

TESTS FOR DROUGHT RESISTANCE IN  
PEARL MILLET  
(PENNISETUM TYPHOIDEUM)

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## CHAPTER I

### INTRODUCTION

The ability of a plant to grow and yield in arid and semi-arid regions depends upon the ability of the plant to grow under drought conditions. This ability varies among genera, species, and within species. The objectives of this study were (a) to investigate differences of drought resistance among pearl millet varieties (Pennisetum typhoideum, L. Rich.), (b) to study different techniques for measuring drought resistance, and (c) to compare different techniques.

## CHAPTER II

### LITERATURE REVIEW

Several methods for testing drought resistance of different crops have been reported (1,2,3,9,10), but no single investigation has been done on pearl millet. Kramer (6) considers drought as a deficiency of soil moisture which causes water deficits in plants severe enough to reduce plant growth. Wright (17) suggested a definition for drought-tolerant range grasses as "those plants which are able to establish, develop, and maintain themselves through drought periods by efficient and economical use of soil moisture." According to Levitt et al. (7), drought is the potential of the environment to influence water loss from the plant. He envisioned drought as consisting of two components: avoidance and tolerance. Both components should be considered in drought-resistance measurements. The literature on the effects of drought on plant growth and production is very extensive and has been thoroughly covered in several publications (1,5,6,12,14, 15).

Osmotic solutions have been expediently used in the drought resistance studies to control water absorption.



Thimann (13) believes that d-mannitol, a hexanhydric alcohol, which is nontoxic to seeds (16), is the best chemical to control osmotic pressures or limit water uptake by plants without affecting the metabolic action of the plant. Some investigators (3,10) have successfully used d-mannitol solutions for drought resistance studies. This chemical is water soluble, and osmotic pressures up to 15 atmospheres may be easily prepared with it.

Recently, Kaloyereas (4) reported a new method of using chlorophyll stability for measuring relative drought resistance. He used chlorophyll stability index (C.S.I.) which is the difference between the colorimetric readings of chlorophyll extract from heated and unheated extracts of leaf samples. He concluded that C.S.I. appears to be a more reliable test of drought resistance than bound water or extractable sulfhydryl groups. Modification of the chlorophyll stability technique has been suggested by Sahadevan (11) and Murty and Majumder (9).

## CHAPTER III

### MATERIALS AND METHODS

Five varieties of pearl millet were obtained and evaluated for drought resistance: Harlan's Bulk and Kutch Bulk from the Fort Reno Livestock Research Station, El Reno, Oklahoma; No. 1 Tifton late synthetic and No. 1 Tift 23 A x Tifton late synthetic pearl millet from G. W. Burton, Georgia Experiment Station, Tifton, Georgia; and Gahi-1 pearl millet certified seed from the Valley Feed and Seed Company, Phoenix, Arizona. Harlan's Bulk was made up of collections from Rajasthan, India, where pearl millet is grown at the edge of the desert under 10 inches of annual rainfall. This variety was expected to be the most drought tolerant. Kutch pearl millet is grown in the Kutch area of India. All of the varieties were 1965 seed. Three different methods were used: a greenhouse pot study using soil and various soil moisture regimes, osmotic solutions of d-mannitol for laboratory germination tests, and chlorophyll stability index of 4-week-old plant leaves.

#### Greenhouse Pot Study

Four varieties of pearl millet (Harlan's Bulk,

Tifton, Tift x Tifton, and Gahi-1) were tested for drought resistance by allowing the soil to dry to three different soil moisture tensions ( $1/3$  atm, 1, and 3 atm). It was found in previous experiments, using 8, 10, and 15 atm of soil tensions as the maximum soil water stress, that plants would not survive. A randomized complete block design, three replications of each variety and soil water tension combinations, was used. The percentage moisture content at the desired level of soil water tension was determined with a pressure membrane apparatus. Three kilograms of air-dried Brewer silty clay loam soil were placed in each pot. Eight seeds of each variety were planted per pot and were considered an experimental unit. The Kutch pearl millet strain was not included in this investigation.

All plants were allowed to grow for four weeks before imposing the treatments. Pots to be subjected to 1 and 3 atm of soil tension were allowed to dry down to the intended soil moisture which was measured by pot weight during the next two weeks. Six-week-old plants were harvested and plant heights and weights measured.

#### Mannitol Study

Solutions of 3, 6, 8, 10, and 12 atm of osmotic pressure were prepared from d-mannitol and distilled water. Plastic boxes with lids were used as germination containers. Absorbent tissue was placed on the bottom of each

container. Distilled water was used as a check. A box containing 50 seeds was considered as an experimental unit. A randomized complete block design was applied with four replications (one replicate per tray). Each box was sealed with tape to prevent evaporation and placed in a germinator at 30 - 35 C with a high humidity for 7 days. To prevent growth until all counts and measurements could be made, boxes were then placed in a refrigerator.

All five pearl millet varieties were tested for drought resistance by this method. Percentage germination of seeds and length of seedling development were determined.

#### Chlorophyll Stability Index (C.S.I.)

A 100 mg sample of fresh, healthy unblemished leaf material excluding the apical and collar regions was placed in 5 ml of 95% ethanol solution and ground with a glass homogenizer. The chlorophyll extract was then filtered and more ethanol was added to bring up the volume to 30 ml. The optical density of one portion of this solution was measured. Another portion of the chlorophyll extract was heated in a temperature-controlled waterbath at  $56 \pm 1^{\circ}\text{C}$  for exactly 30 minutes. The optical density of the heated chlorophyll extract was then measured. The difference between the two readings was recorded as chlorophyll stability index (C.S.I.). This test was made on all five pearl millet varieties.

## CHAPTER IV

### RESULTS AND DISCUSSION

#### Greenhouse Pot Study

The number of germinated seeds per pot in the greenhouse pot study was unequal. These germination percentages were 98.62, 83.37, 80.50, and 76.37 for Tifton, Gahi-1, Harlan's Bulk, and Tift x Tifton, respectively. Duncan's multiple range test at the 5% level showed that seed germination of Tifton pearl millet was better than the other pearl millet varieties. These germination differences may be attributed to the influence of soil moisture tension or differences in seed quality.

The behavior of the varieties to soil water stress indicates the ability of the varieties to survive under drought conditions. No variety x soil water tension interaction existed for plant length (Figure 1) or dry weight (Figure 2). This indicated that in the greenhouse pot study there was no measurable differences in the behavior pattern of pearl millet varieties, (Harlan's Bulk, Tifton, Tift x Tifton, and Gahi-1) under different soil moisture regimes. Consequently, moisture effects and varietal effects were studied on the averages.

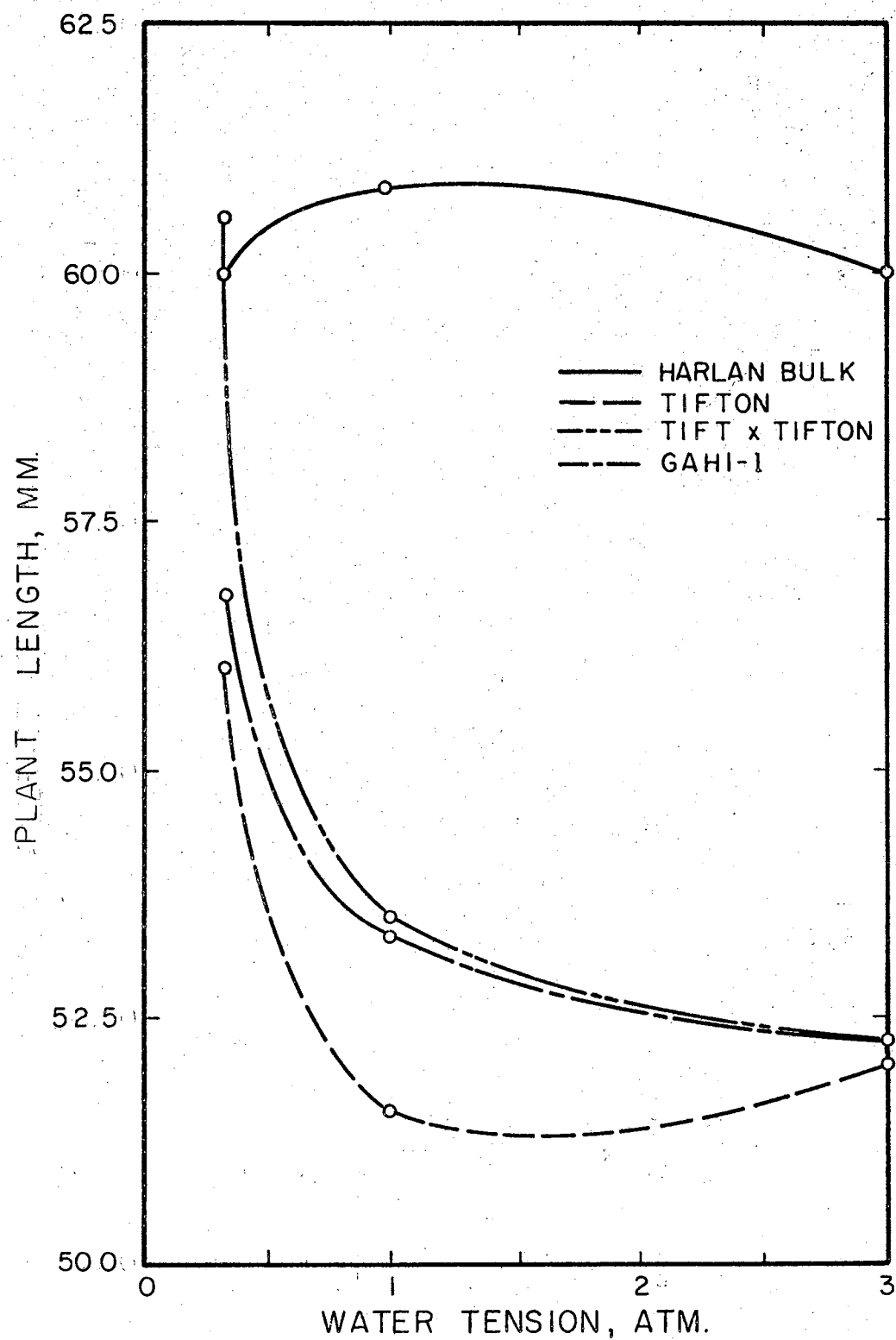


Figure 1. Average Plant Length in Millimeters After Six Weeks' Growth at Three Levels of Moisture

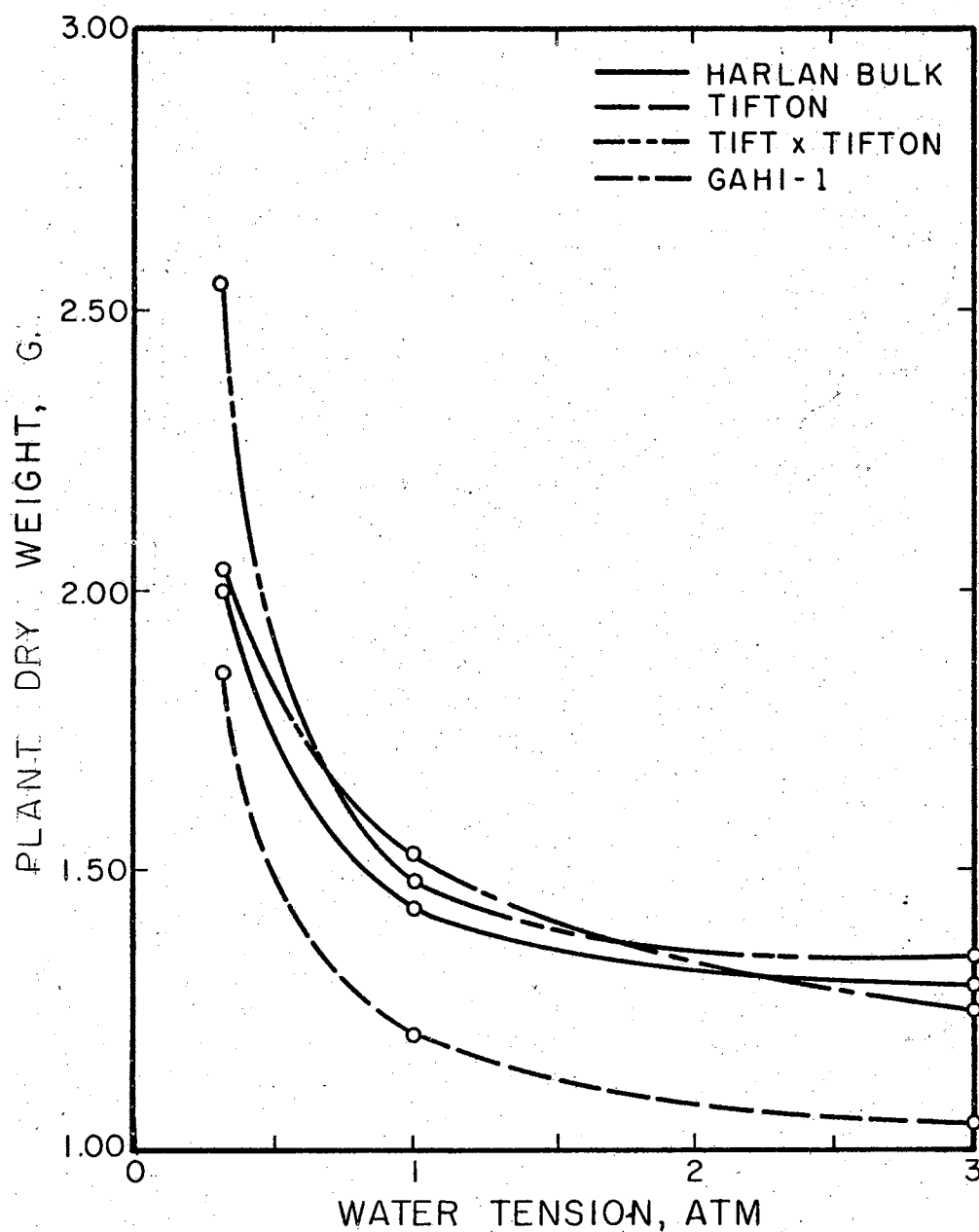


Figure 2. Average Plant Dry Weight in Grams After Six Weeks' Growth at Three Levels of Moisture

Moisture effects were significantly different at the 1% level for average plant length (Table I) and dry weight (Table II). The 1/3 atm treatment was significantly different at the 5% level from both 1 and 3 atm of soil moisture tension, but a significant difference was not detected between soil tensions of 1 and 3 atm. Differences among varieties were significant at the 1% level for average plant length (Table I), and at the 5% level for average plant dry weight (Table II). The ascending ranking of the varieties for average plant length<sup>3</sup> was:

<u>Tifton</u>	<u>Gahi-1</u>	<u>Tift x Tifton</u>	Harlan's Bulk
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and for average plant dry weight<sup>3</sup>:

<u>Tifton</u>	<u>Harlan's Bulk</u>	<u>Gahi-1</u>	<u>Tift x Tifton</u>
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Perhaps the reason that Harlan's Bulk exhibited generally greater length (Figure 1) under most moisture tension is because of its area of origin. These materials came from the northwest Indian desert where the annual rainfall is 10 inches.

Furthermore, if one assumes that the unequal germination of seeds per pot affected plant length and dry weight, the dry weight per unit of plant length was calculated and the data were analyzed. The 1/3 atm treatment was significantly different from both 1 and 3 atm (Table III), but a significant difference was not detected between soil

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<sup>3</sup>Entries on a common underline indicate no significant differences among varieties at the 5% level.



TABLE I  
THE EFFECT OF MOISTURE TENSION ON THE GROWTH OF  
FOUR PEARL MILLET VARIETIES, IN THE  
GREENHOUSE POT STUDY, IN TERMS  
OF THE AVERAGE LENGTH IN  
MILLIMETERS

Variety	Moisture Tension (Atm)			Average
	1/3	1	3	
Harlan's Bulk	595.9	609.5	600.7	602.0**
Tifton	561.0	514.8	520.2	532.0
Tift x Tifton	605.1	536.3	521.4	554.3
Gahi-1	567.4	534.7	521.5	541.2
Average	582.4**	548.8	541.0	557.4

\*\*Significant at the 1% level.

TABLE II

THE EFFECT OF MOISTURE TENSION ON THE GROWTH OF FOUR  
PEARL MILLET VARIETIES, IN THE GREENHOUSE POT STUDY,  
IN TERMS OF THE AVERAGE PLANT DRY WEIGHT IN  
GRAMS

Variety	Moisture Tension (Atm)			Average
	1/3	1	3	
Harlan's Bulk	1.89	1.43	1.28	1.53
Tifton	1.84	1.21	1.06	1.37
Tift x Tifton	2.56	1.48	1.35	1.80*
Gahi-1	2.02	1.53	1.25	1.60
Average	2.08**	1.41	1.24	1.58

\*Significant at the 5% level.

\*\*Significant at the 1% level.

TABLE III

THE EFFECT OF MOISTURE TENSION ON THE GROWTH OF FOUR  
PEARL MILLET VARIETIES, IN THE GREENHOUSE POT STUDY,  
IN TERMS OF THE AVERAGE DRY WEIGHT IN MILLIGRAMS  
PER MILLIMETER OF PLANT LENGTH

Variety	Moisture Tension (Atm)			Average
	$1/3$	1	3	
Harlan's Bulk	3.18	2.35	2.13	2.55
Tifton	3.28	2.36	2.04	2.56
Tift x Tifton	4.23	2.76	2.58	3.19**
Gahi-1	3.57	2.86	2.40	2.94
Average	3.57**	2.58	2.29	2.81

\*\*Significant at the 1% level.

tensions of 1 and 3 atm. This agrees with the results obtained from direct measurements. The ascending ranking of varietal responses<sup>4</sup> was:

<u>Harlan's Bulk</u>	<u>Tifton</u>	<u>Gahi-1</u>	<u>Tift x Tifton</u>
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No variety x soil-water tension interaction was found for dry weight per unit of plant length (Figure 3). This indicates no differences among varieties in their behavior under drought conditions and would support the original data on plant length and dry weight. Thus, the different numbers of plants per pot did not affect the results recorded.

#### Mannitol Study

In the laboratory mannitol study, treatment effects were found to be highly significant at the 1% level for germinated seeds (Table IV). The increasing order of treatment responses for germinated seeds was 12, 10, 8, 6, 3, and 0 atm of osmotic pressure. No significant differences were detected between 0 and 3 atmospheres and between 8 and 10 atmospheres at the 5% level. Varietal effects were significant at the 1% level. Their ascending ranking<sup>4</sup> was:

<u>Harlan's Bulk</u>	<u>Tift x Tifton</u>	<u>Kutch</u>	<u>Gahi-1</u>	<u>Tifton</u>
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Since germination by varieties was significant at the

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<sup>4</sup>Entries on a common underline indicate no significant differences among varieties at the 5% level.

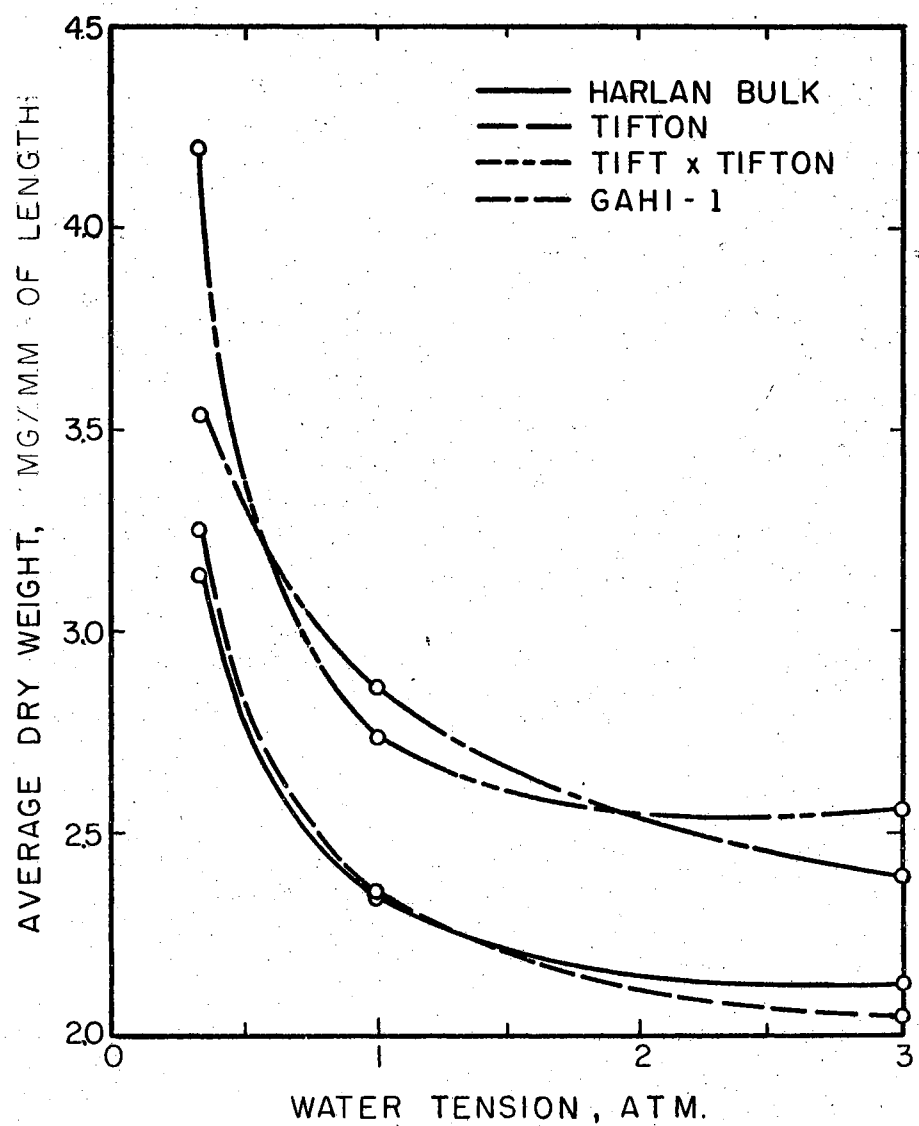


Figure 3. Average Dry Weight in Milligrams Per Millimeter of Length After Six Weeks' Growth at Three Levels of Moisture

TABLE IV  
THE PERCENTAGE GERMINATION FOR FIVE PEARL MILLET  
VARIETIES AT SIX LEVELS OF MOISTURE IN  
THE LABORATORY MANNITOL STUDY

Variety	Moisture Tension (Atm)						Average
	0	3	6	8	10	12	
Harlan's Bulk	72.5	74.0	65.0	54.5	52.5	37.5	59.3
Kutch Bulk	83.5	80.0	70.5	65.0	54.0	45.0	66.3**
Tifton	97.0	91.0	77.0	65.5	66.5	29.0	71.0**
Tift x Tifton	72.5	70.0	69.0	67.0	61.5	39.0	63.2
Gahi-1	82.5	74.5	72.5	64.5	63.0	56.0	68.8**
Average	81.6**	77.9**	70.8	63.3	59.5	41.3	65.7

\*\*Significant at the 1% level.

5% level in the check, 0 atm (Figure 4), investigations for drought resistance should be detected in variety behavior under different osmotic pressures in terms of variety-water stress interaction. Analysis of data indicated that this interaction was significant at the 5% level. However, it was ignored since both varieties and osmotic pressures were highly significant at the 1% level and such interaction might be expected.

All five pearl millet varieties tended to follow the same pattern under 0, 3, 6, 8, 10 and 12 atm of osmotic pressure in the mannitol study.

The data obtained from seedling length of pearl millet varieties at different osmotic pressures in the mannitol study were analyzed by three different statistical methods: (a) method of fitting constants, since the data had many missing observations due to the ungerminated seeds, (b) analysis based on unweighted means, i.e., the average of the length of an experimental unit found by average over the number of germinated seeds (Table V, Figure 5), and (c) based on the consideration that ungerminated seeds had a seedling length of "0" (Table VI, Figure 6). Osmotic pressures and varietal effects were highly significant at the 1% level in all methods of the analysis. Variety x osmotic pressure interaction was significant at the 5% level except in the analysis where the ungerminated seeds were given a value of "0" for length. The latter showed significance at the 1% level. This

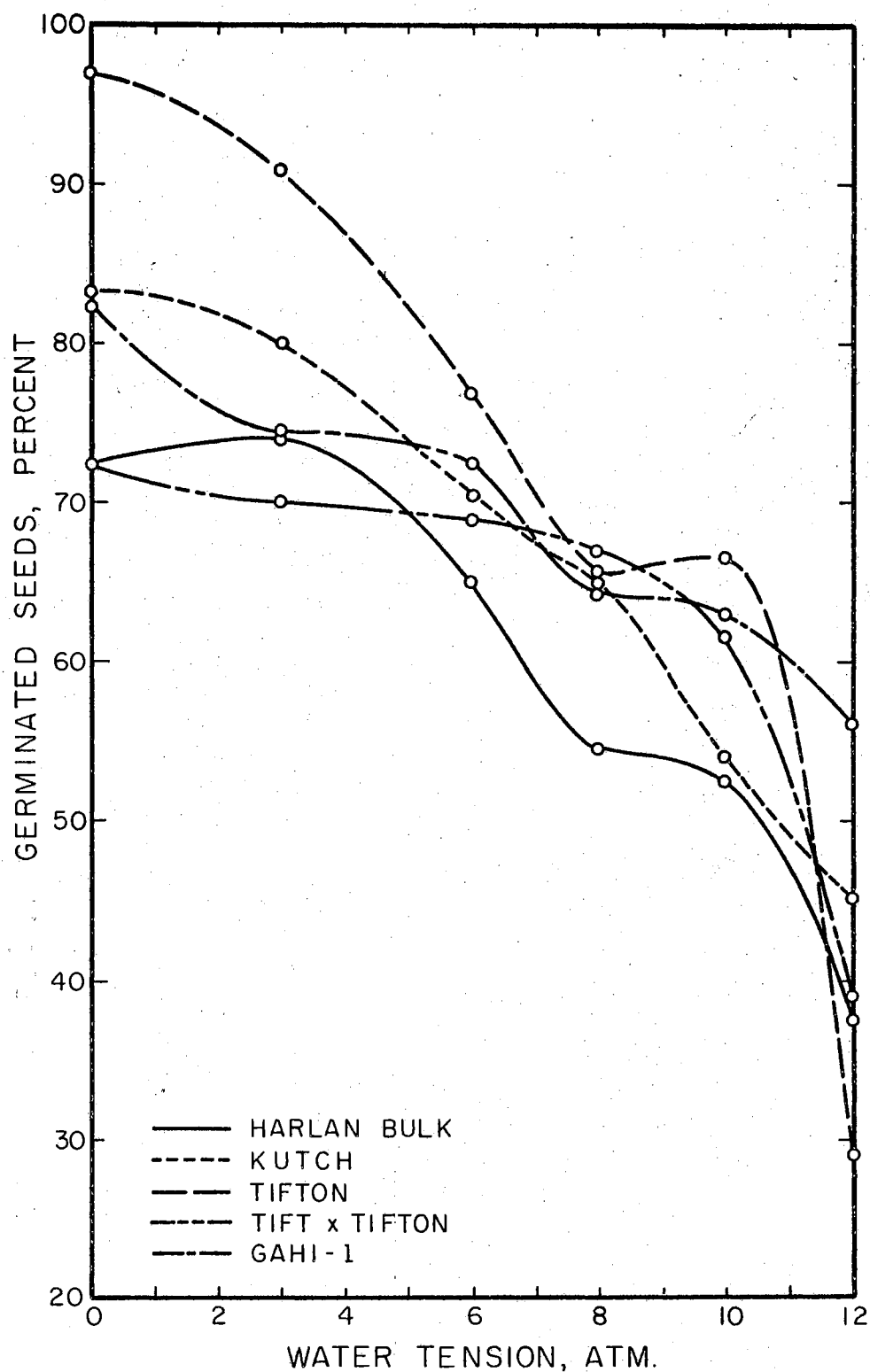


Figure 4. Percentage Seed Germination of Pearl Millet Varieties After Seven Days at Six Levels of Moisture



TABLE V

THE EFFECT OF SIX LEVELS OF MOISTURE ON THE GROWTH OF  
FIVE PEARL MILLET VARIETIES IN TERMS OF  
SEEDLING LENGTH IN MILLIMETERS BASED  
ON THE UNWEIGHTED MEANS IN THE  
LABORATORY MANNITOL STUDY

Variety	Moisture Tension (Atm)						Average
	0	3	6	8	10	12	
Harlan's Bulk	58.70	50.70	33.02	23.90	19.10	12.52	32.99
Kutch Bulk	37.77	38.85	24.95	22.34	14.56	10.17	24.77
Tifton	53.68	43.52	27.92	21.71	14.83	6.18	27.97
Tift x Tifton	55.50	52.03	40.03	32.89	24.53	13.88	36.48**
Gahi-1	56.51	49.79	38.01	24.69	18.40	13.29	33.45
Average	52.43**	46.98	32.79	25.11	18.28	11.21	31.13

\*\*Significant at the 1% level.

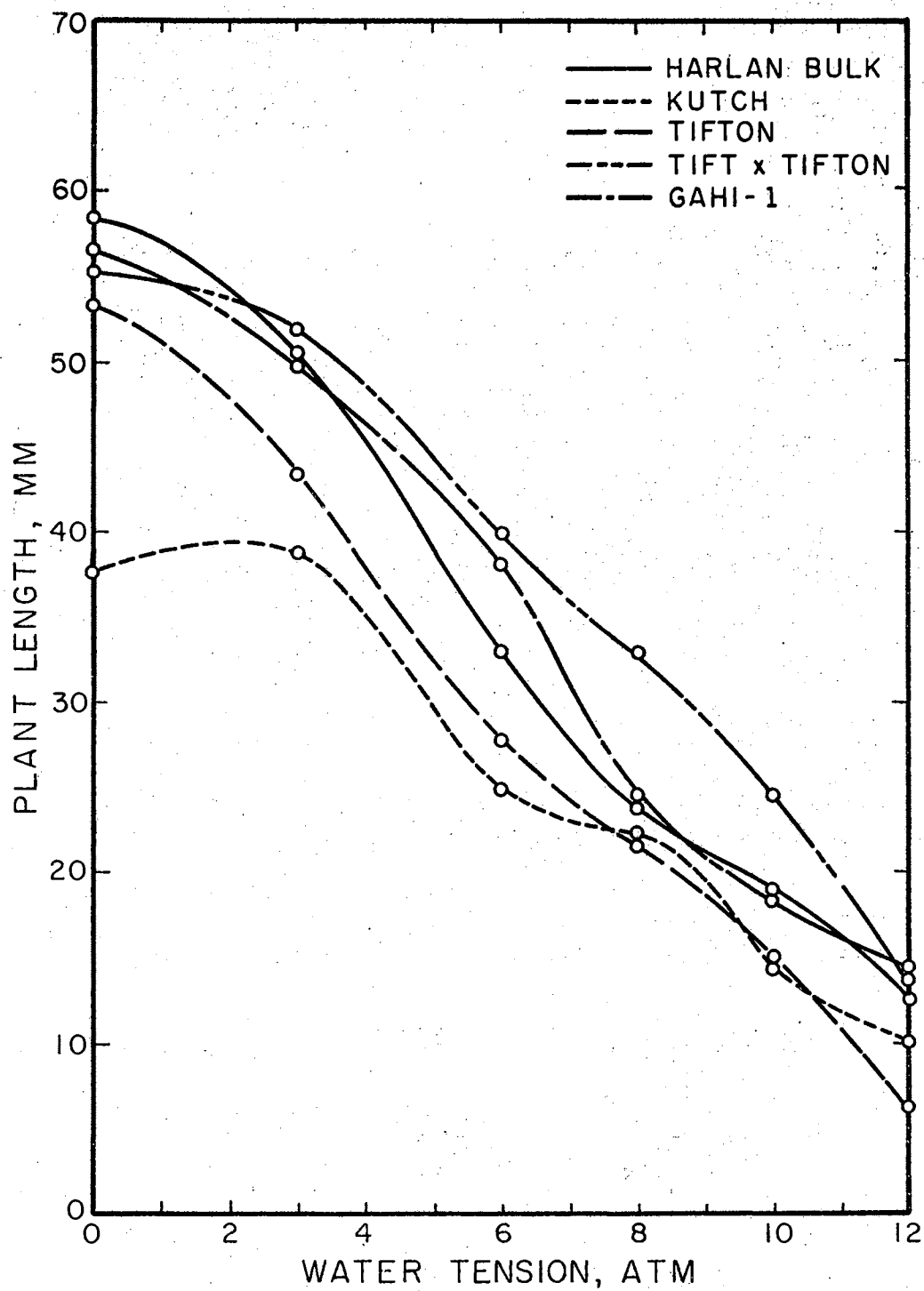


Figure 5. Average Seedling Length in Millimeters, Based on Unweight Means, After Seven Days at Six Levels of Moisture

TABLE VI

THE EFFECT OF SIX LEVELS OF MOISTURE ON THE GROWTH OF  
FIVE PEARL MILLET VARIETIES IN TERMS OF SEEDLING  
LENGTH IN MILLIMETERS WHERE UNGERMINATED SEEDS  
WERE GIVEN A VALUE OF "0" FOR LENGTH

Variety	Moisture Tension (Atm)						Average
	0	3	6	8	10	12	
Harlan's Bulk	42.68	37.46	21.95	12.93	10.09	4.61	21.62*
Kutch Bulk	31.70	31.02	17.32	14.77	7.85	4.70	17.89
Tifton	52.16	39.92	21.79	14.72	9.99	2.01	23.43*
Tift x Tifton	40.16	36.36	27.66	21.98	14.98	5.42	24.43*
Gahi-1	46.67	37.10	27.64	16.17	11.64	7.30	24.42*
Average	42.67**	36.37	23.27	16.11	10.91	4.81	22.36

\*\*Significant at the 1% level.

\*Significant at the 5% level.

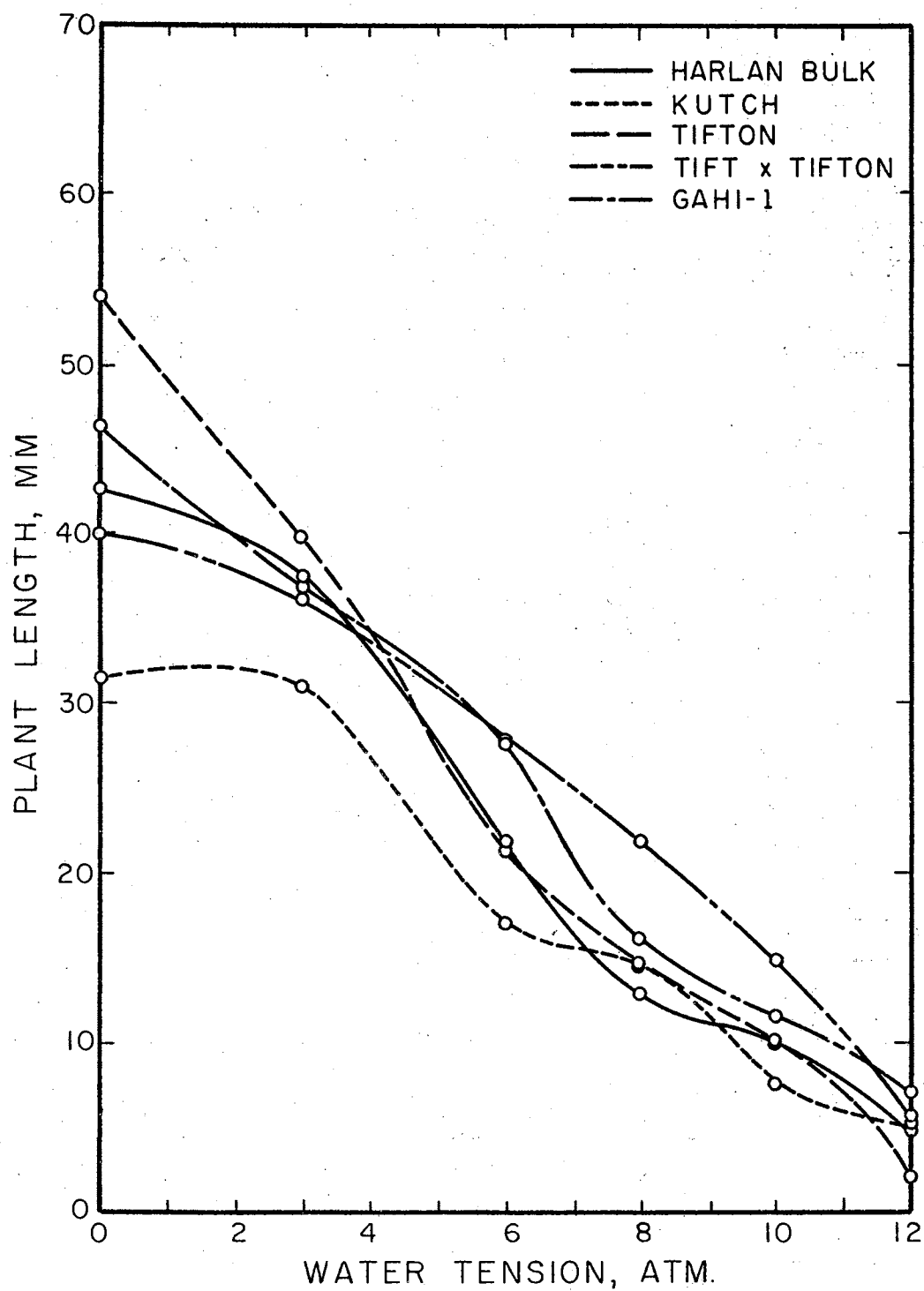


Figure 6. Average Seedling Length in Millimeters, Where Ungerminated Seeds Were Given a Value of "0" for Length, After Seven Days at Six Levels of Moisture

interaction was ignored since both varieties and osmotic pressures effects were highly significant and such interactions might be expected. In general, the behavior of pearl millet varieties Harlan's Bulk, Kutch, Tifton, Tift x Tifton, and Gahi-1 followed the same pattern over the osmotic pressures of 0, 3, 6, 8, 10 and 12 atmospheres.

#### Chlorophyll Stability Index (C.S.I.)

Since the ability of these pearl millet varieties to tolerate drought was found to follow essentially the same pattern, chlorophyll stability index for these varieties should have the same trend on the assumption that C.S.I. is well correlated with drought resistance (4, 9, 11). However, the results obtained (Table VII) indicated differences among C.S.I.'s of pearl millet varieties at the 1% level. The sequence of these varieties in an ascending ranking of chlorophyll stability<sup>5</sup> was:

Harlan's Bulk	<u>Kutch</u>	<u>Tift x Tifton</u>	Tifton	Gahi-1
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Since results obtained for chlorophyll stability index altered the assumption that C.S.I. is well correlated with drought resistance, three interpretations can be drawn: (a) there is little, if any, correlation between C.S.I. and drought resistance of those pearl millet varieties tested; (b) the difference between the two optical

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<sup>5</sup>Entries on a common underline indicate no significant differences among varieties at the 5% level.

TABLE VII  
CHLOROPHYLL STABILITY INDEX (C.S.I.) IN TERMS OF  
OPTICAL DENSITY FOR FIVE PEARL MILLET  
VARIETIES AFTER THREE WEEKS' GROWTH

Variety	Optical Density		Difference (C.S.I.)
	Before Heating	After Heating	
Harlan's Bulk	0.246	0.226	0.020
Kutch Bulk	0.206	0.193	0.013
Tift x Tifton	0.175	0.165	0.010*
Tifton	0.175	0.170	0.005*
Gahi-1	0.163	0.158	0.005*
Average	0.193	0.182	0.011

\*Significant at the 5% level.

densities before and after heating is not of practical importance, and all pearl millet varieties tested can be said to be practically the same with regard to their C.S.I.; and (c) drought resistance of these pearl millet varieties are different but in such a narrow range, that differences cannot be detected by methods used in this study. The first interpretation is the most probable since pearl millet varieties were tested for drought resistance by different methods, and different responses were taken into account. It was concluded that more progress might be made by selection for early maturity, in order to avoid drought than by selection for physiological drought resistance.

## CHAPTER V

### SUMMARY AND CONCLUSIONS

In tests for drought resistance in pearl millet, three methods were used: (1) growth in pots under different soil moisture tension regimes, (2) germination of seeds and growth of seedlings in mannitol solutions of different osmotic pressures, and (3) stability of extracted chlorophyll under heat treatment. The pearl millets studied represented a considerable range of ecological adaptation varying from types grown at the edge of the Rajasthan desert in India to commercially available varieties developed at Tifton, Georgia. The results showed that as the soil moisture tension increased, the growth responses for the pearl millet varieties studied decreased in the same general pattern. Differences in magnitude of responses were also observed among the varieties. It was concluded that more progress might be made by selection for early maturity in order to avoid drought than by selection for physiological drought resistance.



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Master of Science

Thesis: TESTS FOR DROUGHT RESISTANCE IN PEARL MILLET  
(PENNISETUM TYPHOIDEUM)

Major Field: Agronomy

### Biographical:

Personal Data: Born in Fayoum, Egypt, U.A.R.,  
November 9, 1937, the son of Attia and Nazira  
Fanous.

Education: Graduated from Fayoum High School,  
Fayoum, Egypt, U.A.R., in 1954; received the  
Bachelor of Science in Agriculture from Cairo  
University, Giza, Egypt, U.A.R., 1958.

Professional Experience: Agronomist in the Ministry  
of Agrarian Reform and Land Reclamation, Egypt,  
U.A.R., from March 1959 to January 1960.  
Taught Agriculture Sciences in Secondary Agri-  
cultural Schools, Ministry of Education, until  
April 1961. From May 1961 to August 1964 was  
employed as an assistant by the Cotton Seed  
Administration, Ministry of Agriculture.

Memberships: American Society of Agronomy and Crop  
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