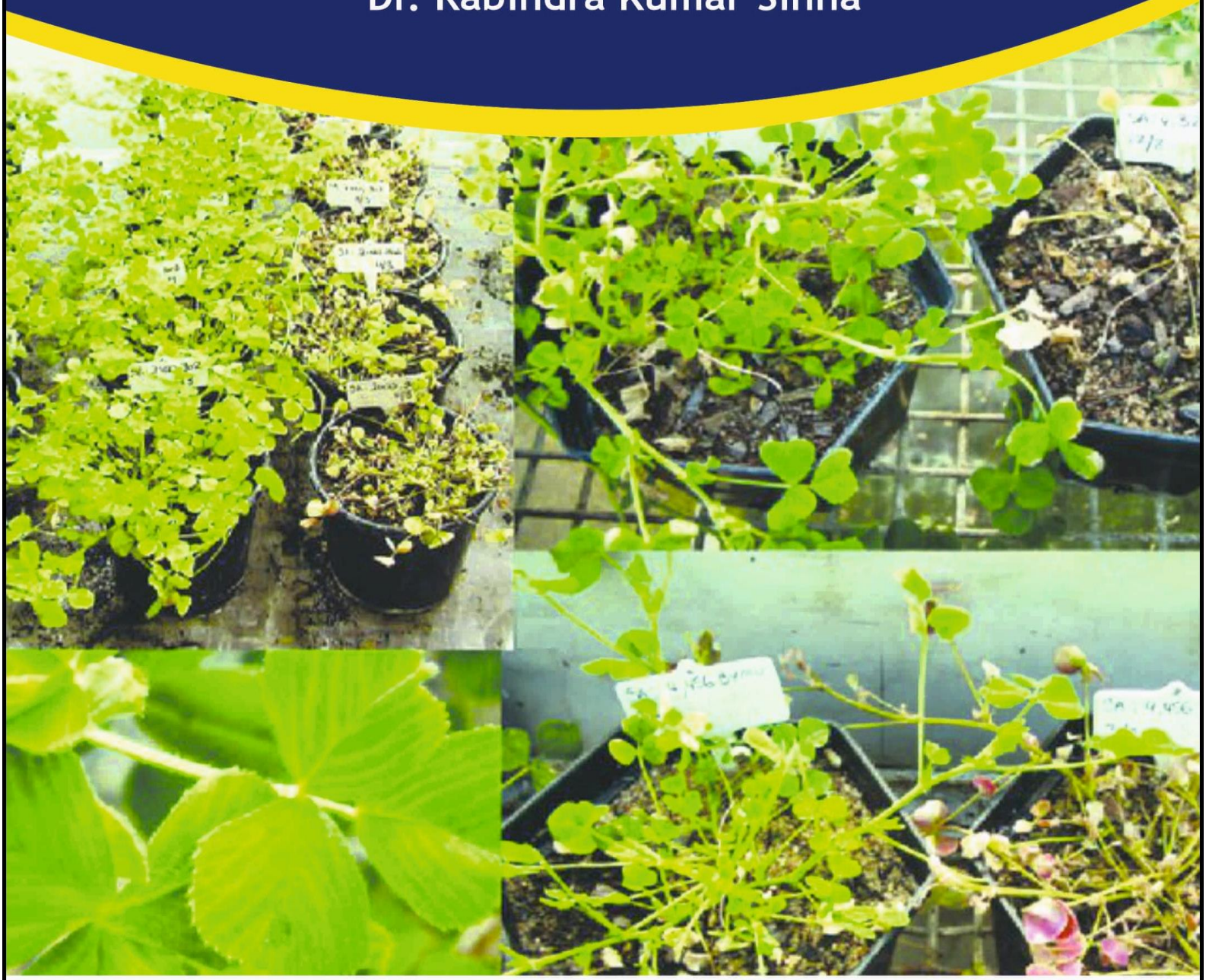
AN INTRODUCTION TO COMPARATIVE BIOLOGY WITH SPECIAL REFERENCE TO MEDICAGO SPP

Dr. Rabindra Kumar Sinha



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INDEX

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Chapter 1

Introduction

1.1 Introduction:

The environment is a complex whole of so many interacting factors. These factors influence every plant and animal species. It is the that genotype determines the range of phenotypic expression. The phenotypic expression of a specific genotype may have some variabilities with regard to different sets of environmental complexes. These phenotypes are objects of immediate concern to taxonomists because of taxa are shaped along the lines of discontinuity of phenotypic characters. Therefore, it becomes worthwhile to examine the nature of adaptation in the light of the physiological effect of the environmental factors. In recent years' attention has been paid to visualize the interrelationships of plant and environment in order to understand their comparative performance which is of great survival value of a species. In such comparative studies, adaptations which enable the species to cope with the environmental fluctuations are looked into. Though such adaptations are genetically determined, their ontogenetic manifestations are influenced by the factors of environment, the magnitude of which determines the ecological amplitude of a species. The fitness of a genotype is directly related to the contribution of its phenotype made to the gene pool of its future generation while interacting with environmental factors. Once it is realized that the success of gene transmission depends upon the interactions between phenotype and its environment then it becomes important to know that why certain phenotypes are better than others in a given environmental condition. This way comparative biologists consider the fitness of a species and is referred to as an adaptational approach.

The technique of comparative culture was first introduced by De Candolle and his contemporaries in the nineteenth century. With the emergence of growth analysis concept (Briggs et.al., 1920; Gergory, 1926) crop physiologists started to judge the performance of crop throughout the season in terms of MRGR (Sinha, 1968, 71; Pandey & Sinha, 1977, 1979, a, b; Parsons & Hunt, 1981; porter, 1983, a, b; Wlodzierz et.al., 1984). Johnson (1985) have used several parameters of growth and morphogenesis for this purpose. Montieth et.al. (1983) designed greenhouse in which almost all variables of the environment can be altered as will without sacrificing the natural growing conditions of the plant.

Such type of comparative studies of a closely allied taxa are also helpful to the experimental taxonomists. Harper (1961), whitehead & Myerscough (1962), Heslop-Harrison (1964), Snaydon (1973); Pandey and Sinha (1977) have stressed the importance of inter specific relationship of taxa for having an insight into their adaptability.

They also considered it as new tool for the modern taxonomy. In such studies the behavior of a species is observed in terms of various growth parameters (RGR, NAR, LAR, SLA, LWR, '$\propto$' and R/S ratio) by experimentally allowing a few of environmental factors to vary while rest are kept constant. These experiments are conducted in controlled or semi-controlled environments.

The present investigation has been carried out under semi-controlled conditions where a few of the variables of the environment have been allowed to vary at will at a time and all others were kept more or less constant.

The three **Medicago** spp i.e., **M. Sativa** L., M. **Lupulina** L. and **M. dentculata** willed have been selected for the study. The germination behavior of a species is also a part of comparative biology. Hence the germination behavior of all the three species mentioned above were studied. However, for growth studies in terms of some well-established parameters of growth only two of them i.e., **M. Sativa** and **M. Lupulina** were selected for the reasons mentioned below: -

A. **M. Sativa** is a perennial plant and cultivated for its medicinal value. It is also used as fodder.
B. M. lupulina is an annual. It grows as weeds and is cultivated as well for fodder.
C. M. Lupulina have good representation in the local flora.
D. Both of them have quick regeneration and shorter life-cycle.
E. The have autogamous, self- pollinated flowers.
F. They are also utilized as source of nitrogen-fixation and soil binders.
G. They are leguminous plants and the experts in the genetic engineering are trying to transfer nitrogen fixing genes to non-leguminous plants.

Medicago sativa, also known as alfalfa, Lucerne is an erect perennial plant. The average life span ranges from five to seven years. The plant is cultivated for its medicinal value. It is also as fodder in Californian area of the United States.
M. lupulina also known as black medick, yellow Trefoil and hop clover is usually annual sometimes perennial. The Plant is a native of Eurasia. Presently it is found throughout the greater parts of the United States and other temperate regions where it occurs in fields and waste place. It has some promises as a green manure and is used as fodder as well.
Literature cited reveals that following studies on these species of **Medicago** have been made:
Germination behavior of Medicago tribuloides in relation to water potential (Collis-George & Sands, 1959); effect of salinity on nodulation, nitrogen fixation and growth of soyabeans and alfalfa (Bernstein & Otaga, 1966); Nudulation of **Medicago Sativa** in solution culture (Muns, 1968); specific leaf weight and photosynthesis in alfalfa (Carlson et.al. 1969).; Stomatal density of alfalfa (M. Sativa L., Cole & Dorbrenz, 1970); some aspects in the ecology of black madick (M. lupulina L. -Sidhu, 1971); Maturity- dormancy relationships in attached and detached seeds of **Medicago lupulina** L. (Black medick- Sidhu & Covers, 1977); Morphological characteristics of alfalfa plants grown at several temperatures (Bula, 1972); Cytogenetic research on hexaploid alfalfa, **Medicago sativa** L. (Mariani, 1975); Nitrogen fixation, nodules development and vegetative regrowth of alfalfa **Medicago sativa** L. following harvest (Vince et.al., 1979); seasonal variation in photosynthesis, respiration and growth componants of non-dormat alfalfa (M. Sativa L.- Delaney et.al., 1974); Structure of floral nectarines of alfalfa (**Medicago sativa** L.) in relation to necter production (Tuber et.al., 1980); relationship between apparent nitrogen fixation and carbon exchange rate in alfalfa (Sheehy et.al., 1980);
Tricin from alfalfa, isolation and physiological activities (Bickoff et.al., (1964); the effect of environment on the growth of alfalfa (Christian, 1977); growth and reproductive development of alfalfa as influenced by 2,3,5- Triideobenzoic acid (Phillips & Chilcote, 1981);
A numerical analysis of major groupings in **Medicago** employing traditionally used characters (Small, 1981); the taxonomic value of floral characters in tribe Trigonellae (Leguminousae) with special reference to **Medicago** (Small, 1981);

Flavinoids of the genus **Medicago** (Classen, 1981); remarkable assymetrics in trifoliate leaves with particular reference to Medicago (Small, 1981); growth and photosynthate partitioning in alfalfa under eight temperature- photosynthetic period combination (Chatterson & Carlson, 1981); Potassium response of alfalfa in solution and sand culture (Romero et.al., 1981); some aspects of the autecology and population biology of black medick (**M.Lipulina** L.- Pavone, 1981); a phenolic -taxometric study of Medicago (Classen et.al., 1982); character set in congruence in **Medicago** (Small et.al., 1982); effect of root environment on the kinetics of the first month growth and nodulation of alfalfa (Macdowell, 1982); the dynamics of seed bank size and seed state of M. lupulina (Pavone & Reader, 1982); Kinetics of first cutting, regrowth of alfalfa plants and nitrogenase activity in a controlled environment with and without added nitrate (Macdowell, 1983); light and electron microscopy of embryo development in perennial and annual Medicago spp (Sangduen et.al., 1983) and frequency and grouping of vessel ending in alfalfa (Medicago sativa L. - Wiebel et.al, 1984).

Thus, it appears that a lot of work on **Medicago** spp has been done. Most of the works on **Medicago** spp specially **M. Sativa** has not been mentioned here. The review of literature reveals that no work has been done pertaining to comparative biology of **Medicago** spp with reference to some well-established parameters of growth. In order to fulfil the requirements of autecological studies on two **Medicago** spp, experiments were designed in laboratory, glasshouse and growth chamber under various ecophysiological conditions. Effort was also made to analyse and assess the optimal conditions of establishment of the species in their natural habitat. In the chapters to follow an attempt has been made to ascertain the relative ecological amplitude of the species to various fluctuations in the environmental and adaphic factors. The different growth parameters used are dry wt accumulation, mean leaf area, relative growth rate (RGR), Net assimilation rate (NAR), Leaf area ratio (LAR), specific leaf area (SLA), leaf wt ratio (LWR) and 'alpha' ($\propto$).

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Chapter 2

Materials and Methods

Figure 2.1: Medicago Sativa L.

Figure 2.2: (a) Medicago Lupulina L.

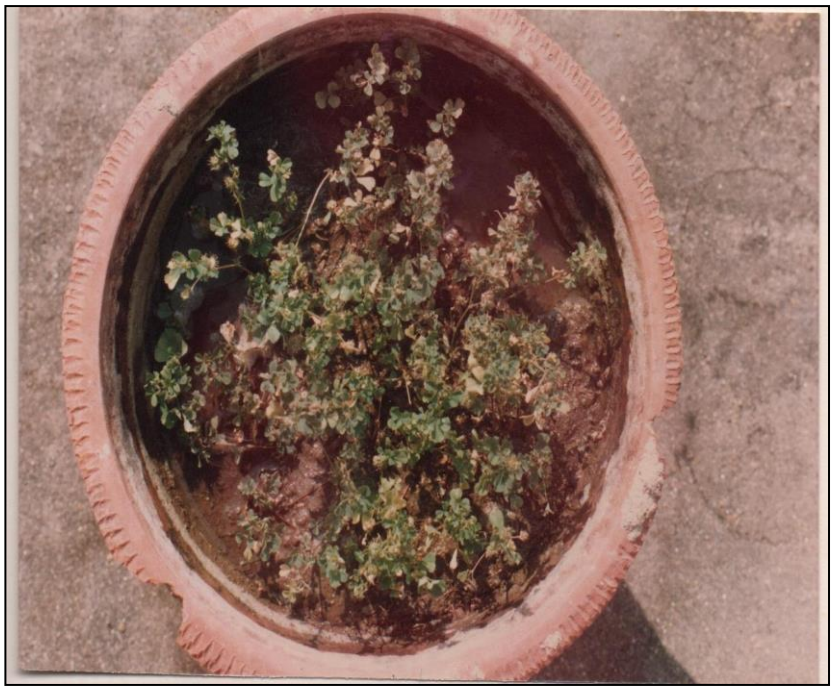

Figure 2.2: (b) Medicago denticulate Willd.

2.1 Introduction:

Fabaceae is a very important family from the view point of self-pollinated flowers and nitrogen fixation. It occupies a vital position in crop plants due to having almost all pulses under this family. The genus **Medicago** is an important member of this family due to its agricultural, industrial and medicinal value. Alfalfa produced from one of the species of **Medicago** (M. sativa). It is used as fodder and can also be used as source of nitrogen fertilizer. Since it is a leguminous plant the experts in agriculture and genetic engineering are trying to transfer nitrogen fixing genes to non-leguminous plants.

In the present study three species of **Medicago** i.e.M. Sativa L., **M. Lupulina** L. and **M. denticulate** willd. Were selected. All of them mainly grow as annual and perennial throughout in Bihar except **M. Sativa**. The seeds of **M. Sativa** L. were procured from Indian Grassland and Fodder Research Institute, Jhanshi, while that of **M. denticulate** Willd. and **M. lupulina** were collected locally. The salient features of Medicago species are as follows:

Table 2.1: Materials and Methods

Sl.No.	Characters	Name of Species		
		M. sativa	M. lupulina	M. denticulate
1.	Nature of plants.	Sub-erect perennial	Diffuse annual	Diffuse annual
2.	Height.	30-60cm branched	Procumbent with pubescent branchese 7.62 - 15cm	Glabrous herb with prostrate branches 5-15cm long.
3.	Leaflets	Narrow, oblong with cuneate base to obovate- bolancedate with sharp teeth 1.25-3.17cm	leaflets obovate or cuneate, obocordate 0.45-1cm	leaflets obovate or obcuneate, sometimes retuse at the apex 1.25cm long, petiole slender 2.54 cm, stipules laciniute.
4.	Flower colour	Light violet	Yellow	Yellow
5.	Pod	Unarmed, silky forming a complete loop or a double spiral, no intramarginal nerve parallel to the suture	Pod in bunch very small, subglobose reniform, with tip coiled	Pod toothed subglobose spiral, muricate with strong nerves running parallel to marging, face reticulate
6.	Pod colour	Brownish	Black	Greyish

Sl.No.	Characters	Name of Species		
		M. sativa	**M. lupulina**	**M. denticulate**
7.	No. of seeds/fruit	2-4	1	2-5
8.	Wt of 100 seeds in gm	0.3345gm	0.1052gm	0.32gm
9.	Cultivation	Cultivated	Weed	weed
10.	Economic importance	As a fodder, as vegetables of premature plants by tribals, as nerve tonic in homeopath/ Ayurvedic system	as fodder	as fodder

2.2 Germinaation:

In all the germination experiment the seeds were first surface sterilized with 0.2@ mercuric chloride to save them from surface borne pathogens. The seeds were germinated in sterilized petridishes of 9cm diameter on single layer filter paper. The filter paper was backed with thin and uniform layer of cotton wool. The filter paper was moistened with distilled water in all experiments except pH. Healthy seeds ot same size and age were selected manually. Fifty seeds were placed in each Petridis and three such replicates were maintained for each treatment. In most of the experiments the seeds were germinated in diffuse day light and at the temperature range of $25+2^0$C in Experimental Taxonomy Laboratory of the Botany Department, Patna University. Some of the experiments like effect of photo period and temperature was carried out in the Seed germinator. Whenever darkness was required the petridishes were kept in light proof cardboard boxes. Emergence of 1mm of radical in the seeds was germinated. In some of the experiments seed were scarified with Conc. H_2SO_4 to break dormancy. The scores of germinations were made at an interval of 24h and was continued upto 264h by the time most of them germinated. The seed were regularly washed with distilled water to prevent fungal growth (Tripathi & Srivastava, 1970). The following experiments under germination was conducted:

A. Effect of organic solvent
B. Effect of chemical scarification
C. Effect of different temperature
D. Effect of different storage periods
E. Effect of light and dark
F. Effect of different photoperiod
G. Effect of different quality of light
H. Effect of different pH
I. Effect of burial
J. Effect of different salt stress (Salinity)
K. Effect of different growth regulators
L. Effect of water stress

2.3 Culture of Plants:

Experiments were conducted with healthy and uniform sized seeds. These seeds were germinated in sterilized petridishes on single layer filter paper backed with a thin uniform layer of cotton wool. Filter paper was moistened with distilled water and kept in seed germinator at required light and temperature.

Two leaved seedlings were transferred to earthenware pots having 15 and 10cm diameter at the top and bottom respectively and depth of 15cm in the glasshouse. The pots were filled with soil mixture consisting of garden soil and farmyard manure in a ratio of 3:1 upto a height of 12-13cm leaving some space for holding water at the time of irrigation. Three seedlings were transplanted in each pot. After establishment of the seedlings two, out of three were cut at the base leaving only one in each pot. During the cutting process the small and weaker ones were removed. Some seedlings were also kept as stand by. The number of seedlings required for each experiment for each species was calculated by using the formula-

Total No. of seedling = Harvest × Treatments × Replicates Pots were watered at an interval of 24h or as and when required with tap water (except otherwise stared) to keep the soil moisture level optimum, except in the studies on the effect of soil moistures itself.

Before the start of the experiment 0.01% solution of Folidol was sprayed upon the seedling to protect them from pathogen & insect. Every effort was made to keep all the variables at the optimum level other than that under investigation. During the experimentation and entire course of investigation care was taken to maintain maximum level of uniformity of conditions under which the plants were grown because the accuracy of the values of growth parameters selected in the present investigation depend upon this factor.

The seedlings were left for seven days to get themselves stabilized and thereafter treatment was started. After seven days' period weekly harvest was done in respective environmental regions. Four such harvests were taken.

Thus first, second, third and fourth harvest were taken on 15th, 22nd, 29th, and 36th day respectively after the start of the treatment. At each harvest three randomly selected plants of each species for each treatment were uprooted. Utmost care was taken to root out maximum root biomass.

The root was washed under a fine jet of water to remove the soil particles adhered to them. Plants were pressed lightly between the folds of blotting paper to remove water droplets. The outline of the leaves was drawn on graph paper for measuring leaf area and at the same time roots, stem and leaves after dissection were kept in well-labelled butter paper packets. The butter paper packets were kept in oven at 80c for 48h.

After 48h butter paper packets were transferred to a dedicator containing anhydrous Calcium Chloride.

The final dry wt of the roots, stems and leaves were taken when the relative humidity remained low.

Thus, primary data in the form of dry wt. of root, shoot and leaves along with leaf area were recorded and from these different parameters of growth were calculated. The experiments conducted are as follows-

- Effect of soil moisture on growth
- Effect of light on growth
- Effect of competition on growth

2.4 Plant Growth Analysis:

There are so many ways to compare the performance of the plants. Growth analysis is one of the best among them. Briggs et.al. (1920) first introduced it on the basis of Blackman's (1919) 'Efficiency Index' which represents increments in size of the plant brought about by the accruement of new tissues using the products of photosynthesis. This 'Efficiency Index' was coined as 'relative growth rate' by Briggs et.al. (1920). Waber (1879,1882) & Harberlandt (1884) used an estimate, called the 'Assimilation senergie' for comparing the species. Briggs et.al. (1920) called it 'unit leaf area' which was later on phrased as 'Net Assimilation rate' by Gregory (1926). After Blackman (1919) and Briggs et.al. (1920) other workers attempted to quantify plant growth by different approaches. These approaches are of two categories (i) the classical approach (ii) the functional approach. Watson (1952) reviewed the classical techniques. Later on the modern statistical theory and invention of electronic computer helped advance in growth analysis. The new methods were and the manipulation of these functions to evaluate, among other things, relative growth and unit leaf rates.

Earlier, growth analysis methods were used to give a preliminary description of the growth of individual species. Recently the methods have been used to assess the effects of particular environmental factor on growth and the interaction of growth by workers like Ranjan et.al. (1971); Hughes & Cockshull (1972); Ranjan & Blackman (1975). Recently Hunt et.al. (1984); Hardwick (1984) and Jollife & Courteny (1984) have given new diamention to the concept of growth analysis.

The overall aim of growth analysis is to assist in explaining growth from the viewpoint of dry matter production. This is done by analyzing total growth into a series of 'components of growth'. The logical beginnings are, therefore, to consider the growth made by an annual plant from seed germination to senescence. It is evident that the total accruement of dry matter is the product of duration of growth and average absolute rate of measurement especially under controlled experimental conditions. It is the rate of growth component of the above partitioning of total growth made which is almost the sole concern of the growth analysist and forms the subject of growth analysis.

The growth analysis's taking into consideration the aim of their experiments and equipment at their disposal decide which one of different approaches is appropriate for a particular experiment. The dry weight of plant parts (root, stem and leaves) together with the leaf area gives the performance of plants. The different parameters of growth along with their derivation and biological significance are given below.

The equation used to derive the different parameters in the present study are market with an asterisk (*).

2.4.1 Morphogenetic Parameters:

i. Leaf weight ratio – The ratio of foliage dry wt to total plant dry et.

LWR =	Total leaf wt. (mg)
	Total plant wt (mg)

It is an index of the leafiness of plants on weight basis and subject to genetic, ontogenetic and environmental control.

ii. Leaf Area Ratio - The Ratio of total leaf area to total plant dry wt.

$$LAR = \frac{\text{Mean total leaf area/plant } (cm^2)}{\text{Mean total dry wt/plant (mg)}}$$

It represents the dry wt by gross photosynthesis.

iii. Specific Leaf Area - The ratio of leaf area to leaf dry wt.

$$SLA = \frac{\text{Leaf area } (cm^2)}{\text{Leaf weight (mg)}}$$

It measures the leaf density or its relative thickness.

2.4.2 Growth Parameters:

A. Mean relative growth rate of the plant as a whole (MRGR).

$$RGR = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1} \quad mg/mg^{-1}/week$$ *(Fisher, 1921)

Where W_1 and W_2 were total dry weights at time T_1 and T_2 respectively. It represents the efficiency of the plant as a producer of new material.

B. Net assimilation rate – assuming leaf area to increase proportionally to dry weight increase. It can be calculated by the equation:

$$NAR = \frac{\left(Log_e LA_2 - Log_e LA_1\right)}{T_2 - T_1} \times \frac{w_2 - w_1}{Log_e LA_2}$$ * (Williams, 1946)

It is an index of photosynthetic efficiency. It can also be calculated on the basis of leaf weight and leaf protein and in some cases they are even more informative.

C. Shoot/Root ratio - It is also an important parameter which is the ratio of either dry wt or length.

$$SR/ratio = \frac{\text{Total dry wt of shoot}}{\text{Total dry wt of root}}$$

D. 'Alpha' ($\propto$) sensu whitehead and Myerscough (1962) is an important parameter concerning allometry in growth of leaf and whole plant and is indicative of 'the proportion of dry wt increment surplus to that required to maintain the morphogenetic proportion of the plant as an efficient photosynthetic form alone '(Hunt, 1978). It can be computed as:

$$'\propto' = \frac{\text{Mean relative growth rate}}{\text{Mean relative rate of leaf area increase}}$$

$$'\propto' = \frac{Log_e w_2 - Log_e w_1 mg/mg^{-1}/week^{-1}}{Log_e LA_2 - Log_e LA_1 cm^2 cm^{-2} week^{-1}}$$

Where W_1 and W_2 were total plant dry wt and LA_1 and LA_2 were total leaf area at times T_1 and T_2 respectively.

Data on dry weight accumulation, leaf area increase, LWR, LAR, SLA, RGR, NAR, S/R ratio and 'Alpha' were analyzed statistically for significant test by analysis of variance according to Bailey (1959):

2.5 Statistical Procedure:

Three-way analysis of variance technique has been adopted to analyse the data. Let xijk denoted the observation due to ith species (sp) on the jth treatment (Tr.) in the kth harvest (Har.). The total sum of squares is given by:

$$\text{TSS} = \sum_i \sum_j \sum_k \left(xijk^{-1} x^{-} ..... \right)^2$$

$$\text{Where } X^{-} \text{ ……..} = \frac{\sum_i \sum_j \sum_k \times ijk}{p \times q \times r}$$

I = 1, 2, ……. p
j = 1, 2……q
k = 1, 2…….. r

This total sum of squares is broken into sum of squares due to species, treatment and harvest, interaction effects of species ×Treatment, species × Harvest, Treatment × Harvest and residual (error).

$$\text{TSS} = \sum_i \sum_j \sum_k \left(xijk - x^{-} ..... \right)^2$$

$$= \sum_i \left(x^{-} i ..... - x^{-} ..... \right)^2 \sum_j \left(x^{-} . j - x^{-} \right)^2 + \sum_k \left(x^{-} .....k - x^{-} ..... \right)^2$$

$$= \sum_i \sum_j \left(x^{-} ij - x^{-} i ..... - x^{-} j + x^{-} ..... \right)^2 + \sum_i \sum_k \left(x^{-} i.k - x^{-} i ..... - x....k + x^{-} ..... \right)^2$$

$$= + \sum_j \sum_k \left(x^{-} . jk - x^{-} . j - x^{-} .....k + x^{-} ..... \right)^2$$

$$= + \sum_i \sum_j \sum_k \left(x^{-} ijk - x^{-} ij - x^{-} ik - x^{-} jk + x^{-} j + x^{-} .....k + x^{-} ..... \right)^2$$

where $x^{-} i = \frac{\sum_h \sum_k}{qr} \times ijk;$

$$x^{-} j = \frac{\sum_i \sum_k \times ijk}{pr}$$

$$\bar{x}k = \frac{\sum_i \sum_j \times ijk}{pq}$$

$$\bar{x}ij = \frac{\sum_k \times ijk}{k}$$

$$\bar{x}jk = \frac{\sum_j \times ijk}{q} \text{ and}$$

$$\bar{x}ik = \frac{\sum_i \times ijk}{p}$$

The assumption extends over all members of the sample pqr in number so that we may replace expression such as:

$$\sum_i \sum_j \sum_k \left(\bar{x}i..... - \bar{x}.....\right)^2 \text{ by qr,}$$

$$\sum_i \left(\bar{x}i..... - \bar{x}.....\right)^2 \text{ etc.}$$

For computational work;

$$\text{TSS} = \sum_i \sum_j \sum_k \times ijk - \frac{T^2}{N}$$

where $T = \sum_i \sum_j \sum_k \times ijk : N = pqr.$

$$\text{Sp Sum of squares} = \frac{\sum_i x^2 i}{qr} - \frac{T^2}{N}$$

$$\text{Tr. sum of squares} = \frac{\sum_j x^2 j}{pr} - \frac{T^2}{N}$$

$$\sum_k x^2 .....k \qquad T^2$$

$$\text{Har. sum of squares} = \frac{}{pq} - \frac{}{N}$$

$$\text{Interaction (Sp} \times \text{Tr) sum of Squares} = \frac{\sum_i \sum_j x^2{}_{ij}}{r} - \text{Sp sum of squares}$$

$$- \text{Treatment sum of squares}$$

$$- \frac{T^2}{N}$$

Interaction (Tr ×Har.) sum of Squares = $\frac{\sum_j \sum_k \times jk}{p}$ – Tr. sum of squares
– Harvest sum of squares
$-\frac{T^2}{N}$

Interaction (Sp ×Har.) sum of Squares = $\frac{\sum_i \sum_k x^2 ik}{q}$ – Sp sum of squares
– Harvest sum of squares
$-\frac{T^2}{N}$

Error sum of squares = Total sum of squares
– Sp. sum of squares
– Tr sum of squares
– Har sum of squares
– Interaction (Sp × Tr) sum of squares
– Interaction (Sp × Har) sum of squares
– Interaction (Tr × Har) sum of squares

Table 2.2: Analysis of Variance Table

Source of variation	Degree of freedom (d.f)	Sum of squares (SS)	Mean sum of squares (MS)	F. ratio
Sp	P – 1	SS Sp	MS Sp	MS Sp / MS e
Tr	q – 1	SS Tr	MS Tr	MS Tr / MS e
Har.	r – 1	SS Har.	MS Har	MS Har / MS e
Interaction (Sp×Tr.)	(p –1) (q–1)	SS Sp/Tr.	MS Sp/Tr.	MS Sp/Tr. / MS e
Interaction (Tr.×Har.)	(q –1) (r–1)	SS Tr./Har.	MS Tr./Har.	MS Tr./Har. / MS e
Interaction (Sp×Har.)	(p –1) (r–1)	SS Sp/Har.	MS Sp/Har.	MS Sp/Har. / MS e
Residual (Error)	(p –1) (q–1) (r–1)	SS e	MS e	
Total	pqr –1			

If MS Sp/ MS e is greater than the table value of F at 5% and 1% levels of significance for the given degrees of freedom, we conclude that the effect due to Sp is significant. In case MS Sp/MS e is less than table value of F. at 5% and 1% levels of significance for the given degrees of freedom, then we say that effect due to species is not significant. Similarly, the effects of the variations are tested. Where, error mean square is greater than Mean square, significant F. ratio has been bracketed.

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Chapter 3

Germination

3.1 Introducton:

The times, place and period of seed germination is an asset for successful establishment of the seedling in nature. Seeds do not necessarily germinate even if the factor/ factors controlling seed germination are favourable. Such seeds are known as quiescent ones. For germination such seeds generally require to be hydrated under conditions which encourage metabolism such as temperature and presence of oxygen. Germination starts with water uptake by seeds and ends with elongation of the embryonic axis. This phenomenon therefore, includes numerous events such as protein hydration, sub cellular structural changes, respiration, macromolecular synthesis and cell elongation. The combined effects of all these events transform a dehydrated resting embryo into one that has a vigorous metabolism culminating in growth.

In the present study three **Medicago** spp were selected. Seeds of **M. Sativa** do not possess any dormancy, whereas, **M. denticulate** and **M. lupulina** have a dormancy block of one, one and half year respectively. The viability of the seeds has also been tested and it was observed that seeds of all the species under reference are viable for at least four years. In the fifth year a loss in viability of seeds in **M. lupulina** and been observed. Seeds of all the three species were experimented to test the effects of various dormancy breaking mechanisms and the environmental variables like, light, temperature, pH, water regimes, storage period and some germination stimulations.

The findings have been used to correlate their germination behavior in nature, in transpacific variability and ecological superiority. The germination behavior of species also give clue regarding geographical origin of plants.

Although the three **Medicago** spp share some common properties, they differ within themselves in so many respects. **M. sativa** is perennial, **M. denticulata** and **M. lupulina** are annuals. These species grow in diverse ecological miches. An attempt has been made to trace their strategies for germination in order to tide over different climatic stresses. This study will be of immense help in planning their growth in future for useful purposes.

3.2 Material and Methods:

Seeds of **M. sativa** were procured from the Indian Grassland Research Centre, Jhansi while that of **M. denticulate** and **M. lupulina** were collected locally.

Seeds were multiplied in the experimental garden of the Botany Deptt., Patna University, Patna. In all the experiments designed for germination studies, the seeds were surface sterilized by treating them in 0.2% mercuric chloride sterilized petridishes on single layer filter paper (except moisture regime) placed over thin and uniform layer of cotton wool and moistened with distilled water (except in pH treatment). In all the experiments three replicates were prepared each containing fifty seeds. Utmost care was taken to select healthy and uniform sized seeds.

In order to study the effect of different scarifying agents such as ethylalcohal, xyleme, ether and acetone, the seeds, were pretreated with them separately for 24h. They were washed in running tap water before being used for germination.

Sulphuric and has been observed to be most successful and is widely used as dormancy breaking chemical.

To test the effect of sulphuric acid, the seeds were treated for varying periods starting from 5 minutes to 50 minutes and after thorough washing they were transferred to petridishes for germination.

To study the effect of different temperature the petridishes with seeds were kept in seed germinator at desired temperature (0^0c –40^0c). In order to study the effect of storage period and temperature one set of seeds of each species was placed in incubator permanently fixed at 30^0c, another set in the middle of the refrigerator (15^0c) and one set was kept in the deepfridge – (0^0c) during the entire period of investigation. In all the case the seeds kept in well labeled and corked glass- tubes.

The seeds were exhumed at an interval of 3 months and their germinability was tested. At the end of the experiment the viability of the seeds was also tested through Tetrazolium chloride test.

Effect of light and dark, different intensities of light and different isolation periods were studied in the growth room of the Botany Department maintained at 30^0C ± 2^0c thermostatically. Lights of different wavelengths were created by covering the incandescent bulbs with cellophane paper of desired colour.

Furred was created by covering the bulb with one layer each of blue and red cellophane paper (Arditti & Arnold, 1968).

The effect f pH on germination was studied by preparing various levels of pH solutions with the help of trishydroxymethyl aminomethane, HCl and citric acid and sodium citrate. The seeds were kept moistened in these solutions in the petridishes.

To study the effect of burial, the seeds were placed in 27 fine mesh nylon bags in nine earthenware pots at three different depths (5, 10 and 15cm).

The seeds were exhumed at an interval of six months and germinated in sterilized petridishes.

Salt stress was created by preparing different concentrations of salt viz Na_2 SO_4, Na_2 CO_3 and NaCl (9.05M– 0.5M). The seeds were pretreated with different concentrations of these salts for 24h. Thereafter, they were placed on moistened filter paper moistened with distilled water in the petridishes for germination.

The effect of different germination stimulators viz, Indole acetic acid (IAA), Gibberellic acid (GA_3), and thiourea were determined by preparing different concentrations ranging from 25 – 100ppm.

The seeds were treated with them for a period of 24h.

Thereafter, they were washed in running tap water and placed for germination in sterilized petridishes. The petridish were placed in light and dark conditions. The results obtained was compared with the control.

Different moisture regimes were created by increasing the number of filter papers in the petridishes and equal amount of water was poured in them. The seeds were placed on the filter paper for germination.

In all the experiments germination percentage was scored at an interval of 24h for 264h upto which most of the seeds germinated. Emergence of 1mm radical was taken as germinated. The results of the germination experiments are summarized below.

3.3 Results and Discussion:

The result of the effect of some organic solvents on germination percentage of Medicago spp has been presented in Table 3.1, Figure 3.3. It shows inhibitory effect of these chemicals in case of **M. sativa** as only 44% (Abs. Alcohol), 72% (Ether), 80% (Acetone and Xylene) germination was achieved as against control with 100% germination.

However, acetone and ether have been observed to be promotive in **M. lupulina**. In **M. denticulate**. Acetone, ether and alcohal was observed to promote germination. The most effective chemical was observed to be ether in case **M. denticulata**.

Barton (1947) found alcohol non-significant in Papilionaceous seeds. Choudhary (1988) also observed these chemicals, ineffective in breaking

Table 3.1: Effect of Organic Solvents on Germination Percentage

Treatment	Germination percentage		
	M. sativa	M.lupunia	M. denticulata
Control	100	10	8
Acetone	80	12	10
Abs. alcohol	44	6	10
Ether	72	12	20
Xylene	80	4	8

Table 3.2: Effect of Chemical Scarification on Germination Percentage

Treatment	Germination percentage		
	M. sativa	M.lupunia	M. denticulata
5	40	50.8	20.8
10	–	70	25.6
15	–	100	27.6
20	–	100	30.6
25	–	100	40.6
30	–	100	50.5
35	–	100	40.4
40	–	90.6	5.2
45	–	60.4	–
50	–	40.2	–

Table 3.3: Effect of Temperature on Germination Percentage

Treatment species	Period of treatment in hours	0^0c	10^0c	20^0c	30^0c	40^0c
M. Sativa UnSc	24h	–	30	90	100	40
M. lupulina UnSc		–	–	–	5	–
M. lupulina Sc		9	20	80	100	10
M. denticulata UnSc		–	–	–	5	–
M. denticulata Sc		4	10	20	30	5
M. Sativa UnSc	48h	–	50	90	100	40
M. lupulina UnSc		–	–	–	10	–
M. lupulina Sc		9	60	90	100	10
M. denticulata UnSc		–	–	–	10	–
M. denticulata Sc		8	20	30	40	5
M. Sativa UnSc	72h	–	70	100	100	40
M. lupulina UnSc		–	–	–	10	–
M. lupulina Sc		9	70	90	100	10
M. denticulata UnSc		–	–	–	10	–
M. denticulata Sc		8	30	30	50	5
M. Sativa UnSc	96h	–	80	100	100	40
M. lupulina UnSc		–	–	5	12	–
M. lupulina Sc		9	80	100	100	10
M. denticulata UnSc		–	–	5	12	–
M. denticulata Sc		8	40	40	50	5
M. Sativa UnSc	120h	–	80	100	100	50
M. lupulina UnSc		–	5	10	12	–
M. lupulina Sc		9	80	100	100	10
M. denticulata UnSc		–	–	10	12	–
M. denticulata Sc		8	40	45	50	5
M. Sativa UnSc	144h	–	80	100	100	50
M. lupulina UnSc		–	5	10	12	–
M. lupulina Sc		9	80	100	100	10
M. denticulata UnSc		–	–	10	12	–
M. denticulata Sc		8	40	45	50	5
M. Sativa UnSc	96h	–	80	100	100	50
M. lupulina UnSc		–	5	10	12	–
M. lupulina Sc		9	80	100	100	10

Treatment species	Period of treatment in hours	0^0c	10^0c	20^0c	30^0c	40^0c
M. denticulata UnSc		–	–	10	12	–
M. denticulata Sc		8	40	45	50	5

Table 3.4: Effect of Storage Temperature on Germination Percentage

Storage period	Temperature	M. sativa	M. lupulina	M. denticulata
3 months	0^0c	–	–	–
	15^0c	90	–	–
	30^0c	100	10	8
6 months	0^0c	–	–	–
	15^0c	90	12	6
	30^0c	100	20	20
9 months	0^0c	7	8	8
	15^0c	90	24	30
	30^0c	100	46	52
12 months	0^0c	16	18	18
	15^0c	95	30	36
	30^0c	100	64	80
15 months	0^0c	10	20	25
	15^0c	95	40	50
	30^0c	100	70	100
18 months	0^0c	5	7	3
	15^0c	90	32	32
	30^0c	90	52	40
21 months	0^0c	–	–	–
	15^0c	40	–	–
	30^0c	75	24	25

Table 3.5: Effect of Light and Dark on Germination Percentage

Species Treatment	M. sativa	M. lupulina		M. denticulata	
	UnSc	UnSc	Sc	UnSc	Sc
Control	100	10	100	8	50
Light (100 W)	100	10	100	8	50
Dark	100	10	100	8	50

Table 3.6: Effect of Photo Period on Germination Percentage

Continuous Dark				6h			12h			Continuous light		
Sca.	M.St.	M.l	M.d.	M.St.	M.l	M.d.	M.St.	M.l	M.d.	M.St.	M.l	M.d.
UnSc	100	8	8	100	8	8	100	12	9	100	12	9
Sc	–	100	15	–	100	50	–	100	50	–	100	50

M.St. = M. Sativa
M.l = M. lupulina
M.d. = M. denticulate
Sca = Scarification

Table 3.7: Effect of Different Wavelengths on Germination Percentage

Treatments Spps	Green	Red	Far-red	Blue	Yellow	Orange	40W incandescent
M. Sativa UnSc	98	100	100	100	98	98	96
M. lupulina UnSc	5	10	10	10	5	5	5
M. lupulina Sc	96	100	100	100	96	96	94
M. denticulata UnSc	4	8	8	8	4	8	8
M. denticulata Sc	40	45	45	50	45	50	45

Table 3.8: Effect of Ph. on Germination Percentage

Range of pH Spp.	Treatment	4	5	6	7	8	9	10
M. Sativa	UnSc	–	–	80	100	80	40	–
M. lupulina	UnSc	–	5	5	10	5	–	–
M. lupulina	Sc	–	60	75	100	80	20	–
M. denticulata	UnSc	–	–	5	10	5	–	–
M. denticulata	Sc	–	20	30	50	40	20	–

Table 3.9: Effect of Burial on Germination Percentage

Treatment Spp	Storage period	5cm	10cm	15cm
M. Sativa	3 month	100	90	40
M. lupulina		10	5	4
M. denticulata		8	6	5
M. Sativa	6 month	100	90	40
M. lupulina		20	10	6
M. denticulata		20	12	8
M. Sativa	9 month	100	90	30
M. lupulina		46	20	10
M. denticulata		52	30	15
M. Sativa		100	90	30
M. lupulina	12 month	64	30	15
M. denticulata		80	40	20

Table 3.10: Effect of Varying Salt Stress on Germination Percentage

Salt		M. sativa	M. denticulata		M. lupulina	
Concentration	Control	UnSc	UnSc	Sc	UnSc	Sc
NaCl	0.05 M	50	4	–	–	28
	0.1 M	70	4	–	–	64
	0.2 M	8	–	–	–	68
	0.3 M	8	–	–	–	4
	0.4 M	–	–	–	–	4
	0.5 M	–	–	–	–	4
Ma_2CO_3	0.05 M	–	–	–	–	–
	0.1 M	–	–	–	–	–
	0.2 M	–	–	–	–	–
	0.3 M	–	–	–	–	–
	0.4 M	–	–	–	–	–
	0.5 M	–	–	–	–	–
$Na_2 SO_4$	0.05 M	70	–	–	–	40
	0.1 M	20	–	–	–	32
	0.2 M	8	–	–	–	4
	0.3 M	–	–	–	–	–
	0.4 M	–	–	–	–	–
	0.5 M	–	–	–	–	–

Table 3.11: Effect of Growth Hormones on Germination Percentage

Concentration (in ppm)		M. Sativa UnSc	M. lupulina		M. denticulata	
			UnSc	Sc	UnSc	Sc
M.H.	Control	100	10	100	50	8
	10	55	8	100	4	40
	20	50	4	50	4	36
	30	30	4	25	–	20
	40	25	–	20	–	12
	50	25	–	20	–	12
GA_3	10	100	5	100	12	46
	20	100	10	96	–	45
	30	90	10	90	–	40
	40	90	5	90	–	40
	50	90	5	90	–	30
IAA	10	100	9	100	8	50
	20	100	5	90	5	30
	30	90	–	90	–	20
	40	80	–	60	–	20
	50	80	–	40	–	15
Thiourea	10	100	9	70	5	42
	20	100	3	50	5	34
	30	100	–	55	9	36
	40	100	–	66	10	38
	50	100	–	68	10	40

Table 3.12: Effect of Moisture Stress on Germination Percentage

Treatment Species	Regime I	Regime II	Regime III	Regime IV	Regime V
M. Sativa	20	36	36	32	16
M. lupulina (UnSc)	4	8	–	–	–
M. lupulina (Sc)	60	72	48	44	32
M. denticulata (UnSc)	16	12	4	–	–
M. denticulata (Sc)	60	16	8	8	8

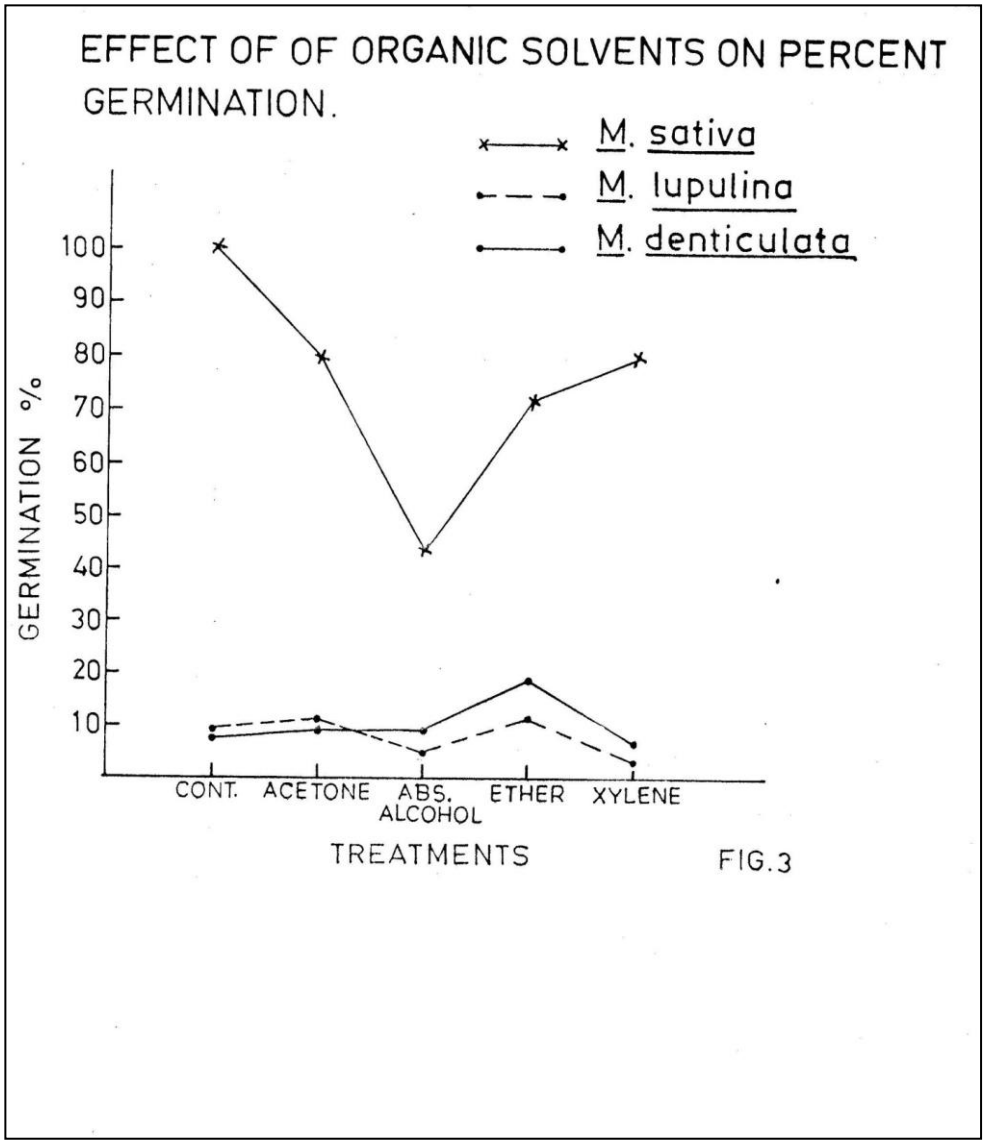

Figure 3.1: Effect of Organic Solvents of Percent Germination

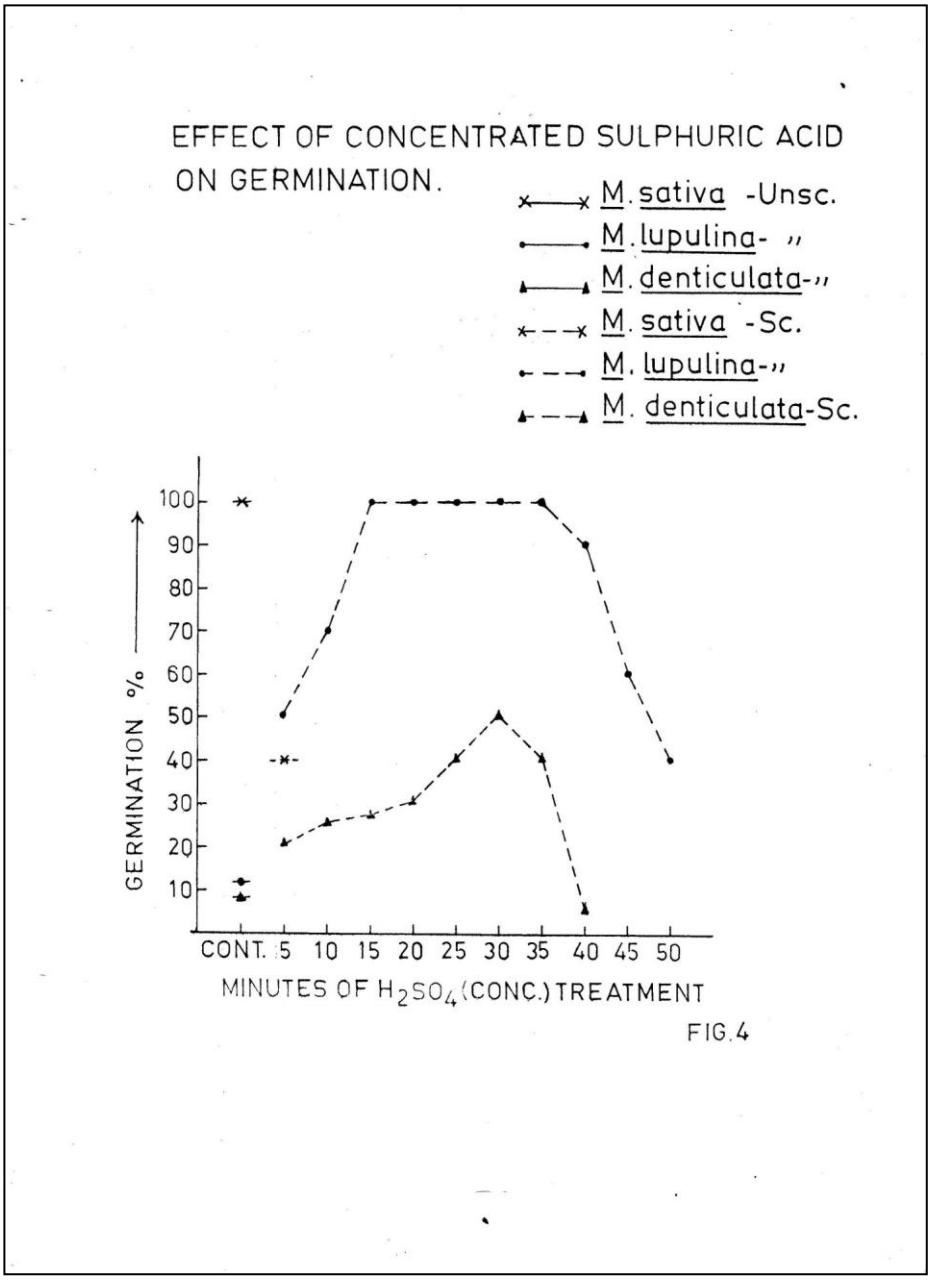

Figure 3.2: Effect of Concentrated Sulphuric Acid on Germination

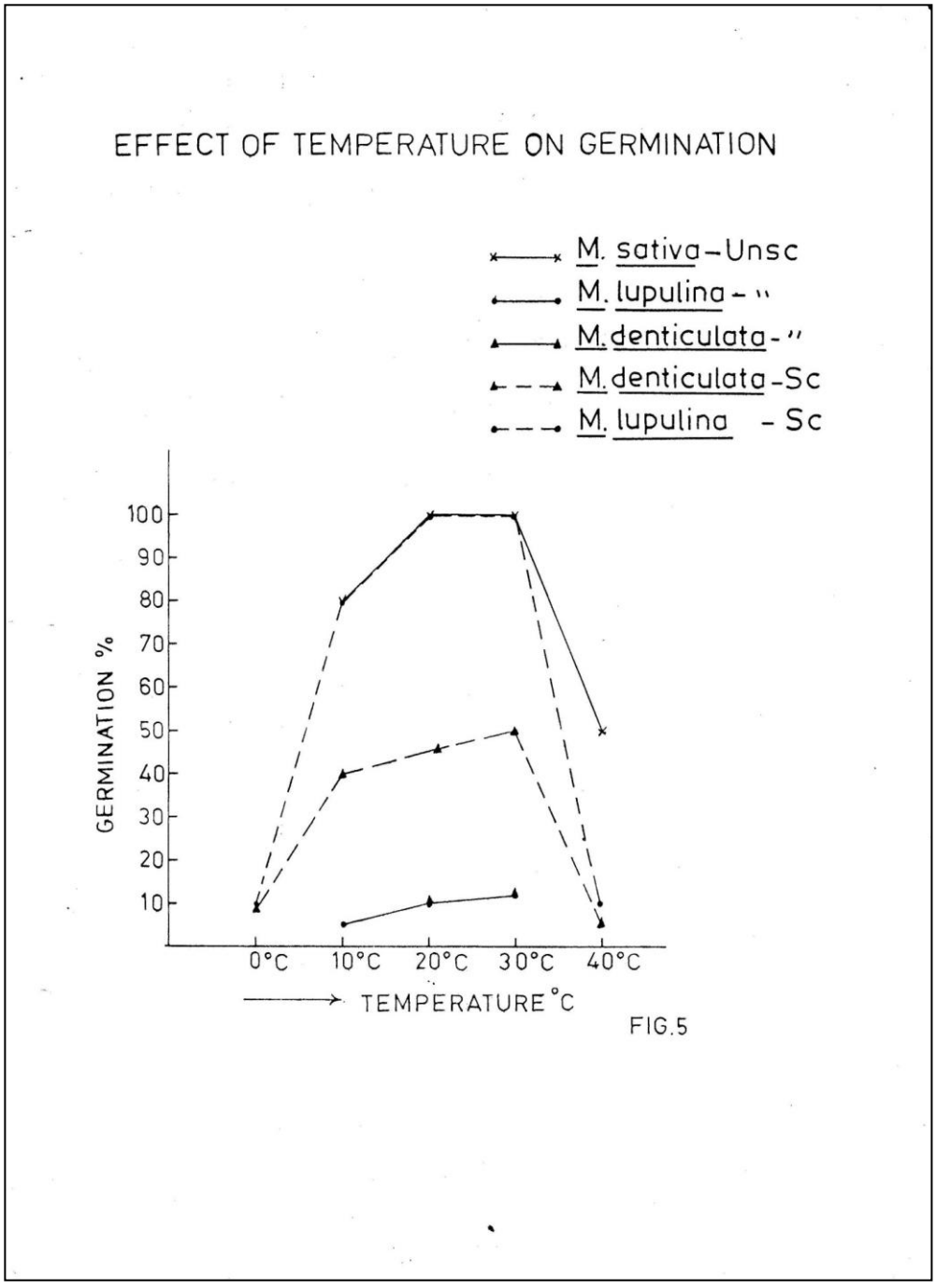

Figure 3.3: Effect of Temperature on Germination

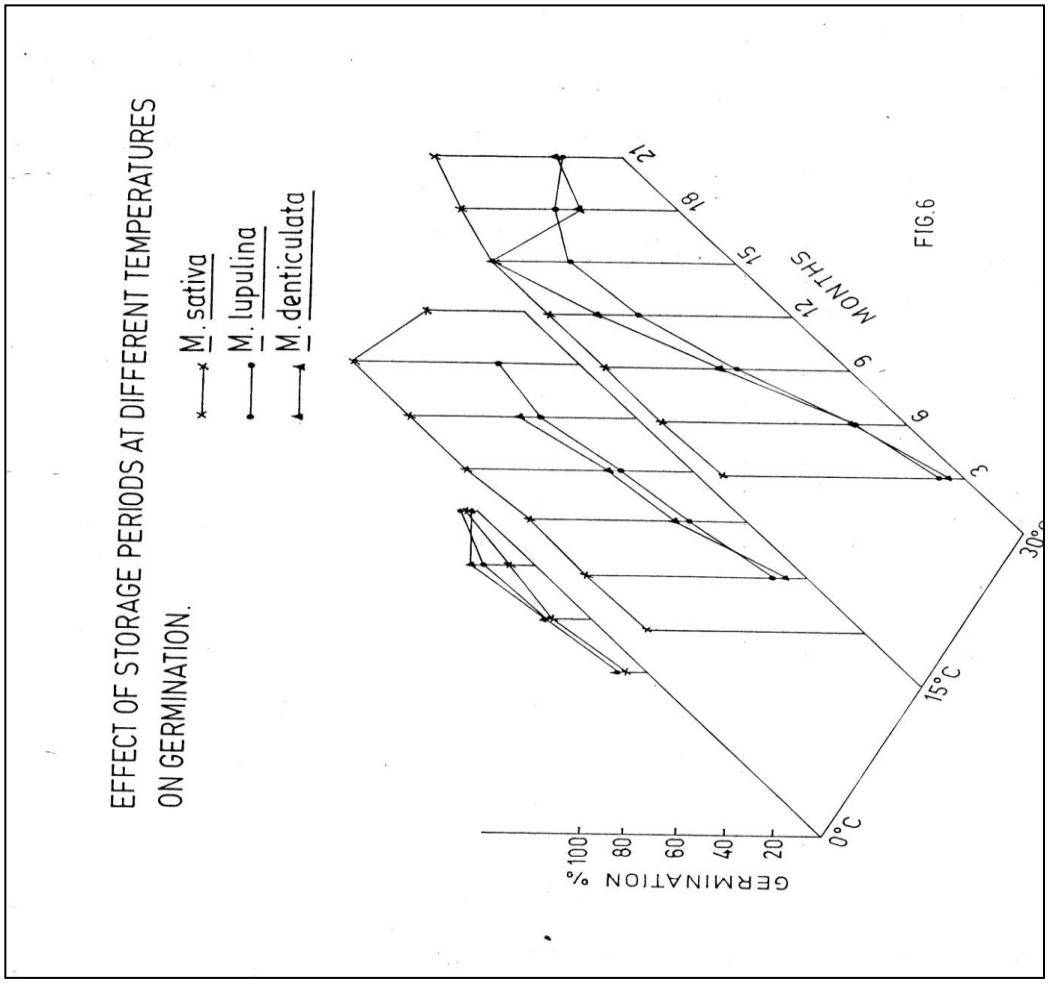

Figure 3.4: Effect of Storage Periods at Different Temperatures on Germination

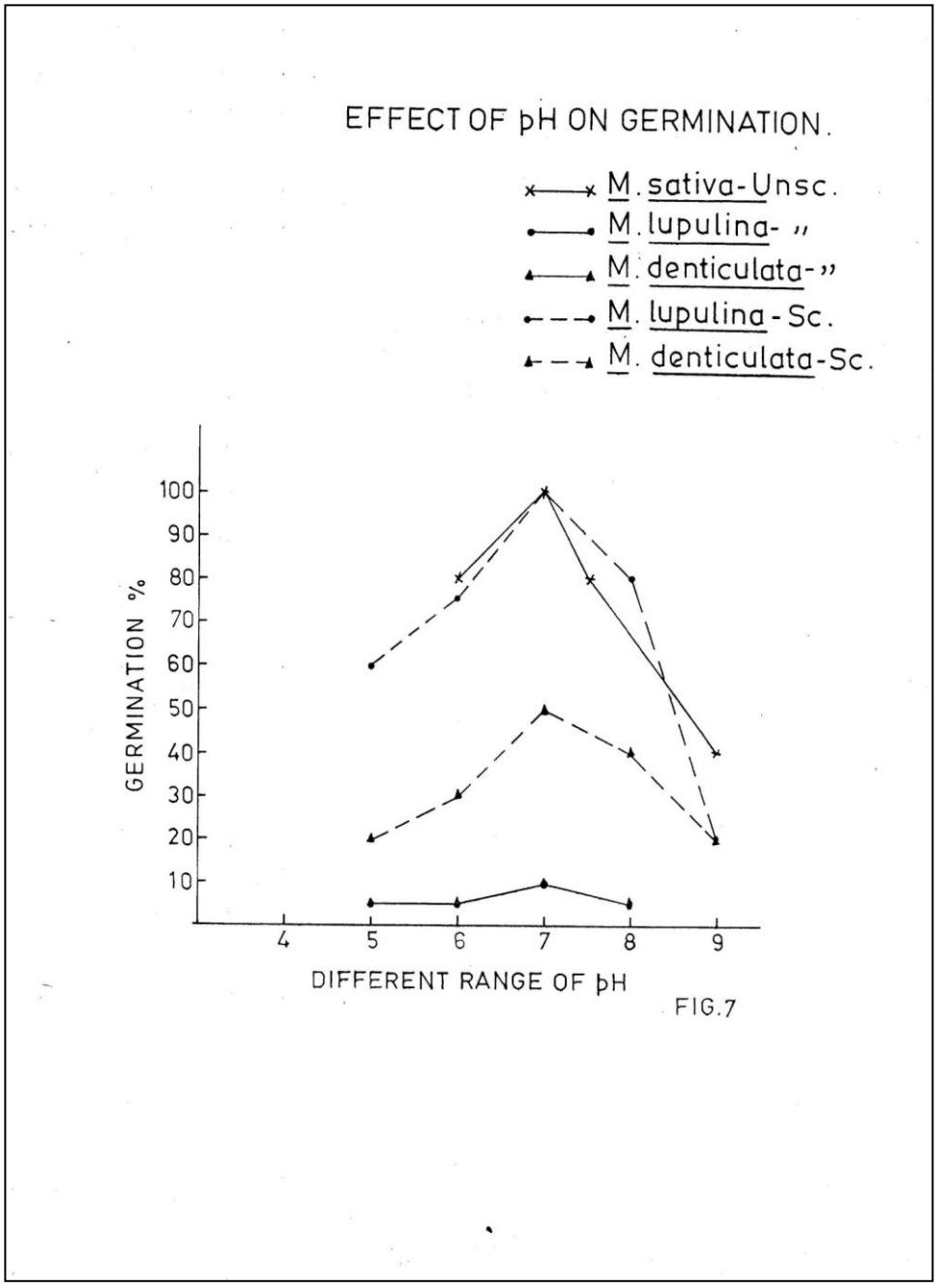

Figure 3.5: Effect of pH on Germination

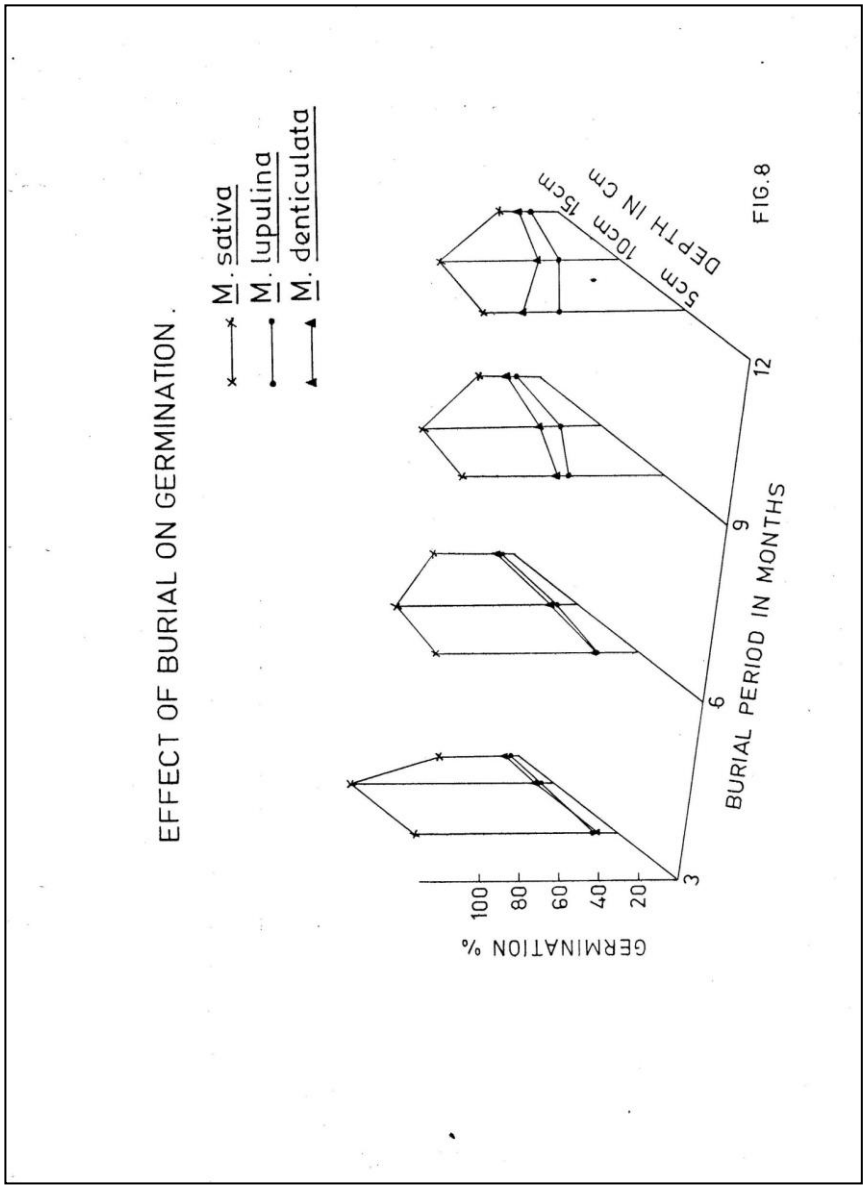

Figure 3.6: Effect of Burial on Germination

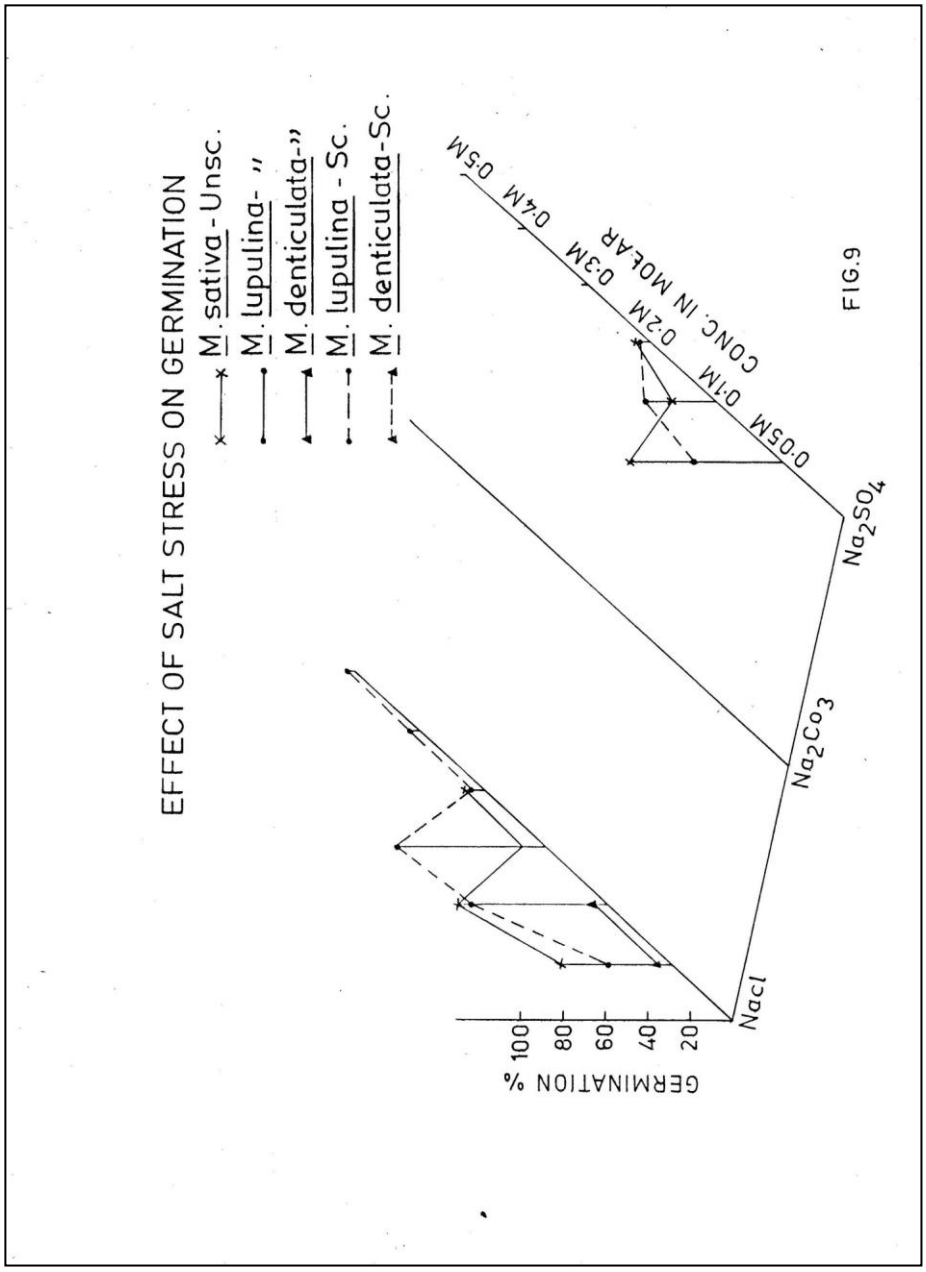

Figure 3.7: Effect of Salt Stress on Germination

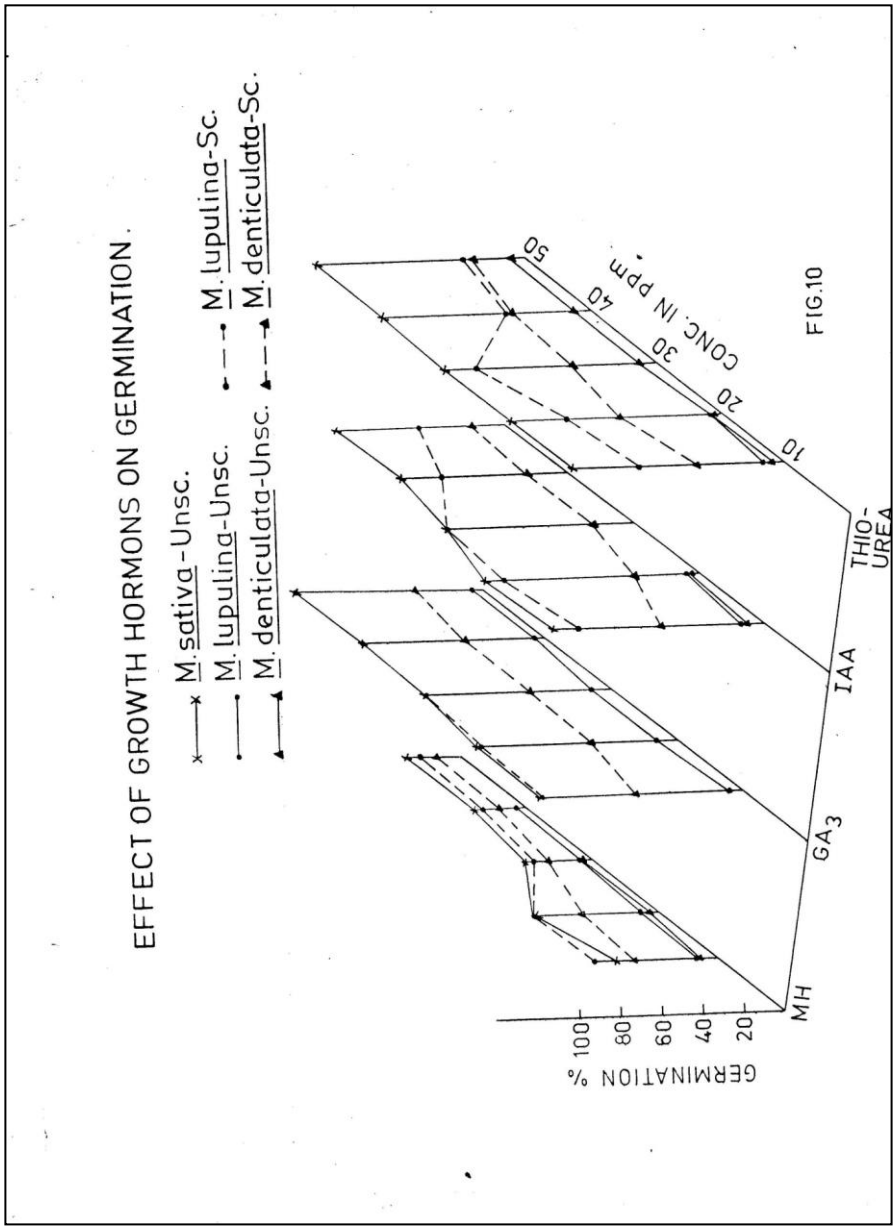

Figure 3.8: Effect of Grwth Hormons on Germination

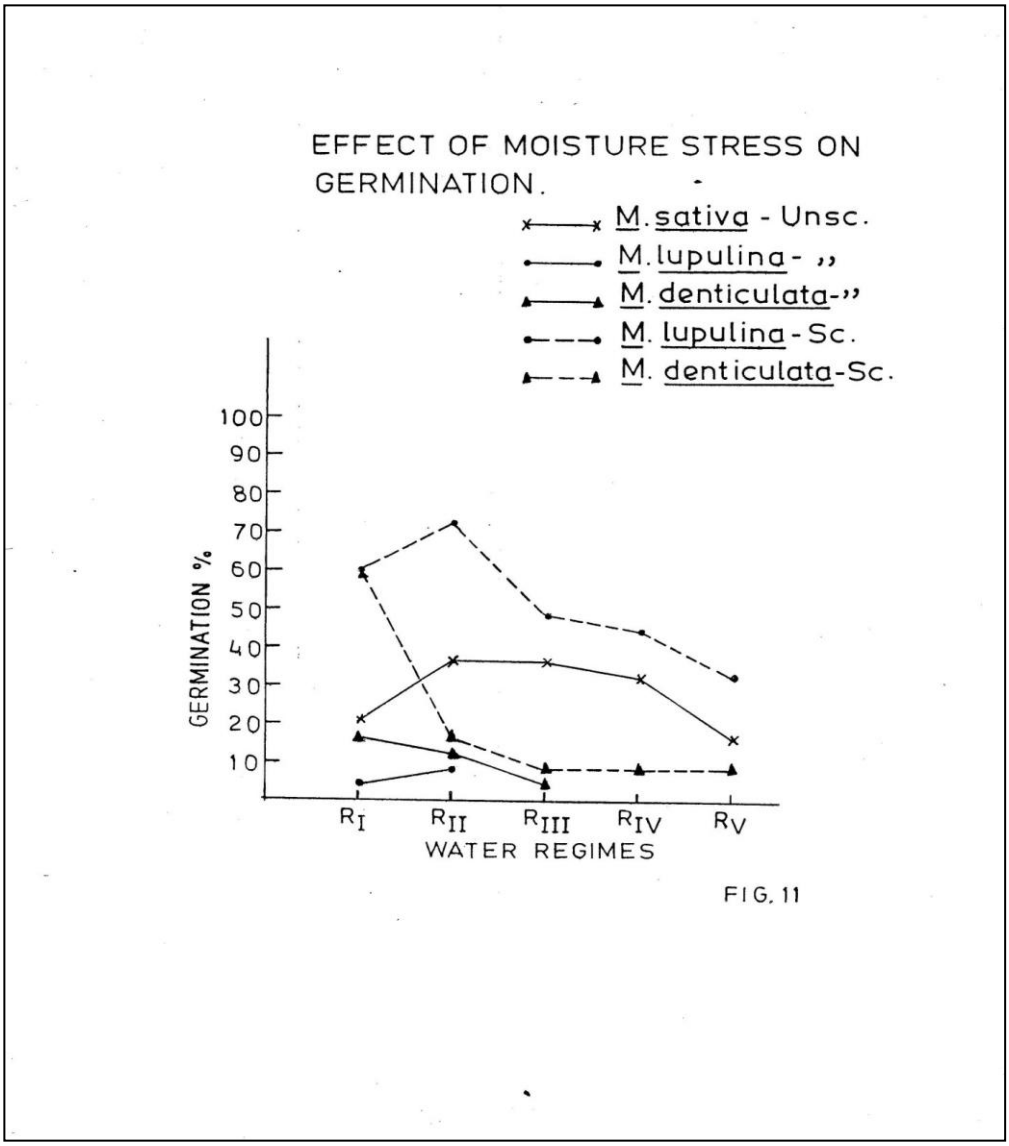

Figure 3.9: Effect of Moisture Stress on Germination

dormancy of **Portulaca** spp. However, Pandey (1976) reported scarifying effect of these chemicals although in a very low scale in case of Crotalaria spp. Cavaaza (1951) found the effect of alcohol variable.

Effect of H2 SO4 on seed germination (Tabe-2, Fig-4) shows that it is the most successful scarifying agent for **M. lupulina** and **M. denticulata** both. In **M. lupulina** 100% germination was achieved with 15 minutes' treatment whereas, in **M. denticulata** 50.5% germination was achieved with 30 minutes' treatment. **M. Sativa** is cultivated plant and thus the seeds do not possess any dormancy. The seeds germinate (100%) anytime without any sort of treatment throughout the year.

Thus, from the result in can be concluded that **M. Sativa** is a cultivated plant with thinner seedocat. Seeds of **M. lupulina** possess hard and impermeable seedcoat which is rendered permeable through H_2SO_4 earlier than **M. denticulata**. Thus, seacoats of **M. lupulina** are thinner than **M. denticulata.** It can also be concluded that M. lupulina has travelled for forwards the cultivated habit than **M. denticulata.** Yadav et.al. (1979) also observed stimulation of seed germination with H_2SO_4 in four Medicago spp (**M. hispidia**, **M. murey**, **M. scutellata** and **M. ciliaris**). He also observed that this stimulation of seed germination can be attributed to the reduction in the content of inhibitors and improvement in the permeability of seedcoat.

The result of the effect of temperatures on germinability of different Medicago spp has been presented in Table 3.3, Figure 3.5. The Table starts with 0^0c and ends with 40^0c as none of the seeds germinated beyond this range. The result suggests that unscarified seeds of all the three species could not germinate at the lowest temperature (0^0c). At the highest temperature (40^0c) only unscarified seed of **M. sativa** could germinate. However, scarified seeds of **M. lupulina** and M**. denticulata** could germinate at the lowest and the highest temperatures. The maximum germination percentage was achieved for **M. sativa** (100%), **M. lupulina** (100%) and **M. denticulata** (50%). The optimum temperature at which maximum seed germinated was observed to be 30^0c for all the three species. However, the species differ within themselves with respect to the time lag. This time lag for **M. sativa** (UNSC) and **M. lupulina** (Sc) was recorded to be 24h whereas, for **M. denticulata** (Sc) to be 72h. Thus, on the basis of range of temperature, optimum temperature and the time lag it can be concluded the **M. sativa** excel **M. lupulina** and **M. denticulata.**

Effect of storage periods of seeds at varying temperatures (Table 3.4, Figure 3.6) shows that in all the three species under reference 15 months' storage at higher temperature (30^0c) result into maximum breakage of dormancy, although the seeds start to germinate from the first exhumption (3 months). After 15 months' period a loss in viability of seeds has been observed for all the three species. The seeds stored at 15^0c start germinating from the first exhumation in **M. sativa** and second exhumption in M. lupulina and **M. denticulata.** The maximum germination was achieved in the 5th exhumption as 95%, 40% and 50% germination were recorded for **M. sativa, M. lupulina** and **M. denticulata** respectively. The seeds stored at the lowest temperature (0^0c) Starts to germinate from the 3rd exhumption in all the three species. The highest germination percentage achieved in case of **M. sativa** (16%) was observed at the IVth exhumption. The same for M. lupulina (20%) and **M. denticulata** (25%) was observed at the 5th exhumption. Thereafter, a decrease in germination was observed for all the species and finally at the VIIth exhumption not a single seed of all the three species germinated. Thus, on the basis of the results it can be concluded that seeds stored at the highest temperature (30^0c) maintain it viability for a longer period than stored at lower temperatures (1^0c and 0^0c). If the ecological superiority of a species in terms of germination, temperature tolerance and viability of seeds are taken into account it appears that **M. sativa** excels both **M. lupulina** and **M. denticulata.**

The result of the effect of continuous light and dark, different photo periods and different wavelengths has been presented in Table 3.5, 3.6 and 3.7 respectively. From the result it is clear that all the **Medicago** spp are unaffected by different light conditions. Baxi (1965) has given similar reports with different **Tephrosia** and **Indigofera** spp.

Similarly, there are large number of reports of similar nature concerning leguminous seeds (Mallick & chaterji, 1967; Chaterji & Mahnot, 1964; Agarwal & Vyas, 1970) Present findings only support these earlier reports and substantiate the general hypothesis that legumes in general are insensitive to light. However, Rao & Reddy (1981) reported slightly better germination in continuous light than diffuse and dark in **Indigofera linifolia**.

The pH of a medium has marked effect of establishment and normal growth of the plant. In some cases, it is also reflected in the germination behavior of seeds (Tripathi & Srivastava, 1970; Singh, 1972). The effect of pH ranges from 4–10 on germinability of **Medicago** spp has been presented in Table 3.8, Figure 3.7. The result is suggestive of the fact that **M. Sativa** seeds could germinate from 6–9 pH range. Whereas, **M. lupulina** and **M. denticulata** germinated from 5–9 pH range. It will be worthwhile mentioning here that only scarified seeds of **M. lupulina** and **M. denticulata** germinated at lower pH (5). The optimum pH was observed to be 7 for all the species. The unscarified seeds of **M. sativa** and scarified seeds of **M. lupulina** yielded 100% germination whereas, **M. denticulata** only 50%. The unscarified seeds of M. lupulina and **M. denticulata** yielded only 10% germination.

Impermeable seed coats permit extension of life to many seeds so that they can secure temporal and spatial distribution (Crocker & Barton, 1953). In seed coat dormant species germination is enhanced as the seed passes time in the seed bank (Wareing, 1963; Bhat, 1968; Babu & Joshi, 1970). In such seeds the activities of the layer of the seed coat to make water uptake possible (Williams & Ellicot, 1960). The result of the effect of burial on germination of **Medicago** spp has been presented in Table 3.9, Figure.3.9, Fig.-8. The results suggest that seeds of all the three **Medicago** spp start to germinate from the first exhumption of all the three depths. In **M. sativa** maximum germination occurs in the first exhumption at all the depths. Thereafter, in the consecutive exhumptions the germination percentage remain same at 5 and 10cm depths. At 15cm depth during the third and fourth exhumption a decrease in germination percentage is observed.

Seeds of **M. lupulina** and **M. denticulata** also start germination increase in the consequitive exhumption at all the depths from the result it is also clear that maximum germination in all the species occur at the uppermost layer of the soil. A decrease in germination percentage with increase in the depth is alo observed. Thus, it appears that better microbial action took place in the uppermost layer of the soil which resulted in better germination for all the three species. Thus, our observations corroborate the findings that better microbial action is possible only in the uppermost layer of the soil.

The physiology of germinating seeds and seedling growth under stressed condition has received due attention (Kabir & Poljakoff-Mayber, 1975; Singh & Singh, 1982; Kole & Gupta, 1982; Dubey 1982; Singh et.al. 1986). The excess of salt in the germinating medium brings about stressed condition and makes the environment unfavourable for seed germination. It affects imbibitions as due to high salt concentration high osmotic pressure develops which in turn creates physiological dryness for the germinating seeds (Bhumble et.al. 1968). Salinity stress also disturbs the hormonal balance controlling mobilization of food reserve to the embryos. Gomes et.al. (1983) reported delayed activation and/ or **de novo** synthesis of enzymes in cotyledone under salinity stress.

The result of the effect of salt stress on seed germination of **Medicago** spp has been presented in Table 3.10, Figure 3.9. Result when perused in appears that seeds of none of the species could germinates in any concentrations of Na_2 CO_3. M. Sativa seeds (unscarified) showed germination in only four concentrations (0.05, 0.1, 0.3M) of NaCl, the percentage being 50, 70, 8 and 8 respectively. It germinated in three concentrations (0.05, 0.1 and 0.2M) of Na_2 SO_4, the percentage being 70, 20 and 8 respectively. Seeds of **M. lupulina** (unscarified) could not germinate in any concentrations of all the three salts studied, whereas, scarified seeds germinated in all the concentration of NaCl, the percentage being 28,64, 68, 4, 4 and 4. It also showed germination in three concentrations of Na_2 SO_4 (0.05, 0.1 and 0.2M), the percentage being 40, 32, and 4 respectively. Unscarified seeds of **M. denticulata** could germinate only in two concentrations of NaCl (0.05 and 0.1M) with a percentage of 4 only. The scarified seed could not germinate in any concentrations of all the salts when the result is compared with the control it appears that all the three salts (in all the concentrations) have inhibitory effect on both scarified and unscarified seeds of all the three **Medicago** spp. If the intensity of inhibition is taken into account it appears that NaCl is less inhibitory than Na_2SO_4 and Na_2 CO_3. The maximum inhibition is caused by Na_2CO_3 in which seeds of all the three **Medicago** spp could not germinate in any concentrations. However, 0.05M concentration of Na_2SO_4 and 0.1M concentration of NaCl showed maximum germination of **M. sativa** and **M. lupulina** seeds. Singh et.al. (1986) observed higher germination percentage under mild salt stress in **Cucumis melo** and **C. sativus**. Similar results have also been reported by Chatterton & Mc kell (1969) in Atriplex polycarpa and lgnaciuk & Lee (1980) in **Salsola kali**. This inhabitation of germination in **Medicago** spp under reference may be assigned to increase in osmotic pressure or ionic toxicity of loss in viability of seeds under prolonged condition of salinity. Vhirts (1946) and Radmann (1974) have shown that the effect of NaCl on germination of **Medicago** sativa was atleast in part, due to ionic toxicity.

Some chemicals viz. Indole acetic acid (IAA), $\propto$ –Naphthyl acetic acid (NAA), Gibberellic acid (GA_3), Potassium nitrate (KNO_3) and thiourea are capable of breaking dormancy of seeds. Normally those seeds which require light or chilling effect or after-ripening exhibit striking responses to these substances. The success of these chemicals in mixed and seeds of many species do not respond at all. These chemicals are not of much importance as only a few of these are encountered by seeds in their natural environment, but the study of these chemicals is important as they help us in understanding the mechanism of releasing dormant seeds to non-dormant condition. In the present study an attempt has been made to assess the effects of these chemicals (IAA, GA_3 thiourea and Maleichydrazide) on seed germination of **Medicago** spp. The result of the effect of these chemicals on germination has been presented in Table 3.11, Figure.3.10. A perusal of the result suggests that in **M. sativa** IAA plays an inhibitory role in higher concentration. The maximum germination (100%) was achieved with 10 and 20 ppm concentration. Scarified seeds of **M. lupulina** and **M. denticulata** showed maximum germination in 10 ppm concentration thereupon it shows a decreasing trend. IAA shows its inhibitory effect upon unscarified seeds of **M. lupulina** and **M. denticulata.**

M. Sativa gives 100% germination with 10 and 20 ppm concentration of GA_3. The higher concentration shows inhibitory effects. Scarified seed of **M. lupulina** and **M. denticulata** yield maximum germination with 10 ppm concentration of GA_3. GA3 also exhibits its inhibitory effect on unscarified seeds of **M. lupulina** but promotive on **M. denticulata**.

With all the concentrations of thiourea M. sativa yields 100% germination. This action of thiourea can be observed as promotive. However, the inhibitory action of thiourea is observed on scarified seeds of **M. lupulina** and **M. denticulata.** Thiourea also shows its inhibitory effect on unscarified seeds of M. lupulina but promotive effect on unscarified seeds of **M. denticulata** in higher concentrations.

Malecic hydrazide shows its inhibitory effect on both scarified and unscarified seeds of all the three Medicago spp in all the concentration. It has also been observed that with increase in concentration a decrease in percent germination occurs.

Thus, it can be concluded that GA_3, IAA and thiourea in lower concentration promotes germination of seeds in M. sativa, whereas, maleic hydrazide has its marked inhibitory effect. GA_3 and IAA in lower concentrations are also effective in promoting germination of **M. lupulina** and **M. denticulata** seeds, whereas thiourea and maleic hydrazide shows its inhibitory effect. From the result it can also be concluded that thiourea has been observed most effective in **M. sativa**.

Water stress has been observed to affect various physiological processes including germination (Shukla, 1971; Sen & Bhandari, 1978; Dutta & Basu, 1978). The term water stress refers to water deficit which induces a potentially injurious effect on the organism (Noggle & Fritz, 1983). Availability of water is compulsory for initiation of germination and its deficit is a adverse condition for seed germination and consequent seeding growth. Harper & Benton (1966), Mc William et.al. (1970), Oomes & Elberse (1980) have reported that the amount of water available to seed affects the final germination percentage. The result of the effect of moisture stress has been presented in Table 3.12, Figure 3.11. Result when perused suggests that in regime I (waterlogged condition) **M. sativa** and **M. lupulina** could not perform well. The performance of both the species is better in regime II with milder stress. Thereupon a decrease in germination percentage with decrease in moisture is observed in both the species. However, **M. denticulata** performed better in regime I (waterlogged condition). A gradual decrease in germination percentage is observed from regime I to II, III, IV and Vth. The maximum germination percentage is observed in case of **M. lupulina** in regime I (60%) and regime II (72%). Thus, in this case **M. Lupulina** excels both the species. Khader et.al. (1987) while working with **Carthamus tinctorius** observed that the essential metabolites break down during the period of water stress paralleled with the increased activity of oxidase and hydrolyzing enzymes and ultimately there was arrest of synthetic activity. Our results are also corroborative to those of Dwyer & Woldeyohannis (1972), Sionet et.al. (1983) and Ojha & Sinha 91987).

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Chapter 4

Effect of Soil Moisture on Growth

4.1 Introduction:

Water is a major component of green plants. It accounts for 70–90% of the fresh wt of most non-woody species. Approximately 85-90% of this water is contained in the cell where it acts as a suitable medium for many biochemical reactions. It is also a suitable medium for the transport of organic molecules, inorganic ions and atmospheric gases.

Other physical properties of water viz. tensile strength and viscocity play important role in the long-distance transport of water and solutes. The plant growth and soil moisture relationship has had been a subject of extensive research.

A large number of workers have contributed to the understanding of growth behavior of plants in relation to different soil moisture conditions. Fowler & Lipman (1917) studied growth of lemon plants in a wide range of moisture regimes. Cykler (1946) obtained high yield in potato under high level of soil moisture.

There are so many reports of the effect of soil moisture of general nature (Pope & Magdwick, 1974; Gates, 1979; Gifford, 1979; Yegappan et.al.; 1980, 1982, Shone et.al. 1983 and Morrison & Gifford, 1984, a, b) and comparative studies involving more than one species (Bannister, 1964, Etherington & Rutter, 1964, Fould,1978; Christopher et.al., 1985) Plant growth in relation to water logging has also been studied extensively (Jones, 1972; Daniels et.al. 1973 and Armstrong, 1975).

Water stress also affects the plant growth and metabolism (Hsiao,1973). Sheehy & Popple (1981) have shown that reduction in leaf area occurs under moisture stress and instead thicker leaves are produced by the plants.

Passiours (1981), Fisher & Charles- Edwards (1982), Raynal et.al. (1985) and Nicolas et.al. (1985) have shown that physiological and biochemical processes and enzymatic activities in plants are altered under moisture stress. However, perusal of literature reveals that only a few studies have been carried out to assess the effect of varying levels of soil moisture regimes on plant growth and morphogenesis with respect to some well- established parameters of growth viz. dry wt, leaf area, RGR, NAR, LAR, SLA, LWR and '$\propto$' (Pandey, 1976, Singh, 1986, Chaudhary, 1988, Prasad, 1988).

In the present investigation to Medicago spp. viz. M. sativa and M. lupulinna were exposed to four different soil moisture regimes. Their growth behavior with respect to some above-mentioned parameters of growth (Chapter II) were analysed in order to assess the plastically, adaptiblity and ecological amplitude.

Experimental procedure: Different soil moisture regimes were created artificially in the glasshouse of the Botany Department by varying irrigational rhythm. Different soil moisture regimes created were a follow: - W_1 (water logged): The pots were placed in closed through on the concrete platform. The trough was filled with water to a height of 12–13cm so as to keep the level slightly above the soil in the pots. The water of the through was replaced regularly ad watering was done twice daily (Morning/Evening) to keep the water level 2cm above the soil in the pots.

W_2 – The pots were watered daily.

W_3 – The pots were watered every alternate day.

W_4 – The pots were watered weekly.

At the time of watering the soil was brought back to the field capacity and the excess of water, if any was drained out from the hole at the bottom of the pots. The soil moisture content of the soil was determined but before watering on three occasions by digging out some soil from the pots. The mean of the three readings were taken as the soil moisture level of the corresponding regimes. The soil moisture content at the different regimes were as follows: -

W_1 – 52%

W_2 – 42%

W_3 – 34%

W_4 – 19%

Total no. of pots required was calculated (species × replicates × harvests × moisture regimes). Seedlings were transplanted in the earthenware pots maintained at different soil moisture regimes. Some extra seedlings of each species were kept as stand by Pots containing plants of W_2, W_3 and W_4 regimes were kept on the platform whereas, W1 (waterlogged condition) in the closed trough. Details of the harvesting and recording of primary data were worked out as described in chapter-2

4.2 Results and Discussion:

The mean dry wt, leaf area and other derived parameters have been presented in Table 13–20 and their graphic presentation in Figures.4.12 –4.19. The analyses of variance with the levels of significance have been presented in Table 4.1A – 4.8A. The mean dries at (Table-4.1, Figure 4.12) reflects identical behavior of both the species. They show minimum dry wt accumulation in W_1 treatment (water logged condition). **M. sativa** is highly susceptible to water logging. The initial effects were usually attributed to lack of oxygen in the root zone which causes necrosis of the root zone as well as yellowing and wilting of leaves.

Maximum dry wt accruement is observed in W_2 treatment for both the species. Thereafter, a decrease in dry wt accruement with decrease in soil moisture content is observed in both of them. Increase in dry wt with harvests is observed in both of them. Increase in dry wt with harvest is observed in both the spp. Both of them have higher dry wt accumulation in W_4 treatment (the lowest moisture regimes) than W1 treatment (water looged condition). Thus, it can be inferred that both the species are more tolerant to drought than the water-logged condition. The highest dry wt accumulation at W_2 treatment suggests that both the species under investigation perform better in the soil moisture level at the field capacity. However, when the superiority of one species over the other is taken into account it appears that **M. sativa** is superior to **M. lupulina**. **M. Sativa** has higher dry wt accumulation than **M. lupulina** in all the harvests. At the final harvest **M. sativa** has 38.0, 87.33,71.13 and 54.3 in treatment W_1, W_2, W_3 and W_4 respectively. The same in **M. lupulina** is 33.5, 65.25, 47.6 and 44.4 at W_1, W_2, W_3 and W_4 respectively. This differential

Table 4.1: Mean Dry Weight (Mg) Of Two Species in Four Soil Moisture Regimes at Each Harvest.

Species	Harvest	Treatment			
		W_1	**W_2**	**W_3**	**W_4**
M. sativa	1	24.2	22.5	15.5	18.1
	2	27.3	32.9	32.8	21.6
	3	31.3	35.9	55.4	36.6
	4	38.0	87.33	71.13	54.3
M. lupulina	1	14.0	15.6	12.6	10.8
	2	15.5	19.9	30.4	12.0
	3	26.8	27.6	31.8	21.7
	4	33.5	65.25	47.6	44.4

Table-4.1A: Analysis of Variance for The Table-4.1

Source of variation	d.f	SS	MS	F.ratio
Species	1	957.1406	957.1406	36.7165 ×
Treatment	3	962.0939	320.6980	12.3022 ×
Harvest	3	6722.4430	2240.8143	85.9590 ×
Sp × Tr	3	34.7455	11.5818	(2.2508)
Tr × Har	9	1389.7332	154.4148	5.9234 ×
Har × Sp	3	75.8519	25.2840	(1.0310)
Residual	9	234.6156	26.0684	
Total	31	10376.6238		

× –significant at 1% level

Table 4.2: Mean Leaf Area (Cm^2) Of Two Species in Four Soil Moisture Regimes at Each Harvest.

Species	Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1	12.41	10.85	7.54	8.20
	2	14.65	18.57	18.56	10.50
	3	18.16	20.35	32.36	20.51
	4	22.11	50.27	42.65	32.12
M. lupulina	1	7.07	7.56	5.51	5.18
	2	7.54	8.65	18.12	5.51
	3	14.45	14.75	18.56	10.55
	4	20.02	38.55	26.99	24.45

Table 4.2A: Analysis of Variance for The Table-4.2

Source of variation	d.f	SS	MS	F.ratio
Species	1	353.4476	353.4476	33.9462 ×
Treatment	3	353.9040	117.9680	11.3300 ×
Harvest	3	2617.5264	872.5088	83.7984 ×
Sp × Tr	3	14.3122	4.7707	(2.1825)
Tr × Har	9	493.4209	54.8245	5.2655 ×
Har × Sp	3	42.1272	14.0424	1.3487
Residual	9	93.7080	10.4112	
Total	31	3968.4462		

× –significant at 1% level

Table 4.3: Effect of Soil Moisture on Relative Growth Rate

Species	Between Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1–2	0.12	0.38	0.75	0.18
	2–3	0.14	0.09	0.52	0.53
	3–4	0.19	0.89	0.25	0.39
M. lupulina	1–2	0.10	0.24	0.93	0.11
	2–3	0.55	0.33	0.08	0.59
	3–4	0.22	0.86	0.37	0.72

Table 4.3A: Analysis of Variance for The Table-4.3

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0187	0.0187	2.1035
Treatment	3	0.2636	0.0879	2.2334
Harvest	2	0.0954	0.477	1.2128
Sp × Tr	3	0.0318	0.0106	3.7064
Tr × Har	6	1.0834	0.1806	4.5894 ××
Har × Sp	2	0.0160	0.0080	4.9078
Residual	6	0.2361	0.393	
Total	23	1.7451		

×× –significant at 5% level

`Table 4.4: Effect of Soil Moisture on Relative Growth Rate

Species	Between Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1–2	0.91	0.73	1.41	0.38
	2–3	0.24	0.15	0.92	1.00
	3–4	0.34	1.54	0.43	0.69
M. lupulina	1–2	0.19	0.51	1.74	0.21
	2–3	1.06	0.67	0.11	1.25
	3–4	0.40	1.50	0.65	1.37

Table 4.4A: Analysis of Variance for The Table-4.4

Source of variation	d.f	SS	MS	F. ratio
Species	1	0.0353	0.0353	5.1763
Treatment	3	0.4845	0.1615	1.1303
Harvest	2	0.1449	0.0725	2.5191
Sp × Tr	3	0.0878	0.0293	6.2375
Tr × Har	6	3.6155	0.6026	3.3009
Har × Sp	2	0.2226	0.1113	1.6399
Residual	6	1.0953	0.1825	
Total	23	5.6859		

×× –significant at 5% level

Table 4.5: Effect of Soil Moisture on Leaf Area Ratio.

Species	Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1	0.51	0.48	0.49	0.45
	2	0.54	0.56	0.57	0.49
	3	0.58	0.57	0.58	0.56
	4	0.58	0.58	0.60	0.59
M. lupulina	1	0.51	0.48	0.46	0.48
	2	0.49	0.43	0.60	0.46
	3	0.54	0.53	0.57	0.49
	4	0.60	0.59	0.57	0.55

Table 4.5A: Analysis of Variance for The Table-4.5

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0045	0.0045	4.7019
Treatment	3	0.0097	0.0032	3.3777
Harvest	3	0.0450	0.0150	15.6122 ×
Sp × Tr	3	0.0010	0.0003	2.8436
Tr × Har	9	0.0094	0.0010	1.0854
Har × Sp	3	0.0029	0.0010	1.0203
Residual	9	0.0086	0.0010	
Total	31	0.0812		

× –significant at 1% level

Table 4.6: Effect of Soil Moisture on Specific Leaf Area.

Species	Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1	1.91	1.90	2.12	1.91
	2	1.93	1.90	1.90	1.97
	3	1.91	1.99	1.98	1.95
	4	1.97	1.93	2.00	2.00
M. lupulina	1	2.14	2.12	2.20	3.45
	2	2.12	1.82	2.01	2.20
	3	1.95	1.92	1.90	1.97
	4	1.98	1.98	1.96	1.93

Table 4.6A: Analysis of Variance for The Table-4.6

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.1770	0.1770	3.0664
Treatment	3	0.2374	0.0791	1.3710
Harvest	3	0.3904	0.1300	2.2526
Sp × Tr	3	0.2228	0.0743	1.2866
Tr × Har	9	0.4152	0.0461	1.2512
Har × Sp	3	0.3852	0.1284	2.2245
Residual	9	0.5195	0.577	
Total	31	2.3473		

× –significant at 1% level

Table 4.7: Effect of Soil Moisture on Leaf Wt Ratio.

Species	Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1	0.27	0.25	0.23	0.24
	2	0.28	0.30	0.30	0.25
	3	0.30	0.28	0.30	0.29
	4	0.32	0.30	0.30	0.30
M. lupulina	1	0.24	0.23	0.21	0.14
	2	0.23	0.24	0.30	0.21
	3	0.28	0.28	0.30	0.25
	4	0.30	0.30	0.29	0.28

Table 4.7A: Analysis of Variance for The Table-7

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0053	0.0053	23.0274 ×
Treatment	3	0.0057	0.0019	8.3425 ×
Harvest	3	0.0228	0.0076	33.2922 ×
Sp × Tr	3	0.0019	0.0006	2.7820
Tr × Har	9	0.0053	0.0006	2.5830
Har × Sp	3	0.0017	0.0006	2.5342
Residual	9	0.0021	0.0002	
Total	31	0.0447		

× –significant at 1% level

Table 4.8: Effect of Soil Moisture on The Value Of ∝.

Species	Between Harvest	Treatment			
		W_1	W_2	W_3	W_4
M. sativa	1–2	0.71	0.70	0.83	0.72
	2–3	0.66	1.00	0.93	0.79
	3–4	0.95	0.99	0.89	0.87
M. lupulina	1–2	1.67	1.85	0.78	1.83
	2–3	0.85	0.60	4.00	0.91
	3–4	0.67	0.90	1.00	0.86

Table 4.8A: Analysis of Variance for The Table-8

Source of variation	d.f	SS	MS	F.ratio
Species	1	1.4406	1.4406	2.4063
Treatment	3	0.8644	0.2881	2.0777
Harvest	2	0.4615	0.2308	2.5945
Sp × Tr	3	0.6390	0.2130	2.8106
Tr × Har	6	3.6230	0.6038	1.0086
Har × Sp	2	0.9347	0.4673	1.2805
Residual	6	3.5920	0.5987	
Total	23	11.5553		

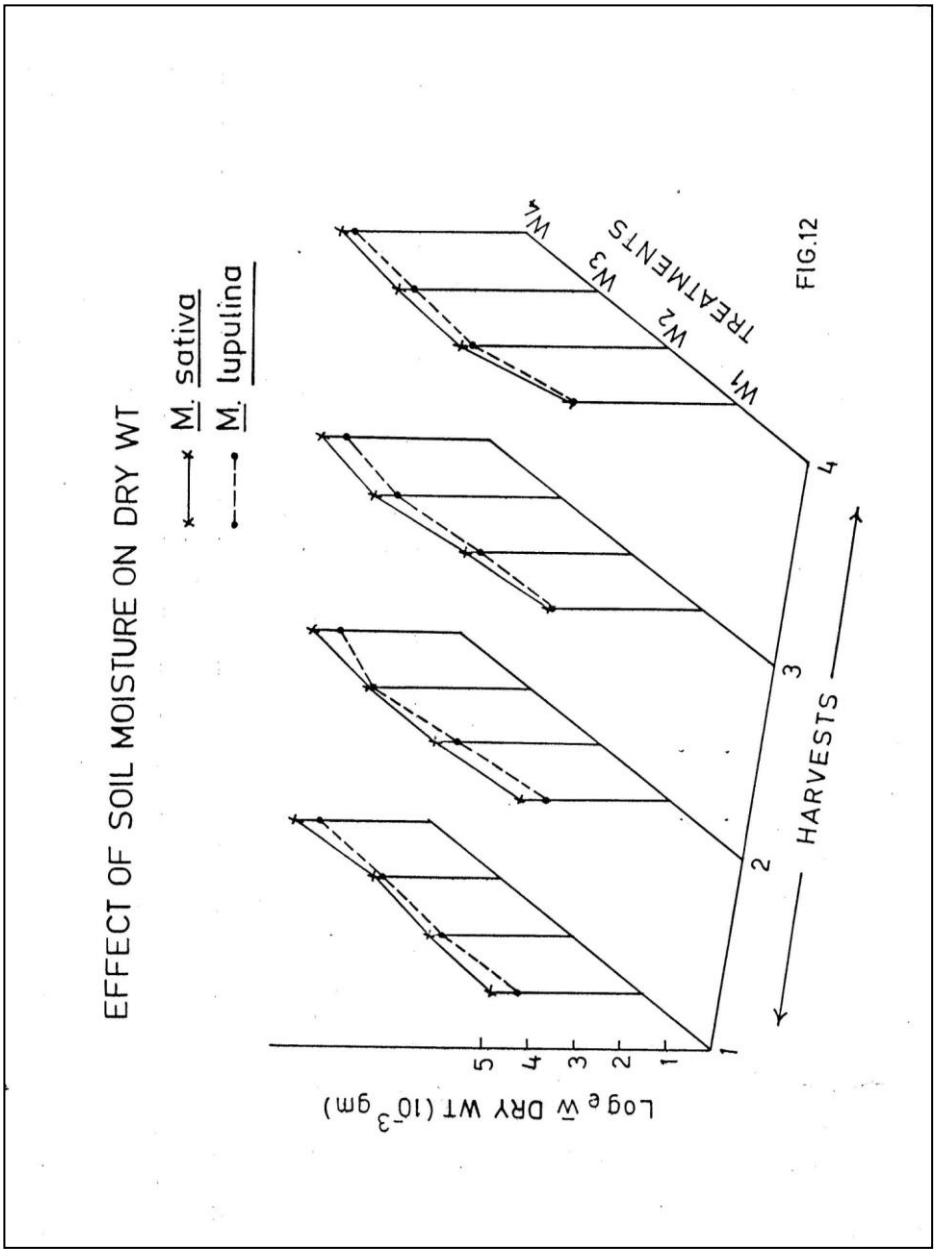

Figure 4.1: Effect of Soil Moisture On Dry WT

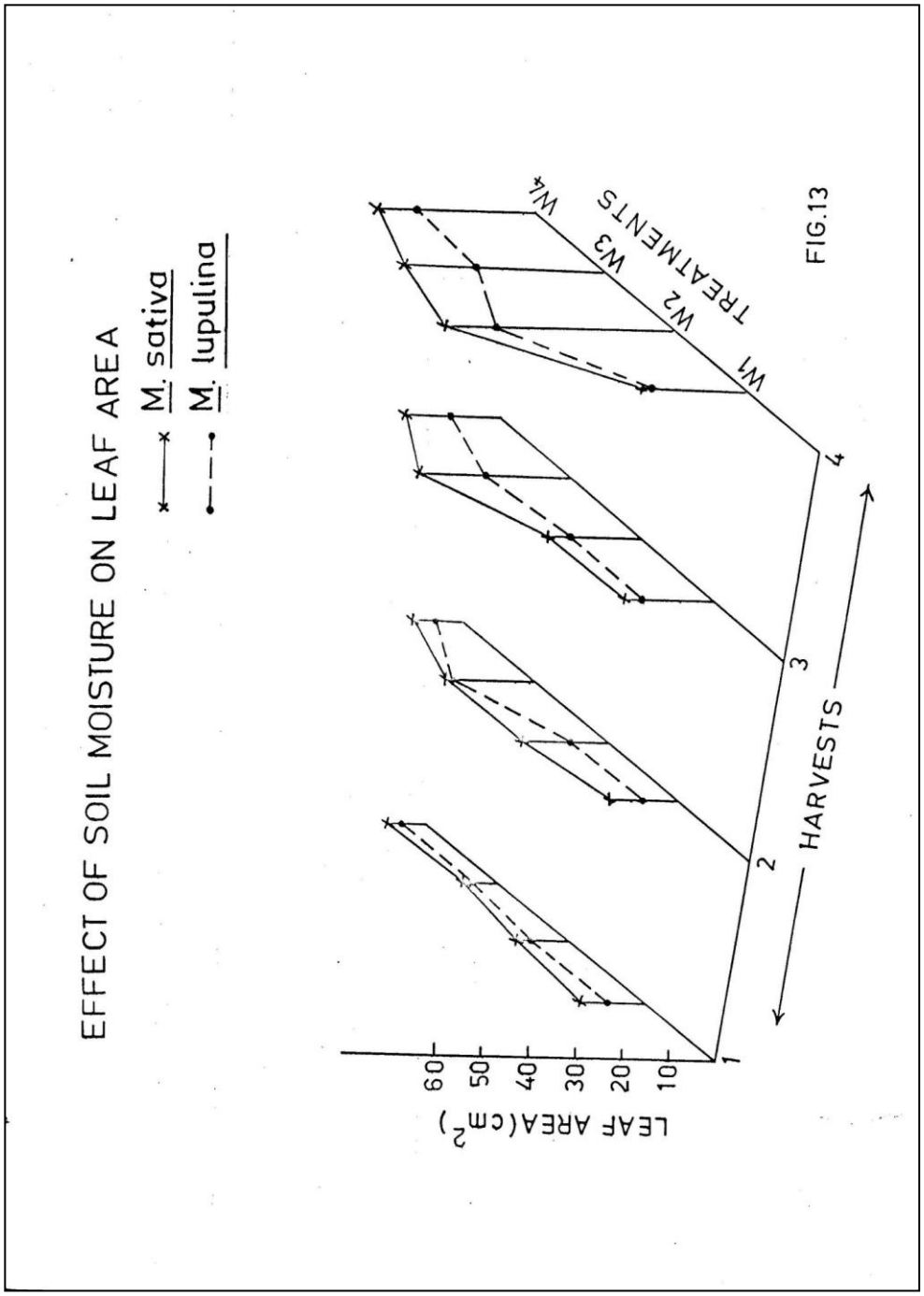

Figure 4.2: Effect of Soil Moisture On Leaf Area

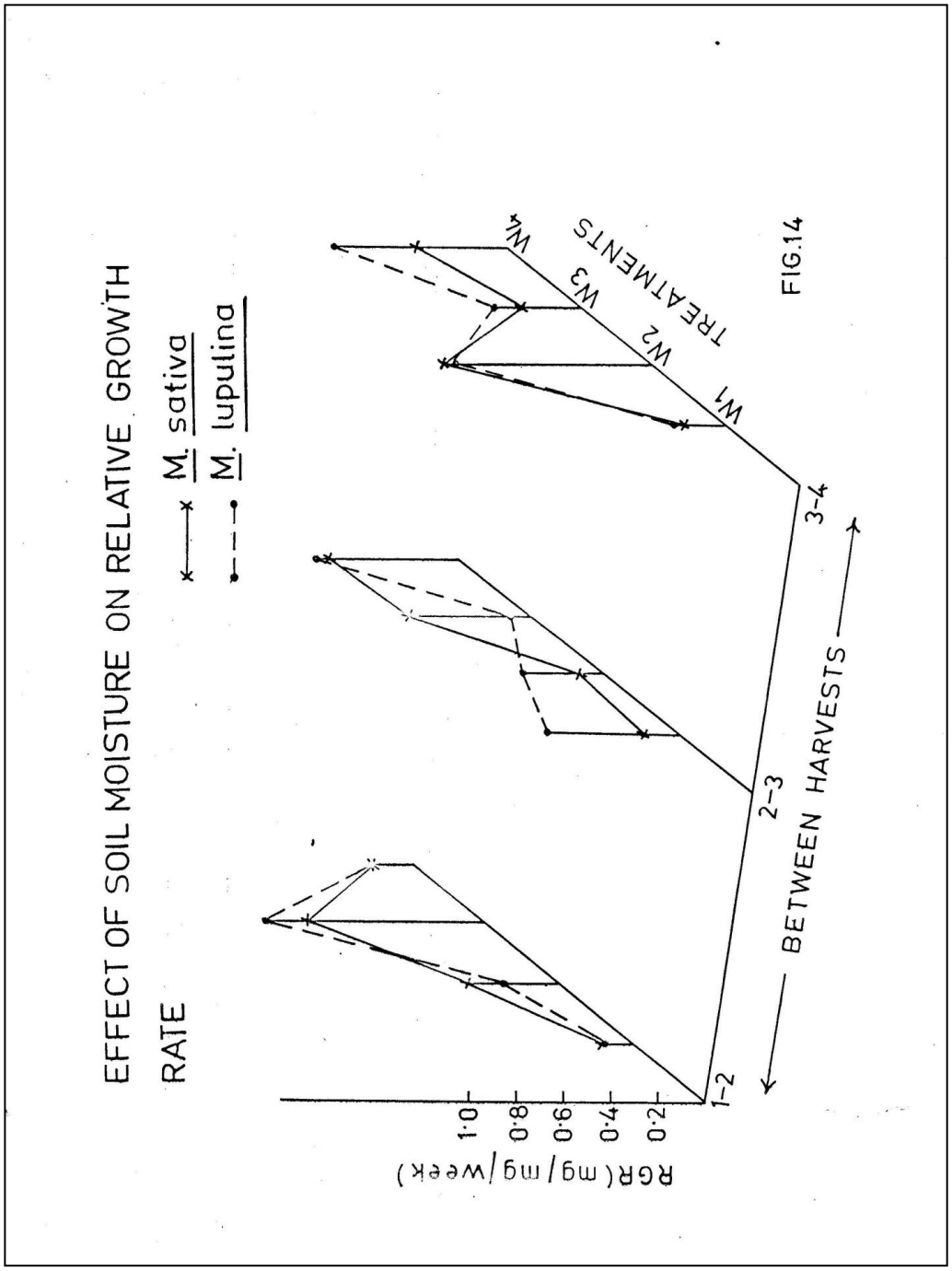

Figure 4.3: Effect of Soil Moisture On Relative Growth

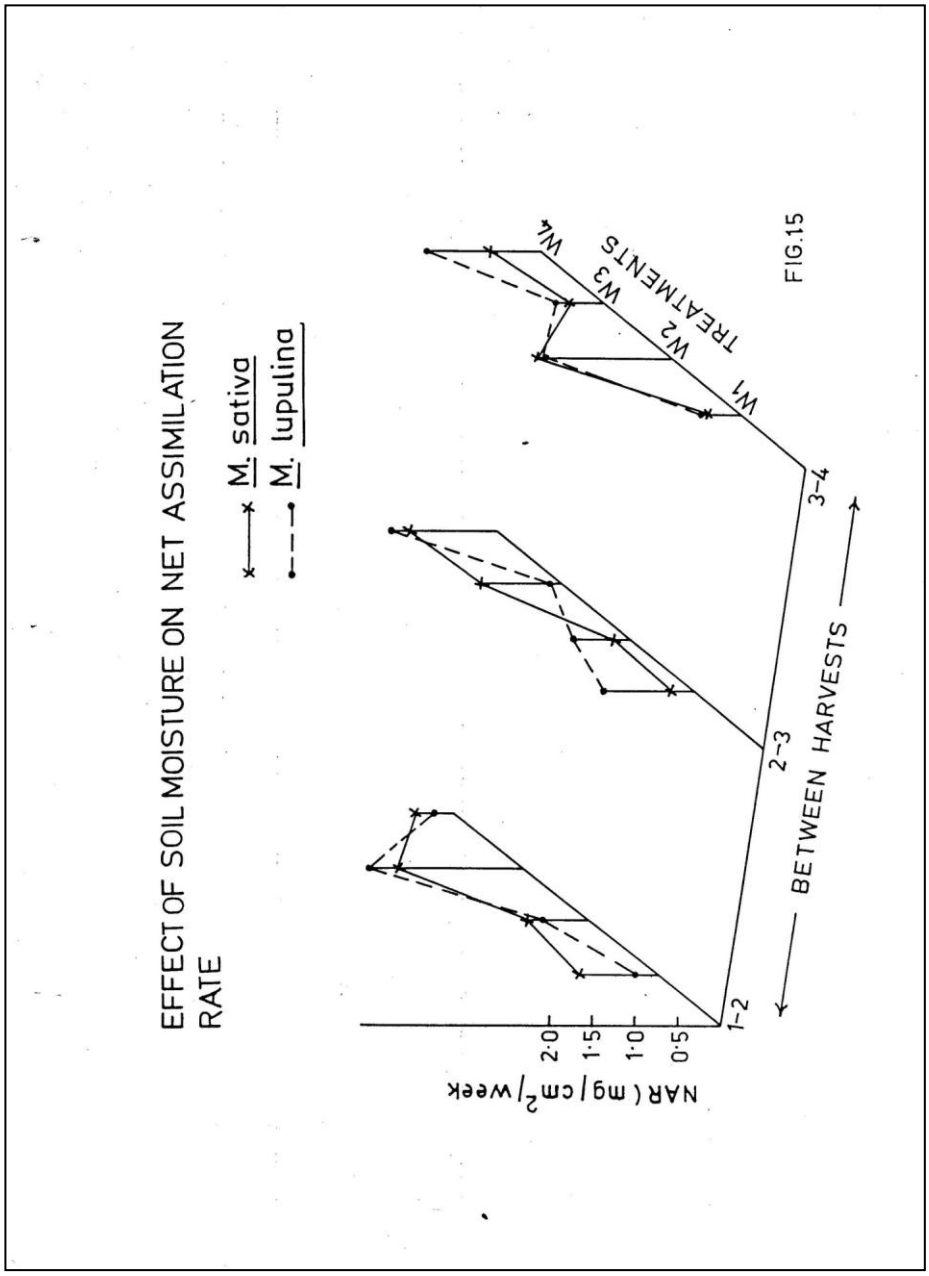

Figure 4.4: Effect of Soil Moisture On Net Assimil Ation Rate

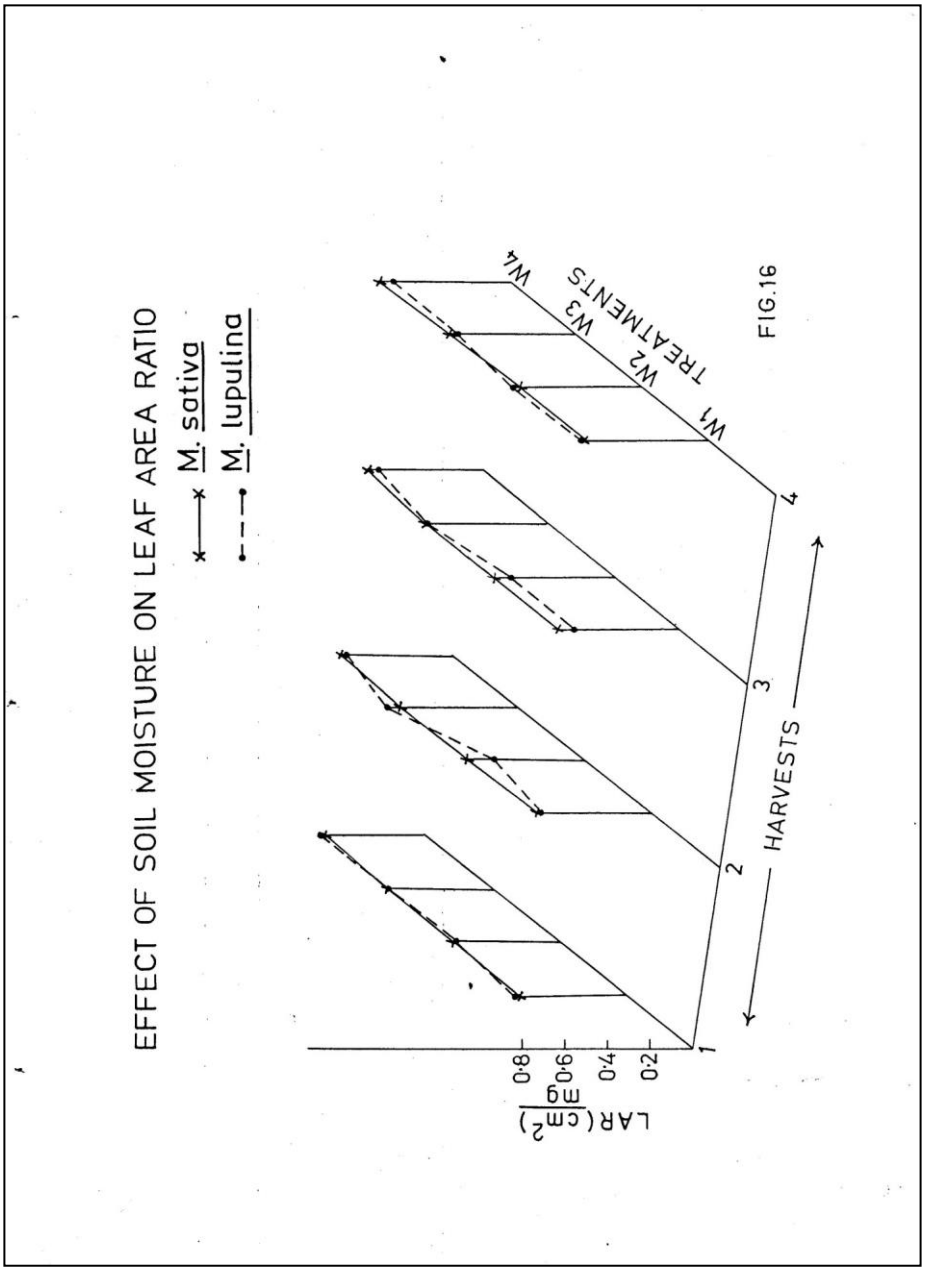

Figure 4.5: Effect of Soil Moisture On Leaf Area Ratio

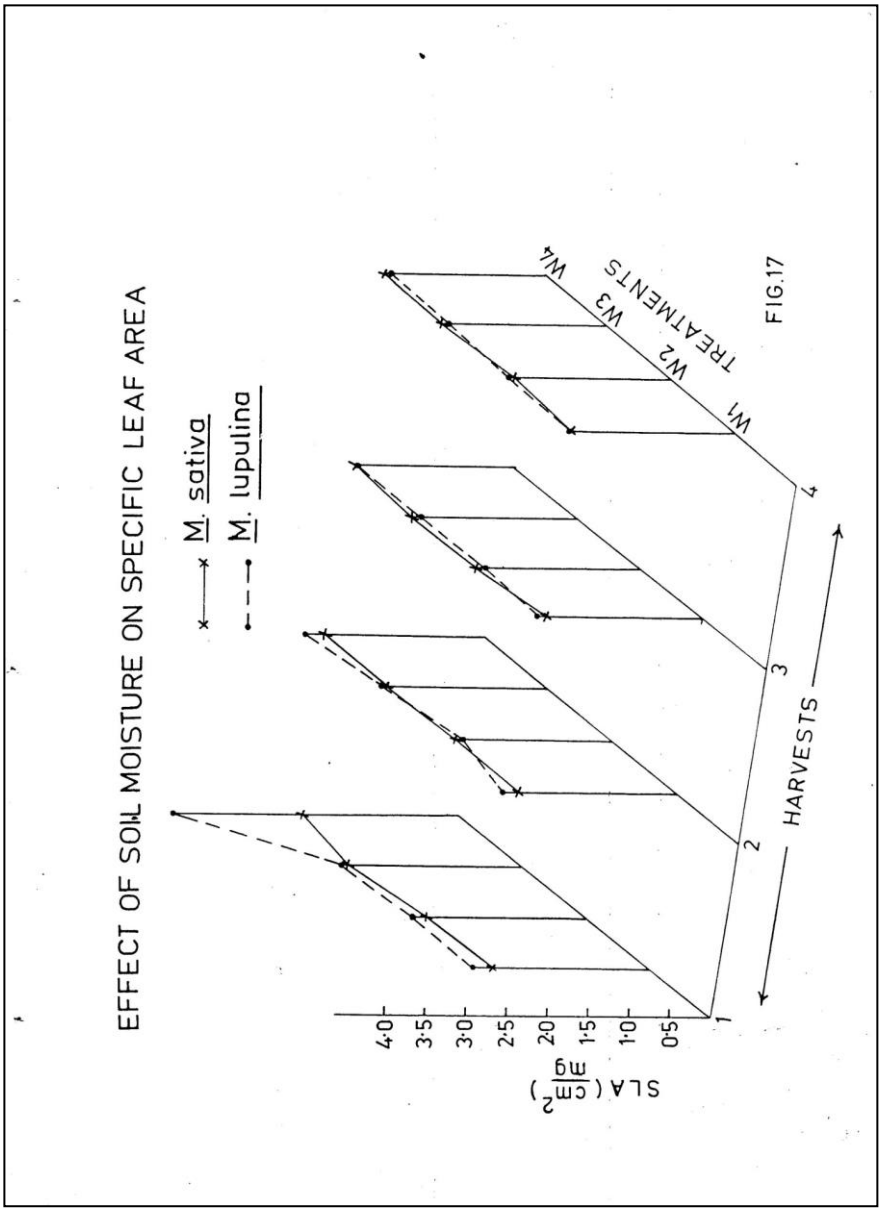

Figure 4.6: Effect of Soil Moisture On Specific Leaf Area

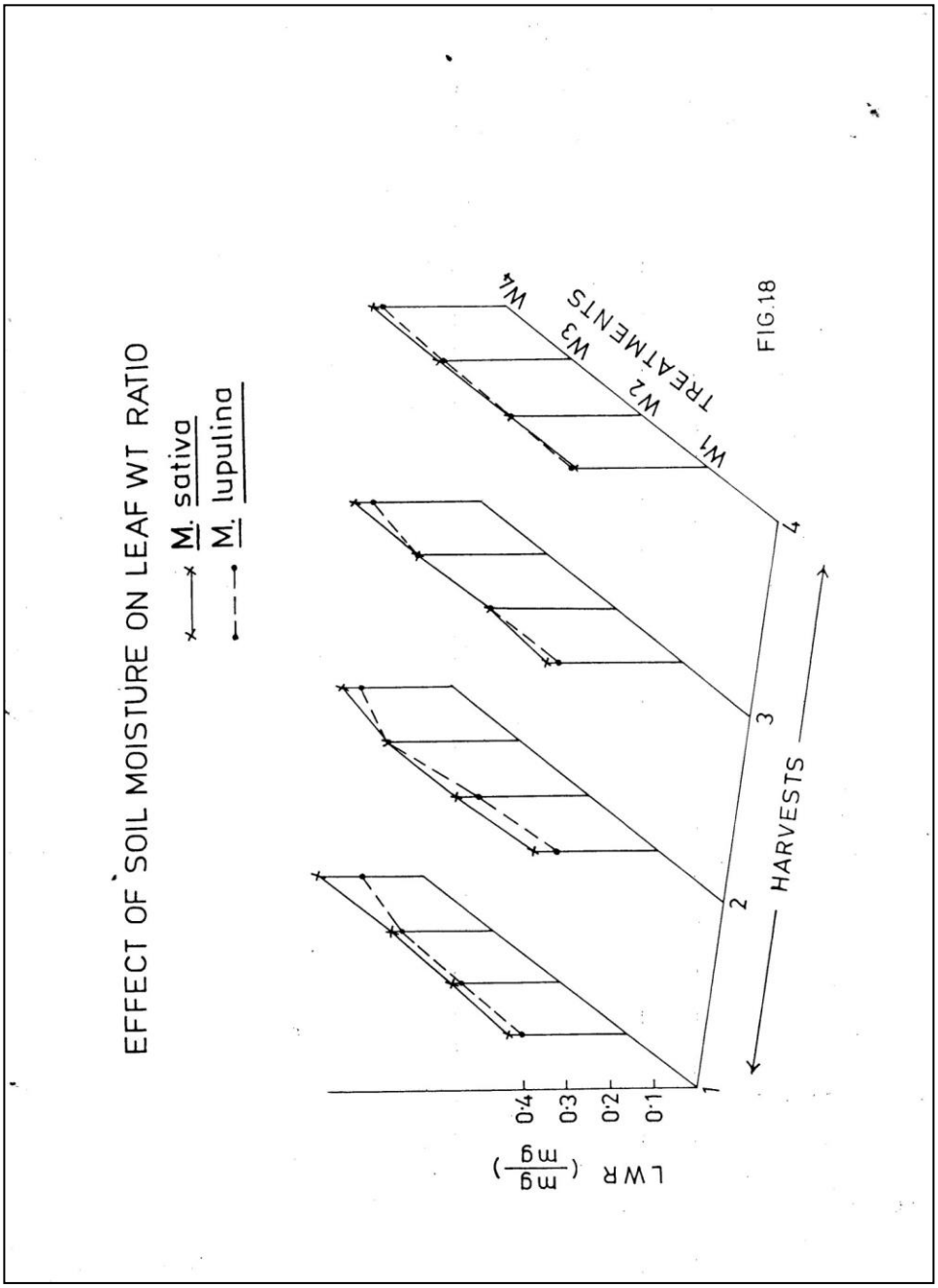

Figure 4.7: Effect of Soil Moisture On Leaf WT Ratio

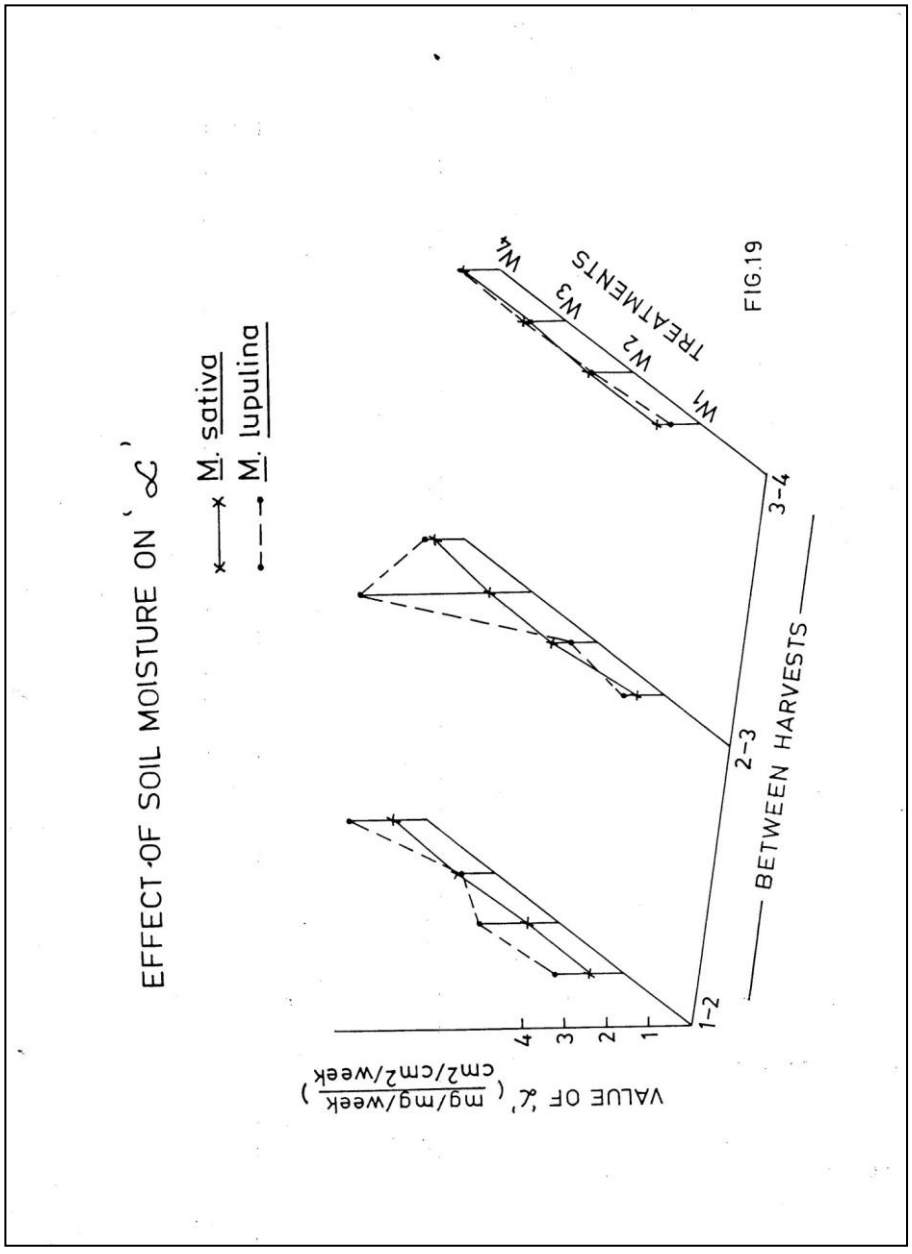

Figure 4.8: Effect of Soil Moisture On 'α'

behavior of the species also becomes apparent from the analysis of variance Table- 4.1A where contributions of all the main factors and Tr × Har. interaction is significant at 1% level.

Table – 4.2, Figure 4.2 represents mean leaf area in cm^2. This follows the trend of dry wt accumulation. When the leaf area of both the species is compared at the two extremes the waterlogged and lowest moisture regimes, it is observed that there is no reduction in leaf area to minimize transpiration.

Orshansky (1954) states that reduction in leaf area plays decisive role in water economy of desert plants. Oppenheimer (1960) also confirmed it to be an effective adaptation under lower moisture conditions. Thus, it appears that none of the species are suitably adapted to the xeric conditions. The analysis of variance for the test of significance (Table- 4.2A) shows contribution of all the main factors and Tr × Har interaction are significant at 1% level. Sp. × Tr and Har × Sp interaction are non- significant.

The RGR Table- 4.3, Figure -4.3 does not show any definite ontogenetic trend in any of the species. In **M. sativa** under waterlogged condition, it increases with harvests whereas, in **M. lupulina** the RGR values are highest between 2–3 harvest interval. In the optimal soil moisture condition **M. Sativa** has the lowest RGR between 2–3 harvest interval whereas, in M. lupulina it increases with harvest. In W_3 treatment (just below the field capacity) the RGR values go down with harvest in **M. Sativa** whereas, **M. lupulina** shows highest RGR values between harvest interval 1–2 and lowest between 2–3. In W_4 treatment (the lowest moisture regime) the highest RGR values are observed between harvest interval 2–3 in **M. Sativa** and **M. lupulina** increase in RGR harvest is observed. The analysis of variance Table-4.3. A show only Tr × Tr interaction significant at 5% level.

The NAR (Table- 4.4, Figure. - 4.4) also like RGR do not show any definite ontogenetic trend in both the species. This suggests better correlation between RGR and NAR. Therefore, NAR also does not throw light on differential behaviour of the species which is supported by analysis of variance for the test of significance (Table- 4.4A) where all the main factors and their interaction are non-significant.

The LAR values (Table- 4.5, Figure - 4.5) increases with harvests in both the species in all the treatment. The values are generally hiher or almost equal under stressed condition i.e. waterlogged and lower moisture regime to the optimal moisture condition. This suggests that both the species tried to maintain its pace through increasing their LAR. Plants in general decrease their area under drought condition to check their rate of transpiration (Evans 1972). The phenomenon is visible to an extent in **M. lupulina** which in W_3 and W_4 conditions has lesser LAR value than waterlogged and optimal soil moisture conditions. However, **M. sativa** does not register any reduction in LAR values, therefore, it must have some inherent capacity to conserve water to face the drought.

It had been observed that evaporation rates in **M. sativa** declines according to the gap between the transpirational demand and the water resources available to the root system as the soil dries out. Thus, it appears that **M. lupulina** is better adapted to xeric conditions than **M. sativa.** However, this conclusion does not bear testimony as the analysis of variance for the test of significance (Table-4.5A) shows contribution of species and all the interactions involving species non-significant. Here only harvest effect is significant at 1% level.

The value of one of the components of LAR i.e., SLA has been presented in Table-4.6, Figure 4.5. A perusal of the SLA value suggests that in **M. sativa** it increase with decrease in moisture content of the soil whereas, in **M. lupulina** it decreases with decrease in moisture content of the soil. Thus, it appears that **M. sativa** increases its LAR with the help of SLA by expending its leaf area **sativa** also exhibits increase in SLA value with harvest whereas, in **M. lupulina** it decreases with harvests.

This differential behavior of the species is not supported by the analysis of variance (Table-4.6A) which shows contribution of all the main factors and their interactions non-significant.

The value of the other component of LAR i.e., LWR have been presented in Table-4.7, Figure-4.7. The LWR values increases with harvests in both species. However, when the species are compared with respect to LWR value, it is observed that in M. sativa LWR value are almost equal atleast in the last harvest in all the treatment. This suggests that species do not increases their LAR through LWR by translocating assimilates from root and stem as there is no change in LWR value in different soil moisture regimes. The LWR values in **M. lupulina** are also almost equal in all the treatment. This suggests that both the species have identical behavior with respect to LWR values. However, the overall LWR values are higher in M. s**ativa**. This differential behavior of the species is also supported by the analysis of variance (Table-4.7A) where contribution of all the main factors are significant at 1% level.

The values of " $\propto$" (Table-4.8, Figure- 4.8) a measure of plants algometry does not appear to be significantly affected by different soil moisture regimes in both the species. The values are generally less than unity in **M. sativa**. These values in M. lupulina are either less than unity or higher. Therefore, on the basis of "$\propto$" values on conclusion can be drawn about the superiority of one species over the other. This conclusion is also supported by the analysis of variance Table- 4.8A, where contribution of the main factors and their interactions are non-significant.

All plants have certain basic requirement without which they cannot exist. The overall relationship of a species to its natural environment is generally different for different species but it generally overlaps. Species with wide ecological amplitude have greater phenotypic plasticity (Banniester, 1978). In the context of the above introductory remark the result of the present investigation has been discussed. Here an attempt is being made to correlated the result obtained in order to have a general picture the responses of the plants under diverse climatic conditions. In nature summer months form a drastic period for survival of the species. During the period the species have to withstand larger period of desiccation. Therefore, a compromise between water holding capacity and one of the assimilatory tissues should occur in the leaf and stem of the plant. This reflects the degree of plasticity with respect to water relations of the plant. Both the species under investigation could not prove to be well- adapted to the xeric conditions, as no reduction in leaf area to any significant level and LAR in the lower moisture regimes were observed. M. Sativa is perennial whereas, M. lupulina is annual. They normally grow in winter months which starts from October and ends in February. Therefore, in nature they do not have to withstand any period of desiccation. Probably this may be cause for the non- adaptability of the species to the xeric conditions or they might be having some inherent mechanism to conserve water in face of drought.

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Chapter 5

Effect of Light on Growth Performance

5.1 Introduction:

Light is an important factor in controlling plant growth and productivity. The eternal source of light is the Sun whose intensity varies from season to season, place to place and even in the different hours of the day. Almost all the physiological processes e.g. germination, growth and flowering are directly affected by the radiant energy. The total radiation received or its components, namely intensity and/or duration affect the process separately as well as concomitantly, and the plants have to adopt themselves accordingly. Briggs et.al. (1920) are the pioneers in analyzing the effect of such environmental factors on growth and yield of plants. Mc Douglal (1903) observed the effect of light and dark on stem elongation, leaf expansion and leaf shape in many species. Thereafter many workers (Hodgson, 1967; Load, 1970; Ranjan et.al. 1971, Hurd & Thornley, 1974, Pandey & Sinha, 1979 a; Packham & Wills, 1982; and Hunt et.al, 1984) have anlysed the effect of light intensity, isolation period and spectral composition on vegetative growth and flowering.

Evans & Hughes (1961) while working on Impatiens parviflora found that different levels of light have important influence on growth. Loach (1970) measured the shade tolerance of various trees. Daubenmire (1959) on the basis of light classified plants into 'heliophytes' and 'sciophytes'. Pandey & Sinha (1977) compared the adeptability of the closely allied species of Crotalaria under different light regions. After the pioneer work of Blackman & Wilson (1951 a, b) other workers (Evens &* Hughes, 1961; Hughes & Evans, 1962, Jarvis, 1964, Grime, 1965; Skuterud, 1977; Packham & Wills, 1977, 1982; Antoniw & Sprent, 1978; Fasehum, 1980; Hunt & Hallington, 1981; Nilwik, 1981; Bourdot et. al. (1984) have subjected many herbaceous and woody plants to different levels of shading in order to understand their morphological and physiological adaptation in stress and, different components of growth have been analysed by growth analysis method. In order they have standardized the techniques of studying the effect of such factors with respect to various parameters such as RGR, NAR and LAR etc. The RGR was observed to be adversely affected by decreasing light intensities whereas, LAR was observed to increase with decreasing light intensities. The linearity of NAR with light was observed by Watson et.al. (1968).

Though a good amount of work on flowering behavior of plants in relation of different photoperiods had been done, there are several reports of photoperiodic effects on vegetative growth and morphogenetic changes in plants (Stackey 1942; Skok & Scally, 1955, Eagles, 1971, Novikava, 1975, Pandey, 1976). The photoperiodic effect on dry matter distribution within the plants have also been reported (Cockshull & Hughes, 1969; Hughes & Cockshull, 1971). The differential responses of plants to photoperiod in terms of some well-established parameters of growth such as mean dry wt, mean leaf area, RGR, LAR and NAR etc. have also been reported (Ryle, 1966; Eagles, 1971, Pandey, 1976).

In recent years Fabaceous plants have received wide attention due to their ability to fix atmospheric nitrogen. The physiology and vegetative growth of **Medicago** in response to environmental factors are not well investigated. The two species of **Medicago** viz **M. sativa** and **M. lupulina** are commonly distributed throughout the plains of India. **M. sativa** is also cultivated for its medicinal value, edible purposes and is used as cattle feed. **M. lupulina** commonly grow wild and is also used as fodder. They are rarely observed in shady places. In the light of these consideration the experiments were designed to assess the effect with respect to various parameters of growth analysis. The experiments performed are as follows:

- Effect of artificial shading.
- Effect of different photoperiods.

5.2 Experimental Procedure:

Artificial shading was created in the glasshouse of the department. First of all, the seeds of both the **Medicago** spp were germinated in sterilized petridishes. As the cotyledons became green and the primordial of first leaf became apparent, the seedlings were transferred to earthenware pots. The pots were filled with a mixture of sandyloam and farm yard manure in the ratio of 3:1. In the beginning 3-4 seedlings were planted in each pot, as the seelings got established, the weaker ones were removed leaving only one in each pot. After seven days period artificial shading was created by providing muslin cloth on wooden frame (1.5m $\times$ 0.8m). One layer of muslin cloth reduced the light intensity to 49% (L_2) while two layer to 31% (L_3). Prevailing light intensity of the glasshouse was taken as 100% (L_1). Light intensity was calculated on the basis of mean of 10 readings on Luxomet (R) Luxmeter on different days (including sunny and cloudy days) in the morning, mid day and evening.

First harvest was taken 15 days after the start of the experiment, allowing one week for acclimatization. Subsequently three weekly harvests were randomly selected. An hour before harvesting pots were watered fully to ensure maximum recovery of root biomass. Plants after uprooting and washing were blotted to remove traces of moisture. Outline of the leaves were drawn on a graph paper for calculating leaf area. Different parts of the plant were separated and put in suitably labeled butter paper packets. The packets were stored in an incubator at 80^0c. Samples were weighed after 48h to determine dry wt of the roots, shoots and leaves. For determining the photoperiodic effect, pots with 15 days old seedlings (as in the previous experiments) were placed in three cabinets of the growth room in the department of Botany, Patna University. The temperature of the growth room was maintained at 80–90^0F with an average 75–85% R.H. Each cabinet of the growth room was fitted with a combination of fluorescent tubes and tungston tubes. In each cabinet 24pots (12 each of **M. sativa** and **M. lupulina**) were placed. They were subjected to 450–500 lumen of light of plant tips level maintaining a distance of 40cms between the tips and light source. Each cabinet with plants were covered with black clothes. To ensure complete darkness and restricting diffuse light from an adjoining illuminated cabinet, curtain of black paper was additionally provided while maintaining a suitable distance for air circulation during the dark period.

The different photoperiodic treatment given to plants were B, 12, and 16h. Harvesting and recording of data with other necessary details were done as in the previous experiment.

5.3 Result and Discussion:

The result of the two aspects of light treatment are discussed here under two sub-heads

- Effect of shading
- photoperiod.

5.3.1 Effect of Shading:

The man dry wt and mean leaf area with other derived parameters are presented in Tables 5.1–5.8 and their analysis of variance for the test of significance in Tables 5.1A–5.8A. Graphic representation of the result are given in Figure.5.1–5.8.

The mean dry wt (Table – 5.1, Figure - 5.1) of both the species in thre light treatments at different harvests suggest similar trend of dry wt accumulation. This dry wt accumulation is highest in L_1 light regime and lowest in L_3 light regime. This decrease in dry wt accumulation with increased level of shading is typical of arable weeds (Blackman & Wilson, 1951). When the species are compared treatment to treatment with respect to first and final harvest, it appears that in between these two harvests

Table 5.1: Mean dry weight (mg) of two species in three light treatments at each harvest.

Species	Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1	20.8	21.2	15.5
	2	35.7	30.5	25.2
	3	55.9	45.2	28.2
	4	96.81	55.4	32.2
M. lupulina	1	10.8	12.6	10.1
	2	25.5	19.2	14.2
	3	35.8	28.3	18.2
	4	72.81	35.1	20.4

Table 5.1A: Analysis of Variance for The Table 5.1

Source of variation	d.f	SS	MS	F.ratio
Species	1	1096.2017	1096.2017	212.7916 ×
Treatment	2	2211.5160	1105.7580	214.6466 ×
Harvest	3	4396.4860	1465.4953	284.4779 ×
Sp × Tr	2	36.2208	18.1204	3.5175

Source of variation	d.f	SS	MS	F.ratio
Tr × Har	6	2000.0081	333.3347	64.7060 ×
Har × Sp	3	90.4683	30.1561	5.8538 ××
Residual	6	30.9092	5.1515	
Total	23	9861.8302		

× – significant at 1% level

× × – significant at 5% level

Table 5.2: Mean Leaf Area (Cm^2) Of Two Species in Three Light Treatments at Each Harvest.

Species	Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1	10.30	10.41	8.20
	2	20.19	18.14	14.01
	3	32.45	26.65	16.61
	4	55.51	32.36	18.52
M. lupulina	1	5.18	5.55	5.17
	2	14.07	8.51	7.10
	3	20.25	16.65	8.21
	4	42.85	20.11	10.20

Table 5.2A: Analysis of Variance for The Table 5.2

Source of variation	d.f	SS	MS	F.ratio
Species	1	412.5104	412.5104	405.3780 ×
Treatment	2	797.9881	398.9941	392.0954 ×
Harvest	3	1657.6552	552.5517	542.9980 ×
Sp × Tr	2	7.9637	3.9819	3.9130
Tr × Har	6	701.9729	116.9955	114.9726 ×
Har × Sp	3	41.3777	13.7926	13.5541 ×
Residual	6	6.1056	1.0176	
Total	23	3625.5736		

× – significant at 1% level

`Table 5.3: Effect of Shading On Relative Growth Rate

Species	Between Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1–2	0.54	0.36	0.33
	2–3	0.45	0.39	0.11
	3–4	0.55	0.55	0.13
M. lupulina	1–2	0.86	0.42	0.34
	2–3	0.34	0.39	0.25
	3–4	0.71	0.22	0.11

Table 5.3A: Analysis of Variance for The Table 5.3

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0187	0.0187	1.6866
Treatment	2	0.4121	0.2060	18.5946
Harvest	2	0.0951	0.0475	4.2903
Sp × Tr	2	0.0080	0.0040	2.7663
Tr × Har	4	0.0995	0.0249	2.2439
Har × Sp	2	0.0111	0.0055	2.0005
Residual	4	0.0443	0.0111	
Total	17	0.6888		

× – significant at 1% level

Table 5.4: Effect of Shading On Net Assimilation Rate

Species	Between Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1–2	1.01	0.67	0.66
	2–3	0.77	0.66	0.20
	3–4	0.96	0.34	0.23
M. lupulina	1–2	1.64	0.96	0.68
	2–3	0.60	0.75	0.54
	3–4	1.23	0.37	0.24

Table 5.4A: Analysis of Variance for The Table 5.4

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.1267	0.1267	3.0446
Treatment	2	1.1604	0.5802	13.9453 ××
Harvest	2	0.5275	0.2638	6.3393
Sp × Tr	2	0.0130	0.0065	6.4118
Tr × Har	4	0.3220	0.0805	1.9348
Har × Sp	2	0.0479	0.0239	1.7380
Residual	4	0.1664	0.0416	
Total	17	2.3639		

× – significant at 5% level

Table 5.5: Effect of Shading On Leaf Area Ratio.

Species	Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1	0.50	0.49	0.45
	2	0.57	0.59	0.56
	3	0.58	0.59	0.59
	4	0.57	0.58	0.58
M. lupulina	1	0.48	0.44	0.51
	2	0.55	0.44	0.50
	3	0.57	0.59	0.45
	4	0.59	0.57	0.50

Table 5.5A: Analysis of Variance for The Table-5.5

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0088	0.0088	3.9065
Treatment	2	0.0046	0.0029	1.0135
Harvest	3	0.0289	0.0096	4.2732
Sp × Tr	2	0.0029	0.0014	1.5792
Tr × Har	6	0.0055	0.0012	2.4659
Har × Sp	3	0.0046	0.0015	1.4733
Residual	6	0.0135	0.0023	
Total	23	0.0688		

Table 5.6: Effect of Shading On Specific Leaf Area.

Species	Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1	2.01	1.98	1.91
	2	1.99	1.99	1.97
	3	1.97	2.05	1.89
	4	1.90	1.98	1.91
M. lupulina	1	3.45	2.19	3.52
	2	1.97	1.85	2.12
	3	1.99	1.88	1.90
	4	2.00	1.99	2.02

Table 5.6A: Analysis of Variance for The Table-5.6

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.4620	0.4620	8.1034 × ×
Treatment	2	0.1520	0.0760	1.3327
Harvest	3	1.3403	0.4468	7.8356 ××
Sp × Tr	2	0.2772	0.1386	2.4310
Tr × Har	6	0.4152	0.0692	1.2137
Har × Sp	3	1.3206	0.4402	7.7202 × ×
Residual	6	0.3421	0.0570	
Total	23	4.3095		

× ×– significant at 5% level

Table 5.7: Effect of Shading On Leaf Wt Ratio

Species	Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1	0.25	0.25	0.24
	2	0.28	0.30	0.28
	3	0.29	0.29	031
	4	0.30	0.30	0.30
M. lupulina	1	0.14	0.20	0.15
	2	0.28	0.24	0.24
	3	0.28	0.31	0.24
	4	0.29	0.29	0.25

Table 5.7A: Analysis of Variance for The Table-5.7

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0096	0.0096	19.6923 ×
Treatment	2	0.0018	0.0009	1.8718
Harvest	3	0.0277	0.0092	18.9288 ×
Sp × Tr	2	0.0016	0.0008	1.6154
Tr × Har	6	0.0009	0.0002	3.1062
Har × Sp	3	0.0039	0.0013	2.6667
Residual	6	0.0029	0.0005	
Total	23	0.0485		

×– significant at 1 % level

Table-5.8: Effect of shading on the value of ∝.

Species	Between Harvest	Treatment		
		L_1	L_2	L_3
M. sativa	1–2	0.81	0.64	0.61
	2–3	0.96	1.03	0.65
	3–4	1.02	1.05	1.18
M. lupulina	1–2	0.87	0.98	1.06
	2–3	0.94	0.58	1.67
	3–4	0.95	1.16	0.53

Table-5.8A: Analysis of Variance for The Table-5.8

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0321	0.0321	5.5395
Treatment	2	0.0044	0.0022	80.5945 ××
Harvest	2	0.0851	0.0426	4.1754
Sp × Tr	2	0.0721	0.0360	4.9323
Tr × Har	4	0.1945	0.0486	3.6558
Har × Sp	2	0.2070	0.1035	1.7174
Residual	4	0.7110	0.1778	
Total	17	1.3062		

× × – significant at 5% level

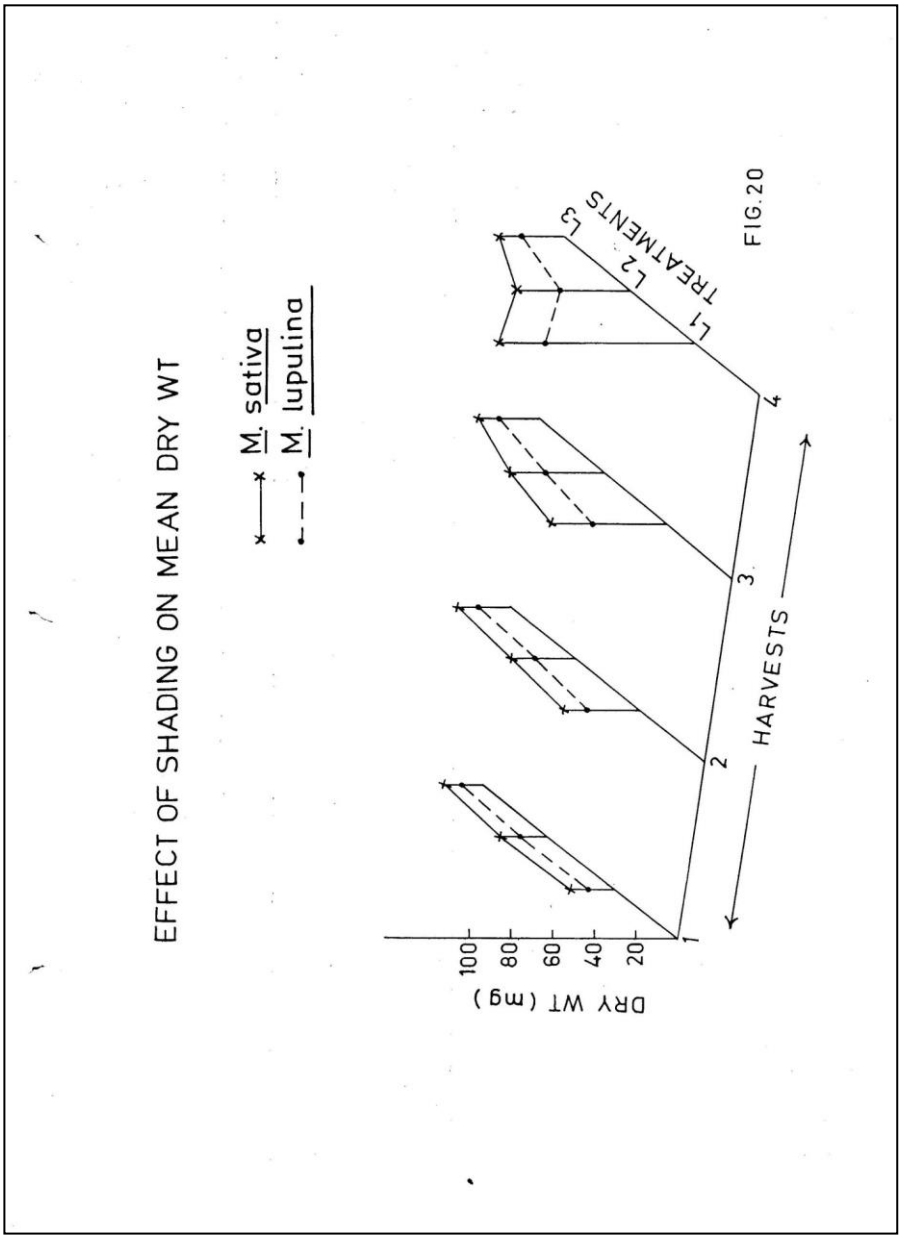

Figure 5.1: Effect of Shading On Mean Dry WT

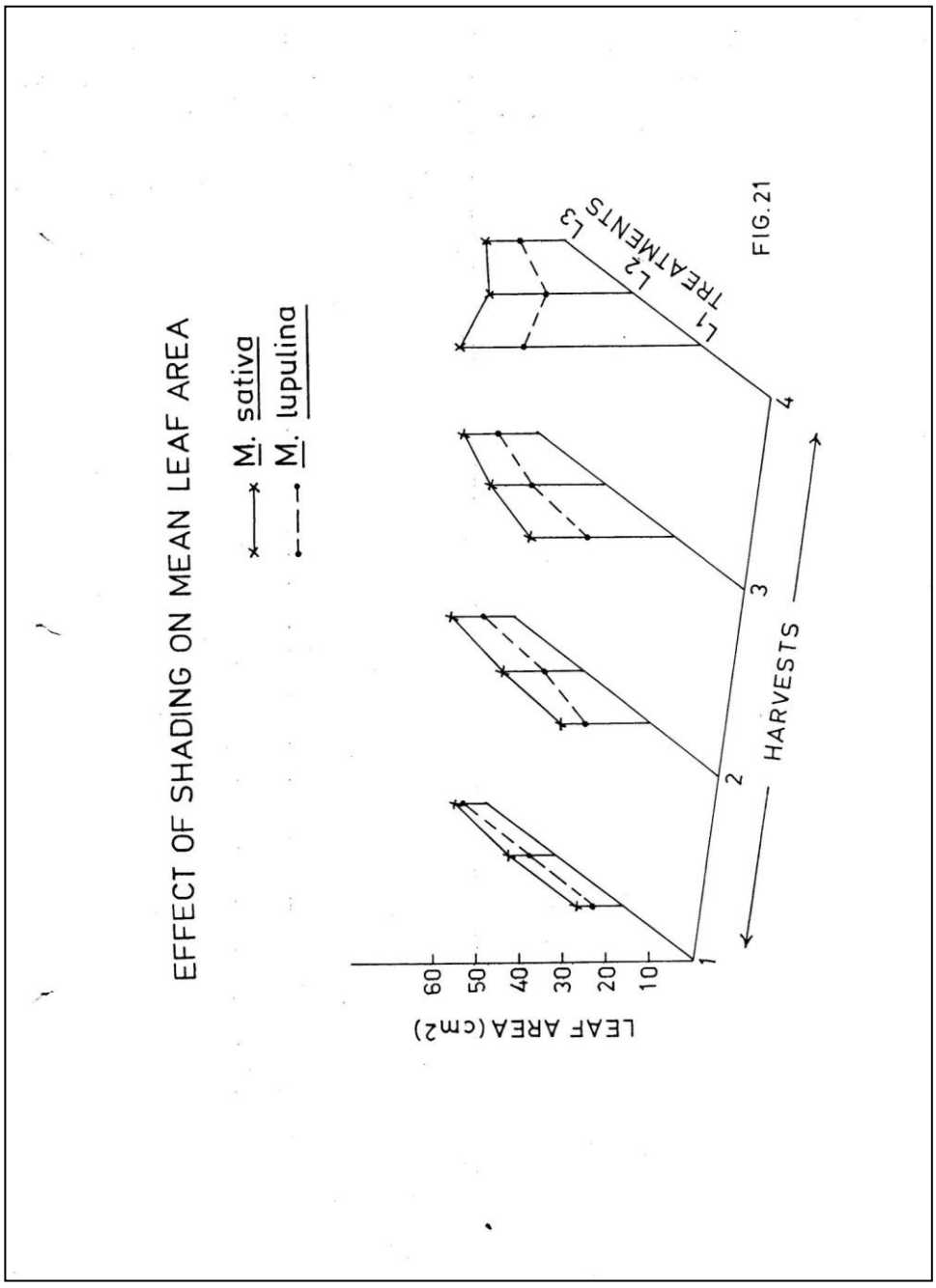

Figure 5.2 Effect of Shading On Mean Leaf Area

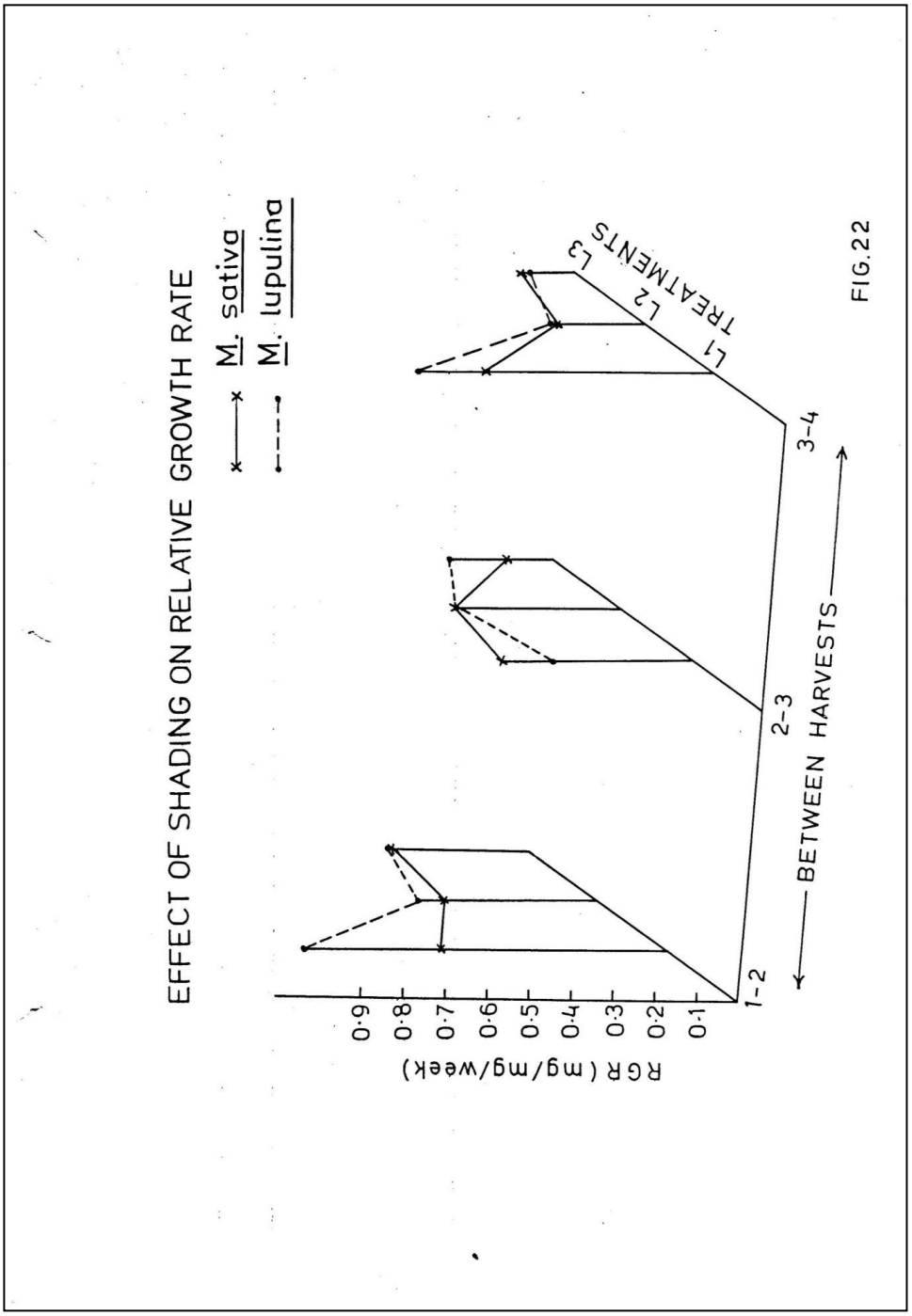

Figure 5.3: Effect of Shading Realative Growth Rate

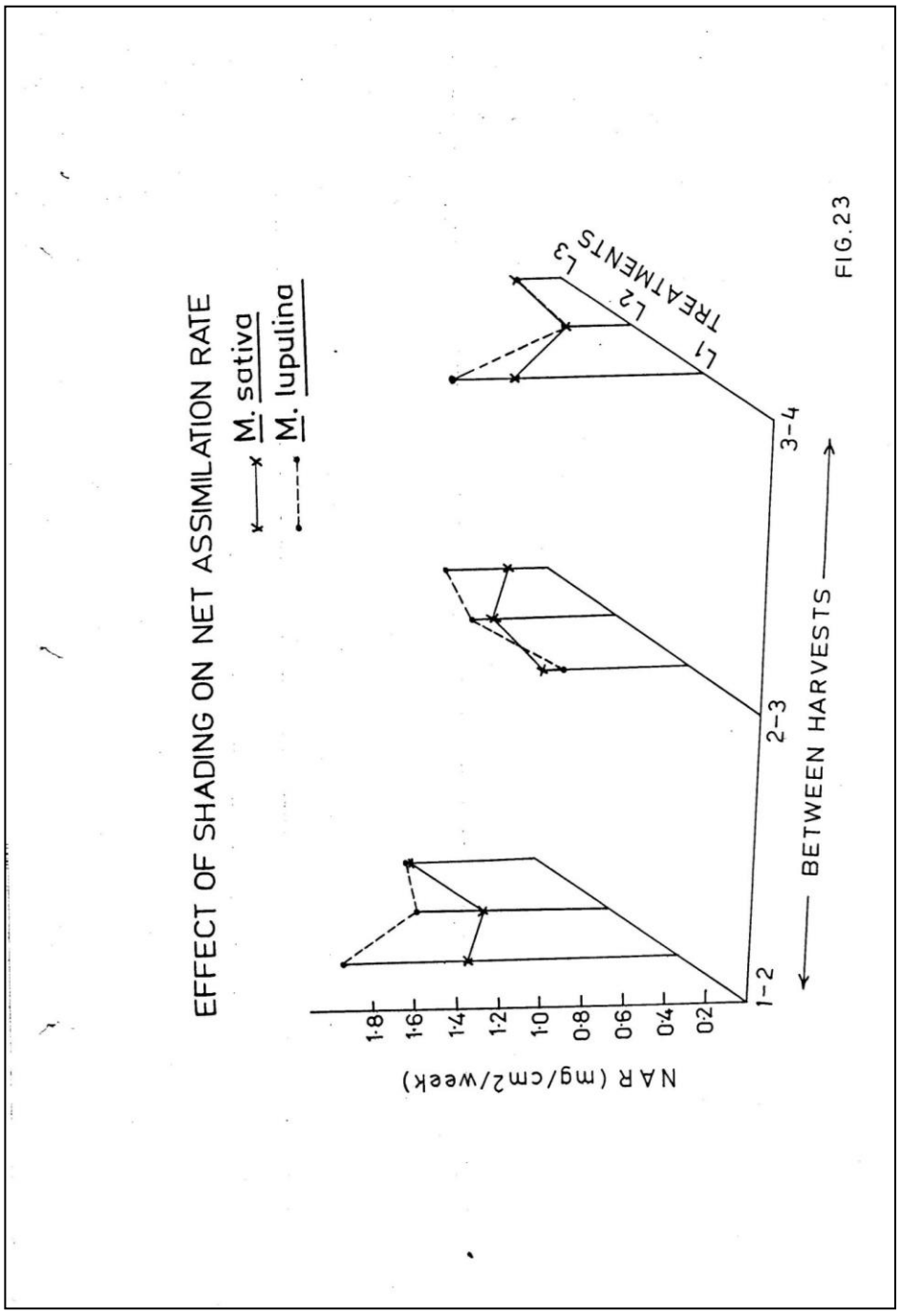

Figure 5.4: Effect of Shading On Net Assimmilation Rate

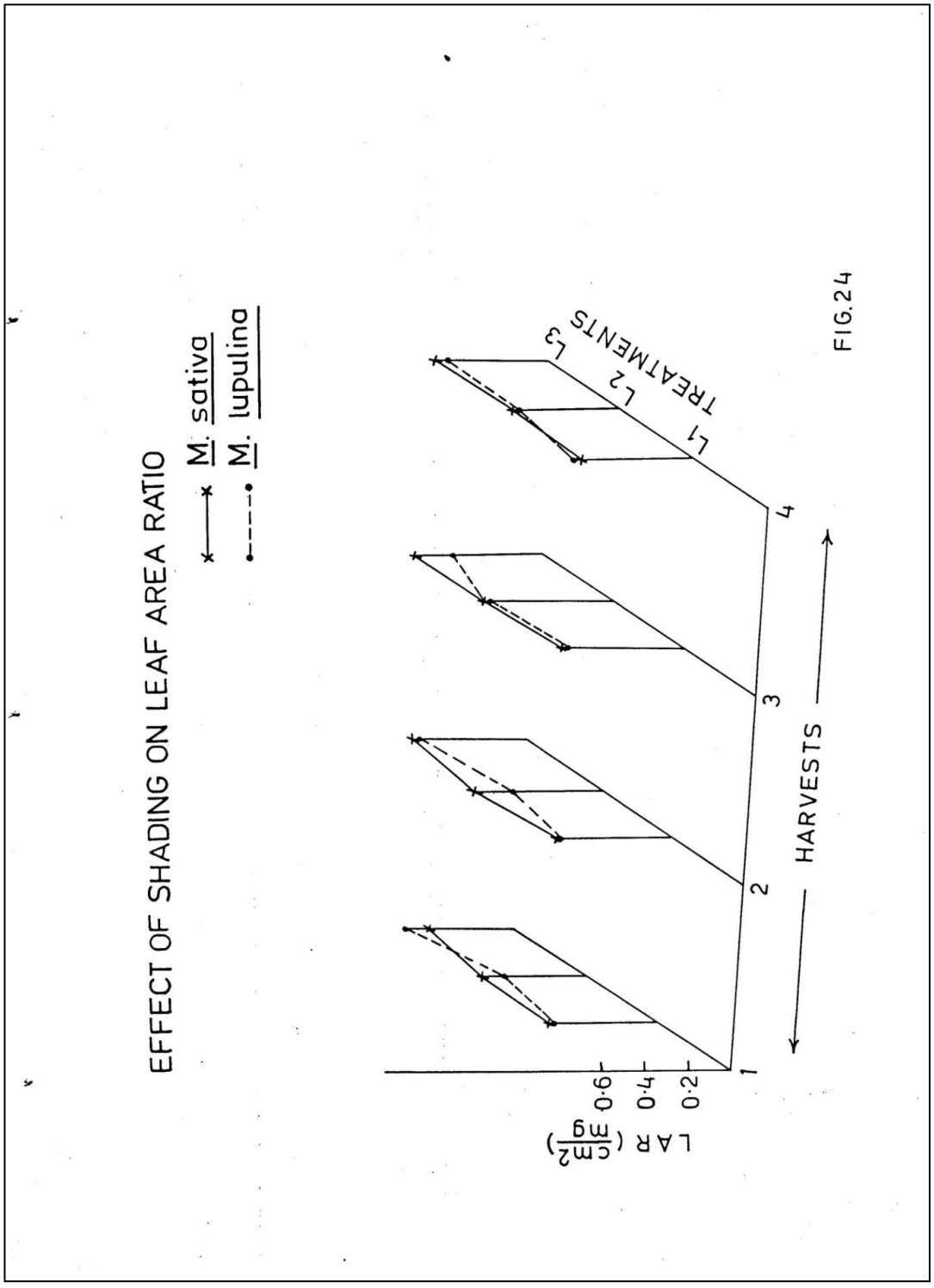

Figure 5.5: Effect of Shading on leaf Area Ratio

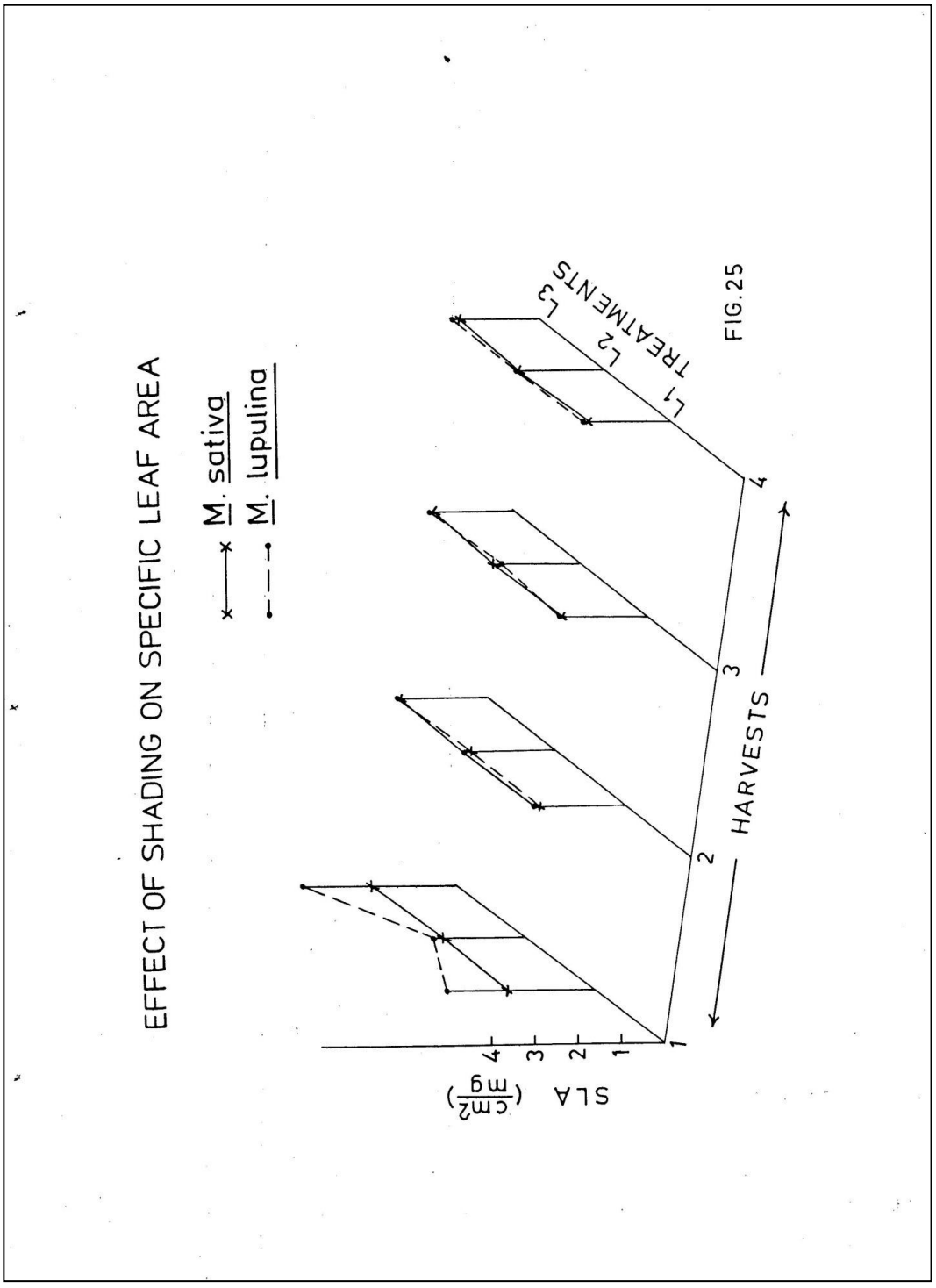

Figure 5.6: Effect of Shading on Specific Leaf Area

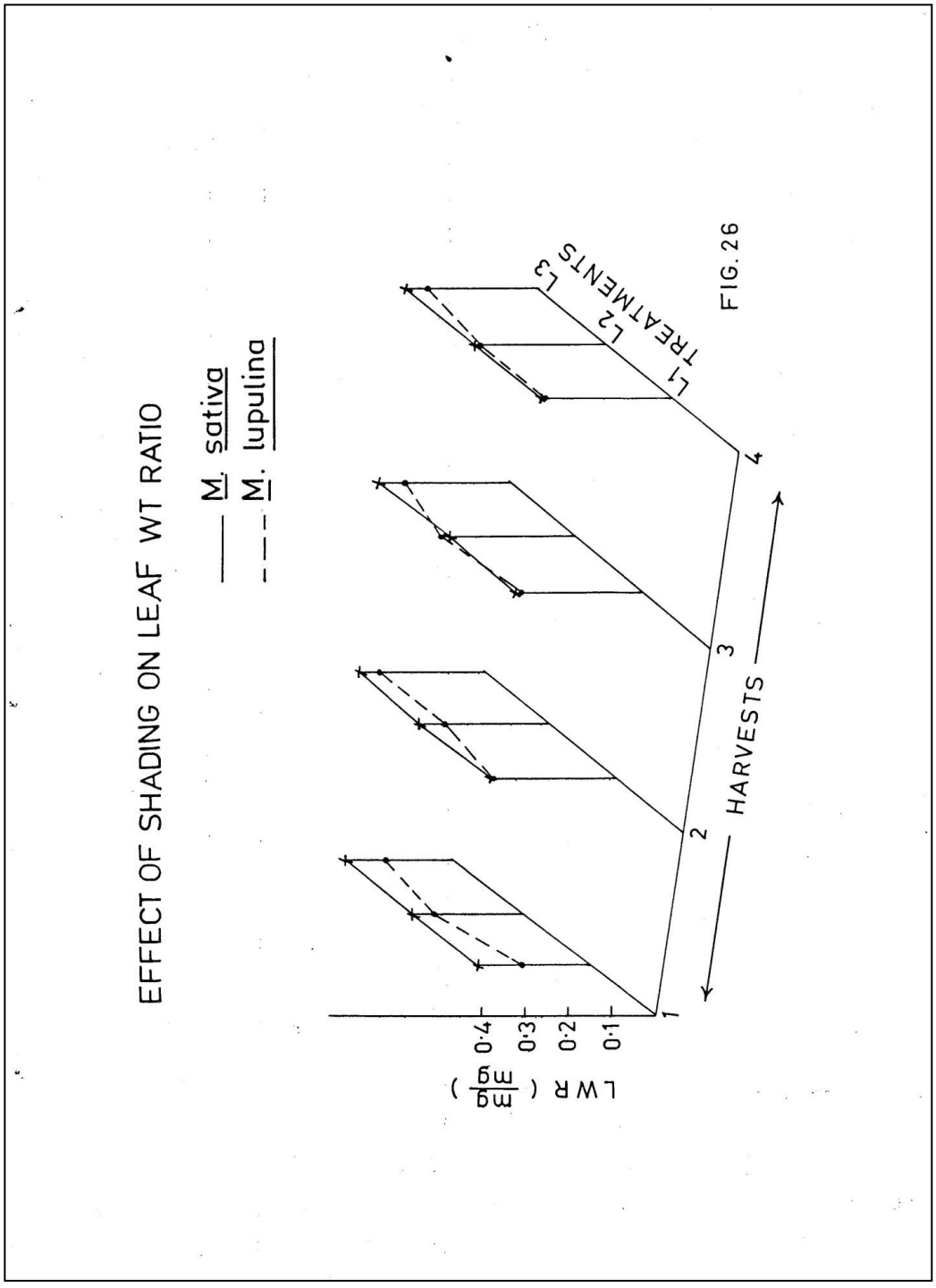

Figure 5.7: Effect of Shading on Leaf WT Ratio

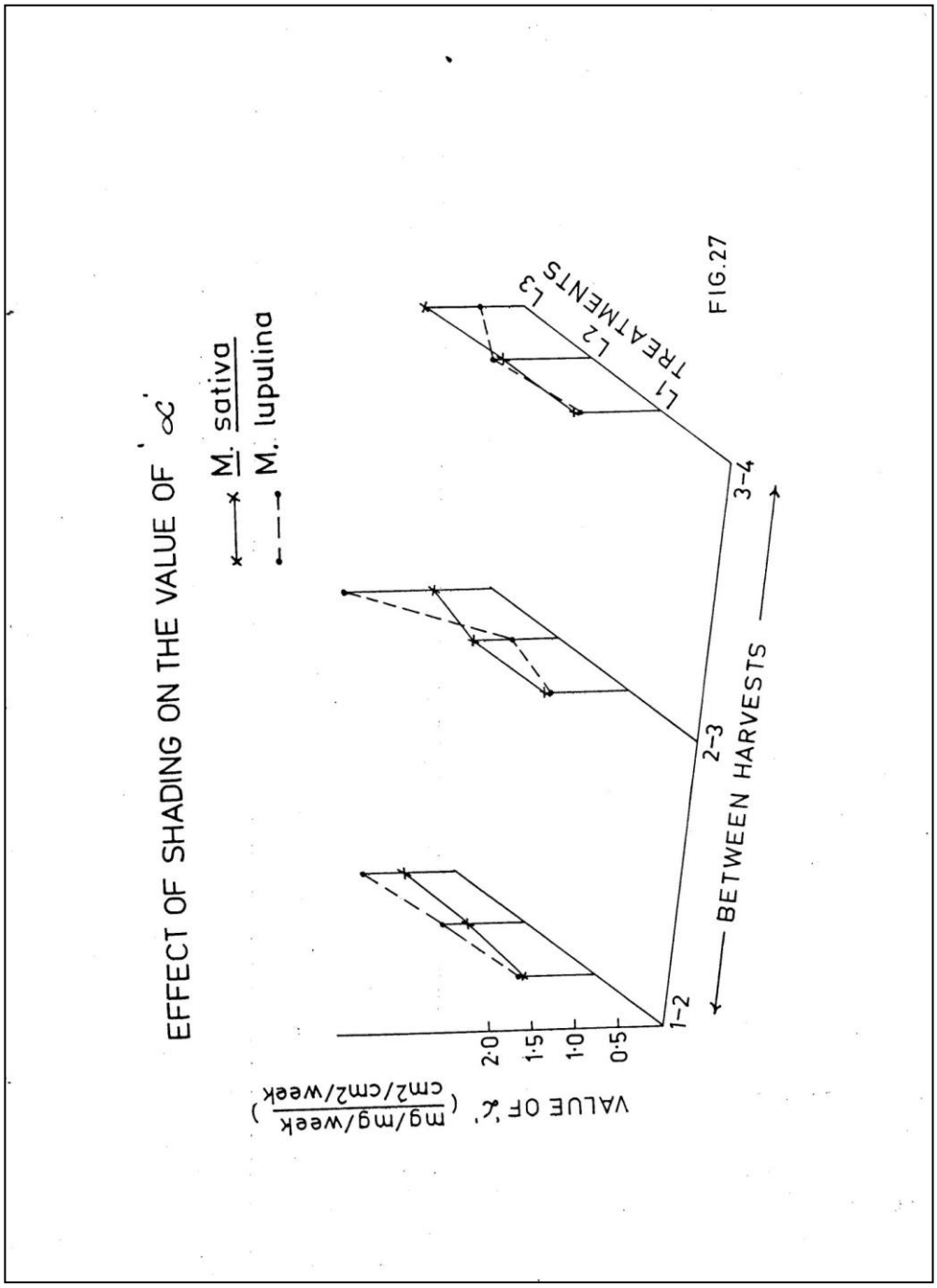

Figure 5.8: Effect of Shading on The Value of '∝'

the dry wt accumulation in M. sativa is 4.67, 2.61 and 1.78 times and in **M. lupulina** 6.74, 2.79 and 2.02 times in L_1, L_2 and L_3 light regimes respectively. Thus, it appears that **M. lupulina** is superior to M. **sativa**, which is not actually the case. This result is perhaps due to initial slower growth of **M. lupulina**.

If the actual mean dry wt is taken into account **M. sativa** has higher dry wt accumulation at all the harvest in all the treatment. Thus **M. sativa** gains superiority over **M. lupulina**. This conclusion is also supported by analysis of variance for the test of significance (Table-5.1A) where all the main factors as well as Tr × Har interactions are significant at 1% level. The Har × Sp interaction has also been observed to be significant at 5% level.

The mean leaf area (Table-5.2, Figure. -5.2) in between first and final harvest in **M. sativa** is 5.30, 3.11 and 2.26 in L_1, L_2 and L_3 light regimes respectively. The same in M. lupulina is 8.27, 3.62 and 1.97 in L_1, L_2 and L_3 light regimes respectively. Thus, it appears that the mean leaf area also follows the same trend as dry wt accumulation. Thus, mean leaf area does not appear to be affected by degree of shading. The mean leaf area was observed to increase with decrease in light intensity by Blackman (1956), Newton (1963) and Bourdot et.al. (1984) for shade tolerant plants. Crotolaria sericea has also been found to be adapted to shading in which reduction in light intensity resulted in small rise in leaf area (Pandey & Sinha, 1977). However, leaf area was not found to be affected with the levels of shading by Buttrose & Sedgley (1978). Our observations are in line with them. However, when the mean leaf area at each harvest in all the treatment is taken into account, M. sativa appears to be superior to **M. lupulina**. The analysis of variance (Table- 5.2A) shows all the main factors as well as Tr × Har and Har × Sp interactions significant at 1% level.

The RGR which measures the average efficiency of each unit of dry matter in the rate of gain in wt is presented in Table-5.3, Figure 5.3. According to Fitter & Hay, (1981) plants when removed to lower light intensity, the immediate effect is reduction of RGR. However, Evens & Huges (1961) could not find a lower RGR in **Impatiens parviflora** grown at 24%-day light. Sprent (1973) also could not observed any difference in RGR of plants grown at 100, 37 and 19%-day light. In both the **Medicago** spp under investigation the RGR in L_1 treatment is higher in between harvest interval 1–2 which goes down in harvest interval 2–3 and again have a rise in between the harvest 3–4. The fall in RGR in between harvest 2 – 3 in both the species can be compared to plants having higher initial RGR (Tainton, 1967; Throne, 1960). This change in RGR can also the ascribed to changes directly or indirectly associated with ageing (Higgs & James, 1969). In L_2 light regime **M. Sativa** has increased RGR between harvest interval 2–3 whereas in **M. lupulina** the RGR decreases with harvests. In L3 treatments **M. Sativa** has the lowest RGR between 2 –3 harvest interval whereas, in **M. lupulina** the RGR decreases with harvests. Both the species show highest RGR in L_1 treatment in all the harvests interval which shows decreasing the trend with the increase in the levels of shading. Thus, on the basis of RGR no conclusion can be drawn about the superiority of the species which is also confirmed by the analysis of variance (Table 5.3A) where only treatment effect is significant at 1% level.

The NAR is an index of photosynthetic efficiency and measures increase in dry wt in mg per cm of leaf surface per week. The NAR values have been presented in Table – 5.4, Figure 5.4. The NAR values almost show the same trend like RGR. This means better correlation between RGR and NAR. It can thus be inferred that both the species do not have better mechanism for shade tolerance.

However, inference with regards to superiority of one species over the other can only draw when the NAR value is compared harvest to harvest and treatment to treatment.

Both the species have lowest NAR values between 2 –3 harvest interval in L_1 light regimes. In L_2 and L_3 light regimes both the species exhibit decreasing NAR values with harvests. At the final harvest both of them show sharp reduction in NAR values in L_2 and L_3 compared to L_1 regimes. Generally lesser reduction in NAR values have been observed in shade tolerant plants. Loach (1970) also observed similar results when little decrease was found in NAR of shade tolerant plants in comparison to in tolerant plants when they were transferred from100 to 40% daylight. Thus, both the species do not appear to be shade tolerant. The overall NAR values are generally higher in **M. lupulina** than **M. sativa**. Thus, on the basis of higher NAR values **M. lupulina** can be considered superior to **M. sativa** which is not supported by the analysis of variance (Table-5.4A) where only treatment effect is significant at the 5% level.

The most important parameters for assessment of adaptation of plants towards shade is LAR. According to Blackman & Wilson (1951, b) small but significant increase in LAR values with decrease in light intensity is a clear-cut pointer to shade tolerance. The LAR values of both the species have been presented in Table -5.5, Figure 5.5. The LAR values in **M. sativa** are generally lower in L_1 compared to L_2 and L_3 light regimes. The same in **M. lupulina** is generally higher in L_1 and L_2 and L_3 light regimes. When the LAR values of both the species are compared treatment to treatment and in between first and final harvest, **M. sativa** appears to have 0.84, 1.18 and 1.28 whereas, M**. lupulina** have 1.23, 1.30 and 0.98 in L_1, L_2 and L_3 light regimes respectively. Thus **M. sativa** has highest LAR values in L_3 light regimes. Similar result has been obtained by other workers on different plant species (Zalensky, 1904; Bendict, 1941; Isagnole, 1944; Blackman & Wilson, 1951, b; Njoku, 1959, Kuriows et.al., 1964; Loach, 1970; Ranjan & Blackman, 1975, Pandey & Singha, 1977; Chaudhary, 1988). According to Newton (1963) leaves under stressed condition have the first call on its products, thus resulting in leaf area increase. Thus, on the basis **M. sativa** can be considered to have better adaptation towards shade than the **M. lupulina**. However, this conclusion about the differential behavior of the species is not confirmed by the analysis of variance for the test of significance (Table – 5.5A) where contribution of all the main factors and their interactions are non-significant.

SLA, one of the constituents of LAR is an important and sensitive index of morphogenesis. Terry (1968 advocates its greater use in comparison of plants as it is the only morphogenetic index independent of plant dry wt. The SLA values (Table -5.6, Figure- 5.6) are highest in L_3 light regimes atleast in the last harvest in both the species. This increased SLA values under shade condition than the full daylight suggest that in shade the leaves gradually become thinner, a phenomenon common to almost all shade plants studied by growth analysis method (Blackman & Wilson, 1951b; Loach, 1967, 1970; Thorne, 1960; Pandey & Sinha, 1977; Packham & Willis, 1977, 1982; Mc Clendon & Mc Millen, 1982; Bourdot et.al. 1984; Taylor & Davies, 1985; Singh, 1986; Chaudhary, 1988).

When both the species are compared with respect to SLA values, it appears that **M. lupulina** has higher values at most of the harvests. Thus, it can be inferred that **M. lupulina** is more suitably adapted to shade with respect to SLA values than **M. sativa**.

The above conclusion is also confirmed by the analysis of variance for the test of significance (Table- 5.6A) where species and Har × Spp interactions are significant at 5% level. The harvest effect is also significant upto 5% level.

LWR is an indicator of percentage of dry wt apportioned to the leaves relative to total dry wt. The LWR values (Table -5.7, Figure- 5.7) in both the species increase with harvests. Thus, both the species have similar trend. When the species are compared with respect to LWR values; it appears the **M. sativa** has consistently higher LWR values in all the three light regimes. The indicates that **M. lupulina** is apportioning more assimilates to its leaves which disturbs its morphogenetic setup balance and there is no such shift in the pattern of dry matter allocation between leaves and the whole plant in **M. sativa**. LAR when compared with respect to SLA and LWR, it appears that in **M. lupulina** the fluctuations in LAR are related to SLA while in **M. sativa** to LWR.

Thus, in both the species LAR is governed in different manner. Events (1972) reported comparatively lesser fluctuations in LWR in comparison to SLA in Impatiens parviflora. Fitter & Ashmore (1974) observed LWR unrelated to severe shade in Veronica Montana (a shade resistant species) both reduced in **V. percica** (an arable weed). Thus, it can be inferred that **M. sativa** is more suitably adapted to shade with respect to LWR values. The analysis of variance Table- 5.7A shows species and harvest effect significant upto 1% level.

'Alpha' ($\propto$) is a parameter for measurement of morphogenetic algometry in plants. It is the ratio of MRGR to MRGR of leaf area increase. The values (Table-5.8, Figure-5.8) of both the species show identical behavior. The values under 100% light in both the species are round about unity. In lower light regimes a few higher and lower values have been obtained. The higher values reflect to higher investment in the non-photosynthetic parts of plants. The lower values suggest that the species is struggling for its survival in deepest shade by producing new leaves. Thus, on the basis of '$\propto$' no conclusion can be drawn about superiority of the species which is also supported by analysis of variance (Table- 5.8A) where only treatment effect is significant at the 5% level.

5.3.2 Photoperiod:

Mean dry wt, leaf area along with other derived parameters are presented in Tables 5.9 –5.6 and their graphic presentations for ready reference and point to point comparison of species in Figure 5.9 –5.6. The three-way analysis of variance involving three photoperiods, four harvest and two species of each parameter has been presented in table 5.9A –5.6A with the level of significance of its contribution marked accordingly.

The dry wt accumulation (Table- 5.9, Figure-5.9) in both the species appears to follow almost identical trend. The dry wt in both the species increases with increase in photoperiod as is generally found in different species (Haxly et.al. 1976; Pandey & Sinha, 1979, a; Nilwik, 1981 b; Hay & Heide, 1983). This increase in dry wt is observed up to 12h, thereafter in 16h photoperiod a drop down is observed. Sharma & Lavania (1977) recorded highest dry at 14h and decrease both ways for Vicia Spp while Hay & Heide (1983) reported highest dry wt accumulation in Poa pretense at 16h. Here in case of both **Medicago** Spp 12h photoperiod has been found to be optimum for dry wt accumulation.

This result is probably because both **Medicago** Spp grow during winter months having shorter photoperiod. A photoperiod of 12h has also been found to be optimum for dry wt accumulation in **Glycine max** by Huxley et.al., (1976) and in **Medicago polymorpha**

Table 5.9: Mean Dry Weight (Mg) Of Two Species in Three Photoperiodic Treatments at Each Harvest

Species	Harvest	Treatment		
		8h	12h	16h
M. sativa	1	22.2	24.8	24.2
	2	35.5	50.5	40.5
	3	48.5	75.21	60.8
	4	55.4	98.51	76.21
M. lupulina	1	15.5	19.5	17.4
	2	25.5	35.2	30.2
	3	32.2	55.4	45.4
	4	40.4	70.81	60.2

Table 5.9A: Analysis of variance for the table 5.9

Source of variation	d.f	SS	MS	F.ratio
Species	1	1125.0443	1125.0443	212.7807 ×
Treatment	2	1502.6626	751.3313	142.0920 ×
Harvest	3	7271.0047	2423.6682	458.3906 ×
Sp × Tr	2	33.3910	16.6955	3.1576
Tr × Har	6	649.8712	108.3119	20.4851 ×
Har × Sp	3	156.6438	52.2146	9.8754 ×
Residual	6	31.7241	5.2873	
Total	23	10770.3417		

×– significant at 1 % level

Table 5.10: Mean Dry Weight (Cm^2) Of Two Species in Three Photoperiodic Treatments at Each Harvest

Species	Harvest	Treatment		
		8h	12h	16h
M. sativa	1	10.75	12.44	12.41
	2	20.18	28.71	22.81
	3	28.25	44.15	36.60
	4	32.36	60.92	44.56
M. lupulina	1	7.54	8.55	9.01
	2	14.07	20.15	16.75
	3	18.52	32.36	26.68
	4	22.75	40.55	36.52

Table 5.10A: Analysis of variance for the table 5.10

Source of variation	d.f	SS	MS	F.ratio
Species	1	430.8690	430.8690	94.9879 ×
Treatment	2	546.2006	273.1003	60.2067 ×
Harvest	3	2985.1785	995.0595	219.3674 ×
Sp × Tr	2	21.5240	10.7620	2.3726
Tr × Har	6	272.4350	45.4058	10.0100 ×
Har × Sp	3	68.4605	22.8202	5.0309 × ×
Residual	6	27.2163	4.5360	
Total	23	4351.1884		

×– significant at 1 % level

× ×– significant at 5 % level

Table 5.11: Effect of Photoperiod on Relative Growth Rate.

Species	Between Harvest	Treatment		
		8h	12h	16h
M. sativa	1–2	0.50	0.71	0.51
	2–3	0.31	0.40	0.41
	3–4	0.14	0.27	0.21
M. lupulina	1–2	0.50	0.59	0.55
	2–3	0.23	0.45	0.41
	3–4	0.23	0.25	0.28

Table 5.11A: Analysis of Variance for The Table 5.11

Source of variation	d.f	SS	MS	F. ratio
Species	1	0.00005	0.00005	56.6667 ×
Treatment	2	0.0048	0.0224	8.6196 ××
Harvest	2	0.3295	0.1648	58.1549 ×
Sp × Tr	2	0.0033	0.0017	1.6920
Tr × Har	4	0.0119	0.0030	1.0490
Har × Sp	2	0.0044	0.0022	1.2782
Residual	4	0.0113	0.0028	
Total	17	0.4093		

× – significant at 1% level

× × – significant at 5% level

Table 5.12: Effect of photoperiod on net assimilation rate.

Species	Between Harvest	Treatment		
		8h	12h	16h
M. sativa	1–2	0.89	1.33	0.96
	2–3	0.54	0.70	0.69
	3–4	0.25	0.44	0.39
M. lupulina	1–2	0.95	1.15	1.08
	2–3	0.41	0.78	0.72
	3–4	0.41	0.43	0.47

Table 5.12A: Analysis of Variance for The Table 5.12

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0024	0.0024	3.5442
Treatment	2	0.1619	0.0810	9.3231 ××
Harvest	2	1.3452	0.6726	77.4593 ×
Sp × Tr	2	0.0097	0.0049	1.7842
Tr × Har	4	0.0422	0.0106	1.2156
Har × Sp	2	0.0064	0.0032	2.6995
Residual	4	0.347	0.0087	
Total	17	1.6027		

× – significant at 1% level

× × – significant at 5% level

Table 5.13: Effect of Photoperiod On Leaf Area Ratio.

Species	Harvest	Treatment		
		8h	12h	16h
M. sativa	1	0.48	0.50	0.51
	2	0.57	0.57	0.56
	3	0.59	0.59	0.60
	4	0.59	0.62	0.58
M. lupulina	1	0.49	0.44	0.46
	2	0.55	0.57	0.55
	3	0.58	0.58	0.59
	4	0.56	0.57	0.61

Table 5.13A: Analysis of variance for the table 5.13

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0018	0.0018	3.9492
Treatment	2	0.0002	0.0001	5.0000
Harvest	3	0.0474	0.0158	33.9195 ×
Sp × Tr	2	0.0005	0.0003	1.6667
Tr × Har	6	0.0010	0.0002	2.6720
Har × Sp	3	0.0005	0.0002	2.5573
Residual	6	0.0028	0.0005	
Total	23	0.0542		

×– significant at 1 % level

Table 5.14: Effect of Photoperiod On Specific Leaf Area.

Species	Harvest	Treatment		
		8h	12h	16h
M. sativa	1	1.92	1.90	1.91
	2	1.99	1.98	1.92
	3	2.01	2.00	2.02
	4	1.98	2.00	1.93
M. lupulina	1	2.12	1.84	2.00
	2	1.97	1.99	1.83
	3	1.91	1.98	2.04
	4	1.93	1.98	2.03

Table 5.14A: Analysis of Variance for The Table 5.14

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0001	0.0001	203.9207
Treatment	2	0.0020	0.0010	30.4606 × ×
Harvest	3	0.0091	0.0030	10.1023 × ×
Sp × Tr	2	0.0028	0.0014	22.0450 × ×
Tr × Har	6	0.0423	0.0070	4.3395 ×
Har × Sp	3	0.0122	0.0041	7.5525
Residual	6	0.1835	0.0306	
Total	23	0.2520		

× ×– significant at 5 % level

Table 5.15: Effect of Photoperiod of Leaf Wt. Ratio.

Species	Harvest	Treatment		
		8h	12h	16h
M. sativa	1	0.25	0.26	0.27
	2	0.29	0.29	0.29
	3	0.29	0.29	0.30
	4	0.30	0.31	0.30
M. lupulina	1	0.23	0.24	0.23
	2	0.28	0.29	0.30
	3	0.30	0.30	0.29
	4	0.29	0.29	0.30

Table 5.15A: Analysis of Variance for The Table 5.15

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0004	0.0004	5.4546
Treatment	2	0.0002	0.0001	1.1455
Harvest	3	0.0105	0.0035	45.7460 ×
Sp × Tr	2	0.00001	0.000005	16.0000
Tr × Har	6	0.00009	0.00002	5.0002 × ×
Har × Sp	3	0.0008	0.00036	3.5637
Residual	6	0.0005	0.00008	
Total	23	0.0125		

×– significant at 1 % level

× ×– significant at 5 % level

Table 5.16: Effect Of Photoperiod On The Value Of '∝'

Species	Between Harvest	Treatment		
		8h	12h	16h
M. sativa	1–2	0.75	0.85	0.84
	2–3	0.91	0.93	0.87
	3–4	1.00	0.84	1.05
M. lupulina	1–2	0.81	0.69	0.74
	2–3	0.85	0.96	0.87
	3–4	1.10	1.09	0.90

Table 5.16A: Analysis of Variance for The Table 5.16

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.00005	0.00005	207.1667
Treatment	2	0.0019	0.0010	10.9035
Harvest	2	0.1412	0.0706	6.8174
Sp × Tr	2	0.0144	0.0072	1.4353
Tr × Har	4	0.0138	0.0034	3.0097
Har × Sp	2	0.0134	0.0067	1.5422
Residual	4	0.0414	0.0104	
Total	17	0.2263		

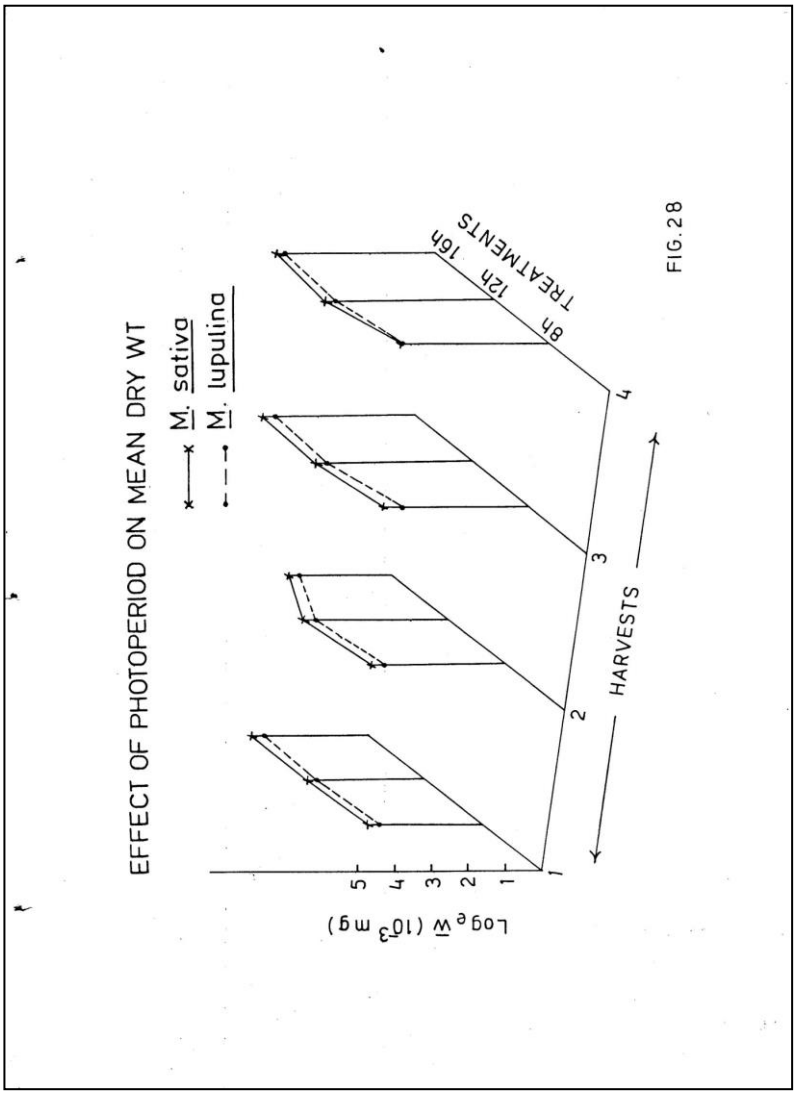

Figure 5.9: Effect of Photoperiod on Mean Dry WT

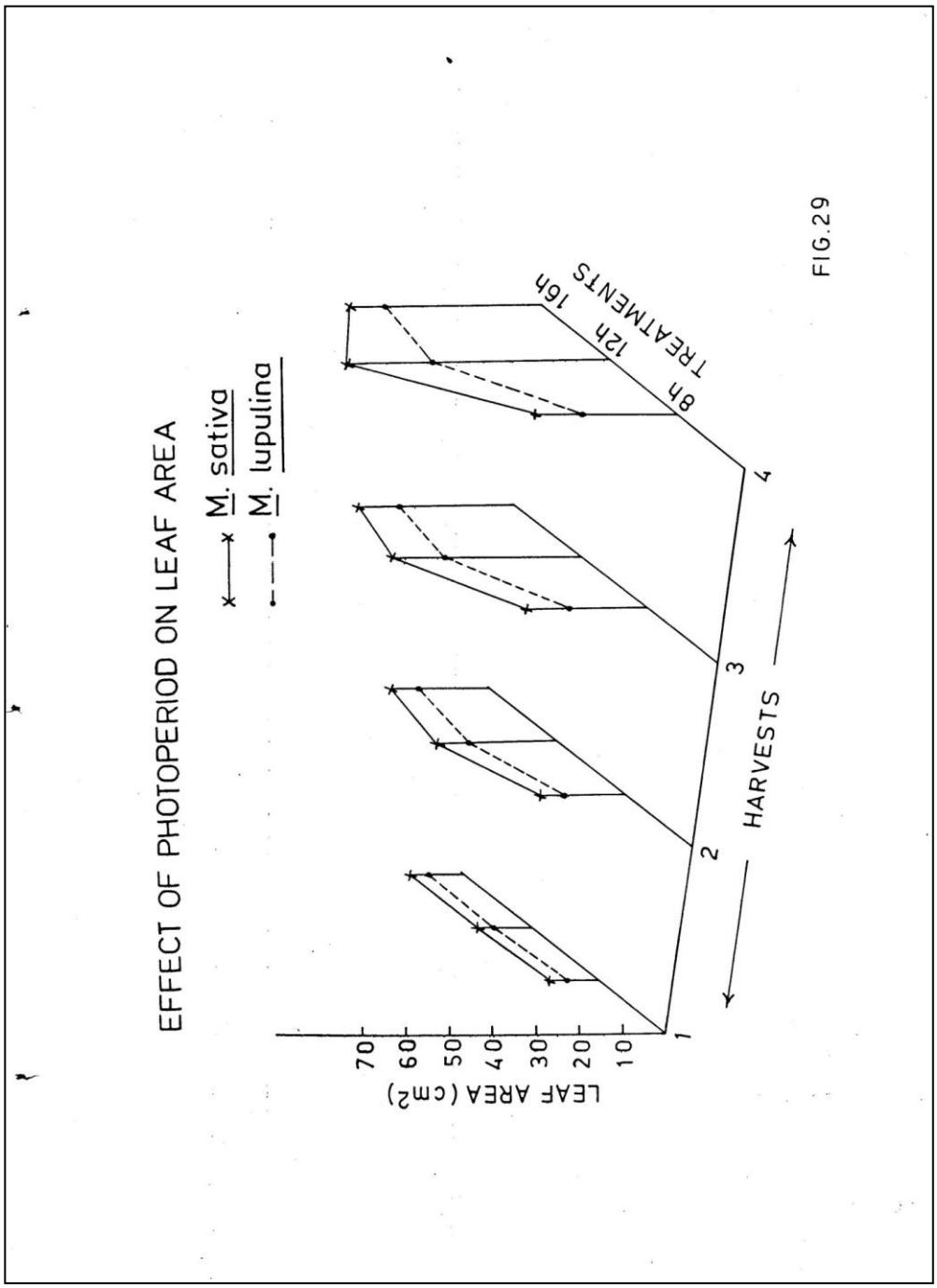

Figure 5.10: Effect of Photoperiod on Leaf Area

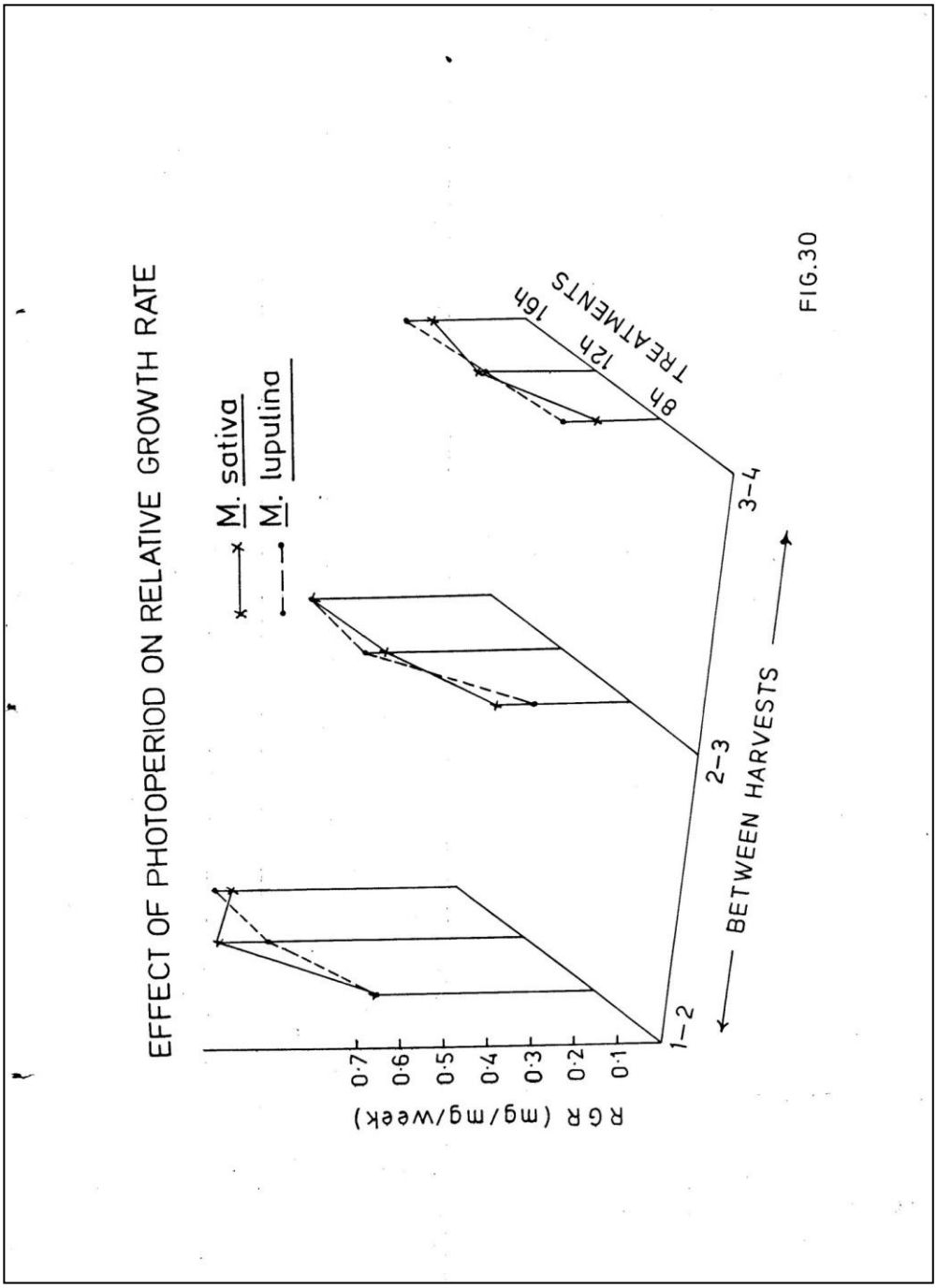

Figure 5.11: Effect of Photoperiod on Relative Rate

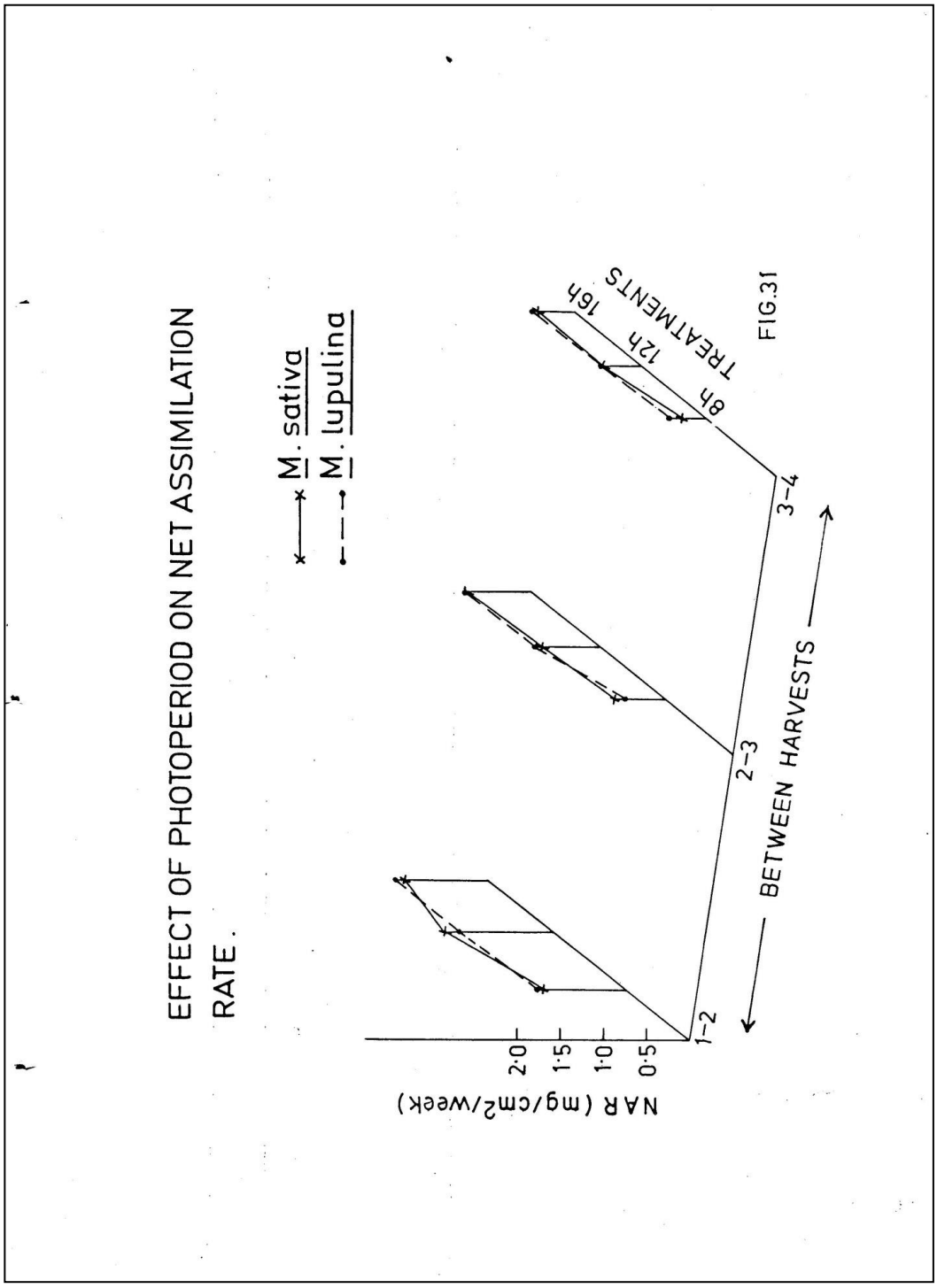

Figure 5.12: Effect of Photoperiod on Net Assimilation Rate

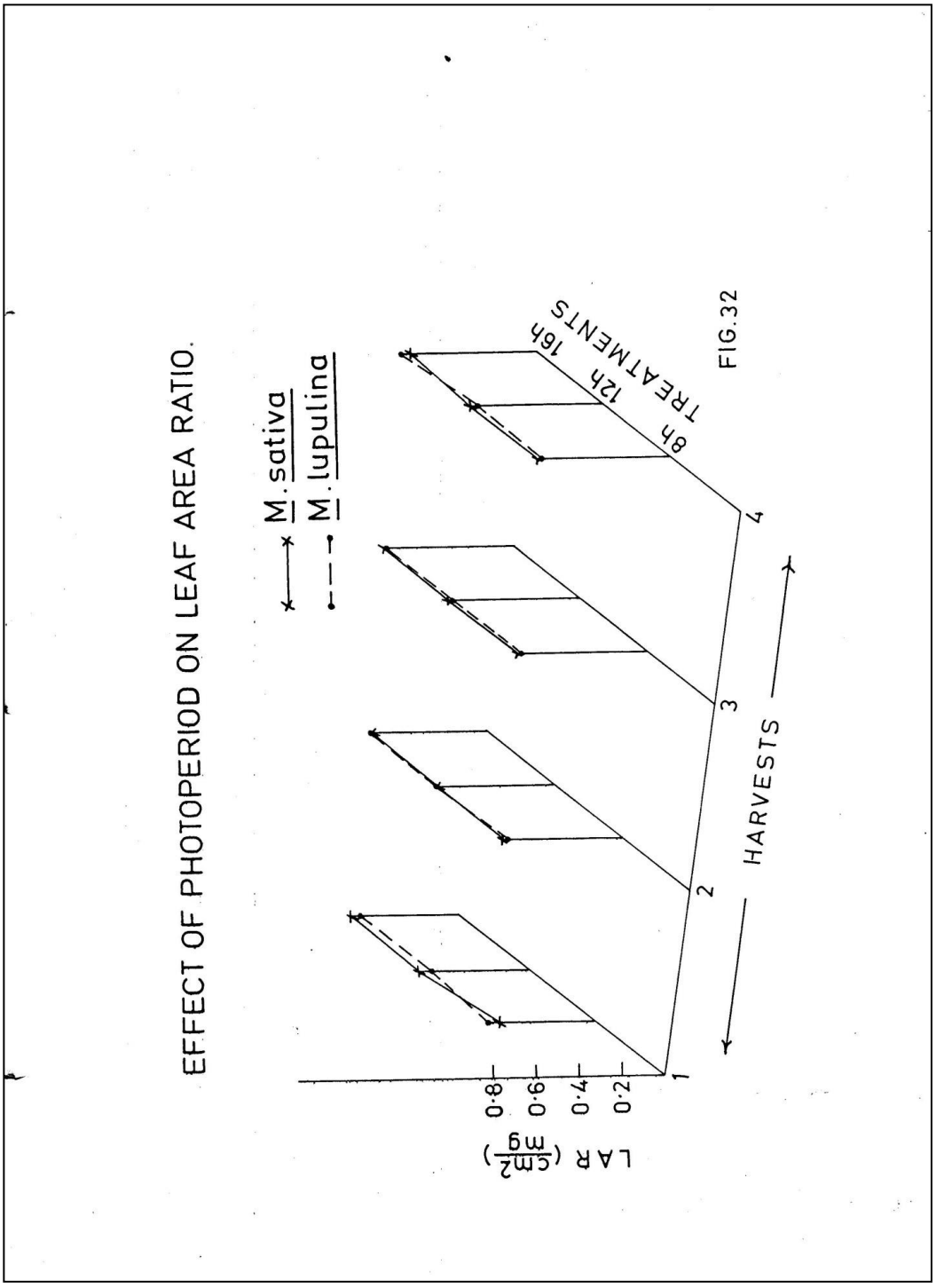

Figure 5.13: Effect of Photoperiod on Leaf Area Ratio

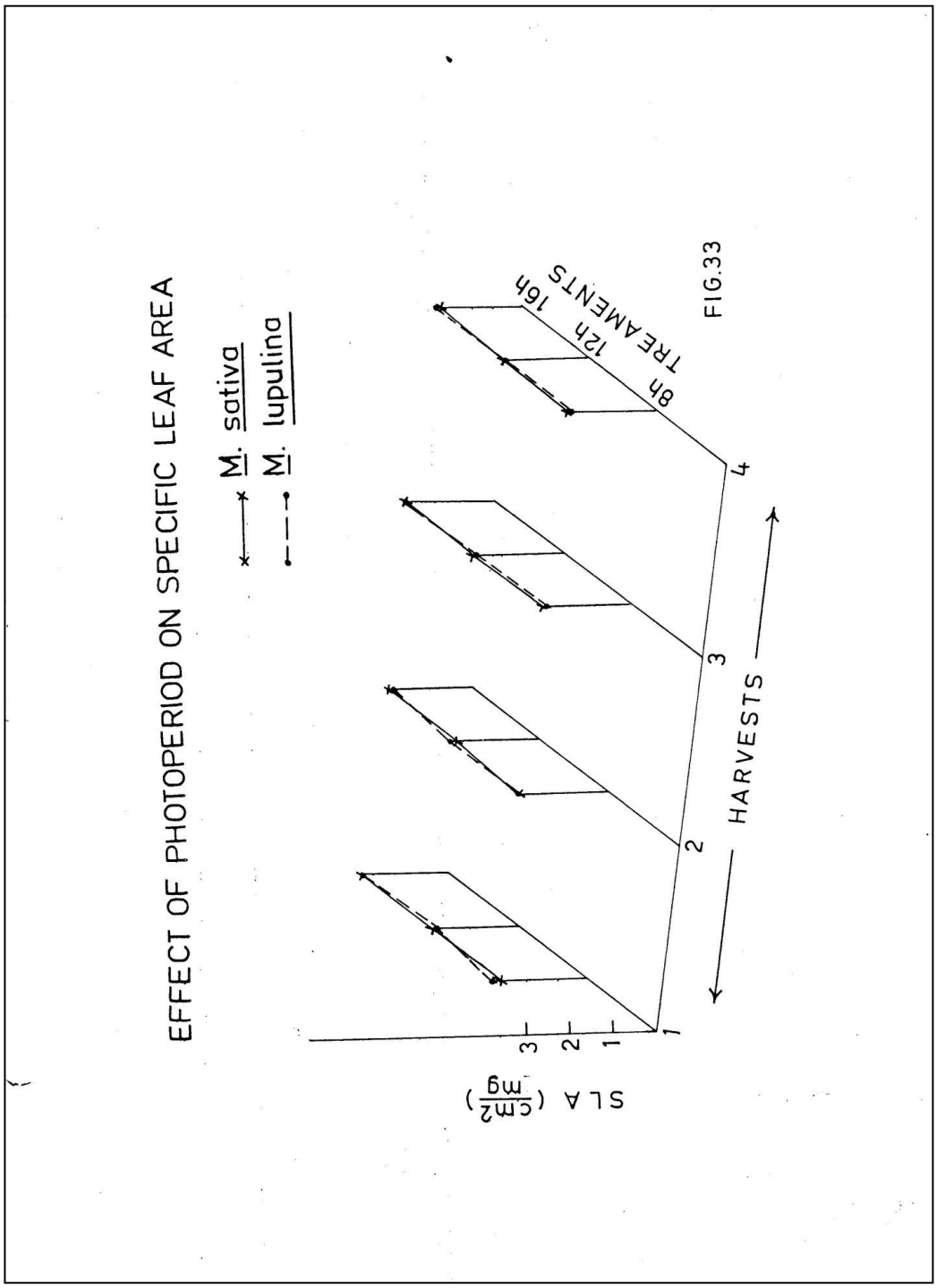

Figure 5.14: Effect of Photoperiod on Specific Leaf Area

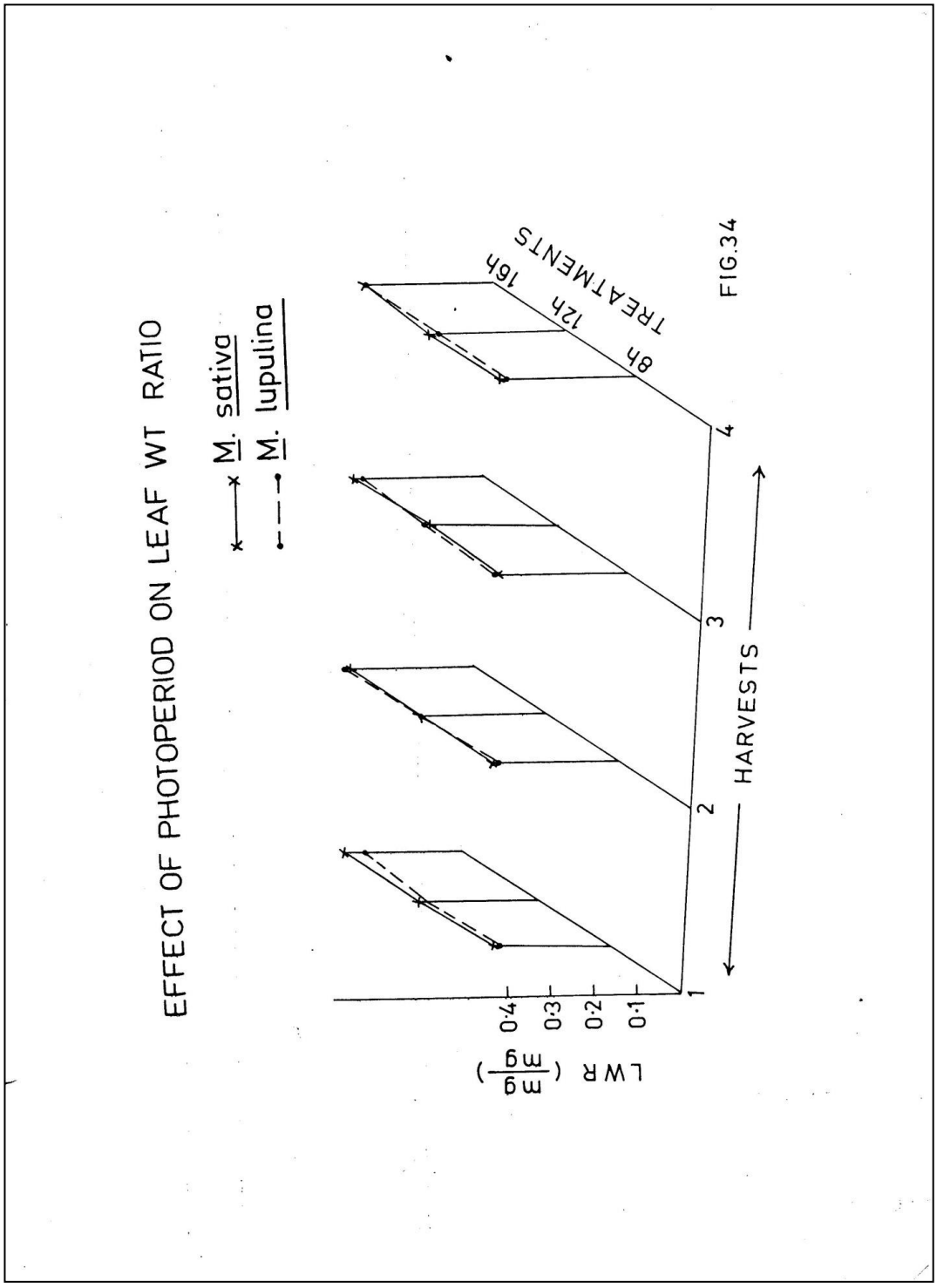

Figure 5.15: Effect of Photoperiod on Leaf WT Ratio

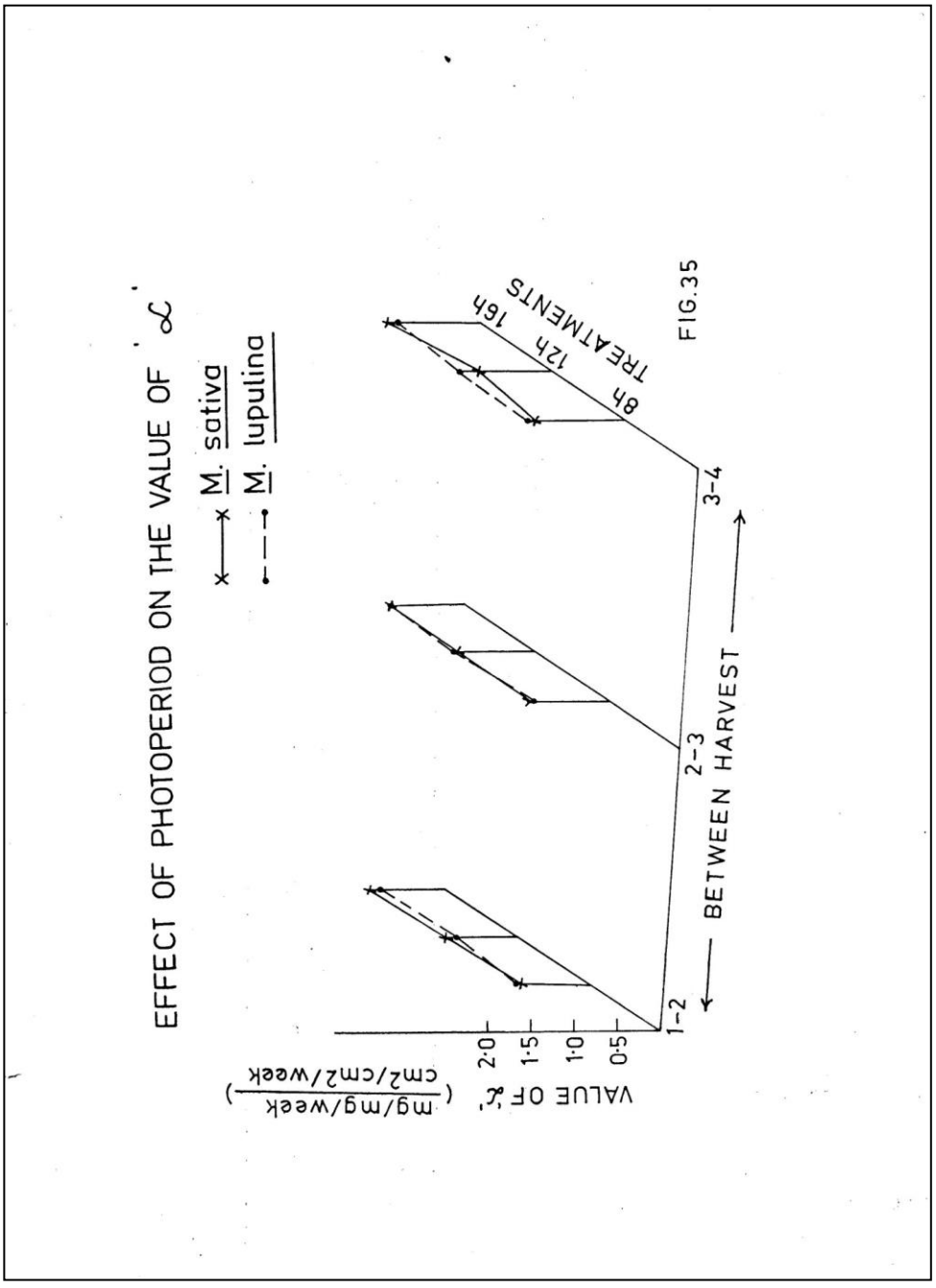

Figure 5.16: Effect of Photoperiod on the Value of '∝'

and **M. littoralis** by Clarkson & Russel (1975). When both the species are compared with respect to maximum dry wt accumulation, it appears that **M. sativa** has an edge over **M. lupulina**. This conclusion is also confirmed by the analysis of variance for the test of significance (Table- 5.9A) where contributions of all the main factors as well as Tr × Har and Har × Sp interactions are significant at the 1% level.

Mean leaf area (Table-5.10, Figure- 5.10) in both the species follows same trend as dry wt accumulation. Mean leaf area increase with harvests in both of the species and in all the treatments. Maximum mean leaf area in both of them is observed in 12h photoperiod. However, when both the species are compared with respect to mean leaf area, it appears that **M. sativa** is superior to **M. lupulina**. This conclusion is also confirmed by analysis of variance (Table-5.10A) where contribution of all the main factors and Tr × Har interaction is significant at the 1% level. The Har × Sp interaction is also significant at 5% level.

RGR (Table- 5.11, Figure - 5.11) in both the species show increasing trend with increase in photoperiod from 8h to 12h, it normally decreases from 12h to 16h but **M. Sativa** and **M. lupulina** between harvests interval 2–3 and 3–4 respectively shows increasing tendency. RGR of both the species shows sharp increase in both of them as the photoperiod increases from 8h to 12h as well as general decrease with passage of time. This decrease is so much so that there remains little difference between different photoperiods at the last harvest interval. Increase in RGR with increase in photoperiod has been reported in various species by many workers (Hofstra et.al., 1960; Ryle, 1966; Nilwil, 1981b and Eze, 1973. As for the decrease of RGR with passage of time, the explanations offered by Hughes & Cockshull (1971) is most appropriate, wherein they state. "It is to be expected that RGR will decline more quickly with time in any treatment giving greater dry matter production because such a decline is always with increasing size under constant condition." The contrasting behavior of two species as well as harvest and treatment effect is clearly demonstrated in the analysis of variance of RGR (Table- 5.31A) where all the main factors are significant.

NAR (Table-5.12, Figure 5.12) in both the species at different photoperiod almost follows the same trend as RGR i.e. increasing with increasing in photoperiod (8h–12h) and decrease with passage of time. Thus, it appears that contributions of NAR towards the maintenance of RGR in both the species are more than that of LAR. The decrease in NAR with passage of time may be assigned to the same as for RGR and similar decrease with age has also been reported by Nilwik 1981b). The increase in NAR with increase in photoperiods have been reported by Eagles (1971), Hughes (1973) and Hay & Heide (1983). The analysis of variance table for NAR (Table- 5.12A) shows harvest effect significant at 1% level and treatment effect at the 5% level, meaning there by that NAR in both the species changes more with harvests than with treatment. However, Njoku (1959) observed that NAR remains constant in constant environment but Watson (1947) found that NAR changes with time.

LAR (Table- 5.13, Figure- 5.13) in both the species increase with harvests and increase in photoperiods. However, this increase is not sharp and consistent. This increase in LAR at longer photoperiods indicate that the species are not well adapted to higher photoperiods. Nilwik (1981a and Hay & Heide (1983) observed increase in LAR with increase in photoperiods. However, Eze (1973) and Eagles (1971) found decreased LAR with increase in photoperiod. Njoku (1959) does not consider LAR as a parameter of any value in comparison of species as there is considerable change of ontogenetic drift. However, in the present investigation there is little change of any such ontogenetic drif as the study pertains to shorter photoperiod of early vegetative growth.

The analysis of variance for the test of significance (Table- 5.13A) shows only harvest effect significant at 1% level meaning there by that LAR in both the species changes with harvests.

SLA is considered to be a very sensitive morphogenetic index as it is the only parameter independent of plant dry wt. Hence it is considered to be more reliable in comparison of treatment differences (Terry, 1968). The SLA values (Table-5.14, Figure – 5.14) do not show any definite trend. In **M. sativa** it generally increases with harvest. The values show decreasing trend with increase photoperiods upto the second harvest. In the successive harvests i.e., third and the fourth harvest, it increases with increase in photoperiods. In **M. lupulina** the SLA values decrease with harvest in 8h photoperiod, whereas, in 12h and 16h photoperiods it increases with harvests. In the first two harvests the values do not have any definite trend of either increase or decrease with increase in photoperiods but in the successive harvests the value increases with increase in photoperiods. However, the common trend for both the species appears to be increase in SLA with increase in photoperiods. The values generally higher in **M. lupulina**. Reports on the effect of photoperiod on SLA are conflicting but in majority of cases it has been found to be directly related to photoperiods (Eagles, 1971; Hughes, 1973; Fawusi & Ormrod, 1981; Hay & Heids, 1983). The conventional analysis of variance of SLA (Table- 5.14A) shows treatment and harvest effect as well as Sp × Tr and Tr × Har interactions significant at 5% level. This suggests that the species differ within themselves with respect to SLA in response to photoperiod with passage of time and treatment.

The other component of LAR i.e. LWR (Table - 5.15, Figure 5.15) do not appear to significantly affected by different photoperiods. In **M. sativa** the values increase with harvests. The values in the 12h treatment is either higher or at par with 8h and 16h photoperiods. In M. lupulina the LWR values increase with harvest upto third harvest. In the fourth and final harvests the values go down. Here in case of M. lupulina also values in the 12h photoperiod is either higher or at par with 8h and 16h photoperiod. Therefore, no conclusion can be drawn about superiority of one species over other. The conventional analysis of variance for the best of significant (Table-15A) shows harvest effect significant at the 1% level. The Tr × Har interaction is also significant at 5% level meaning thereby that LWR values are affected by treatment which changes with time.

The values of '$\propto$' (Sensu whitehead & Myerscough, 1962) have been presented in Table-5.16b, Figure-5.16. Both the species have almost identical behavior with respect to '$\propto$' values. The values are not affected by photoperiods but changes with harvests. However, the values increase with harvests. The conclusion for identical behavior of the species with respect to '$\propto$' values is also supported by analysis of variance for the test of significance (Table-5.16A) where contribution of all the main factors and their interactions are not significant.

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Chapter 6

Effect of Competition on Growth

6.1 Introduction:

The interaction between plants of the same species or among different species is known as 'competition'. However, Harper (1977) defines the term 'competition' as 'interference'. This interference results into changes in the growth pattern of the species which ultimately have a significant effect on the productivity and survival. Two species growing in a space have to compete with each other due to resources being in short supply. Their success, however, depends either upon partitioning of resource of through establishment of competitive superiority. This resource partitioning can easily be visualized in animals as their food items are categories on the basis of their size. However, autotrophic plants have similar basic requirement of CO_2, light, water, O_2 and inorganic ions. Therefore, in plants there must be some criteria for partitioning of such resources. Thus, in nature one plant species having competitive superiority over the other can eliminate it in all appropriate habitats. Competition between individuals is one of the most important density dependent effects. This is why Malthus (1798) visualized that population of organisms are regulated by density dependent factors and mediated through overall performance of organisms.

The pioneer efforts in this field of study was of De Candolle (1820) but the term was defined by Clements (1907). Thereafter a number of workers (Black, 1958; Harper, 1961, Daubenmire, 1968, Allen & Morgan, 1975; Clarke & Simpson, 1978; Tripathi & Gupta, 1980; Muchow et.al., 1982; Fowler, 1984; Sano et.al. 1984; Kumar, 1985; Prasad; 1988) have explained the phenomenon.

Most of the early investigators in this field measured the effect of interaspecific competition in terms of grain or fruit yield. Clements et.al., (1929) and Hall et.al. (1982) were the pioneer in this field. They observed the plastic responses of **Helianthus annus** under density stress. Black (1958) observed that larger plants maintained themselves to be larger while smaller ones remained smaller until a few of them were eliminated. Daubenmire (1968) summarized a number of density dependent adaptations. Ottaviano & Conti (1968) observed higher plasticity in plant height than total dry wt and reverse was established by Bonaparts & Brown (1975). William (1960) found marked differences in the reproductive attributes including number and weight of the fruits in **Lycopersicum esculentum**.

According to Harper (1961) plants with determinate and Indeterminate growth systems, respond differently to density stress. Donald (1963) and Harper (1977) have reviewed literatures concerned with inter- and interspecific competitions.

Burden & Pryor (1975) studied the interspecific competition between **Eucalypts** seedlings. Khan (1973) studied the effect of row spacing on the yield of Buckwhet. Pitelka et.al. (1980) studied the effect of density on plants size and distribution of photosynthesis.

Yeaton & Cody (1976) showed significant correlation between log of photosynthetic area and distance between individuals. Thompson & Brattie (1981) observed decrease of individual biomass with density. Thus, it appears that earlier researches in this fields were manly carried out mainly with agricultural crops and performances of the species were measured in terms of grain and fruit yield. However, the effect of inter or intraspecific competition in terms of sum well established parameters of growth i.e. dry wt accruement, leaf area increases, RGR, NAR, LAR, SLA, LWR, '$\propto$' and S/R ratio have not been studied extensively. Muchow et.al. (1982) Pritsch & Rusell (1983), Carberry (1985) and Cruz & Lamaire (1986) studied the effect of density stress on the rate of dry matter production, leaf area increase and biomass/plant. Fowler (1984) observed that the density effect has marked effect on dry wt and no. of flowers/ plants. Martin & Harding (1982) observed that RGR varied differently in interspecific competitions. Gubbels & Dedio (1986) observed delayed flowering in **Helianthus annus** with density stress.

Idris & Milthorpe (1966) in his experiment with Hordeum vulgare Cv union BH and Sinapis arvensis observed that Hordeum vulgare showed increased growth rates, NAR, root growth and nitrogen uptake rates, as its proportion in the mixture decreased. Naturally occurring plant populations are a mixture of species. In agriculture and forestry also continuous invasion of species (weeds) are of normal occurrence. Thus, the mutual interference of species is of considerable significance. Tripathi & Harper (1973) observed that failure of two species to cohabit in nature may be due to intrinsic effort to exclude the other from its own habitat.

Harper (1977) stressed upon the various limitations towards design of experiments for interpretation of mutual interference. He suggested that a more appropriate way to recognize the ecological differences between pairs of species is to grow them in a variety of conditions. In these conditions plants undertake special efforts towards allocations of limited resources to various activities of such as growth, developments and reproduction. Some species consume more assimilates on vegetative growth while other on its plasticity or multiplication. Therefore, these features should be analysed in order to have a clear understanding of adaptability of different species.

In the light of the above introductory remark the growth behavior of two Medicago spp. has been studied and compared in order to assess the effect of mutual interference on the life strategies of the taxa. The experiments designed in two sets are noted below:

A. Intraspecific competition: Densities corresponding to 1, 2, 3 and 4 plants/ pot were marked as:

S_1 : One plant/pot

S_2 : Two plant/pot

S_3 : Three plants/ pot

S_4 : Four plants/pot

B. Interspecific competition: Densities corresponding to 1MS+1ML, 1MS+2ML, 2MS+1ML and one plant each of MS and ML per pot were taken as control. These were marked as:

S_I : One plant/pot each of MS and ML

S_{II} : 1MS + 1ML/pot

S_{III} : 1MS + 2ML/pot

S_{IV} : 2MS + 1ML/pot

MS = M. sativa and ML = M. lupulina

6.2 Results and Discussion:

6.2.1 Intraspecific Competition:

The results of interaction between the specific have been presented in Table – 6.1 – 6.8, Figures 6.1 –6.8. The mean dry wt (Table – 6.1, Figure 6.1) shows that both the species have identical behavior, they accumulate maximum dry wt in S_1 condition which declines in S_2, S_3 and S_4 conditions. The dry wt increases with harvests in both of them. However, when the dry wt accruement is compared with respect to treatment between first and final harvest it appears that in **M. sativa** it is 3.91, 4.29, 3.24 and 2.05 while the same in **M. lupulina** is 3.34, 3.70, 2.94 and 3.10 in S_1, S_2, S_3 and S_4 treatments respectively. The result show that both the species have lesser dry wt accumulation in S_1 condition than S_2. However, this result is due to initial rapid growth of the species in the S_1 condition. The perusal of the result also suggests that **M. sativa** has higher dry wt accumulation in all the treatments than **M. lupulina**. When the percentage dry wt accumulation at the last harvest in the highest density class i.e.

Table 6.1: Effect of interspecific competition on mean dry weight (mg) of two species in four harvests.

Species	Harvest	Treatment			
		S_1	**S_2**	**S_3**	**S_4**
M. sativa	1	25.9	20.8	19.2	19.4
	2	35.5	32.1	25.5	21.2
	3	65.8	55.4	45.5	35.5
	4	101.2	89.21	62.2	49.4
M. lupulina	1	21.2	16.4	15.5	10.8
	2	30.4	25.5	21.6	15.6
	3	50.6	40.5	28.3	20.5
	4	70.81	60.8	45.5	33.5

Table-6.1A: Analysis of Variance for The Table 6.1

Source of variation	d.f	SS	MS	F.ratio
Species	1	1204.1778	1204.1778	134.8537 ×
Treatment	3	2763.8696	921.2899	103.1736 ×
Harvest	3	9782.8799	3260.9520	365.1889 ×
Sp × Tr	3	17.5582	5.8527	1.5257
Tr × Har	9	1021.2212	113.469	12.7072 ×
Har × Sp	3	438.6534	146.2178	16.3747 ×
Residual	9	80.3656	8.9295	
Total	31	15308.7258		

× –significant at 1% level

Table 6.2: Effect of Interspecific Competition on Mean Lecy Area (Cm^2) Of Two Species in Four Harvest.

Species	Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1	14.12	10.30	8.51	8.53
	2	20.18	18.50	14.07	10.41
	3	38.35	32.36	26.71	20.18
	4	60.94	50.66	36.67	28.55
M. lupulina	1	10.41	7.84	7.54	5.18
	2	18.12	14.07	10.50	7.56
	3	28.73	22.81	16.65	10.25
	4	40.55	36.60	26.71	20.02

Table 6.2A: Analysis of Variance for The Table 6.38

Source of variation	d.f	SS	MS	F.ratio
Species	1	41.68828	416.8828	106.0201
Treatment	3	1041.8984	347.2995	88.3239 ×
Harvest	3	3810.1551	1270.0517	322.9950 ×
Sp × Tr	3	10.8381	3.6127	1.0844
Tr × Har	9	323.4758	35.9418	9.1406 ×
Har × Sp	3	159.7244	53.2415	13.5402 ×
Residual	9	35.3890	3.9321	
Total	31	5798.3636		

× –significant at 1% level

Table 6.3: Effect of Interspecific Competition On Relative Growth Rate

Species	Between Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1–2	0.32	0.43	0.28	0.09
	2–3	0.62	0.55	0.58	0.52
	3–4	0.43	0.48	0.31	0.33
M. lupulina	1–2	0.36	0.44	0.37	0.37
	2–3	0.51	0.46	0.27	0.27
	3–4	0.34	0.41	0.47	0.49

Table 6.3A: Analysis of Variance for The Table 6.3

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0013	0.0013	6.7737
Treatment	3	0.0438	0.0161	1.7625
Harvest	2	0.0785	0.0393	4.294
Sp × Tr	3	0.0133	0.0044	2.0652
Tr × Har	6	0.0341	0.0057	1.609
Har × Sp	2	0.0961	0.0481	5.2546 ××
Residual	6	0.0549	0.0091	
Total	23	0.0549		

×× –significant at 1% level

Table 6.4: Effect of Interspecific Competition On Net Assimilation Rate

Species	Between Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1–2	0.57	0.81	0.57	0.19
	2–3	1.07	0.94	1.01	0.97
	3–4	0.72	0.83	0.54	0.58
M. lupulina	1–2	0.66	0.85	0.68	0.77
	2–3	0.88	0.82	0.50	0.55
	3–4	0.58	0.69	0.80	0.89

Table 6.4A: Analysis of Variance for The Table-6.4

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0007	0.0007	42.661
Treatment	3	0.0977	0.0326	1.0842
Harvest	2	0.1751	0.0876	2.9146
Sp × Tr	3	0.0570	0.0190	27.0041 ××
Tr × Har	6	0.1105	0.0184	1.6308
Har × Sp	2	0.2861	0.1430	4.7612
Residual	6	0.01802	0.0300	
Total	23	0.09074		

×× –significant at 5% level

Table 6.5: Effect of Interspecific Competition on Leaf Area Ratio.

Species	Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1	0.55	0.50	0.44	0.44
	2	0.57	0.58	0.55	0.49
	3	0.58	0.58	0.59	0.57
	4	0.60	0.57	0.59	0.58
M. lupulina	1	0.49	0.48	0.49	0.48
	2	0.60	0.55	0.49	0.48
	3	0.57	0.56	0.59	0.50
	4	0.57	0.60	0.59	0.60

Table 6.5A: Analysis of Variance for The Table-6.5

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0006	0.0006	1.5261
Treatment	3	0.0102	0.0034	3.6419 × ×
Harvest	3	0.0488	0.0163	17.4071 ×
Sp × Tr	3	0.0003	0.0001	10.6825 ××
Tr × Har	9	0.0098	0.0011	1.1605
Har × Sp	3	0.0013	0.0004	2.1365
Residual	9	0.0084	0.009	
Total	31	0.0794		

× –significant at 1% level

× × –significant at 5% level

Table 6.6: Effect of Interspecific Competition On Specific Leaf Area.

Species	Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1	1.97	2.01	1.85	1.84
	2	1.99	1.91	1.97	1.97
	3	1.99	1.98	2.04	1.99
	4	2.00	1.90	1.97	2.00
M. lupulina	1	1.98	2.04	2.12	3.45
	2	2.01	1.97	1.97	2.12
	3	1.98	1.93	1.88	2.01
	4	1.98	2.02	2.04	1.98

Table 6.6A: Analysis of Variance for The Table-6

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.1365	0.1365	1.9168
Treatment	3	0.2226	0.0742	1.0420
Harvest	3	0.1821	0.0607	1.1732
Sp × Tr	3	0.2536	0.0845	1.1868
Tr × Har	9	0.4320	0.0480	1.4837
Har × Sp	3	0.3382	0.1127	1.5828
Residual	9	0.6409	0.0712	
Total	31	2.2058		

Table 6.7: Effect of Interspecific Competition On Leaf Wt Ratio.

Species	Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1	0.28	0.25	0.24	0.24
	2	0.29	0.30	0.28	0.25
	3	0.29	0.30	0.29	0.29
	4	0.30	0.30	0.30	0.29
M. lupulina	1	0.25	0.23	0.23	0.14
	2	0.30	0.28	0.25	0.23
	3	0.29	0.29	0.31	0.25
	4	0.29	0.30	0.29	0.30

Table 6.7A: Analysis of Variance for The Table 6.7

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0021	0.0021	6.8206 ××
Treatment	3	0.0067	0.0022	7.1570 ×
Harvest	3	0.0194	0.0065	20.9058 ×
Sp × Tr	3	0.0012	0.0004	1.3318
Tr × Har	9	0.0041	0.0005	1.4798
Har × Sp	3	0.0017	0.0006	1.7892
Residual	9	0.0029	0.0003	
Total	31	0.0381		

× –significant at 1% level

× × –significant at 5% level

Table 6.8: Effect of Interspecific competition on the value of '∝'

Species	Between Harvest	Treatment			
		S_1	S_2	S_3	S_4
M. sativa	1–2	0.89	0.73	0.56	0.45
	2–3	0.97	0.98	0.91	0.79
	3–4	0.93	1.07	0.97	0.94
M. lupulina	1–2	0.65	0.76	1.00	0.97
	2–3	1.11	0.96	0.59	0.41
	3–4	1.00	0.87	1.00	0.73

Table-6.8A: Analysis of Variance for The Table 6.8

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0008	0.0008	62.3081
Treatment	3	0.155	0.0517	1.0154
Harvest	2	0.1408	0.0704	1.3831
Sp × Tr	3	0.0099	0.0033	15.3937 ××
Tr × Har	6	0.1252	0.0209	2.4391
Har × Sp	2	0.1236	0.0618	1.2141
Residual	6	0.3053	0.0509	
Total	23	0.8605		

×× –significant at 5% level

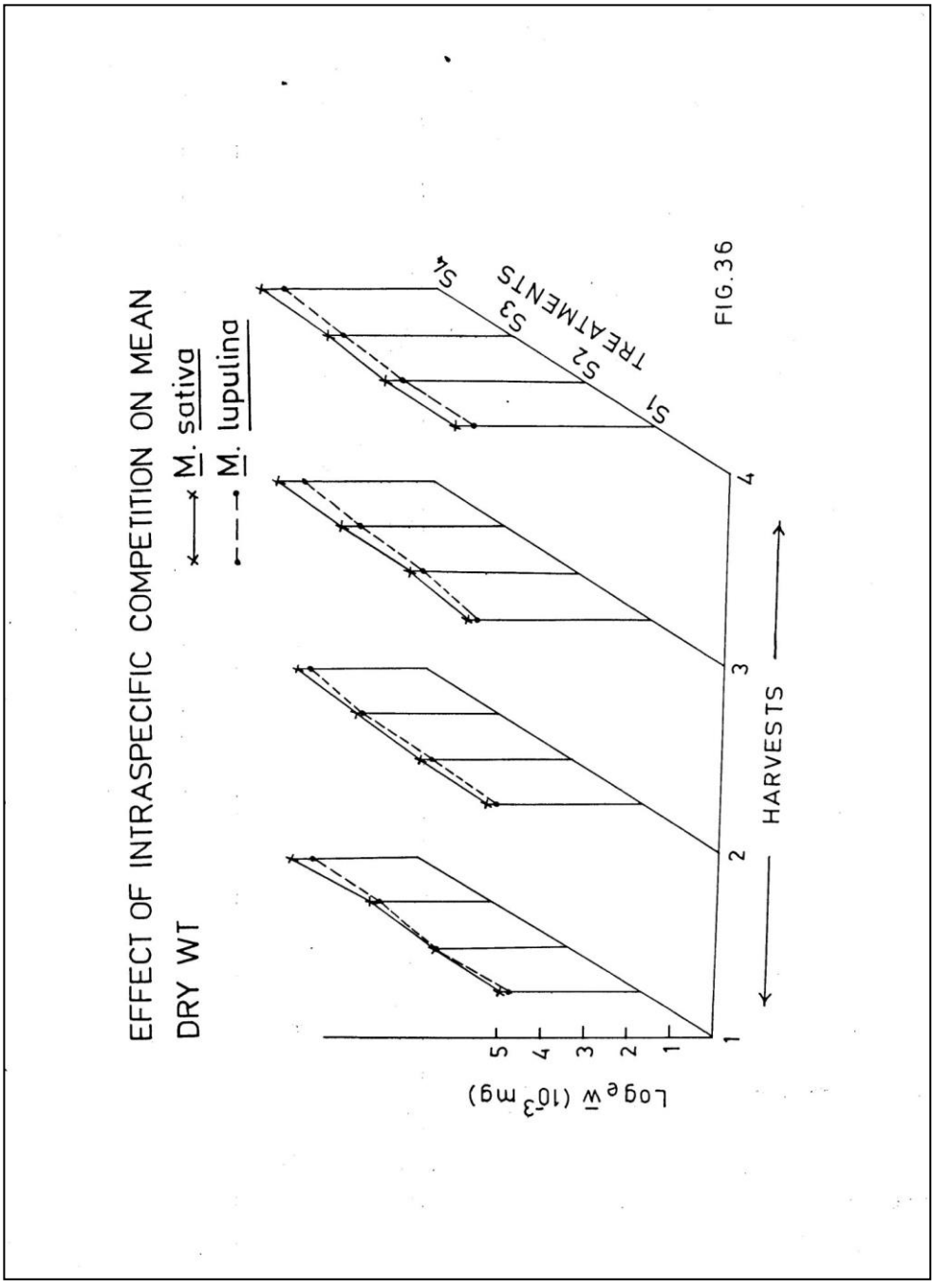

Figure 6.1: Effect of Intrspecific Competition on Mean

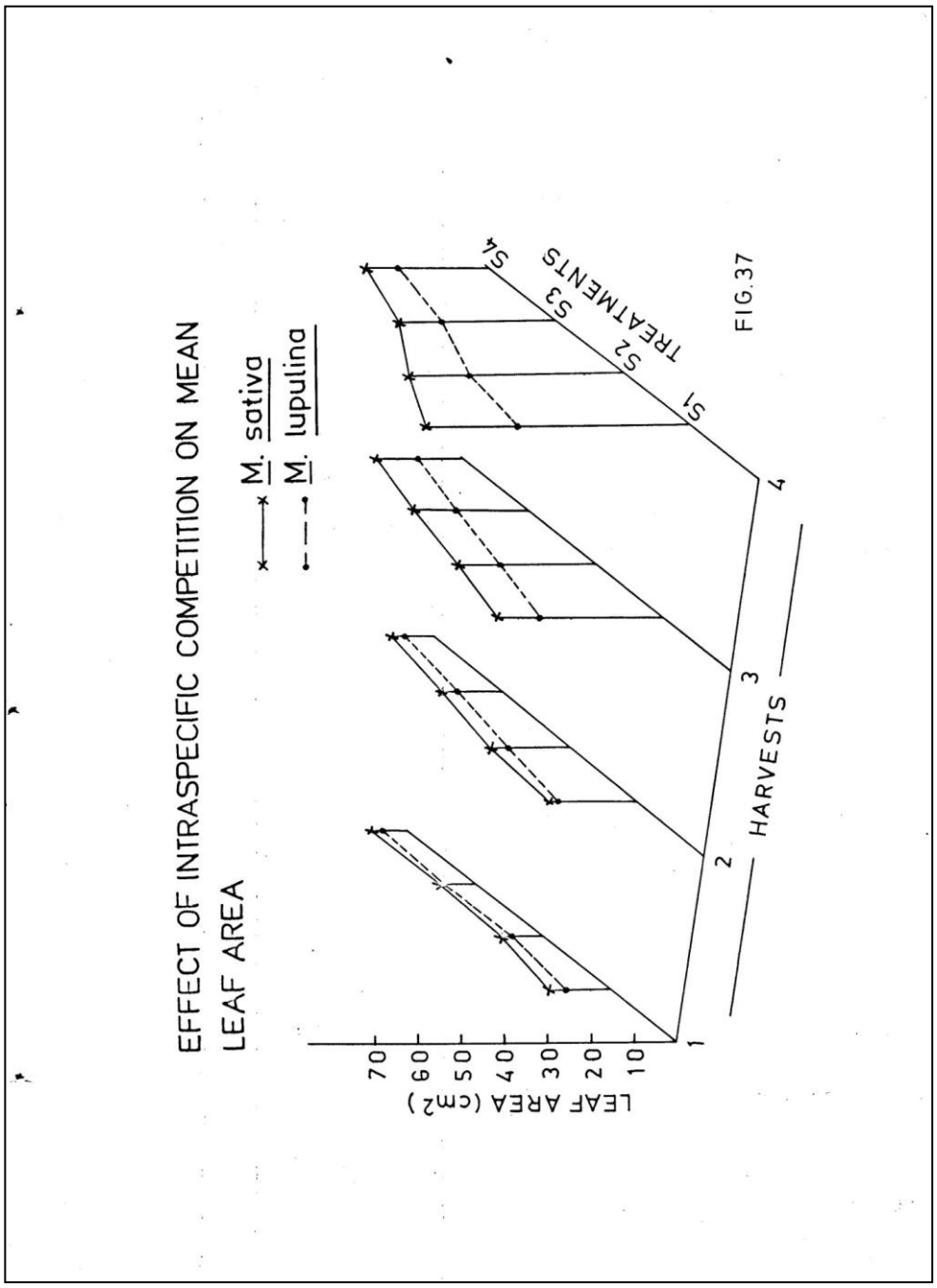

Figure 6.2: Effect of Intrspecific Competition on Mean Leaf Area

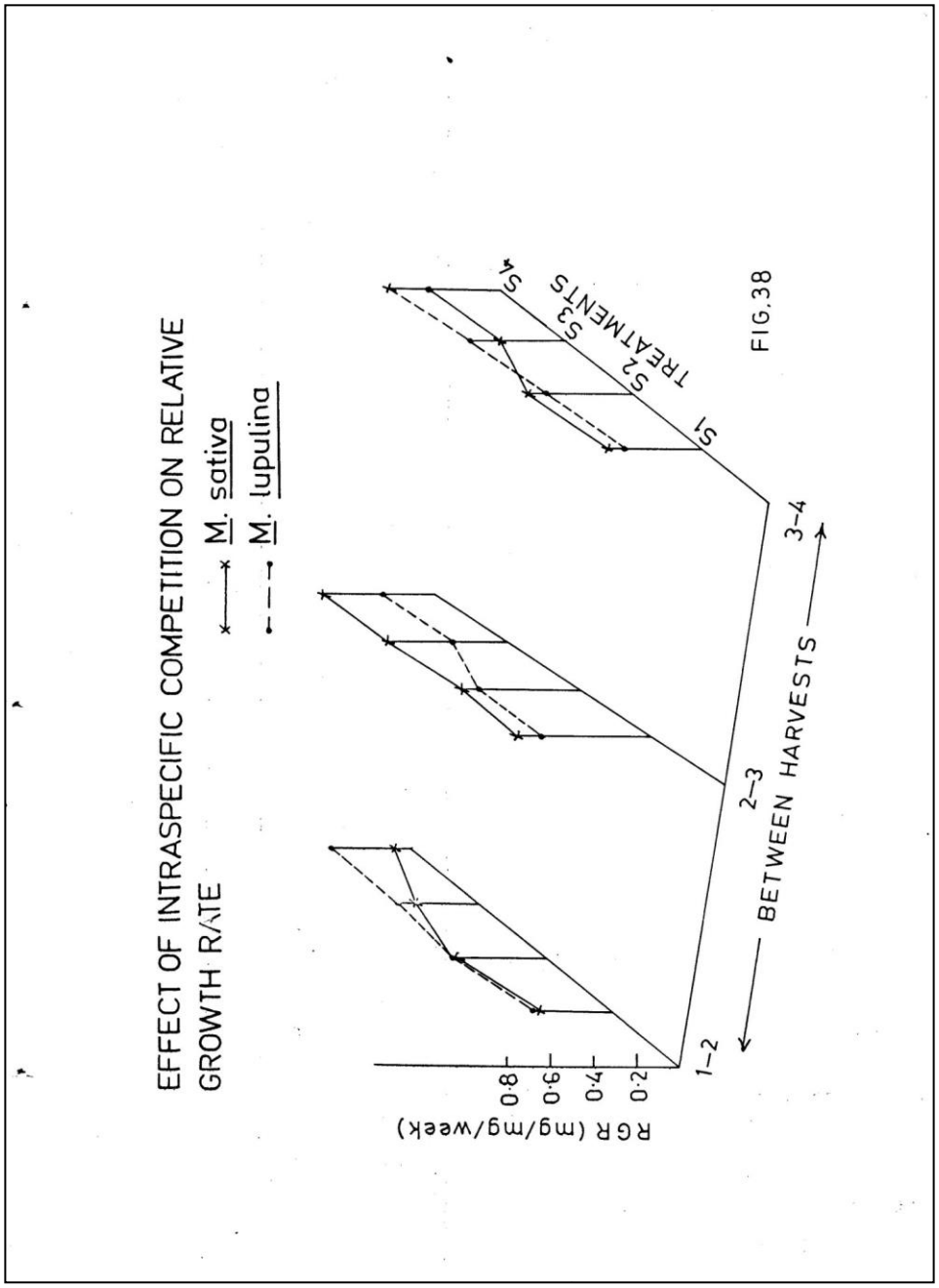

Figure 6.3: Effect of Intrspecific Competition on Relative Growth Rate

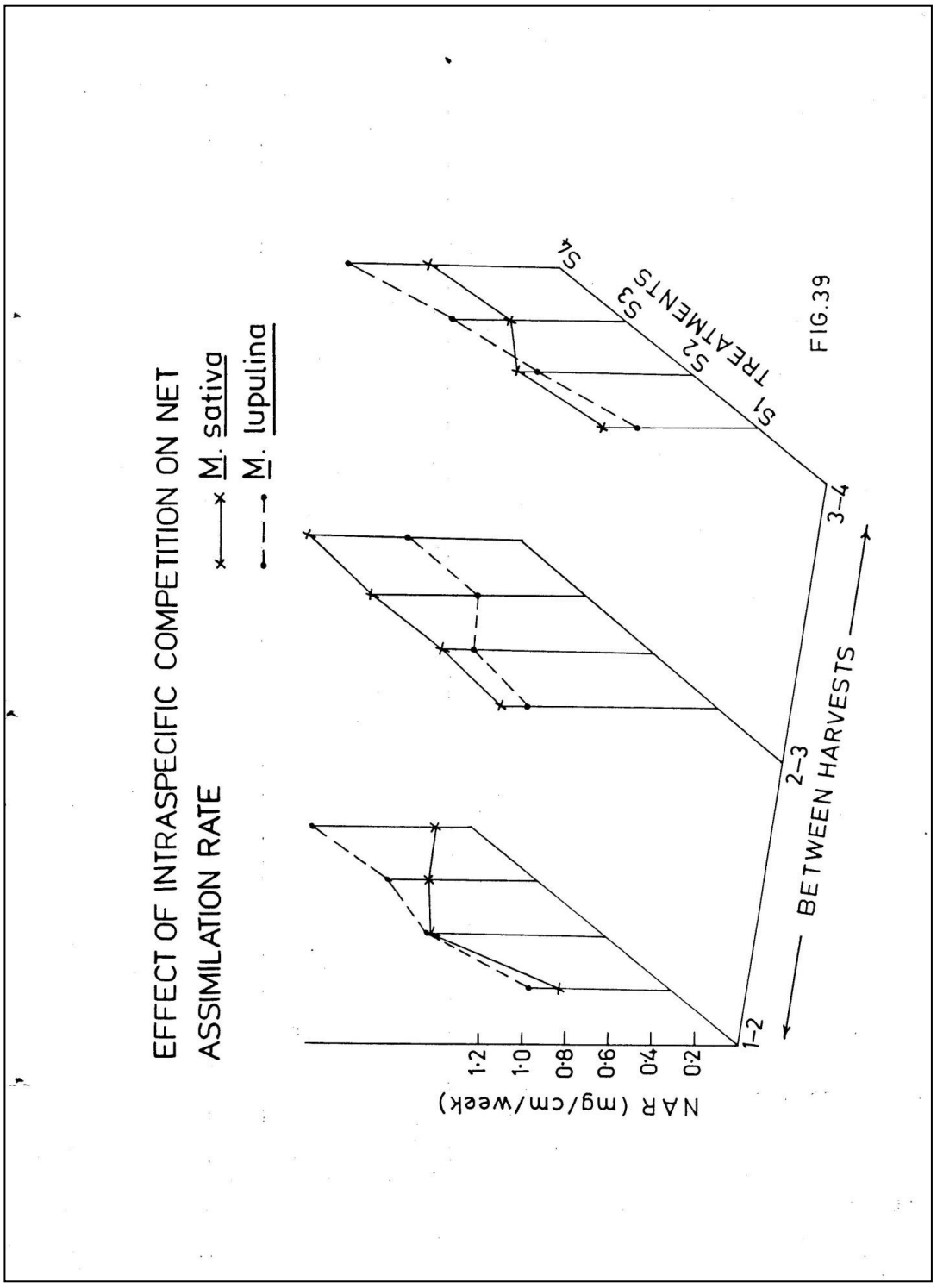

Figure 6.4: Effect of Intrspecific Competition on Net Assimiltion Rate

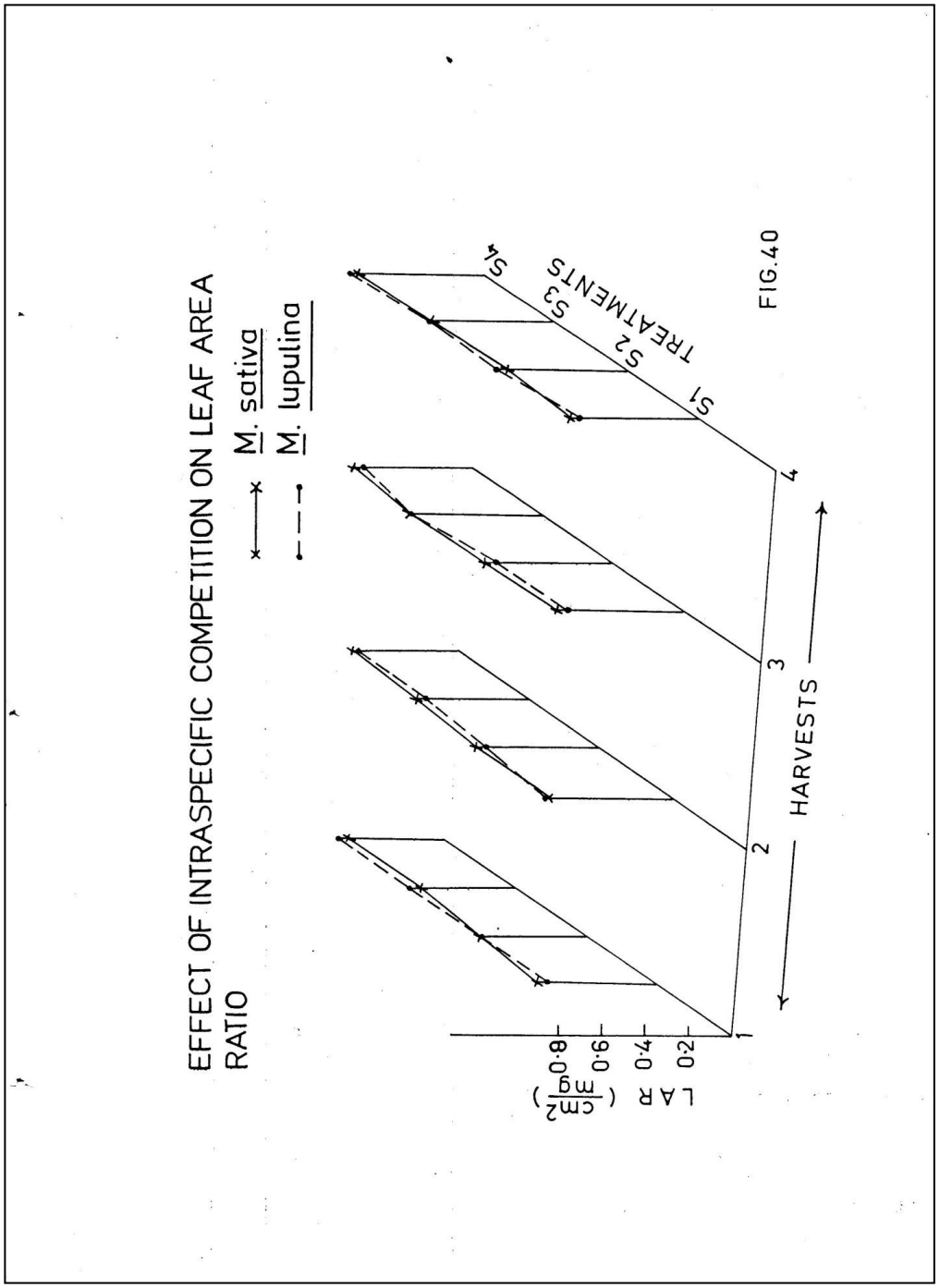

Figure 6.5: Effect of Intrspecific Competition on Leaf Area Ratio

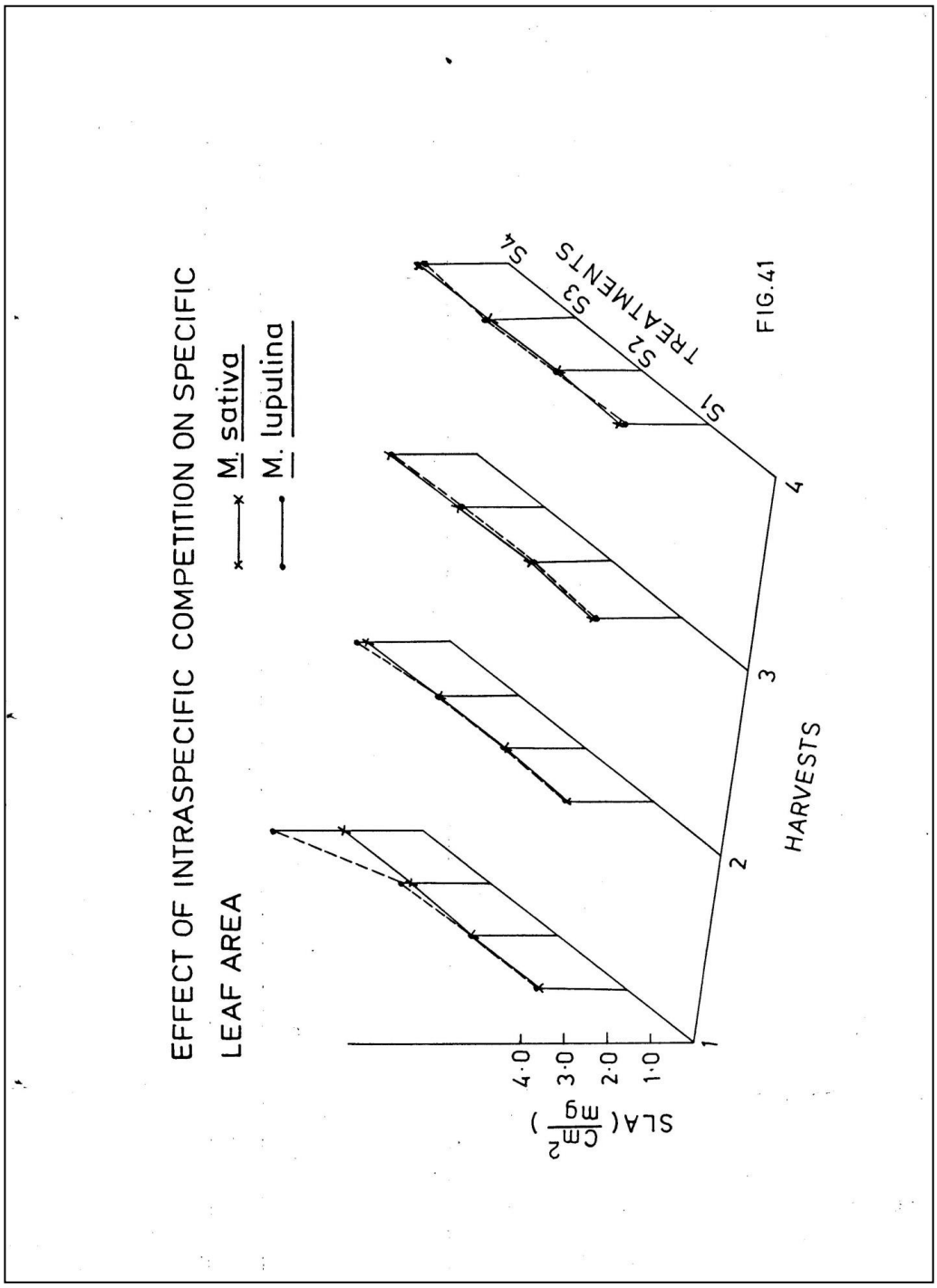

Figure 6.6: Effect of Intrspecific Competition on Specific Leaf Area

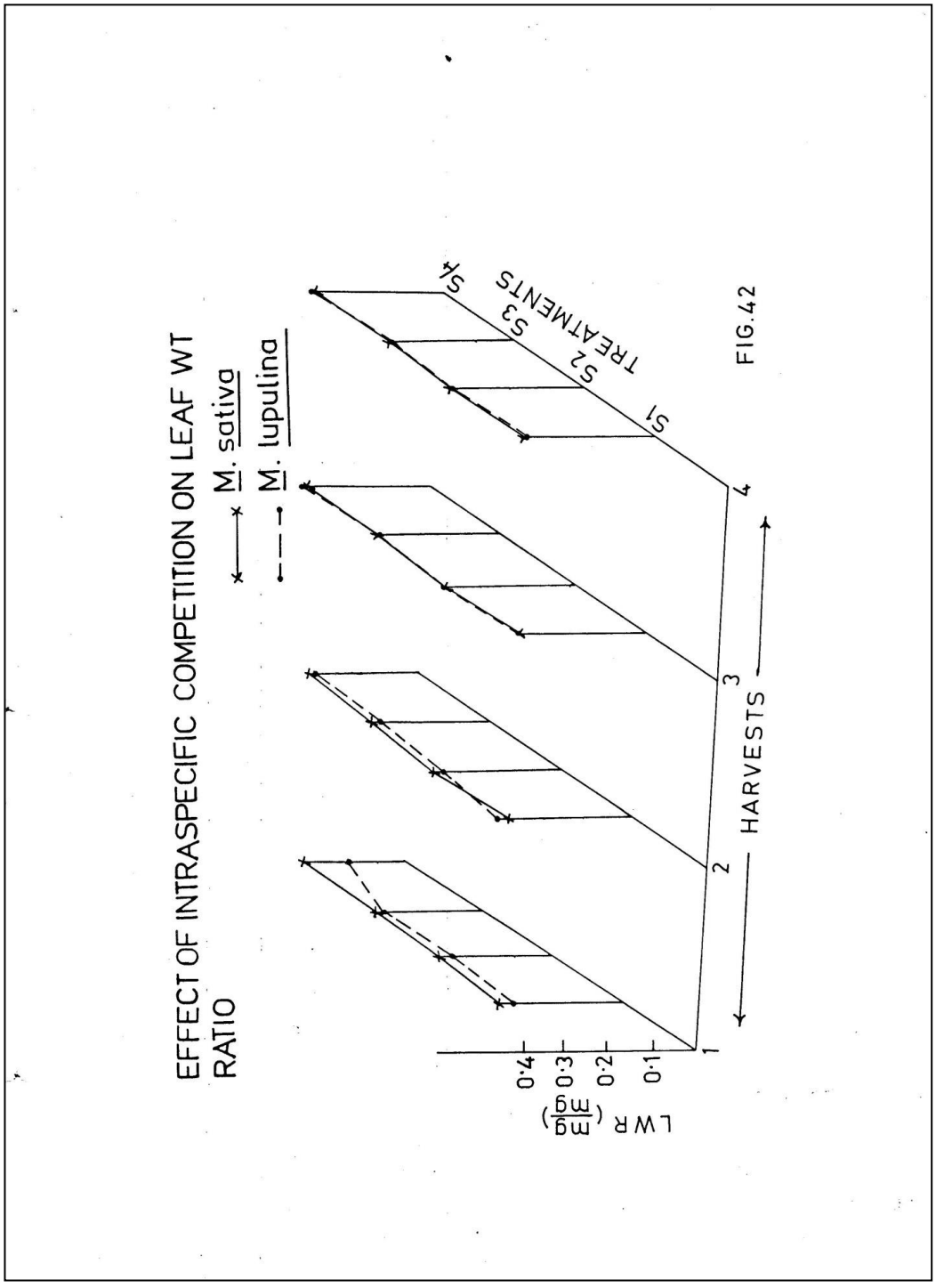

Figure 6.7: Effect of Intrspecific Competition on Leaf WT Ratio

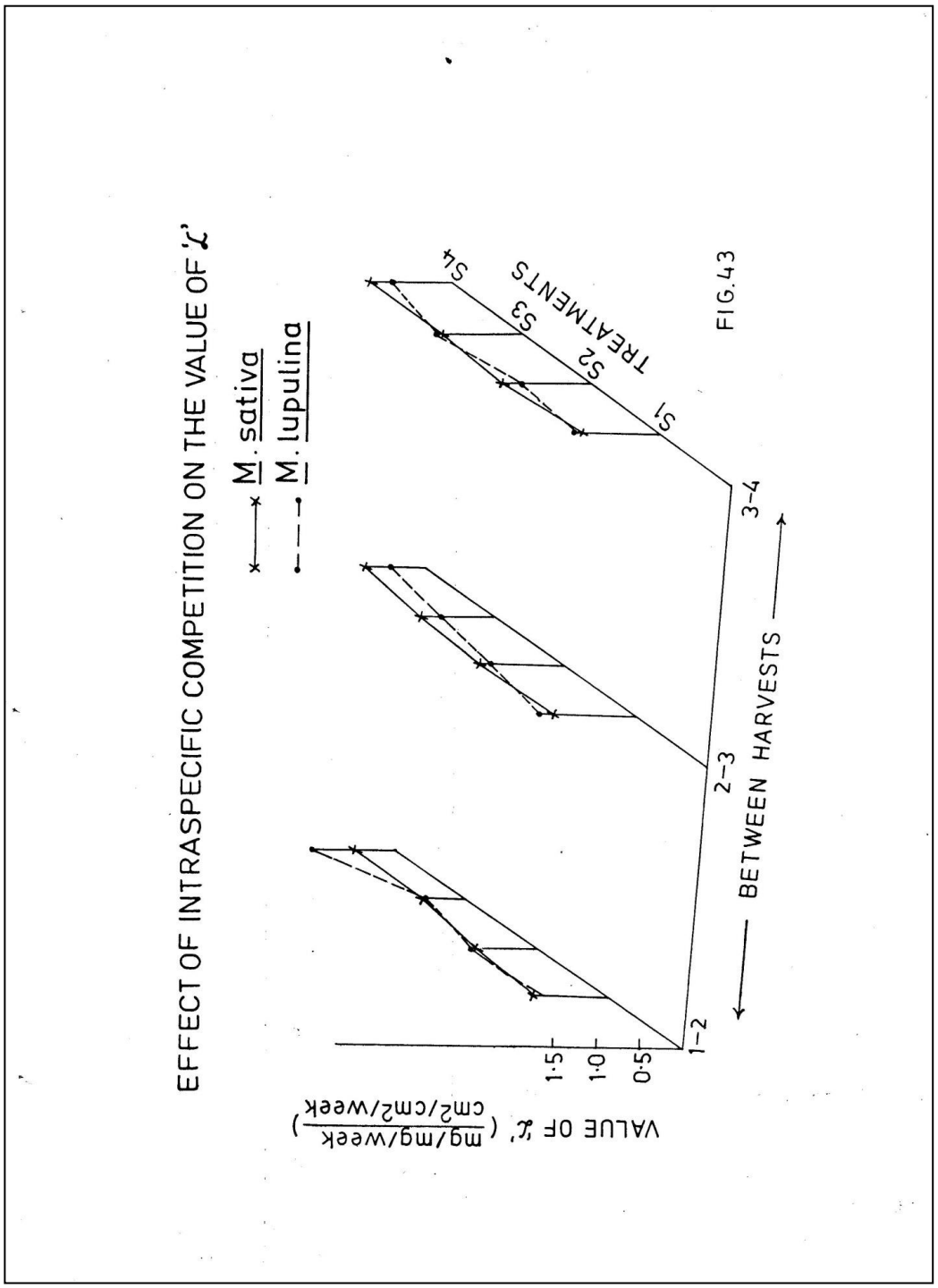

Figure 6.8: Effect of Intrspecific Competition on the Value of '∝'

S_4 treatment with respect to lowest density class i.e. S_1 treatment is taken into consideration it appears that the dry wt in S_4 condition is 48.8% in **M. sativa**. The same in **M. lupulina** is 47.31%. Thus, the reduction in dry wt in the highest density class is maximum in **M. lupulina**. Therefore, on the basis of dry wt accumulation and reduction it can be concluded that **M. sativa** is superior to **M. lupulina**. This differential behavior of the species is also supported by analysis of the variance (Table- 6.1A) were contribution of all the main factors as well as Tr × Har and Har × Sp interactions are highly significant at 1% level. This reflects that the species differ within themselves with respect to treatment and the dry wt changes with time.

The mean leaf area (Table- 6.2, Figure 6.2) have the same trend as the dry wt accumulation. Both the species have maximum leaf area in S_1 condition which decreases with increase in density i.e. S_2, S_3 and S_4 condition. Both the parameters i.e. dry wt accumulation and mean leaf area come under the direct effect of competition. Thus, our result is corroborative to those of Bazzaz & Harper (1976). Tripathi & Gupta (1980), Warick & Thompson (1987) and Renata (1987). The conventional analysis of the variance (Table- 6.2A) shows all the main factors and Tr × Har as well as Har × Sp interaction are highly significant at 1% level.

The RGR values (Table- 6.3, Figure. 6.3) are highest in both the species between harvest interval second and third. These values are in decreasing order i.e. highest in S_1 (lowest density class) and lowest in S_4 (highest density class). Thus, it can be inferred that the density results in the lowering of RGR. This reduction in RGR under denser stand has also been observed by Fowler (1984). Both the species show lowest RGR values between harvest interval first and second. In **M. sativa** at the last harvest the values increase from S_1 to S_2 thereafter, decrease in S_3 and S_4 conditions. In **M. lupulina** the values gradually increase from S_1 to S_4 condition. Thus, it appears that **M. lupulina** at least tried to accelerate its growth. This differential behavior of the species is also supported by conventional analysis of variances (Table-6.3A) where Har × Sp interaction is observed to be significant at 5% level, meaning thereby that the species differ within themselves with respect to harvests.

The NAR (Table – 6.4, Figure – 6.4) values show identical behavior to RGR which is indicative of better correlation between RGR and NAR. The values are highest between harvest interval 2.3 in S_1 condition which decreases with increase in density. Buttery (1969) reported decrease in RGR and NAR with increased population. Here also like RGR the values are lowest between harvest interval first and second. At the last harvest interval in **M. sativa** the value increases from S_1 to S_2 thereby it decreases in S_3 and S_4. The same in **M. lupulina** increases with increase in density. The conventional analysis of variance (Table-40A) show only Sp × Tr interaction significant at 5% level meaning thereby that the species differ within themselves with respect to treatment.

The LAR values (Table-6.5, Figure-6.5) increase with harvests in both the species. In **M. sativa** the LAR values have a general decreasing trend with increase in density. However, this decrease in not acute. Clark & Simpson (1978) observed decreasing trend with density. In **M. lupulina** the LAR values show decreasing trend with increase in density in the first two harvest but in the later harvests the values increase with increase in density. Escasinas et.al. (1981) observed increase in LAR under the influence of density stress. Thus, it appears that both the species differ within themselves with respect to LAR values.

The above conclusion is also confirmed by the conventional analysis of variance for the test of significance (Table- 6.5A) where harvest effect is highly significant at 1% level. The treatment and Sp × Tr interactions are also significant at 5% level meaning thereby that the species differ within themselves with respect to treatment. The overall LAR values are higher in **M. sativa**; thus, it appears that **M. sativa** is superior to **M. lupulina.**

The SLA values (Table-6.6, Figure – 6.6) of both the species do not show any definite trend. In S_1 treatment the values increase with harvest in **M. sativa** but in **M. lupulina** te values remain almost same. In S_2 values decrease with harvests for both the species. In S_3 and S_4 treatment **M. sativa** shows increasing SLA values with change in time. The same in **M. lupulina** is in decreasing order. The overall SLA values are higher in **M. lupulina**. Thus, it can be concluded that the **M. lupulina** is superior to **M. sativa** with respect to SLA values. However, this conclusion is not confirmed by analysis of variance (Table-6.6A) where contribution of all the main factors and their interactions are non-significant.

The LWR value (Table- 6.7, Figure – 6.7) show that it increases with harvests for both the species. However, this increase is more pronounced in **M. lupulina** than **M. sativa**, because **M. lupulina** have lower initial LWR value. The LWR values also show decreasing trend with increase in density for both the species. This is also more pronounced in **M. lupulina** than **M. sativa**. The overall LWR values are higher in **M. sativa** than **M. lupulina**. Thus **M. sativa** have better adaptability than **M. lupulina**. This conclusion is also confirmed by analysis of variance (Table-6.7A) where species effect is significant at 5% level. The treatment and harvest effect are highly significant at 1% level meaning thereby LWR values changes with treatment and harvests.

The values of '$\propto$' has been presented in Table-6.8, Figure – 6.8. A perusal of the result shows a few lower values between harvest interval 1–2 in **M. sativa**. In **M. lupulina** also a few lower values have been obtained in all the harvest intervals. Rest of them are around the unity for both the species. The result is suggestive of the fact that the morphogenetic allometry is almost maintained in **M. sativa** but the same in **M. lupulina** is not. Thus, with respect to '$\propto$' values also **M. Sativa** is superior to **M. Lupulina.** This conclusion is also supported by analysis of variance (Table-6.8A) where Sp × Tr interaction is significant at 5% level which suggest that the species differ with respect to treatment.

6.2.2 Interspecific Competition:

The results of interspecific competition have been presented in Table, 6.9–6.16 and Figure. 6.9–6.16.

The dry wt accumulation (Table- 6.9, Figure – 6.9) shows identical behavior for both the species. The dry wt increases with harvests and decreases with increases in density in both of them. Thus the density effect is evident in both the species with higher values in S_I, which decreases gradually in S_{II}, S_{III} and S_{IV} conditions. Such results have also been observed by Prasad (1988). The dry wt when compared treatment to treatment between first and final harvest, it is 4.21, 4.30, 3.40 and 2.46 in **M. sativa** and 3.55, 3.75, 3.02 and 2.51 in **M. sativa** in S_I, SII, SIII, S_{IV} conditions respectively. The lower dry wt in S_I condition for both the species is due to higher dry wt accumulation in the first harvest.

M. Sativa appears to be superior than **M. lupulina** having higher dry wt accumulation in all the treatments at each harvest. This conclusion is also confirmed by analysis of variance (Table-6.9A) where contribution of all the main factors as well as Tr × Har and Har × Sp interactions are highly significant at 1% level.

Mean leaf area (Table – 6.10, Figureure- 6.10) was observed to correspond with dry wt accruement in both the species as maximum leaf area was recorded in S_I condition which decreases with increase in density. The mean leaf area was also observed to increase with harvests. Generally, the various interspecific combinations imparted have antagonistic effect on this parameter

Table 6.9: Effect of Interspecific Competition On Mean Dry Weight (Mg) Of Two Species in Four Harvest.

Species	Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1	26.2	22.2	20.8	20.4
	2	40.5	35.5	31.2	25.4
	3	75.21	62.2	50.2	38.4
	4	110.2	95.41	70.81	50.2
M. lupulina	1	21.2	17.4	16.2	12.6
	2	32.1	30.4	22.5	20.8
	3	55.4	45.6	35.9	26.8
	4	75.21	65.2	48.9	35.9

Table 6.9A: Analysis of Variance for The Table 6.9

Source of variation	d.f	SS	MS	F.ratio
Species	1	1415.0247	1415.0247	133.8767 ×
Treatment	3	3014.8022	1004.9341	95.0776 ×
Harvest	2	11377.7065	3792.5688	358.8180 ×
Sp × Tr	3	58.1495	19.3832	1.8339
Tr × Har	6	13333.8995	148.21105	14.0224 ×
Har × Sp	2	507.1265	169.0586	15.9948 ×
Residual	6	95.1265	10.5696	
Total	23	17801.8848		

× –significant at 1% level

Table 6.10: Effect of Interspecific Competition On Mean Leaf Area (Cm^2) Of Two Species in Four Harvest.

Species	Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1	14.35	10.75	10.30	10.20
	2	22.81	20.18	18.15	14.05
	3	44.15	36.67	28.65	22.13
	4	60.98	55.11	40.55	28.65
M. lupulina	1	10.41	8.01	7.80	5.55
	2	18.50	18.12	10.85	10.30
	3	32.36	26.72	20.35	14.45
	4	44.15	38.25	28.25	20.35

Table 6.10A: Analysis of Variance for The Table 6.10

Source of variation	d.f	SS	MS	F.ratio
Species	1	474.0121	474.0121	167.9184 ×
Treatment	3	1080.5266	360.1755	127.5186 ×
Harvest	3	4144.6414	1381.5471	489.4119 ×
Sp × Tr	3	9.8709	3.2902	1.1656
Tr × Har	9	431.3215	47.9246	16.9773 ×
Har × Sp	3	132.7479	44.2493	15.6753 ×
Residual	9	25.4059	2.8229	
Total	31	6298.5262		

× –significant at 1% level

Table 6.11: Effect of Interspecific Competition On Relative Growth Rate.

Species	Between Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1–2	0.44	0.47	0.41	0.22
	2–3	0.62	0.56	0.48	0.41
	3–4	0.38	0.43	0.34	0.27
M. lupulina	1–2	0.41	0.56	0.33	0.50
	2–3	0.55	0.41	0.47	0.25
	3–4	0.31	0.36	0.31	0.29

Table 6.11A: Analysis of Variance for The Table 6.11

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0033	0.0033	8.7011
Treatment	3	0.0759	0.0253	1.1237
Harvest	2	0.0714	0.0357	1.2564
Sp × Tr	3	0.0100	0.0033	8.4988
Tr × Har	6	0.0344	0.0057	4.9951 ××
Har × Sp	2	0.0270	0.0135	2.1048
Residual	6	0.1705	0.0284	
Total	23	0.3923		

×× –significant at 5% level

Table 6.12: Effect of Interspecific Competition On Net Assimilation Rate.

Species	Between Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1–2	0.78	0.89	0.76	0.42
	2–3	1.07	0.97	0.83	0.72
	3–4	0.67	0.74	0.61	0.47
M. lupulina	1–2	0.78	1.05	0.68	1.07
	2–3	0.94	0.69	0.89	0.49
	3–4	0.52	0.61	0.54	0.52

Table 6.12A: Analysis of Variance for The Table 6.12

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0009	0.0009	25.9422
Treatment	3	0.1569	0.0523	2.1501
Harvest	2	0.2824	0.1412	5.8059 ××
Sp × Tr	3	0.0607	0.0202	1.2018
Tr × Har	6	0.1174	0.0196	1.2434
Har × Sp	2	0.1190	0.0495	2.4460
Residual	6	0.1459	0.0243	
Total	23	0.8832		

×× –significant at 5% level

Table 6.13: Effect of Interspecific Competition On Leaf Area Ratio.

Species	Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1	0.55	0.48	0.50	0.50
	2	0.56	0.57	0.58	0.55
	3	0.59	0.59	0.57	0.58
	4	0.55	0.58	0.57	0.57
M. lupulina	1	0.49	0.46	0.48	0.44
	2	0.58	0.60	0.48	0.50
	3	0.58	0.59	0.57	0.54
	4	0.59	0.59	0.58	0.57

Table 6.13A: Analysis of Variance for The Table 6.13

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0020	0.0020	3.5134
Treatment	3	0.0047	0.0016	2.8389
Harvest	3	0.0417	0.0139	24.8900 ×
Sp × Tr	3	0.0024	0.0008	1.4597
Tr × Har	9	0.0053	0.0006	1.0520
Har × Sp	3	0.0033	0.0011	1.9544
Residual	9	0.0050	0.0006	
Total	31	0.0643		

× –significant at 1% level

Table 6.14: Effect of Interspecific Competition On Specific Leaf Area.

Species	Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1	1.97	1.92	2.01	2.02
	2	1.93	1.99	1.91	1.97
	3	2.00	1.97	1.98	1.97
	4	1.99	1.89	1.98	1.98
M. lupulina	1	1.98	1.99	2.05	2.19
	2	1.91	2.01	1.90	2.01
	3	1.98	2.04	1.99	1.95
	4	2.00	1.99	2.01	1.99

Table 6.14A: Analysis of Variance for The Table 6.14

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0081	0.0081	9.3449 ××
Treatment	3	0.0078	0.0026	3.0024
Harvest	3	0.0159	0.0053	6.0778 ×
Sp × Tr	3	0.0060	0.0012	2.2934
Tr × Har	9	0.0394	0.0044	5.0303 ××
Har × Sp	3	0.0055	0.0018	2.1114
Residual	9	0.0078	0.0009	
Total	31	0.0905		

× –significant at 5% level

Table 6.15: Effect of Interspecific Competition On Leaf Wt Ratio.

Species	Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1	0.28	0.25	0.25	0.25
	2	0.29	0.29	0.31	0.28
	3	0.29	0.30	0.29	0.29
	4	0.28	0.31	0.29	0.29
M. lupulina	1	0.25	0.23	0.23	0.20
	2	0.30	0.30	0.25	0.25
	3	0.30	0.29	0.28	0.28
	4	0.29	0.30	0.29	0.28

Table 6.15A: Analysis of Variance for The Table 6.15

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0015	0.0015	9.3077 ××
Treatment	3	0.0021	0.0007	4.3333 ××
Harvest	3	0.0129	0.0043	26.3846 ×
Sp × Tr	3	0.0009	0.0003	1.7692
Tr × Har	9	0.0015	0.0002	1.0342
Har × Sp	3	0.0010	0.0003	1.9744
Residual	9	0.0015	0.0002	
Total	31	0.0213		

× –significant at 1% level

×× –significant at 5% level

Table 6.16: Effect Of Interspecific Competition On The Value Of '∝'.

Species	Between Harvest	Treatment			
		S_I	S_{II}	S_{III}	S_{IV}
M. sativa	1–2	0.96	0.75	0.72	0.69
	2–3	0.94	0.93	1.04	0.91
	3–4	1.19	1.05	0.97	1.04
M. lupulina	1–2	0.53	0.68	1.00	0.87
	2–3	0.98	1.05	0.75	0.71
	3–4	1.00	1.00	0.94	0.85

Table-6.16A: Analysis of Variance for The Table 6.16

Source of variation	d.f	SS	MS	F.ratio
Species	1	0.0308	0.0308	1.0906
Treatment	3	0.0287	0.0096	29.5701 ×
Harvest	2	0.2308	0.1154	4.0847
Sp × Tr	3	0.0351	0.0117	2.4139
Tr × Har	6	0.0570	0.0095	2.9725
Har × Sp	2	0.0081	0.0041	6.9481
Residual	6	0.1695	0.0283	
Total	23	0.5601		

×× –significant at 1% level

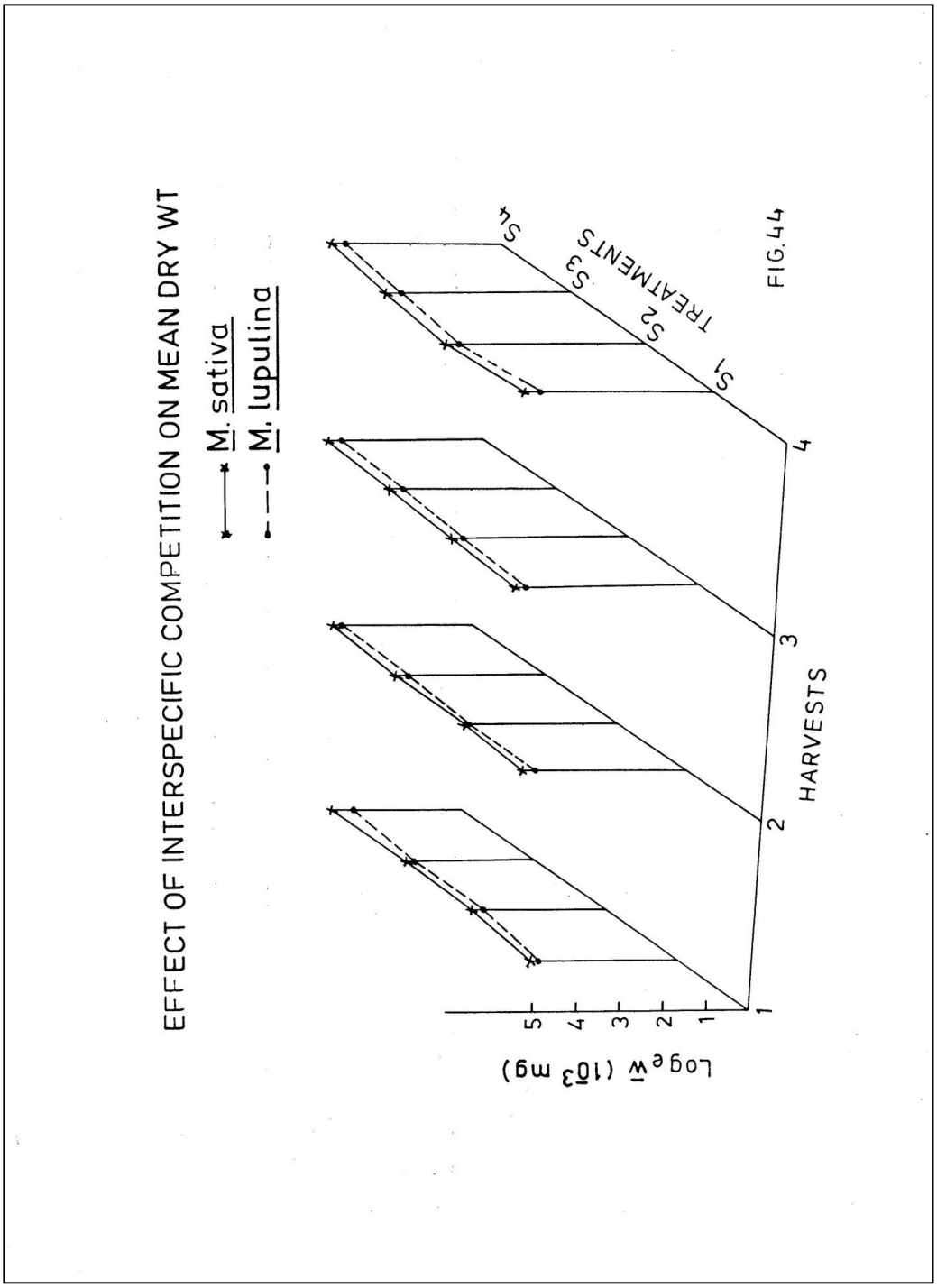

Figure 6.9: Effect of Interspecific Competition On Mean Dry WT.

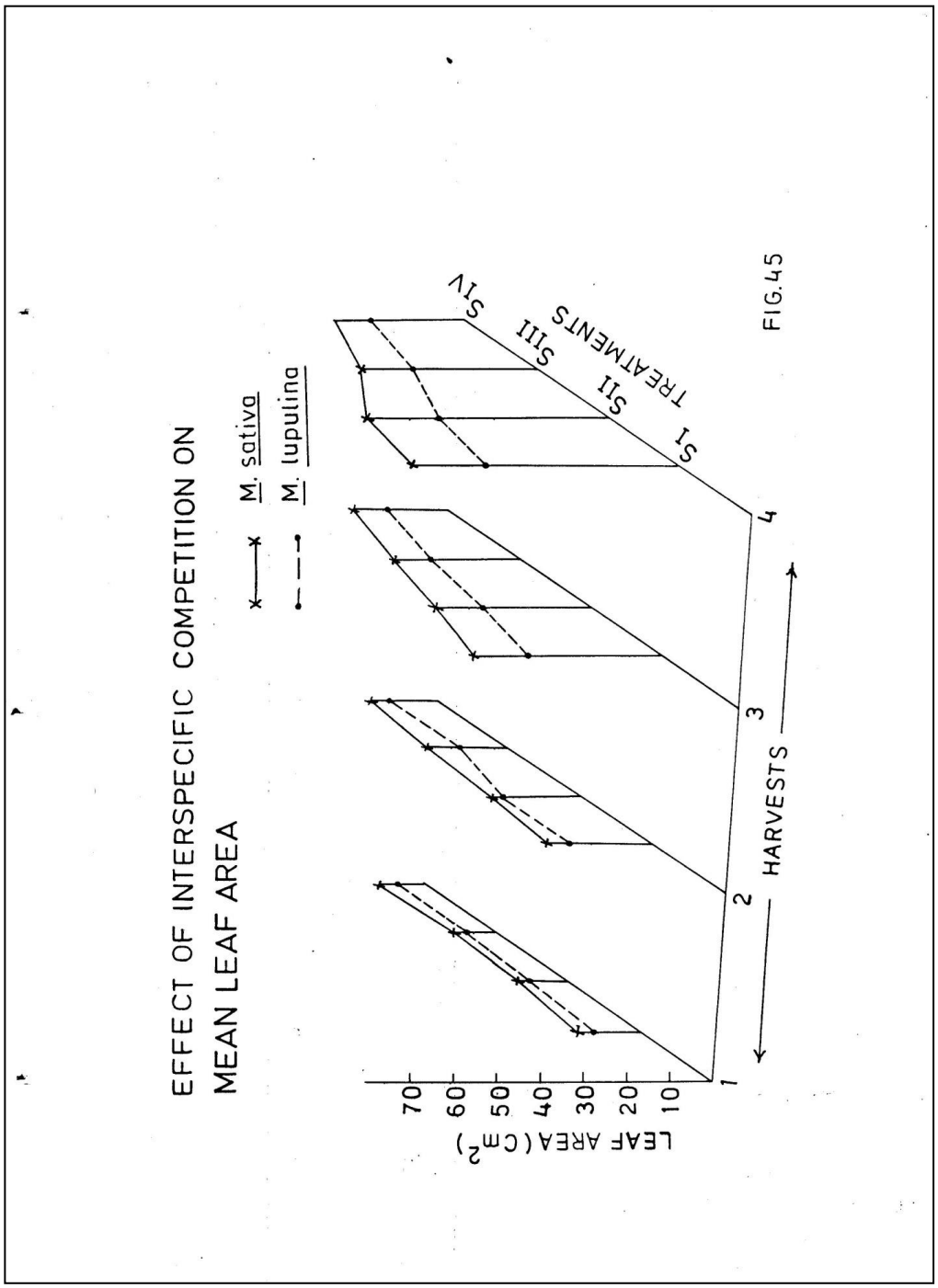

Figure 6.10: Effect of Interspecific Competition On Mean Leaf Area

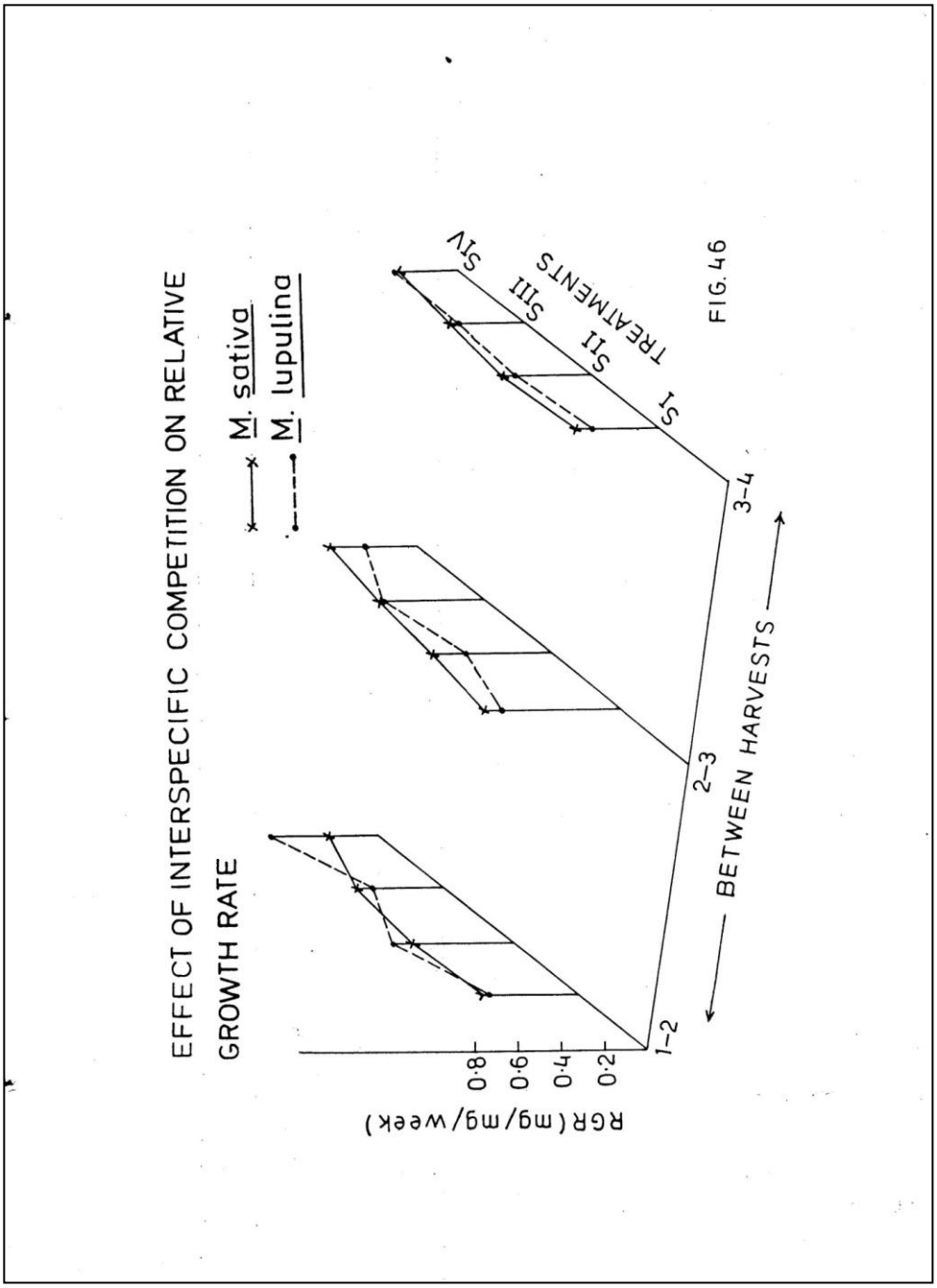

Figure 6.11: Effect of Interspecific Competition On Relative Growth Rate.

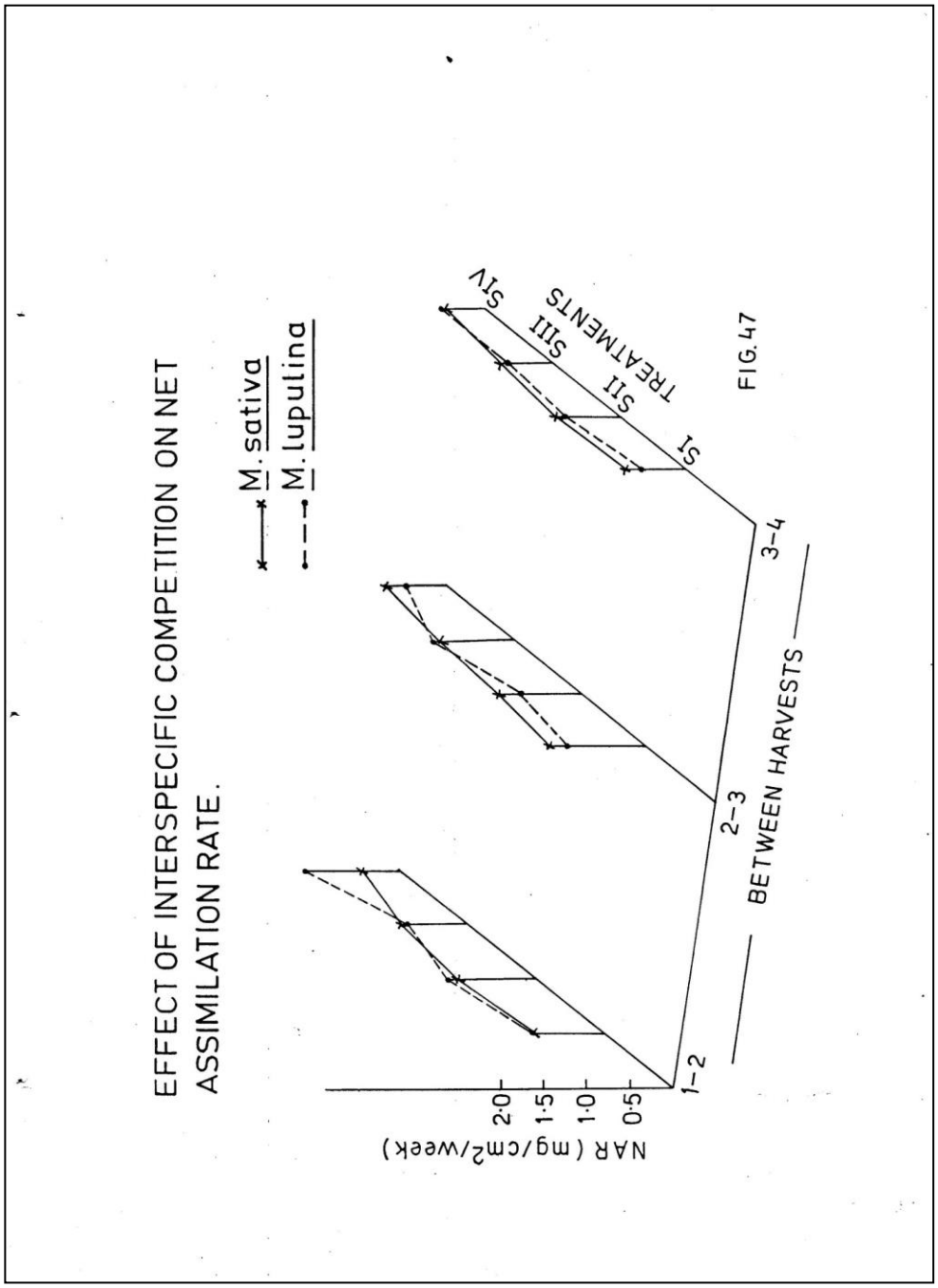

Figure 6.12: Effect of Interspecific Competition On Net Assimilation Rate.

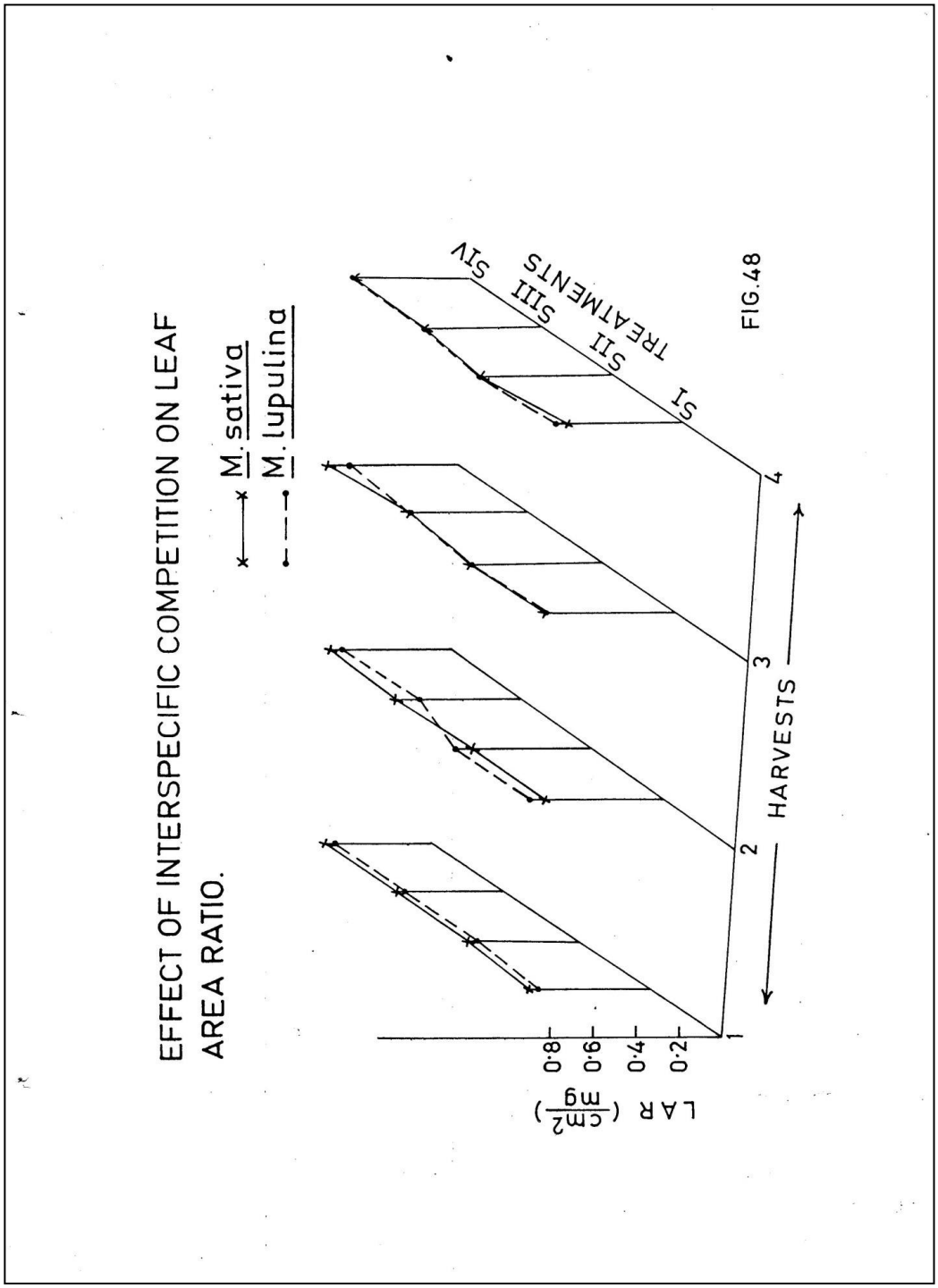

Figure 6.13: Effect of Interspecific Competition On Leaf Area Ratio.

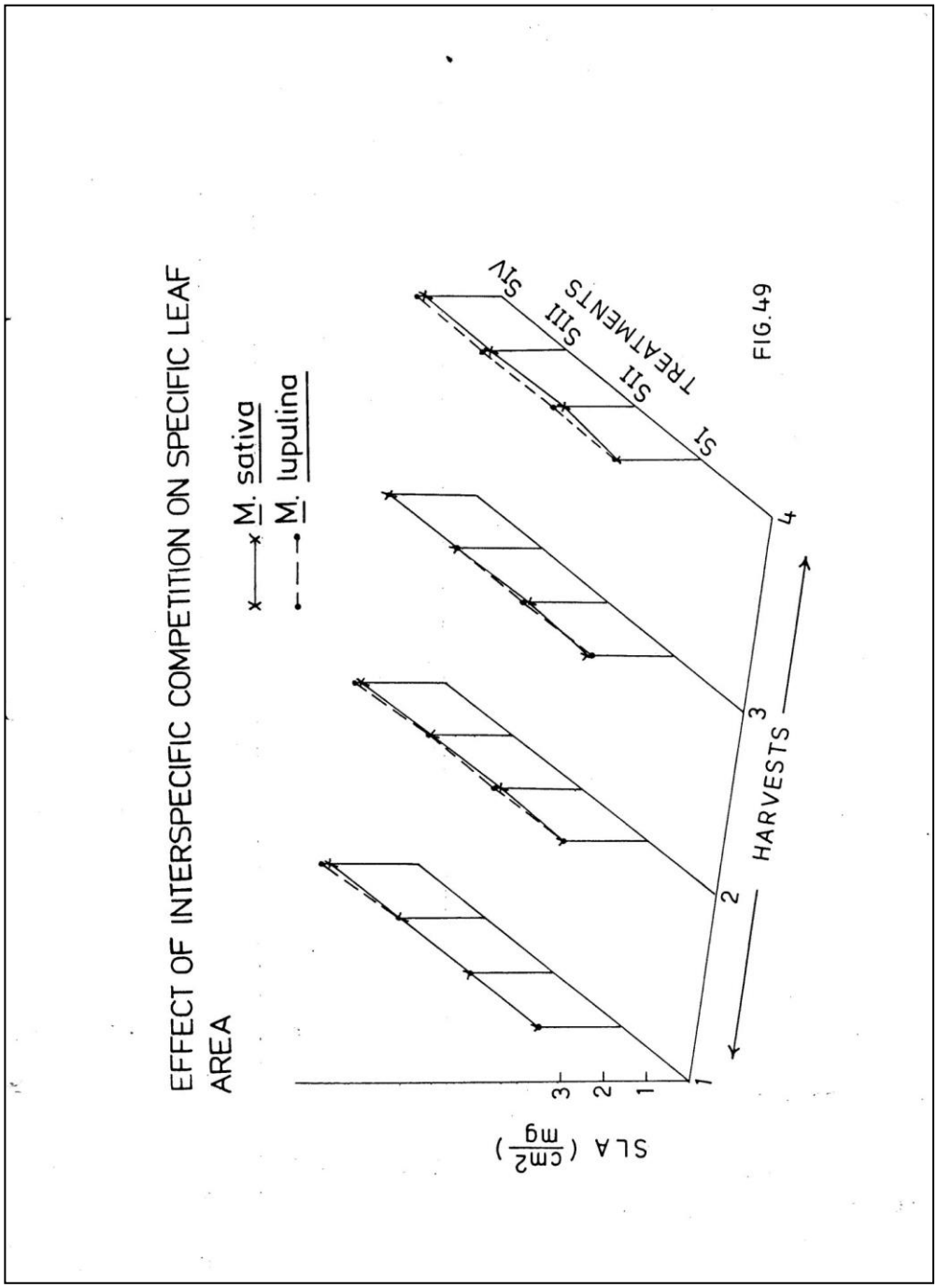

Figure 6.14: Effect of Interspecific Competition On Specific Leaf Area.

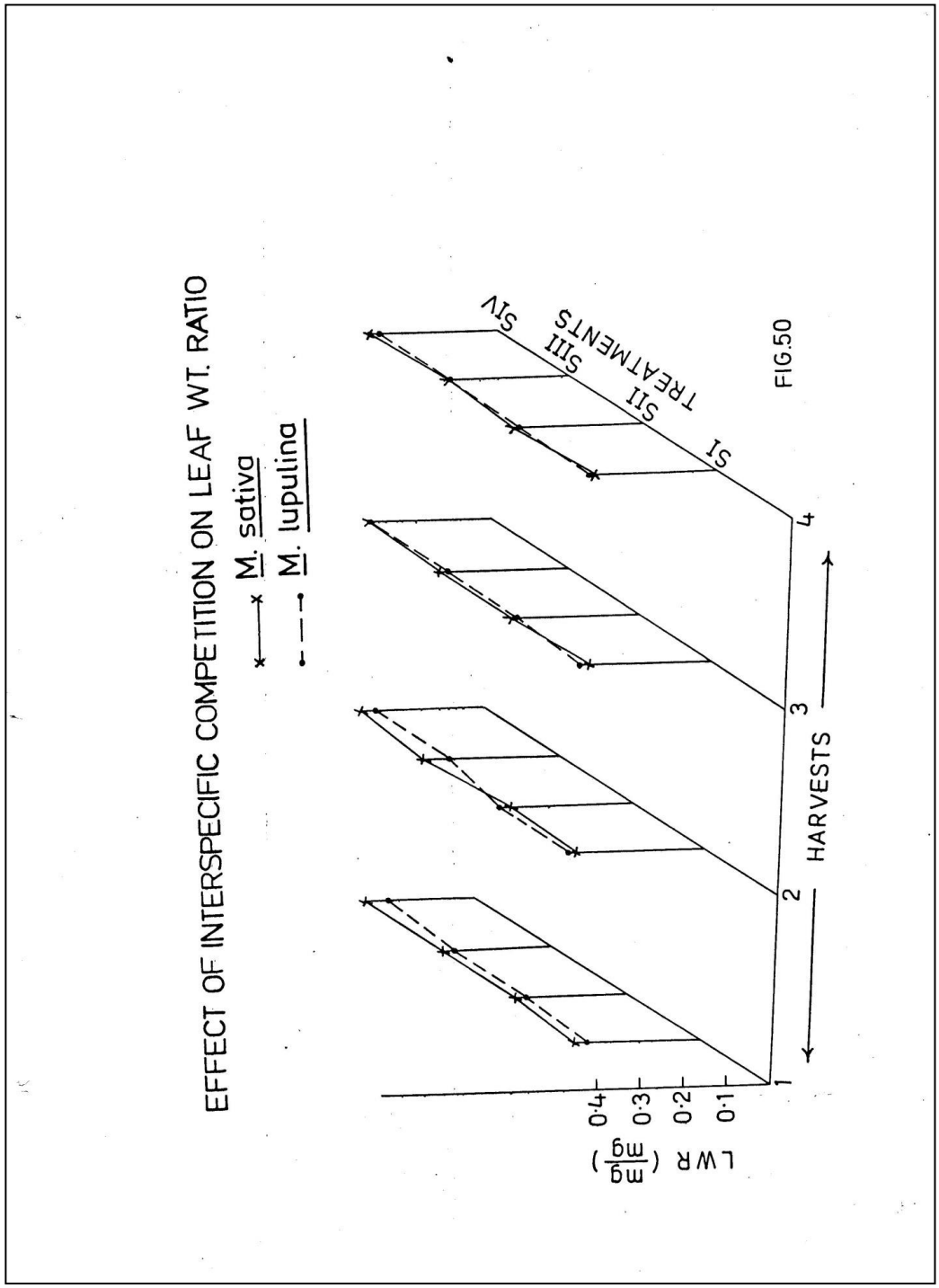

Figure 6.15: Effect of Interspecific Competition On Leaf Wt Ratio.

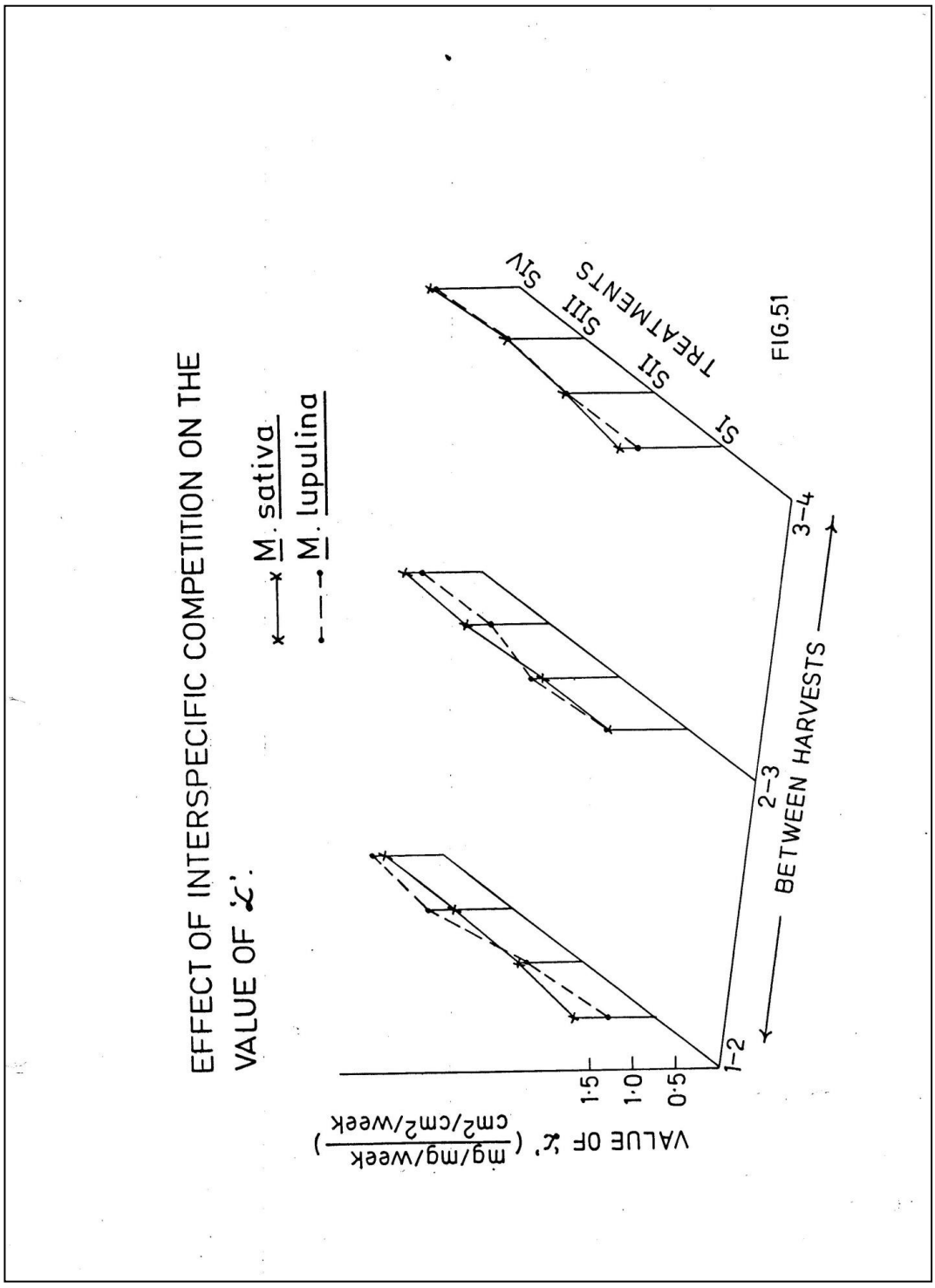

Figure 6.16: Effect Of Interspecific Competition On The Value Of '∝'.

in both the species. However, **M. sativa** with higher leaf area in all the treatment than **M. lupulina** shows its adaptability. This conclusion is also supported by conventional analysis of variance (Table-6.10A) in which contribution of all the main factors, Tr × Har and Har × Sp interactions are highly significant at 1% level.

The RGR (Table-6.11, Figure. 6.11) shows almost identical behavior of both the species. In S_I condition both of them have increased RGR between harvest interval 2–3 than first and last harvest interval. The same is followed by **M. sativa** in S_{II} condition but in **M. lupulina** it is in decreasing order. In S_{III} condition the behavior of RGR values of both the species are like S_I condition. In S_{IV} condition also **M. sativa** shows similar behavior but in **M. lupulina** the RGR values are in decreasing order. The overall RGR values are higher in **M. sativa** than **M. lupulina** which establishes the superiority of the former over the latter. The analysis of variance for the test of significance (Table-6.11A) shows only Tr × Har interaction significant upto 5% level.

The NAR values (Table- 6.12, Figure. 6.12) correspond to RGR in both the species. This reflects better correlation between RGR and NAR. The overall NAR values are also higher in **M. sativa** giving it an edge over **M. lupulina**. However, this conclusion is not supported by analysis of variance (Table-12A) where only harvest effect is significant upto 5% level meaning thereby that the RGR values changes with harvests.

The LAR values (Table-6.13, Figure 6.13) reflect about differential behavior of the species. The LAR values in **M. sativa** increases with harvest upto the third harvest in all the treatments. The LAR values are higher in pure stands at the first harvest decreases in the mixed stands but in second and third harvests the values are either higher or little less in mixed stands compared in pure ones. In the fourth and final harvest the values are higher in the stands than the pure ones. This reflects about the competitive ability of M. sativa. In M. lupulina the LAR values increase with harvest in all the treatments. The values in the pure stands are always higher than the mixed ones. The overall LAR values are also higher in M. sativa than M. lupulina. Thus, competitive superiority of M. sativa over M. lupulina gets established. However, this conclusion is not supported by analysis of variance for the test of significance where only contribution of harvest is highly significant at 1% level.

The SLA values (Table-6.14, Figure. -6.14) change with harvests which does not follow any definite trend for both the species. In S_I condition (pure swards) the SLA values are generally lower than the mixed swards i.e. S_{II}, S_{III} and S_{IV} which also do not follow any definite trend. The SLA values are generally higher in **M. lupulina** than **M. sativa**. The higher SLA value indicates that thinner leaves are produced in different regimes in **M. lupulina**, while reverse is true in case of **M. sativa**. This is also supported by conventional analysis of variance (Table-6.14A) where contribution of species is significant at 5% level. The harvest and Tr × Har interactions are also significant at 5% level meaning thereby that the SLA value changes with treatment and harvest.

LWR values (Table-6.15, Figure – 6.15) for both the species decreases with harvests. **M. Sativa** have higher LWR values in S_I condition than the S_{II}, S_{III} and S_{IV} condition. In the second and third harvest the values in the mixed stands are at par with pure stands but in the fourth harvest the mixed stands have higher LWR values than the pure stands.

In **M. lupulina** the LWR values are generally less in mixed stands than the pure one. In SII condition **M. lupulina** has higher LWR value than S_I in the fourth harvest. The overall LWR values are higher in **M. sativa** than **M. lupulina** which reflects that heavier leaves are produced by **M. sativa** and maximum amount of dry matter is being utilized in the production of leaves. Thus **M. sativa** is more suitably adapted than **M. lupulina** with respect to LWR. This difference is also supported by the analysis of variance for the test of significance (Table-6.15A) where species effect is significant at 5% level. The harvest effect is highly significant at 1% level and the treatment at 5% level.

The '$\propto$' values (Table-6.16, Figure -6.16) for both the species follow almost identical trend. The values are generally around unity for both the species meaning thereby that morphogenetic allometry is maintained. The density effect on this parameter does not follow any definite ontogenetic trend. The result of the statistical analysis of variance (Table-6.16 A) shows only treatment effect to be significant at 1% level.

Usually natural plant populations are mixture of diverse species. In these circumstances interspecific competition is generally less intense as it involves individuals of different aggressiveness. More aggressive species always dominate over the less aggressive ones. In this context it can be concluded that M. sativa is more aggressive than **M. lupulina**.

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Chapter 7

General Discussion

7.1 Introduction:

In order to get maximum yield from their crop plants agriculturists started to manipulates the land and the plants. In the process new germplasms were introduced. These germplasms were combination of wild of related species which resulted into enormous jump in productivity. Thus, a number of varieties of a species came into being. These varieties were observed to perform better in one region but not in the other, although these were having the same gene pool. Their yield and phenotypes were observed to be different in different regions. This part of plant science forms an important facet of study as the combination of conditions among the members of a class of habitat may be observed to be similar but the conditions within each of the habitat such as light, temperature, moisture and pH vary from place to place. In nature different varieties of the environment operate upon individually or jointly affecting whole plants or their parts resulting into phenotypic variations. These resultant phenotypic variations may either due to inherited differences or due to range of environmental factors and is difficult to distangle them. In order to find out whether this resultant variation is due to inharited difference or to range of environmental factors. Plant scientists used the method of comparative culture, reciprocal transplant and provenance trails. Glasshouse and automated chambers like phytotrons and phytocyclons are also used for growing plant populations in such experiments. In the light of developments mentioned above the attention of experimental ecologists and ecophysiologist was drawn to the isolation of factors affecting development and plasticity of individuals. In the light of these consideration the result of the present investigations is being discussed below. An attempt has also been made to correlate the inferences drawn on the basis performance in their natural habitats and under the stress of different environmental factors. This will help in ascertaining the ecological amplitude of the species and establishment of superiority of one over the other as also in planning future line of investigation on the growth of the Spp.

7.2 Germination:

Germination of seeds is an important event which determines further growth and performance interms of morphogenesis. Plants take advantage of ecological situations which increase the probability of successful establishment. Result of some environmental variable on seed germination is being discussed below.

Leguminous plants are generally characterized by seedcoat dormancy and **Medicago** Spp are not exception. In the present study three **Medicago** Spp viz; **M. sativa**, **M. lupulina** and **M. denticulate** were chosen. Seeds of **M. sativa** do not possess any dormancy due to its cultivated habit. Seeds of **M. lupulina** and **M. denticulata** possess seedcoat dormancy. Therefore, effect of some organic solvents as well as H_2SO_4 were tried to release the seed from dormancy.

The result of effect of some organic solvents viz Abs. alcohol, acetone, xylene, and ether (Table-1, Figure. 3) shows that these chemicals have inhibitory effect on **M. sativa**. However, acetone (12%) and ether (12%) were observed to be promotive in **M. lupulina** while acetone (10%) ether (20%) and alcohol (10%) was observed to be promotive in **M. denticulata**. The most effective chemical was observed to be ether (20%) in **M. denticulata**.

Effect of H_2SO_4 on seed germination (Table-2, Figure. -4) suggest that it is most successful scarifying agent. Seeds of M. sativa do not possess any dormancy due to its cultivated habit as it germinates (100%) any time without any treatment throughout the year. The scarifying effect of H_2SO_4 have been observed in **M. lupulina** (100% germination with 15 minutes' treatments) and **M. denticulata** (50.5% germination with 30 minutes' treatment). Thus, on the basis of the result it can be concluded that **M. sativa** is a cultivated plant, **M. lupulina** with thinner seedcoat than **M. denticulata** have travelled far to cultivated habit while **M. denticulata** still possess its wild habit.

A perusal of the result of effect of temperatures on germinability (Table-3, Figure. -5) suggests that at 0^0c unscarified seeds of none of the species could germinates. At 40^0C only unscarified seeds of **M. sativa** could germinate. However, scarified seeds of **M. lupulina** and **M. denticulata** germinated at all the temperatures. The maximum germination was achieved for **M. Sativa** (100%), **M. lupulina** (100%) and **M. denticulate** (50%). The optimum temperature was observed to be 30^0c for all the three species. However, the species differ with each other in respect of time lag. This time/lag for **M. Sativa** (UNSC) and **M. lupulina** (SC) was observed to be 24h whereas for **M. denticulata** (SC) it was 72h. Thus, on the basis of range of temperature, optimum temperature and time/ lag, **M. sativa** excels **M. lupulina** and **M. denticulata**.

The result of the effect of storage of seeds at varying temperatures (Table-4, Figure. -6) shows that fifteen months (5th exhumption) storage at higher temperature (30^0c) results in to maximum breakage of dormancy (**M. sativa**, 100%, **M. lupulina** – 70% and **M. denticulate** – 100%). After fifteen months' period a loss in viability of seeds has been observed. The seeds stored at 15^0c also show maximum germination in the fifth exhumption (15 months) (**M. Sativa** –95%, **M. lupulina** – 40% and **M. denticulata** – 50%). The seeds of **M. lupulina** and **M. denticulate** stored at 0^0c also show maximum germination in the fifth exhumption with 20 and 25% germination respectively. However, **M. sativa** shows maximum germination (16%) in the fourth exhumpation. After fifteen months' storage a loss in viability of seeds was observed at all the temperatures. This loss in viability was maximum at 0^0c followed by 15^0cand 30^0c. The storage of seeds at higher temperature (30^0c) brought about early breakage of dormancy as well as maintained viability of seeds. However, when the ecological superiority of a species in terms of germination percentage, temperature toleranee and viability of seeds are taken into account it appears that **M. sativa** excels both **M. lupulina** and **M. denticulata**.

A perusal of the result on the effect of light and dark, different photoperiods and wavelengths of light (Table-5, 6 and 7 respectively) show that the **Medicago** Spp under reference are unaffected by different light conditions. The effect of pH on the range of germination (Table- 8, Figure. –7) suggests optimum pH to be 7 for all the spp.

The unscarified seeds of **M. sativa. M. lupulina** and **M. denticulate** yielded 100, 10 and 10% germination respectively. Thus **M. sativa** excels **M. lupulina** and **M. denticulate** with respect to pH also.

The result of effect of burial on germination (Table-9, Figure -8) shows that seeds of **M. sativa** yields 100% (5cm), 90% (10cm) and 40% in 15cm depth. **M. lupulina** yielded 64, 30 and 15% in 5, 10 and 15 cm depths respectively. The same in **M. denticulate** was observed to be 80, 40 and 20%. Thus, the result is suggestive of the fact that better microbial action takes place in the uppermost layer of the soil and **M. sativa** with maximum germination percentage excels **M. denticulate** and **M. Lupulina.**

A perusal of the result on the effect of salt stress on seed germination (Table-10, Figure -9) shows that seeds of none of the **Medicago** spp could germinate in any concentration of Na_2CO_3. Seeds of **M. Sativa** germinated at four concentrations of NaCl (0.05M, 0.02M and 0.3M) and three concentrations of Na_2SO_4 (0.05, 0.1 and .02M) with a germination percentage of 50, 70, 8, 8, 70, 20 and 8 respectively. Seeds of **M. lupulina** germination in all concentrations of NaCl (0.05, 0.01, 0.2, 0.3, 0.4 and 0.5M) with percentage of 28, 64,68, 4,4 and 4 respectively. **M. lupulina** seeds also germinated in their concentrations of Na_2SO_4 i.e. 0.05, 0.1 and 0.2M with a percentage of 40, 32 and a respectively. Seeds of **M. denticulate** could not germinate at any concentrations of Na_2SO_4 but it could germinate in two concentrations of NaCl i.e. 0.05, 0.01 with a percentage of 4 only. The result when compared with control shows inhibitory effect in all the three species. However, this inhibition is less in **M. Sativa** which establishes its superiority over other ones.

Effect of some chemical viz. Thiourea, IAA, GA_3 and MH on germination (Table- 11, Figure - 10) shows that with all the concentrations of thiourea 100% germination occurs in **M. sativa**. **M. Sativa** also exhibits 100% germination with 10 and 20ppm concentration of IAA and GA_3. The concentrations above 20 ppm have inhibitory effect. However, all the concentrations of MH have marked inhibitory effect on seed germination of **M. sativa**. Scarified seeds of **M. lupulina** show 100% germination with only 10 ppm concentration of IAA and GA_3. Concentration of IAA and GA_3 above 10 ppm have inhibitory effect.

All the concentrations of thiourea and MH show their inhibitory effect on **M. Lupulina.** The germination of seeds of **M. denticulata** is inhibited with all the chemical in all concentrations except 10 ppm concentration of IAA. However, the percentage of inhibition increases with increase in concentrations of the chemicals.

From the result it can be concluded that none of the chemicals under reference promotes germination but in higher concentrations it has inhibitory effect on all the three **Medicago** spp. However, the intensity of inhibition is less marked in **M. Sativa** than **M. lupulina** and **M. denticulate**.

The result of the effect of moisture stress (Table-12, Figure. - 11) shows that **M. sativa** and **M. lupulina** give optimum germination in regime II (milder stress). However, **M. denticulata** performed better in regime I (water logged). Thereafter a decrease in percent germination is observed in all the regimes. **M. lupulina** with a germination percentage of 60 (regime I) and 72 (regime II) excels both **M. sativa** and **M. denticulate**.

7.3 Growth Analysis:

To measure the growth performance **M. Sativa** and **M. lupulina** have been selected as both species share some common properties. In order to find out some relevant difference between them, they were subjected to various environmental stresses.

The dry wt accumulation is the first parameter used for comparative studies. The result of the effect of soil moisture on growth (Table- 13, Figure. - 12) shows identical trend of dry wt accumulation in both the species. At the final harvest the dry wt. accumulation in **M. Sativa** is 38.0, 87.33, 71.13 and 54.3 in W_1, W_2, W_3 and W_4 treatment respectively. The same in **M. lupulina** is 33.5, 65.25, 47.6 and 44.4 in W_1, W_2, W_3 and W_4 treatments respectively. Thus, optimum soil moisture condition for growth of both the species have been observed to be in W_2 condition which is at the field capacity. Both the species appears to have performed better in the lowest soil moisture condition than in the waterlogged. Thus, it can be inferred that **Medicago** spp are more tolerant to drought than waterlogged condition. The results also suggest superiority of **M. Sativa** over **M. lupulina** as the former have higher dry wt accumulation in all the soil moisture regimes. The man dry wt under different levels of shading (Table-21, Figure - 20) also shows almost identical behavior of the species. The dry wt accumulation is higher in L_1 light regime and lowest in L_3 light regime. This decrease in dry wt accumulation with increased levels of shading is typical of arable weeds (Blackman & Wilson, 1951). When the dry wt accumulation in all the treatment at all the harvests are taken into account, it appears that **M. Sativa** (having higher dry wt accumulation at all the harvests in all the treatments) is superior to **M. lupulina**. The dry wt accumulation under different photoperiodic condition (Table-29, Figure -28) also suggest identical trend of both the species. Both of them have increased dry wt in 12h photoperiodic condition than 8h, thereafter, at 16h photoperiod a drop drown in the dry wt accumulation is observed. Thus, it can be inferred that 12h photoperiod is optimum for both the **Medicago** spp at which maximum dry wt accumulation accurse. However, when the dry wt accumulation is taken into account for establishment of superiority of one species over the other it appears the **M. Sativa** (with higher dry wt in all the photoperiodic conditions) certainly has an edge over **M. Lupulina.**

The dry wt accumulation under different combination of intraspecific competition (Table-37, Figure. -36) also suggest identical behavior of the species as both of them have higher dry wt accumulation in S_1 condition which gradually declines in S_1, S_3 and S_4 conditions. A perusal of the result also suggests that **M. Sativa** have higher dry wt accumulation in all the treatments than **M. Lupulina.** If the percentage of dry wt accumulation at the last harvest in the highest density class (S_4 condition) is taken into account it appears that the same in **M. Sativa** is 48.8% whereas in **M. lupulina** it is 47.31%. Thus, the reduction in dry wt in the highest density class is more in **M. lupulina** than **M. sativa**. Therefore, on the basis of dry wt accumulation and reduction in the dry wt at the final harvest in the highest density class **M. Sativa** is certainly superior to **M. Lupulina.** The result of the dry wt accumulation of interaction of species i.e. interspecific competition (Table-45, Figure. -44) reflects about identical behavior of the species. Both of them shows decrease in dry wt accumulation with increase in density. Thus, the density effect is evident in both of them with highest values in S_I which gradually declines in S_{II}, S_{III} and S_{IV} conditions. The dry wt accumulation at each harvest in all the treatment is higher in **M. Sativa** which shows its superiority over **M. Lupulina.**

The mean leaf area in different soil moisture regimes (Table-14, Figure -13) shows the same trend as dry wt accumulation for both the species. When the leaf area of both the species is compared at both extremes i.e. waterlogged and lowest soil moisture regimes it appears that no reduction in leaf area to miminise transpiration has taken place. Orshansky (1954) and Oppenheimer (1960) considered it to be in important adaptation for desert plants. Thus, none of the species can be considered to be suitably adapted to the xeric condition. However, **M. Sativa** with higher leaf areas has an edge over M. Lupulina. The mean leaf area under different levels of shading (Table-22, Figure. 21) in between first and final harvest is 5.30, 3.11 and 2.26 in **M. Sativa** and 8.27, 3.62 and 1.97 in **M. lupulina** in L_1, L_2 and L_3 light regimes respectively. Blackman (1956), Newton (1963), Pandey & Sinha (1977), Bourdet et.al. (1984) and Choudhary (1988) observed increase in leaf area with decrease in light intensity. This on this basis none of the **Medicago** spp under investigation can be considered to be shade tolerant. However, Buttrose & Sedgley (1978) observed that leaf area is not affected with the degree of shading. When the leaf area at each harvest in all the treatments in taken into account **M. Sativa** shows its superiority over **M. Lupulina.** Mean leaf area under different photoperiodic conditions (Table-30, Figure -29) shows the same trend as dry wt accumulation. However, when both the species are compared with respect to mean leaf area **M. Sativa** establishes its superiority over **M. Lupulina.** The mean leaf area in intraspecific competition (Table-38, Figure -37) also have the same trend as dry wt accumulation. The leaf area is highest in S_1 condition which gradually decline in S_2, S_3 and S_4 conditions. Both the parameters i.e. dry wt accumulation and mean leaf area come under the direct effect of competition and **M. Sativa** shows its superiority over **M. lupulina** with respect to dry wt accumulation, superiority of **M. sativa** over **M. lupulina** with respect to mean leaf area gets established. Mean leaf area in intraspecific competition (Table-46, Figure - 45) shows that it corresponds to dry wt accruement.

Both the species have maximum leaf area in S_I condition which decreases with increase in density i.e., S_{II}, S_{III} and S_{IV} conditions. However, **M. sativa** with higher leaf area in all the treatment shows better adaptability then **M. Lupulina.**

The RGR (Table-15, Figure - 14) under different soil moisture regimes do not show any definite ontogenetic trend in both the species. Therefore, no conclusion can be drawn about superiority of one over the other. The behavior of both the species with respect to RGR (Table-23, Figure.22) is identical. Both the them registered higher values in L_1 (100% light regime) which decreases with decrease in light intensity i.e. in L_2 and L_3 light regimes. Plants when removed to lower light intensity, the immediate effect is reduction of RGR (Fitter & Hay, 1981). On this basis, therefore, both the **Medicago** spp can be said to have adaptation towards shade. However, no conclusion can be drawn about the superiority of on over the other. Both of them show identical behavior with respect to RGR (Table -31, Figure-30) under different photoperiodic treatment. The RGR values in intraspecific competition (Table-39, Figure. 38) shows that in **M. Sativa** it increases from S_1 to S_2 thereafter gradually decreases in S_3 and S_4 condition. **M. lupulina** shows increased value from S_1 to S_4. Thus, it appears that **M. lupulina** atleast tried to accelerate its growth. Therefore, **M. lupulina** can be considered superior to **M. sativa**. In the interspecific competition (Table-47, Figure. -46) both the species show identical behavior. The pattern of variation of NAR values under different soil moisture regimes (Table-16, Figure -15) shows parallelism with RGR values. It means that RGR and NAR values are correlated just like RGR, NAR also does not throw any light on the differential behabiour of the species.

Both the species have identical ontogenetic trend with respect to NAR values (Table- 24, Figure-23) in light regimes under reference. The NAR values (Table-32, Figure -31) in different photoperiodic treatment also do not establish superiority of one species over the other. The NAR values (Table- 40, Figure. -39) show almost identical trend to RGR in intraspecific competition. Thus, on the basis of NAR values **M. lupulina** is superior to **M. savita**. The overall NAR values (Table-48, Figure. 47) in interspecific competition are generally higher in **M. Sativa** giving it an edge over **M. Lupulina.**

Plants in face of drought decrease their leaf area to check the rate of transpiration. The LAR values (Table- 17, Figure - 16) in different soil moisture regimes shows that **M. lupulina** in W_3 and W_4 conditions have lesser LAR values than W_1 (water logged) and W_2 (optiomal soil moisture regime). However, such reduction in LAR values are not observed in **M. sativa**. Thus, it appears that **M. lupulina** have better adaptabilities to xeric conditions than **M. sativa**. Small but significant increase in LAR values tolerant plants. The LAR values (Table-25, Figure. -24) shows that in **M. Sativa** it increases with decrease in light intensity, which is not evident in **M. Lupulina.** Thus, on the basis **M. Sativa** can be considered to have better adaptation towards shade than **M. Lupulina.** The LAR values (Table- 33, Figure. 32) under different photoperiodic treatment do not throw any light on differential behavior of the species. The LAR values (Table-41, Figure. - 40) in intraspecific competition shows that in **M. sativa**, the values have a general decreasing trend with increase in density. In **M. lupulina** the values in the first two harvests have the same trend as **M. Sativa** but in the later harvests (third and fourth) the values increase with increase in density. Escasines et.al. (1981) observed increase in LAR under the influence of density stress. The **M. lupulina** shows its superiority over **M. sativa**. The Lar values (Table-49, Figure. -48) in interspecific competition shows that **M. lupulina** the values in the pure stand are always higher than the mixed stands. the same is true for **M. Sativa** in first two harvests but in the latter harvests the values in the mixed stands are either higher or little less than pure stands, the overall LAR values are also higher in **M. sativa**. Thus, competitive superiority of **M. Sativa** over **M. lupulina** gets established.

A perusal of SLA values (Table-18, Figure. -17) under different soil moisture regimes suggests that in **M. Sativa** it increase with decrease in moisture content of the soil whereas in **M. lupulina** it decreases with decrease in moisture content. Thus it appears that **M. Sativa** increase its LAR with the help of SLA by expanding its leaf area. Thus the superiority of **M. Sativa** over **M. lupulina** gets established. SLA values under different levels of shading (Table-26, Figure. -25) suggest that **M. lupulina** have higher values in lower light regimes than **M. sativa**. Thus it appears that **M. lupulina** is more suitably adapted to shade than **M. Sativa** with respect to SLA values. The SLA values in different photoperiodic treatment (Table-34, Figure. -33) suggest identical behavior of both the species. However, the values are higher in **M. lupulina** which gives it an edge over **M. sativa**. The SLA values in different interspecific combination do not show any definite ontogenetic trend for both of them. The overall values are higher in **M. lupulina** which reflects about its superiority over **M. sativa**. The SLA values (Table-50, Figure. -49) in different interspecific combinations also do not follow any definite trend. The values are generally higher in **M. lupulina** which suggests it superiority over **M. sativa**.

The LWR values in different soil moisture regimes (Table-19, Figure. -18) suggest identical behavior of the species.

However, the values are slightly higher in **M. Sativa** which reflects its superiority over **M. Lupulina.** A perusal of LWR values under different levels of shading (Table-27, Figure. 26) also shows identical behavior of both of them. The higher LWR values of **M. Sativa** suggest its superiority over **M. Lupulina.** The LWR values in different photoperiodic treatment reflect about identical behavior of the species. The overall LWR values in different interspecific combination (Table-43, Figure. 42) are higher in **M. Sativa** which reflects its better adaptability than **M. Lupulina.** The LWR values in different interspecific combination (Table- 51, Figure. -50) show that at the final harvest **M. lupulina** exhibits lower LWR values in the mixed stands than the pure stand. The overall LWR values are also higher in **M. sativa**, suggesting its superiority over **M. Lupulina.**

The values of '$\propto$' (a parameters for measurement of allometry in plants) does appear to be significantly affected different soil moisture regimes (Table -29, Figure, 19), different levels of shading (Table-28, Figure - 27), different photoperiodic treatment (Table-36, Figure -35, and different interspecific combination (Table- 52, Figure. -51), In these treatment the values are round about unity for both the species suggesting there by that morphogenetic allometry is almost maintained. However, a perusal of the result of '$\propto$' values in different intraspecific combination (Table-44, Figure -43) suggest that the morphogenetic allometry is almost maintained in **M. Sativa** but the same in **M. lupulina** is upset. Thus **M. sativa** shows its superiority over **M. lupulina**.

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Summary

1. Present investigation pertains to the comparative biology of **Medicago** spp.
2. Seeds of **Medicago** spp (except **M. sativa**) are characterized by dormancy, therefore, some organic chemicals such as abs. alcohol, acetone, xylene, ether and conc. H_2SO_4 have been tried to release the seeds from dormancy. The effect of some germination promoters and germination inhibitor such as Thioures, IAA, 3 and MH on germination was also studied.
3. Three **Medicago** spp, viz., **M. sativa, M. lupulina** and **M. denticulata** have been experimented upon to assess the effect of different environmental factors, such as, light (guality and duration, temperature, storage temperature and period, burial, pH, salinity and water stress on their germination behavior.
4. The growth and morphogenesis of the species in response to soil moisture, light intensity, photoperiods, intra and interspecific competition was assessed through the methods of growth analysis with respect to some well-established parameters of growth (Evans, 1972).
5. Organic chemicals were observed to be inhibitory in **M. sativa**. Acetone and ether in **M. lupulina** were observed to be promotive, whereas in **M. denticulata** acetone, ether and abs. alcohol were observed to be promotive. Cond. H_2SO_4 was observed to be most successful dormancy breaking substance in **M. lupulina** and **M. denticulata**, both. **M. lupulina** yielded 100% germination with 15 minutes' treatment whereas, **M. denticulata** yielded 50.5% germination with 30 minutes' treatment. Seeds of **M. Sativa** yield 100% germination without any treatment.
6. The optimal temperature for germination was observed to be 30^0c for all the three species. However, the species differ within themselves with respect to time-lag. The time- lag for **M. Sativa** (UNSC) and **M. lupulina** (SC) was observed to be 24h whereas for **M. denticulata** (SC) it was 72h.
7. The result of the effect of storage periods at varying temperatures on germinability reveals that fifteen months' storage at all the temperature (00c, 15^0c and 30^0c) results into maximum breakage of dormancy. Thereafter, a decrease in percent germination is observed. This decrease is maximum at 0^0c followed by 15^0c and 30^0c. The storage at higher temperature (30^0c) yields maximum breakage of dormancy as well as retain viability of seeds.
8. The effect of light and dark different photoperiods and different wavelengths of light shows that all the **Medicago** spp under reference are unaffected by different light conditions.
9. The result of the effect of different pH range suggest optimum pH to be 7 for all the **Medicago** spp.
10. The effect of burial on germination is suggestive of the fact that better microbial action takes place in the uppermost layer of the soil.
11. A perusal of the result of effect of salt stress on seed germination shows all the salt (under reference) causes inhibition of germination. This inhibition is maximum in case of $Na_2 CO_3$ followed by $Na_2 SO_4$ and NaCl.
12. The result of the effect of growth regulations suggest that all the growth regulators studied are ineffective in promoting germination. In higher concentrations they have

inhibitory effect on all the three **Medicago** spp. However, this inhibition is less marked in **M. Sativa** than **M. lupulina** and **M. denticulata**.

13. A perusal of the result of moisture stress shows that **M. Sativa** and **M. lupulina** give optimum germination with milder stress whereas, **M. denticulata** in water logged condition.
14. The growth behavior of two **Medicago** spp viz. **M. Sativa** and **M. lupulina** was studied under different ecophysiological conditions with respect to some well established parameters of growth (Evans, 1972).
15. Under different soil moisture regimes both the species appear to have identical behavior in the pattern of dry wt accumulation, mean leaf area, LAR, and LWR, RGR and NAR do not show any definite ontogenetic trend, this unable to reflect superiority of one species over the other. The '∝' values also do not give any definite ontogenetic trend. However, the species differs within themselves with respect to SLR. **M. Sativa** appears to increase its LAR through SLA which is not the case in **M. Lupulina.** However, **M. Sativa** with higher dry wt accumulation, mean leaf area, LAR and LWR appears to be superior than **M. Lupulina.** Both the species appear to have better performance in the lowest soil moisture regime than the water logged condition.
16. Under different levels of shading both the species appear to exhibit identical behavior with respect to dry wt accruement, mean leaf area, RGR, NAR, LWR and '∝' values. However, the species differs within themselves with respect to LAR and SLA values. **M. Sativa** increase its LAR with decrease in light intensity which is not evident in **M. lulupina**. Small but significant increase in LAR values with decrease in light intensity have been observed to be a clearcut pointer to shade tolerant plants. Thus **M. Sativa** can be considered to have better adaptation towards shade. **M. lupulina** increase its LAR through SLA which is not evident in **M. sativa. M. lupulina** with higher SLA values in lower light regimes may be considered superior to **M. sativa**. However, higher dry wt accumulation, mean leaf area, RGR, NAR and LWR values gives superiority to **M. Sativa** over **M. Lupulina.**
17. The result of the different photoperiodic treatment suggest that both the species have identical behavior with respect to dry wt accruements, mean leaf area, RGR, NAR, LAR, SLA, LWR and '∝' values. However, SLA values are higher in **M. lupulina** which gives superiority over **M. Sativa** with respect to this parameter. The optimum photoperiod was observed to be 12h for both the species. However, **M. Sativa** with higher dry wt accruement, mean leaf area, RGR, NAR, LAR and LWR appears to have an edge over **M. Lupulina.**
18. The result of the different intraspecific combinations reflect that both of them have identical behavior with respect to mean dry wt, mean leaf area, LWR and '∝' values. The RGR and NAR values show identical trend. The RGR values show that **M. lupulina** atleast triend to be accelerate its growth in the denser class which is not evident in **M. sativa**. The overall SLA values are higher in **M. Lupulina.** The LAR values in **M. lupulina** in the last two harvest show increased values which increase in density. Escasinas et.al. (1981) observed increase in LAR values under the influence of density stress.

    Thus, on the basis of RGR, NAR, LAR and SLA values **M. lupulina** reflect its superiority over **M. sativa**. However, increase in dry wt accruement, mean leaf area, and LWR values under denser classes in **M. sativa** gives superiority over **M. Lupulina.**

19. A perusal of the result of different interspecific combinations suggests identical trend of both the species with respect to mean dry wt, mean leaf area, RGR, NAR, LWR and '$\propto$' values **M. Sativa** with almost higher LAR values in the mixed stands shows superiority over M. **Lupulina.** The SLA values do not follow any definite trend for both species. However, M. lupulina with overall higher SLA values show an edge over M. sativa. M. Sativa shows increase in dry wt accrument, mean leaf area, RGR, NAR, LWR in the mixed stands compared to the pure stands, which is not evident in M. lupulina. This reflects about competitive superiority to M. sativa over M. Lupulina.
20. The various eco-physiological studies with respect to germinability and growth studies reveals **M. sativa** to be a cultivated plant. This is followed by **M. lupulina** and **M. denticulata**. The growth studies of two species viz. **M. Sativa** and **M. lupulina** establish superiority to **M. Sativa** over **M. lupulina**; though in some parameters of growth **M. lupulina** excels **M. sativa**.

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Table 8.1: Effect of Chemical Scarification on Germination Percentage

Treatment	Germination percentage		
	M. sativa	M. lupulina	M. denticulata
Control	100	10	8
Acetone	80	12	10
Abs. Alcohol	44	6	10
Ether	72	12	20
Xylene	80	4	8

Table- 8.2: Effect of Chemical Scarification On Germination Percentage

Duration of treatment in minutes	Germination percentage		
	M. sativa	**M. lupulina**	**M. denticulata**
5	40	50.8	20.8
10	–	70	25.6
15	–	100	27.6
20	–	100	30.6
25	–	100	40.6
30	–	100	50.5
35	–	100	40.4
40	–	90.6	5.2
45	–	60.4	–
50	–	40.2	–

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