EFFECT OF WATER STRESS ON GROWTH AND YIELD OF SOYBEAN (*Glycine max (L.) Merrill*)

BY

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B.Sc. [Agri.]

DISSERTATION

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1998

Affectionately dedicated

to my

beloved Parents

CANDIDATE'S DECLARATION

I,

hereby declare that the dissertation

or a part thereof has not been

previously submitted by me

for a degree or diploma

of any University

Place :- PARBHANI

Date :- 29 /06/1998

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CERTIFICATE - I

This is to certify that Mr. ***FAROQODDIN FASIUODDIN SIDDIQUI*** *has satisfactorily prosecuted his course and research for a period of not less than* four *semesters and that the dissertation entitled "* ***EFFECT OF WATER STRESS ON GROWTH AND YIELD OF SOYBEAN (Glycine max (L.) Merrill)*** *" submitted by him is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.*

I also certify that the dissertation or part thereof has not been previously submitted by him for a degree of any university.

Place :- PARBHANI

Date : 29/06/1998

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CERTIFICATE - II

*This is to certify that the dissertation entitled " **EFFECT OF WATER STRESS ON GROWTH AND YIELD OF SOYBEAN** (Glycine max (L.) Merrill) " submitted by Mr. **FAROQODDIN FASIUODDIN SIDDIQUI** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **AGRICULTURAL BOTANY (PLANT PHYSIOLOGY)** has been approved by the student's Advisory Committee after oral examination in collaboration with the external examiner.*

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(F. F. SIDDIQUI)

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Introduction

CHAPTER - 1

INTRODUCTION

Soybean (*Glycine max* (L) *Merrill*) is a native of Asia and the wild forms of Soybean occur in China, Manchuria and Korea. Soybean is a new crop in India. Soybean seed contains 40 per cent protein with good amount of amino acids and 20 per cent oil content with non-cholesterol characteristics. Similarly it contains 4.6 per cent minerals, 20.9 per cent carbohydrates, 0.24 per cent calcium, 0.69 per cent phosphorus and 11.5 milligram iron and has highest energetic value (432 cal/100 gm) than all other vegetarian and non-vegetarian food materials.

Due to its high protein contents, soybean is known as "poor man's meat". Soybean is also called as "miracle" crop of the 20^{th} century because of its multiple uses as in the preparation of bread, biscuits, cakes, chocolates, curd, butter fats and vegetables. The vegetable milk prepared from Soybean flour is easy to digest. It contains comparatively less amount of carbohydrates, therefore it is found to produce good food for the diabetes patients. Soybean is also used in the preparation of medicinal substances like penicillin, streptomycin, tetracycline and erythromycin as antibodies. It has many fold industrial uses like preparation of paints, varnishes, plastic cloth, soap, glycerine, printing ink, rubber and candle.

During the year 1994-95 the total area under Soybean in India was 36.9 lakh hactare with productivity of 11.5 quintals /hactare and production of 36.78 lakh tonnes. The area under soybean cultivation in Maharashtra is 5.16 lakh hactare with 5.26 lakh tonnes production and productivity of 9.38 quintals / hactare. Low productivity of pulses and oilseed crops is mainly because of area under rainfed conditions.

Studies on soybean seed yield response to water supply during specific developmental stages indicated that reproductive development is more sensitive to water deficit than vegetative growth. Similarly the cultivars differ in their response to moisture stress.

Water stress during flowering and pod filling stages reduced the number of pods per plant, seeds per pod and individual seed weight in soybean (Sammons *et al,* 1980; Bartels and Caeser, 1987 and Khodambashi *et al,* 1988).

Water stress at flowering and pod filling stage reduced the number of pods per plant, seeds per pod and 100 seed weight than stress at vegetative stage. (Kpoghomov, 1990 and Sapra and Beyl, 1990).

Water stress at beginning of seed stage caused significant reduction in number of pod bearing nodes on the main stem (13 %), number of pods (18 %), number of seeds (20 %), total seed weight (25 %) and total dry matter (23 %) indicating the importance of this stage (Feroud *et al,* 1993).

There is a vast scope to undertake the soybean cultivation under limited irrigation condition to boost the production in the state. But the research carried on **water stress** of soybean is very meagre in state. Little information is available which describes the effect of **water stress** at different stages of growth with presently cultivated soybeans in Marathwada region. It was therefore felt necessary to take up present field research trial.

The aim of present study was to evaluate the effect of water stress on six soybean genotypes (1) MAUS-33 (2) MAUS-32 (3) MAUS-34 (4) MAUS-2 (5) MAUS-31 (6) PK-472 (check) at critical growth stage of flowering to pod formation stage during *kharif* season 1996.

The broad objectives were

1) To study physiological variation in growth and yield of soybean verieties under water stress.

2) To study variation in physio-chemical parameters of soybean varieties under water stress.

3) To identify suitable variety of soybean for drought tolerance.

Review of Literature

CHAPTER - 2

REVIEW OF LITERATURE

The research work carried out in the past on the topic relevant to present study is summarised in this chapter under appropriate headings.

2.1 Water requirement of soybean

Teodoriu (1977) reported that 2000-2500 m^3 water per hectare during normal years and 2500-3000 m^3 per hectare during dry years was required for normal cultivation of soybean.

Water requirement for maximum production of soybean vary between 450 to 700 mm per season depending on climate and length of growing period (Doorenbos and Kassam, 1979).

Eck *et al.* (1987) reported that seasonal water use of soybean varies from year to year and it ranged between 685 to 813 mm.

Ramesh and Gopalswamy (1990) found that the total water requirement of soybean varies from 350 to 315 mm during the growing season.

2.2 Effect of soil moisture depletion on soybean

Number of studies have shown that soybean is least sensitive to water deficits during vegetative stage more sensitive during pod fill stage (Shaw and Laing, 1966; Shipley and Regier, 1970; Dusek *et al.*, 1971; Doss *et al.*, 1974; Soinit and Kramer, 1977; Constable and Hearn, 1980 and Korte *et al.*, 1983).

Dusek *et al,* (1971) found that soybean growth and yield were maintained at optimum by irrigating when soil moisture in 0.6 M soil depth was depleted to 40 per cent available, but were substantially reduced when it was depleted to 20 per cent available. However, Constable and Hearn (1980), concluded that available soil water could be depleted below 60 per cent during the vegetative stage, but it should be maintained above 60 per cent during pod fill stage.

Doorenbos and Kassam (1979) reported that for normal yield of soybean, soil moisture depletion during pod fill and pod development stage should not exceed 50 per cent availability.

Shahidullah and Islam (1983) and Stegman *et al,* (1990) have also reported that the potential yields of soybean are most likely to occur when irrigations are applied before root zone available water is depleted to 40-50 per cent.

Aldazabal *et al,* (1987) observed that plant growth was most affected by differences in soil moisture during flowering and pod development. In general soil at 65 per cent or 85 per cent field capacity (FC) resulted in better plant growth with best seed yields obtained at 85 per cent FC.

Kpoghomov *et al,* (1990) subjected three cultivators of soybean viz., Lee-74 Wright (drought tolerant) and Ra-401 (drought susceptible) to soil water levels of 100, 75 and 50 per cent of FC on silky loam soils during vegetative, flowering and pod filling stages. They found that water stress at flowering significantly reduced yield but water stress at pod filling caused greatest seed yield reductions while water stress at vegetative phase reduced the number of pods per plant, seeds per pod and 100 seed weight than water stress at flowering and pod filling stages.

Zhang (1991) reported that optimum soil water content for seeding, branching, flowering and pod setting and pod filling stages were 70, 80, 80 and 70 per cent of the soil water holding capacity.

2.3 Effect of water stress on growth parameters

Limited soil moisture in the root zone influences plant height (Momen *et al*, 1970).

Mayaki *et al*, (1976) found significant response of irrigation to increased seasonal average growth rates, leaf area index and total dry matter accumulation at physiological maturity compared to non-irrigated control.

Silvius (1977) reported that water stress reduced the weight of all plant parts except that of the stems and petioles of pod filling plants.

Ashley and Ethridge (1978), Doorenbos and Kassam (1979) reported that water applied prior to blooming greatly increased vegetative dry weight and number as well as dry weight of pods. Total dry matter accumulation at physiological maturity was significantly higher in irrigated soybean compared to non irrigated soybean compared to non irrigated control. Irrigation increased leaf, stem and root dry weight per plant by 49.7, 39.2 and 36.5 per cent respectively (Wang *et al*. 1981).

Ravindranath and Shivraj, (1983) observed that water stress decreased LAI, CGR, NAR and grain yield in sorghum. Detrimental effects of water stress seems, to be due to

1) Impairing sink (reduction in grains/Panicle).

2) Poor grain development (reduced test weight).

Hong *et al*, (1985) reported reduction in test weight in soybeans and groundnuts when it was grown under water stress conditions.

Eck *et al*, (1987) found that early season stress reduced plant height. Stress from early flowering to full bloom reduced the plant height by 11 per cent and LAI by 5.5 per cent while stress from early flowering to beginning of pod development reduced the plant height by 27 per cent and LAI by 3.5 per cent.

Application of irrigation increased the plant height and lodging significantly compared to unirrigated check (Spencht *et al*, 1989).

Dhopte *et al*, (1992) reported that the water stress reduced test weight significantly by 13.5 % in peanut at pod development stage (75 DAS).

Sorte *et al*, (1993) reported in paddy that harvest index was significantly affected with water stress at all the stages. A reduction was noticed by 17, 11 and 19 per cent at 30,50 and 70 DAS respectively.

Feroud et al, (1993) reported that water stress at beginning of seed stage caused significant reduction (7 per cent) in plant height.

2.4 Effect of water stress on yield attributes of soybean

Shaw and Laing (1966) observed maximum reduction in number of pods per plant, seeds per plant and mean weight per seeds when the water stress coincides with flowering, pod development and seed enlargement stages respectively that non-stressed control. Decrease in number of pods per plant and reduction in seed size and weight was observed when soybean plants were subjected to stress during flowering and pod swelling stages (Dusek *et al,* 1970).

Sionit and Kramer (1977) reported that stress applied during pod formation and during pod filling resulted in greatest yield reductions due to greater reductions in number of pods, seeds and weight of seeds at harvest while stress applied during flower induction and flowering which cause production of fewer flowers, pods and seeds with abortion of some flowers.

Growth period most sensitive to water deficits are the flowering (25-35 days) and pod development and pod filling periods (30-40 days) particularly the late flowering and pod development period which may cause heavy flower and pod dropping (Doorenbos and Kassam, 1979 and Puech and Bouniols, 1986).

Dry matter production and seed yield of soybean are directly depending on availability of water during critical reproductive stages (Hunt *et al,* 1986).

Eck *et al,* (1987) reported that stress initiated during early flowering or full bloom and extending to beginning of pod development reduced seed yields by 9-13 per cent but when stress was extended to 3 weeks after full yields were reduced by 46 per cent. Water stress beginning at early pod development and continued there after for about 9 days reduced yields by 19 per cent while imposed at early seed development and relieved at full seed development reduced yields by 15 per cent in one year and 46 per cent in more stressful year.

Bartels and Caeser (1987) reported that two weeks drought reduced seed yield by an average of 18 per cent while drought during seed filling reduced the seed yield by 25 per cent.

Kpoghmov (1990) reported that stress at flowering and pod filling stage reduced the number of pods per plant, seeds per pod and 100 seed weight than stress at vegetative stage. Similar results were obtained by Sapra and Beyl (1990).

Feroud *et al,* (1993) found that water stress at beginning of seed stage caused significant reduction in number of pod bearing nodes on the main stem (13 per cent), number of pods (18 per cent), number of seeds (20 per cent), total seed weight (25 per cent) and total dry matter (23 per cent) indicating the importance of this stage.

Thus the studies reviewed earlier clearly emphasised the importance of optimum moisture availability during flowering, pod set and pod filling stages of reproductive development.

2.5 Effect of Irrigation on yield attributes of soybean

Ashley and Ethride, (1978) reported that water applied prior to blooming greatly increased vegetative dry weight and number as well as dry weight of pods. Beginning irrigation during reproductive stage had little effect on vegetative dry weight but usually resulted in greater number of pods late in the season than the unirrigated check.

Berengene and Roldan, (1979) found that application of irrigation increased dry matter yield, seed yield, 100 seed weight and number of pods per plant over unirrigated control.

Korte *et al,* (1983) found that irrigation at flowering increased number of seeds per plant and number of pods per plant. While irrigation at seed enlargement greatly increased 100 seed weight. This states that irrigation at early reproductive stage greatly reduced flower and pod abortion and increased weight of pods and seeds per plant where as irrigation at later reproductive stages reduced ovule abortion within developing pods.

Boquet and Letlaw, (1984) reported that irrigation increased seeds per plant and seed weight with increased in seed yield.

2.6 Effect of irrigation on yield of soybean

Irrigation levels increased grain yield significantly over unirrigated control (Cassel *et al,* 1978).

Doss *et al,* (1974) observed more response from irrigation water applied after full flowering than when applied earlier. To obtain maximum soybean yields (late) pod fill stage was found most critical for adequate moisture.

Ashley and Ethridge, (1978) reported that full season bloom stage and pod fill stage irrigation treatments produced greater yields than unirrigated during the vegetative growth period is of less importance than during flowering pod set and pod fill stages. However irrigation at flowering was as important as that during later reproductive development.

Heatherly (1983) found that application of irrigation to soybean at pod filling stage significantly increased the grain yield. While Shahidullah and Islam (1983) found that flowering is the most critical stage in soybean for scheduling irrigation.

Korte *et al,* (1983) found that irrigation at flowering had essentially no effect on seed yields, where as a single irrigation at pod elongation are at seed enlargement significantly enhanced seed yield relative to the non-irrigated check. The flowering and pod elongation irrigation treatment increased seed yield above that of both the non-irrigated check and single flowering irrigation but the yield response of flowering and pod elongation irrigation treatment was significantly less than that for a single pod filling or pod elongation irrigation.

Schulze, (1990) obtained maximum seed yield with irrigation at flowering + pod filling without irrigation during vegetative phase.

The studies reviewed earlier clearly emphasised that the irrigation application at vegetative growth enhance vegetative growth but had little effect on yield than applied during reproductive stages.

2.7 Effect of water stress on biochemical parameters

Stewart *et al,* (1966) reported that there is a direct relation ship between proline accumulation and growth rate following upon a period of water stress as it has been suggested that proline may be the major source of energy and nitrogen during immediate post stress metabolism.

Bates *et al,* (1973) reported that proline which increases proportionately faster than other amino acids in plant under water stress has been suggested as an evaluating parameter for irrigation scheduling and for selecting drought resistant varieties. The frequency to analyse numerous samples from multiple replications of field grown materials prompted to development of a single rapid calorimetric determination of proline. The method detected proline in the range of 0.12 to 36 m moles/g of fresh leaf materials.

Ford and Wilson, (1981) suggested that the ability of plants to adjust osmotically through accumulation of potassium, sugars, proline, glycene, betaine and other solutes has been a significant drought resistant mechanism. Species differ in their types of osmoregulatory solutes accumulated in them. It has been reported that accumulation of these osmoregulatory substances can be used as indicators in the selection of species/cultivars for their drought tolerance.

Chopra and Mukhopadhya (1991) reported that the high values of relative water content and osmotic potential were of great significance for drought tolerance on the contrary, low values of chlorophyll stability index and transpiration rate were useful for stress conditions.

Sarkar (1993) reported that proline accumulation is one to the major changes in the nitrogen metabolism of water stressed plants. The relation between nitrate reductase and proline accumulation was examined, Nitrate reductase stability under water stress show significant negative association with proline accumulation during stress ($r = -0.77$). Proline accumulation is symptom of injury. Because the plants which accumulated more proline were less efficient in utilising nitrogen on subsequent relief. From water stress Relationship between proline accumulation and chlorophyll stability was also negative ($r = -0.65$).

Sorte *et al,* (1993) reported that in paddy water stress reduced total root length by 18 to 88 per cent and chlorophyll content in leaves by 10 to 17 per cent. Five days water stress given to plants in stressed plants and control (without water stress) in pots. Then both stressed and control soil sampled for soil moisture content. Soil moisture content ranged from 20.30 to 26.32 per cent in control and 6.98 to 8.05 per cent in stressed plants. The leaf relative water content was recorded from 58.35 to 63.38 per cent in control and 39.64 to 43.20 per cent in stressed plants. It indicated that plants have experienced stress from -15 to -32 bars at various growth stages.

Raja Rajeswari (1995) reported that in cotton relative water content and chlorophyll stability index were associated with drought tolerance in cotton. The positive and significant correlation of days to flowering with chlorophyll stability index reveals that long duration types are highly unstable for drought.

Ramamoorthy and Radha (1995) reported that in soybean cultivar co-1 withholding water at any of the growth phases not exceeding a fortnight did not have any impact on seed yield. This result in a saving of 50 mm water.

Material and Methods

CHAPTER - 3

MATERIAL AND METHODS

Details of the material used and methods adopted for conducting the present investigation are given in this chapter.

3.1 Experimental site and soil

The experiment was conducted in the field of Dryland Agricultural Research Centre, Marathwada Agricultural University, Parbhani during *kharif* season of 1996.

The soil was medium black with moderate moisture retention capacity. The land having uniform topography was used to study, "The effect of water stress on growth and yield of soybean (*Glycine max* (L.) *Merrill*)."

In field 36 plots of gross size 2.1 x 1.5 m and net size 2.0 x 1.2 m are designated. Eighteen plots with 6 varieties in 3 replications with FRBD design randomly sown each in control (natural) and Test House (water stress).

Test House is made up of wooden poles height upto 12 feet from ground level. Water stress is given from flowering to pod formation. In test house prior to flowering before a week one meter length, thick polythene paper (cover) is burried straight one meter deep across all four sides of test house. To upper side of the test house from all sides completely covered by polythene cover. The burried polythene in ground prevents seepage of water from outside the test house and rain water is not allowed from upper side covered by polythene this is ideal conditions for water stress to crop physically. During the rains off upper cover is relieved for aeration and sunlight for the crop, then for accuracy it is really water stress to soybean crop soil moisture tests are taken prior to stress and after water stress given to test house.

3.2 Climate and Weather

Parbhani is situated at north latitude of 19°,16', east longitude of 70°,47' latitude of 930 m above mean sea level and has sub-tropical climate.

The rainfall (mm), mean, maximum and minimum temperature (°C) and humidity in percentage per week during the period of the present investigations are given in Table -1.

Table : Data recorded at department of Agricultural Meteorology, M.A.U. Parbhani for the experimental crop *kharif* season (1996).

3.3 Experimental details

3.3.1 Details of layout

Design : **Factorial Randomised Block design**

Replications : Three (3)

Treatments : Two (1) control (2) water stress

verities

1) MAUS-33

2) MAUS-32

Table 1 : Data recorded at department of Agricultural Meteorology, M.A.U., Parbhani for the experimental crop season (1996).

Met Week No.	Month	Temperature°C		Humidity'		Rainfall (mm)	Evaporation (mm)	Bright sunshine hrs/day	Wind velocity Km / hr
		Max.	Min	AM	PM				
1996									
23	June	41.0	27.1	50	23	15.6	12.6	11.3	08.4
24		36.6	24.3	67	35	25.2	08.0	09.5	06.3
25		36.0	25.0	66	34	00.00	11.5	10.3	14.1
26	July	36.3	24.6	59	32	00.0	13.3	11.0	13.2
27		33.8	23.4	78	48	50.0	07.4	05.0	07.5
28		33.0	23.1	86	50	63.3	05.8	06.8	05.4
29		32.0	23.5	80	54	16.0	05.3	05.4	08.1
30		29.5	23.2	81	61	06.0	04.6	02.1	12.1
31	Aug	30.8	22.4	82	55	22.6	04.5	03.7	08.4
32		29.2	21.8	82	60	20.7	04.1	03.0	08.0
33		31.1	22.0	84	58	87.6	04.7	05.0	05.6
34		29.6	22.2	90	70	66.4	03.1	04.3	03.9
35	Sep	28.9	21.8	91	67	76.4	03.7	04.9	06.9
36		30.1	22.0	90	66	102.8	03.8	05.0	03.0
37		31.1	22.2	91	63	136.5	03.6	07.2	03.5
38		30.5	20.8	89	54	73.4	04.7	08.8	05.0
39		32.7	21.8	87	52	23.6	04.6	08.7	04.0
40	Oct	29.7	22.2	91	65	113.2	03.7	05.8	05.7
41		31.5	16.3	76	41	00.0	06.7	10.3	03.2
42		31.2	16.5	76	44	06.1	05.6	08.4	04.6
43		29.6	21.4	88	68	55.4	03.0	06.8	03.6
44	Nov	30.7	14.5	82	27	22.2	04.2	10.2	02.7
Total						**992.8**			

Data from Table1 indicated that the total precipitation during *kharif* 1996 was 992.8 mm

3) MAUS-34

4) MAUS-2

5) MAUS-31

6) PK-472 (check)

Plot size : Gross : 2.1 x 1.5 m

Net : 2.0 x 1.2 m

Spacing row to row : 30 cm

Plant to plant : 5 cm

Fertiliser : 30 : 60 : 30 (Kg/ha)

Date of sowing : 10th Jully, 1996

The plan of layout is presented in Fig 1.

3.4 Seed and treatments

The certified seeds of soybean varieties : (1) MAUS-33 (2) MAUS-32 (3) MAUS-34 (4) MAUS-2 (5) MAUS-31 (6) PK-472 (check) was obtained from Soybean Research Station, Marathwada Agriculture University, Parbhani.

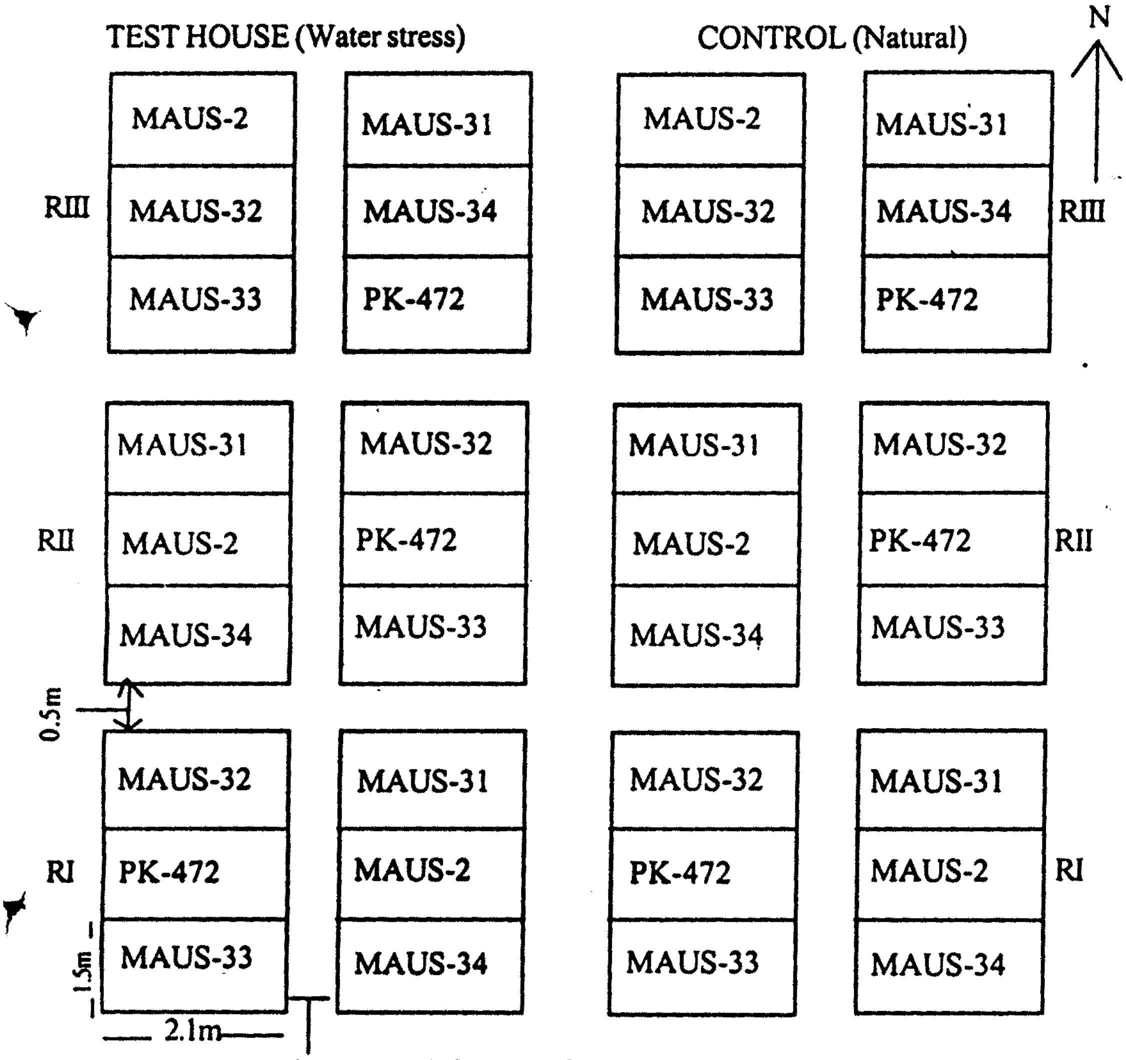
3.5 Layout

The plan of layout adopted is given in fig-1. Each experimental treatment (plot) had gross plot size of 2.1 m x 1.50 m and net plot size of 2.00 m x 1.20 m. The row to row spacing was 30 cm and plant to plant was 5 cm.

3.6 Preparatory tillage

The land was ploughed upto 30 cm deep with tractor plough, then subsequent harrowings were carried out for making soil loose, friable to prepare fine seed bed.

Fig:1



PLAN OF LAYOUT

DESIGN : FACTORIAL RANDOMIZED BLOCK DESIGN

Design	:	FRBD		
Replication	:	Three		
Treatment	:	Two		
Plot size	:	Gross :	2.1 x 1.5m	
		Net :	2.0 x 1.2m	
Spacing	:	30x5cm		
sowing date	:	10th Jully 1996		
		N : P : K		
Fertilizer	:	30 : 60 : 30 kg/ha		

Varieties :
1) MAUS-33
2) MAUS-32
3) MAUS-34
4) MAUS-2
5) MAUS-31
6) PK 472 (check)

3.7 Sowing and thinning

The sowing was done by dibbling method in field on July 10, 1996. Two seeds per hill were dibbled. Emergence count was taken after 10 days from sowing. Plant population of crop was maintained through gap filling. The thinning was done 15 days after sowing and finally one healthy plant was allowed to grow at each hill.

3.8 Fertiliser application

The nitrogen phosphorous and potash were applied at the rate of 30, 60 and 30 kg/ha respectively. Full dose of nitrogen phosphorous and potash was given at the time of sowing.

3.9 Plant Protection measures

Two sprays of Nuvocron (Monocrotophos). First spray 15 days after sowing and second spray after 25 days after sowing.

3.10 Inter cultural operations.

Weedings and hoeings were done as and when required.

3.11 Harvesting and threshing

The soybean crop was matured in 105 to 110 days. The net and gross plot strips of each plot were harvested, threshed, winnowed and cleaned separately. The produce was sundried.

3.12 Biometrics observations

Five plants in each plot in control and Test House were randomly selected for recording all the periodical biometric observations at on interval of 15 days during the growth and development of soybean. The various parameters of observations are indicated below.

3.12.1 Height of the plant

Height of the plant was measured in centimetre from the base of the shoot to the base of last opened leaf.

3.12.2 Number of leaves

The total number of trifoliate green leaves per plant were counted and recorded.

3.12.3 Leaf area per plant

Leaf area was calculated by using the plant samples taken for dry matter accumulation studies from each net plot. The leaves were grouped in three groups viz. small, medium and big. The number of leaves in different categories were counted and leaf area per plant was worked out. The leaf area was calculated as suggested by Watson (1952) and expressed in dm^2

$$A = L \times B \times K \times N$$

Where,

A = Leaf area in dm^2 under particular group

L = Length of leaf (cm)

B = Maximum breadth of leaf (cm)

K = Leaf area constant for soybean # (0.68869)

N = Number of leaves under particular group

3.12.4 Total dry matter accumulation per plant

Five plants from each plot were selected randomly at every stage of observation. The selected plants were uprooted and aerial part was air dried first and then dried in hot air oven at 86° C until the constant weight was obtained.

3.12.5 Leaf and stem dry matter

From above plant sample matter leaf and stem dry matter taken seperately and calculated.

3.12.5.1 Growth analysis

The data on growth characters viz. plant height, leaf area and dry matter per plant of soybean were further analysed to work out relative growth rate (RGR), net assimilation rate (NAR), leaf area index (LAI), crop growth rate (CGR) and harvest index (HI).

3.12.5.2 Relative growth rate (RGR)

Relative growth rate is the increase in plant material per unit of time. It was calculated as per formula given by Fisher (1921) and expressed in g/g /day.

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where,

W_1 = Weight of dry matter at time t_1

W_2 = Weight of dry matter at time t_2

t_1 = Initial time of observation.

t_2 = Final time of observation.

Log_e = Napier logarithm (Logarithm to the base of 2.3026)

3.12.5.4 Leaf area index (LAI)

It is the ratio of leaf area per plant to land area expressed in percentage. The leaf area index was worked by using the formula given by Watson (1947).

$$LAI = \frac{\text{Leaf area per plant } (dm^2)}{\text{Land area per plant } (dm^2)}$$

3.12.5.4 Net Assimilation rate (NAR)

As increase in dry matter per unit increase in leaf area per unit time. It is expressed in $g/dm^2/day$, the concept of NAR on the basis of leaf area was introduced by Gregory (1926).

$$NAR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\text{Loge } A_2 - \text{Loge } A_1)}{(A_2 - A_1)}$$

Where,

W_1 = Total dry weight of plant in g at time t_1

W_2 = Total dry weight of plant in g at time t_2

A_1 = Leaf area per plant at time t_1

A_2 = Leaf area per plant at time t_2

t_1 = Initial time of observation.

t_2 = Final time of observation.

3.12.5.5 Crop growth rate (CGR)

Crop growth rate (CGR) is the absolute growth rate per unit area ground and expressed as $g/m^2/week$.

This was worked out by adopting the formula developed by Watson (1958).

CGR = NAR x LAI

Where,

1) NAR = Net assimilation rate

2) LAI = Leaf area index.

3.13 Post Harvest Studies

3.13.1 Number of pods per plant

The number of developed pods from two observation plant were counted and average per plant was worked out.

3.13.2 Hundred seed weight

Weight of 100 seeds in grams was recorded from the produce of each plot in control and Test House.

3.13.3 Seed yield per hectare

According to plot size and spacing of plant area occupied by total plots and net seed yield per net plot on these basis yield per hectare was calculated and expressed in kg/hactare.

3.13.4 Biological yield per plot

Biological yield per plot was recorded by taking the weight of grain and straw together.

3.13.5 Harvest index (HI)

Harvest index indicated the yielding efficiency of a crop to produce grain yield per unit of total biological yield. Harvest index in different treatments was worked out by the formula given by Donald and Hamblin (1976).

$$HI\ (\%) = \frac{\text{Economic or grain yield (Kg/hactare)}}{\text{Biological yield (Kg/hactare)}} \times 100$$

3.14 Chemical Analysis

The samples of leaves at 70 days after sowing from the field were used for chemical analysis.

3.14.1 Nitrogen percentage in leaves

Micro Kjeldhal's method (A.O.A.C. 1965) was adopted for determining the nitrogen in the leaves and it is expressed in percentage.

$$\text{Percentage of nitrogen} = \frac{\text{ml of HCl} \times \text{normality of std.acid} \times 0.0014}{\text{Weight of sample (g)}} \times 100$$

3.14.2 Soil moisture percentage

Soil moisture percentage at 0 to 60 cm depth was determined by dry weight basis at 45, 60 and 75 days after sowing as per the gravimetric method.

Soil moisture percentage was calculated by

$$\text{Soil moisture \%} = \frac{(W_1 - W_2)}{W_2} \times 100$$

Where,

W_1 = Fresh weight of soil sample

W_2 = Dry weight of soil sample

3.14.3 Water use

Water use calculated by formula given by Kadam *et al*, (1978) and by Jana *et al*, (1983).

3.14.4 Proline accumulation in leaves

Proline content of 70 day old leaves was determined as per Bates *et al* , (1973). The outline of procedure was given below.

500 mg of leaf material was taken and homogenised with mortar and pestle with 3 per cent of sulpha salicilic acid and filtered two ml of above extract was taken in test tube to which 2 ml of Ninhydrine reagent was added along with 2 ml of glacial acetic acid. Above mixture was heated in water bath at 100 ^{0} C for 1 hour. Same reaction mixture was shaked with 4 ml toluene. Coloured organic mixture was shaked with 4 ml toluene. Coloured organic phase was separated from aqueous phase. After the room temperature was attained the optical density (OD) of organic phase was recorded at 520 nm using toluene as a blank. Calibration curve prepared with graded concentrations of proline was used to estimated proline of unknown solutions using this graph.

The proline accumulation content was calculated by using following formula.

$$\text{mg of proline/g of fresh weight} = \text{GR} \times \frac{\text{Volume made from extraction}}{\text{Volume taken for estimation}} \times \frac{1}{\text{Weight of Sample}}$$

3.14.5 Total chlorophyll content in leaf

The total chlorophyll content of grinded leaf sample was estimated at 70 days after sowing following colorimetric methods of analysis (Arnon, 1949).

$$\text{Total Chlorophyll (mg/g)} = \frac{\text{OD 652 nm} \times 1000}{34.5} \times \frac{\text{V.}}{1000 \times \text{W}}$$

OD	=	Optical density
V	=	final volume of 80 per cent acetone (50 m).
W	=	Fresh weight of sample taken (2.5 g).

3.14.6 Chlorophyll stability index (CSI)

Two clean glass tubes were taken and 2.5 g of leaf sample of each treatment was placed with 25 ml of distilled water. One tube of each treatment was then subjected to heat in water bath at 56°C ± 1°C for exactly 30 min. Other tubes were kept as a control. The leaves were then ground in a mortar for five min. with 100 ml of 80 % acetone. The slurry was then filtered with Whatman No. 1 filter paper. This chlorophyll extract was further examined immediately for light absorption with photoelectric colorimeter using red filter. A parallel leaf sample of 2.5 g in another tube was then estimated for chlorophyll content without heating simulteneously and ligh absorption is measured with colorimeters.

The difference in two readings (reading before heat treatment and reading after heat treatment 56°C) is defined as chlorophyll stability index (CSI). This CSI was found to be correlated with drought tolerance.

CSI=Chlorophyll content of control sample-Chlorophyll content of treated sample.

3.15 Statistical analysis

Data obtained on various variables were analysed statistically following the standard analytical methods by Panse and Sukhatme (1976).

Experimental Findings

CHAPTER 4

EXPERIMENTAL FINDINGS

The experimental findings, data, statistical parameters and results of the investigations are presented in this chapter under following sub-heads.

4. Growth studies

4.1.1. Plant height

Data on mean height of plant as influenced by treatments at different stages of crop growth are presented in Table 2.

The data in Table 2 revealed that mean plant height of plant increased continuously upto maturity and reached to its maximum at the time of harvest. The rate of increase in plant height was fast during 30 to 60 days and reduced during 60 to 90 days and then nearly constant upto maturity. Plant height in natural environment is superior over water stress except the 60 days after sowing.

There was significant differences among varieties. Variety MAUS-31 recorded highest plant height at 30, 45, 60, 75, and 90 days of the crop growth. MAUS-33, MAUS-32,MAUS-34 and MAUS-2 recorded more plant height than the PK-472. MAUS-31, was superior over MAUS-34, MAUS-31, and PK-472 in plant height at 30, 45, 60, 75 and 90 days. Interaction effect were nonsignificant.

Table 2 Mean height of plant (cm) at various growth stages of soybean under water stress and control (natural) environment

Treatments	Days after sowing				
	30	45	60	75	90
I) Environment					
1 Water stress	22.83	35.35	41.42	48.23	51.42
2 Control (natural)	23.73	36.35	42.55	50.23	53.51
S E ±	0.23	0.43	0.51	0.36	0.62
C D at 5%	0.84	1.28	NS	1.07	1.89
II) Varieties					
1 MAUS-33	23.36	28.25	38.96	45.82	48.21
2 MAUS-32	25.92	42.97	48.73	57.52	60.71
3 MAUS-34	19.41	32.74	37.01	42.77	45.57
4 MAUS-2	27.32	42.27	49.71	56.97	61.00
5 MAUS-31	28.00	45.96	50.75	59.83	63.41
6 PK-472 (check)	15.69	22.91	26.72	32.53	35.91
S E ±	0.50	0.76	0.88	0.63	1.08
C D at 5%	1.66	2.39	2.68	1.93	3.29
Interaction					
ExV					
S E±	0.70	1.07	1.25	0.89	1.53
C D at 5%	NS	NS	NS	NS	NS
Grand Mean	23.28	35.85	41.98	49.23	52.46

4.1.2 Number of functional leaves per plant

Data on mean number of functional leaves per plant as influenced by water stress and natural environment at different stages of crop growth are presented in Table-3.

Data presented in Table -3 revealed that leaf number increased slowly upto 45 days and at faster rate upto 60 days and there after it declined. However , maximum number of leaves were observed at 75 days after sowing . At maturity there were no leaves mainly due to senescence. There were no significant differences at 30 and 45 days in water stress and natural in number of leaves. At 60,75 and 90 natural environment was significantly superior over the water stress in number of leaves per plant. Variety MAUS-33 recorded significantly superior over the MAUS-32, MAUS-31, MAUS-34, MAUS-2 and PK-472 at all stages 30,45,60,75 and 90 days in number of leaves per plant.

Variety PK-472 recorded lowest number of leaves per plant at 45,60,75 and 90 days after sowing. Varieties MAUS-32, MAUS-34, MAUS-2 and MAUS-31 were found at par at all growth stages 30,45,60,75 and 90 days after sowing. Interaction effects were nonsignificant.

4.1.3. Leaf area per plant

Data on mean leaf area per plant as influenced by treatments at different stages of crop growth are presented in Table-4

The data in Table-4 revealed that mean leaf area per plant progressively increased upto 75 days after sowing and declined there after. The maximum mean leaf area was observed at 75 days after sowing.. The rate of increase in

Table 3 Functional leaves per plant at various growth stages of soybean under water stress and control (natural) environment

Treatments	Days after sowing				
	30	45	60	75	90
I) Environment					
1 Water Stress	6.80	10.61	17.69	20.73	18.57
2 Control (natural)	6.94	10.91	18.91	22.75	20.54
S E ±	0.29	0.26	0.23	0.42	0.29
C D at 5%	N S	N S	0.70	1.33	0.96
II) Varieties					
1 MA US-33	7.80	12.12	20.29	25.58	22.78
2 MAUS-32	7.22	11.10	18.42	22.87	20.62
3 MAUS-34	6.76	10.62	18.62	21.12	19.00
4 MAUS-2	6.74	10.50	17.87	21.25	18.87
5 MAUS-31	7.00	10.37	17.50	20.12	18.23
6 PK-472 (Check)	5.75	9.62	17.15	19.51	17.82
S E ±	0.32	0.46	0.41	0.73	0.51
C D at 5%	0.96	1.45	1.31	2.41	1.64
Interaction					
E x V					
S E ±	0.47	0.66	0.59	0.10	0.72
C D at 5%	N S	N S	N S	N S	N S
Grand mean	6.87	10.72	18.30	21.74	19.55

Table 4 Mean leaf area (cm^2) per plant at various growth stages of soybean under water stress and control (natural) environment

Treatments	Days after sowing				
	30	45	60	75	90
I) Environment					
1 Water stress	599	749	1271	1511	1313
2 Control (natural)	602	757	1372	1674	1495
SE ±	10.19	10.52	23.70	26.04	17.90
C D at 5%	NS	NS	72.13	79.14	54.23
II) Varieties					
1 MAUS-33	645	858	1548	1868	1695
2 MAUS-32	625	773	1353	1681	1513
3 MAUS-34	602	753	1299	1546	1352
4 MAUS-2	589	755	1261	1548	1344
5 MAUS-31	627	702	1238	1493	1282
6 PK-472 (check)	517	677	1230	1421	1241
S E ±	17.65	18.30	41.06	45.10	31.01
C D at 5%	53.95	56.40	133.26	149.08	93.21
Ineraction					
ExV					
S E ±	24.97	25.79	58.07	63.78	43.86
C D at 5%	NS	NS	NS	NS	NS
Grand mean	600	753	1321	1592	1404

mean leaf area was very fast during 45 to 60 days after sowing and fast during 30-45 days after sowing.

There were no significant differences at 30 and 45 days after sowing in water stress and control (natural) environment . There were significantly superior leaf area per plant at 60, 75 and 90 days after sowing in control (natural) over water stress.

Variety MAUS-33 was significantly superior over MAUS-32 MAUS-34 MAUS-2, MAUS-31 and PK-472 (check) at all stages 30, 45, 75 and 90 days after sowing. But found at par with MAUS-32 and MAUS-34 at 30 days after sowing varities MAUS-32, MAUS-34, MAUS-31, MAUS-2 and PK-472 was at per 45, 60 and 75 days after sowing .

4.1.4 Leaf dry matter

Data on mean leaf dry matter accumulation (g) per plant as influenced by the water stress and control (natural) are presented in Table-5.

Data in Table -5 indicated that mean leaf dry matter accumulation per plant increased progressively from sowing upto 90 days of crop. At harvest the leaf dry matter was negligible due to senescence of leaves.

Effect of water stress and control (natural) environment was significant at 75 and 90 days after sowing control (natural) environment significantly superior over the water stress. The difference between control (natural) environment and water stress was nonsignificant at 30, 45 and 60 days after sowing in leaf dry matter accumulation per plant.

Table 5 **Mean leaf dry matter (g) per plant at various growth stages of soybean under water stress and control (natural)enviroment**

Treatments	Days after sowing				
	30	45	60	75	90
I) Environment					
1 Water Stress	1.27	2.75	4.87	5.55	4.08
2 Control (natural)	131	2.77	4.95	6.47	5.16
SE ±	0.06	0.11	0.15	0.14	0.18
C D at 5%	NS	NS	NS	0.45	0.55
II) Varieties					
1 MAUS-33	1.79	3.92	6.36	7.32	5.06
2 MAUS-32	1.25	2.78	5.06	6.18	4.74
3 MAUS-34	1.20	2.38	4.84	5.94	4.75
4 MAUS-2	1.07	2.18	4.14	5.56	4.52
5 MAUS-31	1.40	2.71	5.03	5.81	4.70
6 PK-472 (check)	1.07	2.60	4.07	5.26	3.95
S E ±	0.10	0.21	0.27	0.26	0.32
C D at 5%	0.31	0.85	0.80	0.85	0.99
Interaction					
ExV					
S E ±	0.14	0.29	0.38	0.36	0.45
C D at 5%	NS	NS	NS	NS	NS
Grand mean	1.29	2.76	4.91	6.01	4.62

Variety MAUS-33 was significantly superior over all varieties at all stages except 90 DAS in leaf dry matter accumulation per plant. Variety PK-472 (check) was recorded lowest value of the leaf dry matter accumulation per plant at all stages. Variety MAUS-32, MAUS-31, MAUS-2, MAUS-34 and PK-472 were at par at 30 and 45 days after sowing in leaf dry matter accumulation per plant. Variety MAUS-32, MAUS-34 and MAUS-31 were at per at 60 days after sowing in leaf dry matter accumulation par plant. Variety MAUS-32 and MAUS-2 were at par at 75 days after sowing in leaf dry matter accumulation per plant. Interaction effect were found non-significant.

4.1.5 Stem dry matter

Data on mean stem dry matter accumulation per plant as influenced by water stress and control (natural) environment at different stages of crop growth are presented in Table-6.

Data presented in Table-6 indicated that mean stem dry matter accumulation per plant increased progressively from sowing upto 90 days of crop. At harvest the stem dry matter was extremely more as compared to leaf dry matter due to leaves senes cence .

There were significant differences in control (natural) and water stress at 60, 75 and 90 days after sowing in stem dry matte accumulation per plant. The control (natural) environment was significantly superior over water stress in stem dry matter accumulation per plant.

Variety MAUS-31 was superior over MAUS-33, MAUS-32, MAUS-2, MAUS-34 and PK-474 (check) at all growth stages 30, 45, 60, 75 and 90 days

Table 6 Mean stem dry matter (g) per plant at various growth stages of soybean under water stress and control (natural) environment

Treatments	Days after sowing				
	30	45	60	75	90
I) Environment					
1 Water stress	2.54	4.16	7.23	10.07	13:00
2 Control (natural)	2.40	4.24	7.69	10.79	15.10
SE ±	0.13	0.13	0.07	0.25	1.14
C D at 5%	NS	N S	0.22	0.79	NS
II) Varieties					
1 MAUS-33	2.95	4.19	7.42	10.58	15..09
2 MAUS-32	2.50	4.82	7.13	10.48	12.44
3 MAUS-34	2.12	3.63	7.39	10.05	13.38
4 MAUS-2	1.99	3.80	7.34	9.58	12.25
5 MAUS-31	3.37	5.52	9.13	12.37	18.27
6 PK-472 (check)	1.91	3.25	6.36	9.56	11.92
S E±	0.21	0.22	0.13	0.44	1.32
CD at 5%	0.69	0.68	0.38	1.37	3.98
Interaction					
ExV					
S E ±	0.33	0.32	0.18	0.62	2.80
C D at 5%	NS	NS	NS	NS	NS
Grand mean	2.47	4.20	7.46	10.43	14.05

Table 7 Mean total dry matter (g) per plant at various growth stages of soybean under water stress and control (natural) environment

Treatments	Days after sowing				
	30	45	60	75	90
I) Environment					
1 Water stress	3.79	6.9	11.57	15.62	17.08
2. Control (natural)	3.76	7.02	12.51	17.04	19.38
SE ±	0.13	0.21	0.24	0.16	0.26
C D at 5%	NS	NS	0.83	0.47	0.79
II) Varieties					
1 MAUS-33	4.74	8.02	13.78	17.90	20.15
2 MAUS-32	3.75	7.60	12.19	16.66	18.18
3 MAUS-34	3.32	6.01	10.23	15.99	18.30
4 MAUS-2	3.06	5.98	11.48	15.04	16.95
5 MAUS-31	4.77	8.23	14.16	18.18	22.97
6 PK-472 (check)	2.98	5.96	10.43	14.22	15.87
S E ±	0.23	0.38	0.42	0.27	0.45
C D at 5%	0.71	1.14	1.35	0.86	1.34
Interaction					
ExV					
S E ±	0.33	0.53	0.60	0.39	0.64
C D at 5%	NS	NS	NS	NS	NS
Grand mean	3.77	6.96	12.04	16.33	18.23

after sowing in stem dry matter accumulation per plant. Variety PK-472 was found lowest value of stem dry matter accumulation per plant at all stages 30, 45, 60, 75 and 90 days after sowing. Varieties MAUS-33, MAUS-32 were at par at 30 DAS and 60 DAS. Varieties MAUS-33, MAUS-34 and MAUS-2 were at par at 60 days after sowing. All varieties were at par except MAUS-31at 75 days after sowing in stem dry matter accumulation per plant. At 90 days variety MAUS-31 was found superior over all but at par with MAUS-33 in stem dry matter varieties accumulation per plant. Interaction effects were found nonsignificant.

4.1.6. Total dry matter accumulation per plant

Data on mean total dry matter accumulation per plant as influenced by water stress and control (natural) environment at different stages of crop growth are presented in Table-7

Mean total dry matter accumulation per plant increased progressively from sowing upto 90 days of crop. At harvest total dry matter accumulation per plant was slightly reduced due to senescence of leaves.

There were significant differences between water stress and control (natural) environment in total dry matter accumulation per plant at 60,75 and 90 days after sowing. Control (natural) environment was significantly superior over water stress at 60, 75 and 90 days after sowing while non-significant at 30 and 45 days after sowing in total dry matter accumulation per plant.

Variety MAUS-31 was significantly superior over MAUS-32, MAUS-34, MAUS-2, MAUS-31 and PK-472 (check) but at par with MAUS-33 in total dry

Table 8. Mean relative growth rate (g/g/day) of soybean under water stress and control (natural) environment.

Varieties	Days after sowing							
	31-45		46-60		61-75		75-90	
	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress
MAUS-33	0.046	0.044	0.039	0.035	0.023	0.019	0.010	0.007
MAUS-32	0.049	0.048	0.036	0.032	0.020	0.016	0.007	0.005
MAUS-34	0.045	0.044	0.035	0.033	0.019	0.014	0.006	0.004
MAUS-2	0.045	0.043	0.035	0.031	0.017	0.012	0.007	0.004
MAUS-31	0.046	0.047	0.038	0.034	0.030	0.024	0.012	0.009
PK-472 (check)	0.036	0.035	0.029	0.024	0.020	0.015	0.007	0.004
General mean	0.044	0.043	0.035	0.031	0.021	0.016	0.008	0.005

Table 9. Mean leaf area index at various growth stages of soybean under water water stress and control (natural) environment.

Varieties	Days after sowing									
	30		45		60		75		90	
	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress
MAUS-33	4.31	4.29	5.72	5.71	10.62	10.01	13.27	11.63	12.47	10.13
MAUS-32	4.16	4.15	5.15	5.13	9.49	8.53	11.68	10.72	11.15	9.01
MAUS-34	4.01	4.00	5.02	5.00	9.27	8.05	10.98	9.62	10.10	7.92
MAUS-2	3.92	3.90	5.03	5.01	8.89	7.91	10.82	9.82	10.18	7.74
MAUS-31	4.98	4.17	4.68	4.66	8.91	7.59	10.71	9.19	9.58	7.50
PK-472 (check)	3.45	3.43	4.51	4.49	8.88	7.52	10.19	8.75	9.34	7.20
General mean	4.06	3.99	5.01	5.00	9.34	8.26	11.27	9.95	10.47	8.25

matter accumulation per plant. Variety PK-472 (check) was recorded lowest value of the total dry matter accumulation per plant at all growth stages except 60 days after sowing. Varieties MAUS-32, MAUS-34, MAUS-2 and PK-472 (check) at par at 30 days after sowing. Variety MAUS-34, MAUS-2 and PK-472 (check) at par at 45 days after sowing. Varieties MAUS-32 and MAUS-34 were at par at 90 days after sowing in total dry matter accumulation per plant. Interaction effects were found nonsignificant.

4.2 Growth parameters

The data on growth parameters like relative growth rate, net assimilation rate, leaf area index, crop growth rate and harvest index were calculated.

4.2.1. Relative growth rate (RGR)

Data pertaining to RGR based on dry matter per plant in g/g/day was affected by the environmental treatments water stress and control (natural) are presented in Table-8.

In general during first 45 days from sowing RGR for dry matter increased steadily. Slight reduction in RGR was noticed during 46-60 days from sowing and there after decreasing trend was noticed till maturity.

During 31-45 days MAUS-32 recorded highest RGR for dry matter of (0.079 g/g/day) . The lowest value for RGR was found in PK-472 (0.036 g/g/day)

During 46-60 days the highest RGR for dry matter of (0.039 g/g/day) was recorded in MAUS- 33. Lowest RGR was found in PK-472 (0.029 g/g/day).

Table 10. Net assimilation rate (g/cm²/day) at various growth stages of soybean under water stress and control (natural) environment.

Varieties	Days after sowing							
	31-45		46-60		61-75		75-90	
	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress
MAUS-33	0.0039	0.0038	0.0140	0.0128	0.0032	0.0026	0.0019	0.0011
MAUS-32	0.0035	0.0034	0.0110	0.0101	0.0040	0.0033	0.0015	0.0009
MAUS-34	0.0025	0.0027	0.0100	0.0088	0.0040	0.0032	0.0013	0.0008
MAUS-2	0.0038	0.0037	0.0120	0.0110	0.0036	0.0029	0.0010	0.0005
MAUS-31	0.0034	0.0035	0.0139	0.0127	0.0031	0.0025	0.0037	0.0026
PK-472 (check)	0.0034	0.0033	0.0110	0.0100	0.0026	0.0020	0.0010	0.0004
General mean	0.0034	0.0034	0.0120	0.0109	0.0035	0.0027	0.0015	0.0010

Table 11. Mean crop growth rate (g/m²/week) of soybean under water stress and growth control (natural) environment.

Varieties	Days after sowing							
	31-45		46-60		61-75		75-90	
	Control	Water stress	Control	Water stress	Control	Water stress	Control	Water stress
MAUS-33	0.019	0.020	0.112	0.101	0.035	0.028	0.011	0.0006
MAUS-32	0.016	0.015	0.078	0.069	0.022	0.016	0.015	0.0009
MAUS-34	0.012	0.010	0.069	0.053	0.042	0.034	0.012	0.0007
MAUS-2	0.016	0.016	0.082	0.074	0.034	0.028	0.009	0.0004
MAUS-31	0.014	0.014	0.091	0.079	0.029	0.022	0.030	0.0021
PK-472 (check)	0.013	0.014	0.069	0.079	0.023	0.017	0.008	0.0004
General mean	0.015	0.014	0.083	0.071	0.030	0.024	0.014	0.0008

During 61-75 days the highest RGR for dry matter of (0.030 g/g/day) was recorded in variety MAUS-31 The lowest RGR for dry matter of (0.017 g/g/day) was in variety MAUS-2

During 76-90 days the bighest RGR for dry matter of (0.012 g/g/day) was recorded in MAUS-31 and followed by MAUS-33. It was lowest in variety MAUS-34.

4.2.2. Leaf area index per plant (LAI)

Data in Table 9 reveal that leaf area index of soybean increased progressively from sowing up to 75 days and decreased there after.

The variety MAUS-33 recorded the highest value of the leaf area index at all the observation stages followed by MAUS-32 and MAUS-34. PK-472 (check) recorded lowest leaf area index at all the stages of observation.

4.2.3. Net assimilation rate (NAR)

Data pertaining to net assimilation rate per plant in g/cm2 /day as affected by water stress and control (natural) treatments are presented in Table 10.

Net assimilation rate was highest in variety MAUS-33 at 31-45 and 46 -60 days after sowing. At 61-75 days NAR was highest in MAUS-32 and lowest in PK-472. MAUS-34 was recorded highest value of the NAR at 76-90 days after sowing and MAUS-32 was lowest in net dissimilation rate.

Data on mean crop growth rate in Table 11reveal that during 46-60 days CGR was maximum and subsequently it decreased as the crop advanced to maturity.

Table 12 Mean number of pods per plant at various growth stages of soybean under water stress and control (natural) environment

Treatments	Days after sowing		
	60	75	90
I) Environment			
1 Water stress	30.33	34.36	37.77
2 Control (natural)	39.37	45.19	49.03
SE ±	0.40	0.39	0.35
C D at 5%	1.29	1.26	1.12
II) Varieties			
1 MAUS-33	37.00	42.50	46.00
2 MAUS-32	34.00	39.50	42.60
3 MAUS-34	35.35	40.70	44.00
4 MAUS-2	35.91	40.09	44.70
5 MAUS-31	34.35	39.66	43.75
6 PK-472 (check)	32.50	36.20	39.35
S E ±	0.70	0.68	0.60
CD at 5%	2.16	2.13	1.87
Interaction			
ExV			
S E ±	0.99	0.97	0.85
C D at 5%	NS	NS	NS
Grand mean	34.85	39.77	43.4

Table 13 **Mean seed yield, biological yield and harvest index (%) in soybean influenced by water stress and control (natural)environment**

Treatments	Grain yield (q/ha)	Biological yield (q/ha)	Harvest Index (%)
I) Environment			
1 Water stress	26.37	57.76	46.05
2 Control (natural)	34.03	64.40	49.65
SE ±	0.59	1.11	0.57
C D at 5%	1.93	3.41	1.88
II) Varieties			
1 MAUS-33	35.20	60. 31	48.39
2 MAUS-32	30.98	70.94	43.74
3 MAUS-34	31.13	59.52	52.03
4 MAUS-2	25.68	53.65	47.77
5 MAUS-31	32.66	68.92	47.23
6 PK-472 (check)	25.58	53.19	47.99
S E ±	1.20	1.23	0.99
C D at 5%	3.79	4.10	3.12
Interaction			
ExV			
S E ±	1.42	2.11	1.40
C D at 5%	NS	NS	NS
Grand mean	30.20	61.08	47.85

Table 13a. Environmental effect between water stress and natural condition in soybean for grain yield (q/ha).

Environment	Water stress	Natural condition	Mean
MAUS 33	31.23	39.17	35.20
MAUS 32	27.80	34.16	30.98
MAUS 34	25.68	36.58	31.13
MAUS 2	22.06	29.30	25.68
MAUS 31	28.69	36.63	32.66
PK 472 (check)	22.58	28.58	25.58
SE ±	1.42		
CD at 5%	NS		
Mean	26.34	34.07	30.20

Table 14 Hundred seed weight in (g) and grain yield g/plant

Treatments	100 seed weight (g)	Grain yield g/plant
I) Environment		
1 Water stress	12.20	9.41
2 Control (natural)	13.46	11.83
SE ±	0.39	0.38
C D at 5%	1.32	1.29
II) Varieties		
1 MAUS-33	14.01	12.20
2 MAUS-32	11.99	10.04
3 MAUS-34	13.04	10.21
4 MAUS-2	12.79	10.38
5 MAUS-31	11.97	10.11
6 PK-472 (check)	13.18	10.83
S E ±	0.58	0.68
C D at 5%	1.82	2.29
Interaction		
ExV		
S E ±	0.69	0.96
C D at 5%	NS	N S
Grand mean	**12.83**	**10.62**

4.2.4 Crop growth rate (CGR)

In general CGR was more in all varieties Table 11 reveal RGR during 46-60 days . Highest CGR was found in MAUS-33, MAUS-34 and MAUS-31 at 31-45 and 46-60, 61-75 and 76-90 days after sowing respectively.

4.3. Yield studies

4.3.1 Mean number of pods per plant

Data on mean number of pods per plant influenced by water stress and control (natural) environment at different stages of crop growth are presented in Table 12

The data in Table 12 reveal that pods **per plant** were observed at 60 days after sowing and they were increased upto 90 days after sowing.

There were significant differences between water stress and control (natural) environment at 60, 75 and 90 days after sowing in pod number per plant . This was due to the effect of water stress. The control (natural)environment was significantly superior over environment water stress at all growth stages in number of pods per plant.

Variety MAUS-33 was significantly superior over all varieties at 60,75 and 90 days after sowing recording highest pod number per plant. Variety PK-472 (check) recorded lowest number of pods per plant at all growth stages. Varieties MAUS -32, MAUS-34, MAUS-2 and MAUS-31 MAUS-33 were at par in all observation stages.

4.3.2. Grain yield, biological yield and harvest index

Data on grain yield (q/ha), biological yield (q/ha) and harvest index as influenced by water stress and control (natural) environment were revealed in Table 13. There were significant differences found between water stress and control (natural) environment. Control (natural) environment was significantly superior over water stress in case of grain yield, biological yield and harvest index.

Variety MAUS-33 (35.20 q/ha) was found significantly superior over check PK-472 (25.58 q/ha) but at par with MAUS - 31 (32.66 q/ha) in case of grain yield q/ha. Varieties MAUS-34, MAUS-32 and MAUS-31 were found at par in case of grain yield MAUS-2 was at par with PK-472 in grain yield.

Biological yield was found superior and highest in MAUS-32 (70.94 q/ha) which was at par with MAUS-31 (68.92q/ha). Lowest biological yield was in check PK-472 (53-19 q/ha) which was at par with the MAUS-2 (25.68 q/ha).

Harvest index (percent) was found significantly superior in variety MAUS-34. There were no significant differences amongst other varieties.

4.3.3. Hundred seed and weight, grain yield g /plant

Data revealed in Table -14 indicates that 100 seed weight and grain yield were recorded superior in control (natural) environment than the water stress.

MAUS-33 recorded highest value of the 100 seed weight (14.01 g) and grain yield gram / plant (12.20 g/plant) was superior over all other varieties.

4.4. Chemical analysis

Data on mean nitrogen in leaves (per cent), leaf chlorophyll content (mg/g) and leaf proline content (mg/g) as influenced by environemental treatments water stress and control (natural) are shown in Table 15.

There was significant difference found in control (natural) and water stress environment. Control (natural) environment was superior over water stress in case of leaf chlorophyll, nitrogen, and low in proline content.

Variety MAUS-33 was superior over all other varieties but at par with check PK-472 in leaf nitrogen content. MAUS-32 , MAUS-34, MAUS-2 and MAUS-31 were at par in leaf nitrogen content.

Variety PK-472 found superior chlorophyll content but at par with MAUS-33, MAUS-34 and MAUS-31 were at par in leaf chlorophyll content.

Cholorophyll stability index was found superior in water stress and lowest in control (natural) which is related to drought tolerance.

Variety MAUS-33 recorded lowest value of the chlorophyll stability index which was at par with PK-472 (check) . Highest CSI value was recorded in variety MAUS-34. Interaction effects were non-significant.

Leaf proline content was found lowest in variety MAUS-33 than check PK-472 and other Varieties. Varieties MAUS-32, MAUS-34 and MAUS-33 were at par in leaf proline content. Interaction effects were found non-significant.

4.4.1 Soil moisture studies

Data on soil moisture use and moisture use efficiency (MUE)are presented in Table 16. In natural condition variety MAUS-31 utilized highest

Table 15 **Mean nitrogen in leaves(%), leaf chlorophyll content (mg/g), leaf proline content (mg/g) in soybean under water stress and control (natural)** environment

Treatments	Mean nitrogen in leaves (%)	Leaf chlorophyll content (mg/g)	Leaf proline content (mg/g)	Chlorophyll stability Index
I) Environment				
1 Water stress	1.092	1.490	14.07	0.086
2 Control (natural)	1.69 3	1.990	8.05	0.076
SE ±	0.057	0.090	0.126	0.008
C D at 5%	0.189	0.276	0.396	0.026
II) Varieties				
1 MAUS-33	1.632	2.032	10.25	0.058
2 MAUS-32	1.361	0.972	10.22	0.074
3 MAUS-34	1.300	1.883	10.67	0.074
4 MAUS-2	1.312	1.321	12.87	0.103
5 MAUS-31	1.256	1.797	11.04	0.098
6 PK-472 (check)	1.491	2.425	11.34	0.079
S E ±	0.102	0.156	0.135	0.059
C D at 5%	0.318	0.469	0.587	0.129
Interaction				
ExV				
S E ±	0.142	0.221	0.331	0.124
CD at 5%	N S	N S	NS	NS
Grand mean	1.392	1.742	11.06	0.081

Table 16 Moisture use and moisture use efficiency as affected by treatments from 0.60 cm depth of soybean

Treatments	Natural condition		Water stress condition	
	Moisture use (mm)	Moisture use efficiency (Kg/mm/ha)	Moisture use (mm)	Moisture use efficiency (kg/mm/ha)
1. MAUS-33	293.3	13.35	228.4	13.73
2. MAUS-32	317.3	10.85	226.4	12.29
3. MAUS-34	314.7	11.62	228.2	11.20
4. MAUS-2	327.6	8.94	229.2	9.63
5. MAUS-31	335	10.93	225.0	12.75
6. PK-472 (check)	325.1	8.68	203.9	11.24
Genral mean	12.83	10.62	223.5	11.80

Table 17 **Soil moisture percent at 45,60 and 75 days after sowing in control (natural) and water stress in soybean**

Varieties	45 Days after sowing			
	0 to 30 cm (soil depth)		30 to 60 cm (soil depth)	
	natural	water stress	natural	water stress
1 MAUS-33	37.50	37.40	41.80	42.30
2 MAUS-32	39.00	38.90	43.00	43.10
3 MAUS-34	38.50	38.40	42.10	42.10
4 MAUS-2	37.50	37.60	42.50	42..30
5 MAUS-31	38.50	38.30	42.10	42.10
6 PK-472 (check)	38.40	38.60	41.90	42.00

Varieties	60 Days after sowing			
	0 to 30 cm (soil depth)		30 to 60 cm (soil depth)	
	natural	water stress	natural	water stress
1 MAUS-33	40.20	34.10	42.20	37.70
2 MAUS-32	40.00	33.10	42.10	36.10
3 MAUS-34	40.10	32.60	41.70	37.10
4 MAUS-2	40.70	33.00	42.60	37.20
5 MAUS-31	40.10	33.10	42.70	36.30
6 PK-472 (check)	40.20	34.10	41.90	37.10

Varieties	75Days after sowing			
	0 to 30 cm (soil depth)		30 to 60 cm (soil depth)	
	natural	water stress	natural	water stress
1 MAUS-33	41.90	26.90	42.70	28.70
2 MAUS-32	40.20	25.10	42.00	23.30
3 MAUS-34	40.00	25.30	42.30	27.50
4 MAUS-2	40.50	25.00	42.10	27.40
5 MAUS-31	39.90	24.90	41.20	27.30
6 PK-472 (check)	40.80	26.10	42.30	28.40

moisture of 335.0 mm followed by MAUS-2 , PK-472 (check) and MAUS-32 (327.6, 325.1 and 317.3mm) respectively. The highest MUE was recorded by MAUS-33 (13.35 Kg/mm/ha) followed by MAUS - 34 , MAUS-31 (11.62 and 10.93 Kg/mm/ha) respectively. Where as in water stress condition variety MAUS-2 had recorded the maximum moisture use of 229.2 mm followed by MAUS-33 MAUS-34 , MAUS-32 (228.4, 228.2 and 226.4mm) respectively . Variety MAUS-33 recorded the highest MUE (13.73 Kg/mm/ha) followed by MAUS-31, MAUS-32(12.75 , 12.29 Kg/mm/ha) respectively.

4.4.2 Soil moisture percentage

Data presented in Table 17 reveal that moisture percentage was reduced in water stress condition during 60 and 75 days after sowing as compare to the control (natural) environment.

Discussion

CHAPTER 5

DISCUSSION

The results of present investigations are discussed briefly in this chapter.

5.1 Biometric observations

It is seen from the data that mean plant height of soybean was increased progressively as the crop advanced in age. The rate of increase was slow during first 30 days fast during 30 to 60 days and declined subsequently till maturity of the crop.

Plant height in natural environment was superior over water stress at all stages except the 60 days after sowing. Variety MAUS-31 recorded highest plant height at all stages. PK-472 recorded lowest plant height at all stages of growth. The differences in plant height was due to genotypic differences in safflower was observed by Jadhav (1975). Interaction effects were non-significant.

The mean number of functional leaves and leaf area increased continuously upto 75 days after sowing of the crop and declined there after. It was almost nil at harvest as there was complete senescence of leaves. There were no significant differences natural condition over water stress at 30 and 45 DAS in mean number of functional leaves per plant and leaf area per plant but found significantly superior at 60, 75 and 90 DAS. Leaf area reduced by water stress was given conformity by (schulze, 1990). MAUS-33 recorded superior over all varieties in mean functional leaves and leaf area at all growth stages. Interaction effects were nonsignificant.

Leaf dry matter, stem dry matter and total dry matter (stem + leaf) accumulation per plant increased progressively from sowing up to 90 days of crop. At harvest the leaf dry matter was negligible due to senescence of leaves. Leaf dry matter accumulation in plant was significantly superior in natural condition than water stress at 75 and 90 days after sowing and in stem dry matter and total dry matter accumulation per plant at 60, 75 and 90 days after sowing. Water stress reduced the weight of all plant parts except stem (Silvius, 1977) and total dry matter reduced by water stress, (Doorenbos and kassam, 1979). MAUS -33 was superior over all varieties in mean leaf dry matter acumulation per plant at all stages except 90 DAS per plant. MAUS-31 was significantly superior over all varieties in mean stem dry matter accumulation per plant at all stages. MAUS-31 was found superior in mean total dry matter acumulation per plant at all growth stages and lowest was PK-472 (cheek) except at 60 days after sowing.

5.2 Growth analysis.

In general during first 45 days from sowing RGR for dry matter increased steadily. During 31-45 days MAUS 32 recorded highest RGR (0.049 g/g/day). During 61-75 and 76-90 days highest RGR was found superior in MAUS-31 (0.012 g/gday).

Leaf area index was found highest in variety MAUS-33 and lowest in PK-472 at all growth stages.

Net assimilation rate was highest in variety MAUS-33 at 31-45 and 46-60 days after sowing, at 61-75 highest in MAUS-32 and MAUS-34 highest at 76 90 days after sowing. In general CGR was more in all varieties during 46-60 days. Highest CGR was found in MAUS-33, MAUS-34 and MAUS -31 at 31-45 and 46-60, 61-75 and 76-90 days after sowing.

5.3 Chemical analysis

Nitrogen content in leaf was found highest in variety MAUS-33 and superior Over all other varieties.

Variety PK-472 (check) was found superior in chlorophyll content but at par with MAUS-33. Chlorophyll content in leaves reduced due to water stress by 10 to 17 per cent observed by sorte, *et.al*, (1993). MAUS-33 recorded lowest value of chlorophyll stability index which was at par with variety PK-472 (check). Low chlorophyll stability index and high chlorophyll content character related to the drought tolerance. CSI was related with drought tolerance as reported by Rajeswari (1995).

Leaf Proline content was found lowest in variety MAUS-33 over than PK-472 and other varieties. Proline accumulation increased during water stress was observed by Sarkar (1993)..

In natural condition variety MAUS-31 utilised highest moisture (335.omm). The highest water use efficiency (WUE) was recorded by MAUS-33 (13-35 Kg/mm/ha). In water stress condition variety MAUS-2 had recorded the maximum moisture use of 229.2mm. Variety MAUS-33 recorded the highest MUE (13.73 Kg/mm/ha).

5.4 Yield Studies

Pod number per plant were found superior in natural condition than water stress at 60,75 and 90 days after sowing. MAUS-33 was recorded significantly superior over all varieties at all growth stages in mean pod number per plant. PK-972 (check) was recorded lowest mean pod nmber per plant at all growth stages. Water Stress given at the time of flowering and swelling stages reduced the pods per plant (Dusek *et.al.,* 1971).

There was significant differences in control (natural) environment and water stress in grain yield per hactare. MAUS-33 (35.20 q/ha) recoreded significantly superior over check PK-472 (25.28 q/ha) but at par with MAUS-31 (32.66 q/ha) in grain yield quintal per hactare. Water stress during flowering to pod formation reduced the grain yield reported by Eck *et. al.,* (1987). Water stress at either flowering or pod elongation significantly reduced soybean yields observed by Brown *et.al.*, (1985). Two weeks drought reduced seed yield by an average of 18 per cent, Bartels and caeser (1987).

Biological yield was found superior in variety MAUS-32 (370.94 q/ha) which was at par with MAUS-31 (68.92 q/ha). Harvest index was significantly superior in variety MAUS-34. MAUS-33 recorded highest value of 100 seed weight (14.01g) and grain yield g/plant (12.20 g/plant) over other varieties. Both these values were recorded superior in natural environment than the water stress. Kpoghomov (1990) reported that water stress at pod filling stage reduced 100 seed weight. in soybean.

Summary and Conclusion

CHAPTER 6

SUMMARY AND CONCLUSION

The results of the present investigations are summarised in this chapter.

A field experiment entitled "Effect of water stress on growth and yield of soybean (*Glycine max (L.) Merill*)" was conducted in *kharif* season of 1996 at Dry Land Agricultural Research Centre, MAU , Parbhani with following objectives.

1. To study physiological variation in growth and yield of soybean varieties.
2. To study variation in physiochemical parameters under water stress in soybean varieties.
3. To identify suitable variety of soybean for drought tolerance .

The variety MAUS-31 exhibited maximum plant height at all observation stages. The variety MAUS-33 gave highest number of functional leaves **than** other genotypes at all the observation stages.

The variety MAUS-33 produced highest leaf area per plant during all the observation stages. The variety MAUS-33 produced highest value of leaf dry matter per plant at all observation stages.

The variety MAUS-31 recorded highest stem dry matter and total dry matter accumulation per plant at all observation stages.

Leaf area index was found highest in variety MAUS-33 at all observation stages.

RGR, NAR and CGR values did not show any definite trend.

Pod number per plant was recorded highest in variety MAUS-33 at 60, 75 and 90 days after sowing.

Grain yield q/ha was produced highest by variety MAUS-33.

Biological yield was recorded highest in MAUS-32 and harvest index in MAUS-34.

Hundred seed weight was recorded highest in MAUS-33 and grain yield per plant was also highest in MAUS-33.

Nitrogen content in leaves at 70 days was recorded highest in MAUS-33.

Proline content value was lowest in variety MAUS-33. Chlorophyll content in leaves was highest in variety PK-472. Chlorophyll stability index was found lowest in the variety MAUS-33.

Moisture use efficiency was recorded highest in variety MAUS-33 in control (natural) and water stress environment.

The variety MAUS-33 has recorded lowest proline accumulation in leaf, lowest chlorophyll stability index, highest moisture use efficiency, highest grain yield and highest number of pods. These are the characters which might have helped to MAUS-33 in water stress condition to yield more.

In light of above findings it can be concluded that, in water stress conditions, the genotype MAUS-33 gave maximum grain yield as compared to other genotypes hence this genotype was found tolerant amongst the variety under study. However, further studies needs to confirm the results.

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