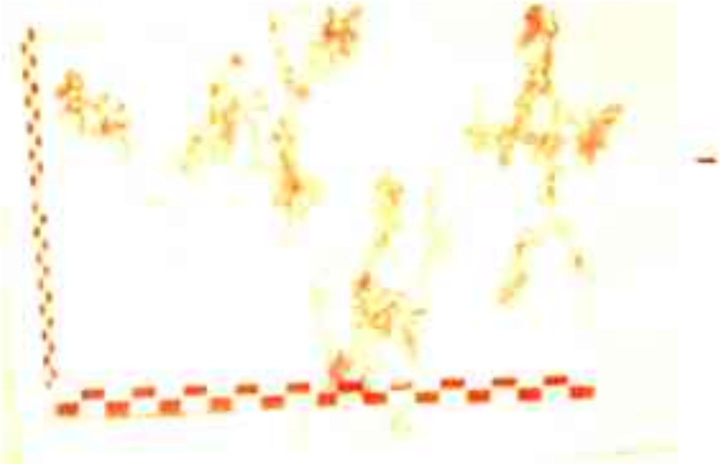
b. Plant v. Insects: The fruit and seed of Z. govindia are eaten by a Coleopteran larvae. Out of the 4 seeds in a fruit, 1-2 seeds were normally eaten and thus the chances of regeneration are halved. It is possible that the insect lays eggs when the flowers bloom and during the course of seed formation the egg also develops into the larval stage to feed on the seeds.

c. Plant v. soil nematodes: Certain plants, when excavated, were noticed with numerous bulging outgrowths (galls) on the roots (Photo. 5.12). The galls, when smeared and studied under microscope, showed numerous cysts with Meloidogyne incognita. Anatomical studies show that this endoparasite is found to attack the cortical and vascular regions, where the xylem portion is distorted (Microphotograph 5.13). A detailed study revealed that the infection brings stunted growth even in young plant (Photo. 5.14). Under microscope, a drop of root washing showed numerous Acrobeles (Photo. 5.15-A,B), which is an ectoparasite.

Photo. 5.11: Effect of *Cuscutta* on *Zaleya* (loss of photosynthetic part and seeds).

Photo. 5.12: *Zaleya* plant showing root galls.

Photo. 5.13: Xylem distortion due to the nematode infection.



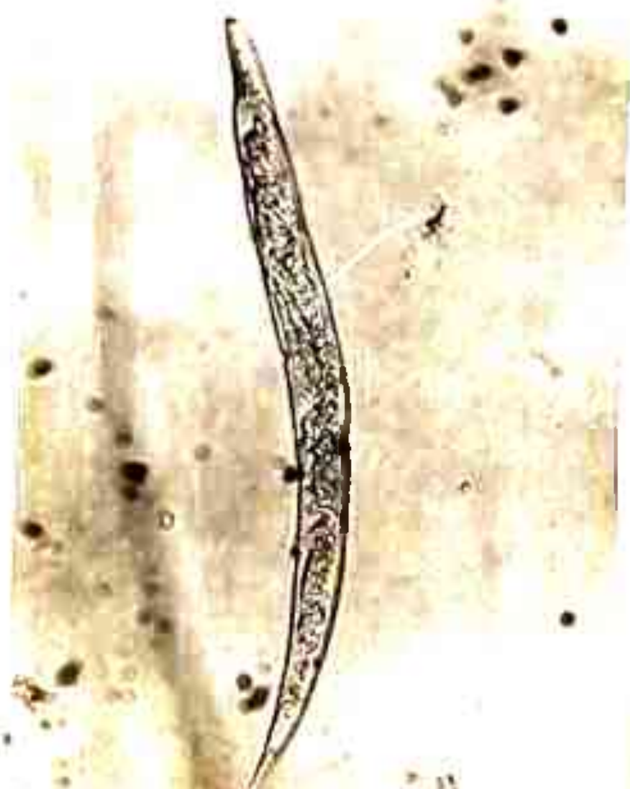
5.11

5.13

Photo. 5.14: Young plant of *Z. govindia* showing root galls and wilted leaves

Photo. 5.15: *Acrobeles* species collected from the root washing of *Z. govindia*: A, entire body; B, anterior portion showing cephalic region.

5.14



5.15-B

CONCLUSION

In spite of many similarities in general morphological features, the two varieties 'rubra' and 'flava' of *Zaleya govindia* show differences in certain characters which may be controlled by their individual genetic make up or by one or more environmental factors. The phenology of both, in nature and culture, is almost similar. The plant passes through many adverse conditions during its life cycle. Perennating habit helps the plant to endure the drought period. The attack of *Cuscuta* retards its photosynthetic efficiency and so also the development of seeds. Regeneration capacity is severely affected by the Coleopteran larva. The presence of *Meloidogyne incognita*, an endoparasite, obliterates the conducting vessels and thus hinders the food translocation. The same nematode is reported to infect the roots of sugar cane (Rangaswamy *et al.*, 1960), Jute (Chattopadhyay and Sengupta, 1955) and many weeds like *Ageratum conyzoides*, *Cleome viscosa*, *Achlypha indica*, *Gynandropsis pentaphylla* (Rangaswamy et al., 1960; Samad, 1960). Distortion of xylem portion is also found in *Corchorus olitorius* (Chattopadhyay and Sengupta, 1955) and *Mazus japonicus* (Pal and Pal, 1967). However, the ectoparasite is not observed to harm the under-ground plant parts.

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CHAPTER 6

PHYTOSOCIOLOGY AND PLANT POPULATION

INTRODUCTION

Ashby (1948), Greig-Smith (1952) and Phillips (1954) have found that the community structure and function are influenced by the distribution of a species in a community and also by one or more factors of the habitat. Greig-Smith (1957), in his review, has emphasised the quantitative aspects of phytosociology. The limiting factors of individual populations have been studied based on quantitative aspects by Kershaw (1958) and Snaydon (1962) and the later has also observed the population control in Trifolium repens L. by pH and exchangeable carbonates. However, the seasonal fluctuations in a species and its ecological limitations are understood in relation to the habitat through the quantitative estimations of the population. Thus, phytosociological studies are found useful in the study of the behaviour of individual species and its associates. Such studies are essential to understand the species diversity in relation to the prevailing dynamic environment. In natural vegetation the relationship of plants to soils is very close one, as it forms the base for plant indicators (Puri, 1960).

The present chapter deals with the quantitative structure of the vegetation during growing season in study sites which more or less support the occurrence of Z. govindia. The population dynamics and the species diversity were obtained by the quadrant method using three parameters, viz., abundance, density and frequency.

METHODS OF STUDY

Sampling of the vegetation in four sites (II, III, IV and V) was started as soon as the plant growth became apparent in the second week of August 1969. The quadrats of 0.5 square metre each were laid down in third week of every month. The sampling was done in the vicinity of the area where *Z. govindia* was growing. This preferential sampling was done in order to find out the inter and intra relations in the two varieties of *Z. govindia* with other species of the study site. From each quadrat, plants were counted and listed. The initial values were first multiplied by 4 to bring them on square metre basis and then computed by methods outlined by Oosting (1956) and Pandeya *et al.* (1968) for the structural parameters as given below:

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Total number of quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrats}}{\text{Number of quadrats of occurrence}}$$

$$\%\ \text{Frequency} = \frac{\text{Number of quadrats of occurrence}}{\text{Number of quadrats studied}} \times 100$$

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total No. of individuals of all the species}} \times 1C$$

The species occurring throughout the observation period in two or more than two sites has been taken as a dominant species in the present investigation.

For soil moisture and pH, the soil samples were collected on the observation dates at the depths of 0-5, 5-10, 10-20, and 20-30 cm. The percentage moisture was calculated on fresh weight basis after drying the soil at 100°C for 24 hours while pH was measured in 1:5 soil water suspension by Blackman pH meter. For mechanical and chemical analyses three composite soil samples were collected from the same depths. They were analysed and the mean was calculated. Standard Endecott's sieves were used for mechanical analysis of soil while total percentage nitrogen and calcium carbonate were, respectively, determined by Kjeldahl and rapid titration methods (Piper, 1944).

OBSERVATIONS

1. Floristic composition:

Based on phytosociological studies of 4 months, starting from August 1969 (growing season) to November 1969 (Pre-winter season), both the varieties of <u>Zaleya govindia</u> ('rubra' and 'flava') are found growing throughout the study period (Table 6.1). The ground flora of the study sites consists of 1 shrub, 27 herbs (including 'rubra' and 'flava'), 11 grasses and 3 sedges, the total being 42 (Table 6.2). Maximum number of species (30) have been recorded on site II while minimum (18) on site V. Site III and IV are found having 25 species each (Table 6.3). It is only site II which supports one shrub. Maximum number (20) of herbs are recorded on site II and minimum (10) on site V while maximum grasses (10) occur on site IV and minimum (6) on site V. Only 2 sedges are found but are not recorded on site II. Thus, a site showing the maximum number of herbs also shows maximum number of species. Similarly the site, where the minimum number of herbs occur, shows a decline in the total species.

Table 6.2: Showing the number of times the species is recorded from August 1969 to November 1969 in four sites

Name of species recorded	Total No. of species	No. of times a species recorded
SHRUB		
Zizyphus nummularia	1	1
	1	
HERBS		
Dorantenthera senegalensis, Convolvulus microphyllus, Gynandropsis gynandra, Indigofera hochstetteri, I. enneaphylla, Trianthema portulacastrum	6	1
Aerva pseudotomentosa, Launea nudicaulis, Mollugo cerviana, Sida cordifolia	4	2
Amaranthus gracilis, Boerhaavia diffusa, Digera muricata, Gisekia pharnaceoides, Mollugo nudicaulis, Portulaca oleracea	6	3
Amaranthus tricolor, Trianthema crystallina	2	4
Boerhaavia repens	1	5
Euphorbia hirta	1	6
Phyllanthus niruri	1	7
Euphorbia thymifolia, Tephrosia hamiltonii	2	8
Corchorus aestuans, Zaleya govindia 'flava' Tribulus terrestris	3	11
Zaleya govindia 'rubra'	1	14
	27	

(Contd.)

Table 6.2 (Contd.)

Name of species recorded	Total No. of species	No. of times a species recorded
GRASSES		
Dactyloctenium sindicum	1	1
Cynodon dactylon	1	2
Cenchrus ciliaris, *Eragrostis tremula*	2	3
Tragus biflorus	1	4
Cenchrus biflorus	1	5
Digitaria adscendens	1	7
Brachiaria ramosa	1	10
Eragrostis poaeoides, *Eragrostis ciliaris*	2	12
Dactyloctenium aegyptium	1	13
	11	
SEDGES		
Cyperus arenarius	1	3
Cyperus compressus	1	6
Cyperus rotundus	1	5
	3	
TOTAL	42	

Table 6.3: Showing number of species on different sites

Species group	Site II	Site III	Site IV	Site V
Shrubs	1	-	-	-
* Herbs	20	15	13	10
Grasses	9	8	10	6
Sedges	-	2	2	2
Total	30	25	25	18

*Values include 'rubra' and 'flava'

Table 6.4: Showing species occurrence in one or more than one study sites

Site	Name of species	Total species
II	Convolvulus microphyllus, Gynandropsis gynandra, Zizyphus nummularia, Dactyloctenium sindicum	4
III	Dorantenthera senegalensis, Indigofera enneaphylla, Trianthema portulacastrum, Cyperus arenarius	4
IV	Indigofera hochstetteri, Trianthema crystallina	2
V	x	
II-III	Aerva pseudotomentosa, Amaranthus gracilis, Boerhaavia diffusa, Sida cordifolia	4
II-IV	Euphorbia hirta, Launea nudicaulis, Portulaca oleracea, Cenchrus ciliaris, Cynodon dactylon	5
II-V	Digera muricata, Gisekia pharnaceoides, Mollugo cerviana, Mollugo nudicaulis	4
III-IV	Eragrostis tremula	1
III-V	Amaranthus tricolor	1

(Contd.)

Table 6.4 (Contd.)

Site	Name of species	Total species
IV-V	Boerhaavia repens, Cyperus compressus	2
II,III,IV	Corchorus aestuans, Phyllanthus niruri, Cenchrus biflorus, Zaleya govindia 'flava'	4
III,IV,V	Tragus biflorus, Cyperus rotundus	2
II,III,IV, V	Euphorbia thymifolia, Tephrosia hamiltonii, Zaleya govindia 'rubra', Tribulus terrestris, Brachiaria ramosa, Dactyloctenium aegyptium, Digitaria adscendens, Eragrostis ciliaris, Eragrostis poaeoides	9

It has been observed (Table 6.4) that only 9 species which include 4 herbs (Euphorbia thymifolia, Tephrosia hamiltonii, Zaleya govindia 'rubra', and Tribulus terrestris) and 5 grasses (Brachiaria ramosa, Dactyloctenium aegyptium, Digitaria adscendens, Eragrostis ciliaris and E. poaeoides) occur in all the four sites. Site II shows the occurrence of Convolvulus microphyllus, Gynandropsis gynandra, Zizyphus nummularia, Dactyloctenium sindicum and species like Doratenthera senegalensis Indigofera enneaphylla, Trianthema portulacastrum and Cyperus arenarius occur only on site III. Indigofera hochstetteri, Trianthema crystallina are confined only to site IV. Site V has got no exclusive species. Rest of the species are common in more than one site (Table 6.4).

It may also be observed that except Zaleya govindia, the most frequent occurring species, based on their record from August to November in two or more than two sites, are Corchorus aestuans, Tribulus terrestris, Dactyloctenium aegyptium, Eragrostis poaeoides and E. ciliaris,which compete with the two varieties of *Z. govindia* (Tables 6.1; 6.2).

ii. Quantitative analysis:

The quantitative analysis indicates that all the 9 dominant species in different sites show higher density figures (Table 6.1). The density of both the varieties of *Z. govindia* first decreases from August to September in all the sites except for site V. The density of 'rubra' and 'flava' on site II and IV falls from August onward while on site V the density of 'rubra' increases from August to September and then declines from September to October. On site III, it falls for both the varieties from August to September but increases from September to October and again declines in November. The frequency of 'rubra' is higher than 'flava' on site IV in the growing season (September and October) while that of 'flava' on site II and III (Table 6.1). Relative density of both 'rubra' and 'flava' (Table 6.5) continuously increases from August to November on site III while it declines on site IV. On site II, they increase from August to September. On site V, the relative density of 'rubra' increases from August to September and then falls from September to October. Variety 'flava' possesses higher relative density than variety 'rubra' on site II and III.

iii. Soil analysis:

The average soil moisture during the study period (Table 6.6) is found maximum on site II while minimum on site V. The moisture percentage range on sites III and IV are more or less the same.

The mean pH on site II, III and IV ranges from 7.6 to 8.5. Maximum pH is measured on site II while minimum on site V. The pH of site III and IV are very close. The range indicates that sites III, IV and V have neutral soil while site II is slightly alkaline in nature(Table 6.6).

The mechanical composition of soil (Table 6.6) shows very little amount of gravel on site V, while it is below 2% on site II and IV and above 2% on site III. Coarse sand percentage is maximum on site III (11.48%) and minimum on site III (~~71.29%~~ 3.47 %). Maximum fine sand is found on site V (88.5%) and minimum on site III (71.29%). Maximum silt and clay is found on site II (21.25%) and minimum on site V (7.66%).

All the sites, except site II, possess poor nitrogen status. These sites, based on the amount of percentage nitrogen and calcium content of the site, can be arranged as site II > site III > site IV > site V. Though the percentage nitrogen on site III and IV are very similar but they differ in their calcium carbonate and exchangeable calcium contents (Table 6.6).

Table 6.6 : Showing mechanical and chemical analysis of soil from different sites (The mean values given are based on the study of three composite soil samples from five sites).

Characters		Site II	Site III	Site IV	Site V	Site VI
Moisture	(%)	7.85	6.56	6.34	0.26	5.17
pH		8.5	7.8	7.6	7.2	8.1
Fine gravel	(%)	1.47	2.65	1.11	0.35	1.93
Coarse sand	(%)	4.20	11.48	8.81	3.47	14.33
Fine sand	(%)	73.41	71.29	75.08	88.51	85.73
Silt and Clay	(%)	21.25	16.78	10.95	7.66	9.47
Nitrogen	(%)	0.127	0.079	0.071	0.059	0.162
Calcium carbonate	(%)	5.20	3.72	1.52	0.74	5.83
Exchangeable calcium (m.e. %)		0.80	0.72	0.59	0.13	

DISCUSSION

It is observed that the habitat conditions considerably affect and deteriorate the species composition. Maximum number of species on site II seems to be due to the partial protection and lack of biotic disturbance on this site. The frequent sweeping on site V seems to be responsible for the small number of species rather than grazing. During sweeping, the seeds of the vegetation are taken away and hence do not get a chance to germinate. The poor moisture status and lack of nutrients on site V also result in the poor vegetation on this site.

Higher density of dominant species like T. terrestris and D. aegyptium than variety 'rubra' may be accounted for their greater number of seedlings as compared to Z. govindia in August. After September, though both the varieties get maturity but continue due to perennating habit while other dominant species, which also have higher density in August, decline in September due to their approaching the senescent stage. Tephrosia hamiltonii and Corchorus aestuans being comparatively less in number do not compete with Zaleya while Tribulus does so only up to September.

On site II, the two varieties having higher relative density as compared to Corchorus and Tribulus, can withstand and overcome these competitors. Since 'flava' possesses higher relative density than 'rubra', it predominates the later on this site. On site III, the increase in relative density of the two varieties of Zaleya and other dominant species (D. aegyptium and and T. terrestris) infers that both the varieties are simultaneously suppressed by these competitors. On site IV, variety 'rubra', though initially high in relative density, is suppressed by D. aegyptium, as the later also shows increase in relative density. Variety 'rubra' is further suppressed by 'flava' in November when the later overtakes the former. Other dominant species like Brachiaria ramosa and Corchorus aestuans do not compete due to less occurrence. However, on site V, variety 'rubra', due to poor relative density, is also suppressed by dominant species (Table 6.5).

It is also observed for variety 'rubra' that the number of individuals per sq. m. decreases from August to September on all the sites (Table 6.7). From August to September, the percentage (relative density) of 'rubra' is increased on sites II, III and V but is decreased on site IV. This shows that the occurrence of 'rubra' is favoured more on site II than site III and minimum on site V. Variety 'flava' also declines per sq. m. from August to September on all the sites but their percentage (relative density) is increased on site II and III and falls on site IV. This indicates that 'flava' variety flourishes best on site II and dominates over the other variety. Based on positive percentage values, it may be concluded that D. aegyptium competes on sites II and IV, T. terrestris on sites II and III and both on site V against Z. govindia.

Table 6.7: Showing percentage increase in the number of individuals per sq. m. of certain dominant species on different sites from August to September, 1969

Species	Site	Relative Density		Percentage increase from August to September
		August	September	
Zaleya govindia 'rubra'	II	8.14	17.64	+ 9.50
	III	4.58	7.90	+ 3.32
	IV	24.64	8.51	-16.13
	V	0.56	1.24	+ 0.68
Zaleya govindia 'flava'	II	9.70	23.52	+13.82
	III	4.25	9.30	+ 5.05
	IV	5.26	3.02	- 2.24
	V	-	-	-
Tribulus terrestris	II	2.37	7.56	+ 5.19
	III	6.41	11.16	+ 4.75
	IV	22.79	7.41	-15.38
	V	1.45	3.42	+ 1.97
Dactyloctenium aegyptium	II	20.37	32.77	+12.40
	III	66.44	26.97	-39.47
	IV	6.79	30.21	+23.42
	V	12.84	30.79	+17.95

Further, on the basis of studies on site II, III and IV, the occurrence of the two varieties of *Z. govindia* seems to be independent of moisture, pH and nitrogen content of the site, these being either negatively correlated or insignificant, statistically (Table 6.8). Hence, these factors may not be responsible for their local distribution. Variety 'flava' shows highly significant correlation for silt and clay ($r = +0.96$; $F = 58.7$), and exchangeable calcium ($r = +0.98$; $F = 102.9$) and so occupies maximum density on site II which has

Table 6.8: Showing correlation of mean density of 'rubra' and 'flava' with different soil characters

Variables Y : X		Corr.Coeff.(r)		Variance (F)		Regression equation	
		Rubra	Flava	Rubra	Flava	Rubra	Flava
Mean density : Moisture	(%)	-0.12	+0.75	0.06^{NS}	5.20^{NS}	Y = 95.8+-4.16X	Y = -127.9+27.0X
" : pH		-0.20	+0.80	0.16^{NS}	7.16^{NS}	Y = 159.6+-11.62X	Y = -336.8+49.[illegible]X
" : Fine sand	(%)	+0.99	-0.70	1191.60***	4.01^{NS}	Y = -983.4+14.3X	Y = 857.8+-10.9X
" : Silt and Clay	(%)	-0.55	+0.96	1.78^{NS}	58.7***	Y = 115.0+-2.9X	Y = -30.7+5.4X
" : Nitrogen	(%)	-0.12	+0.75	0.06^{NS}	5.15^{NS}	Y = 77.1+-109.5X	Y = -8.1+725.5X
" : Calcium Carbonate	(%)	-0.30	+0.86	0.42^{NS}	11.68*	Y = 81.2+-45.0X	Y = 16.4+134.7X
" : Exch. calcium	(%)	-0.60	+0.98	2.30^{NS}	102.9***	Y = 176.6+-155.8X	Y = -131.9+271.1X

DF Treatment 1
DF Error 4

NS Non significant
** $P < 0.01$
*** $P < 0.001$

F value at 5% = 7.71

maximum values for these soil features. High values of fine sand on site V may support the occurrence of variety 'rubra' as it shows highly significant positive correlation ($r = +0.99$; $F = 1191.6$) with fine sand (Table 6.8). Thus, 'rubra' is more favoured by high content of fine sand while 'flava' by high content of silt and clay, and also by exchangeable calcium. Further, these two contents are moderately high on site II, due to which both the varieties seem to grow together with least numeric differences (Tables 6.6; 6.9).

Table 6.9: Showing mean density of 'rubra' and 'flava' on different sites and exchangeable calcium on these sites

Variety	Density			
	II	III	IV	V
'rubra'	67.4	39.6	94.2	1.6
'flava'	81.0	69.8	25.6	x
Exchangeable calcium (m.e. %)	0.80	0.72	0.59	0.13

CHAPTER 7

MORPHOLOGICAL VARIATIONS

INTRODUCTION

Gregor (1938, 1944, 1946) studied the interpopulation variations governed by certain ecological factors. The success of a species population not only depends upon its capacity to cope with its physical environment but also upon the genetic variability (Hanson and Churchil, 1961). The ecological importance of phenotypic plasticity lies in the fact that it has a bearing on the range of habitats a species can occupy, since it tends to make the individual adaptable to more than one habitat. Due to this fact the plants though differ in appearance by distinct morphological features in vegetative parts and reproductive vigour, yet they belong to the same homogeneous genetic stock and are referred as ecads (Daubenmire, 1959). Studies of Bradshaw et al. (1958) and Ramakrishnan (1961a) indicate that various species have wide range of calcium requirements and that these are highly correlated with the edaphic habitat of the species.

In early studies (Chapter 6) the population density of variety 'flava' was found significantly correlated to calcium content, and silt and clay, which differed from site to site with a wide range while 'rubra' to fine sand. Fine sand content variation in the sites was in a narrow range of difference. The present investigation has, therefore, been undertaken to work out the adaptability and tolerance of the two varieties with regard to their variation in morphological characters from site to site and to the edaphic limits with an emphasis to calcium level.

METHODS OF STUDY

15 plants of both the varieties at fruiting stage are randomly collected from sites II, III, IV and V in the end of August 1969. The morphological features (length of the largest branch, number of internodes and length of third internode on the largest branch) in each plant were measured. The soil samples were collected from the region of profuse growth of roots in all the sites, separately, and the soil collected was analysed separately to correlate the soil nutrient studies, specially range of calcium, with the growth of characters and the occurrence of the two varieties. .

In order to study the phenotypic plasticity, observed in the different habitats in each variety, the seeds of both the varieties in each site, were collected and stored separately under laboratory condition. These were sown in September 1968 in culture plots of one sq. m. so as to get in September 1969 10 plants in each quadrat in the Botanical garden. Plants were uniformly irrigated on alternate days and were dug out after 40 days for variations in morphological measurements.

A culture experiment was set up to elucidate the effect of calcium on the growth of the two varieties. Four different regimes of calcium were obtained by adding $Ca(OH)_2$ to the garden soil, which has 3.2% calcium, was mixed with weighed amount of powdered lime to get different percentages of calcium carbonate.

Pots were watered for 30 days before the seedlings were transferred. After the completion of the experiment the soil was analysed for carbonate ~~percentages~~ and exchangeable calcium.

Three replicates were set for each variety and the seedlings germinated from a single stock of seeds of each variety, were transferred at 4 leaf stage to these culture pots. Three plants in each pot were maintained under uniform irrigation conditions and then studied for measurement of growth features. Soil factors like pH, calcium carbonate and exchangeable calcium were determined at the end of the experiment following Piper (1944) and Pandeya *et al*. (1968). The results are recorded below:

	Calcium carbonate added				
	Control	4%	6%	8%	10%
pH	7.0	7.3	7.6	8.0	8.2
Calcium carbonate (%)	3.2±1.1	4.6±2.1	6.2±2.6	8.3±2.5	9.4±3.0
Exchangeable calcium (m.e. %)	10.22±2.0	10.86±2.2	17.73±3.1	25.31±6.1	38.17±7.0

OBSERVATIONS

Significant morphological differences have been observed in nature within the sites in each variety and also from site to site between 'rubra' and 'flava' (Table 7.1). For all the morphological characters, variety 'rubra' shows minimum values on site V and maximum on site II. On the other hand, 'flava' has lowest values on site IV and highest on site VI. Excluding site V, for it supports only 'rubra', the values for morphological characters as well as for dry weight are minimum on site IV for both the varieties while maximum on site II and VI for 'rubra' and 'flava', respectively (Tables 7.1, 2). It may also be noted that the morphological differences between the two varieties are statistically significant in most of the sites (Table 7.1). The dry weight of above ground parts (stem and leaves) in 'rubra' is more on site II (7.19±2.67 g.) than site VI (2.62±1.61 g.) but in 'flava' the values are more or less same in these sites (4.37±3.06 g. on site II and 4.38±1.88 g. on site VI respectively). In nature, the mean length of the largest branch of 'rubra' is found greater than 'flava' in all the sites except site VI, where 'flava' has higher value (-37.20) in this character (Table 7.3). This negative difference between 'rubra' and 'flava' for this character indicates the greater length of the maximum branch of 'flava' than 'rubra' on site VI.

The chemical composition of the soil collected from the region of profuse growth of roots on one site differs from those collected similarly from other sites (Table 7.4). pH ranges from 7.0 to 8.2 for 'rubra' and from 7.4 to 7.8 for 'flava'. Carbonate ranges from 0.07 to 4.06 for 'rubra' and from 3.77 to 9.35 for 'flava' and exchangeable calcium ranges from 3.02 to 20.36 for 'rubra' and from 11.14 to 27.32 for 'flava'. Site VI is highly alkaline while site V seems to be neutral. The other sites also show pH towards alkaline side. Site VI points to have very high carbonate and exchangeable calcium values while site IV possesses lower amount but site V possesses lowest amount of carbonate and exchangeable calcium. It is also clear

Table 7.1: Showing mean and standard deviation of the mean of growth parameters (morphological characters) of 'rubra' and 'flava' collected from different sites in August 196[illegible] (Nature)

(Observations based on the study of 15 plants of each variety at each site)

Site	Characters								
	Length of largest branch (cm)			Number of internode on largest branch			Length of third internode on largest branch [illegible]		
	Rubra	Flava	t Test	Rubra	Flava	t Test	Rubra	Flava	t Test
II	32.2±10.0	26.2±7.3	10.8***	14.4 ±2.8	1[illegible].9±2.6	0.4	1.70±0.[illegible]	1.8±0.[illegible]	0.5
III	20.1± 7.5	15.0±2.8	2.4	9.0 ±2.0	11.2±1.7	3.0*	1.57±0.5	1.6±0.5	0.5
IV	11.7± 2.8	9.6±1.6	3.5**	8.6 ±1.4	7.1±1.1	3.1*	1.44±0.4	1.5±0.7	0.8
V	7.1± 1.5	---	---	6.4 ±1.5	---	...	1.24±0.3	---	---
VI	18.2± 3.0	37.4±10.4	13.2***	11.53±2.2	16.0±2.3	5.2***	1.72±0.2	3.[illegible]±0.4	10.7***
Calculated F = 4.13 (excluding site V)	546.3	131.6		37.0	50.3		142.[illegible]	107.[illegible]	

't' test at 28 degrees of freedom

* Significant at 1% level, table value for t = 2.763
** Significant at 0.2% level, table value for t = [illegible]
*** Significant at 0.1% level, table value for t = [illegible]74

Table 7.2: Showing mean and standard deviation of mean in growth parameters (dry weight of plant parts) of 'rubra' and 'flava' on different study sites in August, 1969 (Nature).

(Observations based on the study of 15 plants of each variety)

Site	Characters							
	Dry weight leaves (gm.)		Dry weight roots (gm.)		Dry weight total shoot (Stem and leaves)		Root/shoot ratio (Dry weights)	
	'rubra'	'flava'	'rubra'	'flava'	'rubra'	'flava'	'rubra'	'flava'
II	3.78±1.75	2.00±1.55	2.75±1.06	2.53±1.97	7.19±2.67	4.37±3.06	0.38	0.57
III	0.68±0.42	0.85±0.32	0.57±0.39	0.80±0.50	1.02±0.65	1.52±0.65	0.55	0.51
IV	0.29±0.12	0.36±0.11	0.54±0.48	0.35±0.10	0.66±0.44	0.69±0.17	0.51	0.50
VI	1.27±0.77	2.07±0.67	1.26±0.89	1.73±0.51	2.62±1.61	4.38±1.88	0.48	0.39

Table 7.3: Showing comparison of morphological characters between 'rubra' and 'flava' from the plants grown in culture (September 1969) and Nature (August 1967)

Site	Characters			
	Difference in the mean length of maximum branch in 'Burma' and 'flava' (Rubra value minus flava value)		Ratio in the mean length of maximum branch in 'rubra' and 'flava' (Flava : Rubra)	
	Culture	Nature	Culture	Nature
II	+37.54	+5.93	1:1.4	1:1.2
III	+40.24	+5.13	1:1.5	1:1.3
IV	+28.30	+2.15	1:1.3	1:1.2
VI	+28.84	-19.20	1:1.3	2:1.0
Mean for positive values	33.85	2.80		

Table 7.4: Showing mean values of the analysis of soil samples collected in different sites from the region of thickly populated lateral roots of 'rubra' and 'flava'

Soil Components	Variety	Site				
		II	III	IV	V	VI
pH	'rubra'	7.8	7.6	7.4	7.0	8.2
	'flava'	7.7	7.5	7.4	-	7.8
Carbonate content(%)	'rubra'	2.54	1.27	0.13	0.07	4.06
	'flava'	5.81	4.93	3.77	-	9.35
Exchangeable calcium (m.e. %)	'rubra'	11.58	10.73	9.12	3.02	20.36
	'flava'	19.03	17.61	11.14	-	27.32

from Table 7.4 that the two varieties have a distinct range of tolerance towards soil calcium. Further, the effect of soil calcium on growth performance, yield and dry weight of plant is highly significant in the two varieties.

The variation in morphological features, when plants are grown in culture in uniform soil, are seen statistically insignificant within the sites in each variety (Table 7.5). However, the differences are significant between the two varie- ties for the length of largest branch but insignificant for the number of internodes and length of third internode on the largest branch. The differences and the ratio in the branch length in between the varieties ('rubra' minus 'flava') for all the sites are very small and close to the mean values (Table 7.3) which reflect uniform behaviour of both the varieties in uniform culture. The increase in the mean length of largest branch of 'rubra' is found 1.4 times more than 'flava' in culture. In nature, the differences in this ratio ('flava':'rubra') is found more or less very close (1:1.2 to 1:1.3) in all the localities except site VI where the ratio is reversed (2:1).

When the values of exchangeable calcium of the soil, collected from the root region of the species from respective sites, are correlated with characters of the corresponding species of the respective site (Table 7.6; Fig. 7.1), variety 'rubra' shows significant positive correlation in sites II, III and IV but the correlation was insignificant when sites II, III, IV and VI are considered and correlated. Variety 'flava' shows a significant positive correlation in all the sites. This clearly infers that 'rubra' is effected in higher

Table 7.5: Showing mean and standard deviation of mean in growth characters of 'rubra' and 'flava' grown in September 1969 from the seeds of different sites collected in September, 1968 (culture)

(Observations based on the study of 10 plants grown from the seeds of each site)

Site	Length of largest branch (cm.)			Number of internodes on largest branch			Length on third internode of largest branch (cm.)		
	'rubra'	'flava'	t Test	'rubra'	'flava'	t Test	'rubra'	'flava'	t Test
II	112.6±16.2	75.0±7.1	6.6***	12.6±2.5	11.7±1.9	1.7	1.7±0.27	1.[illegible]±0.32	[illegible]
III	114.4±10.5	74.1±5.7	10.63***	12.7±2.6	11.0±1.6	1.7	1.8±0.21	1.8±0.22	0.60
IV	105.7±6.2	77.4±8.4	8.47***	14.3±2.3	11.9±2.0	4.7***	1.8±0.23	1.7±0.22	1.82
V	108.0±10.5	---		11.7±1.9	---		1.7±0.21	---	
VI	105.6±32.4	76.7±6.4	3.76***	11.5±1.7	11.7±1.7	0.25	1.[illegible]±0.22	1.8±0.2	1.89

't' test at 18 degree of freedom:

* Significant at 1% level: table value for t = 2.878

** Significant at 0.2% level: table value for t = 3.610

*** Significant at 0.1% level: table value for t = 3.922

Table 7.6: Correlation of exchengeable calcium with branch length, dry weight of root and shoot of 'rubra' and 'flava' in nature

SITE	Variety							
	Rubra				Flava			
	Exch. calcium (m.e. %)	Length branch (cm.)	Dry weight		Exch. calcium (m.e. %)	Length branch (cm.)	Dry weight	
			Root (g.)	Shoot (g.)			Root (g.)	Shoot (g)
II	11.58±3.12	32.2±10.0	2.75±1.06	7.19±2.67	19.06±6.07	[illegible]±7.3	2.53±1.77	4.27±2.04
III	10.73±3.27	20.1±7.5	0.57±0.39	1.02±0.65	17.61±5.18	15.0±2.8	0.80±0.50	[illegible]
IV	9.12±2.91	11.7±2.8	0.54±0.48	0.66±0.44	11.14±3.37	9.6±1.6	0.35±0.10	0.69±0.17
VI	20.36±8.35	18.2±3.0	1.26±0.89	2.62±1.61	27.32±8.19	37.4±10.4	1.73±0.51	4.38±1.86
Correlations (r) with								
Site II,III,IV		(A)0.96***	(B)0.77***	(C)0.79***		(D)0.85**	(E)0.77**	(F)0.78***
Site II,III,IV,VI		0.01 NS	0.14 NS	0.10 NS		(D')0.95***	(E')0.91***	(F')0.82***

For site II,III,IV — DF Treatment 1, DF Error 4

For site II,III,IV,VI — DF Treatment 1, DF Error 6

* Significant
** Very significant
*** Highly significant

(A),(B),.....,(F') Regression equation See Fig. 7.1.

Fig. 7.[illegible] [illegible] of [illegible]

and dry weight of root [illegible]

calcium in nature and culture studie[illegible]

and 'flava'. In nature, the [illegible]

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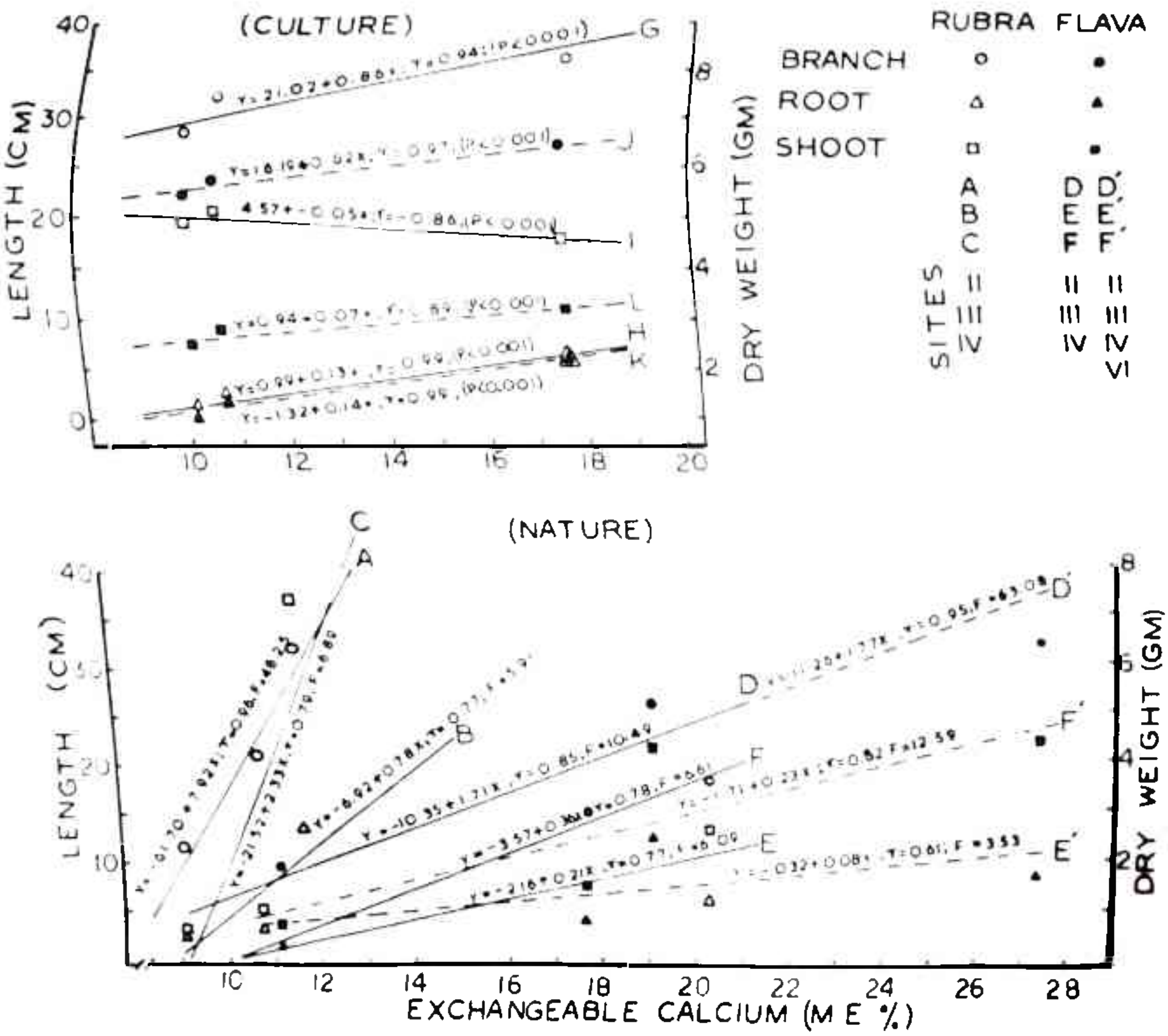
(CULTURE)
(NATURE)
RUBRA FLAVA
BRANCH
ROOT
SHOOT
A D D'
B E E'
C F F'
SITES
II II II
III III III
IV IV IV
VI
LENGTH (CM)
DRY WEIGHT (GM)
EXCHANGEABLE CALCIUM (M E %)
G
J
I
L
H
K
C
A
B
D
D'
F
F'
E
E'
10
12
14
16
18
20
22
24
26
28

FIG. 7.1

concentrations of exchangeable calcium (site VI), while 'flava' remains unaffected (Table 7.6). This limit of tolerance for exchangeable calcium is further supported from culture studies (Table 7.7).

The culture study shows that with the increase in soil exchangeable calcium and calcium carbonate, variety 'rubra' and 'flava' show an increase in branch length and dry weights of root and shoot. However, this increase seems to be limited. Variety 'rubra' exhibits this increase up to 17.73±3.11 m.e. % exchangeable calcium while 'flava' up to 25.31±6.12 m.e. % exchangeable calcium. Thus, the growth seems to be inhibited beyond these concentrations (Table 7.7). Both 'rubra' and 'flava' exhibit negative correlation beyond 17.73±3.11 m.e. % exchangeable calcium (6% $CaCO_3$) but 'rubra' shows a decline in values immediately after this concentration while 'flava' declines after 25.31±6.12 m.e. % exchangeable calcium (8% $CaCO_3$) (Table 7.7). The two varieties, thus, possess distinct range of tolerance for exchangeable calcium and calcium carbonate (Fig. 7.1).

Table 7.7: Correlation of exchangeable calcium with branch length, dry weight of root and shoot of 'rubra' and 'flava' in culture

$CaCO_3$ added to pots	Exchangeable calcium (m.e. 3)	'rubra'			'flava'		
		Length dry weight			Length dry weight		
		Largest branch (cm.)	Root (g.)	Shoot (g.)	Largest branch (cm.)	Root (g.)	Shoot (g.)
Control	10.20±2.01	28.6±13.2	0.38±0.16	3.93±1.02	22.1±8.7	0.16±0.04	1.53±0.83
4%	10.86±2.23	31.8±11.7	0.43±0.20	4.14±1.17	23.6±11.2	0.31±0.11	1.86±0.65
6%	17.73±3.11	36.3±13.9	1.36±0.71	3.65±1.22	27.3±11.8	1.28±0.72	2.18±1.03
8%	25.31±6.12	21.8±9.5	0.64±0.27	1.33±0.87	34.1±13.1	0.86±0.40	2.25±1.17
10%	38.17±7.07	9.2±2.6	0.13±0.03	0.43±0.15	12.6±5.7	0.25±0.07	0.67±0.31
Correlation (r) with: Control, 4%, 6%		(G) 0.94***	(H) 0.99***	(I) 0.86***	(J) 0.97***	(K) 0.99***	(L) 0.89***
Correlation (r) with: Control, 4%, 6%, 8%, 10%		-0.87***	-0.29 NS	-0.96***	-0.37 NS	0.02 NS	-0.55 NS

For - Control, 4%, 6% D.F. Treatment 1
D.F. Error 4

(G), (H), ..., (L) Regression Equations see Fig. 7.1

For - Control, 4%, 6%, 8%, 10% D.F. Treatment 1
D.F. Error 8

DISCUSSION

The present investigation indicates that the two varieties of *Z. govindia* show environmentally induced variations. Such variations within the two varieties further get support when the individual variety is grown in different level of calcium supply. This study clearly indicates the variable behaviour, induced by the calcium content, in the same genome of the two varieties of *Z. govindia*. According to Jafferies and Willis (1964 *a,b*), *Sieglingis decumbens* grows in a site with fairly higher calcium concentration. However, the seedling establishment in higher concentration sometimes fails in culture which have high calcium level, but the transplants survive (Rorison, 1960 *a,b*; Jefferies and Willis, 1964 *a,b*). Studies of Bradshaw *et al.* (1958 1960) and Rorison (1960 *a,b*) indicate that the dry weight and seed output increase with exchangeable calcium up to a certain limit after which the overlimiting brings the toxic effect. On the other hand, Jefferies and Willis (1964*a*) found that at low concentration of calcium, *Origanum vulgare* dies off due to calcium deficiency. Clymo (1962), however, has found that higher levels of calcium brings better growth of some plants because of certain chemical factors which influence the plant growth. The present study shows that the growth performance and dry weight values, up to a certain limit, are increased in individual variety with the increase in carbonates and exchangeable calcium but then suddenly decline at higher concentration. This sudden fall at higher concentration of exchangeable calcium associated with a high pH value (9) may be due to its toxic effect as observed in *Boerhaavia diffusa* (Srivastava and Misra, 1968).

Z. govindia, which occurs in a very wide range of climatic and edaphic limits (Chapter 4), shows diversity in relation to the edaphic factors within the two varieties growing in this region. Such distinct behaviour of the two varieties, within a limited altitude and geographic zone of this region, is due to possible variations in soil nutrient status found in an area of more or less similar vegetational cover where both the varieties occur side by side with wide deviations in the mean values of characters. Such extreme variations in the soil nutrients found over an area, having superficially similar vegetation, have also been observed by Lodge (1952 a,b) in case of Cynosurus cristatus.

The habitat studies for both the varieties in relation to exchangeable soil calcium clearly suggests that the variety 'rubra' grows over a lower but wider range from 3.02 to 20.36 m.e. % while variety 'flava' grows profusely where the soil has high but a slightly narrow range of calcium content, especially exchangeable calcium, ranging from 11.14 to 27.32 m.e. % (Table 7.4). Due to overlapping range of calcium content, the two varieties occur in all the localities but for the site V (Stabilised dunes) where only variety 'rubra' occurs. It may be attributed to its lower requirement for calcium than variety 'flava'. The common occurrence and thick vegetation population of both the varieties on site II, III and IV may be attributed to the narrow range of exchangeable calcium from 9.12 to 11.58 m.e. % for 'rubra' and 11.14 to 19.03 m.e. % for 'flava' (Table 7.4), a difference of 2.46 m.e. % in the former and 7.89 m.e. % in the latter. It may be attributed, based on above facts, that variety 'rubra' seems to be more capable to grow in most of the sites (even on site V) possibly due to its wider range of edaphic requirements.

Studies on Euphorbia hirta Linn. and Eclipta alba Hassk. (Ramakrishnan, 1960 a,c) also indicate similar results. E. alba has a wide range of tolerance with regard to moisture and calcium in the soil while the 'red' and 'green' forms of E. thymifolia have different requirements of calcium in soil. Red form can tolerate a wide range of soil calcium whereas the green can thrive in calcium poor soils. Studies on 'rubra' (red) and 'flava' (green) varieties of Z. govindia also indicate parallel results. Variety 'rubra' can tolerate a wide range of soil calcium whereas 'flava', in contrast to green form of E. thymifolia, thrives better on soil with fairly high calcium.

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CHAPTER 8

SEED AND ITS GERMINATION

INTRODUCTION

Desert seeds are found to possess a complicated germination regulating mechanism (Koller, 1957). Seed germination of arid zone plants has been studied to understand their germination behaviour in nature by investigators like Went (1948, 1949), Went and Westergaard (1949), Koller (1956, 1957), Koller and Cohen (1959), Datta (1965), Chatterji and Baxi (1966), Chatterji and Sen (1966), Capon and Asdall (1967) and Sen (1968). They have analysed the influence of environmental factors on seed germination and thus the occurrence of the plant in the area.

Zaleya govindia grows in a variety of habitats in both open and shade situations in and around Pilani. This weed also perennates through the root stock, in spite of high seed production. The two varieties, 'rubra' and 'flava' normally inhabit together in the areas under study except site V (Chapter 6). Their seedlings occur in nature from time to time and more so after the rainy season. Such behaviour reflects the specific and complex nature of seed and its germination.

The present chapter mainly concerns with the mechanism involved in the complicated germination behaviour of the seed of Zaleys govindia. The study has been aimed to investigate the need for perennation and the occurrence of intermittent germination of this plant. Besides, the two varieties have also been thoroughly investigated to find out the differences in their seed character and seed germination.

MATERIALS AND METHODS

For fruit and seed character, ten plants of each variety were randomly collected in October 1967 from five sites (I, II, III, IV and VI). Fruits of each plant were counted separately. For seed weight, 250 seeds in 5 replicates were separately weighed and the two varieties were compared in each site for the mean seed weight.

While carrying the germination experiments, seeds were found eaten by some insect (Chapter 5). The eaten seeds were, therefore, separated by the external observation of the seed collected from three sites (II, III and IV). Still, the biotic sterile (insect eaten) seeds were not completely eliminated. To eliminate biotic sterile (insect eaten) seeds, a simple procedure was followed. In this method, seeds were allowed to float in a conical funnel filled with water (Fig. 8.1). It was found that the seeds which continued to float on water surface for a long time were biotic sterile while those submerged at the bottom of the funnel were viable seeds.

Further, seeds were also collected from mature plants in October, growing in shade and open situations. Mature (ripe), immature (unripe) and biotic sterile seeds were categorized and their percentage were calculated for both the varieties in the two situations.

For germination experiments, the seeds were carefully collected from the plants of uniform age. These plants were left for air drying for 2-3 days and the seeds were removed by hand to avoid the mixing of unripe seeds. The seeds were stored in glass stoppered bottles under different conditions.

Germination was studied by placing 50-100 seeds (with usually three replicates or as described) in Petri-dishes with filter papers resting on a moist cotton pad. Emergence of radicle was taken as the index of germination. Tap water was used to moisten the seeds and the germinated seeds were counted daily.

Imbibition was studied by putting the seeds in distilled water at room conditions and the percentage imbibition was calculated on dry weight basis. Seeds were treated with concentrated and dilute sulphuric acid for different durations followed by a thorough washing with running tap water. In general, the germination was carried in natural light under laboratory conditions. Continuous light was provided by 200-watt incandescent bulb at a distance of 1 metre from the seeds. For dark treatment, the petridishes were kept in light proof cardboard boxes and were exposed early morning for observation on alternate days. Temperature treatments were given by pre-treating the seeds in refrigerator and hot air ovens set at desired temperatures. Continuous washing was done in running tap water.

Percentage seedling mortality was calculated in growing season (July-August 1969), based on the field observations from fixed permanent quadrats on three sites for 4 weeks by the following formula:

$$\text{Percentage mortality} = \frac{\text{Total seedlings died} \times 100}{\text{Total initial seedlings}}$$

OBSERVATIONS

i. Fruit output:

The number of fruits per plant varies between the two varieties in each site and within the sites in each variety (Table 8.1). In both the varieties the minimum mean capsule (fruit) number has been found on site IV ('rubra' 82.3±39.8; 'flava' 70.8±22.4). Both the varieties have maximum fruit production on site II.

Table 8.1: Showing comparison of the number of fruit per plant (a) between 'rubra' and 'flava' in each site and (b) within 5 sites for each variety. (Observation of 10 plants of each variety).

Site	'rubra' Mean ± S.D.	'flava' Mean ± S.D.	Calculated F	Significant at 5% level (F = 4.20)
II	501.5±179.4	641.5±404.2	2.17	NS
III	399.8±278.1	468.7±335.8	1.27	NS
IV	182.3±89.8	170.8±22.4	2.05	NS
VI	126.5±49.3	390.0±120.4	6.60	*
Calculated F	2.95	8.88		
Significant at 5% level (F=2.84)	*	**		

DF treatment within the sites 3
DF error within the sites 36
DF treatment between varieties 1
DF error between varieties 18

ii. Seed weight:

In both the varieties the weight of 50 seeds (Table 8.2) comes to be minimum on site IV and maximum on site II. Both the varieties are statistically different for seed weight on individual sites and also within all the sites ($P < 0.001$).

Table 8.2: Showing comparison of 'rubra' and 'flava' in the mean seed weight (mg.) of 50 seeds in different sites.

(5 replicates of 50 seeds, i.e., 250 seeds)

Site	'rubra' Mean ± S.D.	'flava' Mean ± S.D.	Difference in means	Calculated F
II	68.84±2.75	72.85±1.31	-4.01	8.58**
III	52.83±1.76	55.93±2.10	-3.10	6.33*
IV	50.32±0.22	47.65±1.22	+2.67	22.99***
VI	58.82±1.45	55.58±1.26	+3.24	14.13***
Calculated F	177.52***	348.9***		

DF treatment within sites	3	*P < 0.05
DF error within sites	16	**P < 0.01
DF treatment between varieties	1	***P < 0.001
DF error between varieties	8	

iii. Seed nature:

a. Biotic infection of seed: The intensity of biotic sterile (insect eaten) seeds in the two varieties differs statistically ($P < 0.001$) from site to site. The maximum insect eaten seeds are found on site IV and minimum on site I (Table 8.3). Thus, a considerable number of seeds are destroyed due to the insect infection. During separation, the floating seeds contained the maximum percentage of biotic sterile seeds (80%) while the submerged ones included 90% (Table 8.4) per cent of viable seeds (Table 8.4).

Table 8.3: Showing percentage biotic sterile seeds of 'rubra' and 'flava' in three sites based on their external appearance. (10 replicates of 10 fruits, i.e., 100 fruits)

Variety	Site I (Mean±S.D.)	Site III (Mean±S.D.)	Site IV (Mean±S.D.)	F value	Significant at 1% (F=5.49)
'rubra'	10.43±4.29	12.63±6.00	30.74±8.90	26.24	***
'flava'	11.39±4.00	11.32±3.07	23.72±3.44	40.95	***

D.F. treatment within sites 2
D.F. error within sites 27

Table 8.4: Showing percentage biotic, viable and non-viable (floating and submerged) seeds in 'rubra' and 'flava'.

Floating seeds					
Variety	Biotic sterile (Mean±S.D.)	Viable (Mean±S.D.)	Non-viable (Mean±S.D.)	F value	Significant at 1% (F=10.92)
'rubra'	72.96±10.01	9.06±3.36	14.03±4.84	84.18	***
'flava'	83.86±6.46	8.06±3.23	8.06±3.26	275.08	***

D.F. treatment within seeds 2; D.F. error within seeds 6

Submerged seeds					
Variety	Biotic sterile (Mean±S.D.)	Viable (Mean±S.D.)	Non-viable (Mean±S.D.)	F value	Significant at 1% (F=13.75)
'rubra'	-	89.06±7.40	7.60±1.85	342.14	***
'flava'	-	91.53±1.55	8.46±1.55	428.71	***

D.F. treatment with seeds 1; D.F. error within seeds 4.

b. Available light and seed nature: In both the varieties the percentage of mature seeds and insect eaten seeds are statistically higher in plants growing in open. Conversely, the number of immature (unripe) seed is more in shaded plants in both the cases. Thus, in both the varieties the ripening of seed and insect infection are promoted in the plants getting more light, but are delayed in the plants growing in deficit light (Table 8.5).

Table 8.5: Showing percentage of ripe, unripe and biotic sterile seeds in 'rubra' and 'flava' growing in 'shade' and 'open' condition

Seed nature	Shade		Open	
	'rubra' (Mean±S.D.)	'flava' (Mean±S.D.)	'rubra' (Mean±S.D.)	'flava' (Mean±S.D.)
Ripe seed	75.16±11.6	70.22±8.79	82.70±7.84	83.80±7.60
Unripe seed	19.66±11.5	21.26±8.43	4.62±2.01	4.62±2.18
Biotic sterile	5.12±5.18	8.44±4.85	12.34±8.15	11.52±6.84
F value	69.32	92.70	210.16	263.51
Significant at 1% (F = 6.93)	***	***	***	***

D.F. treatment within seeds 2
D.F. error within seeds 12

c. Available light and fruit production: Plants growing in open and shade situations highly differ for fruit production. Plants growing in shade (erect) bear a small number of fruits as compared to those growing in open (prostrate) areas (Chapter 5; Table 5.2).

iv. Seed dispersal:

The seed is devoid of dispersal mechanism. Seeds of both the varieties are heavy by weight. The seeds are dispersed indirectly by domestic animals, that eat the plant, and also by man. Some undigested and unmasticulated seeds pass along with the faeces. Ants are also observed carrying the seeds towards their dwelling holes. Being medicinally important, the plant is also collected by local people and thus its dispersal is affected.

v. Seed germination:

a. Effect of fruit wall: 10-month old seeds with (i) fruit wall intact and (ii) fruit wall removed, were germinated in diffused natural light for 20 days (Table 8.6). The ungerminated seeds were decoated for dormancy test.

Table 8.6 : Showing the effect of fruit wall on percentage germination of seeds of 'rubra' and 'flava'.

Variety	Percentage germination Fruit wall intact (Mean±S.D.)	Percentage germination Fruit wall removed (Mean±S.D.)	F. value	Significant at 5% level (F = 7.71)
'rubra'	10.0±4.0	22.6±5.0	11.64	**
'flava'	10.6±2.3	26.6±3.0	52.36	***

D.F. treatment within treatment 1
D.F. error within treatment 4

The percentage germination of the seeds with fruit wall removed was significantly higher than those with fruit wall intact ($P < 0.001$) in both the varieties. It shows that fruit wall restricts the germination to more than half. All the ungerminated seeds were found free from dormancy, which indicates that seed coat also seems to inhibit the germination.

b. Effect of imbibition: 4-month old seeds of 3 localities were imbibed in natural light in November (30.3° to 10.2°C) for varying periods from 6 hours to 3 days (72 hours) and germinated in the same conditions. The percentage imbibition and germination are recorded in Tables 8.7-A, 7-B.

Table 8.7-A: Showing percentage imbibition and germination (cumulative) in 4-month old seeds of 'rubra' from different sites.

Treatment duration (Hours)	Site II		Site III		Site IV	
	Imbibition %	Germination %	Imbibition %	Germination %	Imbibition %	Germination %
6	12.32	-	10.20	-	11.71	-
12	16.46	-	13.72	-	14.91	-
24	18.11	5.0	15.83	4	15.63	3.0
48	22.03	8.0	18.67	7	17.77	5.0
72	23.61	11.0	19.13	10	19.32	8.0

Table 8.7-B: Showing percentage imbibition and germination (cumulative) in 4-month old seeds of 'flava' from different sites.

Treatment duration (Hours)	Site II		Site III		Site IV	
	Imbibition %	Germination %	Imbibition %	Germination %	Imbibition %	Germination %
6	11.92	-	10.11	-	12.02	-
12	15.72	-	12.62	-	13.32	-
24	18.36	4.0	15.02	4.0	14.82	3.0
48	21.74	8.0	18.16	8.0	16.92	5.0
72	22.62	10.0	18.97	9.0	18.37	8.0

In both the varieties, the seeds germinated after 24 hours when the imbibition values vary from 15.63 to 18.11% in 'rubra' and 14.82 to 18.36% in 'flava'. Maximum germination was observed after 3 days with the corresponding high imbibition. The low or high imbibition in different localities is in direct correlation with the seed weight of these localities. It also indicates that the increase in imbibition shows a corresponding increase in germination which seems to be regulated by the impermeable seed coat.

c. Effect of sulphuric acid: Treatment with concentrated sulphuric acid for one minute was found to char the seeds and only 2-3% germination was observed. Seeds, scarified with 1% acid for 5, 10 and 15 minutes, were germinated for 30 days in natural light condition in the laboratory (Table 8.8).

Table 8.8: Showing effect of 1% sulphuric acid treatment on percentage germination of the seeds of 'rubra' and 'flava'.

Treatment duration (minutes)	Percentage germination 5 (Mean±S.D.)	10 (Mean±S.D.)	15 (Mean±S.D.)	F value	Significant at 5% level (F=5.12)
'rubra'	25.0±4.0	14.0±2.3	10.0±5.1	14.87	**
'flava'	18.0±3.2	9.0±2.0	6.0±2.3	5.40	*

D.F. treatment within treatment 2
D.F. error within treatment 9

The results revealed a decline in percentage germination as the treatment duration was increased. The effect of scarification was significant ($P < 0.01$) in the two varieties. A treatment of short duration (5 minutes) shows higher percentage (Fig. 8.2-A).

d. Effect of light: 10-month old seeds were germinated in three different light conditions for 30 days. The percentage germination was higher in natural photoperiod as compared to total dark and light conditions (Table 8.9). The effect of light was statistically significant in both the varieties ($P < 0.05$). However, the percentage was decreased in natural light as compared to dilute acid treated seeds for small duration (Table 8.8). This indicates that seed coat inhibits the germinating embryo (Fig. 8.2-B).

Table 8.9: Showing effect of light treatment on percentage germination in 'rubra' and 'flava'.

Light treatment	Percentage germination Continuous light (Mean±S.D.)	Continuous dark (Mean±S.D.)	(Control) Natural light (Mean±S.D.)	F value	Significant at 5% level (F=4.26)
'rubra'	5.5±1.9	10.0±1.6	14.5±1.9	24.30	**
'flava'	6.0±2.8	9.5±1.9	13.0±2.5	8.01	**

D.F. treatment 2
D.F. error 9

e. Effect of age and washing: Fresh (undispersed) and 1-week old seeds of variety 'rubra' were washed for 8 different durations (3,6,12,24,48,72,96 and 120 hours) in separate lots in running tap water and germinated in natural light laboratory conditions. Unwashed seeds of both the ages were also kept for germination as control. Germination in each lot was recorded for 15 days from the duration of treatment for 120 hours (Table 8.10).

Table 8.10: Showing effect of washing on germination in fresh undispersed and one week old seeds of 'rubra'.

Washing duration (hours)	Percentage germination: Fresh undispersed (Mean±S.D.)	Percentage germination: One week old (Mean±S.D.)
3	12.0±4.0	8.0±4.0
6	13.3±2.3	9.3±2.3
12	13.3±2.3	12.0±4.0
24	14.6±2.3	16.0±8.0
48	17.3±2.3	17.3±6.1
72	22.6±2.3	22.6±6.1
96	29.3±2.3	24.0±4.0
120	36.0±4.0	25.3±4.6
+ Unwashed control	5.2±1.3	2.4±1.1
S.S.	1615.33	948.66
M.S.S.	230.76	135.52
F value	28.84	5.08
Significant at 1% level (F = 3.93)	***	*

D.F. treatment 7
D.F. error 16

+ Not included in statistical analysis

Analysis of variance for Table 8.10

Source of variation	DF	S.S.	M.S.S.	Ratio	Observed fat 1% level
Age	1	108.0	108.0	6.24*	4.17
Washing	7	2405.3	343.6	19.86***	2.33
Agexwashing	7	158.7	22.6	1.31NS	2.33
Error	32	554.7	17.3		
Total	47	3226.7			

Summary table of Age × Washing interaction

	Washing duration in hours					Mean (3)			
Age	3	6	12	24	48	72	96	120	Mean (24)
Fresh undispersed	12.0	13.3	13.3	14.6	17.3	22.6	29.3	36.0	19
1 week old	8.0	9.3	12.0	16.0	17.3	22.6	24.0	25.3	16
Mean (6)	10.0	11.3	12.6	15.3	17.3	22.6	30.6		

C.D. for 3 values ±4.0
C.D. for 6 values ±2.8
C.D. for 24 values ±1.4

In both the treatments, the percentage was gradually increased. However, the mean percentage was more in fresh seeds (19.8%, summary table 8.10, Fig. 8.3) than those of one week old seeds (16.8%). Unwashed seeds of both the ages showed a poor percentage as compared to washed seeds. However, unwashed fresh seeds have more value than those of 1-week old. It was also observed that age and washing had individual influence on germination, but the interaction between age and washing was found insignificant statistically. Statistical analysis also indicates that washing has more influence than age on germination.

f. Effect of washing and temperature: Fresh seeds were washed for 24, 48 and 72 hours in running tap water and germinated at 10°, 35° and 40°C for 20 days (Tables 8.11-A,B).

Table 8.11-A: Showing effect of washing and temperature on percentage germination of seeds in 'rubra'.

Analysis of Variance

Source of	D.F.	S.S.	M.S.S.	Calculated F	Observed F at 5%
Temperature	2	530.6	265.3	11.79***	3.35
Washing	2	130.6	65.3	2.90NS	3.35
Temperature × Washing	4	74.8	18.7	0.83NS	2.73
Error	27	608.0	22.5		
Total	35	1344.0			

Summary table

Washing duration (hours)	Temperature °C Mean (4) 10°	35°	40°	Mean (12)
24	7	10	4	7.0
48	9	14	5	9.3
72	14	17	4	18.3
Mean (12)	10	13.6	4.3	

C.D. for 4 values ±3.9 C.D. for 12 values ±1.5

Table 8.11-B: Showing effect of washing and temperature on percentage germination of seeds in 'flava'.

Analysis of Variance

Source of variation	D.F.	S.S.	M.S.S.	Calculated F	Observed F at 5%
Temperature	2	290.6	145.3	8.96**	3.35
Washing	2	66.6	33.3	2.05^{NS}	3.35
Temperature × Washing	4	18.8	4.7	0.29^{NS}	2.73
Error	27	440.0	16.2		
Total	35	816.0			

Summary table

Washing duration (Hours)	Temperature °C Mean (4) 10°	35°	40°	Mean (12)
24	5	12	8	8.3
48	8	14	8	10.0
72	10	16	9	11.6
Mean (12)	7.6	14.0	8.3	

C.D. for 4 values ±3.4
C.D. for 12 values ±1.3

In both the varieties, the germination was higher in the seeds germinated at 35°C for all the durations but was maximum when washed for 72 hours. The results show that the effect of temperature is of considerable importance ($P < 0.01$). It may also be noticed that the interaction between temperature and washing is insignificant. This infers that washing, as observed in Table 8.9, becomes uneffective if the temperature is unsuitable for germination and seems to play a controlling role in the mechanism of germination.

Fig. 8.1 Separation of biotic sterile (S[illegible]) [illegible] (viable) seeds (S_2) from [illegible] F, funnel; W, water; [illegible], pinchcock [illegible]

Fig. 8.2-A Percentage germination i[illegible] treated in 1[illegible] acid, [illegible] minutes in 'rubra' (R) and [illegible]

Fig. 8.2-B Percenta[illegible] germination [illegible] the seeds kept in continuous [illegible] (C) and [illegible]

Fig. 8.2-C [illegible] seeds germinated at 35°, 40° and 45°C [illegible] cold treatment at 10-15°C [illegible] in 'rubra' (R) and 'flava' [illegible].

Fig. 8.3 [illegible]on between [illegible] (hours) [illegible] undispersed fre[illegible] (o) [illegible] (R) one week old [illegible] (●) [illegible].

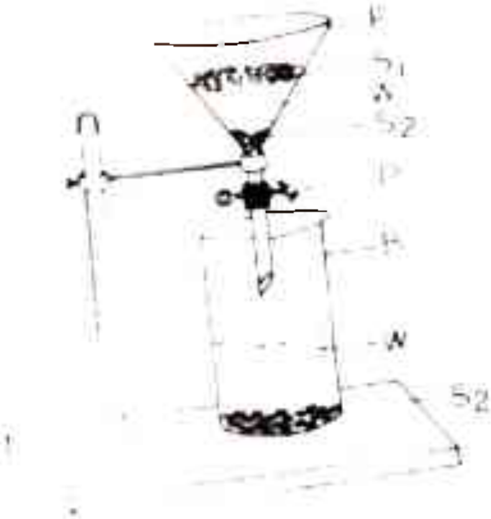

FIG. 8.1

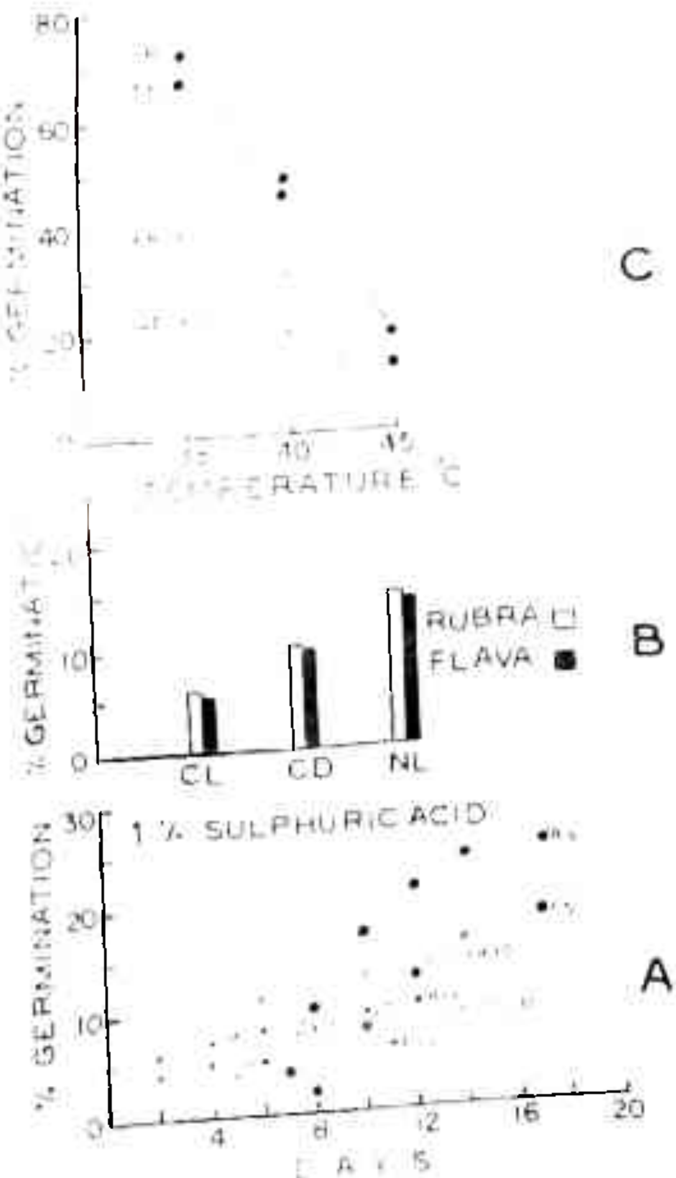

FIG. 8.2

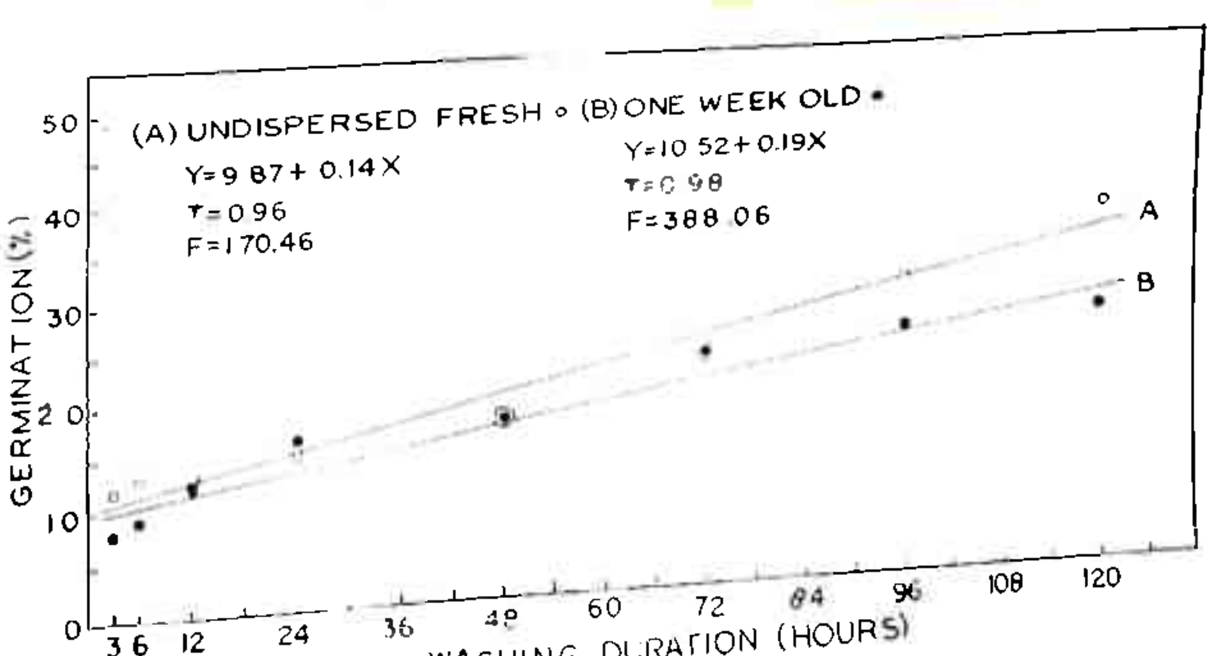

FIG. 8.3

g. Effect of diurnal alternation of temperature: 2-month old seeds of 'rubra' and 'flava' were germinated in November 1968. The seeds were exposed daily to low temperature (15°C) for 0, 4, 8, 12, 16, 20 and 24 hours,# in a 24 hour cycle. The counts were made daily for 40 days (Table 8.12).

Table 8.12: Showing effect of thermoperiodicity on percentage germination of seeds of 'rubra' and 'flava'.

Temperature duration °C		Percentage germination								'rubra'	'flava'
		R_1		R_2		R_3		R_4			
15°C	35°C	'r'	'f'	'r'	'f'	'r'	'f'	'r'	'f'	(Mean±S.D.)	(Mean±S.D.)
0	24	8	12	12	20	20	16	16	20	14.0±2.16	17.0±3.82
4	20	52	8	40	32	56	24	44	26	48.0±7.30	22.5±10.24
8	16	48	20	36	28	36	20	44	24	41.0±6.00	23.0±3.82
12	12	72	20	80	28	64	24	56	32	68.0±5.16	20.0±5.16
16	8	68	36	68	28	72	28	80	32	72.0±5.65	31.0±3.82
20	4	80	60	80	44	76	56	80	64	79.0±2.00	56.0±8.64
24	0	0	0	0	0	0	0	0	0		
Sum of squares										11797.33	3855.50
Mean sum of squares										2359.46	771.10
Calculated F										54.73	18.48
Significant at 1% level (F = 4.25)										***	***

D.F. treatment 5 (for each variety)
D.F. error 18 (for each variety)

R = Replicates

No germination was found in 24-hour low temperature treatment in both the varieties, but it was 14% and 17% respectively at high temperature (35°C) for 24 hours. The percentage was augmented as the low temperature duration was increased. The results show that a longer low temperature treatment with a shorter high temperature exposure result in the highest values in both. The overall effect of low and high temperature treatment is highly significant (P < 0.001) in both the varieties.

#

h. Effect of temperature during storage: Fresh seeds were stored for one month at different temperatures (10°, 35°, 40°, 45° and 50°C) and germinated in natural light in laboratory conditions. A control, stored in laboratory conditions was also run parallel to the experiment. The experiment was continued for 5 months. Percentage germination of each month is recorded in Table 8.13.

Table 8.13: Showing effect of temperature during storage of seeds.

Storage Temp. / Sowing date	Percentage germination in seeds stored at °C											
	Control		10°C		35°C		40°C		45°C		50°C	
	'r'	'f'	'r'	'f'	'r'	'f'	'r'	'f'	'r'	'f'	'r'	'f'
1.8.68	3.3	4.0	2.0	3.2	6.0	5.3	4.0	2.0	5.0	4.0	6.6	5.3
1.9.68	3.0	5.0	3.3	6.5	4.0	6.6	7.1	5.2	10.0	8.2	8.0	7.6
1.10.68	3.6	4.0	6.7	4.1	5.3	8.6	7.3	6.3	11.3	9.3	10.0	11.3
1.11.68	25.3	20.0	17.3	18.6	18.0	16.6	20.0	17.3	16.3	14.2	13.3	12.0
1.12.68	18.0	13.3	10.0	12.0	12.0	10.2	16.0	14.0	8.2	6.6	6.0	4.0
Mean	10.6	10.2	7.8	8.8	9.0	9.4	10.8	8.9	10.1	8.4	8.7	8.0
S.D.	10.3	8.1	6.1	6.4	5.8	4.4	6.7	6.4	4.1	3.7	2.9	3.5
F value between r and f	0.004		0.066		0.014		0.211		0.456		0.128	
Significant at 5% level (F=5.32)	NS		NS		NS		NS		NS		NS	

Both the varieties gave more or less uniform results throughout the experiment in each storage condition as is evident from non-significant results even at 5% level. However, higher percentage was observed in November and also as the storage temperature was increased or decreased above or below 35°-40°C, the percentage of germination declined except in control. Similar results were observed in December though the percentage germination was less than that of November in each treatment.

i. Effect of temperature during germination: 4-month old seeds were germinated in November at different temperatures (10°, 15°, 35°, 40°, 45° and 50°C) for 15 days. They were subjected to cold treatment for 4 and 8 hours separately and again germinated at the same temperature (Tables 8.14, 15, Fig.8.2-C).

Table 8.14: Showing effect of temperature during germination at different temperatures before and after cold treatment.

Temperature during germination (°C)	Percentage germination				
	Before low temp. treatment (15 days)		After low temperature treatment (4 days)		
	'rubra'	'flava'	Hours	'rubra'	'flava'
10-15	0	0	4	0	0
			8	0	0
35	14	17	4	38	22
			8	72	67
40	0	0	4	30	19
			8	48	45
45	0	0	4	8	6
			8	18	12
50	0	0	4	0	0
			8	0	0

Table 8.15: Showing comparison of 'rubra' and 'flava' in percentage germination at different temperatures after 4 hour and 8 hour cold treatment (based on Table 8.14)

Treatment duration (hours)	Germination temp. (°C)	Percentage germination			
		'rubra' (Mean±S.D.)	'flava' (Mean±S.D.)	Calculated F	Significant at 5% level (F=5.99)
4	35	38.0±13.6	22.0±7.6	4.17	NS
4	40	30.0±15.6	19.0±10.0	1.95	NS
4	45	8.0±5.6	6.0±2.3	0.42	NS
8	35	72.0±21.1	67.0±13.6	3.94	NS
8	40	48.0±14.6	45.0±8.8	0.12	NS
8	45	18.0±4.0	12.0±3.2	5.40	NS

D.F. treatment (between 4 and 8) 1
D.F. error (between 4 and 8) 6

Analysis of variance (Table 8.15) for 'rubra'

Source of variance	D.F.	S.S.	M.S.S.	Ratio	F at 5%
Cold temperature	1	5400.0	5400.0	33.87***	4.41
High temperature	2	10901.4	5450.7	34.19***	3.55
Cold × high temp.	2	1984.0	992.0	6.22*	3.55
Error	18	2870.0	159.4		
Total	23	21155.4			

Summary table of cold treatment × high germination temperature interaction ('rubra')

Percentage germination on cold treatment

Cold temperature (hours)	Germination temperature in °C Mean (4)			Mean (12)
	35	40	45	
4	38.0	22.0	9.0	22.6
8	92.0	48.0	18.0	52.6
Mean (8)	65.0	35.0	13.0	

C.D. for 4 values ±10.8
C.D. for 8 values ± 6.5

C.D. for 12 values ±4.3

Analysis of variance (Table 8.15) for 'flava'

Source of variance	D.F.	S.S.	M.S.S.	Ratio	F at 5%
Cold treatment	1	2992.7	2992.7	28.69***	4.41
High temperature	2	6601.4	3300.7	31.64***	3.55
Cold × high temp. treatment	2	878.8	439.4	4.21*	3.55
Error	18	1878.5	104.3		
Total	23	12351.4			

Summary table of cold treatment × high germination temperature interaction ('flava')

Percentage germination on cold treatment

Cold temperature (Hours)	Germination temperature in °C Mean (4)			Mean (12)
	35	40	45	
4	32	19	6	19.0
8	67	45	12	41.3
Mean (8)	49.5	32.0	9.0	

C.D. for 4 values ±8.8
C.D. for 8 values ±5.2
C.D. for 12 values ±3.5

In both the varieties, the germination was observed only at 35°C within 15 days before the low temperature treatment. The seeds, kept at 10°-15°C and 50°C, did not germinate at these temperatures even after low temperature treatment. Those incubated at 35°, 40° and 45°C yielded, after low temperature treatment, 38%, 30% and 8% in 'rubra' and 22%, 19% and 6% in 'flava' at 4-hour cold treatment, and 72%, 48% and 18% in 'rubra' and 67%, 45% and 12% in 'flava' at 8-hour cold treatment respectively. The results show that both the low temperature (4- and 8-hours) treatment and high temperature affect the percentage germination significantly in both the varieties. The influence is uniform in both, when compared, as shown by insignificant ratio (Table 8.15). The percentage germination during 8-hour treatment at 35° and 40°C is more than 2 times than at 4-hour. The overall effect shows that the percentage germination decreases with increase in temperature, but a longer low temperature treatment is more favourable for the process.

j. Effect of cold and warm temperature, and washing treatment:

One month old seeds were subjected to 11 sets of treatment to break the dormancy and also to investigate the effect of washing, cold and warm temperature treatment. Washing was done in running water, cold treatment in refrigerator (10°-15°C) and warm temperature treatment in hot air oven (35°C). Each treatment was for a constant duration of 24 hours. The seeds were germinated in natural light condition in the laboratory after treating 11 sets as given below:

SET OF TREATMENT	TREATMENTS			
A	WASH	COLD	WARM	GERMINATION
B	WASH	WARM	COLD	GERMINATION
C	WASH	WARM	GERMINATION	
D	WASH	COLD	GERMINATION	
E	WASH	GERMINATION		
A'	COLD	WASH	WARM	GERMINATION
B'	COLD	WASH	GERMINATION	
C'	COLD	WARM	GERMINATION	
A"	WARM	WASH	COLD	GERMINATION
B"	WARM	WASH	GERMINATION	
C"	WARM	COLD	GERMINATION	

The results of treatment of cold, warm and washing (Table 8.16) are as follows:

Table 8.16: Showing effect of different combination of treatments (wash, cold and warm) on percentage germination in 'rubra' and 'flava'

S.No.	Treatments	Percentage germination 'rubra'	'flava'
+ A	Wash, cold and warm	12.9±1.71	10.8±4.56
B	Wash, warm and cold	2.0±0.22	3.0±0.53
+ C	Wash and warm	40.8±4.55	37.8±4.56
D	Wash and cold	3.0±1.23	4.0±1.71
+ E	Wash	39.0±9.00	34.8±6.24
+ A'	Cold, wash, warm and wash	63.9±4.56	60.7±6.12
+ B'	Cold and wash	43.8±6.24	40.8±1.71
+ C'	Cold and warm	9.9±1.71	7.8±2.04
+ A"	Warm, wash and cold	7.8±1.71	7.8±4.59
+ B"	Warm and wash	27.9±1.71	30.0±3.00
C"	Warm and cold	6.1±2.91	5.3±1.52
	Calculated F	53.69	44.50
	Significant at 1% level (F = 4.03)	***	***

+ D.F. treatment 7
D.F. error 16

1. Germination is blocked if the seeds are finally treated with COLD (B, D, A", C").

2. Germination is one step increased if the COLD is followed by WARM treatment (C').

3. Germination is two steps increased if the seeds are washed prior to COLD and WARM treatment (A).

4. It is further increased if the seeds are only WASHED (E). However, the germination again increases if WASHING is followed by WARM treatment (C) but declines if the treatment is reversed, i.e., vice versa (B").

5. It may further increase if the seeds are COLD treated before WASHING (B').

6. Germination is maximum (A') if the seeds get a combination of treatments (B') and (B").

vii. Percentage mortality:

Percentage mortality of 'rubra' and 'flava' is maximum on site IV (59.0±13.6 and 40.6±3.6, respectively) and minimum on site III (32.3±4.0 and 36.0±3.6, respectively). On site II, the mortality is intermediate. Thus, the mortality values differ from locality to locality. The differences are statistically significant ($P < 0.01$) - (Table 8.17).

Table 8.17: Showing percentage mortality in the seedlings of 'rubra' and 'flava' on 3 different sites

Variety	Site II (Mean±S.D.)	Site III (Mean±S.D.)	Site IV (Mean±S.D.)	F value	Level of signifi- cance at . . 5%
'rubra'	39.8±8.25	32.3±4.05	59.0±13.62	8.43	**
'flava'	38.2±5.23	36.0±3.67	64.6±3.67	5.25	*

D.F. treatment 2
D.F. error 9

DISCUSSION

The present investigation reveals that the fruit production in *Zaleya govindia* statistically differs from site to site (Table 8.1). These differences may be attributed to to the factors like light, soil moisture, nutients and biota of the site. The two varieties do not differ for fruit production from each other significantly in all the sites, except site VI. A higher production by both the varieties on site II may be due to their preference for optimum calcium content on these sites (Chapter 7). Significant differences for fruit production on site VI may be attributed to a sufficient higher calcium content which favours 'flava' than 'rubra'. Poor availability of the plant material due to continuous removal by scraping and, to some extent, the edaphic features may also be responsible for lower fruit production on site IV. Site II, having better soil moisture and nutrients, possesses heavier seeds while such conditions are poor on site VI and so the lightest seed weight (Table 8.2). Fruit output and seed weight have also been observed to vary with the amount of soil calcium of the site in *Eclipta alba* (Ramakrishnan, 1960 *c*), *Tridax procumbens* (Ramakrishnan and Jain, 1965), *Euphorbia thymifolia* (Ramakrishnan, 1966) and *Cynodon dactylon* (Ramakrishnan and Singh, 1966). They have found that a moderate dose of calcium favours the high production of seed and a higher concentration may reduce the output. In the present investigation, the fruit production is higher when the substratum has moderate supply of calcium content but is found discernible in case of high calcium concentration. Site VI, though shows best growth for 'flava' (Chapter 7) but the fruit production is lowered as has also been noticed in Setaria glauca (Ramakrishnan, 1963). Fluctuation in the behaviour of same species with regard to different population have also been noticed in Tridax procumbens (Ramakrishnan and Jain, 1965) and also in the present investigation.

Although the seed production in A. govindia is high, but the embryo of the seed is eaten up by some Coleopteran larva and so the reduction of viable seeds and ultimately in plant population. Least infection by Coleopteran larvae on site I may be due to better protection of the site where the transference of the parasite (larvae) from one host (plant) to the next host (unknown) for further development may not be possible (Table 8.3). The biotically infected seeds have been separated based on their density differences (the insect eaten seeds, being reduced in weight float on the water surface while the normal healthy viable seeds, having density higher than water, sink to the bottom). The sunken seeds are used, for germination, for they possess more than 90% viable seeds (Table 8.4).

The percentage of mature (ripe) seed (Table 8.5) is observed more in open condition than in shade which may be due to light which seems to accelerate the plant growth (Chapter 5) and the photosynthetic processes in the plants growing in open situation where the intensity of light is more than in shade. Comparatively more growth in open condition (Chapter 5) probably helps in high fruit and seed production and their maturation as the supply to seed is greater and the optimum condition for ripening the seed seems to be satisfied in open situations, but not in shade and so more number of unripe seeds in the latter.

In light situations, the seeds are maximum eaten by the insect (biotic sterile). It may be possible that the plant (host) shows better growth in full sunlight (Chapter [illegible]; Table 5.[illegible]) and the larvae (parasite) are better developed and nourished due to more available food (more number of fruits). In shade, where the plants get lower intensity of light as compared to those in open situation, the plant growth is reduced and so the number of fruit production (Chapter 5, Table 5.2). Since a small number of fruits is produced in shade, the parasitic influence is also reduced. Singh (1969 a) and Singh and Misra (1969 b) have also noticed a decline in plant growth and inflorescence in *Eleusine indica*, a true heliophyte. Similarly *Zaleya govindia* also shows declined growth, a feature of heliophytic plant. Better growth in plants grown in full sunlight as compared to those grown in shade has also been reported by Burkholder (1936), Shirley (1936) and Benedict (194 Thus, the nature of the seed (mature, immature and sterile) depends upon the habitat where the parent plant grows.

Seed germination regulation (Dormancy)

In *Z. govindia*, the embryo is covered by a hard impermeable seed coat with rough surface outside making the germination complicated. The coat restricts the smooth entry of water until the seeds are allowed to imbibe for sometime (Germination increases with the increase in imbibition, Table 8.16-A, B). Further, the heavier seeds are capable to imbibe more water and so the higher percentage germination in the seeds of site II (Tables 8.2, 16-A, B). Higher imbibition and germination is also found in Mimosa hamata (Chatterji and Mukherji, 1968), a common weed of semi-arid zone. Also, the germination was found positively correlated to imbibition in Trianthema govindia (Nigam and Joshi, 1970).

The inhibitory function of seed coat has also been noticed in decoated and acid treated seeds (lower concentration) when the former treatment gives total germination while the latter treatment, as compared to control, Table 8.9, still gives higher values, Table 8.7. Seed coat may, therefore, be accepted as a barrier of dormancy. In nature such scarifications are not possible and the seed has to find certain natural factors to regulate the germination. Such factors may be like washing and temperature. In the present investigation, washing treatment increases the germination of fresh seeds as compared to 1-week old seeds and untreated ones (Table 8.9). Correlation in washing duration and germination is in high positive value in both seeds (Fig. 8.3). This shows that washing also helps in the removal of seed coat dormancy and the latter increases with age. Interactions between age and washing and between temperature and washing are insignificant (Tables 8.10-A, B; 11-A, B) and that the temperature superimposes the effect of washing (Table 8.11-A, B). Further, a combination of 20-hour cold (15°C) and 4-hour high temperature (35°C) is found more favourable for both the varieties ('rubra' 80%; 'flava' 56%) and the dormant seeds become free from dormancy as the seeds undergo such combinations of temperature during summer.

Alternation of temperature, therefore, clearly accounts for the success of Zaleya as has also been reported for Convolvulus arevenis, Euphorbia esula, Lepidium draba and Solanum carolinense (Crocker and Barton, 1957). Diurnal alternation of temperature promotes the seed germination in many seeds (Evenari, 1965) in which light promotes seed germination (Toole et al., 1955; Evenari, 1965). On the contrary, seeds of Z. govindia are light inhibited but their percentage is successfully increased by alternation of temperature. Favourable effect of daily alternation of temperature on germination has been observed by Harrington (1923), Warington (1936), Mall (1955), Crocker and Barton (1957), Cohen (1958), Mayer and Poljakoff-Mayber (1963) and Mall and Dubey (1966). The reason, due to which alternating temperatures are effective in seed germination, is not yet understood. Various workers have attributed different reasons such as favourable effect upon water intake of seeds (Haberlandt, 1875), solubility of surplus food material at higher temperature and its subsequent availability at low temperature (Von Liebenberg, 1884), Oxygen relation (Gassner, 1911), accumulation and actual metabolism of oxygen at low temperature used for inception of growth processes at high temperature (Harrington, 1923) and to thermo-periodic responses (Asakawa, 1964).

Combinations of low and high temperatures are although observed during early summer (February-March), but the seeds do not germinate frequently even after the brief and rare rains during these months, except a few which germinate intermittently. Similarly, in extreme summer months (April-June), the seedlings of Z. govindia are not seen even after receiving brief and infrequent rains, probably due to higher temperatures. This shows that the seeds, besides moisture, definitely need a suitable temperature for successful germination. Effect of storage temperature confirms the suitability of temperature for germination (35°C). Since the stored seeds are not subjected to diurnal alternation of temperature, they do not exhibit a good germination except at 35°C in November when the mean minimum and maximum temperatures ranged from 10° to 30°C (Table 8.12). This indicates that a suitable temperature during seed germination is also equally important as they could be germinated at this temperature even after a storage at 50°C for 3 months. It may also be concluded that under unfavourable germination conditions, the seeds develop 'Secondary dormancy' (cf. Crocker and Barton, 1957) as is clearly indicated by poor values during December (5.6° to 24.6°C).

Though the seed germination is possible around 35°C, but the germination can be augmented if they are treated at low temperature (15°C) and germinated at 35°C. This percentage is again lowered if they are germinated at higher temperatures (Summary table 8.14). Thus, a low temperature treatment enhances the germination in Z. govindia,but the percentage may further be increased if they are germinated at 35°C after a low temperature treatment in both the varieties. Similar observations have been reported in Trapella (Kawahara and Takada, 1961) and Alternanthera (Datta and Biswas, 1968). A decrease in percentage germination with an increase in temperature is also observed in Launaea glomerata and L. mucronata (Datta,1965), the two arid zone species. Inhibition of germination by relatively high temperature, as has also been observed in this species (Nigam and Joshi, 1970), is not a particularly rare phenomenon (Toole et al., 1955) and the mechanism appears to be relatively common among desert plants (Barton, 1936). The optimum germination conditions (temperature and light) in the seeds of certain plants of arid and semi-arid regions may be compared with Zaleya govindia as follows:

Species	Temperature (°C)	Light	Reported by
1. Launaea glomerata	25	Dark	Datta, 1965
2. Launaea mucronata	30	Diffuse	Datta, 1965
3. Alternanthera sessilis	Room temp.	Diffuse	Datta and Biswas, 1968
4. Calotropis procera	30	Dark	Sen, 1968
5. Cryptostegia grandiflora	30	Dark	Sen, 1968
6. Leptadenia pyrotechnica	30-35	Dark	Sen, 1968
7. Pergularia daemia	30,35	Dark	Sen, 1968
8. Zaleya govindia	35	Diffuse	Present study

It may not be improper to conclude that factors like cold, washing and temperature are responsible for seed germination in this species (Table 8.15). Since, such combinations of naturally occurring treatments are quite possible in nature, the seedlings of Z. govindia are seen germinating intermittently. Before winter (October), fresh seeds germinate in nature. It is possible because the seeds are naturally washed by the occasional rains in October and germinate when the atmospheric temperature fluctuates between 16.9° to 34.8°C. During winter, the seeds which get cold treatment, show intermittent germination in March and April due to the occasional rains when the temperature ranges from 11.7° to $31.4^{\circ}C$ (March) and 16.7° to $37.0^{\circ}C$ (April), respectively. They do not germinate normally from November to January and February mainly because of insufficient soil moisture during this period. Thus, all the seeds do not germinate at one time but get natural restriction in germination and is dependent upon the favourable environmental factors, viz., temperature and moisture.

The foregoing account reveals that if the seeds are only washed they exhibit low germination value which can be increased by alternation of temperature treatment. Besides, the germination temperature is also a necessary evil and acts as a controlling factor. Thus, the seed germination in *Z. govindia* is hindered at one or the other step in nature by any of these reasons. Such blocks in germination are possible in nature (Toole *et al.*, 1956). A partial germination is favoured due to washing by which the seed coat inhibitors are washed and the seed is free from seed coat dormancy but as they mature and age, they acquire embryonal dormancy when the cold treatment seems to invigorate the dormant embryo.

Mortality (Table 8.17) is highest on site IV because of maximum biotic interference and comparatively less soil moisture available to the germinating seedlings. A partial shade on site II might be responsible for more mortality than on site III which is perfectly open and the seedlings get sufficient light (Chapters 2,6).

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CHAPTER 9

SOIL-PLANT-WATER RELATIONS

INTRODUCTION

'The maintenance of favourable balance between the loss and absorption of water in the plant is essential for the economy of a plant, since the growth and development of the latter depends upon the adequate water supply' (Crafts, Currier and Stocking, 1949). The survival of herbaceous perennials in the arid regions is considered as a special adaptability as they chiefly grow on stabilised, closely packed hard soils, which harbour comparatively more moisture than the loose sandy soils. Zaleya govindia is one such herbaceous perennial, which is distributed mostly in a wide range of environmental conditions of arid and semi-arid regions of Rajasthan (Chapter 4). Many desert chamaephytes, in nature, exhibit seasonal dimorphism with a seasonal reduction in the transpiring surface (Orshan, 1964). Similar feature is also observed in Z. govindia (Photo. 5.5-A,B) which mostly inhabits in arid and semi-arid environment (Chapter 4).

The present chapter deals with the investigations on the plant water requirements and the supply potentials in a selected area which contribute towards the adaptive features under adverse environment in the life history of Z. govindia.

MATERIALS AND METHODS

The experiment was conducted in the month of February, June and October of 1968 on site II. The experimental procedures are as follows:

i. Leaf area:

During the experimental months, the leaves of 10 plants of uniform age and of different sizes, were outlined on a standard paper to estimate their area by planimeter. The leaves of each plant were separately dried for 24 hours and weighed for constant weight. The leaf dry weight of individual plant and their corresponding leaf area was correlated. The area of the leaves growing at third node, was taken as standard and was studied separately in corresponding seasons to study the per cent reduction in the transpiring surface.

ii. Plant water content:

During October, 20 plants at the site of experiment were uprooted and their leaves, stem (leafless) and roots were separately weighed for fresh weight. These were then dried for 24 hours at 80°C and reweighed till constant dry weight. The total moisture content in these organs was calculated as follows:

Total moisture = Fresh weight - Dry weight

iii. Soil moisture:

Soil samples were collected from freshly excavated holes at three different zones of root, based on their extension in soil. (Zone 1 : 0 (Surface) to 50 cm.; Zone 2 : 51 to 100 cm.; Zone 3 : 101 to 150 cm.). The soil samples were brought to laboratory in sealed polythene bags. After fresh weight, the samples were dried at 100°C and reweighed for constant weight.

The soil moisture percentage is expressed on dry weight basis as follows:

$$\text{Moisture percentage} = \frac{(\text{Fresh weight}) - (\text{Dry weight})}{(\text{Dry weight})} \times 100$$

iv. Soil moisture tension:

The soil water tension at different levels of soil moisture was measured by a calibration curve drawn between the soil water tension (atm.) and soil moisture percentage (using the soil of the experimental site) to findout the availability of soil moisture and soil water tension from different soil zones at the experimental site.

v. Leaf surface:

For the uniformity of experimental results and less errors, the leaves at fixed nodes (third and fifth from the distal end) were utilised for the experiments related to plant-water-relation findings. The number of stomata per unit area has been determined from fresh peelings of upper and lower surfaces of the leaves, growing at same nodes from the distal end of the largest branch. Besides, the epidermal hairs were also studied and their number in unit area of 1 sq. mm. was calculated under the lower power of microscope.

During the analysis of various factors at the experimental site, the extent of stomatal opening was also recorded from the leaves at third and fifth nodes with the help of impression technique. In this technique, thin layers of quickfix were spread on the leaf surface. The dried layers, having the impression of the leaf surface, were then brought to the laboratory and studied under the microscope. The stomatal openings were measured with occulometer and calculated for percentage aperture values.

vi. Plant water deficit:

20 discs of uniform size from fresh leaves were weighed and saturated with distilled water on a moist plate of polythene foam. They were reweighed after three and six hours and then dried at 80°C for constant weight. The leaf discs, during saturation, were kept in laboratory in diffused light, as the compensation point of light intensity was not possible. The water deficits are expressed as 'per cent of water content below the saturation point' by the formula of Catsky (1963):

$$\% \text{ W.S.D.} = \frac{(2 \times \text{wt. after 3 h.}) - (\text{wt. after 6 h.}) - \text{initial wt.}}{(2 \times \text{wt. after 3 h.}) - (\text{wt. after 6 h.}) - \text{dry wt.}} \times 100$$

vii. Osmotic potential and water potential in plant:

These were estimated in the field by applying Schardakow-dye-method (1956). For D.P.D. (= W.P., water potential) whole leaves were immersed in corked test-tubes with sucrose solution of various concentrations and for O.P. (= Osmotic potential) the leaves were crushed to bring the leaf sap in contact with the sucrose solution. The corresponding sucrose test solution, in which the drop of dye was diffused, was taken as isotonic solution with O.P. or D.P.D. (= W.P.) of the tissue. The corresponding osmotic values were obtained from standard table given by Ursprung and Blum (1916).

viii. Evaporation:

Rate of water loss per minute was measured by using 'torsion balance'. The Whatman filter paper discs (64 sq.cm.) were first soaked in distilled water and then exposed immediately to the air (Stocker, 1929, 1956; Hellmuth, 1968). The evaporation rates were measured just before and after the transpiration measurements and are expressed in mg./dm^2./minute. The total evaporation for 24 hours is also computed from the means of diurnal evaporation values of that experimental day.

ix. Transpiration:

Water loss was measured in the field from the twigs detached up to third node of the largest branch for three minutes by 'rapid weighing' method (Stocker, 1956). The leaves were then dried and their corresponding area was computed through the standard regression line (Fig. 9.1). The transpiration and evaporation rates are expressed in mg./dm^2./minute.

A hygro-thermograph was also run for 24 hours on the site of study to record the temperature and humidity on the experimental day.

OBSERVATIONS

The present investigation reveals that the total dry leaf weight per plant and their leaf area varied from season to season (Table 9.1). The total dry weight of leaves per plant during growing season (October) ranges from 2.33 to 4.82 g. and the leaf area from 344.84 to 713.36 sq. cm. In winter (February), leaf dry weight ranges from 0.84 to 2.28 g. and area between 68.54 to 184.06 sq. cm. The values for summer (June) are very low and the dry weight varies from 0.08 to 0.47 g. and leaf area ranges between 2.27 to 13.34 sq. cm. The leaf area for unit dry weight varied from season to season. Within each seasonal lot of leaves, the leaf area increased with an increase in dry weight (Fig. 9.1). The regression curves between leaf dry weight and leaf area indicate that a unit gram dry weight of leaf approximately occupies an area of 148 sq. cm. during rainy season, 78 sq. cm. in winter and 27 sq. cm. during summer months. The mean area of leaves at third node is reduced from 279.2 sq. mm. to 127.8 sq. mm. (54.2%) in winter and to 64.0 sq. mm. (77%) in summer (Table 9.2; Fig. 9.2).

Table 9.1: Showing leaf dry weight (g.) and leaf area (sq. cm.) in the plants growing in three different seasons. (Leaf area has been computed from the regression line between leaf area and leaf dry weight plotted for respective season)

Season	Month	Leaf dry weight (gm)			Leaf area (sq. cm.)		
		Min.	Max.	Mean±S.D.	Min.	Max.	Mean±S.D.
Rainy	Oct.	2.33	4.82	3.22±0.90	344.84	713.36	477.29±134.41
Winter	Feb.	0.84	2.28	1.43±0.48	68.54	184.06	117.34±39.56
Summer	June	0.08	0.47	0.24±0.10	2.27	13.34	6.96±3.10

Table 9.2: Showing percentage reduction in the area of leaves growing at the third node

Season	Mean area of leaves at third node in sq. mm.	Per cent reduction in leaf area
Growing (Oct.)	279.2	100%
Winter (Feb.)	127.8	54.2%
Summer (June)	64.0	77.0%

Fig. 9.1 Regression lines between total leaf dry weight [illegible] leaf area for monsoon (●), winter (▲) [illegible] (■) seasons.

Fig. 9.2 Percentage reduction in the leaf area of the leaves at third node. 54.2% from growing [illegible] to winter, [illegible]. [illegible] from winter to summer [illegible] 77.0% from growing to summer season.

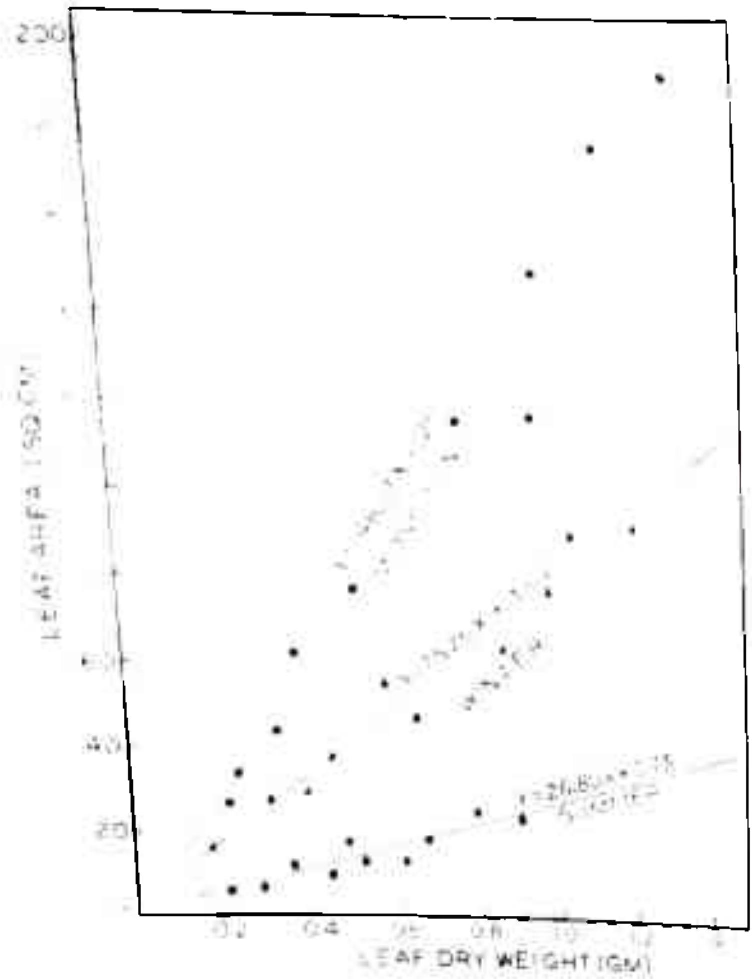


FIG. 9.1

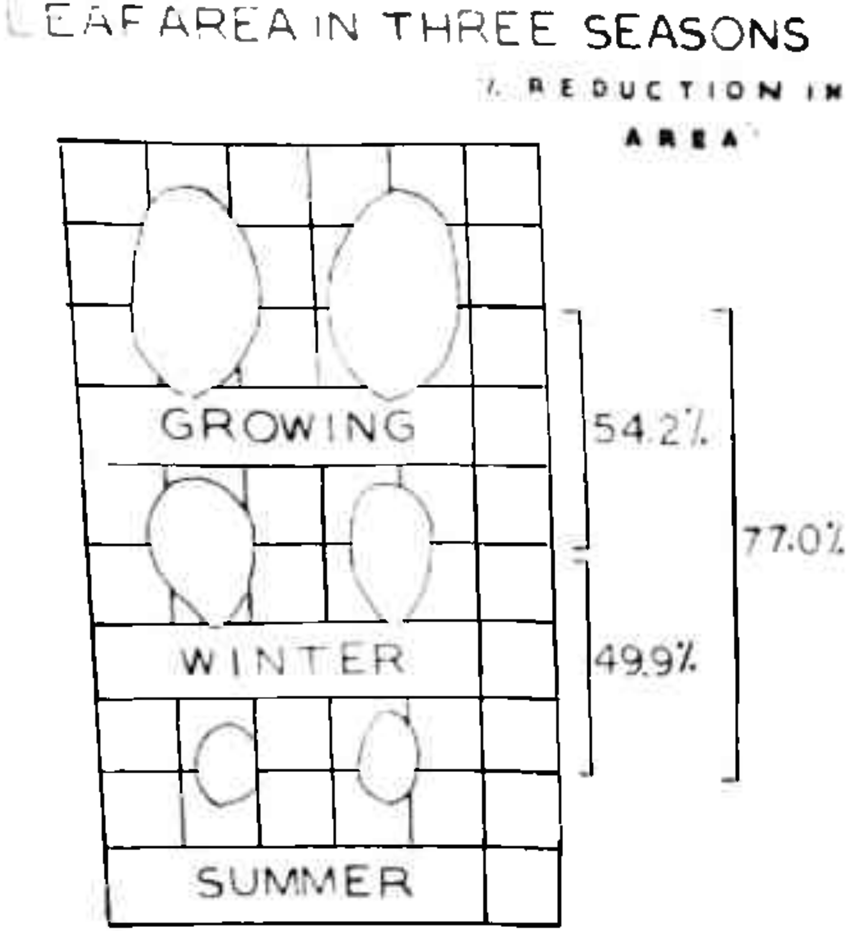

LEAF AREA IN THREE SEASONS
% REDUCTION IN AREA
GROWING
WINTER
SUMMER
54.2%
49.9%
77.0%

FIG. 9.2

The number of stomata per unit area do not differ much in the leaves growing at third and fifth nodes but the number of epidermal hairs per unit area are observed to be reduced from leaves at third node to the leaves at fifth node (Table 9.3). A study of epidermal pealings indicates that the stomata are of Alfalfa type (Loftfield, 1921) due to their opening and closing behaviour in normal conditions.

Table 9.3: Showing mean and st. deviation in the means of stomatal cells and epidermal hairs per sq. mm. counted from the pair of leaves at third and fifth node of largest branch from its distal end

(Observations based on 10 leaves of each node)

Position of leaf	Number of stomata Upper surface	Lower surface	Number of epidermal hairs Upper surface	Lower surface
Third node	9.5±2.4	10.4±2.6	44.87±6.37	42.43±5.10
Fifth node	8.7±2.6	10.0±1.8	40.81±4.71	37.52±4.36

i. Water content in plant organs:

With an increase in dry weight in the plant parts (leaves, stem and roots), the absolute moisture content present in them also increases (Fig. 9.3). A unit gram dry weight of these parts shows maximum moisture in leaves (5.0 g.) whereas minimum in roots (1.4 g.) as shown in Table 9.4.

Table 9.4: Showing mean and st. deviation in the means of dry weight and moisture in the plant parts and the moisture present in unit gram of dry weight in respective parts (dry weight basis)

Plant part	Dry weight (g.)	Moisture (g.)	Moisture present in unit gram dry weight	F value (dry weight) and moisture
Leaves	0.03±0.01	0.15±0.06	5.0	246.4***
Stem (Leaf less)	0.02±0.01	0.07±0.01	3.5	124.8***
Roots	0.05±0.01	0.07±0.02	1.4	45.5***

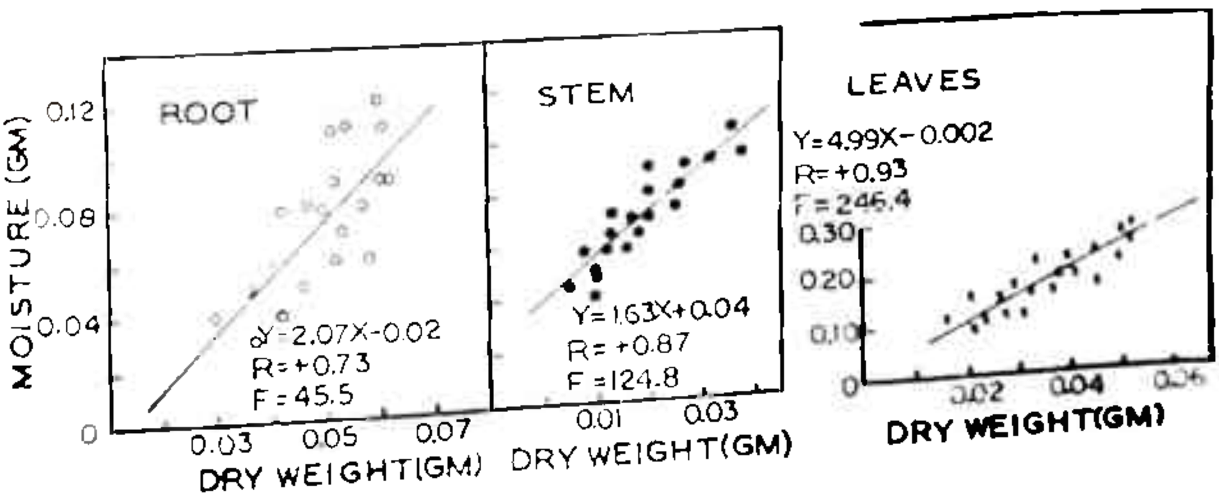
*** Highly significant at 1% level (Table value F = 7.31)

ii. Soil moisture percentage and soil moisture tension:

The soil moisture values (Table 9.5) range between 4.5 to 5.9% (Mean 5.2) in October, 3.8 to 4.6% (Mean 4.1%) in February and 3.4 to 3.7% (Mean 3.6%) in June. The soil moisture tension (Table 9.5), when calibrated from the standard curve (Fig. 9.4) has been found to vary from -2.5 to -7.0 atm. (Mean -4.5 atm.) in October, -6.5 to -15.0 atm. (Mean -10.3 atm.) in February and -13.0 to -29.0 atm. (Mean -22.6 atm.) in June. Thus, the minimum range of soil moisture corresponds to the maximum depression in the range of soil water tension, i.e., as the soil moisture percentage falls the soil water or soil moisture tension increases in the months from October to February and February to June.

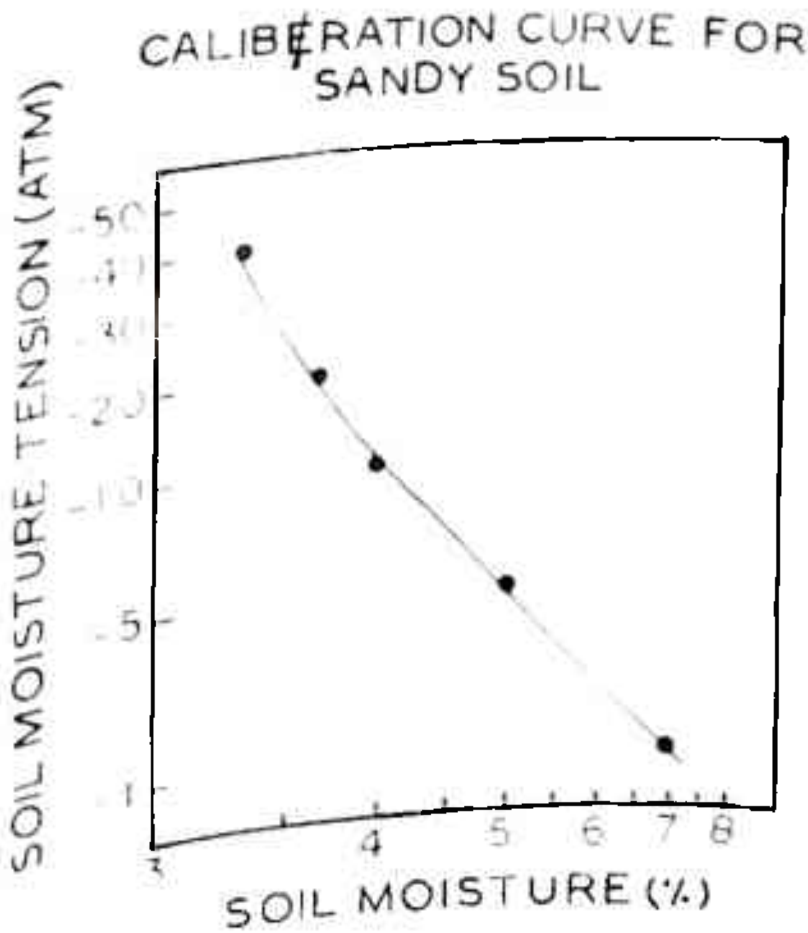
Fig. 9.3 Moisture content in roots, [illegible] and their corresponding [illegible] weights.

Fig. 9.4 [illegible] curve between soil moisture tension (atm.) and percentage soil moisture found out for the [illegible] soil [illegible].



ROOT
STEM
LEAVES
MOISTURE (GM)
DRY WEIGHT(GM)
DRY WEIGHT(GM)
DRY WEIGHT(GM)
Y=2.07X-0.02
R=+0.73
F=45.5
Y=1.63X+0.04
R=+0.87
F=124.8
Y=4.99X-0.002
R=+0.93
F=246.4

FIG. 9.3



CALIBRATION CURVE FOR SANDY SOIL
SOIL MOISTURE TENSION (ATM)
SOIL MOISTURE (%)

FIG. 9.4

Table 9.5: Showing soil moisture (%) and soil moisture tension (atm.) at 3 different soil zones of experimental site in 3 seasons

Month	Date	Z_1 = 0 to 50 cm. (%)	(atm.)	Z_2 = 51 to 100 cm. (%)	(atm.)	Z_3 = 101 to 150 cm. (%)	(atm.)	Mean (%)	(Atm.)
Oct.	7.10.68	4.5	- 7.0	5.3	- 4.0	5.9	- 2.5	5.2	- 4.5
Feb.	14.2.68	3.8	-15.0	4.1	- 9.5	4.6	- 6.5	4.1	-10.3
June	10.6.68	3.4	-29.0	3.6	-21.0	3.7	-18.0	3.6	-22.6

* Mean of 3 samples: Z_1 = Zone 1, surface to 50 cm. depth
Z_2 = Zone 2, 51 cm. to 100 cm. depth
Z_3 = Zone 3, 101 cm. to 150 cm. depth

iii. Stomatal behaviour:

The stomata behave basically like the Alfalfa type since they close in night and open in day time (Photos. 9.1.,2). In *Zaleya*, the stomata normally start opening after 6.00 hours (0.8 to 1.7 µ; 18.18 to 38.65%) and are virtually closed between 18.00 to 21.00 hours (0.3 to 0.5 µ; 6.81 to 11.36%)-(Table 9.6). Thus, they are more or less regulated by light but under water deficits in summer days they are almost closed around 12.00 to 15.00 hours (0.4 to 0.2 µ; 9.09 to 4.55%) - (Table 9.6; Fig. 9.5-B). Their maximum opening is recorded 4.4 µ (100%) in October. In February, the opening continues widening till 12.00 hours (3.3 µ; 75.0%) and then is reduced. The optimum or maximum stomatal opening in winter is lower than the extent of opening in summer. Thus, in winter the stomata reduce the transpiration by reducing their aperture values as compared to that of the growing season after 12.00 hours. This may be due to reduced available water during winter as compared to growing season. In hot summer days (June), when the soil moisture is drastically reduced at all levels of substratum, the stomata are sufficiently open after 6.00 hours in the morning and the maximum aperture is attained at 9.00 hours (0.2 to 0.4 µ; 4.55 to 9.09%) when minimum transpiration is recorded. However, they are found closed at 12.00 hours but reopen after 15.00 hours till 18.00-21.00 hours (1.6 µ; 36.36%). This stomatal closure results in an efficient check on the water loss through them during severe summer months. Thus, due to high water deficits in the plant and low available soil water in summer days, the plants reach a critical water deficit stage and the loss of turgor in guard cells induces a premature closure during extreme summer months.

Table 9.6: Showing stomatal aperture in microns (µ) and percentage of aperture based on maximum (4.4 µ) wide opening recorded

Time (Hours)	Aperture in Oct. (µ)	(%)	Aperture in Feb. (µ)	(%)	Apreture in June (µ)	(%)
3.00	0.0	-	0.0	-	0.0	-
6.00	1.1	25.00	0.8	18.18	1.7	38.65
9.00	2.2	50.00	1.8	40.90	2.4	54.55
12.00	4.4	100.00	3.3	75.00	0.4	9.09
15.00	3.8	86.36	2.2	50.00	0.2	4.55
18.00	2.2	50.00	1.1	25.00	1.6	36.36
21.00	0.3	6.81	0.3	6.81	0.5	11.36
24.00	0.0	-	0.0	-	0.0	-

iv. Evaporation:

Evaporation values are found maximum in summer (June) and minimum in winter (February). The evaporation curves of the three seasons roughly follow the corresponding curves of the temperature and humidity (Fig. 9.5-A, 6). In growing (October) and winter (February) months, the maximum evaporation was observed around 12.00 hours (86.5 mg./dm^2./minute and 57.1 mg./dm^2./minute, respectively) and minimum at 24.00 hours (8.1 mg./dm^2./minute and 7.4 mg./dm^2./minute, respectively). In summer (June), the maximum evaporation is found to be 150.3 mg./dm^2./minute at 12.00 hours and minimum at 31.6 mg./dm^2./minute at 3.00 hours. The mean evaporation for October, February and June are observed as 25.7, 24.1 and 95.9 mg./dm^2./minute, respectively.

In winter, when the mean evaporation is lowest, the mean transpiration and stomatal aperture are 15.68 mg./dm^2./minute and 1.18 μ respectively. In growing season, the mean evaporation is more than winter with a simultaneous increase in the mean transpiration (19.47 mg./dm^2./minute) and mean stomatal aperture (1.75 μ). In summer month (June), when the mean evaporation value is very high, the corresponding value for mean transpiration (21.75 mg./dm^2./minute) is higher than that of the growing month (October), but the mean stomatal aperture is much reduced (0.85 μ).

It may also be noted that evaporation curves, in all the seasons, are more or less close to the temperature curves of the respective seasons (Figs. 9.5-A, 6).

v. Transpiration:

The transpiration ranges from 6.8 to 46.5 mg./dm^2./minute in growing season (October), 5.0 to 30.0 mg./dm^2./minute in winter (February) and 6.1 to 45.3 mg./dm^2./minute in summer

(June). In October, when the corresponding stomatal opening is 4.4 µ, the transpiration value is found to be 46.5 mg./dm^2./minute around 12.00 hours. At the same time, the transpiration is 45.3 mg./dm^2./minute around 9.00 hours in summer (June) when the aperture is 2.4 µ only. Though the stomatal ~~aperture~~ in summer are almost closed around 6.00 and 18.00 hours (1.6 and 1.7 µ, respectively) but the transpiration rate is sufficiently high (23.6 and 37.5 mg./dm^2./minute). Transpiration values are lower in winter than in October.

vi. Water deficit:

The diurnal water deficit (Fig. 9.5-B) ranges from 14.10 to 27.62% in growing season (October); from 16.80 to 34.61% in winter (February) and from 25.50 to 41.50% in summer (June). The mean water deficit, as calculated, shows a minimum water deficit in growing season (19.97%) and maximum in summer months (33.46%) whereas the intermediate mean deficit is in winter month (21.35%).

The high values for water deficit in Z. govindia seem to be unusually higher than those of the normal mesophytic plants (cf. Kozlowski, 1964). This may be attributed to the ballon-shaped epidermal hairs in younger leaves (Mean 47.3 hairs/mm.^{2}) as observed in the leaves at third node (Fig. 9.7). This indicates that the higher water deficit in young leaves is due to the absorption of water into these hairs at the time of measuring the saturation deficit. Since young leaves outnumber the mature leaves of a shoot, the overall values for water deficit may not be taken as absolute values for comparing the water deficit with other native plants (Hellmuth, 1968).

Fig. 9.5-A Transpiration (Trans.) and [illegible] ([illegible].) curves at different hours on experimental dates during February, October and June ([illegible]).

Fig. 9.5-B Stomatal aperture (µ), water saturation deficit ([illegible]), water potential (W.P.) and osmotic potential ([illegible]) at different hours on experimental days during February, October and June (1968).

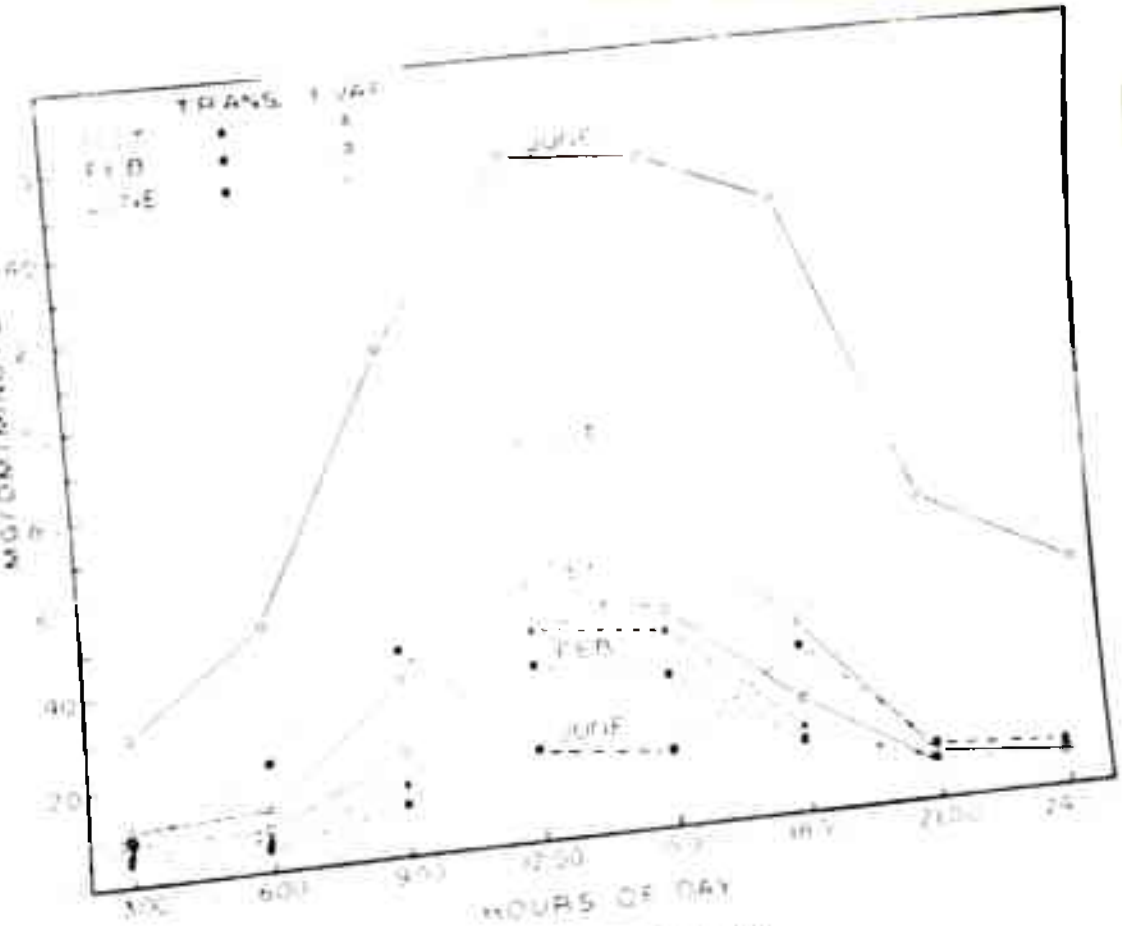


FIG. 9.5-A

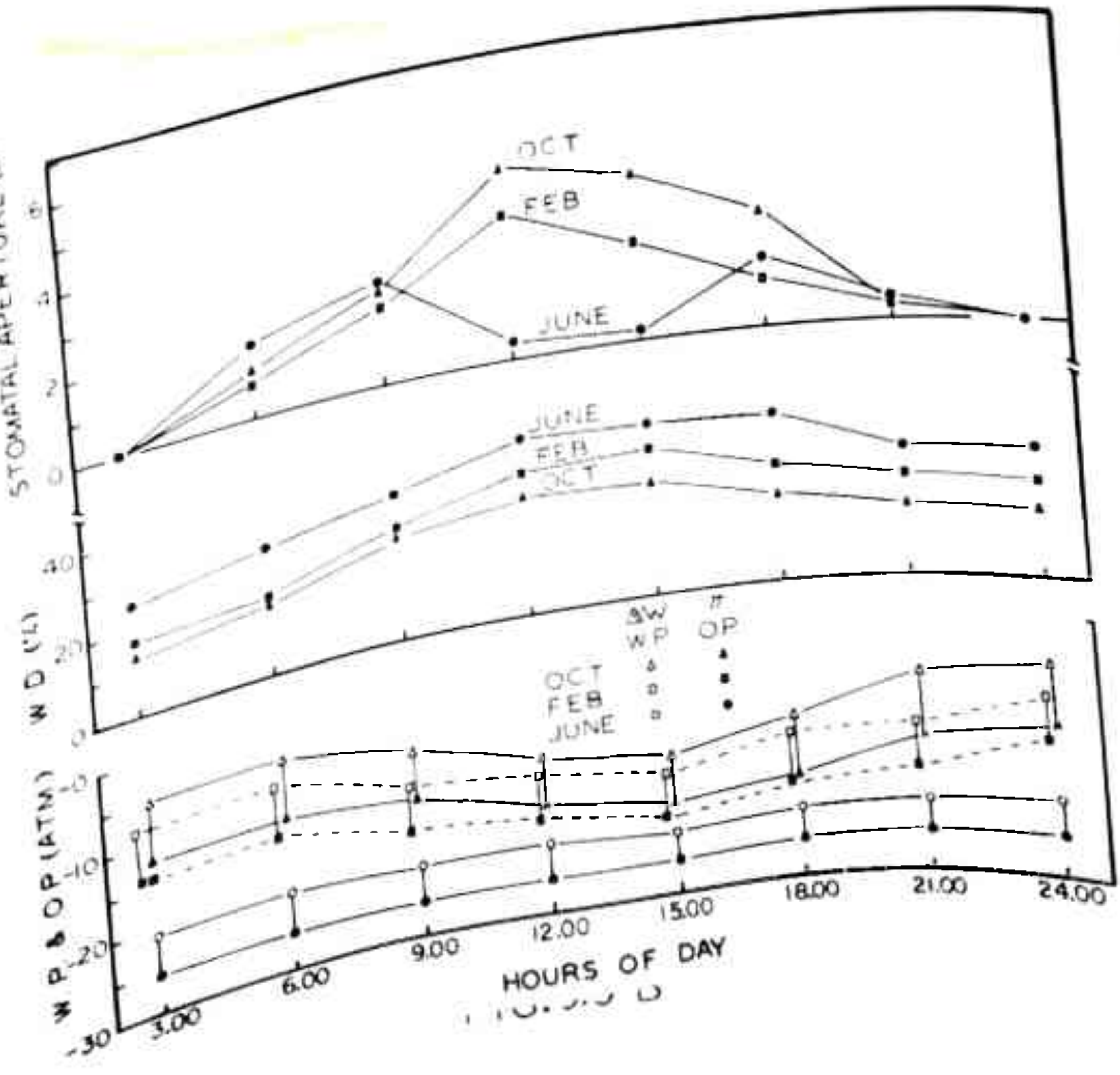


FIG. 9.5-B

Fig. 9.6 Temperature (°C) and relative [illegible] at different hours on the [illegible] February, October and June 1969.

Fig. 9.7 Balloon shaped hairs on leaf epidermis which invariably increase the water deficit.

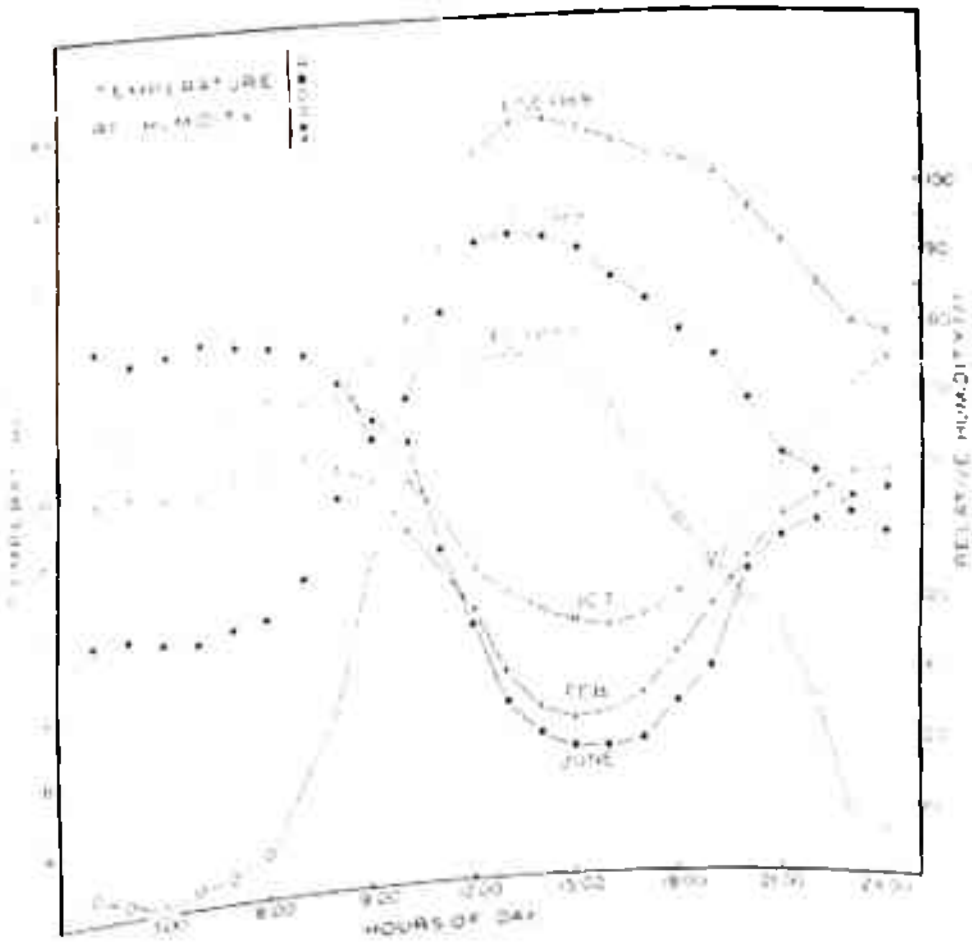
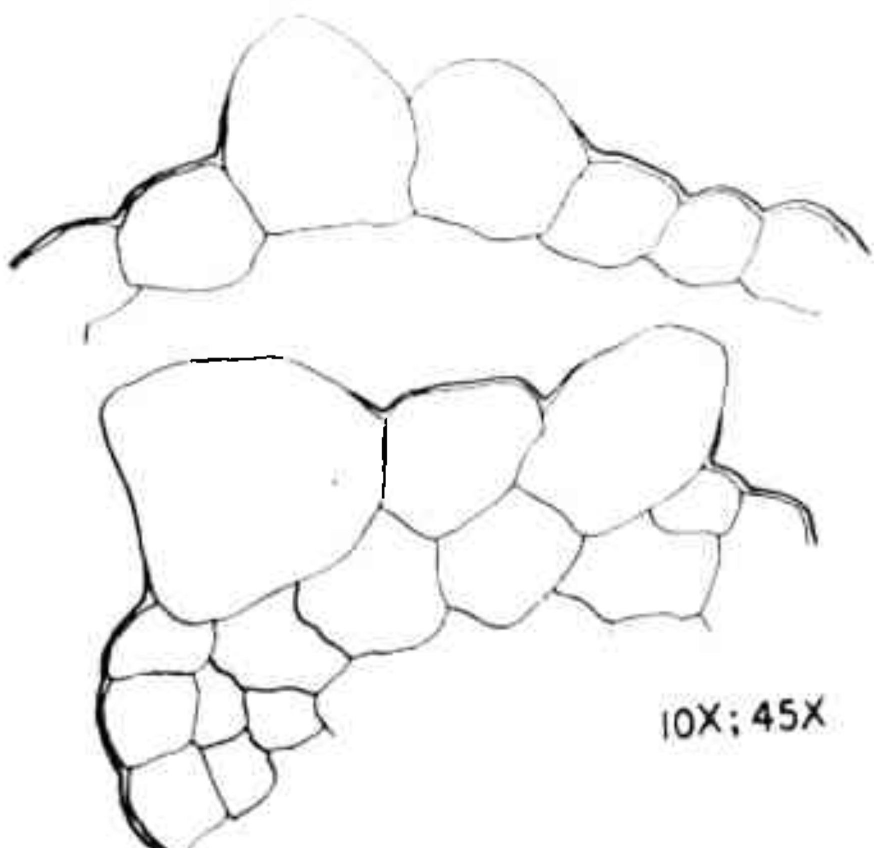


FIG. 9.6



10X; 45X

FIG. 9.7

vii. Osmotic and water potentials:

Osmotic potentials (π) have been measured diurnally on all the experimental days in the corresponding hours (Fig. 9.5-B). The osmotic potential in plant ranges from -12.7 to -19.6 atm. in growing (October), -14.3 to -21.5 atm. in winter (February) and -25.5 to -26.5 atm. in summer (June). The average osmotic potential values are found to be -8.6, -11.8 and -22.0 atm. in October, February and June with the corresponding water potentials (ΔW) as -15.2, -17.4 and -25.8 atm., respectively. The water potential vaires between -5.3 and -14.3 atm. in October, -8.1 and -16.0 atm. in February and -21.5 and -23.1 atm. in June. Thus, water potential runs more or less parallel to the osmotic potential in this plant (Fig. 9.5-B). Applying the standard equation for water potential, i.e., D.P.D. = O.P. - T.P., the turgor pressure has been found to be 6.6, 5.6 and 3.6 atm. in growing, winter and summer months respectively for the corresponding hours. The highest T.P. in growing season (6.6 atm.) indicates the plants with sufficient moisture while the lowest T.P. in summer days (3.6 atm.) reflects the water deficiency in the photosynthetic parts so much so that the plants loose the transpiring organs to reduce the water loss and are subjected to a check in growth of the aerial parts (Chapter 5). A considerable loss in T.P. during winter (5.6 atm.) does not seem to be crucial, for the plant transpiring organs are not subjected to fall off at all.

The water tension in soil has been found at a higher deficit in zone 1 (-7.0, -15.0 and -29.0 atm. in October, February and June, respectively) - (Table 9.7). From zone 1, the plants do not seem to avail soil moisture between 21.00 hours to 6.00 hours in any season. This is because the water potential in the plant rose to a lesser deficit by absorbing water (with less transpiration) from zone 3, where soil moisture tension is quite low (-2.5, -6.5 and -18.0 atm. in October, February and June, respectively). This is further supported by the approximately equal water potential in the plant to that found in the soil at zone 1 between 21.00 and 6.00 hours (i.e., between -5.3 and -6.7 atm. in leaves against -7.0 atm. in soil in October). In October when peak water deficits of a day corresponds to maximum transpiration, the water potential in the leaves rose to a maximum of -14.3 atm. at which moisture is available from all the 3 zones of the soil. However, maximum water replenishment seems to be from zone 3 because of the minimum water tension in this zone.

In February, soil moisture from zone 1 with soil water tension of -15.0 atm., was available to the plant only at noon hours when the leaf water potential fell to -16.0 atm. between 12.00 and 15.00 hours. Moisture from zone 2 with -9.5 atm. was available to the plants from 9.00 to 21.00 hours only (-12.7 to -16.0 atm.) as the water potential depresses in plant during these hours was higher than the soil water tension (-9.5 atm.) as compared to that during 24.00 to 6.00 hours (-8.1 atm.). However, the soil water tension was minimum (-6.5 atm.) in zone 3 and the moisture was available to the plant throughout the day, as the leaf water deficit was not observed below the soil water tension at this level.

Table 9.7: Showing the available soil water tension from different soil zones (Z_1, Z_2, Z_3) at different hours of the diurnal cycle in 3 seasons. (W.P. = Water potential in leaf; S.P. = Soil water potential; Z = Zone)

Month and date.	Soil water at different zones	Range of leaf water potential in atm. in 24 hours: From 24.00 hrs.	To 6.00 hrs.	From 9.00 hrs.	To 12.00 hrs.	Soil water potential	From 12.00 hrs.	To 15.00 hrs.	From 18.00 hrs.	To 21.00 hrs.
October 7.10.68		-5.3	-5.3	-8.1	-12.7		-12.7	-14.3	-11.1	-6.7
	S.P. Z_1					-7.0				
	Z_2					-4.0				
	Z_3					-2.5				
February 14.2.68		-8.1	-8.1	-12.7	-14.3		-14.3	-16.0	-14.3	-12.7
	S.P. Z_1					-15.0				
	Z_2					-9.5				
	Z_3					-6.5				
June 10.6.68		-21.5	-21.5	-22.3	-22.3		-22.3	-23.1	-22.3	-21.5
	S.P. Z_1					-29.0				
	Z_2					-21.0				
	Z_3					-18.0				

← Direction of soil moisture from soil zones to shoot

In summer, the moisture tension in soil rose to a great degree of -29.0 atm. in zone 1, reflecting little or no available moisture at any time. The moisture tension of -21.0 atm. in zone 2 was almost as high as the water potential recorded in a few surviving leaves of the plant (-21.5 to -23.1 atm.). The only moisture supplying zone was between 101-150 cm. depth (zone 3) with -18.0 atm. tension and the plant had to draw the water supply only from the deeper roots.

Soil moisture tension and water potential of the plant, as seen from Table 9.7 and as described above, indicate that the plant is chiefly surviving on the moisture drawn from the zone at a depth of 101-150 cm. (zone 3). The least water tensions are recorded from this zone uniformly in all the three seasons (-2.5 atm., -6.5 atm. and -18.0 atm. in October, February and June, respectively), which are less to those of the corresponding leaf-water-potential found in all the three seasons as -5.3, -8.1 and -21.5 atm. in the leaves of Zaleya.

DISCUSSION

Stocker (1960), while reviewing the physiological and morphological changes in plants due to water deficiency, states that water deficit has a direct influence on the plant life processes through the impairment of the water status. The present investigation shows that the loss in total leaf dry weight and total leaf area (Table 9.1) in Zaleya during winter and summer seasons are due to the reduction of plant surface by shedding the leaves when they do not get enough water to balance their unavaoidable water losses (cf. Oppenheimer, 1960).

The summer leaves, being reduced in their size,provide a means of adaptation for reduced transpiration (Fig. 9.2). Such a phenomenon has also been noticed in plants like *Ononis leiosperma* and *O. natrix* (cf. Oppenheimer, 1960). In *Z. govindia* the surface is reduced 54% from growing to winter season and 77% from growing to summer season. A higher surface reduction has also been observed in *Larrea cuneifolia* (80%) by Morello (1951), in *Zygophyllum dumosum* (85%) and *Z. dumosi* (80%) by Zohary and Orshan (1954), and in *Poterium spinosum* (84.5%), *Artemisia monosperma* (76.0%) and *Helianthemum ellipticum* (62.8%) by Orshan (1954). Reduction of leaf is the most important factor in water economy and survival of a variety of desert plants of the Near East (Orshan, 1954). In the same context, Oppenheimer (1960) has emphasised that a number of desert and semi-desert shrubs reduced the shoot weight from one-third to more than three-fourths. Since the water holding area (leaves) in *Z. govindia* is being reduced from season to season, mostly in dry months, their total water content is reduced. Simultaneously, due to the reduction in water content (continued increase in water saturation deficit from growing to summer season) the values of osmotic and water potentials (= D.P.D.) also go high.

The present investigation reveals quite low values for water deficit in *Z. govindia* during the growing season. This shows that a water deficit up to 27%, as found in October, exercises no restraining effect on transpiration rates since the stomatal transpiration and evaporation curves roughly follow each other. However, a high transpiration in October may be attributed to the maximum opening of stomata accompanied by high atmospheric temperature, humidity and sufficient soil moisture in October. In winter the water deficit is invariably increased (up to 34.6%) with a simultaneous decrease in the transpiration and so the transpiration curve closely follow evaporation curve (Fig. 9.5-A,B). A higher water deficit in winter, however, does not indicate the stomatal control of transpiration as is evident from the evaporation and transpiration curves (Fig. 9.5-A,B). This leads to the conclusion that the transpiration is partially controlled by the partial reduction in the stomatal aperture, lower values of temperature (32^oC), relative humidity (30%) and insufficient soil moisture.

In summer, the water deficit still goes up (41.5%) and the stomata close to reduce the transpiration (mean 21.75 mg./ dm^2./minute). An early closure in Alfalfa type of stomata, as found in Z. govindia, under conditions of high evaporation and water stress, is in conformity with the observations of Willis and Jefferies (1963) in Seneico jacobaea and Cynoglossum officinale. A midday closure, as observed in Z. govindia, has also been reported in Caffea arabica (Loftfield, 1921 and Sayre, 1926) and Rhagodia baccata (Hellmuth, 1968). Midday closure of stomates and reduction in transpiration commonly occur (Rees, 1958; Kramer and Kozlowski, 1960) and the mechanism is complicated (Kozlowski, 1964). In some species midday stomatal closure has been linked to high temperature operating through an increase in CO_2 in intercellular spaces (Heath and Meidner, 1957). This is supported by observations that raising leaf temperatures from 25 to 35^oC caused stomata to close, but not if the leaf interior was flooded with CO_2-free air. In case of Zaleya govindia, the midday closure of stomata in summer may partially be encountered by the rise in leaf temperature (which has not been measured in the present experiment) since the leaves in prostrate plants are very near to soil surface which is naturally warmer during hot summer days (43.6°C at 12.00 hours in June).

Loftfield (1921) has reported that stomata do not effect the transpiration until they are 50% closed. Similar situation is found in Z. govindia during summer around 9.00 hour when the maximum transpiration (43.3 mg./dm^2./minute) remains uneffected at 54.88% stomatal opening (i.e., 45-52% closure, which is approximately equal to that reported by Loftfield, 1921). But beyond this, a drastic reduction around 12.00 hour in transpiration rate (19.4 mg./dm^2./minute) occurs due to reduced aperture (9.0% opening, i.e., 91% closure), which is in conformity with the statement of Loftfield (1921). However, Stalfelt (1955) states that the water content has even greater effect on stomatal opening than light. Since heavy transpiration, specially in summer, develops an invariably high internal water deficit, the stomata may close by mid-day or even before (Kramer, 1959), as is also seen in Z. govindia. Thus, at higher water deficit, the guard cells loose the sensitivity to light and work as safety device to prevent the stomatal response (Stalfelt, 1955). This shows a general parallelism of transpiration rate and size of stomatal aperture in Z. govindia, suggesting that the transpiration rates are influenced mainly by the extent of stomatal aperture. This has also been indicated by the experiments of Milthorpe and Spencer (1957). Further, the water loss from the leaves of Z. govindia during summer, is prevented by early stomatal closing (before 12.00 hour) during each day of drought and by temporary mid-day stomatal closure. This is in conformity with the observation of Kramer and Kozlowski (1960).

According to Kozlowski (1964), water deficit, CO_2, light and temperature are the centrally important environmental factors in stomatal opening and closing. Stalfelt (1955) considers stomatal opening under slight water deficit as 'hydropassive' movement, while 'hydroactive' stomatal closure occur under more severe water stress (cf. Kozlowski, 1964). In Zaleya, during summer, under slight water deficit in morning hours, the stomatal opening may be caused by 'hydropassive' movement whereas their closure during mid-day hours may be attributed to the 'hydroactive' movement. Working with Vicia faba, where the stomata are CO_2 sensitive, Stalfelt has emphasized that water deficit is the most important factor influencing stomatal movement and not the light or CO_2. However, stomatal opening and closing are conditioned by a rather complicated interacting group of factors (cf. Kozlowski, 1964).

It is to be noted that the plant under investigation survives in dry situation, when the water deficit is as high as 41.5% and the water potential is increased to -23.1 atm. Pisek and Winkler (1953) noted a considerable increase in water deficit in European tree species when the stomata were closed. Similar are the findings of Hellmuth (1968) in case of Rhagodia baccata, a perennial shrub. A rapid closure of stomata before the critical water deficit (41.5%) is attained in Z. govindia. Plants showing such character, like Z. govindia, may be considered as drought resistent under arid climatic conditions. The curves for stomatal aperture, water deficit and osmotic quantities in Z. govindia during October and February are separate but follow the same course. This indicates that the seasonal variation in the plant water status is not significantly different in the two seasons (growing and winter).

In Z. govindia, the values for osmotic and water potentials increase from October to February and become maximum in dry month of June. Weaver and Clements (1929) have interpreted a high O.P. (= Osmotic potential) as an adaptation to drought and the former is influenced by the environmental conditions affecting the transpiration, i.e., available water. A high osmotic potential in the plants growing in dry places has also been observed by Harris and Lawrence (1917). The increase in osmotic quantities of Z. govindia may be due to the increased atmospheric temperature (43.6°C) in summer accompanied by low water content and high water tension in soil (Table 9.5). The range of available soil water to plants, according to Meyer et al. (1960), is narrow in sandy soil, wider in loam soil and widest in clay soil. This view is in close conformity with the present observation for sandy soil where Z. govindia inhabits.

The rise in leaf water potential is found to be closely related to the rise in soil moisture tension from season to season. However, the leaf water potential values remain higher than soil moisture tension in all the months (Table 9.7). A soil moisture tension between the range of -2.5 to -7.0 atm. which exists in October, is favourable for this plant while the range between -6.5 and -15.0 atm. also has no visible adverse effect, since the curves of osmotic potentials closely follow each other in the two seasons. As the plants reach the dry period of summer, the soil potential (or moisture tension) considerably increases from -18.0 to -29.0 atm. which is very close to theleaf potential values (-21.5 to -23.1 atm.); there by, the plants suffer from a lack of water gradient.

The availability of soil moisture to plants from 3 zones (Table 9.7), at different hours of the day varies from season to season. In October, the leaves avail the soil moisture from all the three zones. During February, the plants draw water mostly from zone 2 and 3. In extreme summer month (June) no soil moisture is available from zone 1 (S.P. Z_1 = -29.0 atm.), but the plants are found to get water through deep penetrating roots only from deeper zones, i.e., zones 2 and 3 (S.P. Z_2 = -21.0 atm.; S.P. Z_3 = -18.0 atm.) (Photo. 9.4). Thus, a narrow range of water exists at all the soil zones studied during dry summer months (Table 9.7), which being insufficient for plant requirement, develops a high water potential in the leaves (soil moisture between 3.4 to 3.7% with the corresponding soil water tension of -29.0 to -18.0 atm. (Table 9.5). Thus, a decline in leaf potential and an increase in soil potential reflect the adverse summer conditions which the plant endures either by leaf drop or reduced leaves to compensate the water deficit in plant body.

The present observations indicate that _Z. govindia_ markedly contributes towards the seasonal diamorphism similar to those of many chamaephytes of arid regions and regulates the water loss through surface reduction during the dry summer in the arid and semi-arid climate of Rajasthan. It may also be concluded that _Z. govindia_ exhibits a phenomenon of seasonal body reduction as partial drought evasion, since its extensive growth during favourable months is shed off in summer (cf. Orshan, 1964). It may also be pointed out that the following characters help this plant to inhabit in arid environment and resist the water deficiency in the course of water economy:

1. Rooting characteristics: Zaleya possesses an inherent capacity to produce deeply penetrating and branching root systems which avail water from deeper zones most efficiently (Photo. 9.3, 4).

2. Leaf characteristics: Reduction in leaf surface (small transpiring surface in adverse situations) is achieved by (i) shedding the old leaves (Chapter 5) and (ii) developing smaller leaves in dry situations (Photo. 5).

3. Stomatal dynamics: A rapid stomatal closure under developing water stress is supposed to be another factor in drought tolerance (Kozlowski, 1964) which is also satisfied in Zaleya. The capacity of water retension, as seen in this plant, is a function of rapid stomatal closure with decreasing water content (cf. Kozlowski, 1964).

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Photo. 9.1: Closed stomata in upper epidermis of *Z. govindia* during night time.

Photo. 9.2: Open stomata in upper epidermis of *Z. govindia* during day time.

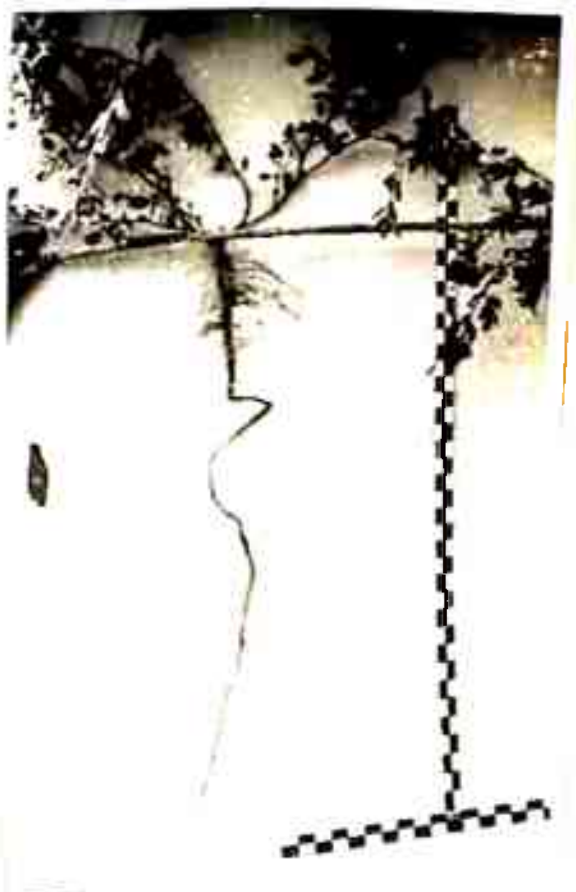
Photo. [illegible]: Extensive development of roots in a perennial plant of *Z. govindia* from the base of earthen pot.

Photo. [illegible]: Root morphology of *Z. govindia* with profuse development of later[illegible]e top region.

9.1

9.2

9.3



9.4

Photo. 9.5: Plants of Z. *[illegible]* showing reduction in leaf size during (A) growing, (B) winter and (C) summer seasons.

9.5

CHAPTER 10

PLANT BIOMASS AND PRODUCTIVITY

INTRODUCTION

Boysen Jensen (1932) and Monsi and Saeki (1953) have opined that dry matter production is the key function in ecological and sociological life of plants. According to Wiegert and Evans (1964) all organisms of a community above the level of primary producers depend upon the photosynthetic plants (autotrophic). The production of organic substance is the fundamental energy fixing process which supports life on earth and the rate of its production sets the finite limits on the amounts and types of life supported in the biosphere (Lieth, 1965). The measurement of the rate of energy fixation by the vegetation thus provides a starting point for describing the functional aspects of an ecosystem (Wiegert and Evans, 1964). Hence the determination of dry matter is of utmost importance since it provides the basis for further studies in production ecology.

Net primary production has been defined as the photosynthesis of all the plants in an ecosystem in excess of the respiratory losses of all the plants and animals of the system i.e., apparent photosynthesis less primary consumption (Pearson, 1965). According to Odum (1960), net primary productivity is the apparent photosynthesis, i.e., total photosynthesis minus plant respiration.

Net primary production has been evaluated by two prevalent methods: Harvest and Gas analysis method. Pearson

(1965) has pointed certain disadvantages in the gas analysis method which may underestimate the values (Verduin et al., 1959). Generally net primary production is underestimated because of failure to take into account the removal of photosynthate by animals and because of infrequent sampling so that the production of plant parts such as inflorescences is missed (Ovington, 1965).

Since the dominant species are treated as the main contributors in the functional and structural composition of the vegetation, the present work was carried out taking Z. govindia as one of the dominant species of this region. Since the two varieties of this species, 'rubra' and 'flava', are associated in most of the localities (Chapter 6), it was worth investigating the productive efficiency of both the varieties towards the net productivity of a few selected sites which differ from each other at the level of herbage removal, soil moisture content and vegetational composition. The productive capacity of some other dominant species, which were found associated with this variety, have also been investigated and emphasised in order to study their individual role on the dry matter production of both the varieties of Z. govindia.

With this view point the study has been grouped in structural and functional features of the vegetation as followed by Golley (1965). In the present chapter the structure includes the density and above-and underground biomass while the function includes the net primary production by the harvest method.

MATERIALS AND METHODS

i. Study sites and herbage removal:

Four sites (II, III, IV and V) were selected for the structural (density and biomass) and functional (net primary productivity) aspects of the vegetation with special emphasis on Z. govindia. The selection of sites was primarily based on the topographic features and secondarily on the herbage removal (Chapter 6).

Site II, though partially protected, experiences infrequent selective scraping by local people and moderate grazing by astray animals. The vegetation on site III is selectively removed by scraping practice and is grazed by livestock animals like cows and goats. Site IV also contributes towards herbage removal. The vegetation is cut nearly to the ground level and is frequently grazed by livestock animals and also by dairy cows and buffaloes at least twice a month. The vegetation on site V is browsed by the domestic animals (cows, buffaloes, goat, sheet, etc.) and wild animals (rodents). The frequency of visit by these animals is maximum on this site. In addition, the site experiences scraping as well as oft-repeated sweeping of dunes for fallen mixed dry vegetation which is used as fuel. Thus, the herbage removal is in the order of: Site V > Site IV > Site III > Site II (Photo. 10.1,2,3).

ii. Experimental procedure:

a. Sampling technique and handling of material: The monthly sampling (third week of every month) of the vegetation was started from August 1969 and carried up to November 1969.

Photo. 10.1: Selected scraping of [illegible] green vegetation along with *Zaleya* by local people.

Photo. 10.2: Grazing of ground vegetation along with *[illegible]* by domestic animals.

Photo. 10.3: Complete removal of dried and shattered vegetation on site II in November 19[illegible].

10.1

10.2

The course of the study was limited, for most of the herbaceous vegetation (except a few perennials) at the ground level is finished (most of the annuals complete their life cycle by this time) before the advent of severe winter. As the study was pertaining to the two varieties of Z. govindia, the sampling was done in a way to include the two varieties besides the dominant species of the site (Chapter 6).

November onward, the study was continued only on site III and IV to study the contribution of only Z. govindia towards the site production during the off season.

For the evaluation of the above-ground biomass, the vegetation was scraped to the ground level and for under-ground biomass monoliths were carefully dug out from any of the sample plots used for above-ground vegetation.

Ten quadrats of 0.5 sq. m. each were sampled on each site every month. Out of these 10 quadrats, total above-ground vegetation was scraped and collected from 5 quadrats (including dead fallen leaves and litter) separately and from the rest of the 5, the vegetation was scraped off leaving an area of 25 sq.cm. in each quadrat for collecting under-ground roots. In this area of 25 sq. cm. the soil block (25 × 25 × 25 cm.) was dug out carefully together with the roots and the corresponding shoot system except on site V. Here the soil, being loose, it was difficult to lift and bring the soil cores to laboratory. The root systems of this area were, therefore, collected from the loose soil blocks at the spot and the diffused soil was brought to laboratory for further recovery of the roots. The standing green individuals of each species were clipped at ground level (each grass clump and each herb stem was taken as an individual). Standing dead vegetation was also clipped and collected separately for each quadrat. The litter was removed from the surface and shaken in a sieve to remove the sand.

Both above- and under-ground vegetation including litter and standing dead were brought to laboratory and thoroughly washed in water tanks. The roots were carefully washed so as to expose them from the adhering dirt. The material was then left on blotting paper for air drying and easy handling. The vegetation of each quadrat was then listed and each species was separately put for drying in oven at 80°C for 48 hours and weighed to 0.01 g. accuracy in Torsion Balance. The standing dead and mixed litter were also similarly washed, dried and weighed. The dry weight of each species per quadrat added and the mean dry weight per quadrat was calculated and represented in g./sq.m. for shoot and root values. Apart from the peak values for standing biomass (g./sq.m.) of individual species, the dry weight per sq.m. were then grouped into Z. govindia 'rubra', Z. govindia 'flava', Tribulus terrestris, Dactyloctenium aegyptium, Eragrostis poaeoides, mixed herbs, mixed grasses, standing dead, litter and extra roots for comparative studies. The sampling technique and further data processing were uniformly followed in all the sites throughout the course of study.

November onward, for above-ground biomass all the species were mixed as standing green, except the two varieties of Z. govindia, and dried as mentioned. Standing dead and litter were also separately dried. In case of below-ground material, only roots of Z. govindia were included.

b. Parameters used: The botanical compositin was found out in support of the present study basing on the phytosociological observations (Chapter 6). Certain parameters like average density, maximum density and per cent frequency have also been recorded together with the peak standing crop as followed by Golley and Gentry (1966).

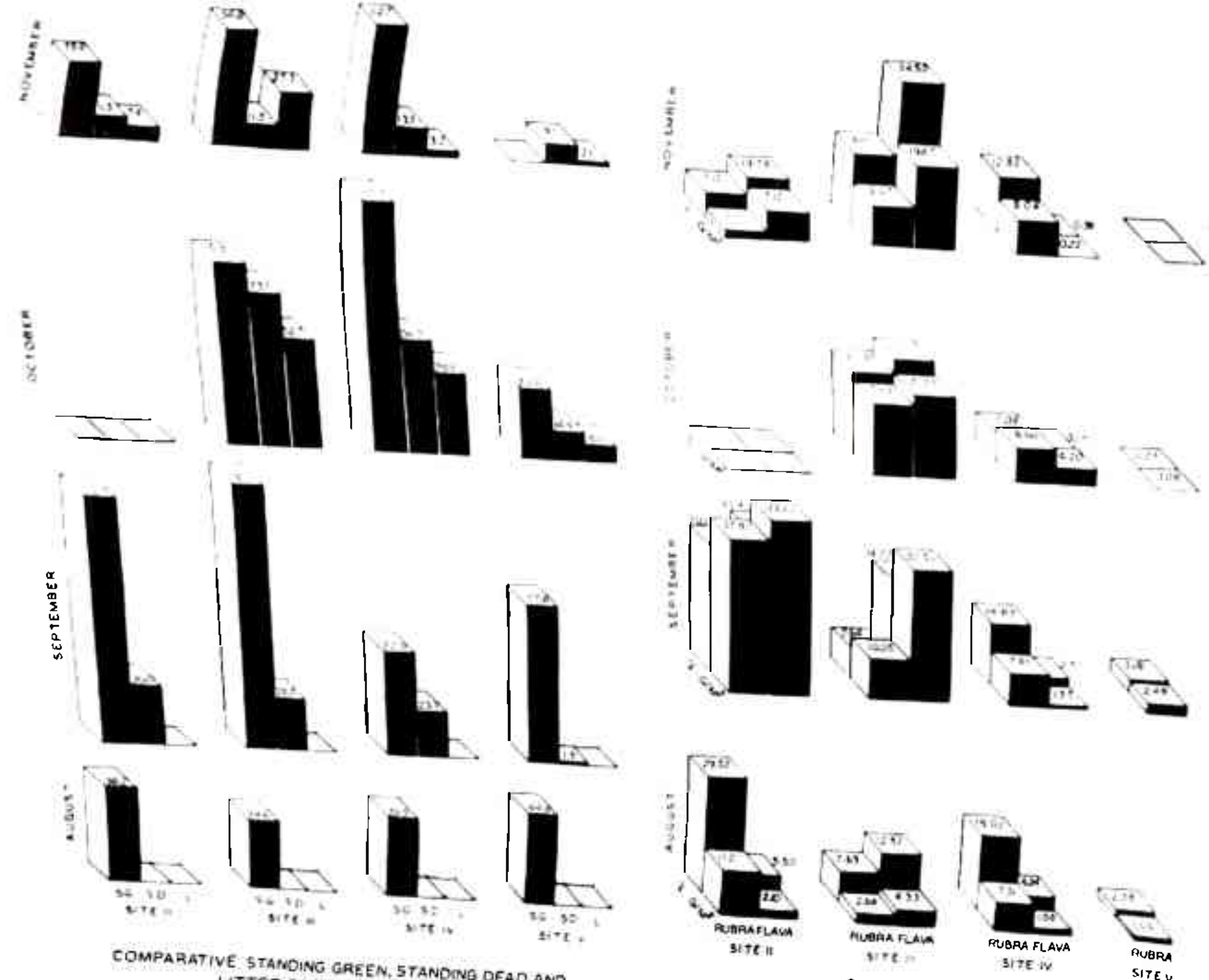
Thus, the average density per sq.m. has been used as the average number of plants during the months when the species was present; maximum density is the highest density of any month occupied by the species; and average per cent frequency is taken as the mean of the per cent frequency in a sq.m. plot during the study period (Golley and Gentry, 1966).

The peak standing crop of biomass, as evaluated in the present investigation indicates the minimal productive capacity of the species which comprise the vegetation (Golley and Gentry, 1966). With a peak standing crop of more than 1 g. per sq.m. per year has been used as a criterion of a dominant species as proposed by Odum (1960) and used by Golley (1965), Golley and Gentry (1966) and Singh (1968).

According to Hadley and Kieckhefer (1963), in the harvest method, net production is measured by the total dry weight of the herbage at the end of growing season. On the other hand, Ovington, Heitkamp and Lawrence (1963) have used the difference between the recorded maximum weight and lowest over wintering weight of above-ground plant biomass to estimate the annual production in central Minnesota. The same method was followed by Singh (1968) in the grasslands of Varanasi, India. However,

Fig. 10.1. Comparative aboveground dr[illegible] standing green ([illegible]), standing [illegible] (SD) [illegible] (L) on [illegible] study [illegible] from [illegible]

Fig. 10.[illegible] [illegible] ([illegible] and [illegible]/[illegible]. [illegible]) [illegible] aboveground [illegible] of 'rubra' and '[illegible]' on [illegible] study [illegible] from August 1969 to November [illegible].



COMPARATIVE STANDING GREEN, STANDING DEAD AND LITTER PRODUCTION (G/M²)

A

CHANGE (% & G/M²) IN ABOVE-GROUND STANDING BIOMASS OF RUBRA & FLAVA

B

FIG. 10.1

it has also been determined by adding together the peak standing crops of above-ground biomass of each species during the growing season (Odum, 1960; Golley, 1965; Golley and Gentry, 1966). According to Golley (1966), this method does not include the vegetation that dies before the peak standing crop of a species is reached, nor the vegetation that is consumed by herbivores during the growing period. In the present investigation the peak values of the species, found during the growing season, are summed to get the net production as used by Golley and Gentry (1966).

Structural and functional features have been studied in detail in growing season while in off season the study has been emphasised more on the two varieties of *Z. govindia* towards the site production, being perennial. The observations have therefore, been separated for the growing (August to November 1969) as well as for the rest of the months of the year (December 1969 to June 1970).

OBSERVATIONS

(A) Structural aspects:

i. Density:

The present study (August to November 1969) showed that the species differed from site to site to achieve the highest average density (Table 10.1). *E. poaeoides* had the highest density (384.8/sq.m.) on site II while *D. aegyptium*, *T. terrestris* and *E. poaeoides* had highest densities on sites III, IV and V respectively, the values being 581.3, 169.2 and 68.2/sq.m. Higher densities, but lower than those described above, were achieved on site II by D. aegyptium (158.6/sq.m.), Z. govindia 'flava' (81.0/sq.m.), E. hirta (74.3/sq.m.), D. adscendens (70.4/sq.m.), B. ramosa (68.8/sq.m.) and Z. govindia 'rubra' (67.4/sq.m.); on site III by C. rotundus (67.2/sq.m.), E. ciliaris (52.2/sq.m.) and T. terrestris (47.4/sq.m.); on site IV by D. aegyptium (119.0/sq.m.), C. compressus (68.4/sq.m.) and T. crystallina (58.2/sq.m.), and on site V by E. poaeoides (68.2/sq.m.) and D. aegyptium (50.2/sq.m.).

Maximum density (Table 10.1) is recorded 784.8 individuals/sq.m. of E. poaeoides on site II, 1624.4 individuals/sq.m. of D. aegyptium on site III; 342.4 individuals/sq.m. of Z. govindia 'rubra' on site IV, and 148.0 individuals/sq.m. of E. poaeoides on site V. Besides, T. terrestris has achieved higher densities on sites III and IV (156.8 and 316.8 individuals/sq.m. respectively).

On site II, 'flava' occurred with 100%, 'rubra' with 56.6% and D. aegyptium with 80% while on site III D. aegyptium occurred in 100% of the plots and the next most frequent species of this site were Z. govindia 'rubra' (95%) and T. terrestris (85%). On site IV species like T. terrestris and D. aegyptium occurred with 100%, then C. aestuans (90%) and C. compressus (85%). The two varieties 'rubra' and 'flava' are found on this site with a close per cent frequency of 75 and 80 respectively. The variety 'flava' has occurred with higher per cent frequency as compared to 'rubra' on all the sites except on site V where the former is absent.

Table 10.1: Showing average density, maximum density, Percentage frequency and peak standing crop (g/sq.m. and percentage) on four study sites

	Site III		Site IV			Site V			
					Average	...ding	Av.	Max.	Average Frequ-	Peak Standing corp

Table 10.1: Showing average density, maximum density, Percentage frequency and peak standing cro... (g/sq.m. and percentage) on four study sites

Species	Site II Av. Density	Site II Max. Density	Site II Average Frequency %	Site II Peak Standing crop g./sq.m.	Site II Peak Standing crop %	Site III Av. Density	Site III Max. Density	Site III Average Frequency %	Site III Peak Standing Crop g./sq.m.	Site III Peak Standing Crop %	Site IV Av. Density	Site IV Max. Density	Site IV Average Frequency %
...seudotomentosa	2.8	4.8	25	.264	.18	6.4	6.4	20	7.344	4.30	-	-	-
...hus gracilis	5.6	5.6	50	.720	.50	12.8	12.8	20	2.480	1.37	-	-	-
...color	-	-	-	-	-	.8	.8	20	.568	.31	-	-	-
...haris linearis	-	-	-	-	-	.8	.8	20	.800	.44	-	-	-
...rhaavia diffusa	1.4	1.6	15	1.208	.83	-	-	-	-	-	-	-	-
... repanda	-	-	-	-	-	1.6	1.6	40	1.730	.96	2.8	4.8	30
...volvulus microphyllus	1.6	1.6	10	.032	.02	-	-	-	-	-	-	-	-
...chorus aestuans	29.9	86.4	46.6	2.096	1.45	19.2	64.0	45	7.610	4.22	2.8	7.2	90
...yera alternifolia	44.0	56.0	70	3.784	2.61	-	-	-	-	-	-	-	-
...horbia hirta	74.3	12.8	36.6	3.336	2.30	-	-	-	-	-	5.3	9.6	46.6
...ifolia	16.4	30.4	40	1.616	1.11	3.2	3.2	40	10.960	6.08	6.8	10.4	70
...kia pharnaceoides	9.6	9.6	40	.196	.20	-	-	-	-	-	-	-	-
...andropsis gynandra	1.6	1.6	10	.062	.04	-	-	-	-	-	-	-	-
...ofera anabaptista	-	-	-	-	-	-	-	-	-	-	.8	.8	20
... prostrata	-	-	-	-	-	.8	.8	20	1.040	.58	-	-	-
... nudicaulis	4.8	4.8	60	1.920	1.32	-	-	-	-	-	1.6	1.6	20
...ugo cerviana	68.8	68.8	60	.122	.08	-	-	-	-	-	-	-	-
... nudicaulis	4.8	4.8	30	.032	.02	-	-	-	-	-	-	-	-
Phyllanthus niruri	40.8	78.4	30	1.704	1.17	2.0	2.4	20	1.256	.69	21.3	3.2	40
Portulaca oleracea	3.6	6.4	20	.544	.37	-	-	-	-	-	.8	.8	20
Sida cordifolia	.8	.8	20	.236	.16	.8	.8	20	.936	.52	-	-	-
Tephrosia hamiltonii	4.0	4.0	80	5.096	3.52	15.8	44.8	50	[illegible]	3.18	.8	.8	[illegible]
Tribulus terrestris	20.5	51.2	66.6	16.760	11.57	47.4	156.8	85	11.032	6.12	169.2	316.8	100
...				-	-	.8	.8	20	.472	.26	-	-	-
									-	-	58.2	211.2	65
													75

ii. Biomass

a. Above-ground biomass of standing crop: A study from August to November 1969 indicates that D. aegyptium had a maximum above-ground standing crop on all the sites (Table 10.1). Excluding the two varieties of Z. govindia, D. aegyptium was followed by T. terrestris, with a standing crop above 10.0 g./sq.m. on sites III and IV but was below on site V (8.03 g./sq.m.). The species, other than these, with the values above 10.0 g./sq.m. are E. thymifolia (10.96 and 12.18 g./sq.m. on sites III and IV respectively); T. hamiltonii and E. poaeoides (18.48 and 11.62 g./sq.m. respectively on site V).

Applying the criterion of a dominant species to the present investigation with the limitations based on the observations of the growing season, when the plants attain maximum growth as compared to the rest of the seasons, very few species can be considered as dominant. Based on the peak values for green biomass (standing crop) of each species (Table 10.1), the dominant species are 17 on site III, 16 on site IV, and 12 on site V. A few dominant species, common to all the sites, are E. thymifolia, T. terrestris, Z. govindia 'rubra', B. ramosa and D. aegyptium. The peak values of site II have not been considered since the data for October was not available.

The standing dead vegetation reached the peak in October on all the sites, site III being maximum (73.12 g./sq.m.) and site V minimum (14.40 g./sq.m.) (Table 10.2; Fig. 10.1-A). The litter, which also constitutes a part of the above-ground standing crop, attains the highest values (Table 10.2; Fig. 10.1-A) in October on all the sites (site III, 52.72; site IV, 38.96 and site V, 8.16 g./sq.m.).

Table [illegible]. [illegible] total and percentage above and underground biomass of [illegible] sites from August 1969 to November 1969 for certain [illegible] species, mixed herb, grasses, standing dead and litter.
(Standing dead, litter and roots are not included for percentage calculation)

[illegible]	Site I Above ground g/sq.m	Site I Biomass %	Site I Under ground g/sq.m	Site I Biomass %	Site II Above ground g/sq.m	Site II Biomass %	Site II Under ground g/sq.m	Site II Biomass %	Site IV Above ground g/sq.m	Site IV Biomass %	Site IV Under ground g/sq.m	Site IV Biomass %	Site V Above ground g/sq.m	Site V Biomass %	Site V Under ground g/sq.m	Site V Biomass %
[illegible] 'Pyrus'	11.21	29.?2	2.?1?	2?.?3	2.64?	7.5?	0.736	6.80	7.136	18.02	2.496	15.25	1.062	2.36	0.120	2.23
S. [illegible] '[illegible]'	?.160	[illegible]	0.5??	?.7	4.536	12.52	1.728	15.97	1.000	?.24	0.672	4.10	-	-	-	-
[illegible]	.1?	1?.??	0?2?	?.0?	11.052	31.?7	1.376	12.72	17.4??	44.17	2.340	13.6?	6.500	14.56	0.4??	7.46
[illegible]	?.515	1?.?6	?.???	31.?6	6.160	17.79	2.560	23.??	5.84?	14.77	4.000	24.43	10.618	23.70	1.920	35.79
[illegible]	0.096	0.25	?.?04	0.6?	2.992	8.64	1.088	10.05	0.032	0.08	-	-	11.624	26.04	1.5??	3?.19
[illegible]	7.297	1?.??	0.4??	4.74	2.272	6.56	0.416	3.84	0.384	2.48	0.368	2.25	10.312	23.1?	?.232	5.21
[illegible] grasses	7.4??	19.57	2.176	23.05	5.176	14.95	2.916	26.95	6.424	16.22	6.592	40.27	4.520	10.12	0.564	1?.1?
Standing dead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Litter(AG)/Roots (UG)	-	-	.326	-	-	-	3.332	-	-	-	6.720	-	-	-	0.272	-
Total	30.255		17.?36		34.616		14.202		39.592		23.088		44.634		5.535	
[illegible] 'rubra'	37.?24	31.00	7.456	31.15	10.056	7.64	6.432	14.02	7.816	14.83	14.240	41.7?	2.434	3.15	2.224	12.46
S. [illegible] 'Flava'	43.200	35.41	10.592	44.25	32.536	24.72	25.920	56.62	1.320	2.52	1.184	3.47	-	-	-	-
S. [illegible]	16.760	13.73	1.??8	7.??	10.384	7.89	1.376	3.00	12.008	22.79	2.272	6.6?	8.032	10.34	1.576	?.?3
[illegible]	16.496	13.52	2.560	10.69	51.776	39.34	7.360	16.05	20.576	39.04	4.992	14.65	1?.144	23.30	1.??6	10.6?
S. [illegible]	0.454	0.38	-	-	1.080	0.82	0.384	0.84	0.160	0.30	-	-	10.6??	13.??	1.672	9.37
[illegible]	4.692	3.84	1.200	5.35	13.896	10.56	1.408	3.07	4.592	8.71	1.024	3.00	27.504	35.31	8.8??	49.80
[illegible] grasses	2.570	2.10	0.160	0.67	11.8??	9.03	2.876	6.49	6.215	11.79	10.36?	30.42	11.076	14.22	1.592	6.92
Standing dead	30.056	-	-	-	26.316	-	-	-	23.762	-	-	-	1.592	-	-	-
Litter(AG)/Root(UG)	-	-	11.296	-	-	-	?.332	-	-	-	36.120	-	-	-	1.3??	-
Total	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	
[illegible]	[illegible]		[illegible]		[illegible]		[illegible]	33.10	[illegible]	7.2?	21.020	21.?	0.080	0.23	-	-
[illegible]											11.076	11.?	-	-	-	34.72

b. Changes in the above- and under-ground biomass within each site: On site II, between August and September the above-ground biomass was increased (Table 10.3-A) with a gain of 11[illegible] g./sq.m. and the increase was 297.4% with a rate of 3.79 g./sq.m./day (30). The under-ground biomass (Table 10.3-B) was increased from 17.83 to 35.21 g./sq.m. with a gain of 17.38 g./sq.m. The production was increased by 97.47% with a rate of 0.57 g./sq.m./day.

On site III, the above-ground biomass (Table 10.3-A) between August and September was increased with a gain of 123.31 g./sq.m. and the production was increased by 35[illegible].2% with a rate of 4.11 g./sq.m./day (30). Between September and October it was again increased with a gain of only 53.8 g./sq.m. and the percentage increase was 34% with the rate of 1.73 g./sq.m./day (31). It was decreased between October and November with a loss of -115 g./sq.m. This loss was found -28.5% with a rate of -0.72 g./sq.m./day (30). Thus the biomass continuously increased from August to October and thereafter decreased.

The under-ground biomass on site III between August and September (Table 10.3-B) was increased from 14.20 to 55.18 g./sq.m.

with a gain of 40.98 g./sq.m. The production was increased by 288.59% with a rate of 1.36 g./sq.m./day (30) between this period. Further, the production was declined from September to October (55.18 to 39.02 g./sq.m.) and from October to November (39.02 to 37.60 g./sq.m.) with the respective loss of -16.16 and -1.42 g./sq.m. Thus the rate of decline was more sharper between September and October (-0.52) than between October and November (-0.04).

On site IV, between August and September the above-ground biomass was increased with a gain of 36.86 g./sq.m. and between September and October it was increased with a gain of 134.61 g./sq.m. The production was respectively increased by 93.1% with a rate of 1.23 g./sq.m./day (30), and by 176% with a rate of 4.34 g./sq.m./day (30), it was decreased between October and November with a loss of -131.67 g./sq.m. This loss was -62.3% with the rate of 4.39 g./sq.m./day (30).

The under-ground biomass between August and September on site IV (Table 10.3-B) was from 23.08 to 70.20 g./sq.m. with a gain of 47.12 g./sq.m. The biomass was increased by 204.15% with a rate of 1.57 g./sq.m./day (30). The production was further augmented from 70.20 to 122.03 g./sq.m. with a gain of 73.83 g./sq.m. biomass. This incorporation was slightly accelerated as compared to previous month with a rate of 1.67 g./sq.m./day (31) but the percentage gain was comparatively reduced (73.93%). Between October and November, the under-ground biomass was decreased from 122.03 to 74.63 g./sq.m. with a loss of -47.6 g./sq.m. The percentage production was also reduced (-38.84) with a rate of -1.58 g./sq.m./day (30). (Table 10.3-B).

On site V, the above-ground (Table 10.3-A) was increased between August and September with an increase of 34.85 g./sq.m. The gain in production was 78%. with a rate of 1.16 g./sq.m./day (30). In the subsequent month the production was decreased throughout. Between September and October it was decreased with a loss of -22.44 g./sq.m. and the loss was -28.5% with a rate of -0.72 g./sq.m./day (31). Between October and November, it was reduced with a loss of -45.7 g./sq.m. This reduction was 80.1% with a rate of -1.19 g./sq.m./day (30).

On site V, the under-ground production between August and September (Table 10.3-B) was increased from 5.63 to 19.22 g./sq.m. This gain was increased by 241.38% with a gain of 13.59 g./sq.m. with a rate of 0.45 g./sq.m./day (30). In the subsequent month the production was reduced to -15.96 g./sq.m. (-83.03%) with a rate of -0.51 g./sq.m./day (31)-(Table 10.3-B).

c. Changes in the above- and under-ground biomass among the 4 sites in each month: In August, the maximum above-ground biomass was observed on site V (44.63 g./sq.m.) and minimum on site III (34.61 g./sq.m.) while slightly higher, as compared to site III, was observed on sites II and IV (38.25 and 39.59 g./sq.m. respectively)-(Table 10.3-A). In September higher biomass was recorded on sites II and III (152.06 and 157.93 g./sq.m. respectively) and a relatively lower on sites IV and V (76.45 and 79.48 g./sq.m. respectively). In October, the above-ground biomass was still higher on sites III and IV (211.74 and 211.06 g./sq.m.) but reduced on site V (57.0 g./ sq.m.). In November, the biomass was considerably reduced on all the sites, the values being 54.74, 95.70, 79.39 and 11.32 g./sq.m. on sites II, III, IV and V respectively. It may also be observed that a period between August and September constitutes the period of maximum growth (Table 10.3-A) because the rate of production between these two months was highest.

It may also be observed that in between the sites the above-ground biomass differed narrowly in August but greatly in September. For September, the values on sites II and III (157.9 and 152.0 g./sq.m. respectively) are about two times more than that of sites IV and V (76.4 and 79.4 g./sq.m. respectively), but in October the biomass of sites III and IV (211.7 and 211.0 g./sq.m. respectively) were approximately more than three times greater than that of site V (57.0 g./sq.m.).

Maximum under-ground biomass occurred on all the sites in September (35.21, 55.18 and 19.22 g./sq.m. corresponding to sites II, III and V) except site IV were it was maximum (122.0 g./sq.m.) during October. The biomass was increased, from August to September, approximately two times on site II, four times on site III, three times on site IV and 3.4 times on site V. It was further increased from September to October only on site IV by approximately 1.7 times and decreased about 1.4 times on site III and 6.4 times on site V (Table 10.3-B).

Thus, the under-ground biomass was substantially incorporated on all the sites between August and September, the highest being on site IV (47.12 g./sq.m.) and lowest on site V (13.59 g./sq.m.). In the subsequent duration, i.e., between September and October, the gain was negative on all sites except site IV (73.83 g./sq.m.).

Table 10.3-A: Showing increase or decrease (change) in the weight, rate and per cent above-ground biomass (standing crop) between the two successive months

Site	A.G. Biomass (g./sq.m.)		Change in A.G. biomass between Aug. and Sept.			A.G. Biomass (g./sq.m.)		Change in A.G. biomass between Sept. and Oct.			A.G. Biomass (g./sq.m.)		Change in A.G. biomass between Oct. and Nov.		
	Aug.	Sept.	Weight	Rate	%	Sept.	Oct.	Weight	Rate	%	Oct.	Nov.	Weight	Rate	%
II	38.25	152.06	113.80	3.79	297.4	152.06	-				-	54.74			
III	34.61	157.93	123.31	4.11	356.2	157.93	211.74	53.81	1.73	34.0	211.7	95.70	-116.0	-0.72	[illegible]
IV	39.59	76.45	36.86	1.23	93.1	76.45	211.06	134.61	4.34	176.0	211.0	79.39	-131.6	-4.39	[illegible]
V	44.63	79.48	34.85	1.16	78.0	79.48	57.04	-22.44	-0.72	-28.5	57.0	11.32	-45.7	-1.19	-80.1

Table 10.3-3: Showing increase or decrease (change) in the weight, rate and per cent under-ground biomass between two successive months

Site	U.G. Biomass (g./sq.m.)		Change in U.G. biomass between Aug. and Sept.			U.G. Biomass (g./sq.m.)		Change in U.G. biomass between Sept. and Oct.			U.G. Biomass (g./sq.m.)		Change in U.G. biomass between Oct. and Nov.		
	Aug.	Sept.	Weight	Rate	%	Sept.	Oct.	Weight	Rate	%	Oct.	Nov.	Weight	Rate	%
II	17.83	35.21	17.38	0.57	97.47	35.21	-	-	-	-	-	16.21	-	-	-
III	14.20	55.18	40.98	1.36	288.59	55.18	39.02	-16.16	-0.52	-29.28	39.02	37.60	-1.42	-0.04	-3.63
IV	23.08	70.20	47.12	1.57	204.15	70.20	122.03	73.33	1.67	73.83	122.03	74.03	-47.40	-1.58	-38.84
V	5.63	19.22	13.59	0.45	241.38	19.22	3.26	-15.96	-0.51	-83.03	3.26	-	-	-	-

d. Standing green biomass in relation to Z. govindia:

The two varieties together contribute considerably towards the standing green biomass on most of the sites. (Table 10.2; Fig. 10.1-B). In August, they hardly substantiated the dry matter as compared to other dominant species like T. terrestris and D. aegyptium. From August to September the combined biomass of the two varieties is increased from 13.3 to 81.0 g./sq.m. on site II, from 6.98 g./sq.m. to 42.59 g./sq.m. on site III, from 8.8 to 9.1 g./sq.m. on site IV, and from 1.0 to 2.4 g./sq.m. on site V with the corresponding increase in total standing green biomass from 38.2 to 122.0 g./sq.m., from 34.6 to 131.0 g./sq.m., from 39.6 to 52.7 g./sq.m. and from 44.6 to 77.9 g./sq.m. on the corresponding sites. From September to October, the two varieties on different sites behaved differently to increase or decrease the standing biomass of the site. The values of Z. govindia together narrowly declined on site III from 42.58 to 37.8 g./sq.m. with the corresponding decrease in standing biomass from 131.6 to 85.9 g./sq.m. but there was a sharp decline on site V from 2.48 to 0.08 g./sq.m. with corresponding decrease in green biomass from 77.9 to 34.5 g./sq.m. and a slight increase on site IV from 9.1 to 12.8 g./sq.m. with the corresponding increase from 52.7 to 118.0 g./sq.m. in standing biomass. From October to November, the combined values of the two varieties of Z. govindia and total standing biomass fell on all the sites. It was declined for Zaleya on sites III and IV (Fig. 10.2) from 37.8 to 29.1 and from 12.6 to 8.2 g./sq.m. with the corresponding fall from 85.9 to 56.8 and from 118.0 to 62.7 g./sq.m. respectively (Table 10.2; Fig. 10.2).

The individual biomass of the two varieties differed from site to site. Though both the varieties attain highest dry matter in most of the sites during September, yet it was maximum on site II. On all the sites their biomass increased from August to September and decreased from September onward. Thus the time between August to September constitutes the period of maximum growth for both the variteiss (Table 10.2; Fig. 10.2).

On site II, from August to September the above-ground biomass as well as the percentage contribution of 'rubra' and 'flava' was increased. On site III, the biomass of 'rubra' and 'flava' was increased up to October and then decreased. The percentage contribution increased in October for 'rubra' but was considerably high for 'flava' throughout up to November. On site IV 'rubra' and 'flava' added a small amount to the standing biomass and their percentage contribution was reduced throughout. On site V, the standing biomass and the percentage contribution by 'rubra' was increased only in September (Fig. 10.1-B).

<u>Z. govindia</u> has throughout contributed towards the increase of root biomass on all the sites (Table 10.2). From August to September the two varieties have jointly increased the under-ground biomass from 3.45 to 18.04 g./sq.m. on site II, from 2.46 to 32.35 g./sq.m. on site III and from 3.16 to 15.42 g./sq.m. on site IV, which could increase the total under-ground biomass of the respective sites from 9.44 to 23.93 g./sq.m. (site II), 10.82 to 45.85 g./sq.m. (site III) and 16.36 to 34.08 g./sq.m. (site IV). From September to October, the under-ground

biomass is slightly declined on site III from [illegible] to [illegible] g./sq.m. [illegible] increased on site IV from [illegible] to [illegible] g./sq.m. resulting a loss in total biomass from [illegible] to [illegible] g./sq.m. on site III and an increase from [illegible] to 35.71 g./sq.m. on site [illegible].

[illegible] percentage increase in the under-ground biomass was up to October on site III and then a decrease was observed. On site IV, it was declined in October and again increased in November. On site II, it was increased throughout but for October when the data was not recorded. The under-ground biomass on site II, in case of 'rubra' and 'flava', was increased from August to November. On site III it was increased from August to September in case of 'rubra' but was decreased in October for 'flava'. On site IV, 'rubra' showed an increase up to November but 'flava' was declined in this month. On site V, the biomass was declined in October. The percentage contribution towards the standing biomass was increased from August to September and then decreased in most of the sites. It could also be noted that in November both the varieties (Table 10.2) contribute a highly percentage of above- and under-ground dry matter towards the standing biomass.

e. Role of 2 major species in the contribution of biomass:
The productive potential of a community is directly influenced by the species which occur throughout in abundance to increase or decrease the biomass of the site. The following two species, out of the dominant ones found growing along with the two varieties of *Z. govindia*, were selected for detailed study

Fig. 10.2 Comparative above-ground [illegible] standing dead ([illegible]), standing [illegible] crop (SC) on sites III and IV [illegible] June 1970. Aboveground bio[illegible] of *Z.* [illegible] also been shown for comparision.

COMPARISON OF LITTER, STANDING DEAD, STANDING GREEN, STANDING CROP AND ZALEYA IN G/M² ON SITE III & IV FROM AUG 1969 TO JUN 1970

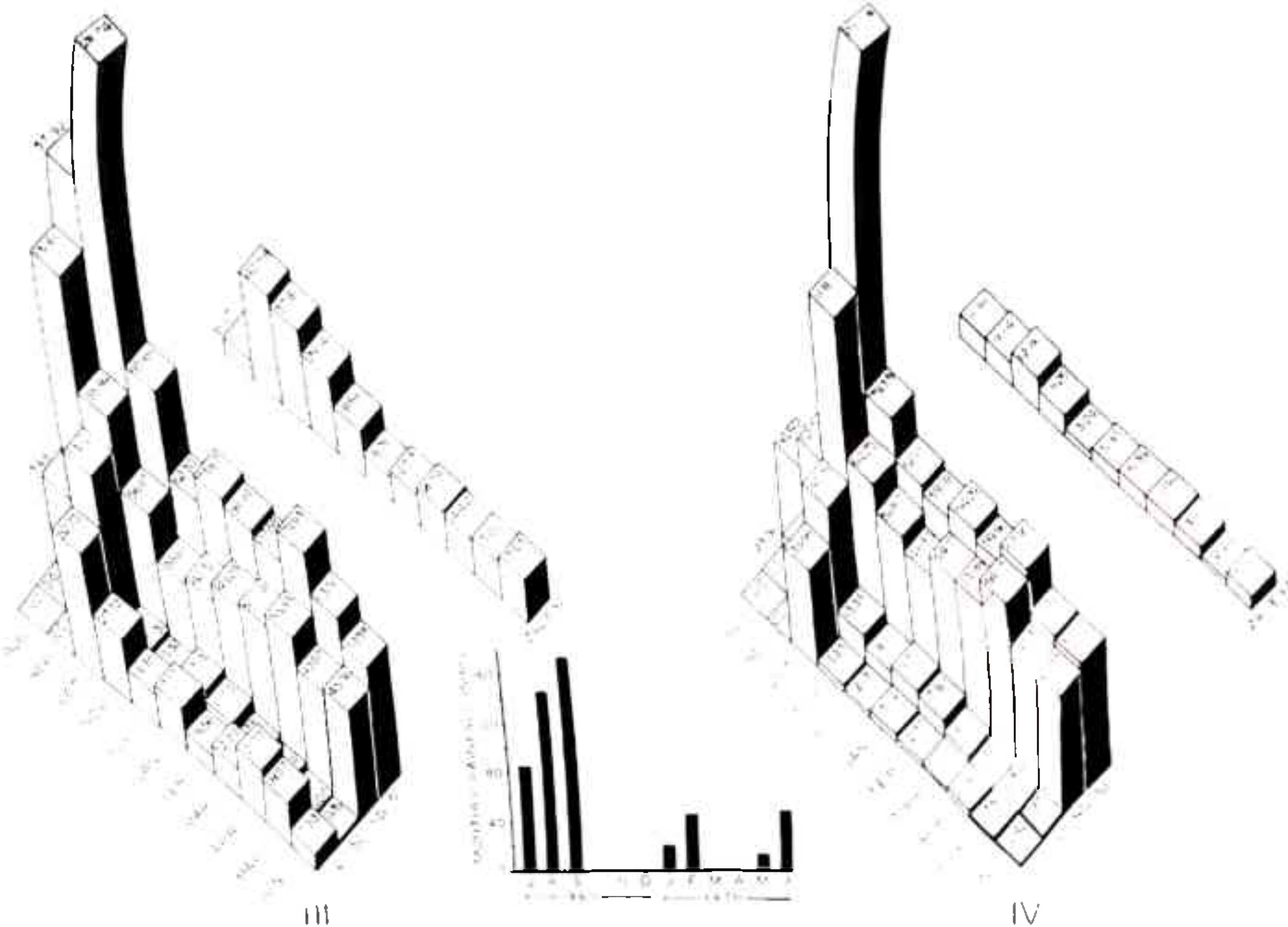


FIG. 10.2

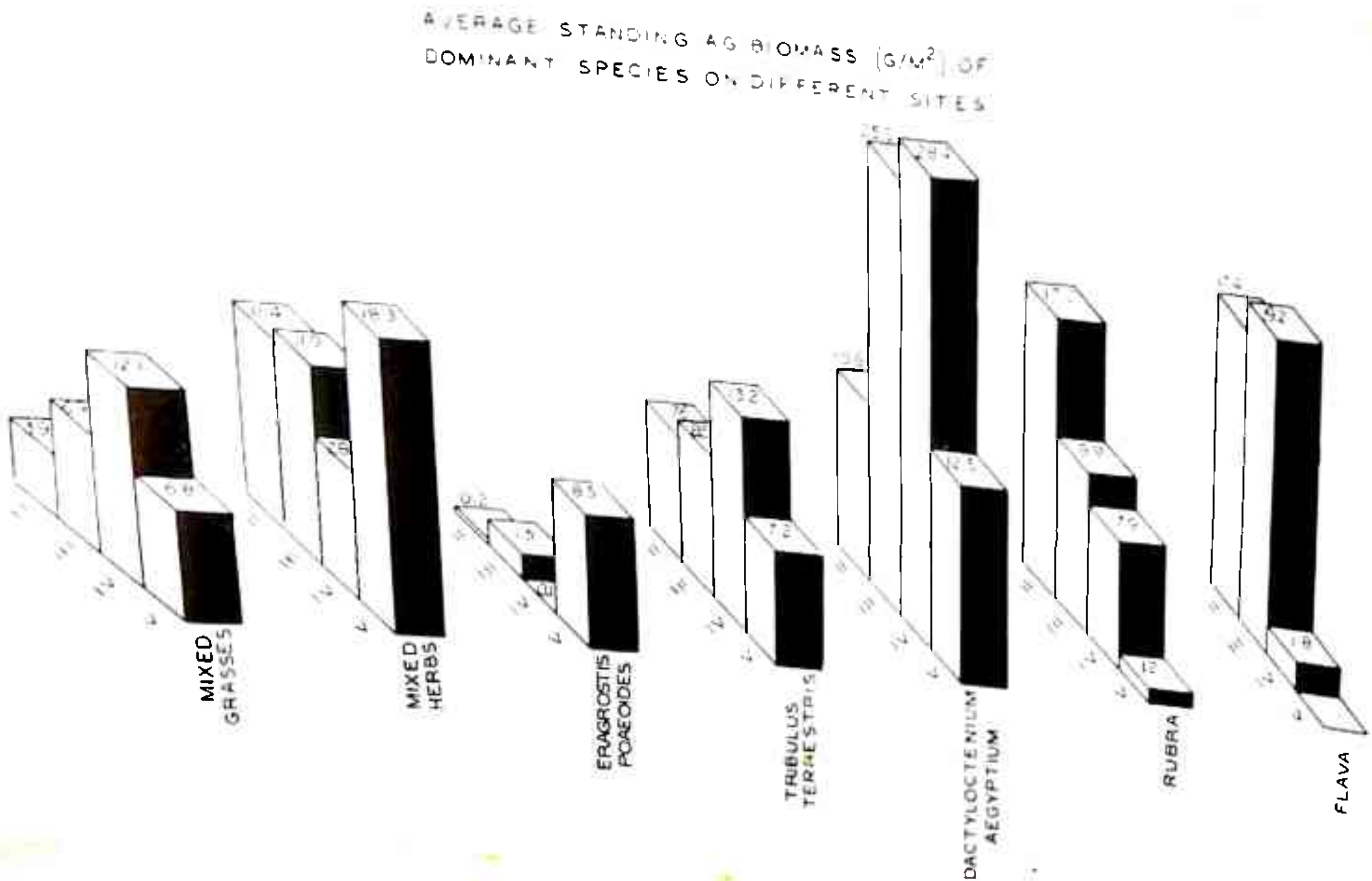
with regard to their contributory role in the increase or decrease of total biomass of the community and of *Zaleya*.

1. *Tribulus terrestris*: On site II, the percentage above-ground standing biomass of this species (Table 10.2) is less than *Zaleya* throughout but on site V it has higher contribution. On site III and IV the two varieties have contributed less than *Tribulus* in the beginning but later on they have achieved higher values. Thus, except site II, the biomass of *Zaleya* has been reduced in the beginning but later on it suppresses *Tribulus*.

2. *Dactyloctenium aegyptium*: On site II, this plant has contributed less than *Zaleya* throughout but on site III and IV it has achieved higher percentage than *Zaleya* in the beginning and is completely absent in November on site III but has higher percentage on site IV. On site V it is always higher than *Zaleya* ('rubra').

During the period of maximum growth between August and September, the percentage contribution towards the standing biomass by *T. terrestris* is lower than *Zaleya* on site II and III but higher on site IV and V. This percentage is further declined in the months to follow. *D. aegyptium*, during this period, has contributed less than *Zaleya* on site II but more than this on site III, IV and V. The mean percentage contribution of *Tribulus* and *Dactyloctenium* as compared to *Zaleya* is less on sites II and III and more on site IV and V (Table 10.4). The average above-ground biomass of dominant species has been shown in Fig. 10.3.

[illegible] Average standing above ground [illegible] mixed grasses, mixed [illegible] species on [illegible] study sites.



AVERAGE STANDING AG BIOMASS (G/M²) OF DOMINANT SPECIES ON DIFFERENT SITES
MIXED GRASSES
MIXED HERBS
ERAGROSTIS POAEOIDES
TRIBULUS TERRESTRIS
DACTYLOCTENIUM AEGYPTIUM
RUBRA
FLAVA

FIG. 10. 3

Table 10.4: Showing the mean percentage contribution by *T. terrestris*, *D. aegyptium*, *E. poaeoides* and the two varieties of *Z. govindia* towards the above-ground standing biomass

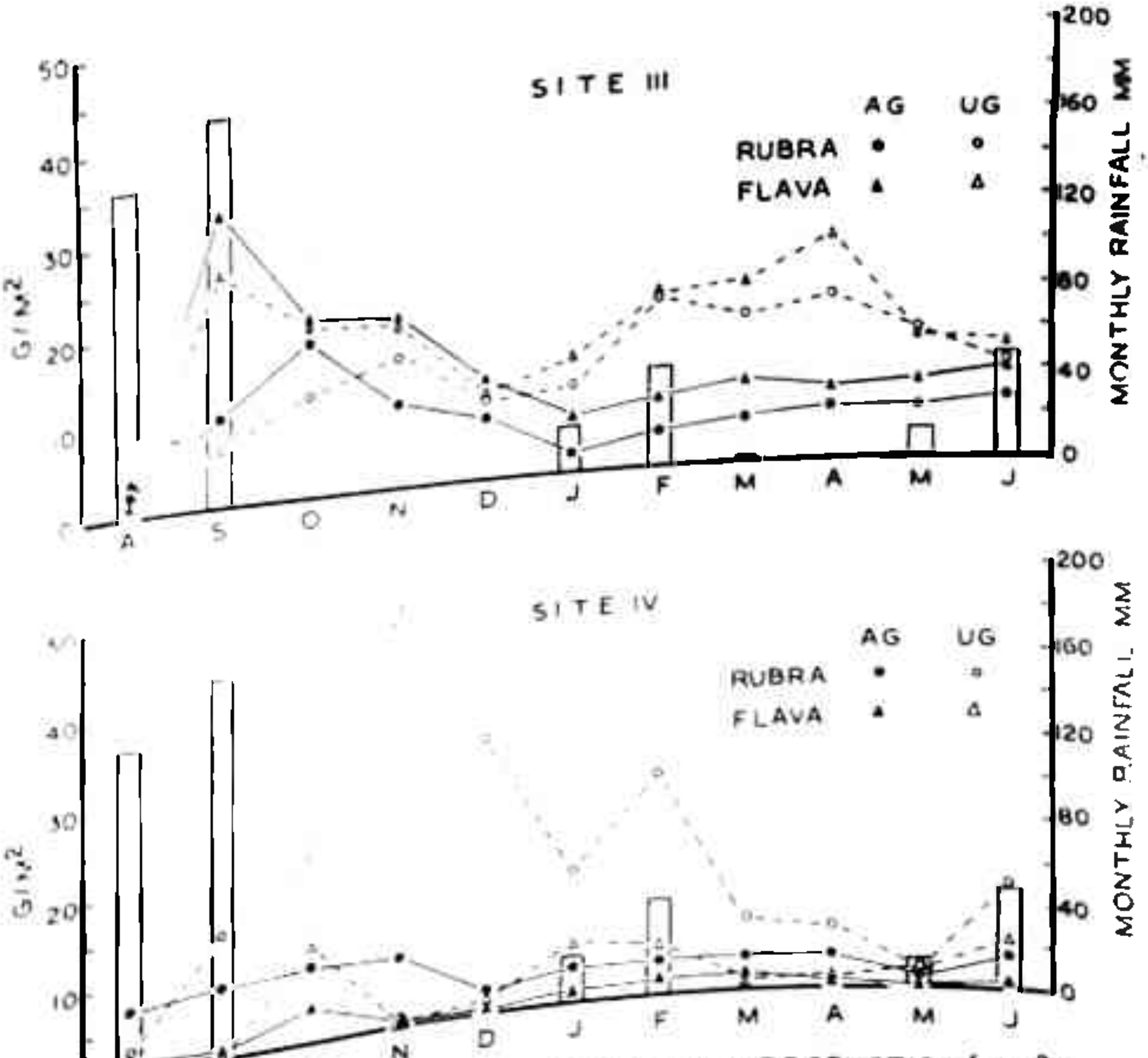
Species	Mean percentage biomass			
	Site II	Site III	Site IV	Site V
T. terrestris	9.98	14.08	25.19	12.43
D. aegyptium	10.34	26.74	34.63	24.30
E. poaeoides	0.31	3.39	0.24	16.48
Z. govindia	42.20	36.95	15.91	1.93*

* Contribution of variety 'rubra' only.

f. Off season biomass on sites III and IV: From November to January, the values for standing green and standing crop (which includes standing green, standing dead and litter) on these sites decrease but again increase up to April. It is further declined on either sites up to June. The values on site IV are comparatively lower than those on site III throughout from December to June. Values for standing dead and litter also fluctuate from month to month. However, the values for standing dead are more on site III than site IV but for litter, site III shows sufficiently higher values as compared to site IV (Fig. 10.4).

The above-ground biomass of both the varieties also declines up to January on both the sites. The two varieties increase in biomass from March onward on site III but decrease on site IV. The overall values of biomass are lower on site IV than site III.

Fig. [illegible] Above [illegible] under[illegible]round [illegible] production ([illegible]./[illegible].[illegible].) by [illegible] sites III and I[illegible] from Au[illegible]ust 19[illegible] to Jun[illegible] 1970.



ABOVE AND UNDERGROUND DRY MATTER PRODUCTION (G/M²) BY RUBRA & FLAVA ON SITE III & SITE IV

FIG. 10.4

The decline in under-ground biomass is shown by both the varieties on either sites in December. It again increases up to April on site III but decreases on site IV from March. In June the values on site IV are slightly higher (Fig. 10.4).

iii. Average biomass:

The accumulated above-ground standing crop (standing green, standing dead and litter) and under-ground plant biomass have been averaged on the basis of monthly observations. Average biomass is maximum on site III for above-ground (124.99 g./sq.m.) and on site IV for under-ground (72.49 g./sq.m.). It is minimum on site V for both above- and under-ground biomass (48.12 and 8.79 g./sq.m. respectively) - (Table 10.6).

(B) Functional aspects:

Net primary production, estimated as the sum of peak standing crops, differed from site to site (Table 10.6). It is maximum for above-ground on site III (180.2 g./sq.m.) and for under-ground on site IV (148.7 g./sq.m.). It is minimum for both on site V (80.3 g./sq.m. for AG; 12.0 g./sq.m. for UG).

Net primary production, contributed by herbs, is maximum (Table 10.5) for above-ground on site II (121.7 g./sq.m.) and for under-ground on site IV (6[illegible].9 g./sq.m.). Grasses and sedges possess the highest values both for above- and under-ground on site IV (91.9 g./sq.m. and 15.6 g./sq.m. respectively for AG; 12.3 g./sq.m. and 67.4 g./sq.m. respectively for UG).

Table 10.5: Showing net-community production (above- and under-ground) by herbs, grasses and sedges on 4 sites from August 1969 to November 1969 (Peak values are added)

Vegetation category	Site II		Site III		Site IV		Site V	
	AG	UG	AG	UG	AG	UG	AG	UG
Herbs	121.715	25.496	102.380	54.464	54.940	68.992	39.436	6.986
Grasses	23.074	4.008	76.638	11.488	91.930	12.328	40.704	4.784
Sedges	-	-	1.184	1.348	15.632	67.456	0.184	0.320
N.C.P.	144.789	29.504*	180.202	67.300	162.502	148.776	80.384	12.090

* Based on the observation of August and September 1969.

Table 10.6: Showing total and average biomass, net community production and rate of production (g./sq.m./day) on 4 sites during growing period (August 1969 to November 1969)

Site	Total biomass (g./sq.m.)		Average biomass (g./sq.m.)		Net community production (g./sq.m./year)		Rate of production (g./sq.m./day)	
	AG	UG	AG	UG	AG	UG	AG	UG
II	245.063	69.280	91.68	23.09	144.79	29.50	-	-
III	499.985	146.014	124.99	36.50	180.20	67.30	1.98	0.74
IV	406.500	289.956	101.62	72.49	162.50	148.77	1.78	1.63
V	192.486	26.388	48.12	8.79	80.38	12.09	0.89	0.13

Rate of production (g./sq.m./day) has been calculated by dividing the net community productivity by the number of days during which that much growth is recorded (Singh, 1968; Kumar *et al.*, 1970). In the present study, for the rate of production, the values of community production of sites III, IV and V are divided by 91 days. For site II, it has not been calculated due to lack of values for October. The rate of production, as calculated (Table 10.6), is highest on site II for above-ground (1.98 g./sq.m./day) and on site IV for under-ground (1.63 g./sq.m./day). It is lowest on site V for both above- and under-ground (0.89 and 0.13 g./sq.m./day respectively).

DISCUSSION

A study into the botanical composition of the selected sites reveals that the higher values for average density and per cent frequency are achieved by C. aestuans, E. hirta, E. thymifolia, M. cerviana, T. hamiltonii, T. terrestris, Z. govindia 'flava', B. ramosa, D. aegyptium, D. adscendens, E. ciliaris, E. poaeoides and T. biflorus on more than one site. Except for M. cerviana and T. biflorus, rest of the species (11) have also achieved higher values for peak standing crop. However, only five species, i.e., E. thymifolia, T. terrestris, variety 'rubra', B. ramosa and D. aegyptium are most dominant (on the basis of 1 g./sq.m./year) and common. They may, therefore, be considered as playing the major role in the herbage production.

Out of the most dominant species D. aegyptium possesses the maximum mean frequency of 93.3% and contributes 26.94% towards the peak standing crop. Varieties 'rubra' and 'flava' are other important species having the mean frequency of 67.0% and 91.6% respectively with the contribution of 14.7 and 16.8 to the peak standing crop. T. terrestris, although possesses higher mean frequency (80.4%), but contributes only 9.6%.

Table 10.7: Showing the mean of the average % frequency, mean % contribution to peak standing crop (PSC) and mean biomass (g./sq.m.) of certain dominant species and *Z. govindia*

Species	*Dactyloctenium aegyptium*	*Tribulus terrestris*	*Z. govindia* 'rubra'	*Z. govindia* 'flava'
* Mean per cent frequency	93.3	80.4	67.0	91.6
* Mean per cent contribution to PSC	26.9	9.6	14.7	16.8
** Average biomass (g./sq.m.)	19.4	9.2	9.0	12.8

* By dividing the sum of respective value of a species (Table 10.[illegible]) in all the sites by the number of sites of occurrence.

** By dividing the sum of above-ground standing biomass (Table 10.2) of a species in all the sites by the number of times of occurrence.

Thus, *D. aegyptium* is the first among the dominant species, which contributes maximum for the peak standing above-ground biomass (Fig. 10.3). The percentage contribution towards the peak standing crop by this species in four sites is in the order of IV > III > V > II (45.09, 28.73, 22.57 and 11.39% respectively). The next most dominant species are variety 'rubra' and 'flava', the percentage contribution of the former to the peak standing crop is in the order of II > III > IV > V (26.12, 9.70, 5.29 and 3.09 respectively) and that of the latter is in the order of II > III > IV (29.63, 18.05 and 2.58% respectively). *T. terrestris* which is also one of the most dominant species and contributes to the peak standing crop in the order of II > IV > V > III ([illegible], 10.76, 10.00 and 6.12% respectively). Other species, which have contributed more than 5 per cent towards the peak standing crop, are *L. thymifolia*, *A. ramosa*, *C. rotundus* and *E. tremula* (Table 10.1).

Total and standing green above-ground biomass:

Maximum above-ground biomass on site III and IV (211.739 and 211.060 g./sq.m. respectively) is in October but on site V it is in September (79.488 g./sq.m.) (Table 10.2-A). Maximum biomass on sites III and IV in October may be accounted for the high values of standing dead and litter. A high percentage contribution by 'flava' on site III (9.6%) and *D. aegyptium* on site IV (34.72%) may also be attributed to this fact (Table 10.2-A). However, on site V the biomass is maximum during September due to the maximum standing green biomass in that month which is mainly contributed by *D. aegyptium* (22.82%) and mixed herbs (34.6%). Except site IV, the standing green biomass has been observed maximum in September on all the sites, the reason being the maximum rain in September which might have accelerated the growth of ephemeral flora dominating in those sites. Maximum standing green biomass on site IV is found in October. However, the unexpected low standing green biomass on site IV in September, though it is initially high in August, may be due to the occasional removal by man or grazing of full blooming standing green vegetation sometimes in September by dairy animals before the data for this month was taken.

Maximum under-ground biomass is found on site IV and minimum on site V. Site IV possesses maximum root biomass due to the maximum number of perennating species, particularly sedges, while such perennating plants are very few on site V. Under-ground biomass of herbs and sedges is also higher on site IV than site III since more number of herbs and sedges had achieved highest growth on site IV (Table 10.1). A considerable amount of root biomass is also added by the two varieties of *Z. govindia* on site IV.

Change in the total biomass:

From August to September, the above-ground biomass is increased maximum on site III with a highest rate of production. Site IV stands next to it. Maximum biomass is achieved due to the higher rate of growth of rainy season ephemerals besides perennials as the moisture content is more on site III. On site V, this increase is least with lowest rate of production and may be accounted for the lowest available soil moisture due to poor water holding capacity of the soil in spite of heavy rain in September. Site IV, in spite of having 16 dominant species out of the total 25, shows small increase in biomass as compared to site III from August to September. This may be attributed to the biotic pressure which is being encountered more on this site (IV) than site III by dairy animals and local stock animals besides the scraping of the vegetation. These result a loss of more than three times on site IV as compared to site III (Table 10.2).

From September to October, site IV conversely shows maximum increase in above-ground biomass and site III the minimum, while on site V it is quite low (Table 10.3-A). This reversed behaviour in the dry matter production between sites III and IV for this period may be because of the preponderance of the sedges like C. compressus and C. rotundus, which achieve greater values during this period on site IV but not on site III. The negative values on site V is primarily due to a check in growth in the absence of soil moisture and secondarily due to the loss in litter which is often swept away from this site. The loss in soil moisture on site V is due to sandy soil of stabilized dunes with least plant cover to check the water loss from the superficial soil.

Change in the UG biomass:

The increase in the under-ground biomass between August and September is higher on site III and IV but the increase in root mass is checked on site III from September onwards. A higher root production between August and September is more due to the occurrence of both ephemeral annuals and perennial plants which make fast growth in this month after getting considerable rain water. Since site III lacks sedges, the root production is meagre on this site. Contrarily, site IV bears higher density and frequency of dominant species like D. aegyptium, C. compressus and C. rotundus resulting in a more under-ground reserves. The root growth is continued to increase with a higher rate of production up to October. The lowest root production with least rate on site V may be due to lack of grasses and herbaceous species. A poor moisture supply in this site is also responsible for retarding the root growth resulting in the lowest root [illegible].

Change in the standing biomass of above-ground (green) and under-ground parts:

In August, standing biomass is maximum on site V which is contributed by E. poaeoides (20.[illegible]% for AG and 33.[illegible]% for UG by ephemerals which come up early and before they suffer the drought situation of the site in the following month, they grow faster as compared to other sites and finish their life cycle in favourable conditions. In September, the maximum biomass is found on site III where it is mainly contributed by 'flava' (24.72% for AG and 56.[illegible]% for UG) and D. aegyptium (39.34% for AG and 16.09% for UG) - (Table 10.2). It is also to be noted that the peak growth is achieved in September on all the sites except site IV. Despite the number of dominant and total species being nearly the same for site III and IV yet they achieve their peak standing crop in different months. It is more likely that site IV could also have achieved the peak standing vegetation in September but due to more biotic exploitation on site IV for the above-ground standing biomass, this site is found with low standing vegetation. In October, the standing green biomass on site IV is higher than site III since the dominant perennial sedges (C. compressus and C. rotundus), which are absent on site III, continuously contribute towards the standing green biomass in spite of heavy removal of the biomass through the grazing species. In November, due to lack of soil moisture the standing biomass and total biomass are decreased in all the sites yet a few herbs particularly *Z. govindia* show an increase in the green biomass values. Similarly, on site II, where the vegetation was completely removed, shows considerably high values for standing green matter. This may be explained mainly on the fact that certain perennials rejuvenate their growth in this month as they might have received the moisture from dew water possibly due to lowering of atmosphere temperature at the advent of winter season. Thus it is very likely that dew provides a water supply in the region of scanty rainfall (Braun-Blanquet, 1932) and this source of water becomes significant for plants in the arid climates (Daubenmire, 1959).

The two varieties of *Z. govindia* show maximum contribution of root mass on site IV than site III. It may be because of their highest values for maximum density on site IV. Variety 'rubra' shows peak standing under-ground biomass on site IV, because of maximum average density and per cent frequency on this site than sites III and V (though the peak for AG is too reduced due to grazing). Site III bears peak under-ground biomass for 'flava' since this variety had acquired peak values for average density and per cent frequency. Its maximum occurrence on this site may be due to favourable nutrient status of the soil (Chapter 7).

The two varieties continue throughout and increase the under-ground production. Being perennating, their root mass is continuously increased in all the sites even up to November. They rarely show lower values which may be due to sampling.

However, they have been observed to achieve peak biomass even in November (site IV) which confirms the continuous growth in the root. The deep penetrating root system in these varieties may also be held responsible for the continuous root growth. It is also observed that the two varieties contribute nearly 80-90% of the total under-ground biomass and, therefore, they alone add considerable root mass in these sites.

Standing dead and litter:

Standing dead vegetation is found only from September onward when the plants have reached the maturity and started drying and shattering. The maximum standing dead in October on site III is found due to comparatively less biotic disturbances and lack of sweeping. However, minimum values for standing dead vegetation on site V is partially due to lack of vegetation to form the source of standing dead and partially due to cleaning of the area for dry shattered vegetation used as fuel. Litter production has been found from October onward and it acquired peak values on all the sites in this month.

Average biomass and net community production:

The highest value for above-ground peak standing crop on site III seems to be responsible for the maximum contribution by this site towards total and average above-ground biomass, NCP and its rate. The number of dominant species (17) is also maximum on this site. Site IV has 16 dominant species which have also contributed nearly equal to site III for above-ground biomass but could not contribute more towards under-ground due to poor density of dominant sedges, e.g., C. <u>compressus</u> and

C. rotundus which have contributed 4.43 and 40.91% respectively to the under-ground net production on site IV. Site V shows poorest values both for above- and under-ground production due to a few perennials and dominant species (12) with only 2 sedges having lower values.

A high NCP and its rate on site III and IV, as compared to site V for above- and under-ground production, can be explained as follows:

1. Sites III and IV have more number of perennials species than site V which help in the increased production. Since the photosynthate is transferred to the under-ground parts during off season the perennial root systems increase the below-ground production on sites III and IV.

2. The number of species are maximum on site III and minimum on site V. This is in support of the findings of Singh (1968), Singh and Misra (1969) for the grassland vegetation of Varanasi and Kumar and Joshi (1970) for the herbaceous vegetation of different habitats in Pilani. On the contrary, McNaughton (1967, 1968) has found decrease in production for Californian grassland due to diversity.

3. Site III is subjected to medium grazing and the intensity is increased in the direction site III < site IV < site V. Thus, grazing deteriorates the production in this region whereas grazing increases the production in sub-humid climate at Varanasi (Singh, 1968). Such deterioration of the vegetation is possible in arid and semi-arid regions where the sparse plant cover (mainly due to lack of sufficient soil moisture) is subjected to heavy biotic exploitations.

4. Repeated sweeping of the dunes (site V) resulting in the removal of detritus may also be counted as major factor for lowest production, since it leads to poor nutrient status of soil. The water holding capacity of dune soil is also less due to its loose nature. These all adverse factors have an accumulative negative effect on the production. Similar loss of production has also been observed by Kumar *et al.* (1970) and Kumar and Joshi (1970). Productivity on site V may also partly be limited by the shade afforded by scrub vegetation on the dunes (Kumar and Joshi, 1970).

5. As regards the productivity of main associate species of *Zaleya*, *D. aegyptium* plays a dominant role and suppresses the productivity potential of both the varieties of *Zaleya* to a great extent in initial stages. *Zaleya* compensates this loss, which is due to competition, by achieving at later stage, a high peak standing crop values. The productivity of *T. terrestris* is found lower than *D. aegyptium* and both the varieties of *Zaleya*. It may, therefore, be concluded that lack of sufficient soil moisture and poor water-holding capacity are some of the features which have considerably reduced the productivity in the area. Apart from these, biotic disturbances leads to the maximum deterioration of the productive efficiency of most of the sites studied.

It may also be stated that the productivity of *Z. govindia* is quite high but is subjected to competition with *D. aegyptium*, one of the most dominant species in this region (Kumar and Joshi, 1970) due to which its dry matter production is affected and result in the poor values for production. At the same time *D. aegyptium* continues and in the later stage it plays a main role towards the productive potential of the site when other species are vanished faster in unfavourable situations. It may be possible that optimum content of calcium in soil may help in the dry matter production of the two varieties of *Saleya* as it affects the physico-chemical conditions of the soil (Braun-Blanquet, 1932).

In addition, factors like species diversity, occurrence of other perennial species and soil nutrient status of a site also influence in the increase or decrease of the productivity of these two varieties. In the off season their increase or decrease is also more in relation to the rainfall. It is due to long perennating roots which get water from the deeper strata and store food even in off time when the growth is very less as compared to growing season. However, a slight decline in root mass may be due to the partial decomposition of root system. The rainfall also help in the increase of the biomass which is mainly contributed by the species which come now and then due to occasional and brief rains in the off season.

CHAPTER 11

GROWTH ANALYSIS

INTRODUCTION

According to Boysen Jensen (1919), studies of photosynthesis and dry matter production is the physiological and ecological basis of analysis of plant life in nature. Briggs et al. (1920 a,b) developed the quantitative analysis of plant growth. Black (1957) studied the effect of light on growth of herbage plant. The complex effect of light and temperature on the growth of leaf has been studied by Black (1955), Blackman (1957, 1968), and Friend (1965). Effect of shade has been noted by Blackman and Wilson (1951), Blackman and Black (1959), Evans and Hughes (1961), Nomoto et al. (1961), Hiroi and Monsi (1963) and Sinha (1968). Nutrition of several minerals, e.g., Calcium (Bradshaw et al., 1958; Jefferies and Willis, 1964 a,b), Nitrogen (Bradshaw et al., 1964) and Almunium and Phosphorus (Clarkson, 1966, 1967) also found to influence the plant growth. Bradshaw et al. (1964) and Clarkson (1966) found low growth rates as a factor to survive on soils with low nutrient. Higgs and James (1969) have also concluded similar results. Thorne (1960) attributed the variation with age on growth. Similar studies were carried in 4 grasses by Higgs and James (1969).

Relationship between plant growth and environmental factors have been investigated through several growth parameters like RGR, NAR and LAR by many workers (Williams, 1946; Watson, 1947, 1958; Morton and Watson, 1948; Blackman, 1950; Blackman and Wilson, 1951; Whitehead and Myerscough, 1962; Jackson, 1963).

It was first pointed out that the growth of an intact plant was a continuous process owing to the gain in weight (Blackman, V.H. 1919). The daily rate of gain (RGR) is determined by two parameters; the net diurnal efficiency of assimilation per unit of assimilatory surface (NAR) and the ratio of total assimilatory surface to total plant weight (LAR). Hence, the external factor such as light, temperature, water or nutrient, which change the RGR, also influence either or both the components of growth (NAR and LAR). It was, therefore, concluded by Briggs, Kidd and West (1920-21) that if the growth is preceding on exponential basis, then the relative growth rate = Net assimilation rate × leaf area ratio.

The present investigation is carried in natural conditions in order to find out the difference in the RGR of the two varieties of Z. govindia, the differential effect of shade and sunlight on dry matter production and RGR, and also to group the varieties into 'sun' and 'shade' plants based on the above observations.

MATERIALS AND METHODS

i. Design of the experiment:

Seeds, collected from garden, were sown in July 1969 in earthen pots. When the seedlings reached 4 leaf-stage, they were transplanted in August 1969 in beds of 1 sq.m. each with a uniform spacing and density (10 plants/sq.m.) in full exposed open situation (100% light) and in shade (25% light). Thus a total of 6 beds were maintained. Each variety was watered normally on alternate days. At the same time the leaves, stem and roots of 10 seedlings of each variety of same age were measured, dried and recorded as the initial dry weight of the plant before the treatment.

ii. Sampling procedure:

On 6 occasions, at fortnightly intervals, from August 30, 1969 to November 8, 1969, the plants from one randomly selected bed were dug out. They were washed in water tanks on sieve and measured for morphological characters. Each plant was then partitioned into leaves, stem and root and dried separately at 100°C for 48 hours. The fallen dried plant material was also picked up carefully and categorised, before drying, into standing dead and litter. Thus, a total of 6 harvests were measured on the fixed date, the first harvest being for the initial data of seedlings. For other experiments, the plants were grown in sun and shade and were uprooted after a growth of 30 days. Each plant was measured similarly for morphological characters followed by drying.

iii. Measurement of leaf area:

It was measured following the method as outlined by Blackman and Wilson (1951) with a few changes as described here. Immediately after the separation of leaves from the stem, the leaves of 2-3 plants were placed between 2 glass sheets illuminated from below and outlined on a standard paper of uniform thickness. The leaves so outlined, were then cut out with a pair of scissors and weighed (X g.). A square of paper from the same sheet, measuring 1[illegible] sq.cm. was also cut out and weighed (Y [illegible]). A standard factor was found from these three weights. This factor was multiplied with the dry weight of the leaves to get the area of leaves:

1 g. of dry leaves weighs = $\frac{X}{Y \times Z}$

where X = weight of cut paper leaves (g.)

Y = weight 1[illegible] sq.cm. paper (g.)

Z = weight of the leaves (g.)

iv. Calculation of growth papirameters:

The range, mean and standard deviation of the growth parameters were calculated for each harvesting date. For the other experiment, only one observation has been taken at the end of the experiment. Each parameter was then analysed statistically for t-test between the means of two harvests and F-test for all the [illegible] harvests.

The following growth parameters were used for the growth analysis:

a. Dry matter production (standing green biomass): It has been calculated as the dry weight in g./sq.m.

b. Rate of dry matter production (RDMP): It has been calculated in g./sq.m./day by dividing the dry matter production of any harvesting date by the number of days between the two consecutive harvests (i.e., 15 days).

c. Relative growth rate (RGR): It has been found out in g./g./day following the formula used by Blackman (1968):

$$RGR = \frac{(\log_e W_2 - \log_e W_1)}{t_2 - t_1}$$

where W_1 and W_2 are dry weights at times t_1 and t_2.

According to Fisher (1920) this equation of RGR is valid irrespective of the relationship between weight (W) and time (t) and the derivation of the component parameters of RGR, namely net assimilation rate (NAR) and mean leaf: weight ratio (MLWR) are limited. Williams (1946) has emphasized that the conventional derivations are valid only where a linear relationship exists between weight (W) and leaf area (L). Where the intervals between successive samples are short, W:L closely approximates to linearity. For the purpose of this experiment, with samples intervals of 15 days, these parameters have been calculated by the usual formulae:

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)}$$

$$MLWR = \frac{(L_2 - L_1)}{(\log_e L_2 - \log_e L_1)} \times \frac{(\log_e W_2 - \log_e W_1)}{(W_2 - W_1)}$$

where

W_1 = total dry weight at time t_1,

W_2 = total dry weight at time t_2,

L_1 = leaf area at time t_1,

L_2 = leaf area at time t_2.

It has been found that small sampling errors may give rise to considerable variation in the derived data for RGR and NAR, which may lead to confusion. It is, therefore, suggested by workers like Williams (1946) and Blackman (1968) that minor deviation in the curve for weight (W): time (t) should be smoothed out based on the primary data.

OBSERVATIONS

1. Growth analysis:

The range, mean and standard deviation in the mean of growth character are given in Table 11.1A,B. The root achieves maximum length and spread in 45 days while the maximum diameter is found after 90 days in both the varieties. This shows that root length and spread are faster in early period which slows down later on but the diameter continuously increases with a slow rate. It is also observed from table 11.1-A and 11.1-B that the increase in the mean shoot length, spread and diameter are slowed down after 45 days of growth.

The increase is resumed in the subsequent period to reach the peak at the end. Mean length of the largest branch varies from 7.14±1.02 to 47.01±11.71 cm. in 'rubra' and from 11.15±4.50 to 58.63±19.95 cm. in 'flava'. The mean length of the fifth internode on largest branch increases in the beginning but later on considerably fluctuates.

It is noted that the length of fifth internode is nearly minimum at the end of the experiment in both the varieties. Mean number of internodes on largest branch continuously increases in both the varieties. The largest branch of 'rubra' variety bears the mean number of fruit from 2.2±1.13 to 201.8±161.37 and that of 'flava' from 3.4±3.66 to 213.4±171.3.

The mean dry weight of roots per sq. m. is higher in 'rubra' than 'flava'. The leaves in 'rubra' possess more dry weight than that of 'flava'. It may also be noted that the leaf dry weight considerably increases up to 45 days in both the varieties but then declines and again attains highest dry weight at the end after 90 days. Standing dead has been found after 45 days and litter production is observed after 60 days of growth (Table 11.1-A, 11.1-B).

The morphological parameters show marked statistically significant differences in the growth of the plants grown in shade and open situations (Table 11.1-C, Fig. 11.1). In open, better growth in 'rubra' and 'flava' can be observed in most of the characters like root length, shoot length, number of internodes and maximum branch, flowering nodes, length of third internode and number of fruits (Table 11.1-C). However, these differences are not marked when they are grown in shade but for a few characters, e.g., shoot length, number of inter-nodes on maximum branch, flowering node, length of third inter-node and number of fruits where variety 'flava' achieves higher values than 'rubra'. The plants grown in shade become erect as found in nature (Chapter 5).

ii. Dry matter production:

There are overall uniform differences in the DMP of the two varieties (Table 11.2-A, Fig. 11.2). By the 6th harvest there is large difference in the total dry matter production of the two varieties. The two components (root and stem) show a constant increase after 2nd harvest (H_2 - 30 days). However, in case of leaves the dry matter increases in both the varieties up to 3rd harvest (H_3 - 45 days) and then declines. It again increases in both the varieties after 4th harvest (H_4 - 60 days) and continues up to 6th harvest (Table 11.2-A, Fig. 11.2).

Table 11.1-A. Range, mean and standard deviation in the mean values for growth parameters at 6 harvests in V..

Days	15		30		45		60		72
Number of harvests	I		II		III		IV		V
Growth Parameters	Range	Mean±S.D.	Range	Mean±S.D.	Range	Mean±S.D.	Range	Mean±S.D.	Range
Root length (cm)	5.6 - 9.1	6.24 ± 1.12	7.0 - 10.0	8.29 ± 1.11	12.5 - 23.0	17.17± 3.48	12.0 - 18.0	14.40± 2.32	15.1 - 29.5
Root spread (cm)	3.1 - 5.8	4.42 ± 0.92	5.0 - 13.0	8.25 ± 2.24	11.0 - 24.0	16.72± 4.43	8.1 - 25.0	15.94± 5.43	8.0 - 22.1
Root diameter (cm)	0.101-.128	0.112±0.009	0.128-0.230	0.182±0.029	0.264-0.402	0.330±0.049	0.196-0.476	0.306±0.096	0.255-0.445
Shoot length (cm)	2.5 - 5.1	3.68 ± 0.95	7.0 - 11.0	9.05 ± 1.28	19.3 - 38.5	27.89±6.89	16.1 - 60.5	32.05±15.76	31.0 - 70.8
Shoot spread (cm)	4.1 - 6.3	4.98 ± 0.76	7.0 - 14.0	10.50±2.22	52.3 - 68.0	52.36±12.48	29.2 -100.1	54.07±26.77	42.0 -106.2
Shoot diameter (cm)	0.112-.135	0.12 ± 0.01	0.136-0.231	0.201±0.031	0.224-0.267	0.241±0.015	0.170-0.310	0.229±0.056	0.217-0.350
Largest branch (i) Total branch length(cm)	-	-	5.4 - 8.5	7.14 ± 1.02	18.2 - 36.1	26.26±6.42	15.2-59.1	30.54±15.80	29.5-69.1
(ii) length 5th internodes (cm)	-	-	-	-	3.5 - 6.8	5.09 ± 1.27	3.2- 6.5	4.34±1.47	4.5- 6.3
(iii) No.of internodes	-	-	2.0 - 3.0	2.70 ± 0.48	6.0 - 9.0	6.8 ± 1.31	7.0-12.0	8.20 ±2.04	7.0-13.0
(iv) No.of fruit	-	-	1.0 - 4.0	2.20 ± 1.13	3.0 -67.0	23.7±20.98	17.0-72.0	35.61±21.02	30.0-206.0
Total fruit	-	-	1.0 - 6.0	2.80 ± 1.93	3.0 -96.0	39.3±29.13	28.0-391.0	139.50±126.56	39.0-326.0
Root dry weight (gm)	0.005-0.015	0.008±0.003	0.04-0.180	0.086±0.047	0.13-0.43	0.263±0.101	0.09-0.72	0.32± 0.26	0.50-1.10
Stem dry weight (gm)	0.001-0.030	0.013±0.008	0.03-0.053	0.185±0.152	0.43-1.98	1.07± 0.53	0.65-2.56	1.755±0.65	0.63-8.16
Leaves dry weight(gm)	0.020-0.045	0.033±0.011	0.10-0.70	0.324±0.20	0.68-2.227	1.406±0.54	0.32-3.35	1.13±1.10	0.77-3.18
Leaf area (sq.cm)	1.705-6.147	3.70±1.75	10.815-87.122	39.266±25.893	84.482-286.432	176.69±68.57	43.16-494.80	166.21±104.03	112.76-469.62
Standing dead (gm)	-	-	-	-	-	0.034	-	0.072	-
Litter (gm)	-	-	-	-	-	-	-	0.002	-

	15		11							
Number of harvests	1									
Growth parameters	Range	Mean+S.D.	Range	Mean+S.D.	Range	Mean+S.D.	Range	Mean+S.D.	Range	
Root length (cm)	5.2 - 9.1	6.36 + 1.05	5.0 - 12.5	8.10 + 2.22	8.5 + 23.0	16.10 + 4.60	12.5 ± 16.0	14.6 ± 1.28	10.1 - 21.1	15
Root spread (cm)	3.1 - 6.2	4.28 ± 0.93	4.0 - 10.0	6.55 ± 2.03	11.2- 21.2	16.30± 2.97	9.0 - 17.0	11.8 ± 2.97	9.2 - 16.2	1
Root diameter (cm)	0.10- 0.117	0.109±0.006	0.126-0.214	0.178±0.027	0.230-0.417	0.351±0.057	0.256-0.340	0.301±0.030	0.23 - 0.43	0.
Shoot length (cm)	2.5 - 5.0	3.58 ± 0.84	5.7 - 21.0	11.77±5.09	22.0 -42.6	34.59±8.05	30.0 -43.1	32.38± 6.27	23.1 - 53.2	38
Shoot spread (cm)	3.2 - 5.6	4.41 ± 0.81	6.0 - 32.0	16.3 ± 8.71	40.1 -74.5	59.49±12.67	44.8 -66.0	54.68± 6.84	34.6 - 91.5	59
Shoot diameter (cm)	0.113-0.128	0.121±0.006	0.132-0.233	0.205 ±0.031	0.240-0.391	0.288±0.055	0.210-0.316	0.258±0.038	0.196-0.336	0.
Largest branch			6.0 - 20.0	11.15±1.50	21.0 - 41.0	32.77±7.84	23.1-41.0	30.90±6.13	22.3-50.0	36
(i) Total branch length (cm)	-	-	-	-	2.3 - 7.0	5.22 ± 1.46	4.2 - 6.9	5.36 ±0.85	3.5 - 4.6	4.
(ii) Length of 5th internode (cm)	-	-	3.0 - 6.0	4.1 ± 0.99	6.0 - 11.0	8.0 ± 1.41	6.0 - 10.0	7.2 ± 1.55	8.0 - 13.0	10
(iii) No. of internode	-	-	2.0 - 12.0	3.4 ± 3.86	11.0-87.0	49.4±29.1	17.0- 66.0	41.8±18.4	55.0-195.0	10
(iv) No. of fruit	-	-	2.0 - 22.0	5.1 ± 6.82	17.0-133.0	72.0±42.2	26.0-92.0	58.5±21.4	71.0-193.0	13
Total fruit	-	-	0.03-0.06	0.042±0.010	0.10-0.20	0.207±0.068	0.08 - 0.44	0.21 ± 0.11	0.13 ±1.09	0.
Root dry weight (gm)	0.005-0.010	0.007±0.002	0.07-0.170	0.094±0.029	0.16-1.66	0.65 ± 0.45	0.21 - 5.88	1.67 ± 2.02	0.98 -5.76	2.
Stem dry weight (gm)	0.005-0.080	0.012±0.008	0.06-0.280	0.146±0.070	0.43-1.45	0.922 ± 0.39	0.25 - 1.42	0.56 ± 0.41	0.58 -2.84	1.
Leaves dry weight (gm)	0.016-0.070	0.032±0.017	7.62-40.20	20.36±10.47	62.41-213.45	135.27±58.53	10.81-178.47	68.98±52.34	71.78-358.83	15
Leaf Area (sq.cm)	0.146-7.005	2.254±2.150	-	-	-	0.029	-	0.054	-	
Standing dead (gm)	-	-	-	-	-	-	-	0.002	-	
Litter (gm)	-	-								

Table 11.1-C: Showing the differences in 'rubra' and 'flava' varieties between the plants grown in 'open' and 'shade' conditions in garden

Characters / Varieties	'rubra'			'flava'		
	Open Mean±S.D.	Shade Mean±S.D.	't' test	Open Mean±S.D.	Shade Mean±S.D.	't' test
Root length (cm)	45.20±9.8	7.40±1.6	11.9	24.20±[illegible].0	7.30±3.1	[illegible].2
Root diameter (cm)	0.71±0.22	0.14±0.01	7.7	0.68±3.21	0.16±0.06	7.[illegible]
Shoot length (cm)	112.90±9.8	7.30±2.5	3[illegible].7	75.17±21.7	11.01±[illegible].45	8.9
Shoot diameter (cm)	0.65±0.17	0.20±0.05	7.87	0.30±0.05	0.17±0.03	[illegible].24
No. of internode on maximum branch	15.50±0.85	4.40±1.43	21.10	1[illegible].30±1.56	4.90±1.37	11.24
Flowering node on maximum branch	14.20±1.23	2.50±1.58	18.47	11.20±1.75	3.20±2.28	7.62
Length of third inter-node on maximum branch (cm)	6.50±1.29	1.55±0.42	11.53	6.81±1.31	1.78±0.62	10.[illegible]
Diameter of third inter-node on maximum branch (cm)	0.27±0.06	0.13±0.01	7.67	0.25±0.03	0.13±0.01	10.03
Fruits on maximum branch	586.40±251.9	3.60±2.50	7.31	33.30±17.73	14.10±19.65	[illegible]
Total fruits	856.40±207.4	17.50±26.6	12.68	391.20±37[illegible].8	21.50±11.67	3.16
Dry weight root (g)	4.79±1.91	0.12±0.10	7.59	2.44±1.76	0.16±0.05	4.10
Dry weight leafless stem (g)	43.45±16.5	0.13±0.17	8.27	22.[illegible]4±25.0	0.09±0.01	[illegible].83
Dry weight leaves (g)	17.9[illegible]±6.70	0.08±0.09	8.44	11.76±2.70	0.05±0.03	13.9[illegible]
Dry weight total shoot (g)	61.44±2[illegible].9	0.21±0.27	8.4[illegible]	34.31±[illegible].3	0.14±0.12	4.10

Table 11.2-A: Showing change in dry matter production in plant parts and total plant of 'rubra' and 'flava' in culture (density = 10 plants/sq.m.)

Variety	Harvests / Parameters	I* Bio-mass	I* RDMP	II Bio-mass	II RDMP	III Bio-mass	III RDMP	IV Bio-mass	IV RDMP	V Bio-mass	V RDMP	VI Bio-mass	VI RDMP
Rubra	Root	0.08	0.005	0.86	0.028	2.63	0.055?	[illegible]	0.053?	[illegible]	[illegible]	[illegible]	[illegible]
	Stem (Leaf-less)	0.13	0.008	1.85	0.061	[illegible]	0.238	17.5	[illegible]	30.?	[illegible]	44.0	[illegible]
	Leaves	0.35?	0.022	3.24	0.108	14.0?	0.312	11.3	0.188?	16.1	[illegible]	21.?	[illegible]
	Total	0.54	0.035	5.95	0.197	27.39	0.608	32.0	0.533	[illegible]	0.713	74.3	[illegible]
	Standing dead	-	-	-	-	0.34	0.007	3.72?	0.012?	4.41	[illegible]	[illegible]	[illegible]
	Litter	-	-	-	-	-	-	0.02	[illegible]	0.79?	0.0105?	[illegible]	[illegible]
Flava	Root	0.07?	0.004	0.42	0.014	2.07	0.046	[illegible]	0.035?	[illegible]	0.074	[illegible]	0.120
	Stem (Leaf-less)	0.12	0.008	0.94	0.031	6.50	0.144	16.76	0.278	[illegible]	0.294?	36.1	[illegible]
	Leaves	0.32	0.021	1.46	0.048	[illegible]	0.205	[illegible]	0.093?	[illegible]	0.150?	19.?	0.220?
	Total	0.51	0.033	2.82	0.093	17.79	0.395	24.46	0.406?	39.7	0.523?	[illegible]	0.741
	Standing dead	-	-	-	-	0.29	[illegible]	0.54	0.009	[illegible]	0.038?	3.21?	[illegible]
	Litter	-	-	-	-	-	-	0.02	0.0003	0.4?	[illegible]	[illegible]	[illegible]

Biomass = dry weight in g/sq.m.; RDMP = Rate of dry matter production in g/sq.m./day

* Initial weight of seedlings.

Table 11.2-3: Showing the increase in dry [illegible]atter [illegible] and leaf area [illegible] the two varieties grown in 'sun' and 'shade' [illegible] with the control (initial) [illegible]

Parameters / Date	Aug. 4, 68. Control (Mean ±S.D.)	Sept. [illegible] Shade (Mean ± S.D.)	Sept. [illegible] Open (Mean ± S.D.)	t [illegible] Control and shade	t [illegible] Control and open
'rubra'					
Dry weight root (g)	0.003±0.001	0.158±0.04[illegible]	4.7[illegible]±1.91	10.1[illegible]	7.[illegible]
Dry weight leafless stem (g)	0.005±0.003	0.05[illegible]±0.026	43.45±1[illegible]	[illegible]	[illegible]
Dry weight leaves (g)	0.013±0.009	0.058±0.042	17.[illegible]	[illegible]	[illegible].47
Leaf area (sq. cm.)	1.900±1.430	7.320±6.320	265[illegible].60±993.4	[illegible]	[illegible]
'flava'					
Dry weight root (g)	0.004±0.002	0.146±0.06	[illegible].44±1.76	7.37	4.35
Dry weight leafless stem (g)	0.008±0.005	0.096±0.09	2[illegible].54±[illegible].07	2.87	2.8[illegible]
Dry weight leaves (g)	0.014±0.009	0.048±0.033	11.75±[illegible].6[illegible]	3.13	13.7[illegible]
Leaf area (sq. cm.)	1.600±1.15	4.200±4.18	1[illegible]91.70±34[illegible]	[illegible]	13.7[illegible]

Fig. 11.1 [illegible] variety 'ru[illegible]ra' [illegible] 'fl[illegible]' grown [illegible] and shade situations.

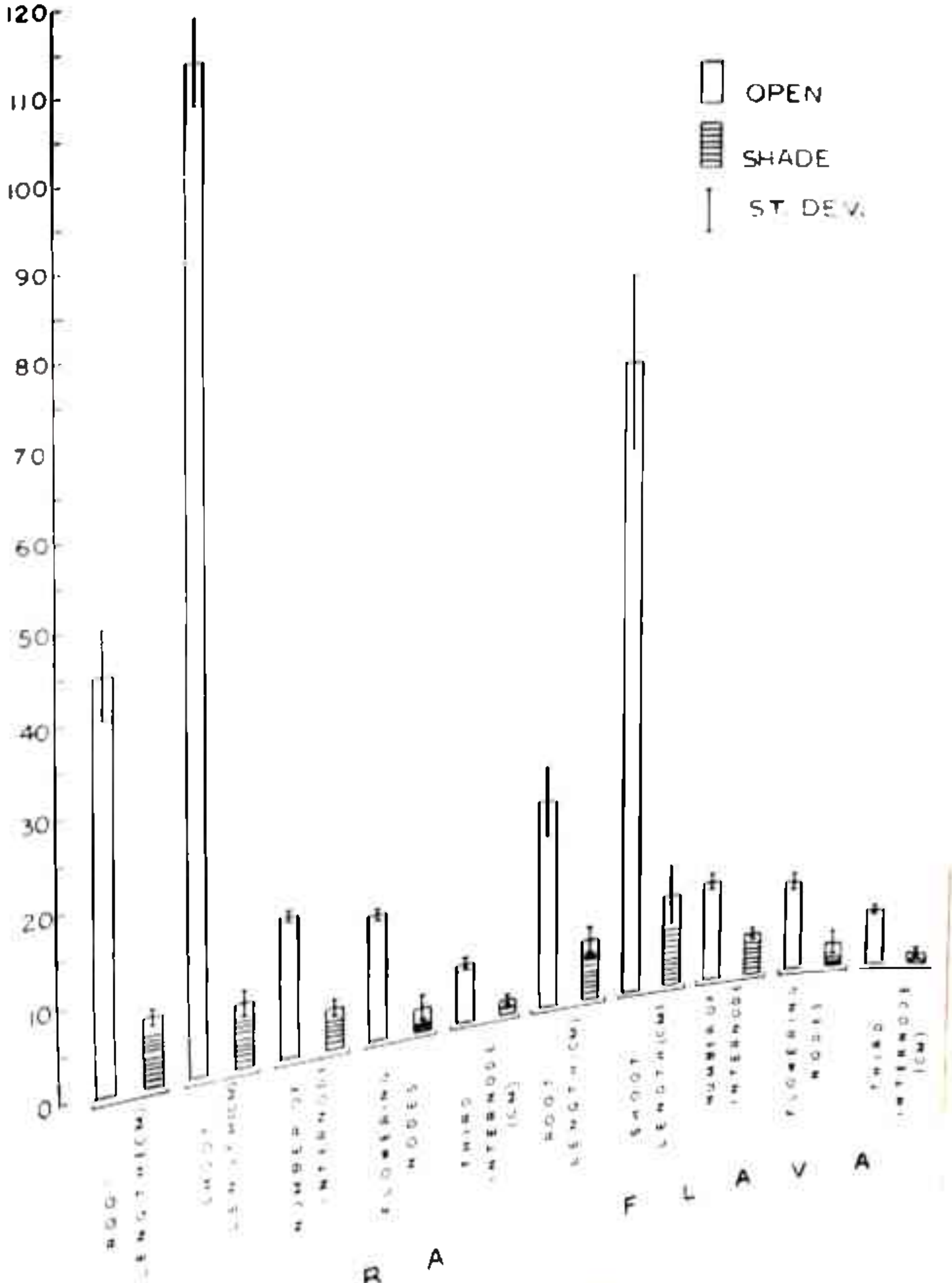

OPEN
SHADE
ST. DEV.
120
110
100
90
80
70
60
50
40
30
20
10
0
R U B R A
F L A V A

FIG. II.1

Fig. 11.2 Dry wei[illegible] [illegible] [illegible]

dr[illegible] matter [illegible] (DMP), st[illegible] [illegible]

in 'rubra' [illegible] 'flava' at 6 harvests.

[illegible], 'rubra'. F, 'flava'. [illegible]

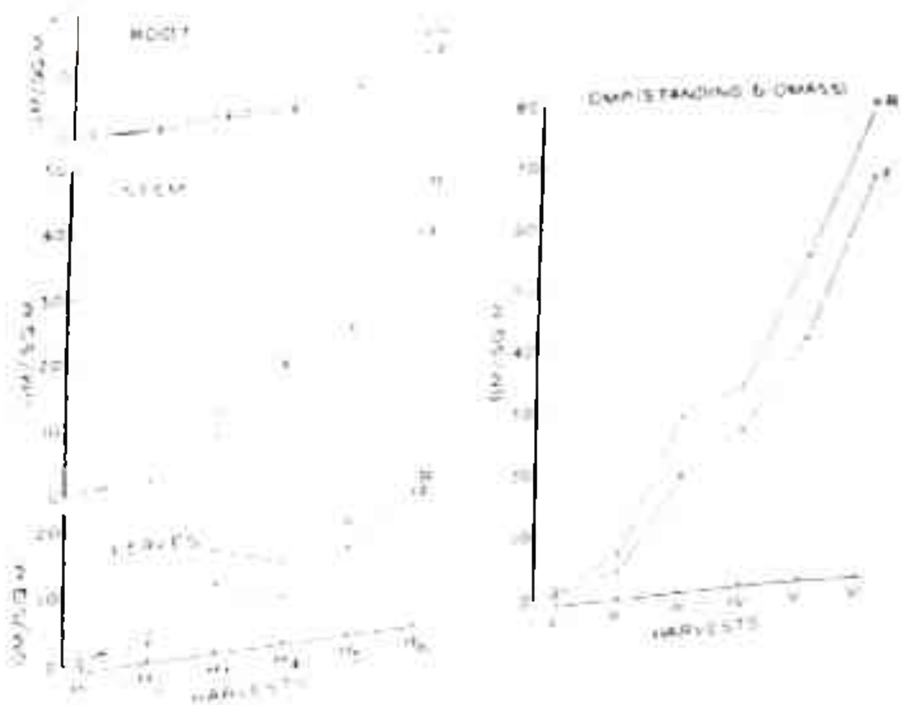


FIG. II.2

In open situation the dry weight values of 'rubra' for root, stem and leaves are higher than that of 'flava'. However, in shade also 'rubra' achieves higher production than 'flava' (Table 11.2-B). In both the varieties, the increase in dry matter is high and statistically significant in the plants grown in open than those grown in shade (Tables 11.1-C, 2-B).

iii. Rate of dry matter production (g./sq. m./day):

The two varieties uniformly differ throughout as in case of DMP (Fig. 11.2). They exhibit an abrupt increase in the rate up to 45 days (3rd harvest). Though both the varieties show an increase in DMP, yet variety 'rubra' achieves higher production rate than that of 'flava' till the last harvest (Table 11.3, Fig. 11.3).

iv. Relative growth rate (g./g./day):

Table 11.3 shows that both the varieties have different relative growth rates (RGRs) but they vary uniformly with time interval. RGRs of both the varieties (Fig. 11.4) are considerably high during early period of growth up to II harvest interval (HI_1) but they are considerably declined at the III harvest interval (HI_3). RGR of 'rubra' sharply declines up to III harvest interval (HI_3) and then again rises. RGR curve of 'flava' first shows a peak of II harvest interval (HI_2), decreases at III harvest interval (HI_3) and again shows an increase. Thus, the two varieties appear to be different in the early phase of development but later on as they mature, they

TOTAL RATE OF DRY MATTER PRODUCTION
(GM / SQ M / DAY)

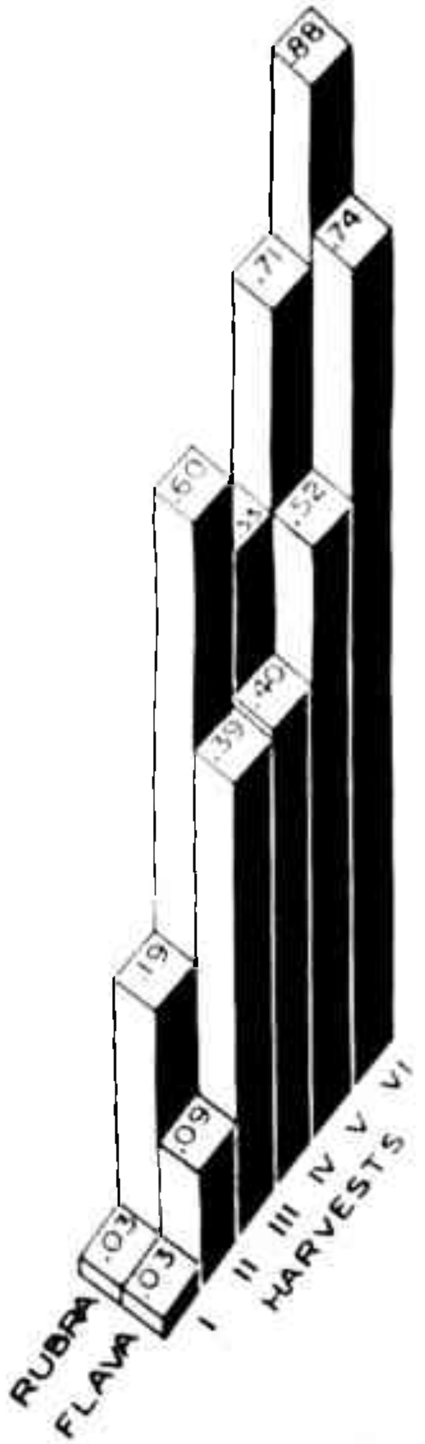


Fig. 11.4 [illegible]et [illegible] rates [illegible], [illegible]

rates [illegible]), mean [illegible]

rate of dr[illegible] matter [illegible]roductio[illegible]

([illegible]) and [illegible] ([illegible]) [illegible], [illegible]

([illegible]) to [illegible] [illegible] interval [illegible].

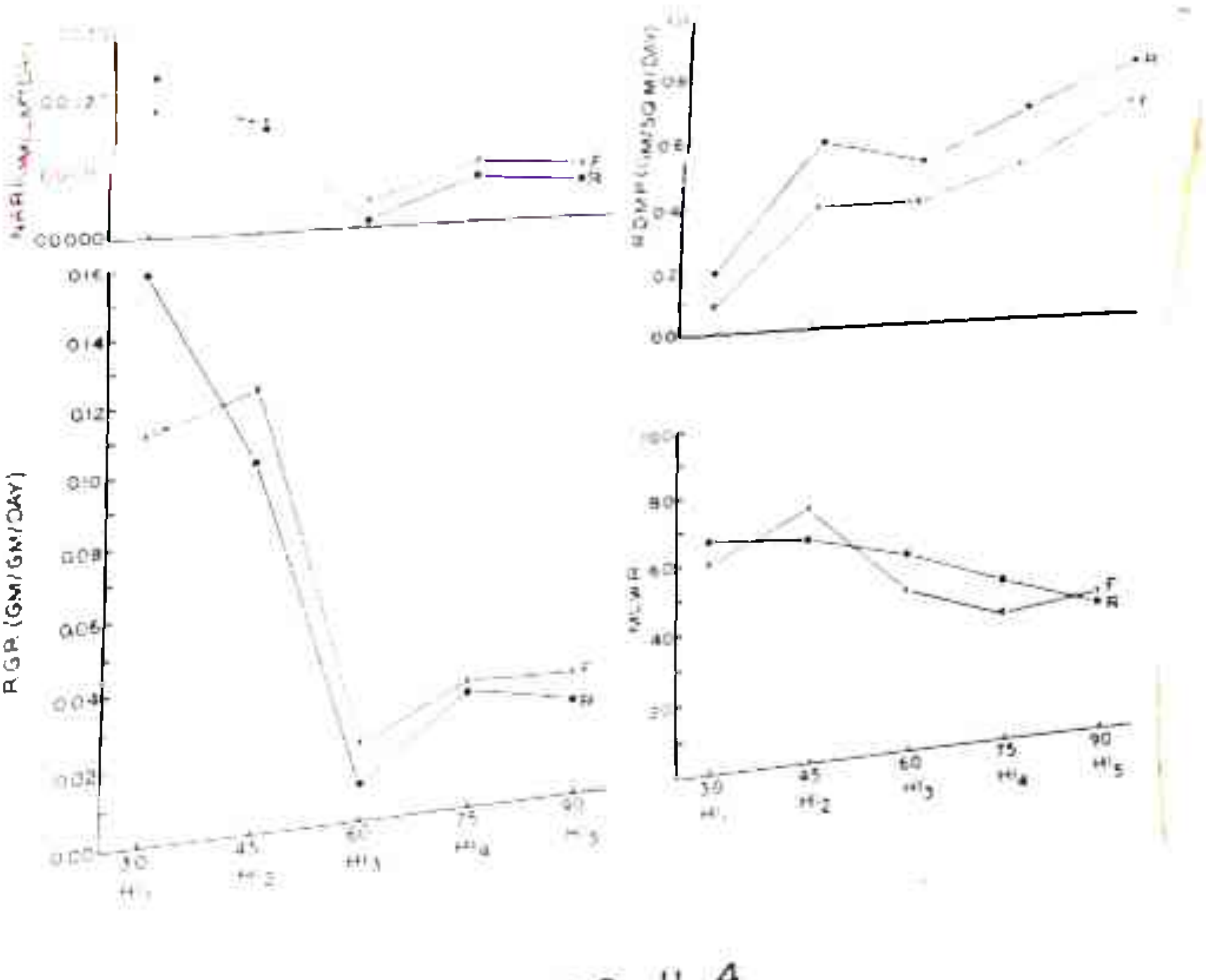


FIG. II.4

Table 11.3: Showing comparison of 'rubra' and 'flava' for RGR, MLWR, DMP and RDMP at different harvest interval

Growth parameters / Harvest intervals	RGR (g/g/day)		NAR (g/cm²/day)		MLWR (cm²/g)		DMP (g/m²)		RDMP (g/m²/day)	
	'rubra'	'flava'	'rubra'	'flava'	'rubra'	'flava'	'rubra'	'flava'	'rubra'	'flava'
I	0.1592	0.1125	0.0023	0.0016	66.57	60.44	[illegible]	[illegible]	[illegible]	[illegible]
II	0.1017	0.1227	0.0015	0.0016	65.06	74.69	27.34	17.79	[illegible]	[illegible]
III	0.0136	0.0212	0.0001	0.0004	57.70	47.01	[illegible]	24.46	[illegible]	[illegible]
IV	0.0324	0.0340	0.0007	0.0009	45.28	38.44	[illegible]	39.70	0.712	[illegible]
V	0.0262	0.0344	0.0006	0.0008	35.78	41.01	79.30	[illegible]	0.680	0.741

RGR = Relative growth rate; NAR = Net assimilation rate; MLWR = Mean leaf:weight ratio

DMP = Dry matter production (standing biomass); RDMP = Rate of dry matter production show similar pattern (Fig. 11.4). Further, RGR of 'rubra' is being overlapped by 'flava' at II harvest interval (HI_2) and thus the latter variety achieves higher values than the former up to the final harvest, though the former variety consistently produces more dry matter.

When the two varieties are grown in sun and shade for a uniform time period of 30 days, variety 'rubra' achieves higher value of RGR than that of 'flava' in both the situations (Table 11.4A, 11.4-B). Variety 'rubra' contributes 76.1% in sun (100% light intensity) and 23.9% in shade (25% light). Similarly, 'flava' contributes 75.3 and 24.7% respectively in 100% and 25% light intensities (Table 11.4-A). When the two varieties are compared in one condition they again show marked differences (Table 11.4-B). Thus in shade, variety 'flava' contributes 48.5% while 'rubra' 51.5% which is 3% more than 'flava'. In open condition (100% light) 'rubra' has 52.7% and thus contributes 5.4% more than that of 'flava' (47.3%). Thus RGR declines in both the varieties due to change in the available light intensities (Fig. 11.4).

v. Net assimilation rate (g./sq.cm./day):

Differences in RGRs are determined by the variations found in LARs and NARs. In Fig. 11.4 the mean overall values of NAR for each harvest intervals (HI) are plotted. Both the varieties follow the same pattern as RGRs. In general, the two varieties show rather gradual decline in NAR up to the 3rd harvest interval (60 days - HI_3) but later on they consistently increase as found in RGR. It is also observed that the NAR

Table 11.4-A: Showing comparison between 'sun' and 'shade' plants for RGR in 'rubra' and 'flava'

Variety / Light condition	'rubra' g/g/day	'rubra' %	'flava' g/g/day	'flava' %
Sun (100%)	0.267	76.1	0.240	75.3
Shade (25%)	0.084	23.9	0.079	24.7
Difference	0.183	52.2	0.161	50.6

Table 11.4-B: Showing comparison between 'rubra' and 'flava' for their RGR in 'sun' (100% light) and 'shade' (25% light) plants

Light condition / Variety	'Sun' (100% light) g/g/day	'Sun' (100% light) %	'shade' (25% light) g/g/day	'shade' (25% light) %
'rubra'	0.267	52.7	0.084	51.5
'flava'	0.240	47.3	0.079	48.5
Difference	0.027	5.4	0.005	3.0

of 'flava', though low initially than 'rubra', overlaps the latter around 45 days and maintains higher values than 'rubra'.

vi. Mean leaf weight ratio:

The two varieties differ from each other in the values of LWR. However, both show a general fall in the ratio throughout the experimental period (Table 11.3, Fig. 11.4).

DISCUSSION

The results of the growth behaviour in the two varieties of Z. govindia seem to be in a parallel fashion. The curves for total dry matter production are more or less parallel but variety 'rubra' shows higher production than 'flava'. A better growth in 'rubra' has also been found when the two varieties, growing in nature, are compared for their growth and morphological characters. This shows that the overall growth of 'flava' on the decrease side may be due to some edaphic features. However, the leaf weight is decreased in both the varieties after 3rd harvest (Table 11.2-A, Fig. 11.2), when the plants of both the varieties have reached full maturity and old leaves have fallen. A further increase after the 4th harvest is due to the freshly developed leaves from the new developing branches. Such leaves are found developing in plants of perennating habit.

Rate of dry matter production is overall lower in 'flava' than 'rubra' as is found in natural sites. A comparatively lower rate around 4th harvest may also be attributed to the fall of the mature leaves when the plants reach maturity. Similarly, the increase in the rate from 5th harvest onward is due to the addition of more leaves arising from the new branches.

In uniform light conditions, RGR of 'rubra' is considerably higher than 'flava' at the initial stage due to both high NAR and high MLWR at the corresponding harvest interval (Fig. 11.4). Higher RGR, NAR and MLWR have also been recorded in Poplar than that of Birch and Sycamore (Pollard and Wareing, 1968). However, more growth in 'rubra' increases the shading thereby resulting a further fall in RGR (HI_2 - Fig. 11.4), while in 'flava' at the same time a slower growth does not influence shading and results in higher RGR than 'rubra'. Higher RGR in 'flava' at HI_2 (Fig. 11.4) is also due to the higher NAR and MLWR for this variety. Higher RGR in 'flava' and lower RGR in 'rubra' in the later stage may again be attributed to the same reason, i.e., more growth in 'rubra' increases shading and declines the RGR as compared to 'flava'. However, conversely in the later stage, the higher RGR of 'flava' does not correspond to the higher MLWR of 'flava'. It may be due to the lower ratio between leaf area and plant weight in 'flava'. Such a reciprocal relationship between NAR and MLWR has also been observed in agricultural crops (Watson, 1958) and woody species (Pollard and Wareing, 1968). Higgs and James (1969) have opined that Agrostis has higher RGR than that of Lolium though the latter has considerably produced more dry matter. Similarly 'flava' has overall high RGR than that of 'rubra' though the later variety has higher values for dry matter production. A decline in the RGR in both the species may not be attributed to any environmental condition since the climatic conditions are uniform for both the varieties throughout the experiment. According to Blackman (1968) RGR is highest in the early vegetative phase and minimal as the maturity is reached when the leaves become senescent or are shed off. Similar is the case with the two varieties of Zaleya. The decline in RGR at HI_3 (Fig. 11.4) may be associated with the plant ageing as has also been observed by Thorne (1960) and Higgs and James (1969). However, a further increase in the RGR of both the varieties may be attributed to the growth of the freshly developed leaves, when the corresponding NAR curve also exhibits an increase.

NAR varies with the demand made upon the leaf for assimilation. It shows the net diurnal efficiency of assimilation per unit of assimilatory surface (Blackman, 1968). Both the curves for RGR and NAR follow the identical course in both the species. It shows that both RGR and NAR are mutually related due to some acting factor. As the plant ages the level of shading also increases with the result a decreased NAR and RGR in both the varieties. Freeland (1952) has found that ageing decreases the NAR in Pinus sylvestris. The parallel behaviour of both RGR and NAR curves have also been found in Populus trichocarpus (Poplar) and Pinus radiata by Pollard and Wareing (1968).

Blackman (1968) is of the opinion that NAR reaches a maximum value at the beginning and it shows a sharp decrease in the first few weeks. This dimunition is associated to the changes with age in the efficiency of photosynthesis of the leaves and the manner in which the leaves shade each other as the plants [illegible]. Increase in NAR in the harvest interval 4 and 5 (HI_4 and HI_5) may similarly be attributed to the new leaves. This general increase, in part, is the effect of the solar radiation as noted by Pollard and Wareing (1968) and Higgs and James (1969). To some extent the new leaves are able to maintain the capacity to respond to the favourable environmental conditions like availability of moisture, in so far as they affect the photosynthesis, by maintaining a continuous succession of new leaves as observed by Pollard and Wareing (1968) in case of Poplar and P. radiata.

It may, therefore, be concluded that the uniform fluctuation in the growth behaviour of both the varieties are more encountered by the ageing rather than other factors like shade.

The plants at 25% of light intensity show a marked reduction in the total dry weight and the morphological characters, when compared to the plants grown in 100% light intensity. A similar decrease in dry weight due to reduced light has also been noticed by Blackman (1957). Reduction in light has also been found to decrease the growth and dry matter production in Marquis wheat (Friend et al., 1962); Apple trees (Maggs, 1963); Fagopyrum esculentum, Pisum sativum (Blackman, 1968); Tribulus terrestris (Pathak, 1969); and Eleusine indica (Singh and Misra, 1969b). However, increase in internode length has also been observed in E. indica by Singh and Misra (1969b). Conversely in two varieties of Z. govindia the length of internode is declined in reduced light intensity (Fig. 11.1). Adaptation of erect habit in reduced light, as found in these varieties, has also been observed in E. indica (Singh and Misra, 1969b).

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CHAPTER 12

PLANT COMPETITION

INTRODUCTION

Life of plants rests upon the supplies available in the substrata they occupy. The performance of a plant in a natural community is the resultant of its growth behaviour and the effect of growth factors like water, light and nutrients. According to Harlan ([illegible]), all plants, that live together in a community, are in competition with each other to some degree throughout their life cycle. The extent of adverse effect of competition depends upon the competitive ability of a plant. According to Welbank (1963), the competitive ability of a plant is its ability to depress the growth of other plants. However, when the demand for the requirements in an ecosystem exceeds the availability, competition ensures resulting into depressed or modified growth of the competing individuals (Misra, 1968).

According to Iwaki (1959), the principal phytosociological factor in plant succession and the geographical distribution of plant species is naturally the interspecific competition, which selects the plant species that can survive in nature after severe and long struggle with other species. The classic work in this line was carried earlier (Clements, Weaver and Hanson, 1929) and now many ecologists are devoted in such studies with special reference to weed control in crop fields (Lazenby, 1955 a,b; Holmgren, 1956). Such studies provide the effect of interspecific competition under various ecological and phytosociological conditions but only a few have studied the working mechanism of competition. Kramer and Decker (1944) have concluded that Pine fails in competition with Oak because of the heavy reduction of its photosynthesis in shade. Walter (1956) has reported that the proportion of photosynthate distributed into the photosynthetic organs (leaves) and non-photosynthetic ones (stems, roots, etc.) might be the factor of primary importance in determining the final result of competition.

It has been observed (Chapter 6) that both the varieties of *Zaleya govindia* grow together in most of the natural sites examined. Their individual and mixed competitive effect cannot be well understood in fields as they are removed by men and animals. In order to examine the growth behaviour of varieties in single variety cultures (intra-varietal) and mixed varieties cultures (inter-varietal) at different densities under uniform environmental conditions like light, water and nutrients, the experiments, related to inter and intra-varietal competition, have been dealt within the succeeding pages of this chapter. Development of productive structure has also been studied to find the distribution pattern of photosynthate to the various organs following the methods used by Hiroi and Monsi (1966).

MATERIALS AND METHODS

Competition studies have been studied as below:

1. Intravarietal competition: i. 'rubra' vs. 'rubra'
   ii. 'flava' vs. 'flava'
2. Inter-varietal competition: i. 'rubra' vs. 'flava'
   ii. 'flava' vs. 'rubra'

i. Design of the experiment and sampling:

Earthenware pots of uniform size were filled with equal amount of garden soil. Seeds of both the varieties of _Zaleya_ were sown in September 19[illegible]. Seedlings of two-leaf stage were thinned according to the experimental design. Each treatment was replicated thrice as described. The pots were kept in open area (for uniform light) and watered uniformly on alternate days. After 40 days, the plants were dug out, washed and measured for their growth performance under each set of treatment separately. For productive structure, the plant parts were separated into two systems, photosynthetic (leaves) and non-photosynthetic (stems and roots). Subterranean parts were carefully washed to remove soil particles. The plants were oven dried at 100°C for 24 hours and measured for dry weights.

ii. Calculation of growth parameters:

The growth has been calculated as the mean per pot which has been further analysed for variance between the number of plants per pot. The total plant dry weight per pot and per plant have been calculated as below:

$$\text{Total plant dry weight per pot} = \frac{\text{Total dry weight in all the pots}}{\text{Number of replicates (pots)}}$$

$$\text{Total plant dry weight per plant} = \frac{\text{Total dry weight in all the pots}}{\text{Number of total plants}}$$

Productive structure has been calculated by working out the ratio as given below:

i. $$F/W = \frac{\text{Leaf dry weight}}{\text{Total plant dry weight}}$$ (Hiroi and Monsi, 1966)

ii. $$C/F = \frac{\text{Non-photosynthetic system}}{\text{Photosynthetic system}}$$ (Hiroi and Monsi, 1966)

These have been measured for each density set from the dry weight values per pot.

Percentage reduction in dry weight of competing varieties (varietal competition) is calculated using the following expression:

$$\% \text{ reduction} = \frac{X - Y}{X} \times 100 \quad \text{(Misra, 1968)}$$

where X = dry weight per pot without competition

Y = dry weight per pot with competition

A positive result will indicate that the gain in weight with competition is far less than that obtained without competition and vice versa. Thus, a positive reduction shows that the productive potential of the varieties is increased when growing with no competition while a negative percentage reduction expresses that the potentiality of a variety is increased when growing in competition with another variety.

OBSERVATIONS

1. Intravarietal competition:

a. Morphological features: All the morphological features when calculated per plant basis exhibit a decline towards higher plant density in both the varieties (Tables 12.1-A, B; Figs. 1-8). The values are increased when calculated per pot basis. Decline in shoot spread is steeper than root spread but this decline is more smooth in the length of root and shoot, diameter of root and shoot and largest branch. Number of fruits are also reduced up to a density of 4 plants/pot. Thus, maximum value is recorded at lowest density and minimum at higher density (Figs. 12.1-8).

Table 12.1-A: Showing the effect of crowding [illegible] on the growth performance of *Z. [illegible]* '[illegible]'

S.No.	Growth parameters		Number of plants per pot				[illegible]	[illegible]
			1	2	4	6		
1.	Root spread/pot	(cm)	41.25±7.54	67.57±6.91	117.[illegible]	11[illegible]	[illegible]	[illegible]
	Root spread/plant	(cm)	41.25±7.54	33.77±4.45	29.20±[illegible]	[illegible]	[illegible]	[illegible]
2.	Root length/pot	(cm)	48.50±6.40	70.31±1[illegible].93	13[illegible].75±30.91	1[illegible]6.3[illegible]	[illegible]	[illegible]
	Root length/plant	(cm)	48.50±6.40	35.3[illegible]±[illegible].45	33.[illegible]2	29.[illegible].11	[illegible]	[illegible]
3.	Root diameter/pot	(cm)	0.53±0.04	0.77±0.07	1.4[illegible]±0.12	[illegible].11±[illegible]	1[illegible].50	[illegible]
	Root diameter/plant	(cm)	0.53±0.04	0.3[illegible]±0.03	0.3[illegible]±0.03	0.3[illegible]	[illegible].11	[illegible]
4.	Shoot spread/pot	(cm)	74.37±5.87	112.00±10.74	1[illegible].50±15.[illegible]	240.5[illegible]	62.[illegible]	[illegible]
	Shoot spread/plant	(cm)	74.37±5.87	5[illegible].97±5.34	48.75±3.72	40.10±[illegible]	16.40	[illegible]
5.	Shoot length/pot	(cm)	43.62±6.04	65.27±7.94	11[illegible].0[illegible]±7.7[illegible]	15[illegible].[illegible]±1[illegible].68	[illegible].2[illegible]	[illegible]
	Shoot length/plant	(cm)	[illegible].6[illegible]±6.04	32.[illegible]5±4.0[illegible]	[illegible]3.50±1.95	[illegible]±2.78	14.0[illegible]	[illegible]
6.	Shoot diameter/pot	(cm)	0.38±0.02	0.60±0.04	1.12±0.06	1.6[illegible]±0.0[illegible]	168.23	[illegible]
	Shoot diameter/plant	(cm)	0.38±0.02	0.30±0.02	0.28±0.02	0.27±[illegible]	29.02	[illegible]
7.	Largest branch length per pot	(cm)	41.50±5.44	61.75±8.09	109.80±8.88	144.8[illegible]±14.4[illegible]	91.50	[illegible]
	Largest branch length per plant	(cm)	41.50±5.44	30.87±4.05	27.44±[illegible].21	24.15±[illegible]	15.95	[illegible]
8.	5th internode length per pot	(cm)	7.17±0.23	12.85±0.80	25.[illegible]±[illegible].16	32.30±3.[illegible]	153.55	[illegible]
	5th internode length per plant	(cm)	7.17±0.23	6.42±0.40	6.01±0.33	[illegible].38±0.[illegible]	5.19	[illegible]
9.	Fruits on largest branch/pot	(cm)	188.75±49.05	136.00±6.37	206.75±41.93	296.75±81.9[illegible]	6.5[illegible]	[illegible]
	Fruits on largest branch/plant	(cm)	188.75±49.05	68.00±3.18	51.67±10.4[illegible]	49.5[illegible]±1[illegible].69	26.22	[illegible]
10.	Fruits total plant/pot	(cm)	298.75±70.28	257.50±17.07	354.75±52.18	543.75±170.[illegible]	6.90	[illegible]
	Fruits total plant/plant		298.75±70.[illegible]8	12[illegible].75±8.[illegible]	8[illegible].6[illegible]±[illegible]	[illegible]±28.4[illegible]	[illegible]	[illegible]

PLANT DENSITY/POT   PLANT DENSITY/POT   PLANT DENSITY/POT

Table 12.1-B: Showing the effect of crowding ([illegible]) on the growth performance of [illegible]

(4 replicates for each treatment)

S.No.	Growth parameters		Number of plants per pot				[illegible]ate	[illegible]
			1	[illegible]	[illegible]	[illegible]		
1.	Root spread/pot	(cm)	2[illegible].75±2.36	42.50±8.02	5[illegible].[illegible]±16.33	[illegible]	[illegible]	[illegible]
	Root spread/plant	(cm)	25.75±2.36	21.25±4.01	1[illegible].07±[illegible]	[illegible]	17.04	[illegible]
2.	Root length/pot	(cm)	54.00±6.79	[illegible]7.00±11.51	117.[illegible]±25.01	1[illegible].75±51.[illegible]	11.[illegible]	[illegible]
	Root length/plant	(cm)	54.00±6.79	43.50±5.7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3.	Root diameter/pot	(cm)	0.51±0.02	0.91±0.15	1.[illegible]±0.12	[illegible]	[illegible]1.70	[illegible]
	Root diameter/plant	(cm)	0.51±0.02	0.45±0.06	0.3[illegible]±0.02	[illegible]	[illegible]	[illegible]
4.	Shoot spread/pot	(cm)	78.00±4.34	1[illegible]4.50±31.41	1[illegible]1.69±[illegible].10	[illegible]	[illegible]	[illegible]
	Shoot spread/plant	(cm)	78.00±4.34	[illegible].1[illegible]±15.66	37.97±5.[illegible]	[illegible]	[illegible]	[illegible]
5.	Shoot length/pot	(cm)	43.42±2.94	71.42±17.[illegible]	10[illegible].[illegible]±8.19	[illegible]±19.[illegible]	[illegible].34	[illegible]
	Shoot length/plant	(cm)	43.42±2.94	35.71±8.63	2[illegible]±2.[illegible]	[illegible]3.[illegible]±3.1[illegible]	[illegible].87	[illegible]
6.	Shoot diameter/pot	(cm)	0.34±0.01	0.62±0.05	0.95±0.0[illegible]	1.36±0.0[illegible]	1[illegible]5.7[illegible]	[illegible]
	Shoot diameter/plant	(cm)	0.34±0.01	0.31±0.03	0.24±0.01	0.2[illegible]±0.01	32.[illegible]	[illegible]
7.	Largest branch length/pot	(cm)	40.87±[illegible].40	67.35±1[illegible].75	77.05±[illegible].50	1[illegible]1.[illegible]±18.[illegible]	[illegible].17	[illegible]
	Largest branch length/plant	(cm)	40.87±[illegible].40	33.67±8.37	2[illegible].[illegible]±2.13	21.[illegible]±3.[illegible]	[illegible]	[illegible]
8.	5th internode length/pot	(cm)	6.65±1.01	10.60±2.01	21.65±1.1[illegible]	[illegible]	1[illegible].21	[illegible]
	5th internode length/plant	(cm)	6.65±1.01	5.42±1.18	5.40±0.27	[illegible].04±0.[illegible]	[illegible]	NS
9.	Fruits on largest branch/pot	(cm)	137.50±58.05	165.75±27.10	163.[illegible]±[illegible].02	[illegible]	3.12	[illegible]
	Fruits on largest branch per plant	(cm)	137.50±58.09	82.88±18.56	40.[illegible]±12.31	44.40±1[illegible]	[illegible].11	[illegible]
10.	Fruits total plant/pot	(cm)	280.50±122.81	203.50±47.62	283.[illegible]±[illegible]8.84	3[illegible].00±1[illegible]	1.47	[illegible]
	Fruits total plant/plant	(cm)	280.50±122.[illegible]	1[illegible]1.7[illegible]±82.[illegible]	70.[illegible]0±17.22	[illegible].[illegible]7±1[illegible]	7.[illegible]	[illegible]

DF of treatment 3 (For Tables 12.1-A,B) Table value at 0.05 probability 3.4[illegible] (For Tables 12.1-A,B)

" error 12 (" ")

PLANT DENSITY/POT PLANT DENSITY/POT PLANT DENSITY/POT

Fig. [illegible] Plot [illegible] of [illegible] not [illegible] and [illegible]

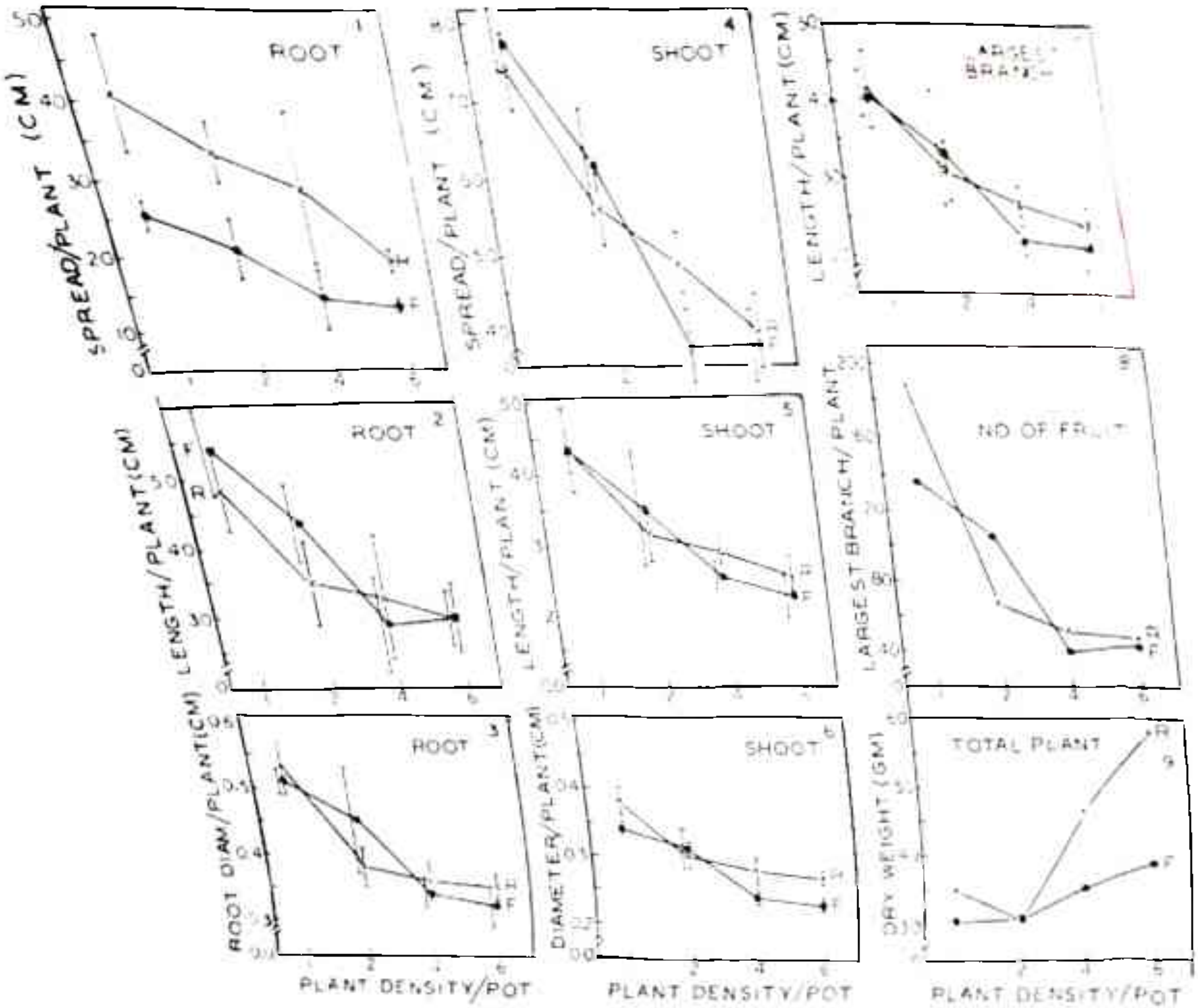

ROOT
SPREAD/PLANT (CM)
SHOOT
LENGTH/PLANT (CM)
ROOT
LENGTH/PLANT(CM)
SHOOT
LARGEST BRANCH/PLANT
NO OF FRUIT
ROOT
ROOT DIAM/PLANT(CM)
SHOOT
DIAMETER/PLANT(CM)
TOTAL PLANT
DRY WEIGHT (GM)
PLANT DENSITY/POT
PLANT DENSITY/POT
PLANT DENSITY/POT

FIG.12.1-9

b. Dry matter production: Dry weights of root, stem and leaves decrease per plant but are increased per pot with the increase in plant density of both the varieties (Table 12.2). Total dry weight for each density set is also increased with increase in density (Table 12.2; Fig. 12.9). The values for total plant dry weight per pot show a rise towards higher densities, but the total plant dry weight values per plant are decreased (Table 12.2; Fig. 12.10).

Table 12.2: Showing the effect of crowding (Inter-varietal competition) on dry matter production of *Z. govindia* 'rubra' and 'flava'

(4 replicates per treatment)

Growth parameters		Number of plants per pot			
		1	2	4	6
'rubra'					
Root dry weight/pot	(gm)	1.37±0.47	1.64±0.43	2.82±0.49	3.15±0.62
Root dry weight/plant	(gm)	1.37±0.47	0.82±0.24	0.71±0.12	0.52±0.10
Stem dry weight/pot	(gm)	5.25±1.50	4.32±0.22	5.82±1.06	8.42±2.44
Stem dry weight/plant	(gm)	5.25±1.50	2.16±0.11	1.46±0.27	1.40±0.40
Leaves dry weight/pot	(gm)	2.15±0.53	1.92±0.41	2.95±0.80	2.96±0.58
Leaves dry weight/plant	(gm)	2.15±0.55	0.95±0.20	0.73±0.19	0.49±0.09
Total plant dry weight in all pots	(gm)	35.12	31.62	46.5	58.1
Total plant dry wt./pot	(gm)	8.78	7.90	11.62	14.52
Total plant dry wt./plant	(gm)	8.78	3.95	2.90	2.42

(Contd.)

Table 12.2 (Contd.)

Growth parameters		Number of plants per pot			
		1	2	4	6
'flava'					
Root dry weight/pot	(gm)	1.2[illegible]±0.47	1.89±0.99	2.40±0.89	2.[illegible]±0.[illegible]
Root dry weight/plant	(gm)	1.[illegible]±0.47	0.94±0.49	0.60±0.22	0.49±0.11
Stem dry weight/pot	(gm)	4.[illegible]±1.53	5.[illegible]±3.[illegible]9	4.17±1.68	4.[illegible]2±1.44
Stem dry weight/plant	(gm)	[illegible].2[illegible]±1.53	2.64±1.94	1.04±0.4[illegible]	0.80±0.24
Leaves dry weight/pot	(gm)	[illegible]±0.[illegible]2	[illegible].31±1.33	[illegible].37±0.53	1.94±0.98
Leaves dry weight/plant	(gm)	2.24±0.62	1.15±0.66	0.5[illegible]±0.13	0.32±0.16
Total plant dry weight	[illegible]	31.18	31.53	35.78	38.87
Total plant dry wt/pot	(gm)	7.79	7.88	8.94	9.72
Total plant dry wt/plant	(gm)	7.79	3.94	2.23	1.62

c. Productive structure: It has been observed (Table 12.3) that F/W ratio tends to become smaller while C/F ratio is increased with increasing density.

Table 12.3: Showing the effect of plant density on F/W and C/F ratio in 'rubra' and 'flava'

Plant density/pot	'rubra'			'flava'		
	Dry wt./pot (g)	F/W	C/F	Dry wt./pot (g)	F/W	C/F
1	8.78	0.245	3.07	7.79	0.287	2.52
2	7.90	0.243	2.76	7.88	0.293	3.10
4	11.62	0.253	5.91	8.94	0.265	2.77
6	14.52	0.203	8.20	9.72	0.199	4.01

ii. Inter-varietal competition:

a. Morphological features: When the individuals of variety 'rubra' with a fixed density are allowed to grow with varying density of 'flava', ~~the values of 'flava'~~, the values for shoot spread and number of stems per pot are increased in both up to a density ratio of 2:4 and then decreased in both the varieties (Table 12.4-A; Fig. 12.11-A). When the density of variety 'flava' is kept constant and that of 'rubra' varies, the values of 'flava' are declined throughout but that of 'rubra' is decreased for a density ratio of 2:4 and then increased (Table 12.4-B; Fig. 12.11-B).

b. Dry matter production: The dry weight of 'rubra', when its density is fixed, continuously increases up to a density ratio of 2:4 ([illegible]) and then declines. It continuously increases in 'flava' with the increase in its density per pot. When the density of variety 'flava' is fixed and that of 'rubra' is changed the former shows a continuous fall but the latter shows a decline up to 2:4 density and then increases. Almost similar course is followed by the individual component of dry matter production.

c. Percentage reduction in dry matter production: Varying the density of 'flava', the percentage reduction in dry matter of variety 'rubra' (fixed) is negatively increased towards the increase in density of 'flava' (Table 12.5-A). This percentage reduction is also increased in case of 'flava' (fixed) with increasing density of 'rubra', but the reduction is positively increased when the density of later is increased (Table 12.5-B).

	Shoot growth		[illegible]		Root dry weight		Stem dry weight		Leaves dry wt.		Total shoot (stem+leaves) dry weight		Total plant dry weight	
	cm/pot		[illegible]		g/pot		g/pot		g/pot		g/pot		g/pot	
[illegible]	R	F	R	F	R	F	R	F	R	F	R	F	R	F
[illegible]	31.4±3.[illegible]	-	[illegible]	-	1.[illegible]±[illegible].1	-	4.[illegible]±0.4	-	3.1±0.3	-	7.0±0.6	-	[illegible].0±0.7	-
[illegible]	-	[illegible]±[illegible].7	-	[illegible]±117.7	-	[illegible]	-	[illegible]±1.0	-	2.8±0.6	-	7.0±1.5	-	7.8±1.6
[illegible]	36.4±3.4	35.1±2.9	117.0±3.5	172.0±12.0	0.[illegible]±0.1	0.5±0.[illegible]	3.9±1.1	2.4±0.4	2.0±0.3	1.3±0.3	5.9±1.5	3.7±0.4	6.7±1.6	4.3±0.7
[illegible]	-	47.[illegible]±10.[illegible]	-	341.3±60.2	-	1.6±0.1	-	10.4±1.1	-	10.3±0.6	-	20.7±0.6	-	[illegible].6±0.7
[illegible]	43.5±3.9	50.2±[illegible]	138.0±19.0	168.0±21.6	1.0±0.2	1.2±0.1	4.9±0.5	[illegible].3±[illegible].7	6.4±0.9	7.2±0.8	11.4±1.0	13.6±1.5	12.4±1.1	14.8±1.4
[illegible]	-	39.[illegible]±3.5	-	192.0±26.7	-	1.4±0.1	-	10.4±1.2	-	[illegible].8±0.2	-	17.2±1.2	-	19.2±1.3
[illegible]	44.5±5.5	46.4±7.2	9[illegible].0±12.[illegible]	184.6±17.2	1.2±0.1	3.2±0.3	7.5±0.7	21.4±1.0	5.6±0.5	8.6±0.6	13.1±0.1	30.1±0.4	14.3±0.2	33.3±0.6
[illegible]	-	42.5±3.[illegible]	-	91.2±[illegible].7	-	4.2±1.4	-	19.9±1.4	-	18.7±0.8	-	38.7±2.3	-	42.9±3.5
[illegible]	44.2±2.8	45.[illegible]±10.[illegible]	[illegible]7.7±17.6	83.2±20.6	1.0±0.0[illegible]	5.3±1.1	4.0±0.7	29.2±3.2	4.3±0.4	11.0±1.1	9.3±1.0	40.3±3.7	10.3±0.9	45.6±4.6
[illegible]	4	7	4	7	4	7	4	7	4	7	4	7	4	7
[illegible]	10	16	10	16	10	16	10	16	10	16	10	16	10	16
[illegible]	5.26	2.18	21.84	7.50	4.25	20.67	9.75	117.42	24.10	103.40	25.36	109.48	21.81	137.07
[illegible]ility	NS	NS	***	**	*	***	**	***	***	***	***	***	***	***

[illegible]/pot		[illegible]/pot		g/pot		g/pot		g/pot		g/pot		[illegible]/pot	
F	R	F	R	F	R	F	R	F	R	F	R	F	R
73.[illegible]±26.7	-	[illegible]±101.2	-	2.5±0.2	-	7.0±0.8	-	5.0±0.6	-	14.0±0.7	-	16.[illegible]±0.9	-
-	[illegible]	-	13[illegible]±[illegible]5.0	-	0.6±0.2	-	3.1±0.3	-	3.3±0.2	-	6.4±0.1	-	7.1±0.36
75.0±19.6	[illegible]±11.3	77[illegible]±11[illegible].1	[illegible]±70.5	1.[illegible]±0.3	1.3±0.2	6.1±1.6	8.7±2.8	5.2±0.6	5.1±1.3	13.4±2.4	13.3±3.7	14.7±2.7	14.7±4.0
-	[illegible]	-	21[illegible]±24.5	-	3.1±0.9	-	14.1±0.9	-	8.3±1.9	-	22.4±2.7	-	25.0±3.6
77.1±3.5	76.[illegible]±[illegible].5	1[illegible].0±1[illegible]	[illegible]±15.[illegible]	1.[illegible]±0.1	[illegible].1±0.[illegible]	[illegible].1±0.2	7.2±0.5	2.7±0.2	3.8±2.1	6.9±0.1	11.1±0.6	[illegible].1±0.3	13.2±0.[illegible]
-	7[illegible]±1[illegible]	-	[illegible]±[illegible].5	-	2.1±0.4	-	9.1±0.2	-	5.3±1.5	-	14.4±1.0	-	1[illegible].0±1.4
6[illegible]±4.8	52.3±4.[illegible]	70.[illegible]±[illegible].5	12[illegible].4±[illegible]	[illegible].6±0.1	1.8±0.[illegible]	1.6±0.1	[illegible].4±1.1	1.1±0.05	3.6±0.4	2.8±0.2	[illegible].3±1.5	3.4±0.3	11.1±1.7
-	65.5±7.[illegible]	-	12[illegible].5±15.5	-	2.6±0.4	-	7.4±0.9	-	[illegible].0±0.6	-	13.5±1.4	-	1[illegible].1±1.7
[illegible].2±7.3	6[illegible]	[illegible].1±[illegible]	1[illegible].7±10.5	6.[illegible]±0.6	2.9±0.6	1.5±0.1	12.2±1.3	1.1±0.3	8.4±0.5	2.7±0.4	20.[illegible]	[illegible]	[illegible]
4	9	4	7	4	7	4	7	4	7	4	7	4	7
10	10	10	10	10	10	10	10	10	10	10	10	10	10
5.6[illegible]	[illegible].89	5.00	30.1	44.68	9.29	44.4[illegible]	[illegible]	50.61	10.58	[illegible]	15.71	54.45	15.61

Fig. [illegible] Plant [illegible] [illegible] [illegible]

[illegible] densities [illegible]

Fig. [illegible] [illegible]ect of inter-varietal c[illegible] [illegible] [illegible]

[illegible]l features [illegible] [illegible] [illegible]

the density of [illegible] (12.11-[illegible]) [illegible] of [illegible]

(12.11-[illegible]).

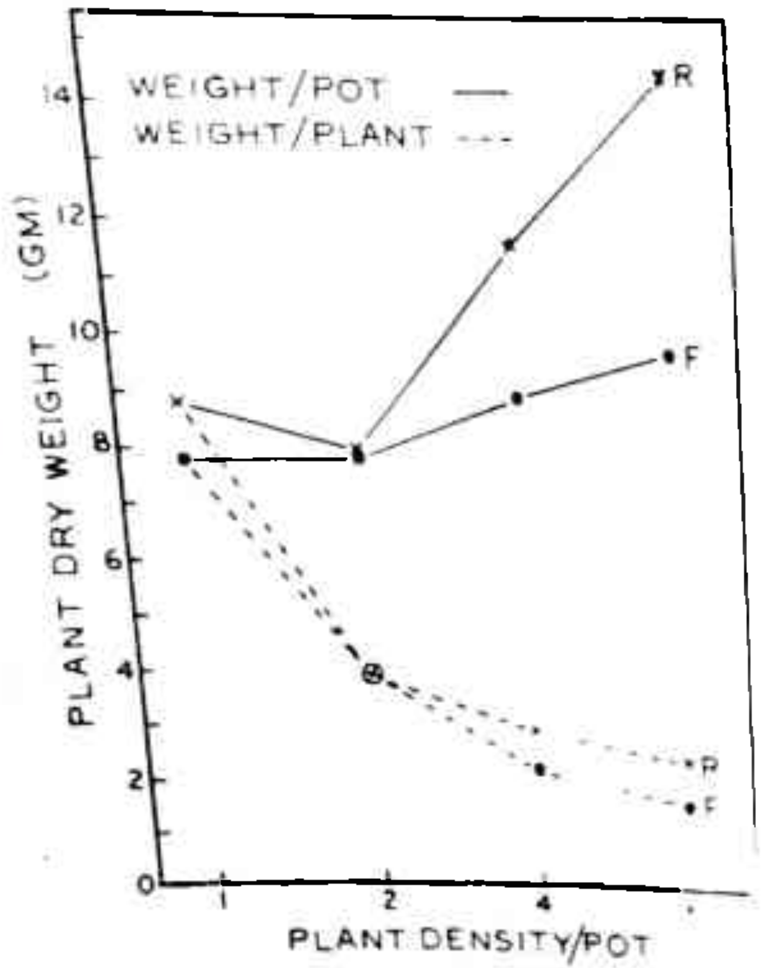


FIG. 12.10

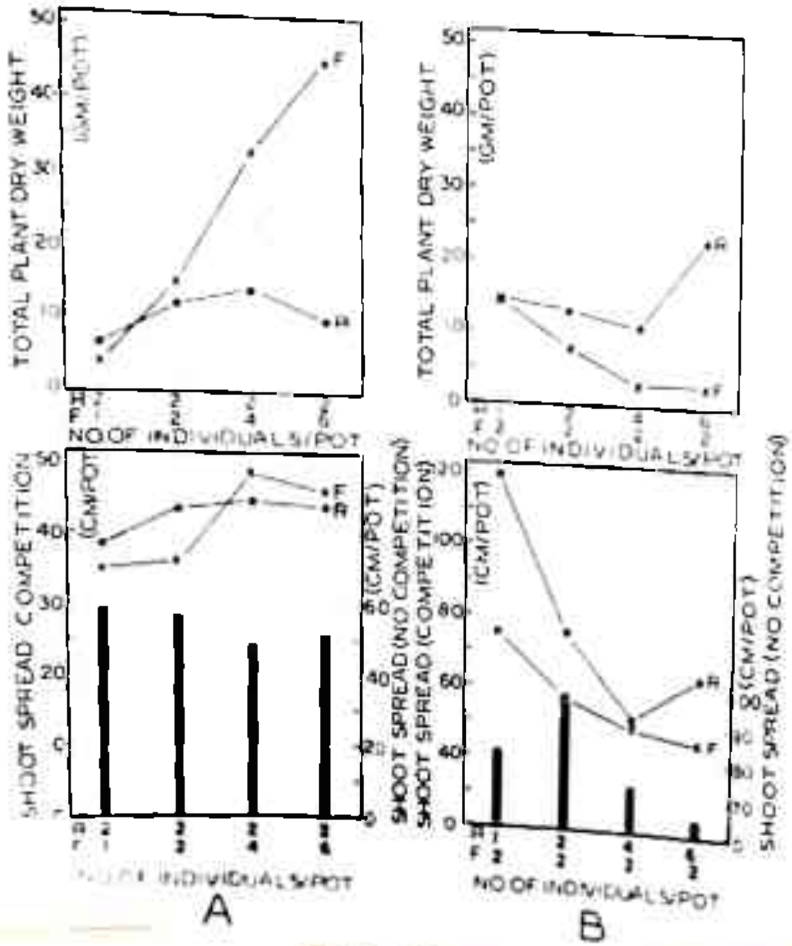


FIG. 12.11

Table 12.5-A: [illegible] the percentage reduction in total plant dry matter production of variety 'rubra' due to presence of variety 'flava'

[illegible]		[illegible] reduction in total plant dry matter production	
[illegible]	[illegible]	'rubra'	'flava'
[illegible]	1	[illegible]	[illegible]
[illegible]	2	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	-19.1	-69.2

Table 12.5-B: [illegible] the percentage reduction in total plant dry matter production variety 'flava' due to presence of variety 'rubra'

No. of plants per pot		[illegible] reduction in total plant dry matter reduction	
'flava'	'rubra'	'flava'	'rubra'
2	1	10.8	-106.8
2	2	50.6	84.1
2	4	78.9	32.7
2	6	79.9	-99.2

DISCUSSION

The influence of intravarietal competition within the two varieties, 'rubra' and 'flava', by increasing the plant density, are clearly demonstrated in morphological features, seed production and dry weights. A marked decline per plant in shoot spread, length and diameter, largest branch and fruits with increasing plant density may be due to overcrowding for limited space. Decreased growth of roots with increasing density indicates the competition for water and nutrients, which is reflected by reduced growth of above ground plant characters and reproductive potentiality during intravarietal competition.

According to Salisbury (1942) an increase in density has been believed to decrease the seed production in a number of species. In both the varieties the seed production is nearly halved when the density is made double. This infers that in S. govindii the magnitude of competition is sufficient to reduce the seed production even if the density is two-plants per pot. In Cassia tora the fruit production has been suppressed only after the density crosses 17 plants/quadrat (Singh, 1969b).

Plant growth progresses through the interaction between physiological functions and environmental factors (Kuroiwa, 1960) and it integrates the situation when plants compete for nutrients, water and light, etc., either simultaneously or in rapid succession (Bleasdale, 1960). The dry matter production or plant weight may be taken as an index of the outcome of competition (Bleasdale, 1960). The present study indicates that dry matter of root, stem and leaves and total plant dry weight per plant decreases but is increased per pot towards the higher plant density in both the varieties. This shows that as the density increases the potentiality of individual plant is decreased due to intra-varietal competition. However, it shows increased production in unit area (more total dry weight at higher densities). Thus, by increasing the density, the values for morphological features and dry matter yield of individual plants are declined. Deleterious effect of higher densities have also been found in

C. tora (Singh, 1969b).

Iwaki (1958) has found that an increased density causes a marked suppression of growth in individual plant weight in Fagopyrum esculentum in intra-specific competition. Growth in total dry weight of individual plants was markedly retarded at higher degree of self shading of leaves and plant density in Helianthus annuus (Hiroi and Monsi, 1966).

F/W ratio is smaller but C/F ratio is increased under higher density. This is due to loss in leaf dry weight (F) which may be attributed partially to the shade at dense planting condition and to the fall of mature leaves. Similar decline at higher density was also observed in Helianthus annuus (Hiroi and Monsi, 1966). In Fagopyrum esculentum an increase in the plant density causes an increase in proportion of dry matter distributed to non-photosynthetic organs (C) at the expense of that used for leaves (Iwaki, 1958). The same fact may be attributed to Z. govindia (Table 12.2) where the value of non-photosynthetic system (root and stem) is higher than that of photosynthetic system (F). Hiroi and Monsi (1966) have noted a loss in C/F ratio in Helianthus annuus at higher density due to deep shade and dense planting condition.

The influence of plant density in relation to inter-varietal competition on growth characters and yield of the two varieties reflects their interesting features and behaviour which effect each other. During inter-varietal competition, when variety 'rubra' is kept constant and variety 'flava' is increased, the growth characters and dry matter yield are increased

(Table 12.3-A) in both the varieties but are decreased (Table 12.3-B) when the condition is reversed ('flava' is constant and 'rubra' is changed). This shows that variety 'rubra' is unaffected on increasing density of 'flava' (Fig. 12.11-A), i.e., the variety 'rubra' is capable to increase its yield even if the density of other variety is increased. On the contrary, the increase in the density of 'rubra' has a deleterious effect on 'flava' (Fig. 12.11-B). This fact may also be supported from the observations taken for percentage reduction in total dry matter (Table 12.4-A, B). A negative percentage reduction in 'rubra' also indicates its better potentiality under inter-varietal competition but this potentiality is increased up to a ratio of 2:4 (-55.6%). On the other hand a positive reduction in 'flava' implies that this variety looses its potentiality under inter-varietal competition. Based on these observations, it may also be argued that variety 'rubra' prefers inter-varietal competition while 'flava' is favoured by intra-varietal competition. It is because the variety 'rubra' is capable to deteriorate the yield of 'flava' even if the later is increased in its density but it is not possible in case of later variety.

In the words of Donald (1963), "One of the species is aggressor, able to exploit more than its 'share' of the factors of the environment, while the other is suppressed because it is able to secure only a lesser part of the light, water and nutrients". McCown and Williams (1968) have found that _Erodium_ is always favoured and _Bromus_ is depressed by the mixture. Based on Donald's expression they conclude that _Erodium_ is the 'aggressor' and that the growth of *Bromus* is lessened by its association with *Erodium*. It may, therefore, be tentatively concluded based on present findings that variety 'rubra' is aggressor, though the causative environmental factor for its superiority, as observed by Donald (1963) and McCown and Williams (1968), could not be studied and are not known.

....

CHAPTER 13

PHYTOCHEMISTRY AND ENERGY RELATIONS

INTRODUCTION

The production of organic substance is the fundamental energy fixing process which supports life on earth (Lieth, 1965). According to Golley (1965) plant pigments and energy contents are attributed under structural features of the community. In net primary productivity, the rate of storage of organic matter in plant tissues in excess of respiration utilization by the plant is considered. It can, therefore, be measured by other indirect methods other than harvesting the plant material, e.g., gaseous exchange, leaf area and chlorophyll content. The determination of calorific values and combustion heat is of great interest for various technical purposes (Lieth, 1965). The radiant energy and CO_2; H_2O, NO_2 and PO_4, together with mineral elements of the protoplasm, are converted to potential energy, O_2 and heat energy. Thus, the mineral elements of the plant are equally important though calorific value is the essential part in productivity studies but academic and practical significance can be obtained if other chemical analyses are performed (Milner and Hughes, 1968). Thus, the estimation of chlorophyll and energy values of a plant reveal the richness of the producer organisms (chiefly green plants). The present chapter contributes to the measurement of chlorophyll content, its corresponding increase by the increase in leaf area and dry weights in the two varieties of Z. govindia. Besides, the estimation of energy values and analysis of chemical composition of the plant ash has also been carried in both the varieties. The differences in the constituting minerals of the two varieties were also found out, for the mineral elements in the foliar part and their corresponding quantity in the soil indicate the nutrientional status of the individual (Lundegardh, 1943).

MATERIALS AND METHODS

i. Chlorophyll:

Sufficient leaves of varieties 'rubra' and 'flava' were separately plucked from the naturally growing plants in garden. In each variety the leaves of different sizes were grouped and outline traced on standard paper. 10 groups were made in each variety based on size differences. The paper was cut out and weighed in torsion balance to determine the area indirectly. This is an attempt to measure the relationship between leaf area and production (Watson, 1958; Takeda, 1961).

In order to find out the effect of increase of leaf area by increasing the number, i.e., amount of leaves on chlorophyll content and also to distinguish the two varieties in their chlorophyll components, the leaves of uniform size and age were plucked early morning from the botanical garden. The leaves were kept in plastic bags in dark card board boxes and stored in refrigerator to minimize the water loss and pigment breakdown. Leaves in two sub-samples were weighed for 1,2,3, 4, and 5 g. as fresh weight. One of the samples was used for the determination of percentage dry weight by drying to a constant weight in an hot air oven at 80°C and the other for

Chlorophyll determination. The later sample was cut into small pieces and crushed in a mortar using acetone as solvent for about 10 minutes to effect the complete extraction of the pigment. The extract, after double filtration by suction, was measured for optical density in a B.L. Spectronic "20" Colorimeter at wavelengths 480, 510, 630, 645, 650 and 665. It was then calculated in milligram/liter by the following formulae:

$$\text{Chl. A mg./1/} = 15.6\ OD_{665} - 2.0\ OD_{645} - 0.8\ OD_{630}$$

$$\text{Carotenoid mg./1/} = 7.6(OD_{480} - 1.49\ OD_{510})$$

Duxbury and Yentsch (1956)

$$\text{Total chlorophyll (A and B) mg./1/} = \frac{OD_{650} \times 1000}{34.5}$$

(Arnon, 1949)

The mean dry weight was converted into leaf area applying the regression equation and the correlations have been estimated for chlorophyll components with dry weight and leaf areas in both the varieties.

ii. Calorific values:

The calorific values of the two varieties have been measured by "Mahler-Cook" Bomb calorimeter (capacity of bomb 425 ml.). The leaves were first dried to a constant weight in a hot air oven at 80°C and then powdered. The material was sieved through a fine mesh and tablets of 1 g. pure material were prepared . The ready-weighed tablet was placed in the Oxygen bomb and burnt within a solid bomb under 30 atm. oxygen pressure. The rise in temperature per minute was read on Beckmann thermometer and the calorific value was calculated in Calorie/g. by the formula:

$$\frac{(2500 + 670)(t^o_2 - t^o_1\ C)}{}$$

t_1 = initial temperature ^oC

t_2 = final temperature ^oC

= weight of material in g.

2500 = weight of water in calorimeter vessel (g.)

670 = water equivalent of Bomb, Thermometer, etc.

iii. Plant composition:

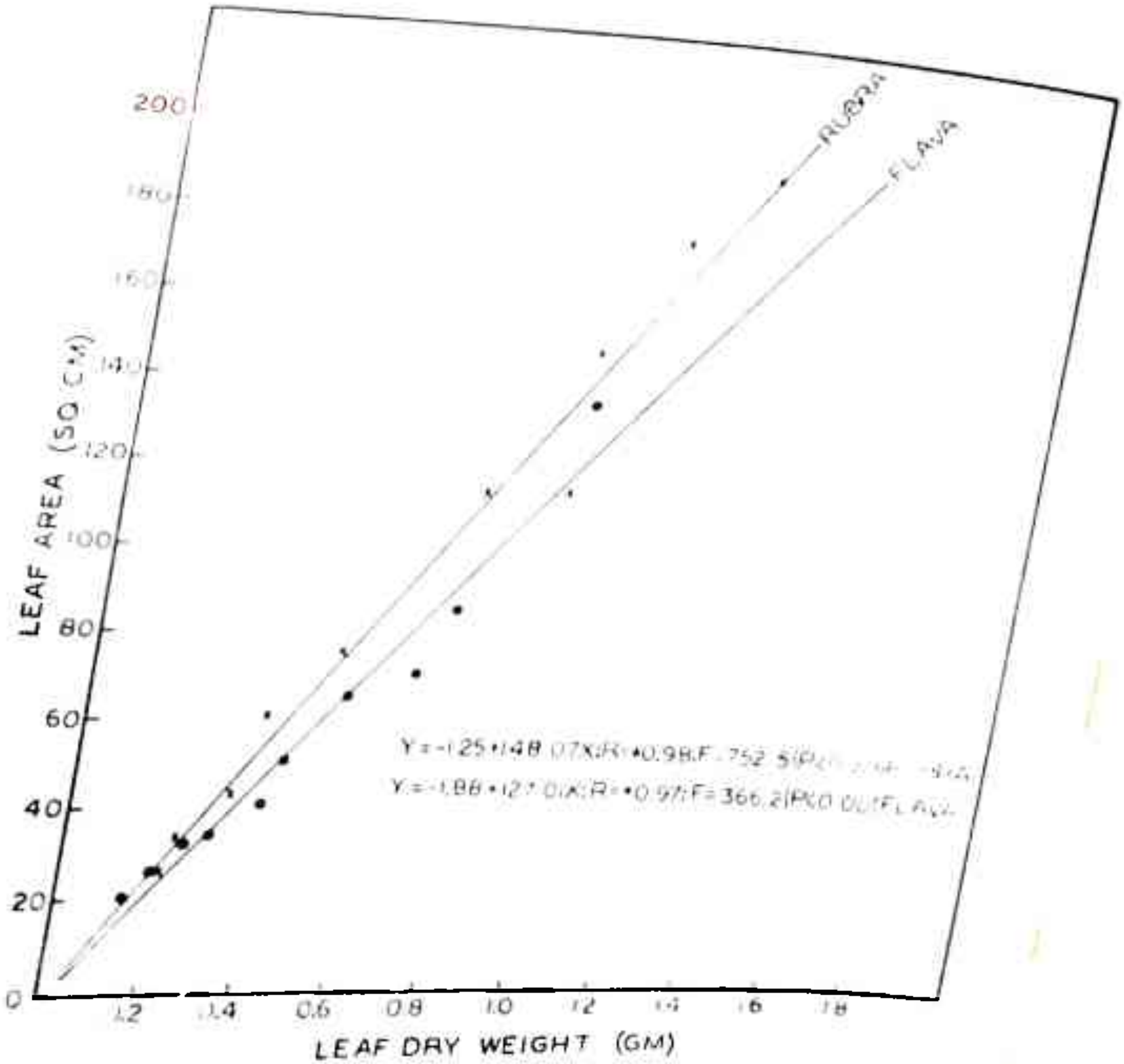
Mature plants of each variety in fruiting stage are collected in morning hours from sites II, III and IV and washed in water tanks to remove the adhering dirt. The healthy leaves were plucked from a number of plants of each site and mixed to get composite samples. They were dried in hot air oven at 80^{o}C and powdered in a mortar. Two sub-samples of 5-6 g. oven dried leaf powder were analysed for carbon, silica, calcium and magnesium by following methods as outlined by Piper (1944) and Puri et al. (1968).

RESULTS AND DISCUSSION

The positive correlation coefficient between leaf dry weight and area is found highly significant in both the varieties (r = +0.98) for 'rubra' and (r = +0.97) for 'flava'. Regression line indicates that variety 'rubra' possesses greater dry weight values than 'flava' for an uniform area (Fig. 13.1). It may also be observed that 100 sq. cm. leaf area of 'rubra' weighs 0.68 g. dry weight to that of 'flava' which is 0.80 g. Thus, the productive value of 'rubra' is more than 'flava'.

Fig. [illegible]. [illegible] tion between leaf [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible]



RUBRA
FLAVA
LEAF AREA (SQ CM)
200
180
160
140
120
100
80
60
40
20
0
.2
.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
LEAF DRY WEIGHT (GM)
Y = -1.25 + 148.07X; R = +0.98; F = 752.5
Y = -1.88 + 127.0 X; R = +0.97; F = 366.2 (P<0.0

FIG. 13.1

Chlorophyll content shows an increase with increase in leaf weight. The correlation between leaf dry weight and total chlorophyll, chlorophyll 'A' and Carotenoid are found highly significant in both the varieties (Fig. 13.2-A,B). The chlorophyll contents are also in significant correlation with the leaf area which have been calculated from regression equations of each variety $Y_r = 1.25 + 148.07X$ for 'rubra' and $Y_f = 1.85 + 127.07X$ for 'flava' (Fig. 13.1). A unit gram of dry leaves of 'rubra' and 'flava' contains 1.75 mg. and 1.04 mg. total chlorophyll respectively. On leaf area basis 'rubra' is found having 5.82 mg./sq.m. total chlorophyll and 'flava' 4.76 mg./sq.m. (Table 13.2). Comparing the values of total chlorophyll on fresh weight basis, *Z. govindia* has higher values than *Typha* and *Borreria* but lower than the locally growing grasses (Table 13.2).

Table 13.1: Showing the regression equation and correlation coefficient values in 'rubra' and 'flava'

Chlorophyll	Dry weight (g.)		Leaf area (sq. cm.)	
	Regression equation	Correlation coefficient	Regression equation	Correlation coefficient
'rubra'				
Chlorophyll 'A' (mg./l.)	Y=-0.006+5.847X	0.993	Y=0.043+0.039X	0.993
Total chlorophyll (mg./l.)	Y=0.199+7.670X	0.994	Y=0.264+0.051X	0.994
Carotenoid (mg./l.)	Y=0.000+1.205X	0.998	Y=0.010+0.006X	0.998
'flava'				
Chlorophyll 'A' (mg./l.)	Y=0.059+4.827X	0.993	Y=0.432+0.027X	0.918
Total Chlorophyll (mg./l.)	Y=0.396+7.582X	0.993	Y=0.508+0.059X	0.993
Carotenoid (mg./l.)	Y=-0.003+0.832X	0.979	Y=0.009+0.006X	0.979

X = Dry weight Y = Chlorophyll

Fig. 13.[illegible]- Correlation between [illegible] and

chlorophyll content in 'ruby[illegible]'.

Fig. 13.[illegible]-B Correlation between le[illegible] dry [illegible] and

chlorophyll content in 'Cl[illegible]'.

FLAVA

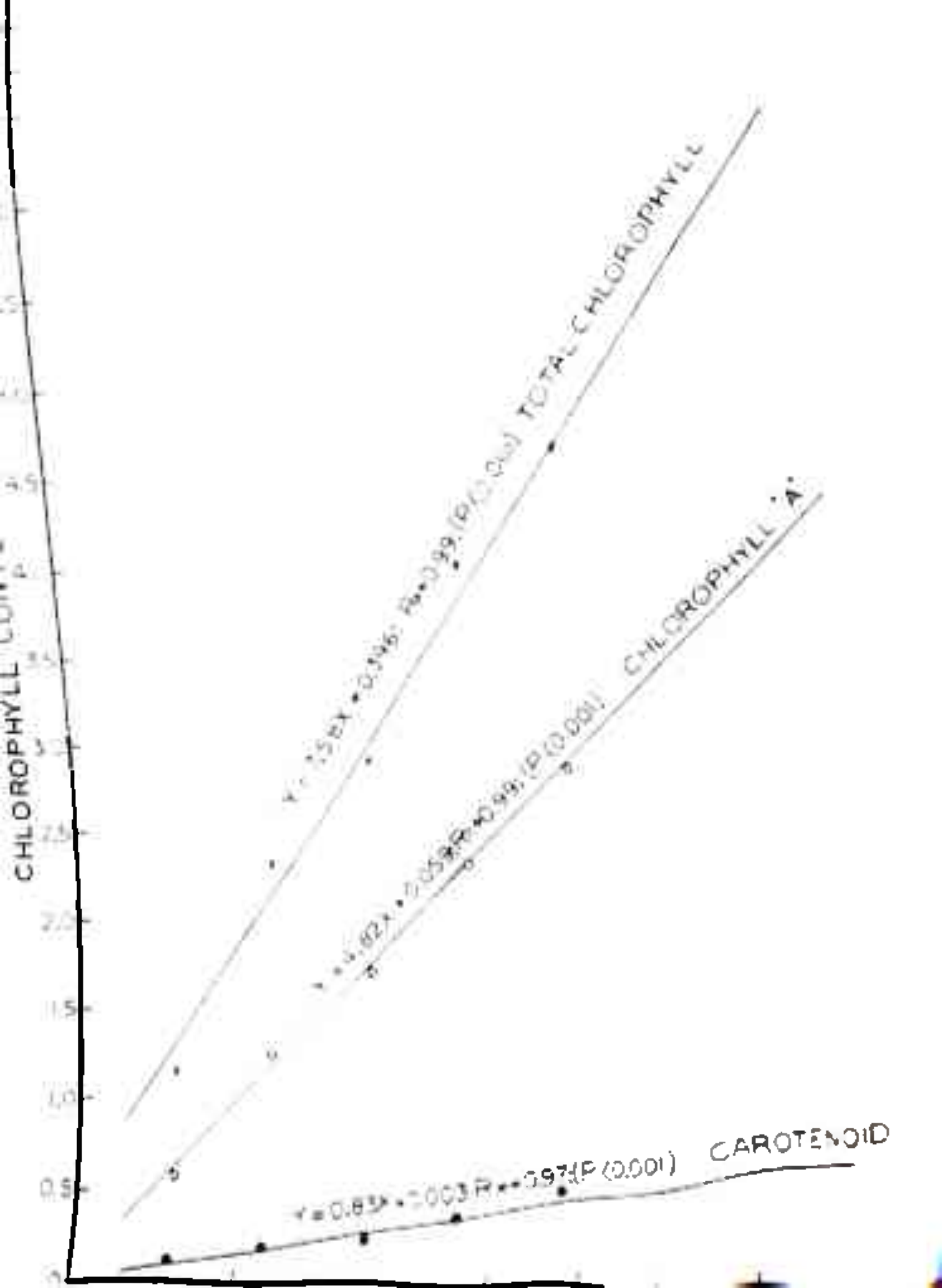

CHLOROPHYLL CONT
TOTAL CHLOROPHYLL
CHLOROPHYLL 'A'
CAROTENOID
0.5
1.0
1.5
2.0
2.5
4.5

Table 13.2: Showing the chlorophyll in two varieties of *Z. govindia* and its comparison with the values of other species

Species	Chl. A	Chl. A+B	Chl. A+B	Chl. A+B	Place	Investigator
Unit	$mg.\ gm.^{-1}$	$mg.\ gm.^{-1}$	$mg.sq.m.^{-1}$	$mg.\ gm.^{-1}$		
	Dry wt. basis	Dry wt. basis	Area basis	Fresh wt. basis		
'rubra'	1.261	1.748	5.82	1.25	Rajasthan, India	Present work
'flava'	0.595	1.038	4.76	1.00	Rajasthan, India.	Present work
Borreria articularis				1.079	Rajasthan, India	Ramesh Babu (1970)
Typha latifolia				0.601-1.05	North America	McNaughton (1966)
T. angustifolia				0.811-0.895	North America	McNaughton (")
T. domingensis				0.360-0.641	North America	McNaughton (")
Dactyloctenium aegyptium				1.44-2.745	Rajasthan, India	Arun Kumar (1970)
Cenchrus biflorus				1.44-2.89	Rajasthan, India	Arun Kumar (1970)
C. ciliaris				1.54-1.96	Rajasthan, India	Arun Kumar (1970)

The calorific value ranges from 4.259 to 4.479 Kcal./g. in 'rubra' and 4.171 to 4.286 in 'flava'. These values are comparable to many herbaceous plants (Table 13.3). The calorific value of *Z. govindia* is quite higher than many herbaceous species, e.g., *Solanum tuberosum*, *Helianthus annuus*, *Phaseolus vulgaris* and *Zea mays*. On the contrary, species like *Borreria articularis*, *Chenopodium album*, *Setaria glauca* and *Digitaria sanguinalis* bear higher values than the two species of *Zaleya*.

Table 13.3: Showing the caloric values of 'rubra' and 'flava' and comparison with other herbaceous plants (Lieth, 1965)

Name of the species	Place and region	Investigator	Caloric value (Kcal./gm. dry weight)
Z. govindia 'rubra'	Rajasthan India.	Present work	4.259-4.479
Z. govindia 'flava'	Rajasthan India	Present work	4.171-4.286
Borreria articularis	Rajasthan India.	Ramesh Babu (1970)	4.184-4.358
Chenopodium album	New Jersey	Botkin and Malone ([illegible])	[illegible]
Setaria glauca	New Jersey	Botkin and Malone (1968)	[illegible]
Digitaria sanguinalis	New Jersey	Botkin and Malone (1966)	4.63
Solanum tuberosum	North America	Long (1934)	3.4-3.8
Helianthus annuus	North America	Long (1934)	4.3
Phaseolus vulgaris	Germany	Pflanz (1964)	3.8-4.0
Helianthus annuus	Germany	Lieth (1965)	4.3
Zea mays	Germany	Lieth (1965)	4.2

The plant ash analysis indicates that the percentage of carbon, silica, calcium and magnesium varies in individual variety and also from site to site in the two varieties. The plants are rich in these elements on site II. However, the amount of calcium in 'flava' is more than 'rubra' in all the sites (Table 13.4).

Table 13.4: Showing the percentage of carbon, silica, calcium, magnesium and nitrogen in the leaves of 'rubra' and 'flava' of different sites

Sites	II		III		IV	
Foliar constituents	'rubra'	'flava'	'rubra'	'flava'	'rubra'	'flava'
Carbon (%)	26.37	25.43	22.66	24.05	19.73	20.29
Silica (%)	2.04	5.33	1.55	1.64	2.02	4.12
Calcium (%)	0.14	1.35	0.10	0.81	0.08	0.10
Magnesium(%)	0.56	1.44	0.58	0.53	0.14	0.63
Nitrogen (%)	3.56	4.14	3.87	3.99	3.98	4.32
C/N Ratio	7.4	6.1	5.8	6.0	4.9	4.7

The composition of plant ash varies with the species and with the environmental conditions (Meyer et al, 1960). According to Puri et al. (1968), the chemical composition of the plant is affected both by hereditary-physiology environmental factor and the chemical composition of leaves reveal interesting relationship to the environment of the plant. Similar facts are also revealed by the phytochemical studies in the two varieties of *L. govindia*.

The study of the constituting elements of the dominant species in arid and semi-arid regions of Rajasthan are lacking except in *Prosopis spicigera* Linn. (Sharma, 1966) and *Aerva* [illegible] Spreng. (Sharma, 1967). The plant nutrient [illegible]

status and the [illegible] *javanica* may be compared with [illegible]

[illegible] of *Zaleya govindia* are rich in carbon and

Both the [illegible] in calcium and magnesium values. The

[illegible] shows slight differences. In case of C/N

percentage o[illegible] the varieties, being rich in nitrogen, possess

ratio. [illegible] *Aerva javanica*. However, both the varieties

[illegible] have significant positive correlation between

of [illegible] calcium and leaf calcium (Table [illegible]

[illegible] noted in *Aerva javanica* (Sharma, 1967).

[illegible] foliar calcium increases with the

increase [illegible] soil calcium in exchangeable form.

[illegible] the correlation coefficient (r), [illegible] between soil exchangeable [illegible] (X) and leaf calcium (Y).

Variety	[illegible] (r)	[illegible] (per cent)	[illegible] (m.g. [illegible])
'rubra'	+0.93	27.12*	Y = -0.132+0.022X
'flava'	+0.96	50.01***	Y = -1.531+0.143X

D.F. treatment [illegible]
D.F. error [illegible]

* Significant
** Very significant
*** Highly significant

CHAPTER 14

GENERAL SUMMARY

Indian pentandrous species (Zaleya govindia) has been found different from that of African species (Trianthema pentandra) in their distribution and also in the structure and form of operculum. Nair (1966) has finally established the Indian genus Trianthema as Zaleya with 3 new combinations.

Zaleya govindia shows a wide geographic range. It has been recorded from latitude 11° (Coimbatore) to 33°.37'N (Rawalpindi) and longitude 67°.4' (Karachi) to 84°.25'E (Aurangabad). The plant shows its preference towards the arid environment, as it has been recorded from most of the sub-physiographic zones of India and is in abundance in western sandy arid and semi-arid transitional plain of Rajasthan, roughly falling between 25° and 30°N latitude and 70° and 78°E longitude. With regard to different environmental factors like rainfall, temperature and soil, the plant has a wide range of tolerance and withstands extremes of temperature and low rain-fall. It shows maximum affinity towards desert soil though it has been recorded on different types of soils.

The two varieties 'rubra' and 'flava' are more or less similar in general morphological features but differ in certain characters from site to site. Though the plant is available throughout the year by means of perennating root stalks, yet at various times in its life cycle faces the attack of Cuscuta, Coleopteran larva and certain root nematodes which reduce the photosynthetic efficiency, seed output and food translocation respectively.

Species composition is noted to be affected by the habitat conditions like biotic disturbances and to some extent by the moisture and nutrient status of the soil. Dominant species like *Tribulus terrestris* and *Dactyloctenium aegyptium* are found to be associated with *Zaleya govindia* to compete in all the sites. The two varieties, under present investigation, are suppressed at the initial stage but in later stages, they being perennial, dominate. However, the inter-varietal competition cannot be ruled out as both of them occur and grow simultaneously in most of the sites. In the present investigation, factors like soil moisture, pH and nitrogen content of the site could not be related to the occurrence of the two varieties of *Z. govindia* but a positive correlation was found with calcium content and silt and clay for 'flava' and with fine sand for 'rubra'. Site II, having moderately higher values for these features, could support both the varieties with least differences.

Further, a study of both the varieties for their growth behaviour (Length of branch, dry weights of root and shoot) in relation to calcium carbonate and exchangeable calcium, as estimated from the region of profuse growth of root, was significant and positively correlated up to a certain limit for individual variety. This was again confirmed by culture studies where the individual variety declined in growth beyond their specific tolerance range for calcium carbonate and exchangeable calcium.

Both the varieties have high fruit production but the number of viable seed is considerably low due to the infection of Coleopteran larvae. However, the infection was comparatively low in protected sites. Mature seeds are found more in plants growing in open situation than in shade. This is probably due to the slow growth in shade (being a true heliophyte) and so the maturation of seed. Seed dispersal is activated by agencies like goat, sheep, cow and buffalo and also by man who uses it for medicinal purposes. Seeds show primary dormancy due to seed coat. It could be overcome by allowing water imbibition for long duration, treatment of sulphuric acid with lower concentration and washing in running water. Temperature superimposes the germination facilitated by washing. A combination of 20-hour cold (15°C) and 4-hour high temperature (35°C) is found most favourable for germination, which is quite possible in nature. Seeds do not germinate in nature when the atmospheric temperature is not suitable to the germinating embryo. Germination of seed is also not favoured during extreme winter as indicated in stored seeds where they seem to acquire a secondary dormancy due to unfavourable germination condition. Maximum germination is favoured within 30° to 35°C. It declines with the increase in temperature as is reported in several other arid zone species, e.g., <u>Launaea glomerata</u> and <u>L. mucronata</u> (Datta, 1965). Besides, the intermittent germination is also favoured in desert situation when the temperature fluctuates quite often diurnally.

In adverse situations, <u>Z. govindia</u> reduces the evaporation of water from the leaf surface by reducing the surface of total leaves in plant. This condition is met either by reducing the size of leaf (microphylly) or by shedding the leaves or both. The reduction in leaf area is found to vary from season to season which is about 54% from growing to winter season and 77% from growing to summer season. In adverse condition, the reduction in leaf area decreases the leaf water content and so the increase in osmotic and water potential values. A water deficit of 24% during October (growing season) does not affect the transpiration rate because the curves for stomatal transpiration and evaporation roughly follow each other. In January (winter season), the water deficit is increased (up to 34%) and so the decrease in transpiration. The latter is partially controlled by the partial reduction in the stomatal aperture, differences in atmospheric temperature and humidity and insufficient soil moisture as compared to growing season. Water deficit is further increased (41.5%) in June (summer season) and the transpiration is reduced by early closure of stomata under high evaporation and water stress condition. 45.52% stomatal closure does not appear to effect the transpiration during summer in morning hours but their complete closure by midday hours, when the plant is at still higher water deficit, help the plant to check the water loss. Thus, except for favourable situations (growing as well as winter), the stomata not only help but certainly act as a safety device to regulate and reduce the transpiration in unfavourable conditions during summer. A soil moisture potential range of -2.5 to -7.0 atm. (during October) is found favourable for _Z. govindia_ and a range of -6.5 to -15.0 atm. (during January) also does not harm the plant's water balance. However, in a range of -18.0 to -27.0 atm. (during June) being quite close to leaf water potential, the plant is observed to suffer water deficiency. Increase in osmotic potential under drier conditi... is also noted in Z. govindia. Plants under such situation without showing their physical death may, therefore, be well suited to xeric environment. Thus, the plants have to tide over such situations due to increase in summer temperature (47.6°C) which is conditioned by low water content in plants and high water tension in soil. The plant meets such a deficiency and compensates it by developing small leaves. Thus, Zaleya plants exhibit seasonal diamorphism in leaves and develop drought resistance mechanism.

Five species, i.e., E. thymifolia, T. terrestris, Z. govindia 'rubra', B. ramosa and D. aegyptium are most dominant species (1 g./sq.m./year) and contribute maximum in herbage production. The species, which contribute maximum towards the peak standing crop, are in the order of D. aegyptium > variety 'flava' > variety 'rubra' > T. terrestris, the values being 26.9, 16.8, 14.7 and 9.6% respectively. The same species contribute maximum towards the peak standing above-ground biomass. Maximum above-ground biomass is found in October in most of the sites (211.73 and 211.06 g./sq.m. on III and IV respectively). This contribution is maximum by 'flava' on site III (9.6%) and D. aegyptium on site IV (34.7%). However, maximum standing green biomass is observed in September after rains. Fluctuation in biomass on different sites is mainly subjected to biotic disturbances coupled with availability of soil moisture. Maximum under-ground biomass is found on site IV due to more perennial herbs and sedges. Both 'rubra' and 'flava'

Varieties contribute considerably high values towards above- and under-ground biomass on sites III and IV, but the biotic pressure reduces the values more on site IV. Features like over-grazing deteriorate the production and [illegible] sweeping of dunes leads to poor nutrient status of dune soils. *D. aegyptium* is found to suppress the productivity potential of both the varieties of *Z. govindia* in the initial stages. However, the plant compensates this loss at a later stage. Factors like soil calcium content, soil nutrient status, species diversity and preponderance of perennial species also influence the productivity of the site. In off season, the two varieties continue growing, though slow, due to deep seated roots.

Both the varieties show parallel growth but 'rubra' possesses higher values than 'flava'. Both exhibit a decline in leaf weight after 3rd harvest followed by an increase. Variety 'flava' shows lower rate of dry matter production. RGR is found initially high which decreases in both the varieties by self-shading of leaves of individual plant. Net assimilation rate and MLWR, which are initially high, continuously decline. Plants grown at 25% light intensity show marked decrease in their morphological characters and total dry weight values as compared to those grown at 100% light.

In both the varieties during intra-varietal competition, the values for morphological character and dry weight, decline on per plant basis but an increase is noted on per pot basis towards higher plant density. The F/W ratio decreases whereas C/F ratio increases towards higher density. During inter-varietal competition, with a fixed density of 'rubra', the

Values for shoot spread and seed number per pot increase up to a density ratio of 2:4 and then decline in both the varieties. When the density of 'flava' is fixed, it declines throughout but the values of 'rubra' decrease up to a ratio of 2:4 and then increase. Similar behaviour is noted in dry weight values. The percentage reduction in dry matter production is found negative for 'rubra' but positive for 'flava' when the density per pot was changed for 'flava' and 'rubra' respectively.

Plant chlorophyll and calorific values are higher in 'rubra' than in 'flava'. Similar are the findings in case of foliar analysis for chemical elements. Variety 'rubra' possesses higher percentage values than that of 'flava' in all the constituting elements analysed in the present investigation. Besides, the foliar calcium has been found in positive correlation with soil exchangeable calcium.

In view of the present findings it is clear that *I. govindia* passes through many hardships round the year in its life cycle. In spite of having large seed production, it has developed perennating habit. Seed infection by coleopteran larvae and the attack of *Cuscutta* are the susceptible factors in keeping the continuity of the life of this plant. However, the perennating root system keeps the plant existing in all the adverse situations of the habitat. The physiology of the plant is found well regulated where it struggles and survives under desert conditions. Water loss from evaporating surface is checked and regulated by the stomatal opening, while a high osmotic potential in the leaves is capable to draw the water from deeper regions through the deep seated roots. Survival of *Quercus*, *Juglancs*, *Gleditsia* and *Maclura* under extreme drought is attributed to their deeply penetrating root systems (cf. Kozlowski, 1964). Thus the preponderance of *Z. govindia* in different habitats is regulated by the natural fluctuations in the environmental conditions, which check the seed germination in unsuitable conditions.

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ABBREVIATIONS

A	abundance
AV.	average
AG.	aboveground
atm.	atmosphere
cm.	centimeter/s
°C.	degree centigrade
dm.	decimeter/s
D	density
D.P.D.	diffusion-pressure deficit (atm.)
e.g.	for example
F	variance ratio, frequency
'f'	'flava'
g./gm.	gram/s
g./sq.m.	gram/s per square metre
h.,hr.	hour/s
i.e.	that is
Kcal.	Kilocalorie
l.	liter/s
m.	metre/s
mg.	milligram/s
mm.	millimetre/s
ml.	milliliter/s
m.e.	milliequivalent
NS	non significant
NCP/N.C.P.	net community production
O.D.	optical density
O.P.	osmotic potential (atm.)
PSC/P.S.C.	peak standing crop
R/r	regression coefficient
RD	relative density
R_1, R_2...	replicates
'r'	'rubra'
S.D.	standard deviation
SD	standing dead
S.C.	standing crop
S.G.	standing green
sq.	square
T	temperature
't'	't' test
UG	underground
v./vs.	versus, against
viz.	namely
W.P.	water potential (atm.)
W.S.D./W.D.	water saturation deficit (%)
wt.	weight