EFFECT OF MOISTURE STRESS ON SEED QUALITY IN GROUNDNUT GENOTYPES

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BY

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CERTIFICATE

This is to certify that the thesis entitled "Effect of Moisture Stress on Seed Qulaity in Groundnut Genotypes" submitted in partial fulfilment of the requirements for the degree of "Master of Science of the Andhra Pradesh Agricultural University, Hyderabad, is a record of the bonafide research work carried out by Miss. Jayanthi Srinivasan under my guidance and supervision. The subject of the thesis has been approved by the Student"s Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma or has been published. Published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been duly acknowledged.

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CERTIFICATE

Miss. Jayanthi Srinivasan has satisfactorily prosecuted the course of research and the thesis entitled "Effect of Moisture Stress on Seed Quality in Groundnut Genotypes" submitted 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 thesis or part thereof has not been submitted by her for a degree of any University.

Dr. J.H.WILLIAMS
CHAIRMAN

DECLARATION

I, JAYANTHI SRINIVASAN, hereby declare that the thesis titled "EFFECT OF MOISTURE STRESS ON SEED QUALITY IN GROUNDNUT GENOTYPES" is a result of the original research work done by me. It is further declared that the thesis or any part therof has not been published earlier in any manner.

(JAYANTHI SRINIVASAN)

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LIST OF ABBREVIATIONS

CV	=	Cultivar
DAS	=	Days after sowing
ICRISAT	=	International Crop Research Institute for the Semi Arid Tropics
EB	=	Erect bunch
FAO	=	Food and Agricultural Organisation
NMR	=	Nuclear Magnetic Resonance
NS	=	Non-significant
P	=	Pattern
SAT	=	Semi-Arid Tropics
S.E	=	Standard Error
S	=	Significant
SP	=	Spanish
U	=	Uniform
VAL	=	Valencia
VB	=	Virginia Bunch

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ABSTRACT

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The effect of moisture deficit on seed quality was investigated in seed samples of a range of groundnut genotypes collected from field experiments conducted during 1982-'83 and 1983-'84 post rainy seasons at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Patencheru, Hyderabad. Variable levels of water deficit were imposed at different crop growth phases in the field by line source sprinkler system. The oil analysis was done using Nuclear Magnetic Resonance technique (NMR) and Soxhlet methods.

The results indicated that there was severe reduction in the oil % and oil yield when moisture deficit occurred during the seed filling phase, relative to treatments in which water deficits occurred during pod development. The former resulted in reduction of shelling percentage, seed size and 100-seed weight. Stress during flowering and pegging had little effect on the oil % but did reduce the oil yield mainly by affecting the seed yields. In general variety *vulgaris* (Valencia) of sub-species *fastigiata* had higher oil content than variety *fastigiata* (Spanish) at all levels of irrigation treatments. Positive association was observed between seed size and oil content.

INTRODUCTION

EFFECT OF MOISTURE STRESS ON SEED QUALITY IN GROUNDNUT GENOTYPES.

1.INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the important legume crops of the Semi-Arid Tropics (SAT) regions of the world. India ranks first in the world production (6.2 million tonnes) followed by China (2.8 million tonnes) and USA (1.8 million tonnes) (FAO , 1980).

Groundnut is cultivated mainly as a rainfed crop but wherever possible it is also grown with irrigation. Yield of groundnut in semi-arid tropical (SAT) India are low and variable due to the erratic rainfall and other climatic factors (Kanwar et al., 1983).

Drought, depending upon its time of occurence, intensity and duration can affect groundnut yields. Stansell and Pallas (1979) and Nageswara Rao *et al*. (1985) found that the seed filling stage is the most sensitive phase to drought.

In addition to understanding the drought effects on yield it is equally important to know its effects on the seed quality and oil content since a major proportion of production is used for oil in India. Rasve *et al*. (1983) found oil % to be maximum when 540 mm of water was applied in 9 irrigations at 10 days interval and that the oil % decreased when the amount of total irrigation water decreased. Published information about the effects of drought on seed quality and oil content is limited. Present study was conducted to examine the effects of moisture stress occurring at different timings of crop's life on seed quality and oil content in a range of groundnut genotypes.

The major objectives of the investigation were :

1. To study the effect of drought with variable intensities occurring during different stages in crop's life on the oil content in a range of groundnut genotypes.
2. To examine the extent of geneotype variability in seed quality, and oil content in groundnut in the above drought patterns.

REVIEW OF LITERATURE

2.REVIEW OF LITERATURE

Groundnut (Arachis hypogaea L.) is one of the important legume crops of the Semi-Arid Tropics (SAT). Approximately 70% of the world production comes from the SAT regions of the world. Groundnut has specific moisture needs due to their unique feature of developing the pods just underground. The pods take up moisture and calcium directly from the soil and are therefore sensitive to drought and attack by soil organisms. The soil must be in a friable condition both at the time of peg penetration into the soil and at harvest. This subterranian fruiting habit contributes a number of individual pecularities to the requirements for growth of groundnuts; some of which assist its drought tolerance, while others make it prone to moisture stress (Airey, 1980).

Several stages in the groundnut's life cycle have been reported to result in reduced pod yields : intense flowering (Billaz and Ochs., 1961); full pegging and pod development (Joshi and Kabaria., 1972); pod formation (Subramanian *et al*., 1975); early vegetative and late pod setting stage (Williams *et al*., 1978) and peak flowering to early fruiting (Su and Lu., 1963, Su *et al*., 1964). Detailed effects of drought occurring at different timings on Indian cultivar Robut 33-1 is well described by Sarma (1983).

Although the effects of drought on groundnut crop and yields are described well in the literature the information about the effects of drought on oil content and other seed quality aspects is very limited. This chapter provides the available literature about the effect of drought on seed quality and oil. The review presented is divided into following sections :

2.1. Moisture stress effects on oil content.

2.2. Moisture stress effects on shelling percentage.

2.3. Moisture stress effects on 100-seed weight.

2.4. Moisture stress effects on dseed size.

2.1.Moisture stress effects on oil content :

There is very little work done on the effect of moisture stress on the oil content.

Yao et al (1982) reported that drought at flowering increased the number of shrivelled kernels with no effect on oil content but reduced the protein content. However moisture stress during the seed development phase reduced the seed oil content but increased the protein content.

The results from the experiments conducted by Rasve et al (1983) revealed that application of 540mm water with a 10 days irrigation interval proved most beneficial in increasing the oil

% (to 50.39 %) when groundnut crop was grown in summer season. Rao et al (1983) concluded from experiments conducted at Khargone during the monsoon season 1978 that oil % had significant positive association with shelling % and its association with 100 kernel weight was found to negative.

Sarma (1983) observed that with the imposition of early moisture stress on Robut 33-1 (moisture stress imposed from emergence to peg initiation) increased the seed quality in terms of oil and protein content. He also observed that when moisture stress was imposed from flowering to the end of pod set this resulted in decreased oil but improved protein content. As with groundnut, in soyabean with irrigation there was increase in oil content (Vasiliu et al., 1980). The experiments conducted by Ramalingaswamy et al (1976) on soyabean concluded that the % of oil was observed to decrease as the intensity of moisture stress increased from irrigation at 25% depletion of available moisture to irrigation at 75% depletion of available moisture.

2.2. Moisture stress effects on shelling percentage :

Shelling percentage and the ratio of kernel to whole plant dry matter decreased and the proportion of unfilled pods increased when groundnut crop was subjected to moisture stress. Shelling percentage was increased with irrigation relative to that with no irrigation (Reddy, 1978; Pallas et al., 1977).

The occurrence of moisture deficit during peg and pod development was considerably more deterimental to pod filling than earlier moisture stress at flowering (Balasubramanian et al., 1981) ; when stress was applied 9-13 weeks after sowing it adversely affected kernel development more in cv.Samaru 38 than Spanish cultivars, lowered the uptake of nitrogen and increased the proportion of unfilled pods thus reducing the yield. The experiment conducted by Rasve et al (1983) found that the shelling percentage was increased to 71.9% with the application of 540 mm water with 10 days interval. These results were in accordance with Saini and Sandhu (1973) who reported an increase in shelling per cent by the application of 2 irrigations, one at flowering and another at fruiting as compared to no irrigation.

Bhaskara, (1980) investigated the effect of frequency and depth of irrigation on yield attributes and concluded that the number of total and filled pods were maximum with high frequency of irrigation. High frequency irrigation increased shelling% and pod weight.

The experiment conducted by Stansell et al (1979) on groundnut cv Florunner showed that a 70 day drought beginning at 36 days after sowing (DAS) reduced the percentage of marketable seeds by 34 % while a 70 day drought treatment starting at 71 DAS reduced % marketable seeds by 69% compared to control. The percentage of other seeds (immature, shrivelled etc) was increased by drought from 36-105 days but not by drought from 71-140 days.

2.3.Moisture stress effects on 100-seed weight:

One of the major components of the final yield is 100-seed weight. Information available in the literature is limited on the effect of moisture stress on 100 seed weight. Water deficit in general decreased the seed weight, while increasing the percentage of other damaged or shrivelled kernels (Pallas et al., 1979). Sarma (1983) observed that early moisture stress (moisture stress imposed from emergence to peg initiation) increased the seed weight but when stress was imposed from flowering to last pod set it resulted in poor seed filling thus reducing the individual seed weight. The sowing of bold seeds was shown to result in significantly high yield (Gorbet, 1977), increased seedling weight, rate of increase in dry matter content and relative growth rate (Naidu and Narayanan, 1981) and greater LAI and chlorophyll concentration (Dhillon et al., 1981), than in crops sown using small seeds resulting from water deficit during the crops life. Significant positive association was found for pod yield per plant with plant height, 100 pod weight and kernel weight (Rao et al., 1983).

Individual seed weight was significantly influenced by the planted seed size with a positive correlation of r= 0.925 between planted seed size and 100 seed weight of harvested seeds (Gorbet, 1977).

2.4. Moisture stress effects on seed size :

There is very little work reported on the effect of moisture stress on seed size. Drought at flowering reduced the seed size and increased the number of shrivelled kernels (Yao *et al*., 1983). However when Florunner experienced 3 weeks of drought during the 8 to 11th week of the growth this had no significant effect on pod size but significantly delayed maturity (Boote *et al*., 1976), suggesting that the results of Yao *et al* (1983) were due to immature seeds included in harvest.

Rate of emergence and seedling vigour significantly effected by planted seed size and positively associated with increased seed size (Gorbet, 1977).

Blakenship *et al* (1983) concluded that the pod size tended to be reduced under drought condition. Argikary (1957) found that there was appreciable association between the size of the parental seed and the pod yield of the resultant crop.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 EXPERIMENT I

3.1.1.SOURCE OF MATERIAL

3.1.2.INTRODUCTION :

The experiment was primarily conducted at ICRISAT centre during 1982-'83 post rainy season to examine the effects of single and multiple drought patterns on the yield of 25 groundnut genotypes.

3.1.2. TREATMENTS

Out of 25 genotypes ten (Table 1) were selected for this study. Among them NCAC-17090 is drought tolerant genotype, TMV-2, JL-24 and Robut 33-1 are the cultivars which are released and the other cultivars viz ; ICGA-11, ICGS-20, ICGS-21, ICGS-24, ICGS-35 and ICGS-36 are to be released. From this experiments 4 drought patterns, each with eight intensities of drought and three replications were selected to study the effect of timing and intensity of moisture stress on oil percent and quality of seed.

The 4 patterns selected were either single and multiple water stresses with varied duration occurring during the reproductive phase of the crop (Table 2). Within each pattern the genotypes were subjected to eight levels of water application using line-source.

EXPERIMENT I :

VARIETIES :

TABLE - 1

	GENOTYPE	HABIT
1.	ICGS-11	EB
2.	ICGS-20	VB
3.	ICGS-21	EB
4.	ICGS-24	EB
5.	ICGS-35	EB
6.	ICGS-36	EB
7.	TMV-2	EB
8.	ROBUT 33-1	VB
9.	NCAC-17090	VAL (Valencia)
10.	JL-24	EB

EB : Erect bunch VB : Virgir

TABLE - 2

Treatments :-

Schedule of irrigations for the 4 drought patterns in Expt I (1982-'83 post rainy season) :

	Drought patterns			
DAS	P1	P2	P3	P4
0	U	U	U	U
15	U	U	U	U
29	LS	U	U	U
39	LS	U	U	U
51	LS	U	U	U
57	U	U	U	U
66	U	U	U	LS
72	U	U	U	LS
82	LS	LS	U	LS
93	LS	LS	LS	U
100	LS	LS	LS	LS
111	U	LS	LS	LS
118	U	LS	LS	LS
129	U	U	U	U

DAS : Days after sowing. LS : line source irrigation.

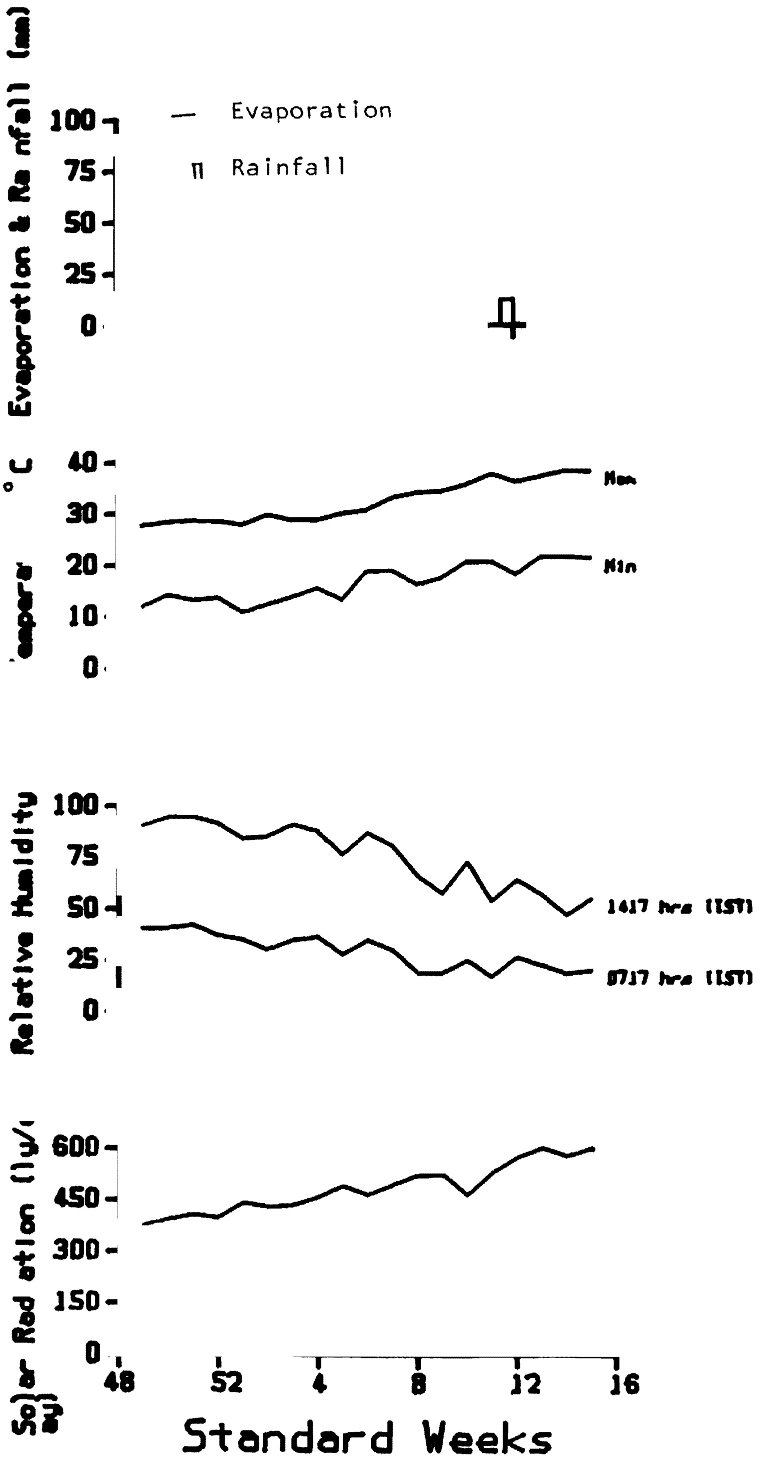

Fig 1: Metereological data recorded during 1982-'83 post-rainy season.

3.1.3. MEASUREMENTS :

Most of the seed samples were analysed for oil percentage by Nuclear Magnetic Resonance (NMR) technique. For a few samples, where the seed material was not sufficient for oil analysis by NMR technique, oil % was analysed by Soxhlet method.

3.1.4. CROP MANAGEMENT :

During cultivation of the field a basal dose of di-ammonium phosphate (18N : $46P_2O_5$) was incorporated into the soil at the rate of 100 kg/ha. Raised beds of 1.2 m wide were prepared each being separated by a furrow of 0.3 m.

Sowing was done on 6-12-1982. Seeds of all entries were treated with Captan and Thiram at the rate of 3 gms/kg of seeds as a precaution against possible seedling infections. Each variety was sown by hand in 2 rows of 12 m length across 8 plots (beds), with an inter-row spacing of 30 cm and 10 cm between the plants.

The crop was uniformily irrigated until 30 days after sowing (DAS) to establish the crop after which the variable irrigation patterns were introduced. During the pattern period only the beds received variable amount of water by line source irrigation (Hanks et al.,1976), otherwise, crops were uniformily irrigated. The crop was protected against pests and diseases until maturity.

The crop was harvested on 15-4-83 (130 DAS) after an uniform irrigation on 129 DAS. The plants from each plot were uprooted and pods were seperated. The pods were cured in the shade for 10 days and weighed. The pods weights were adjusted to oven dry basis using the oven dry weights of the representative pod samples.

3.2. EXPERIMENT II :

3.2.1. SOURCE OF MATERIAL

INTRODUCTION :

In this experiment, an attempt was made to examine if there were any difference between varieties *fastigiata* and *vulgaris* of ssp *fastigiata* with respect to the effects of drought on oil. The groundnut seeds used for these investigations were from a field experiment in which genotypes were screened for drought resistance during the 1983-'84 post rainy season at ICRISAT centre.

3.2.2. TREATMENTS :

For the present study twelve genotypes were selected (Table 4).

This field experiment consisted of 3 drought patterns, each with eight intensities and three replications. The timing of drought and their duration is presented are table 5.

3.2.3. MEASUREMENTS :

For 11 genotypes the oil % was measured by NMR technique. For a single spanish genotype (GNP # 1032) the seeds harvested from each water level were graded forsize and the oil content of each grade determined.

EXPERIMENT II :

Table : 4

	Genotypes	Habi·
1.	GNP # 1032	SP
2.	GNP # 1050	SP
3.	GNP # 1061	SP
4.	GNP # 1081	SP
5.	GNP # 1122	SP
6.	GNP # 1143	SP
7.	GNP # 1017	VAL
8.	GNP # 1053	VAL
9.	GNP # 1056	VAL
10.	GNP # 1027	VAL
11.	GNP # 1094	VAL
12.	GNP # 1109	VAL

SP : Spanish   VAL : Valencia

Table : 5

Treatments :-

Schedule of irrigation for 3 drought patterns in Expt II (1983-'84 post rainy season).

DAS	P1	P2	P3
0-53	U	U	U
54-89	LS	LS	U
90-138	LS	U	LS

DAS : Days after sowin

U : Uniform

LS : line source irrigation

P : Pattern

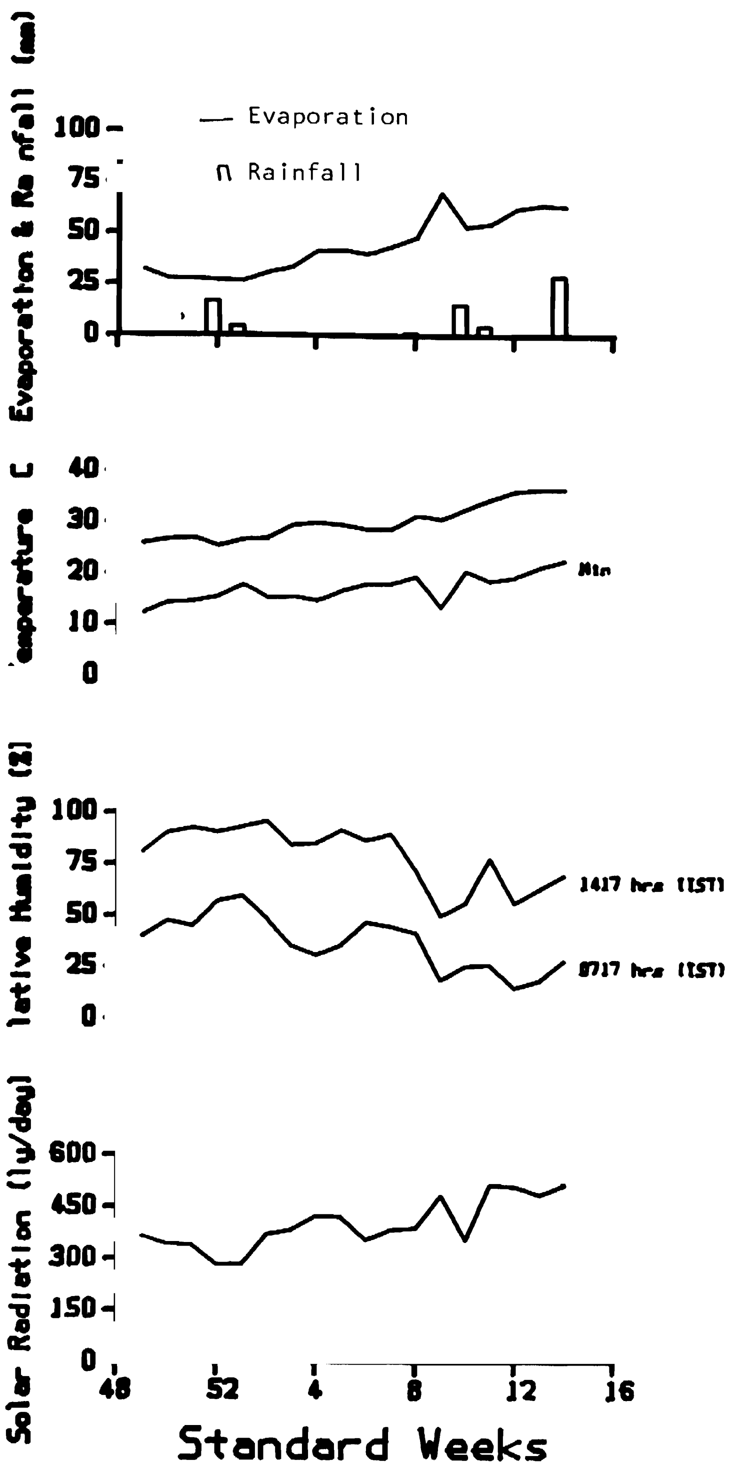

Fig 2 : Metereological data recorded during 1983-'84 post-rainy seaon.

The other measurements viz; shelling %, largest seed size, 100-seed weight were made in seeds harvested from each water level in all drought patterns.

3.2.4. CROP MANAGEMENT :

The experimental management was done as described earlier for experiment I. The genotypes were sown by hand on 2nd, 3rd and 4th December 1983, with a spacing of 30 cm between the rows and 10 cm in between plants within the rows. The crop was regularly irrigated until flowering after which patterns were introduced.

The crop was uniformly irrigated until 53 DAS after which variable intensities of drought were applied using Line source irrigation (Hanks et al., 1976) over 3 different phases of crop growth.

The crop was lifted on 5-4-1984 when about 70% of pods in the nonstress plots (Bed 1) were matured. Plots on each bed were harvested separately for each variety, and the pods were picked and air dried for 7 to 10 days before weighing.

3.3. IRRIGATION MANAGEMENT

In both the experimental periods the patterns either with or without droughts was created by altenating uniform sprinkler irrigations with line source sprinkler system of irrigation.

The line source sprinkler system was used to create 8 levels of soil moisture deficits (drought intensities) in the field. The sprinkler heads, 1/8" and 5/32" size nozzles with an output of about 9.3 gal/min were operated at a pressure of 275 kilo pascals (40 PSI). They were operated during periods when the wind velocity was minimal (less than 3 km/hr), usually at night. The water applied during each irrigation by line source only during the period of treatment was measured in catchcans placed perpendicularly to the sprinkler line in each of the 8 beds at 4 different locations for a given bed. The volume of water collected in each of the catchcans was measured and averaged over 4 locations for each bed to estimate the amount of water applied to the bed (Table 3 and 6).

The drought intensity was characterised in terms of % water deficit which was calculated using the formula :-

$$\% \text{ water deficit} = \frac{X1 - X2}{X1} \times 100$$

Where X1 = Cumulative evaporation occurred only during the period of drought pattern.

Table 3 : Cumulative irrigation in cm (including rain) applied to the 8 levels of drought created by line source in the four drought patterns (Expt I).

Pat	Rep	Drought intensities Water applied (cm)							
		B1	B2	B3	B4	B5	B6	B7	B8
1	1	31.2	27.5	24.2	19.6	14.4	8.8	3.8	1.3
1	2	30.7	28.1	25.0	18.7	13.5	8.2	4.0	1.4
1	3	27.7	26.5	22.9	17.1	13.6	7.5	4.4	1.4
2	1	23.0	21.3	17.5	16.0	11.0	7.6	3.6	1.2
2	2	25.9	24.1	22.3	16.5	10.9	6.5	2.7	1.1
2	3	23.1	21.7	18.6	15.3	9.3	4.7	2.4	0.9
3	1	19.3	17.2	16.2	12.8	9.1	5.3	2.4	0.7
3	2	19.4	17.6	14.6	11.8	8.2	4.0	1.7	0.3
3	3	18.7	16.9	14.4	11.8	8.6	5.0	2.4	0.5
4	1	32.9	32.6	30.4	25.3	18.3	12.3	6.7	5.2
4	2	32.4	31.6	28.1	23.5	17.9	11.6	7.0	5.4
4	3	31.6	29.5	26.1	21.5	15.7	10.7	6.7	5.0

B1 to B8 : Bed 1 to bed 8.

Rep : Replication.

Pat : Pattern.

Table 6 : Cumulative water in cm (including rain) applied to 8 levels of drought created by line source system in 3 patterns (Expt. II) :

		Drought intensities							
		Water applied (cm)							
Treatment	Rep	B1	B2	B3	B4	B5	B6	B7	B8
1	1	49.1	46.3	41.8	35.1	26.3	15.0	6.6	1.6
1	2	50.7	45.6	43.1	35.8	26.7	16.0	7.1	1.9
2	1	23.2	21.7	18.7	15.4	10.6	5.1	2.5	0.4
2	2	23.9	21.6	19.7	16.7	12.7	9.9	2.4	0.4
3	1	18.4	16.6	15.7	13.5	11.6	8.2	4.3	1.3
3	2	16.8	15.7	13.8	12.8	9.9	7.3	4.0	1.4

B1 to B8 = Bed 1 to bed 8.

Rep = Replication.

X2 = Cumulative amount of water applied for the pattern period only during the period of pattern with Line source.

Oil yield in Expt II was calculated by the following formula

Seed yield (gm / sq mt) X Oil %

3.4. METHOD OF OIL ANALYSIS :

Two methods of oil analysis were used viz; NMR and Soxhlet. A good correlation between these two methods were established (Jambunathan et al., 1985).

3.4.1. OIL ANALYSIS BY NMR TECHNIQUE :

Principle: The nuclei of certain materials when placed in magnetic field are able to absorb radio energy of a specific frequency. This phenomenon is known as nuclear magnetic resonance (NMR). The absorption frequency is proportional to the magnetic field and in the case of the nuclei of hydrogen atoms, the frequency is 4.26 KHz per gauss. In the 630 gauss field provided by the permanent magnet of the Analyser, hydrogen nuclear resonance occurs at 2.7 MHz. More details about this instrument is provided in AOCS. Official method Ab 3-49 (1981).

Method :

Experiments were carried out using a Newport NMR Analyser Mark III, (Newport Instrument Limited, Blakelands North, Milton Keynes, Bucks MK14, 5AW, England) with a steady field value of 635 gauss and a radio frequency of 2.7 MHz.

Pure oil extracted with n-hexane from a mixture of several cultivars (to represent uniform fatty acid composition) was used as a reference standard. The oil standard and seed samples to be analysed were kept at room temperature. A weighed quantity of pure oil was filled upto the etched mark in the NMR tube (Nessler glass tube). The tube was placed in the sample compartment and after necessary adjustments the standardized NMR reading was recorded. A weighed quantity of groundnut seed was filled upto the mark in another NMR tube and NMR reading of the seed was recorded. NMR oil equivalent was obtained by the equation.

$$\frac{\text{weight of oil}}{\text{NMR reading of oil}} \times \frac{\text{NMR reading of sample}}{\text{Weight of sample}} \times 100$$

After NMR analysis, the seed samples were oven dried at 110^{0} C for 16 hrs to determine moisture content. The moisture content was substracted from NMR oil equivalent to get NMR oil percent.

Since the quantity of seed for some samples was insufficient for the NMR technique the "Soxhlet" method of oil extraction was used for these samples.

3.4.2. Soxhlet Method :-

Oil Extraction method : About 10 g seed was blended in a Krupps KM75 blender and weighed into two portions of 5 g each. The meal was transferred into cellulose extraction thimbles and placed in Soxhlet extractors. Samples were extracted initially for 8 hrs with a n-hexane (b.p 60^0 C) and re extracted further for a period of 10 hrs after regrinding. The solvent was evaporated and the oil was dried to a constant weight on a sand bath (90 min) and subsequently oven dried for one hour at 110^0 C.

For a few samples the amount of seed material was not sufficient for oil estimation both by NMR technique and Soxhlet method, hence the seed material was ground and the flour was used for oil estimation by NMR technique only.

3.5. METHODS OF MEASUREMENTS

3.5.1. Shelling percentage:

A known weight of pods were shelled and the weight of kernels were recorded for each experimental plot. The shelling percentage was calculated using the formula:

$$\frac{\text{Seed weight}}{\text{Pod weight}} \times 100$$

3.5.2. 100-seed weight:

100 seeds were picked at random from each of experimental plot and weight was recorded.

3.5.3. Seed Size:

The seed material was passed through the 6 sieves of different size. The official grades are indicated below:-

Sieve No.	Official grade
1	3/4" X 15/64"
2	3/4" X 16/64"
3	3/4" X 17/64"
4	3/4" X 18/64"
5	3/4" X 19/64"
6	3/4" X 20/64"

The largest seed size of all 11 genotypes in different levels of droughts for each pattern was recorded.

3.6. STATISTICS

Since the drought intensities created by line source system were systamatic in nature, statistical analysis by conventional designs was not possible hence the analysis of results were confined to regression techiques only.

Since the water applied to plots to create 8 drought intensities were different in the two replications (Table 3 and 6) the regression analysis was done using 16 values (8 from each replications). The crop parameters viz; oil percentage, shelling percentage, 100-seed weight and largest seed size obtained from the seed samples harvested from the plots with variable drought intensities were regressed upon the % water deficit experienced by respective plots within each pattern. The intercept (a) on the 'X' axis represent the results achieved under no water deificit conditions and the slope of the regression line indicate degree of sensitivity of genotype to the particular drought pattern. Where regression co-efficient was not statistically significant, the mean response of genotype(s) across the range of water deficit along with associated standard error is given in results.

INDEX FOR TABLES :

% VAR = The differences between residual and total mean squares expressed as a percentage of the total mean square.

CV (%) = Square root of mean sum of squares divided by the cultivar mean expressed as a percentage.

RESULTS

4.RESULTS

4.1.EXPERIMENT I

4.1.1. MAIN EFFECTS OF DROUGHT INTENSITY ON OIL:

In pattern 1 drought from 29 to 56 DAS and 82 to 110 DAS had no affect on the mean oil percentage (Fig 3a).

In pattern 2, (drought applied from 82 to 128 DAS) response of oil % to water deficit was in a curvilinear fashion (Fig 3b). In pattern 2 intensity of drought did not reduce the oil percentage but a rapid decline in oil % was observed with water deficit above 80%.

In pattern 3, where the drought occurred from 93 to 128 DAS reduced the oil percentage linearly at a rate of 0.20 % oil / % water deficit) (Fig 3c) while in pattern 4 where drought occurred from 66 DAS to 92 DAS the oil % was reduced at a rate of 0.15 % oil / % water deficit (Fig 3d).

4.1.2. GENOTYPE RESPONSE :

In pattern 1 (Table 10a) the reduction in the oil percentage was observed only in 3 cultivars, viz; ICGS-11, ICGS-35 and NCAC 17090 at the rate of 0.04, 0.06 and 0.05 % / % water deficit

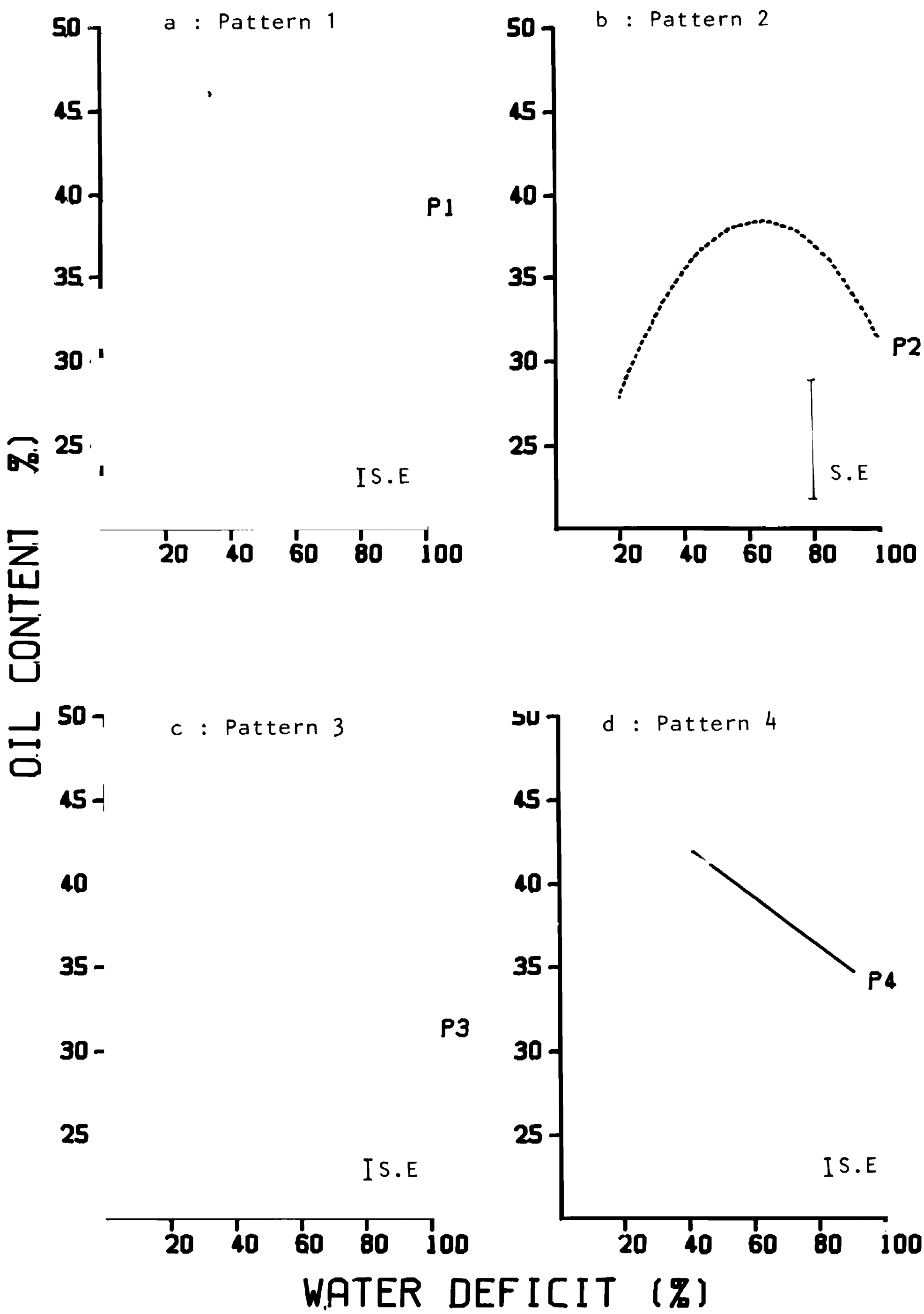

Fig.3 : Main effect of timing and intensity of drought on oil content (%) (Expt. 1).

TABLE 10a : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON OIL CONTENT IN EXPERIMENT I.

PATTERN 1 (DROUGHT APPLIED FROM 29 TO 56 DAS AND 82 TO 110 DAS).

Cv.No.	Sig	Oil %	S.E ±	% oil/ % water deficit^{-1}	S.E ±	% Var	CV %
1. ICGS-11	S	42.6	1.45	-0.04	0.021	24	
2. ICGS-20	NS	39.6	1.38				4.7
3. ICGS-21	NS	39.7	1.93				6.5
4. ICGS-24	NS	41.7	2.04				7.5
5. ICGS-35	S	43.0	1.12	-0.06	0.017	48	
6. ICGS-36	NS	40.1	1.28				3.6
7. TMV-2	NS	38.4	1.09				3.9
8. Robut 33-1	NS	39.6	1.95				6.7
9. NCAC-17090	S	43.8	1.73	-0.05	0.025	22	
10.JL-24	NS	40.6	2.03				6.9
MEAN	S	41.6	0.83	-0.02	0.012	17	

TABLE : 10b

PATTERN 11 (DROUGHT APPLIED FROM 82 TO 128 DAS).

Cv.No.	Sig	Oil %	S.E ±	% oil/ % water deficit^{-1}	S.E ±	% oil/ % water deficit^{-1}	S.E ±	% Var	CV %
1.ICGS-11	S	-20.2	26.1	1.660	0.729	-0.0119	0.0049	26	
2.ICGS-20	NS	38.0	50.2						15.8
3.ICGS-21	S	45.0	16.0	-0.107	0.447	-0.0002	0.0029	36	
4.ICGS-24	S	-23.7	29.4	1.886	0.830	-0.0134	0.0056	24	
5.ICGS-35	S	18.0	15.0	0.671	0.423	-0.0054	0.0028	41	
6.ICGS-36	S	-120.7	24.5	4.906	0.712	-0.0372	0.0050	86	
7.TMV-2	NS	37.5	34.7						16.7
8.Robut 33-1	S	-24.8	21.1	1.769	0.618	-0.0124	0.0044	32	
9.NCAC-17090	S	59.7	26.5	-0.383	0.768	0.0005	0.0053	49	
10.JL-24	NS	37.1	11.2						5.6
MEAN	S	16.3	9.7	0.691	0.272	-0.0054	0.0018	63	

S : Significant NS : Non-significant P < 0.05% S.E : Standard Error respectively. In other genotypes, the effect of water deficit was similar.

In pattern 2 (Table 10b), a significant reduction in oil percentage was observed in 7 genotypes. Among them only ICGS-24 was observed to have oil % more than mean while other cultivars were similar to the mean.

In pattern 3 (Table 10c), water deficit in general, reduced the oil content in all the cultivars. The rate of reduction was observed to be the highest in TMV2 (0.32 % / % water deficit) followed by ICGS-35 (0.23 % / % water deficit) and ICGS-11 and NCAC 17090 (0.20 % / % water deficit) relative to the mean. The least reduction was observed in genotype JL-24 (0.15 % / % water deficit).

In pattern 4 (Table 10d), only two cultivars viz; ICGS-21 and JL-24 showed little effect due to the water deficits. Among the genotypes TMV2 and ICGS-36 showed the rapid rate of decline (0.22 % / % water deficit) followed by ICGS-20 and ICGS-24 where the rate of reducton of oil content was 0.21 % oil / % water deficit respectively.

TABLE 10c : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON OIL PERCENTAGE IN EXPERIMENT I.

PATTERN III (DROUGHT APPLIED FROM 93 to 128 DAS).

Cv.No.	Sig	Oil %	S.E ±	% oil/ % water deficit^{-1}	S.E ±	% Var
1.ICGS-11	S	50.5	1.89	-0.20	0.025	75
2.ICGS-20	S	48.3	1.97	-0.16	0.026	63
3.ICGS-21	S	49.5	2.06	-0.18	0.027	66
4.ICGS-24	S	51.1	2.13	-0.17	0.027	62
5.ICGS-35	S	53.0	1.95	-0.23	0.025	79
6.ICGS-36	S	50.6	2.05	-0.18	0.027	66
7.TMV-2	S	59.2	4.45	-0.32	0.059	58
8.Robut 33-1	S	50.2	3.36	-0.19	0.044	44
9.NCAC-17090	S	53.9	1.70	-0.20	0.022	78
10JL-24	.S	47.1	2.69	-0.15	0.036	53
MEAN	S	51.4	1.34	-0.20	0.018	85

TABLE : 10d

PATTERN IV : (DROUGHT APPLIED FROM 66 to 92 DAS and 100 to 128 DAS).

Cv.No.	Sig	Oil %	S.E ±	% oil/ % water deficit^{-1}	S.E ±	% Var	CV %
1.ICGS-11	S	46.4	3.61	-0.17	0.057	36	
2.ICGS-20	S	50.8	2.77	-0.21	0.045	53	
3.ICGS-21	NS	38.4	3.19				9.7
4.ICGS-24	S	54.6	1.17	-0.21	0.018	87	
5.ICGS-35	S	49.9	2.56	-0.17	0.040	52	
6.ICGS-36	S	52.7	2.31	-0.22	0.035	64	
7.TMV-2	S	52.4	2.30	-0.22	0.037	64	
8.Robut 33-1	S	47.9	4.38	-0.16	0.069	20	
9.NCAC-17090	S	50.9	1.44	-0.18	0.023	78	
10JL-24	.NS	38.3	3.06				9.
MEAN	S	48.2	1.24	-0.15	0.018	74	

S : Significant NS : Non-significant $P < 0.05\%$ S.E : Standard Error

4.2. EXPERIMENT II

4.2.1. MAIN EFFECT OF DROUGHT INTENSITY WITHIN PATTERNS.

In pattern 1 a long term drought from 54 to 138 DAS did not have any severe effect on the oil percentage (Fig 4a). In this drought pattern, increasing intensities of drought had little effect on oil contents.

In pattern 2, also the effect of drought had little effect on the oil percentage (Fig 4b). and there was not much difference in the oil % between the non-stressed plot (bed 1) and severely stressed plot (bed 8) (Fig 4b).

In pattern 3, oil % was substantially reduced in a curvilinear fashion (Fig 4c). The rapid decline in the oil % occurred in plots with water deficit exceeding 70 % (Fig 4c).

In general in all the 3 patterns spanish group showed slightly lesser oil % than the valencia group at all levels of water deficit.

4.2.1. GENOTYPE RESPONSE :

In pattern 1 (Table 11a), among the spanish varieties GNP 1122 had the least oil % (39.3) in non-stress conditions but

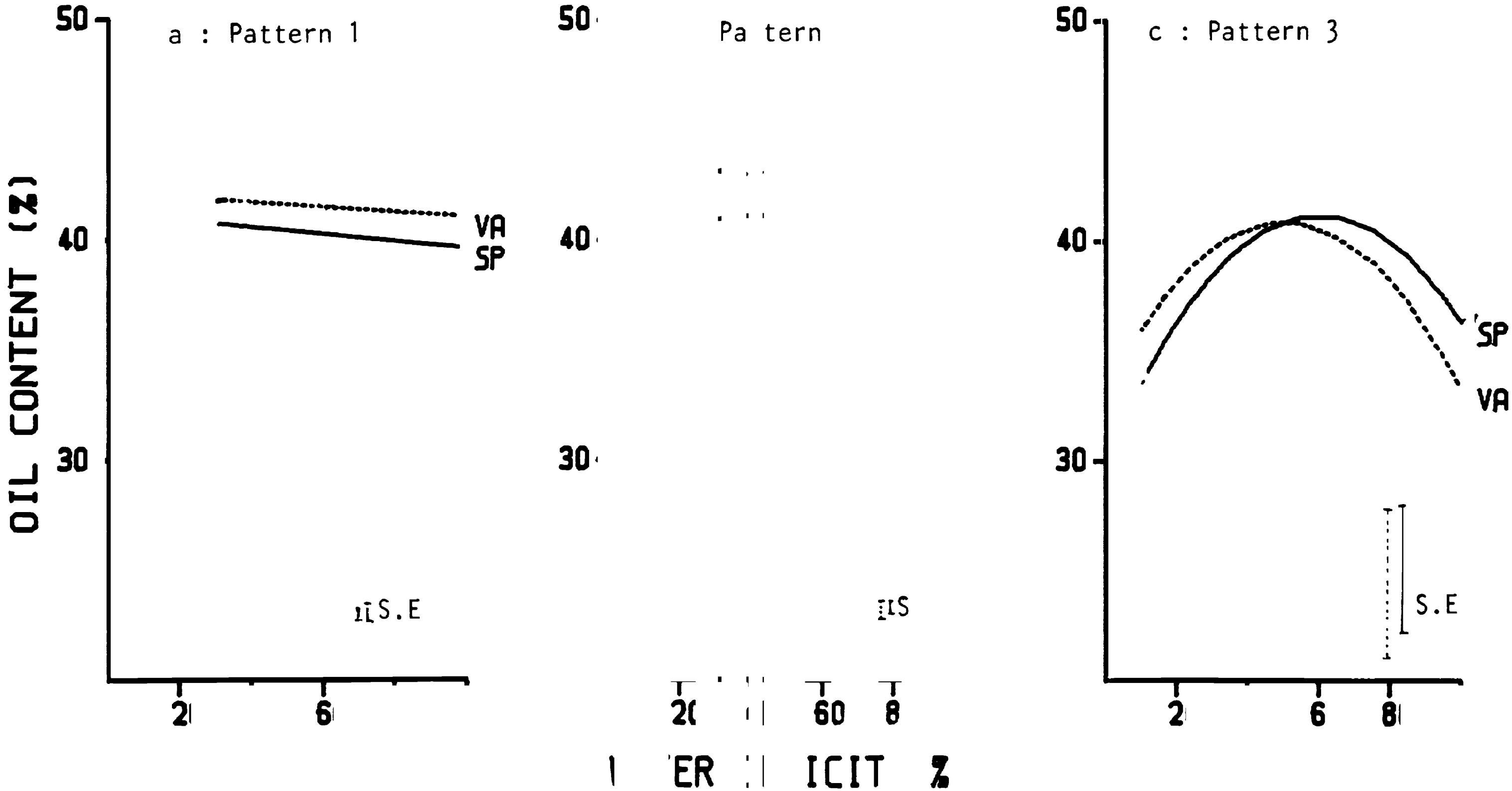

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TABLE 11a : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON OIL CONTENT IN EXPERIMENT II.

PATTERN I DROUGHT APPLIED FROM 54 DAS TO 138 DAS.

Cv.No. GNP #	Sig	Oil %	S.E ±	% oil/ % water deficit	S.E ±	% Var	CV %
1. 1050	S	41.2	0.63	-0.02	0.010	25	
2. 1061	S	41.5	0.41	-0.02	0.007	44	
3. 1081	NS	41.6	1.36				4.[illegible]
4. 1122	NS	39.3	0.75				2.[illegible]
5. 1143	NS	40.6	0.68				2.[illegible]
6. 1017	NS	40.7	0.77				2.[illegible]
7. 1053	S	44.9	0.76	-0.03	0.011	27	
8. 1056	S	39.4	0.93	0.03	0.014	26	
9 .1027	S	45.3	0.64	-0.03	0.011	33	
10.1094	NS	39.8	0.99				4.[illegible]
11.1109	NS	40.1	0.71				2.3
X(CV 1-5)	S	41.3	0.45	-0.02	0.007	21	
X(CV 6-11)	NS	41.5	0.60				

TABLE : 11b

PATTERN II DROUGHT APPLIED FROM 54 DAS TO 89 DAS.

S.No. GNP #	Sig	Oil %	S.E ±	CV %
1. 1050	NS	40.7	0.77	2.26
2. 1061	NS	40.0	1.70	4.45
3. 1081	NS	42.4	1.04	3.19
4. 1122	NS	39.8	0.84	2.71
5. 1143	NS	41.7	0.89	2.28
6. 1017	NS	41.5	1.55	4.84
7. 1053	NS	44.2	0.63	1.86
8. 1056	NS	43.5	2.87	8.42
9.1027	NS	44.5	2.60	7.52
10.1094	NS	42.4	3.48	10.25
11.1109	NS	40.1	2.10	6.62
X(CV 2-6)	NS	41.0	0.54	
X (CV 7-12)	NS	42.7	1.03	

showed less reduction due to increased drought intensities. The other 4 spanish genotypes had similar oil % in non-stressed plots, but genotypes GNP 1050 and 1061 decreased the oil % as the intensity of drought increased.

In pattern 2 (Table 11b) (drought from 54 to 89 DAS) increasing water deficits did not significantly reduce the oil % as indicated by the regression (Table 11b). Among the spanish genotypes tested, GNP 1122 had the lowest oil % (39.8) and GNP 1081 had the highest percent of oil. In genral all the genotypes belonging to valencia group had higher oil % than the genotypes of spanish. Among the valencia genotypes tested in these experiments GNP # 1027 recorded the highest oil content (44.5 %).

In pattern 3 (Table 11c), where the drought was applied from 90 to 138 DAS, increasing water deficits reduced the oil % in all genotypes tested both in spanish and valencia. Based on the data, it was observed that among spanish lines GNP # 1143 and 1061 had higher oil % at all levels of water deficits relative to the mean of 5 spanish genotypes.

4.3.EFFECT OF TIMING AND INTENSITY OF DROUGHT ON OIL YIELD.

4.3.1. MAIN EFFECT OF DROUGHT INTENSITY WITNIN PATTERNS.

In all three patterns 1, 2 and 3 drought had affected the oil yield significantly (Fig 5a,b,c).

TABLE 11c : EFFECT OF INTENSITY AND TIMING OF DROUGHT ON OIL CONTENT IN EXPERIMENT II.

PATTERN III DROUGHT APPLIED FROM 90 DAS TO 138 DAS.

Cv.No. GNP #	Sig	Oil %	S.E ±	% oil/ % water deficit	S.E ±	% oil/ % water deficit	S.E ±	% Var
2. 1050	S	40.6	12.50	0.07	0.330	-0.001	0.0021	60
3. 1061	S	28.8	10.30	0.35	0.277	-0.003	0.0018	50
4. 1081	S	40.6	8.53	0.16	0.226	-0.002	0.0015	93
5. 1122	S	34.0	12.90	0.21	0.341	-0.002	0.0022	60
6. 1143	S	25.0	9.51	0.55	0.249	-0.005	0.0016	88
7. 1017	S	34.8	13.90	0.28	0.365	-0.003	0.0023	80
8. 1053	S	33.8	11.10	0.27	0.291	-0.002	0.0019	42
9. 1056	S	32.6	11.60	0.39	0.308	-0.003	0.0020	82
10.1027	S	31.8	13.30	0.45	0.346	-0.004	0.0022	71
11.1094	S	44.6	8.73	-0.05	0.231	-0.001	0.0015	87
12.1109	NS	40.7	10.2					
X(CV 2-6)	S	30.4	6.10	0.36	0.161	-0.003	0.0010	90
X(CV 7-12)	S	33.4	7.29	0.30	0.192	-0.003	0.0012	85

S : Significant NS : Non-significant P < 0.05% S.E Standard error.

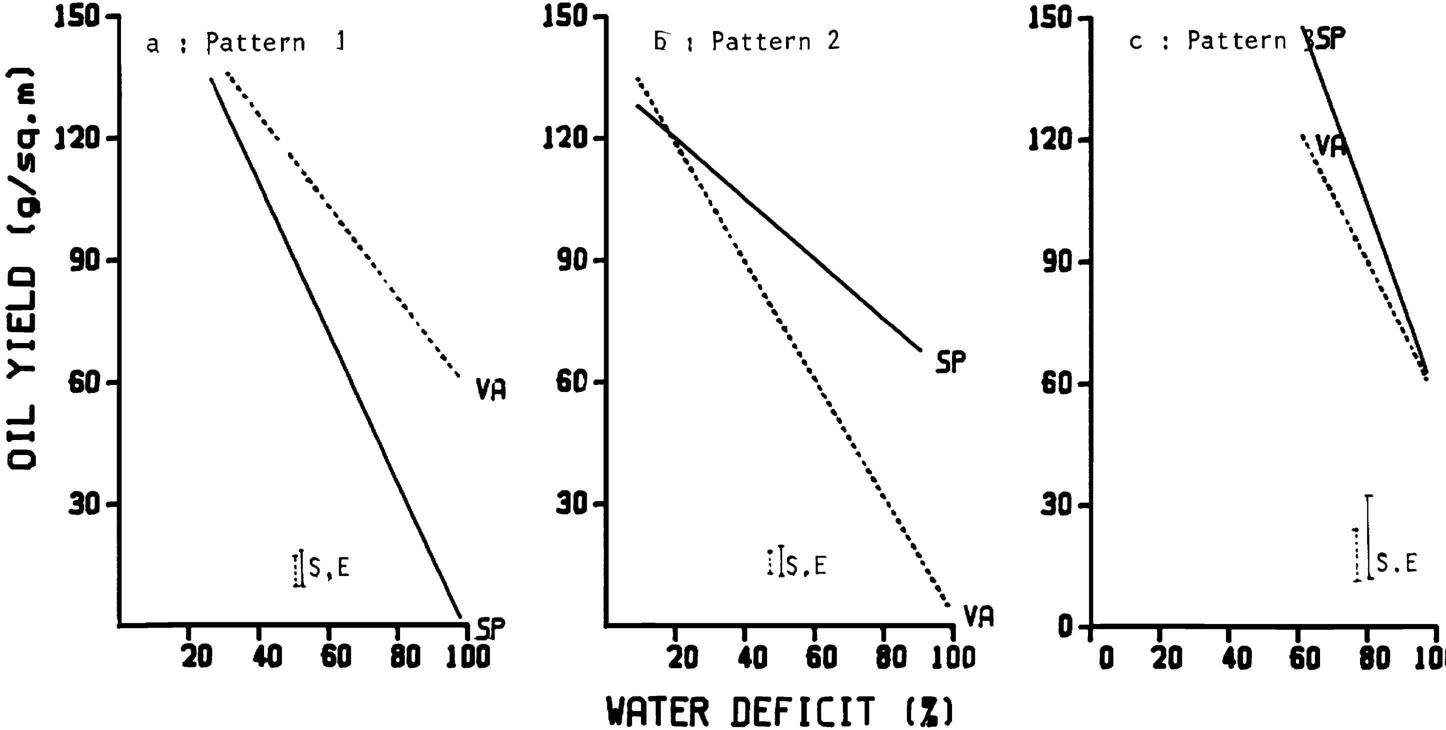

Fig .5 : Main effect of timing and intensity of drought on oil yield (Expt.II).

In pattern 1 (Fig 5a), the oil yield reduced as the drought intensity was increased. There was about 100 % reduction in the oil yield between non-stress plot (bed 1) and stressed plot (bed 8).

In pattern 2 (Fig 5b) and 3 (Fig 5c) the oil yield was reduced by about 50 % when the as water deficit increased from 30 % to 100 %.

4.3.2. GENOTYPE RESPONSE:

In pattern 2 (Fig 5b) and 3 (Fig 5c) spanish group in general was found to be superior in oil yield than valencia group at all intensities but in pattern 1 valencia was superior to Spanish at all ranges of water deficit.

In pattern 1 (Table 12a) all the spanish and valencia genotypes reduced the oil yield at all levels. Among the spanish genotypes there was significant reduction in GNP # 1061 at a rate of 2.26 gm oil / m^{-2} / % water deficit^{-1} and the least reduction was observed in GNP # 1122 at a rate of 1.04 gm oil/ m^{-2} / % water deficit^{-1}. Among the valencia lines, in GNP # 1094 showed significant reduction in oil yield at a rate of 2.40 gm oil / m^{-2} / % water deficit^{-1} , while in other cultivars the oil yield was reduced at a similar rate (mean 1.69 gm oil / m^{-2} / %

TABLE 12a: EFFECT OF TIMING AND INTENSITY OF DROUGHT ON OIL YIELD IN EXPERIMENT II

PATTERN 1 (DROUGHT APPLIED FROM 54 TO 138 DAS).

Cv.No GNP #	Sig	Oil Yield (gm)	S.E ±	Oil gm/ % water def^{-1}	S.E ±	% Var
2. 1050	S	201.2	9.2	-2.04	0.140	94
3. 1061	S	213.7	13.8	-2.26	0.234	89
4. 1081	S	173.2	11.7	-1.70	0.203	84
5. 1122	S	100.3	9.8	-1.04	0.170	72
6. 1143	S	184.9	14.6	-1.72	0.255	79
7. 1017	S	197.0	17.5	-1.91	0.304	75
8. 1053	S	185.2	17.6	-1.85	0.268	77
9. 1056	S	173.8	15.0	-1.73	0.227	82
10 1027	S	179.0	15.1	-1.79	0.277	77
11.1094	S	228.8	10.4	-2.40	0.170	94
12.1109.	S	124.2	8.7	-1.19	0.138	84
X(Cv2-6)	S	173.2	7.8	-1.73	0.122	93
X(Cv7-12)	S	145.5	6.7	-0.82	0.105	80

TABLE 12b

PATTERN II (DROUGHT APPLIED FROM 54 TO 89 DAS).

Cv.No GNP #	Sig	Oil Yield (gm)	S.E ±	Oil gm/ % water def^{-1}	S.E ±	% Var	CV%
2. 1032	S	139.9	16.1	-0.82	0.259	43	
3. 1061	S	154.4	13.4	-0.81	0.280	54	
4. 1081	S	145.6	14.7	-0.65	0.241	31	
5. 1122	S	79.9	6.6	-0.46	0.114	54	
6. 1143	S	143.1	14.3	-0.64	0.271	32	
7. 1017	S	172.9	12.2	-0.83	0.197	55	
8. 1053	S	171.0	12.3	-0.59	0.205	33	
9. 1056	S	157.6	9.1	-0.80	0.151	66	
10.1027	S	147.3	12.3	-0.70	0.202	44	
11.1094	S	165.4	19.4	-0.75	0.309	29	
12.1109	S	103.7	13.6	-0.18	0.241	19	
X(Cv2-6)	S	147.4	8.0	-0.69	0.133	63	
X(Cv7-12)	s	143.6	6.0	-1.38	0.100	93	

S :Significant NS : Non-significant P < 0.05% S.E : Standard error.

TABLE 12c : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON OIL YIELD IN EXPERIMENT II.

PATTERN III (DROUGHT APPLIED FROM 90 TO 138 DAS).

Cv.No GNP #	Sig	Oil Yield (gm)	S.E ±	Oil gm/ % water def^{-1}	S.E ±	% Var	CV%
1. 1050	S	209.1	29.9	-1.18	0.386	41	
2. 1061	S	313.0	26.9	-2.37	0.360	78	
3. 1081	S	225.2	26.5	-1.70	0.848	70	
4. 1122	S	181.2	23.5	-1.40	0.306	61	
5. 1143	NS	235.3	57.6	-1.52	0.751	19	
6. 1017	S	323.9	23.8	-2.83	0.309	86	
7. 1053	S	223.9	32.0	-1.38	0.432	41	
8. 1056	S	220.1	26.0	-1.71	0.337	67	
9. 1027	NS	174.2	43.4	-0.89	0.558	11	
10.1094	S	245.2	32.3	-1.92	0.422	58	
11.1109	NS	114.7	30.2	-0.63	0.397	10	
X(Cv2-6)	S	255.7	20.8	-1.83	0.274	74	
X(Cv7-12)	S	219.3	13.3	-1.59	0.175	85	

S :Significant NS : Non-significant $P < 0.05\%$ S.E : Standard error.

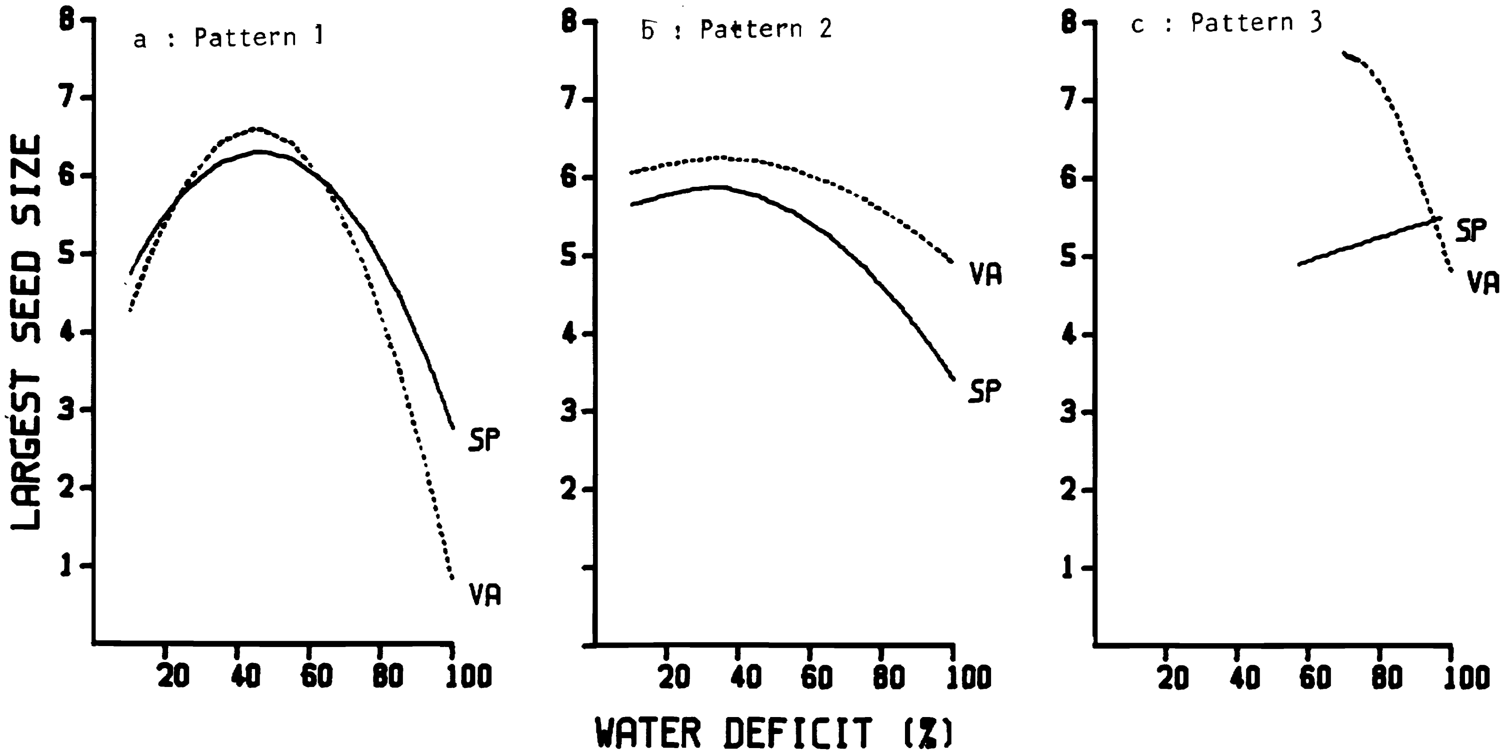

Fig. 6 : Main effect of timing and intensity of drought on largest seed size (sieve no.) (Expt. II).

size interms of sive number from 6 to 1.

In pattern 2 (Fig 6b), water deficit above 50 % reduced the seed size from 6 to 4.

In pattern 3 (Fig 6c) there was only a slight increase in the seed size as the water stress increased in Spanish genotypes and in case of valencia genotypes seed size in terms of sieve number reduced from 7 to 5.

In all patterns except pattern 3 spanish and valencia groups showed similar responses.

4.4.2. GENOTYPE RESPONSE :

In pattern 1 (Table 9a), water stress reduced the seed size in all the 11 cultivars with no apparent difference between the two taxonomic groups. However, among the spanish lines GNP # 1050 (sieve no.6) and 1122 (sieve no.6) recorded seed sizes above the mean (sieve no.5) at all levels of water deficit and in valencia GNP # 1017 (sieve no.7) and 1094 (sieve no. 6) were above the mean (sieve no.5) and GNP # 1053 (sieve no.4) had the lowest seed size.

In pattern 2 (Table 9b), among the genotypes tested GNP 1080 (sieve no.6) showed tolerance to reduction in seed size .pa whereas GNP # 1061 (sieve no.4) showed higher reduction in seed size due to increasing water deficit. Among the valencia group

Table 9a : LARGEST SEED SIZE (SIEVE NO.) IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 54 TO 138 DAS IN EXPERIMENT II.

INDEX :

Cv2 = GNP # 1050 Cv7 = GNP # 1017 B1 to B8 : Bed 1 to bed 8
Cv3 = GNP # 1061 Cv8 = GNP # 1053
CV4 = GNP # 1081 Cv9 = GNP # 1056
Cv5 = GNP # 1122 Cv10= GNP # 1027
Cv6 = GNP # 1143 Cv11= GNP # 1094
Cv12= GNP # 1109 * = Missing data.

CV	B1	B2	B3	B4	B5	B6	B7	B8
CV02R1	7	7	7	7	*	6	4	3
CV02R2	7	7	6	7	7	6	2	3
CV03R1	7	5	4	4	4	3	3	*
CV03R2	5	7	4	6	4	3	1	*
CV04R1	6	6	7	6	6	7	3	2
CV04R2	6	5	7	7	6	6	2	*
CV05R1	7	7	5	6	*	7	3	*
CV05R2	6	6	6	7	7	4	3	*
CV06R1	4	4	4	5	7	4	3	2
CV06R2	5	5	7	6	5	5	4	*
CV07R1	7	7	7	7	7	7	5	*
CV07R2	7	7	7	7	7	5	4	*
CV08R1	*	5	5	5	6	5	2	2
CV08R2	4	5	5	5	5	5	3	1
CV09R1	6	7	6	7	5	6	*	2
CV09R2	7	*	7	7	7	4	*	2
Cv10R1	6	6	7	7	6	6	2	*
Cv10R2	6	6	7	7	7	5	*	*
Cv11R1	7	7	7	7	7	*	2	1
Cv11R2	7	7	7	7	7	6	2	*
Cv12R1	6	6	6	7	6	6	5	2
Cv12R2	7	7	6	4	6	*	*	*

Table 9b : LARGEST SEED SIZE (SIEVE NO.) IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 89 TO 138 DAS IN EXPERIMENT II.

INDEX :

Cv2 = GNP # 1050 Cv7 = GNP # 1017 B1 to B8 : Bed 1 to bed 8
Cv3 = GNP # 1061 Cv8 = GNP # 1053
CV4 = GNP # 1081 Cv9 = GNP # 1056
Cv5 = GNP # 1122 Cv10= GNP # 1027
Cv6 = GNP # 1143 Cv11= GNP # 1094
Cv12= GNP # 1109 * = Missing data.

CV	B1	B2	B3	B4	B5	B6	B7	B8
CV02R1	7	*	7	7	7	*	5	5
CV02R2	6	5	*	7	5	5	6	5
CV03R1	5	5	4	6	*	4	3	3
CV03R2	*	5	5	7	5	4	4	3
CV04R1	7	6	6	*	5	5	3	4
CV04R2	7	7	7	6	7	5	6	4
CV05R1	6	5	6	7	*	5	5	4
CV05R2	6	6	7	6	6	6	4	4
CV06R1	5	5	7	6	5	5	4	*
CV06R2	4	5	5	5	5	5	5	*
CV07R1	7	6	7	7	6	6	5	4
CV07R2	7	7	*	4	7	7	*	3
CV08R1	6	4	5	5	6	4	5	3
CV08R2	5	5	5	4	4	4	5	3
CV09R1	7	5	6	5	*	7	3	5
CV09R2	7	7	6	5	5	5	4	5
Cv10R1	6	5	7	6	6	6	6	4
Cv10R2	7	7	6	7	*	6	4	5
Cv11R1	7	7	7	7	*	7	5	5
Cv11R2	7	7	6	*	7	7	7	3
Cv12R1	5	5	6	6	6	5	5	*
Cv12R2	6	7	5	6	7	6	6	5

Table 9c : LARGEST SEED SIZE (SIEVE NO.) IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 90 TO 138 DAS IN EXPERIMENT II.

INDEX :

Cv2 = GNP # 1050 Cv7 = GNP # 1017 B1 to B8 : Bed 1 to bed 8
Cv3 = GNP # 1061 Cv8 = GNP # 1053
CV4 = GNP # 1081 Cv9 = GNP # 1056
Cv5 = GNP # 1122 Cv10= GNP # 1027
Cv6 = GNP # 1143 Cv11= GNP # 1094
Cv12= GNP # 1109 * = Missing data

CV	B1	B2	B3	B4	B5	B6	B7	B8
CV02R1	6	7	7	7	7	7	7	5
CV02R2	7	*	7	*	5	*	6	7
CV03R1	5	4	4	5	*	5	4	4
CV03R2	7	5	5	*	4	6	3	*
CV04R1	7	7	7	7	6	6	7	6
CV04R2	7	*	7	*	6	5	*	6
CV05R1	6	7	7	7	*	6	7	6
CV05R2	7	7	7	*	6	6	5	7
CV06R1	5	*	6	5	5	5	5	4
CV06R2	5	5	7	*	5	6	5	6
CV07R1	*	7	7	7	6	6	5	7
CV07R2	*	7	7	7	7	5	*	6
CV08R1	4	4	5	6	4	*	4	4
CV08R2	6	4	5	5	5	3	4	5
CV09R1	7	5	6	5	6	5	7	4
CV09R2	7	7	7	*	7	5	5	4
CV10R1	6	5	5	5	6	7	5	6
CV10R2	*	*	6	6	6	7	5	4
CV11R1	7	6	7	7	5	7	5	6
CV11R2	7	7	7	6	7	6	5	5
CV12R1	6	6	7	7	6	7	6	6
CV12R2	7	*	7	*	5	7	7	6

GNP # 1056 (sieve no.6) and 1094 (sieve no.6) had larger seed relative to the mean (sieve no.5) across all levels of water deficits, while, GNP # 1053 (sieve no.4), showed rapid reduction in seed size relative to the mean.

In pattern 3 (Fig 4c) genotypic variation was noticed between spanish and valencia genotypes. Spanish genotypes increased the seed size with incresing water deficit while valencia genotypes reduced the seed size. However, in valencia group the seed size in GNP # 1017 (sieve no.6) and 1094 (sieve no.6) was above the mean (sieve no.5) at all levels of water deficit while GNP # 1053 (sieve no.4) seed size was lower than the mean.

4.5. EFFECT OF TIMING AND INTENSITY OF DROUGHT ON SHELLING PERCENTAGE

4.5.1. MAIN EFFECT OF INTENSITY OF DROUGHT WITHIN PATTERNS:

In pattern 1 (Fig 7a) there was an increase in shelling % upto 50 % water deficit and above 50 % water deficit the shelling percentage reduced from 70 to 40% (Fig 7a).

In pattern 2 (Fig 7b), there was a reduction in shelling percentage (from 70 to 60%) as water deficit increased (Fig 7b).

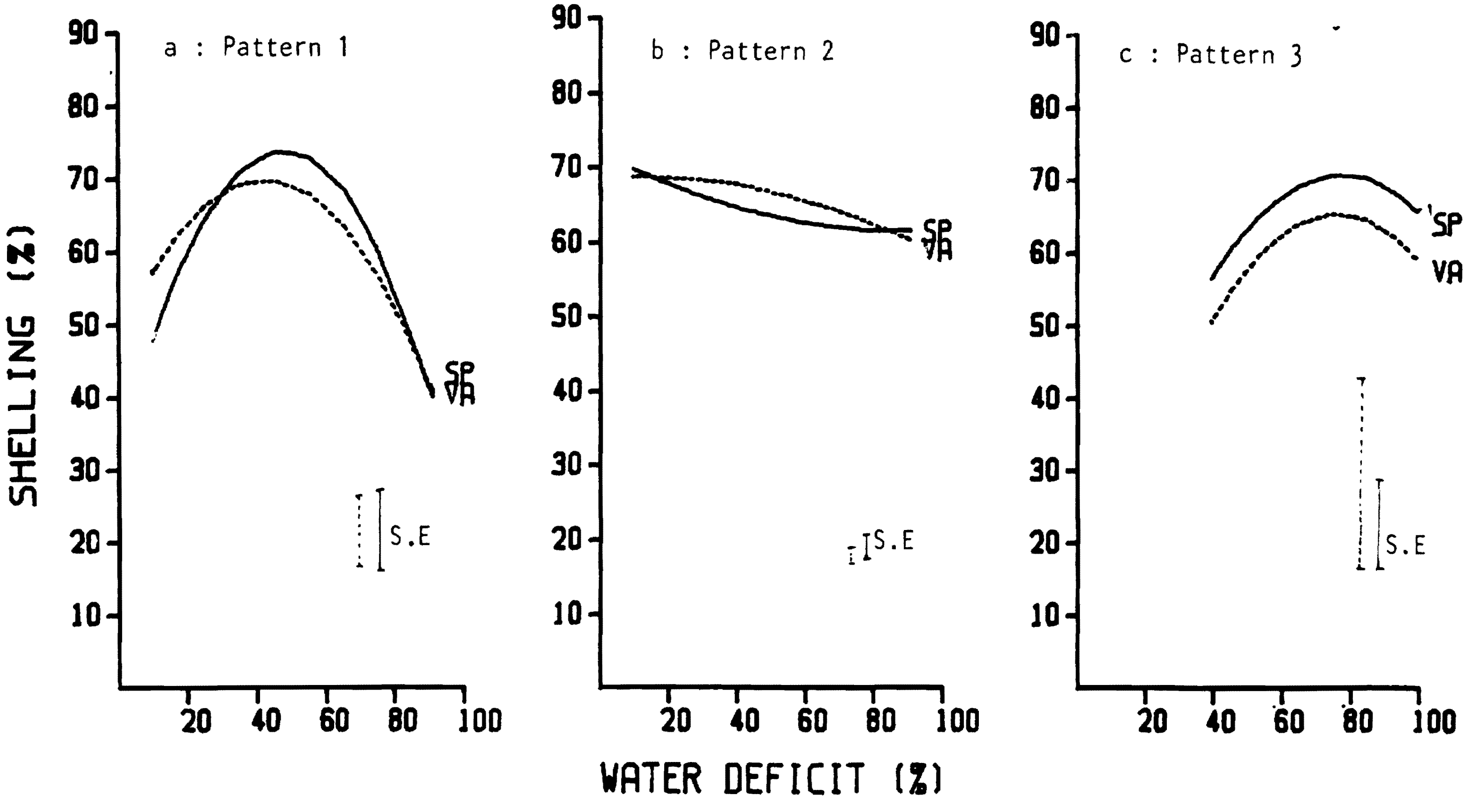

Fig. 7 : Main effect of timing and intensity of drought on shelling percentage (Expt. II).

In pattern 3 (Fig 7c) there was increase in shelling percentage upto 80% water deficit and further increase in intensity of drought reduced the shelling percentage from 70 to 60%.

The reduction in shelling percentage was similar and in a curvilinear fashion in both spanish and valencia groups in all the patterns.

4.5.2. GENOTYPE RESPONSE :

In pattern 1 (Table 13a) all the cultivars were affected similarly by water deficit. Among the spanish lines GNP # 1061 and 1122 recorded higher shelling % (66 and 67% respectively) than the mean (59%) and GNP # 1050 had lower shelling % (55%) than the mean (Table 7a). Among valencia genotypes GNP # 1053 and 1027 recorded higher shelling % (62 and 64% respectively) than mean (58%) and GNP # 1017 had lower shelling % (53%) relative to the mean (Table 7a).

In pattern 2 (Table 13b), all the cultivars of spanish did not reduce the shelling % due to water deficit. However, the valencia genotypes were affected by the water deficit. Among them GNP # 1027 and 1053 had higher shelling % (66 and 67% respectively) than mean (65%) and GNP # 1017 (64%) had lower shelling % than the mean at all levels of water deficit (Table 7b).

TABLE 13a : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON SHELLING PERCENTAGE IN EXPERIMENT II

PATTERN I (DROUGHT APPLIED FROM 54 TO 138 DAS).

Cv.No GNP #	Sig	Shel %	S.E ±	Shel %/ % water def^{-1}	S.E ±	Shel %/ % water def^{-1}	S.E ±	% Var
1. 1032	S	33.5	19.1	1.65	0.720	-0.018	0.0059	68
2. 1050	S	28.2	8.5	1.81	0.315	-0.020	0.0025	94
3. 1061	S	50.9	13.3	1.30	0.518	-0.012	0.0044	75
4. 1081	S	23.7	18.0	2.05	0.677	-0.215	0.0055	76
5. 1122	S	23.0	17.2	2.15	0.679	-0.021	0.0058	69
6. 1143	S	57.0	14.8	0.68	0.567	-0.008	0.0046	51
7. 1017	S	18.3	9.4	2.19	0.352	-0.023	0.0029	93
8. 1053	S	68.3	23.3	0.33	0.840	-0.006	0.0066	50
9. 1056	S	36.4	9.2	1.26	0.340	-0.014	0.0027	87
10.1027	S	45.7	11.0	1.18	0.427	-0.013	0.0037	79
11.1094	S	37.4	14.3	1.56	0.537	-0.018	0.0044	87
12.1109	S	75.5	28.4	-0.03	1.060	-0.004	0.0084	38
X(Cv 1-6	S	32.4	10.4	1.72	0.384	-0.018	0.0030	90
X(Cv 7-12)	S	48.3	9.0	1.01	0.333	-0.012	0.0027	90

TABLE : 13b

PATTERN II (DROUGHT APPLIED FROM 54 TO 89 DAS).

Cv.No GNP #	Sig	Shel %	S.E ±	Shel %/ % water def^{-1}	S.E ±	Shel %/ % water def^{-1}	S.E ±	% Var	CV %
1. 1032	NS	67.6	2.30						4.3
2. 1050	NS	58.2	13.40						28.2
3. 1061	NS	67.5	2.60						3.7
4. 1081	NS	64.2	5.18						10.5
5. 1122	NS	64.8	5.24						10.3
6. 1143	NS	68.0	2.93						5.3
7. 1017	S	63.3	2.21	0.350	0.1060	-0.0044	0.00097	78	
8. 1053	S	68.7	2.65	0.215	0.1280	-0.0027	0.00118	44	
9. 1056	S	65.2	2.15	-0.068	0.1090	-0.0003	0.00100	56	
10.1027	S	73.0	4.91	-0.157	0.2490	-0.0001	0.00228	39	
11.1094	S	69.7	1.71	0.063	0.0893	-0.0017	0.00082	81	
12.1109	NS	64.8	6.08						12.2
X(Cv 1-6)	S	72.1	3.08	-0.243	0.1490	0.0014	0.00137	33	
X(Cv 7-12)	S	68.7	1.73	0.026	0.0840	-0.0013	0.00077	73	

S :Significant NS : Non-significant $P < 0.05\%$ S.E : Standard error.

TABLE 13c : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON SHELLING PERCENTAGE IN EXPERIMENT II

PATTERN III (DROUGHT APPLIED FROM 90 TO 138 DAS).

Cv.No GNP #	Sig	Shel %	S.E ±	Shel %/ % water def^{-1}	S.E ±	Shel %/ % water def^{-1}	S.E ±	% Var	CV %
1. 1032	NS	66.9	28.40						3.6
2. 1050	S	31.7	16.00	1.02	0.423	-0.0072	0.0027	61	
3. 1061	NS	69.9	44.90						5.1
4. 1081	NS	68.8	24.70						3.2
5. 1122	NS	71.8	17.20						2.1
6. 1143	S	-110.3	32.70	4.66	0.858	-0.0294	0.0055	67	
7. 1017	S	64.4	27.90	0.19	0.732	-0.0023	0.0047	40	
8. 1053	NS	70.7	48.00						5.5
9. 1056	NS	62.4	47.20						6.6
10.1027	S	-160.5	85.80	5.60	2.240	-0.0336	0.0143	39	
11.1094	NS	64.7	91.20						12.9
12.1109	NS	68.9	49.90					25	6.5
X(Cv 1-6)	S	10.7	10.70	1.55	0.283	-0.0100	0.0018	66	
X(Cv 7-12)	S	1.2	22.50	1.67	0.592	-0.0105	0.0038	32	

S :Significant NS : Non-significant P < 0.05% S.E : Standard err

Table 7a : SHELLING PERCENTAGE IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 54 TO 138 DAS IN EXPERIMENT II

INDEX :

Cv1 = GNP # 1032   Cv7 = GNP # 1017   B1 to B8 = Bed 1 to Bed 8.
Cv2 = GNP # 1050   Cv8 = GNP # 1053
Cv3 = GNP # 1061   Cv9 = GNP # 1056
Cv4 = GNP # 1081   Cv10= GNP # 1027
Cv5 = GNP # 1122   Cv11= GNP # 1094
Cv6 = GNP # 1143   Cv12= GNP # 1109
\- = Missing data.

CV	B1	B2	B3	B4	B5	B6	B7	B8
Cv1R1	70.3	65.9	67.3	67.8	67.2	69.5	55.8	19.8
Cv1R2	68.8	66.6	66.1	71.3	67.7	52.6	17.3	-
Cv2R1	65.8	66.3	67.1	66.7	66.3	52.3	27.9	18.6
Cv2R2	66.3	66.9	64.7	64.3	66.6	63.5	37.9	16.4
Cv3R1	69.2	-	81.2	63.4	-	68.1	45.7	-
Cv3R2	70.5	71.2	71.4	70.4	69.3	59.2	41.9	-
Cv4R1	68.2	66.1	68.9	70.0	70.8	72.4	37.8	21.5
Cv4R2	65.1	65.8	70.0	65.3	64.3	57.3	12.6	-
Cv5R1	71.5	72.8	74.0	72.5	-	69.9	50.6	-
Cv5R2	63.5	65.3	73.7	68.2	79.7	60.8	28.4	-
Cv6R1	75.3	69.6	67.4	76.4	-	73.8	57.4	-
Cv6R2	71.5	69.1	73.4	56.9	64.7	66.8	53.6	40.4
Cv7R1	67.6	62.4	60.1	67.9	66.6	57.0	33.1	7.4
Cv7R2	63.0	66.1	66.5	68.6	66.5	55.7	27.8	-
CV8R1	-	70.2	72.3	73.2	73.2	69.1	48.4	45.9
Cv8R2	69.7	71.7	71.7	72.6	69.9	22.4	42.0	43.8
Cv9R1	66.9	59.8	63.4	63.6	59.2	58.4	40.3	33.1
Cv9R2	61.9	62.6	60.1	61.3	62.5	61.4	34.2	23.2
Cv10R1	70.0	66.7	71.8	70.7	72.0	65.2	39.4	-
Cv10R2	71.4	69.1	68.7	69.8	58.7	63.0	39.9	-
Cv11R1	68.3	69.0	67.9	66.8	69.6	-	12.9	15.0
Cv11R2	68.4	67.8	64.9	73.5	62.6	49.1	44.5	-
Cv12R1	73.1	87.5	76.1	69.6	33.1	75.5	30.6	22.6
Cv12R2	68.6	59.2	67.6	61.7	60.0	-	58.8	47.6

Table 7b : SHELLING PERCENTAGE IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 89 TO 138 DAS IN EXPERIMENT II

INDEX :

Cv1 = GNP # 1032 Cv7 = GNP # 1017 B1 to B8 = Bed 1 to bed 8.
Cv2 = GNP # 1050 Cv8 = GNP # 1053
Cv3 = GNP # 1061 Cv9 = GNP # 1056
Cv4 = GNP # 1081 Cv10= GNP # 1027
Cv5 = GNP # 1122 Cv11= GNP # 1094
Cv6 = GNP # 1143 Cv12= GNP # 1109
\- = Missing data.

Cv	B1	B2	B3	B4	B5	B6	B7	B8
Cv1R1	68.1	71.9	65.4	65.8	68.6	68.2	63.0	60.1
Cv1R2	70.8	-	66.3	68.9	66.0	69.2	69.9	63.4
Cv2R1	67.0	-	66.7	67.1	55.7	-	49.5	58.8
Cv2R2	66.8	63.2	-	65.7	64.8	57.3	56.7	54.5
Cv3R1	65.7	71.6	68.8	69.0	-	68.3	65.8	66.5
Cv3R2	-	-	70.4	62.6	68.1	64.5	66.5	65.4
Cv4R1	72.7	66.8	58.5	-	58.2	67.0	56.5	61.5
Cv4R2	65.0	83.9	63.0	59.4	61.7	70.1	64.9	58.7
Cv5R1	60.2	60.2	78.4	70.9	-	63.3	-	64.9
Cv5R2	70.2	72.1	70.0	69.2	63.2	52.2	62.0	53.7
Cv6R1	68.4	72.6	71.5	71.9	72.6	-	65.3	-
Cv6R2	71.9	69.3	69.1	64.3	-	60.1	-	65.8
Cv7R1	68.9	69.3	65.0	67.8	69.4	66.3	58.0	49.0
Cv7R2	64.1	67.6	-	70.7	69.2	66.3	62.1	55.6
Cv8R1	72.0	68.8	73.1	67.8	72.4	70.3	69.2	64.2
Cv8R2	68.7	74.4	72.5	74.6	70.9	69.6	70.7	55.3
Cv9R1	63.7	68.0	63.6	62.7	-	60.0	60.3	56.8
Cv9R2	64.8	63.6	62.8	59.4	57.4	62.4	56.7	51.1
Cv10R1	73.2	67.9	72.3	65.4	66.7	62.4	63.1	65.7
Cv10R2	67.1	79.1	68.1	61.1	-	63.3	44.3	54.7
Cv11R1	70.9	68.2	71.5	69.7	-	64.8	59.3	55.2
Cv11R2	70.7	70.2	69.6	-	65.1	67.9	62.8	61.4
Cv12R1	71.9	73.0	67.8	70.2	70.8	67.2	63.9	-
Cv12R2	64.6	67.5	68.6	68.8	47.1	45.2	64.2	62.7

TABLE 7c : SHELLING PERCENTAGE IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 90 TO 138 DAS IN EXPERIMENT II.

INDEX :

Cv1 = GNP # 1032 Cv7 = GNP # 1017 B1 to B8 = Bed 1t Bed 8
Cv2 = GNP # 1050 Cv8 = GNP # 1053
Cv3 = GNP # 1061 Cv9 = GNP # 1056
Cv4 = GNP # 1081 Cv10= GNP # 1027
Cv5 = GNP # 1122 Cv11= GNP # 1094
Cv6 = GNP # 1143 Cv12= GNP # 1109
\- = Missing data.

Cv	B1	B2	B3	B4	B5	B6	B7	B8
Cv1R1	71.3	66.0	64.3	66.0	-	66.1	68.8	64.4
Cv1R2	63.2	67.5	65.3	-	69.0	66.0	69.2	68.0
Cv2R1	66.0	65.9	69.3	67.5	65.7	65.5	64.7	61.2
Cv2R2	66.9	-	68.2	-	-	68.0	66.0	63.3
Cv3R1	70.0	60.4	68.6	69.8	-	68.9	70.6	68.5
Cv3R2	73.4	73.4	71.0	-	70.5	71.4	73.0	-
Cv4R1	69.4	68.6	70.3	71.6	70.5	68.6	67.7	67.5
Cv4R2	65.1	70.3	71.4	-	67.1	-	69.0	62.4
Cv5R1	70.0	70.4	68.2	70.6	70.8	73.2	73.2	70.7
Cv5R2	72.6	71.7	73.7	-	72.3	73.2	75.0	72.0
Cv6R1	56.3	-	73.5	71.4	77.1	71.7	71.6	63.7
Cv6R2	63.7	67.5	70.4	70.8	73.5	72.4	70.9	69.5
Cv7R1	66.6	70.9	67.3	65.3	67.8	61.4	66.5	63.4
Cv7R2	-	67.3	63.9	66.8	65.6	66.1	62.5	57.5
Cv8R1	65.3	68.1	73.2	64.0	64.7	-	72.4	-
Cv8R2	72.7	74.8	67.1	74.1	73.0	71.9	72.7	72.3
Cv9R1	62.3	-	61.0	63.2	51.1	61.8	62.2	57.4
Cv9R2	67.1	65.6	63.4	-	65.2	63.4	63.5	62.4
Cv10R1	33.1	66.8	67.7	68.3	68.4	63.9	69.0	70.1
Cv10R2	-	-	70.4	68.2	67.1	70.6	70.8	68.6
Cv11R1	66.7	37.7	69.9	57.5	71.7	69.7	66.3	65.7
Cv11R2	68.3	70.5	65.5	67.8	66.1	67.1	61.7	62.4
Cv12R1	68.0	69.3	72.6	67.8	69.2	73.8	75.3	66.6
Cv12R2	55.1	63.4	65.8	-	71.8	75.4	71.6	68.6

In pattern 3 (Table 13c) most of the cultivars in both spanish and valencia groups were not affected by water stress. However GNP # 1032 (spanish) recorded higher shelling % (72%) than the mean (69%) and GNP # 1122 (66%) had lower shelling % than the mean (Table 7c). Among the valencia cultivars GNP # 1109 and 1017 had higher shelling % (69 and 70%) than the mean (66%) and the shelling % of GNP # 1053 (65%) was lower than that of the mean at all levels of water stress (Table 7c).

4.6. EFFECT OF TIMING AND INTENSITY OF DROUGHT ON 100-SEED WEIGHT

4.6.1. MAIN EFFECT OF INTENSITY OF DROUGHT WITHIN PATTERNS :

In pattern 1 (Fig 8a) there was slight increase in 100-seed weight up to 40 % water deficit and above 40 % deficit there was severe reduction in 100-seed weight from 45g to 15 g as the water deficit increased.

In pattern 2 (Fig 8b) also there was reduction in the 100-seed weight (from 40 to 35g in spanish and 45 to 5g in valencia) as drought intensity increased.

In pattern 3 (Fig 8c) there was no change in 100-seed weight up to 70 % water deficit and increase in water deficit above 70 % decreased the 100-seed weight from 45 to 30g.

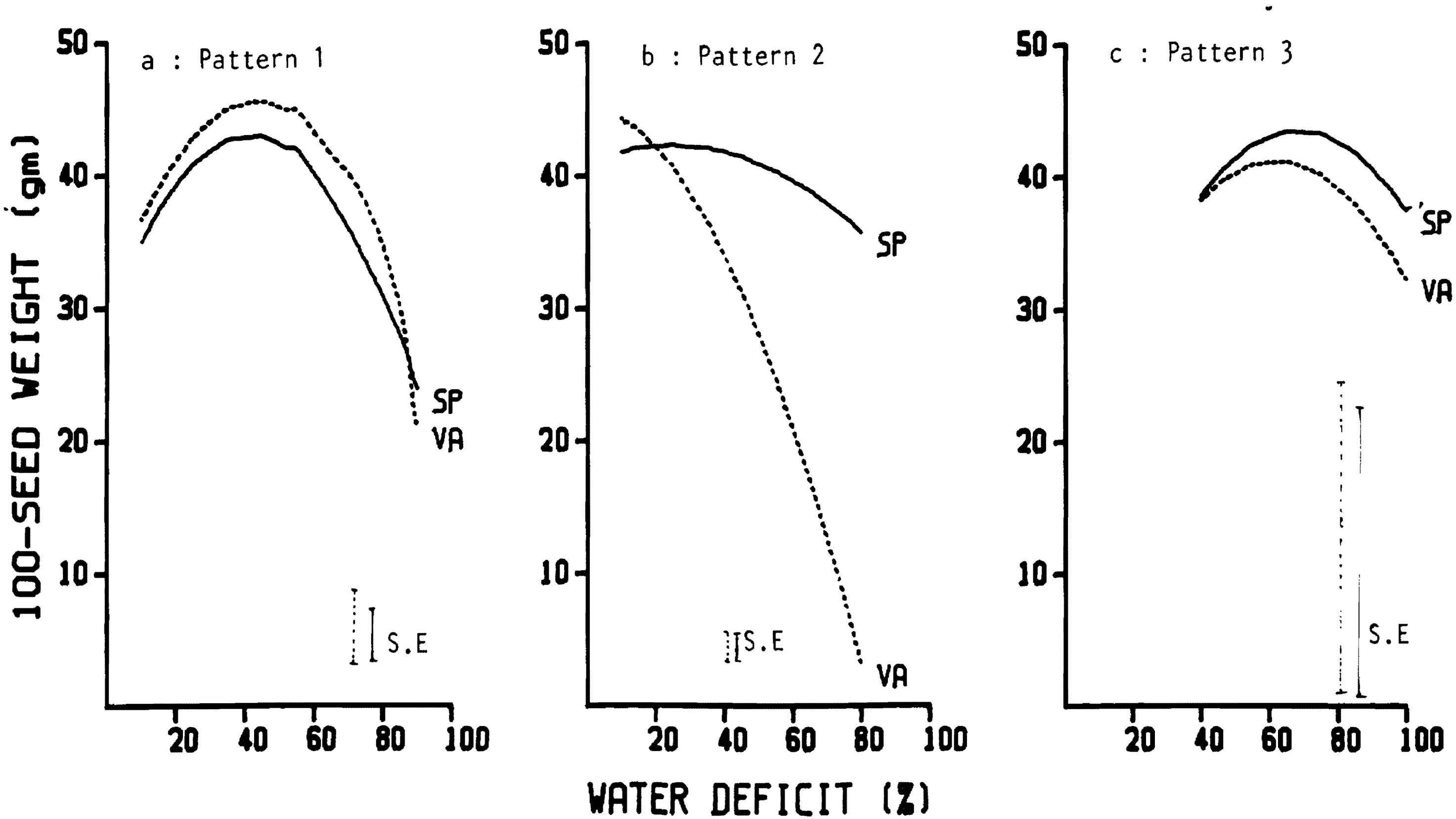

Fig. 8 : Main effect of timing and intensity of drought on 100-seed weight (g) (Expt.II).

The reduction in 100-seed weight in all the 3 patterns was in a curvilinear fashion.

In general valencia had higher seed weight than spanish but in pattern 3 spanish had higher 100-seed weight than valencia.

4.6.2. GENOTYPE RESPONSE :

In pattern 1 (Table 14a) 100-seed weight was reduced by increased water deficits in all the cultivars of spanish and valencia. However spanish genotype GNP # 1050 (39g) had higher seed weight than the mean (35g) and in GNP # 1061 (27g) and 1143 (32g) the 100-seed weight was lower relative to the mean (Table 8a). Among the valencia group GNP # 1109 (40g) and 1017 (45g) had higher seed weight than the mean (37g) and GNP # 1056 (35g) recorded lower seed weight than the mean at all levels of water stress (Table 8a).

In pattern 2 (Table 14b), all the cultivars showed reduction in the seed weight with increased water deficicts. Among them GNP # 1050 (46%) and 1081 (42%) had higher seed weight than the mean (39%) and GNP # 1061 (28g) and 1143 (33g) of spanish was observed to have lower seed weight than the mean at all levels of stress (Table 8b). GNP # 1094 (52g) and 1017 (44g) (valencia) recorded higher 100-seed weight than mean (41g) and GNP # 1053 (32g) had lower seed .pa weight relative to the mean in pattern 2 (Table 8b).

TABLE 14a : EFFECT OF TIMING AND INTENSITY OF DROUGHT ON 100-SEED WEIGHT (TEST WEIGHT) IN EXPERIMENT II.

PATTERN I DROUGHT APPLIED FROM 54 DAS TO 138 DAS.

Cv.No. GNP #	Sig	Test Wt. (g)	S.E ±	Test wt g/ % water deficit	S.E ±	Test.wt g/ % water deficit	S.E ±	% Var
1.1032	S	23.6	14.00	1.05	0.528	-0.011	0.0043	61
2.1050	S	49.7	6.29	0.17	0.237	-0.005	0.0019	94
3.1061	S	19.7	6.38	0.57	0.249	-0.007	0.0021	80
4.1081	S	21.8	6.33	1.11	0.242	-0.013	0.0020	94
5.1122	S	26.2	7.86	0.85	0.300	-0.010	0.0025	87
6.1143	S	21.9	7.29	0.77	0.270	-0.009	0.0022	82
7.1017	S	21.5	10.10	1.33	0.394	-0.014	0.0034	79
8.1053	S	3.9	7.96	0.99	0.286	-0.009	0.0022	68
9.1056	S	36.3	9.67	0.30	0.352	-0.005	0.0028	80
101027.	S	26.0	7.83	0.83	0.295	-0.010	0.0025	86
111094.	S	29.9	5.41	1.05	0.204	-0.012	0.0017	96
121109.	S	35.7	6.18	0.54	0.234	-0.007	0.0019	89
X(CV 1-6)	S	29.4	3.7	0.66	0.139	-0.008	0.0011	96
X(CV 7-12)	S	30.7	5.6	0.69	0.208	-0.008	0.0017	92

TABLE : 16b

PATTERN II DROUGHT APPLIED FROM 54 DAS TO 89 DAS.

Cv.No. GNP #	Sig	Test Wt. (g)	S.E ±	Test wt g/ % water deficit	S.E ±	Test.wt g/ % water deficit	S.E ±	% Var	CV %
1. 1032	S	48.4	2.17	0.004	0.1010	-0.0015	0.00091	79	
2. 1050	S	45.4	3.80	0.325	0.1750	-0.0044	0.00157	64	
3. 1061	S	32.0	1.42	0.001	0.0673	-0.0100	0.00597	87	
4. 1081	S	41.9	2.49	0.274	0.1250	-0.0039	0.00115	74	
5. 1122	S	43.2	2.10	0.056	0.1200	-0.0014	0.00118	52	
6. 1143	NS	33.1	1.82						5.8
7. 1017	S	49.5	4.08	-0.059	0.1950	-0.0007	0.00179	36	
8. 1053	S	34.3	2.03	0.028	0.1020	-0.0010	0.00940	52	
9. 1056	S	44.8	10.91	-0.184	0.0957	0.0003	0.00088	82	
10.1027	S	40.8	2.33	0.070	0.1180	-0.0014	0.00109	43	
11.1094	S	56.4	2.12	0.079	0.1110	-0.0024	0.00102	86	
12.1109	S	49.3	1.58	-0.232	0.0781	0.0013	0.00074	69	
X(CV 1-6)	S	41.2	1.51	0.101	0.0732	-0.0021	0.00067	82	
X(CV 7-12)	S	45.6	1.67	-0.050	0.0810	-0.0060	0.00741	75	

S : Significant NS : Non-significant P < 0.05% S.E Standard error.

TABLE 14c : EFFECT OG TIMING AND INTENSITY OF DROUGHT ON 100-SEED WEIGHT (TEST WEIGHT) IN EXPERIMENT II.

PATTERN III DROUGHT APPLIED FROM 90 DAS TO 138 DAS.

Cv.No. GNP #	Sig	Test Wt. (g)	S.E ±	Test wt g/ % water deficit	S.E ±	Test.wt g/ % water deficit	S.E ±	% Var	CV %
1. 1032	S	21.9	27.90	0.74	0.737	-0.006	0.0047	49	
2. 1050	NS	47.5	59.40						9.7
3. 1061	NS	29.0	25.70						7.1
4. 1081	NS	43.2	102						18.4
5. 1122	NS	44.0	86.6						17.7
6. 1143	S	8.0	36.50	0.84	0.956	-0.006	0.0061	14	
7. 1017	S	77.9	67.5	-0.54	1.740	0.001	0.0109	42	
8. 1053	NS	30.5	42.4						12.0
9. 1056	S	2.8	27.10	1.17	0.712	-0.009	0.0046	61	
10. 1027	S	13.5	27.80	0.83	0.725	-0.006	0.0046	37	
11. 1094	NS	50.5	62.3						10.7
12. 1109	S	10.5	31.00	1.12	0.823	-0.008	0.0053	48	
X(CV 1-6)	S	15.5	20.70	0.82	0.546	-0.006	0.0035	43	
X(CV 7-12)	S	18.4	22.70	0.74	0.599	-0.006	0.0039	50	

S : Significant NS : Non-significant P < 0.05% S.E Standard error.

Table 8a : 100-SEED WEIGHT (g) IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 89 TO 138 DAS IN EXPT II

INDEX :

Cv1 = GNP # 1032
Cv2 = GNP # 1050
Cv3 = GNP # 1061
Cv4 = GNP # 1081
Cv5 = GNP # 1122
Cv6 = GNP # 1143
\- = Missing data.

Cv7 = GNP # 1017
Cv8 = GNP # 1053
Cv9 = GNP # 1056
Cv10= GNP # 1027
Cv11= GNP # 1094
Cv12= GNP # 1109

B1 to B8 = Bed 1 to bed 8

Cv	B1	B2	B3	B4	B5	B6	B7	B8
Cv1R1	46.5	43.8	40.5	43.0	46.3	52.3	-	45.0
Cv1R2	44.6	45.2	54.3	46.0	42.7	38.7	-	-
Cv2R1	49.6	49.9	46.4	47.7	-	36.3	-	-
Cv2R2	51.4	49.7	51.3	46.5	38.9	35.3	18.6	-
Cv3R1	30.2	26.3	35.9	26.8	29.2	21.7	17.3	-
Cv3R2	32.0	30.5	29.8	31.5	31.6	20.7	-	-
Cv4R1	45.2	49.8	43.0	41.3	41.6	35.3	18.3	-
Cv4R2	42.3	40.9	43.1	47.4	-	34.6	-	-
Cv5R1	45.1	40.6	46.8	46.8	-	34.1	-	-
Cv5R2	-	42.3	40.6	41.4	44.8	-	-	-
Cv6R1	32.6	47.1	33.4	43.0	36.0	32.0	25.7	-
Cv6R2	34.6	38.6	37.4	41.0	36.1	27.9	20.0	14.9
Cv7R1	48.3	57.8	42.1	55.6	49.1	37.0	-	-
Cv7R2	49.0	47.0	45.3	51.5	53.0	42.8	-	-
Cv8R1	-	-	31.8	33.1	-	29.9	19.8	-
Cv8R2	28.1	22.9	22.1	30.5	29.7	26.2	-	-
Cv9R1	44.9	46.9	40.8	39.8	34.7	32.0	18.5	41.5
Cv9R2	39.0	-	30.6	33.7	37.6	-	-	-
Cv10R1	-	40.1	45.2	43.2	38.0	36.8	-	-
Cv10R2	42.1	-	43.7	41.9	38.6	-	-	-
Cv11R1	52.8	51.0	50.7	53.8	46.1	-	-	-
Cv11R2	49.0	49.5	47.9	47.6	52.9	37.0	-	-
Cv12R1	50.3	47.0	47.4	48.4	41.4	37.2	-	31.1
Cv12R2	41.1	44.1	45.3	47.1	-	-	32.6	28.6

Table 8b : 100-SEED WEIGHT (g) IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 90 TO 138 DAS IN EXPT. II.

INDEX :

Cv1 = GNP # 1032 Cv7 = GNP # 1017 B1 to B8 = Bed 1 to bed 8
Cv2 = GNP # 1050 Cv8 = GNP # 1053
Cv3 = GNP # 1061 Cv9 = GNP # 1056
Cv4 = GNP # 1081 Cv10= GNP # 1027
Cv5 = GNP # 1122 Cv11= GNP # 1094
Cv6 = GNP # 1143 Cv12= GNP # 1109
\- = Missing data.

Cv	B1	B2	B3	B4	B5	B6	B7	B8
Cv1R1	47.0	46.5	50.0	42.9	43.3	38.0	34.5	38.3
Cv1R2	50.7	-	46.1	48.4	43.8	45.2	37.8	30.2
Cv2R1	51.8	-	47.7	49.4	49.1	-	35.7	40.7
Cv2R2	46.6	48.0	-	52.7	50.1	49.8	44.7	25.6
Cv3R1	30.4	31.1	31.4	30.3	-	28.7	23.1	22.0
Cv3R2	-	33.0	33.2	31.1	28.4	25.2	22.6	23.0
Cv4R1	46.1	42.8	50.5	-	40.9	35.5	31.7	28.2
Cv4R2	41.0	46.2	45.6	46.3	46.3	46.1	38.9	35.4
Cv5R1	42.9	44.1	45.9	44.1	-	36.0	39.1	-
Cv5R2	41.7	42.7	44.0	45.8	-	36.0	39.1	-
Cv6R1	32.0	35.6	33.6	32.9	36.8	33.3	29.2	-
Cv6R2	-	35.2	34.4	31.3	35.8	33.6	33.7	29.3
Cv7R1	50.7	51.6	53.1	53.7	46.2	39.5	37.9	36.3
Cv7R2	43.9	49.6	-	35.4	38.0	42.8	43.2	35.4
Cv8R1	34.3	30.6	36.0	-	33.4	29.3	27.2	25.1
Cv8R2	34.8	40.5	30.8	32.4	32.1	33.0	30.3	27.9
Cv9R1	43.0	40.7	43.4	36.5	-	-	31.4	28.2
Cv9R2	47.9	37.2	39.5	38.6	37.6	34.3	30.0	30.2
Cv10R1	41.1	42.7	42.7	36.0	43.2	40.3	34.5	31.2
Cv10R2	45.2	37.1	41.1	41.6	-	40.6	-	35.4
Cv11R1	60.0	54.9	56.1	57.2	-	47.6	40.2	38.5
Cv11R2	55.5	58.7	55.1	-	51.0	54.4	43.1	44.1
Cv12R1	48.2	47.2	45.5	40.6	42.6	40.8	37.2	-
Cv12R2	46.7	44.4	45.3	42.7	39.3	37.3	43.2	37.7

Table 8c : 100-SEED WEIGHT (g) IN DIFFERENT GENOTYPES SUBJECTED TO VARIABLE DROUGHT INTENSITIES FROM 90 TO 138 DAS IN EXPT. II.

INDEX :

Cv1 = GNP # 1032 Cv7 = GNP # 1017 B1 to B8 = Bed 1 to bed 8
Cv2 = GNP # 1050 Cv8 = GNP # 1053
Cv3 = GNP # 1061 Cv9 = GNP # 1056
Cv4 = GNP # 1081 Cv10= GNP # 1027
Cv5 = GNP # 1122 Cv11= GNP # 1094
Cv6 = GNP # 1143 Cv12= GNP # 1109
- = Missing data.

Cv	B1	B2	B3	B4	B5	B6	B7	B8
Cv1R1	46.4	49.0	46.9	45.4	45.8	43.6	45.9	39.8
Cv1R2	41.9	50.9	47.8	-	46.4	44.1	38.7	40.4
Cv2R1	53.3	49.3	54.7	51.1	49.2	36.5	49.1	-
Cv2R1	46.9	-	45.9	-	-	48.8	44.0	40.4
Cv3R1	31.9	29.1	25.7	30.8	-	29.1	25.6	26.7
Cv3R2	27.6	30.8	32.5	-	30.2	28.0	26.9	-
Cv4R1	50.8	55.9	26.9	42.8	44.5	42.8	44.4	30.3
Cv4R2	45.5	43.7	45.7	-	-	-	-	41.6
Cv5R1	36.2	37.5	46.4	48.8	38.3	41.2	39.5	42.9
Cv5R2	44.0	49.8	42.9	-	41.6	67.5	41.5	37.0
Cv6R1	38.7	-	34.3	33.5	37.6	35.9	26.8	29.3
Cv6R2	34.3	36.1	35.8	38.1	39.1	37.6	-	36.0
Cv7R1	-	45.9	48.1	46.9	49.7	45.8	33.8	39.9
Cv7R2	-	44.7	56.3	44.4	41.2	35.1	37.1	38.7
Cv8R1	27.4	23.8	28.6	29.5	32.6	-	28.5	34.5
Cv8R2	34.4	36.0	34.8	31.9	28.3	28.3	31.0	28.9
Cv9R1	41.3	-	38.8	43.0	42.9	40.1	36.1	28.9
Cv9R2	41.0	42.7	38.9	-	39.6	38.6	35.1	37.8
Cv10R1	44.0	38.3	37.0	38.1	40.3	40.1	34.9	34.7
Cv10R2	-	-	43.3	42.7	42.1	39.8	39.1	35.6
Cv11R1	50.9	50.7	58.6	52.6	53.9	53.0	51.7	50.7
Cv11R2	54.1	42.3	50.7	53.0	-	45.3	36.7	49.2
Cv12R1	48.5	48.2	47.8	50.1	47.2	46.3	46.0	44.8
Cv12R2	45.2	49.2	45.4	-	-	45.9	43.4	35.2

In pattern 3 (Table 14c) GNP # 1032 (45g) and 1122 (47g) (spanish) had significantly higher seed weight than the mean (41g) and GNP # 1061 (29g) of spanish had lower seed weight than the mean (Table 8c). In the valencia genotypes GNP # 1094 (51g) and 1109 (46g) seed weight was observed to be above the mean and GNP # 1053 (31g) seed weight was below the mean at all levels of water deficits (Table 8c).

4.7. RELATIONSHIP BETWEEN SEED SIZE (SEED AREA) AND OIL CONTENT (%):

To examine the relationship between the seed size and oil content (%), the seeds of one genotype (GNP # 1032) from drought in Pattern 1 of Expt II were graded for their size and oil content (%) was seperately analysed for individual seed size. The relationship is presented in Fig 9. It is apparent that the oil content is positively associated to seed size (r=.85). The oil content increased from 37.6% in smallest seeds to 42.4% in largest seed size.

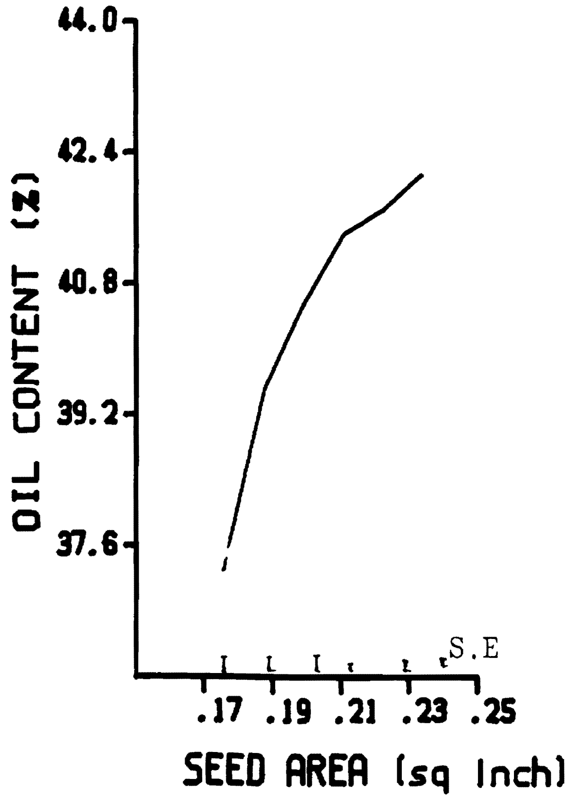

Fig 9 : Relationship between seed size (seed area) and oil content (%).

FIGURE LEGENDS

EXPERIMENT I

1. Fig 3a : Main effect of timing and intensity of drought on oil percentage in pattern 1 (drought applied from 29 to 56 DAS and 82 to 110 DAS).

$$Y = 41.6 - 0.02x \quad (\% \text{ Var} = 17\%)$$
$$\text{S.E} = (\pm 0.833) \quad (\pm 0.012)$$

2. Fig 3b : Main effect of timing and intensity of drought on oil percentage in pattern 3 (drought applied from 82 to 128 DAS).

$$Y = 16.3 + 0.691x - 0.0054x^2 \quad (\% \text{ Var} = 63\%)$$
$$\text{S.E} = (\pm 9.7) \quad (\pm 0.272) \quad (\pm 0.0018)$$

3. Fig 3c : Main effect of timing and intensity of drought on oil percentage in pattern 3 (drought applied from 93 to 128 DAS).

$$Y = 51.4 - 0.20x \quad (\% \text{ Var} = 85\%)$$
$$\text{S.E} = (\pm 1.34) \quad (\pm 0.018)$$

4. Fig 3d : Main effect of timing and intensity of drought on oil percentage in pattern 4 (drought applied from 66 to 92 DAS and 100 to 128 DAS).

$$Y = 48.2 - 0.15x \quad (\% \text{ Var} = 74\%)$$
$$\text{S.E} = (\pm 1.24) \quad (\pm 0.018)$$

EXPERIMENT II

5. Fig 4a : Main effect of timing and intensity of drought on oil percentage in pattern 1 (drought applied from 54 to 138 DAS).

Spanish

$$Y = 41.3 - 0.02x \quad (\%\ Var = 21\%)$$
$$S.E = (\pm 0.45) \quad (\pm 0.007)$$

6. Fig 4c : Main effect of timing and intensity of drought on oil percentage in pattern 3 (drought applied from 90 to 138 DAS).

Spanish

$$Y = 30.4 + 0.36x - 0.003x^2 \quad (\%\ Var = 90\%)$$
$$S.E = (\pm 6.10) \quad (\pm 0.161) \quad (\pm 0.0012)$$

Valencia

$$Y = 33.4 + 0.30x - 0.003x^2 \quad (\%\ Var = 85\%)$$
$$S.E = (\pm 7.29) \quad (\pm 0.192) \quad (\pm 0.0012)$$

7. Fig 5a : Main effect of timing and intensity of drought on oil yield in pattern 1 (drought applied from 54 to 138 DAS).

Spanish

$$Y = 173.2 - 1.73x \quad (\%\ Var = 93\%)$$
$$S.E = (\pm 7.8) \quad (\pm 0.122)$$

Valencia

Y = 145.5 - 0.82x (% Var = 80%)

S.E = (±6.7) (±0.105)

8. Fig 5b : Main effect of timing and intensity of drought on oil yield in pattern 2 (drought applied from 54 to 89 DAS).

Spanish

Y = 147.4 - 0.69x (% Var = 63%).

S.E = (±8.0) (±0.133)

Valencia

Y = 143.6 - 1.38x (% Var = 93%).

S.E = (±6.0) (±0.100)

9. Fig 5c : Main effect of timing and intensity of drought on oil yield in pattern 3 (drought applied from 90 to 138 DAS).

Spanish

Y = 255.7 - 1.83x (% Var = 74%)

S.E = (±20.8) (±0.274)

Valencia

Y = 219.3 - 1.59x (% Var = 85%)

S.E = (±13.3) (±0.175)

10. Fig 6a : Main effect of timing and intensity of drought on largest seed size (sieve no.) in pattern (drought applied from 54 to 138 DAS).

Spanish

$Y = 3.78 + 0.11x - 0.0012x^2$ (% Var = 88%)

S.E = ($\pm$0.922) ($\pm$0.034) ($\pm$0.00027)

Valencia

$Y = 2.78 + 0.17x - 0.0019x^2$ (% Var = 95%)

S.E = ($\pm$0.778) ($\pm$0.029) ($\pm$0.00023)

11. Fig 6b : Main effect of timing and intensity of drought on largest seed size (sieve no.) in pattern 2 (drought applied from 54 to 89 DAS).

Spanish

$Y = 5.4 + 0.03x - 0.0005x^2$ (% Var = 81%).

S.E = ($\pm$0.27) ($\pm$0.013) ($\pm$0.00012)

Valencia

$Y = 5.9 + 0.02x - 0.0003x^2$ (% Var = 58%).

S.E = ($\pm$0.37) ($\pm$0.019) ($\pm$0.00017)

12. Fig 7a : Main effect of timing and intensity of drought on shelling percentage in pattern 1 (drought applied from 54 to 138 DAS).

Spanish

$Y = 32.4 + 1.72x - 0.018x^2$ (% Var = 90%).

S.E = ($\pm$10.4) ($\pm$0.384) ($\pm$0.0030)

Valencia

$$Y = 48.3 + 1.01x - 0.012x^2 \text{ (\% Var = 90\%).}$$

$$S.E = (\pm 9.0) \quad (\pm 0.333) \quad (\pm 0.0027)$$

13. Fig 7b : Main effect of timing and intensity of drought on shelling percentage in pattern 2 (drought applied from 54 to 89 DAS).

Spanish

$$Y = 72.1 - 0.243x + 0.0014x^2 \text{ (\% Var = 33\%)}$$

$$S.E = (\pm 3.08) \quad (\pm 0.1490) \quad (\pm 0.00137)$$

Valencia

$$Y = 68.1 + 0.026x - 0.0013x^2 \text{ (\% Var = 73\%)}$$

$$S.E = (\pm 1.73) \quad (\pm 0.026) \quad (\pm 0.00077)$$

14. Fig 7c : Main effect of timing and intensity of drought on shelling percentage in pattern 3 (drought applied 90 to 138 DAS).

Spanish

$$Y = 10.7 + 1.55x - 0.0100x^2 \text{ (\% Var = 66\%)}$$

$$S.E = (\pm 10.70) \quad (\pm 0.283) \quad (\pm 0.0018)$$

Valencia

$$Y = 1.20 + 1.679x - 0.0105x^2 \text{ (\% Var = 32\%)}$$

$$S.E = (\pm 22.50) \quad (\pm 0.593) \quad (\pm 0.0038)$$

15. Fig 8 a: Main effect of timing and intensity of drought on 100-seed weight (test weight) in pattern (drought applied from 54 to 138 DAS).

Spanish

$Y =$	29.4 +	0.139x −	$0.0080x^2$ (% Var = 96%)
S.E =	(±3.7)	(±0.139)	(±0.0011)

Valencia

$Y =$	5.6 +	0.208x −	$0.008x^2$ (%Var = 92%)
S.E =	(±5.6)	(±0.208)	(±0.0017)

18. Fig 8b : Mean effect of timing and intensity of drought on 100-seed weight (test weight) in pattern 2 (drought applied from 54 to 89 DAS).

Spanish

$Y =$	41.2 +	0.101 −	0.0021 (% Var = 82%).
S.E =	(±1.51)	(±0.0732)	(±0.00067)

Valencia

$Y =$	45.6 −	0.050 −	0.0060 (% Var = 75%).
S.E =	(+1.67)	(+0.0810)	(+0.00741)

19. Fig 8c : Mean effect of timing and intensity of drought on 100-seed weight (test weight) in pattern 3 (drought applied from 90 to 138 DAS).

Spanish

$Y =$	15.5 +	0.82 −	0.006 (% Var = 43%)
S.E =	(=20.70)	(±0.546)	(±0.0035)

Valencia

$Y =$	18.4 +	0.74 −	0.006 (% Var = 50%).
S.E =	(+18.4)	(+0.74)	(±0.0039)

DISCUSSIONS AND CONCLUSIONS

6.DISCUSSION AND CONCLUSIONS

Groundnut (Arachis hypogaea. L.) is largely grown in rainfed conditions in India, although it is also grown in post rainy season subject to the availability of irrigation. Bulk of the production is used for oil production in our country unlike in Western countries where it is mostly used for confectionary purposes. In India 1,156 thousand tonnes (Anonymous, 1980/81) of groundnut oil is produced per year compared to world average of 3,254 thousand tonnes (Anonymous, 1981/82).

It is well known that the groundnut yields realised under rainfed conditions are very low and highly variable and one of the main factors which contribute to the low yields under these circumstances is erratic rainfall resulting in drought of variable timing and intensities. Realisation of low yield also influences oil production by affecting pod yield/unit ground area as well as oil content in seed itself. However information is available in literature about drought effects on crop yields in general, but very little information is available on the effect of drought with variable timings and intensities on seed quality and oil.

In the present study, effects of droughts with variable timings and intensity on oil productivity was examined in seed material in a range of genotypes collected from 2 different experiments conducted at ICRISAT centre during 1982-'83 and 1983-'84 post rainy season.

In Experiment I and II droughts with variable intensities were created in 4 and 3 patterns respectively. Among these, pattern 3 of both the experiments (drought occurring from 93 to 128 DAS and 89 to 138 DAS in Expt I and II respectively) resulted in severe reduction of oil content. This phase corresponds with active seed filling phase in crop's life.

It is also observed that drought during seed filling phase reduced the seed yield (Davidson et al., 1973) as well as oil percentage (Yao et al.,1983) as is the case in this study also.

However, multiple droughts during the podding and seed filling phase (pattern 4) drought from 66 to 92 DAS and 100 to 128 DAS resulted in less reduction in oil percentage relative to the shorter droughts during the end of the season. Droughts with intermittent releases as in the case of pattern 1 and pattern 4 in Expt. I had little effect on oil percentage. It is possible that the drought during pod initiation phase would have reduced the number of pegs to penetrate into the soil as found by Balasubramanian et al . (1981) resulting in fewer pods to exploit the soil environment in a better way.

The subterranean nature of pods in this crop makes the phenomenon of drought and its effects more complex. Even the small showers during the seed filling phase may be of critical importance for the seed development since it is found that the water and other nutrients like (Ca^{++}) are absorbed by pods independently (Skelton and Shear,1971). Drought during the seed filling phase depending on the intensity may limit the availability of moisture and Ca^{++} to developing pods.

Water deficit in general results in stomatal closure leading to reduction or inhibition of gaseous exchange from the leaves. It is possible that the non-availabiltiy of photosynthates to the seed may affect oil systhesis as well. The oil synthesis is affected due to lack of photosynthates as most of the fats are synthesied from the photosynthate by Gluconeogenesis pathway.

Another stress factor that may be associated with drought at seed filling stage is high soil temperatures. It is possible that lack of availability of moisture associated with high temperature may inhibit seed metabolism affecting oil synthesis. However it is known from the basic enzymological work that the optimum range of temperature for most of the enzyme activity is 24-34^{0}C and temperature above this can cause denaturation of enzymes due to break in the amino acid chain of the proteins.

In Expt II among the droughts (P1 & P3 where the droughts were from 54 to 138 DAS and 90 to 138 DAS respectively reduced the shelling % severely in a curvilinear fashion. In pattern 1 and 2 (drought from 54 to 138 DAS and 89 to 138 DAS respectively) reduced the seed size in a curvilinear fashion. All the patterns, 1, 2, and 3 (drought from 54 to 138 DAS, 54 to 89 DAS and 90 to 138 DAS respectively) reduced the 100-seed weight.

The moisture deficit during pegging and pod development resulted in reduction of shelling percentage, seed size and 100-seed weight (Balasubramanian et al., 1981 ; Sarma, 1983 ; Stern, 1968 ; Reddy, 1978 ; Pallas et al., 1977) due to immature seeds or shrivelled seeds and unfilled pods which may also be due to high soil temperature (De Beer, 1963 ; Ono et al.,1974). It was found by Ono et al. (1974) that the optimum temperature for pod development is 31-33° , while 15-17°C is minimum and 37-39°C is the maximum. Adequate moisture in pod zone enable peg penetration and initiation of pod development (Skelton and Shear, 1971 and Sarma, 1983).

The peanut plant can partially compensate for an early drought period by initiating a flush of reproductive growth when moisture becomes adequate, but this may require delaying harvest time until later fruits mature (Vivekanandan and Gunasena, 1976).

In patterns 1, 2 and 3 in Expt II, the weight per pod was lower because the late fruits lacked time to fill. This differs from , a late season water deficit which may also cause lower weight per pod by reducing the photosynthate availability to fill the pod. Similar to their findings, in the present study also the seed weight reduced as the harvest was not delayed to the peanut plants which experienced early drought.

The oil analysis from graded seed showed that seed size and oil % are positively associated. The increase in seed size resulted in increased oil content.

Based on the above discussion, the following conclusions are drawn :

1. Moisture stress during the seed filling stage severely reduced oil content and oil yield.

2. Moisture stress during pod development to maturity did not much affect the oil content.

3. Moisture stress during flowering and pegging had little effect on the oil content but reduced the oil yield by affecting the seed yield.

4. Variety vulgaris (Valencia) gave higher oil content than var fastigiata (spanish) even under drought conditions.

5. Moisture stress from flowering to seed filling was found to be critical as this affected shelling %, 100-seed weight, seed size and oil content.

6. Moisture stress during filling stage did not have severe

impact on shelling %.

7. Positive association was observed between seed size and oil content.

SUMMARY

SUMMARY

The effect of moisture stress on seed quality was investigated in seed samples of a range of groundnut genotypes collected from field experiments conducted during 1982-'83 and 1983-'84 post rainy seasons at the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Patencheru, Hyderabad. Variable levels of water stress was imposed on the crop at different phases in the field by line source sprinkler system. The oil analysis was done using Nuclear Magnetic Resonance technique (NMR) and Soxhlet methods.

The results indicated that there was severe reduction in the oil % and oil yield when moisture stress occurred during the seed filling stage. In treatments where drought occurred from pod development to maturity (54 to 138 DAS in pattern 1 of Expt.II) there was not much reduction in the oil %. Stress during flowering and pegging had little effect on the oil % but did reduce the oil yield mainly by affecting the seed yields. Variety *vulgaris* (Valencia) of sub-species *fastigiata* had higher oil content than variety *fastigiata* (Spanish) at all levels of irrigation treatments.

The analysis of other parameters related to marketable seed quality indicated that moisture stress during flowering and pod development reduced the shelling percentage at all levels of moisture stress, but, stress during seed filling stage did not

have severe impact on shelling percentage.

Moisture stress during flowering, pod development and seed filling stage reduced the 100-seed weight in all the cases but there was severe reduction for the samples which experienced drought during flowering stage. Moisture stress during flowering and pod development reduced the seed size similar to 100-seed weight. Water stress during seed filling stage did not reduce the seed size.

Positive association was observed between seed size and oil content.

Moisture stress during flowering stage reduced the shelling %, 100-seed weight and seed size while oil content was affected with moisture stress during seed filling stage. Hence the critical stage for seed quality in groundnut is from flowering to seed filling.

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EFFECT OF MOISTURE STRESS ON SEED QUALITY IN GROUNDNUT GENOTYPES

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