DEVELOPING A RAPID SCREENING METHOD FOR DETERMINING DROUGHT RESISTANCE WITHIN VEGETABLE CROPS

By

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

There has been a rising demand for knowledge of plant responses to water deficit in the past decade stimulated by the awareness of the importance of water in food production in developing areas and increasing concern for water as a critical resource in the industrial nations. Water relations of plants are simply one concern.

Water is essential for seed germination, and is the single most important factor in germination. The seed imbides water which activates metabolic processes that initiate germination. In the absence of water this metabolic activity is suppressed. Seeds of different cultivars respond differently to water deficits. Some seeds can germinate and grow under very low water conditions while some can not. It is important in this present era when water as a natural resource is becoming increasingly scarce and expensive and water quality is decreasing, for the grower to maximize yield with the minimum possible cost. With the screening method we will describe, information would be readily available to the growers through researchers on cultivars that can survive and produce under severe water deficit conditions. This would cut costs on the part of the growers in that less water could be used throughout the life cycle of plants. Some geographical areas are so arid that agricultural practices are minimal. Cultivars that will tolerate low water potentials might be grown in these areas with some economically feasible irrigation system.

This screening method would also enable breeders to screen for drought resistant cultivars, which has not been done in the past.

This investigation was concerned with developing a rapid screening method for determining drought resistance in vegetable crops. This objective was met in two experiments, using two vegetable crops - tomato and pepper. Information on drought resistance of these crops was not available from previous investigations. This made it difficult to select cultivars to be used. However, Pratt and Bresson (16) determined Red Rock to be a tolerant cultivar as compared with Knox. Other information about varieties used was obtained from breeders who recommended the following cultivars for tomato. Peppers were simply an assortment of cultivars, since no information was available.

TOMATO	PEPPER
1. Red Rock	1. El Paso
2. Chico III	2. PS 1008
3. Campbell 28	3. Coronado
4. Campbell 38	4. California Mild
5. U.S. 141	5. Papri Mild
6. PETO-76	

Six tomato and five pepper cultivars were used. Red Rock and Chico III were suggested by breeders as tolerant tomato cultivars, Campbell 28 and 38 were recommended as susceptible cultivars, while U.S. 141 and PETO-76 were suggested to perform somewhat intermediate. No prior information was available about the pepper cultivars.

The two experiments were performed as follows:

Experiment I: Germination of the six tomato cultivars and the five pepper cultivars in eleven different water potentials ranging from 0 to -10 bars at 1 bar intervals using PEG 8000 to produce the various water deficits. Percent germination and radicle elongation were taken at two, four, and six days after commencement of the experiment.

Experiment II: Pregermination of the same six tomato cultivars and five pepper cultivars in a germination column then transferring them to eleven different water potentials ranging from 0 to -10 bars at 1 bar intervals. Percent survival and radicle elongation were taken at two, four, and six days after transfer for tomato and two, four, six, and nine days for the peppers.

Seed Germination and Moisture Stress

The germination of seeds and the subsequent development of the plant is of great importance in agriculture. Germination, emergence, and early seedling growth are critical stages in plant development as they affect density of plant stand, degree of weed infestation, and also limit yield.

The problem of seed germination is more complex under semiarid and arid conditions. Under these situations the rate of soil moisture evaporation is high, soil crusting can occur, and soil salinity problems may result. High soil temperatures generally accompany dry soil. Though soil moisture may be adequate for plant growth, often the surface layer of soil dries rapidly and prevents seed germination and seedling establishment.

Mayor and Poljakoff (12) have reviewed the physiology of seed germination. The effect of soil moisture in seed germination has been discussed by Hillel (5). In his review, Hillel established six areas that relate to the physiological behavior and basic environmental requirements for germination of a particular species. These characteristics are:

1. The relationship of the seed's water content to its water potential.
2. The lowest value of water potential at which the seed can germinate.
3. The possible presence of germination inhibitors, and the mode and rate of their dissipation.
4. The time rate of inhibitors, the time required for germination (radicle emergence), and time rate of rootlet elongation at different ambient temperatures and water potential values.
5. The minimal water content at which the seed begins to germinate and the hydration level at which seed water uptake becomes biologically irreversible.
6. The minimal depth from which the seedling once germinated can successfully emerge.

This thesis will be concerned with the effect of water stress on seed germination and on the germinated seed.

Hegarty and Ross (4) have shown that the Calabrese (*Brassica oleracea* var. italica) and Cress (*Lepidium sativum*) radicle growth immediately after germination was less sensitive to water stress than during germination. A later study by Hegarty and Ross (3) reported that a similar response to water stress was found in seven different families of vegetables consisting of 13 species. Obroucheva (15) found that the initiation of cell elongation and the elongation process are under different metabolic controls in roots. Hegarty and Ross (3) have suggested that the initiation of cell elongation may be the process in seed germination that is most sensitive to environmental stress.

Hegarty and Ross (4) suggested that the water stress sensitive stage occurred very shortly before growth (radicle emergence) started. They also concluded that seeds with the radicles emerged can continue growth in a water stress that was totally inhibitory to their germination.

Effects of Water Stress on Plant Growth

The essential feature in plant water relations is the internal water balance, water stress, or degree of turgidity which exists in plants. This controls those physiological processes and conditions which in turn determine the quantity and quality of growth. In order to understand why water deficit reduces plant growth it is necessary to understand how water affects plant processes.

Kramer (9) defines four general functions of water in plants.

1. It is the major constituent of physiologically active tissue.
2. It is a reagent in photosynthesis and in hydrolytic processes such as starch digestions.
3. It is the solvent in which salts, sugars, and other solutes move from cell to cell and organ to organ.
4. It is essential for the maintenance of the turgidity necessary for cell elongation and growth.

It is probable that almost every process occurring in plants is affected by water deficits. The role of water in relation to the physiological processes is discussed in some detail by Kramer (10) and by

Richards and Wadleigh (17). Hence, only a few examples will be given here.

Vegetative growth is particularly sensitive to water deficits because growth is closely related to turgor and loss of turgidity stops cell enlargement and results in small plants (2). Water deficits not only reduce the total amount of growth, but they also change the pattern of growth. The root:shoot ratio often is increased by water stress. The thickness of the cell walls and the amount of cutinization and lignification often are increased by water stress. Leaf area usually is reduced, but leaf thickness is increased (9).

Water stress in plants causes premature closure of the stomata which reduces water loss. But stomata closure also interferes with the entrance of carbon dioxide which is undesirable because this reduces photosynthesis.

Plant water stress reduces photosynthesis directly because dehydrated protoplasm has a lowered capacity for photosynthesis. It reduces it directly by reducing the leaf area and causing closure of the stomates. Plant water stress sometimes causes increased rates of respiration (9).

The nature and course of various biochemical reactions often are changed by water deficits. Increased conversion of starch to sugar frequently occurs and nitrogen metabolism often is disturbed. The rate of destruction of RNA seems to be increased (2, 8). The total nitrogen content and the nicotene content of cigarette tobacco is increased, but the yield and burning quality are decreased by water stress (21). Changes in mineral metabolism and rapid senesence of leaves is also caused by water stress (9).

Sometimes desirable changes are caused by water deficits. For example, the rubber content of quayule is increased by moderate water stress, although the total fresh weight is decreased (22). The quality of apricots and pears is said to be improved by water stress late in the growing season and the aroma of Turkish tobacco is increased by water stress (23). Water stress appears to be necessary for breaking dormancy of flower buds and causing flowering of coffee trees (1).

One of the most fruitful yields of research in plant water relations probably will be the study of biochemical effects of water stress on plants. To be productive, however, such studies must be accompanied by quantitative measurements of plant water stress.

Plant Growth in PEG-Nurtient Media

Most investigators use PEG as an osmotic agent to alter the osmotic potential of a solution for simulated studies of water deficit. It has been recently suggested that the osmotic potential of PEG media can be used to approximate soil matric potential with respect to rates of seedling emergence (20). This terminology has led to a misunderstanding of the properties and usefulness of PEG in conducting research in plant-water relations. In fact, PEG solutions of high molecular weight and in concentrations used in physiological experiments behave like colloids, and matric forces are a major component of the resulting water potential.

Thill et al. (20) thus suggested that PEG should be referred to as a "matricum" rather than an osmoticum. In this thesis, the term osmoticum will be used. Steuter (18) showed that, although considerable research in the field of plant-water relations has depended on the use of PEG for simulating water stress, little is known about the behavior of PEG in reducing water potential. He also suggested the possibility of the existence of cation-active polyxonium ion affecting the availability of nutrients to plants growing in PEG-nutrient media.

Steuter (18) stipulated that PEG has been widely used to maintain experimental media at predetermined water potential values. Several researchers have reported that PEG has toxic effects on plants. Lagerworf et al. (11) attributed PEG 6000 toxicity to associated heavy metals and recommended dialysis or passage through ion exchange columns to remove these impurities.

Jackson (6) has shown that there is no evidence assocated with toxicity of PEG 6000 solutions to cell membranes of beet roots, although grass seedlings root hairs seemed to respond abnormally. Michel (14) checked for the possible dialyzable contaminants by using two 30 ml samples of PEG 6000 solution (196 g/liter) and placing them in closed, rigid osmometers. On each, a stainless steel screen supported 30 cm^2 of U Zephyr membrane on which $CN_2Fe(CN)_6$ had been precipitated. The samples were dialyzed against water (150 ml/volumes, charged two and three times) for 18 and 20 hours. Both solution and water were continuously stirred by magnetic bars. The dialyzed solutions were made up to -4.3 bars (163 g/liter). He determined whether possible contaminants were heat-labile by heating 20 g of PEG for 22 hours at 105°C (losing 66 mg). Michel (14), in his experiment, then tested the effect of the dialyzed PEG 6000 to the dialysate and found no significant increase in elongation of the avena coleoptile sections.

He showed that inhibition of avena coleoptile is not a result of toxicity.

The use of PEG to reduce the water potential of nutrient solutions has become an accepted technique to create water stress in plants. The majority of researchers report satisfactory results and indicate that PEG is usually superior to salts, sugars, or other organic compounds (13).

James (7) has shown some activities of PEG 6000 in pepper plants systems as follows:

1. Toxic effect - PEG 6000 showed no signs of toxicity or very slight toxicity as a result of the manufacturing process.
2. Concentrations of PEG in expressed sap - The smaller the molecule of the PEG used, the greater the concentration in the expressed sap of the leaves.
3. Accumulation in leaves and roots - PEG accumulation in plants was inversely related to the molecular size and directly related to the time of exposure and the decrease in osmotic potential of the nutrient solution. The major portions of PEG 4000 were found in the roots with very small quantities in the leaves.
4. Relationship between transpiration and accumulation of PEG - He showed that the greater accumulation per g of water transpired during the first 24 hours resulted from a rapid uptake shortly after roots were placed in solution of low osmotic potential plus a reduced rate of transpiration during the period. The initial reaction to the reduced water potential undoubtedly was a reduction in turgidity which could have

altered the root permeability allowing for a surge of PEG into the roots. In this experiment, the pepper plants were transferred to the PEG solution while they were rapidly transpiring. It seems likely that the shock to the plants and the accompanying surge of PEG into the roots would have been less if the transfer had been made while plants were in the dark or if the PEG had been added in small increments during light periods.

5. Growth and transpiration - The similarity of changes in rate of growth and transpiration in the pepper plants grown in solutions of different molecular sizes indicate that the source of the response was primarily the osmotic potential of the nutrient solution and not molecular size.

6. Filtering capacity of roots - PEG molecules entered the roots in a random manner and the number of molecules entering the roots was related to the sizes of the pores or passages in the filtering membrane. There was an appreciable number of pores of a size to permit passage of PEG 400, but fewer pores large enough for PEG 4000 to enter the roots.

CHAPTER II

MATERIALS AND METHODS

Dry seeds of six tomato cultivars, Red Rock, Chico III, Campbell 28, Campbell 38, U.S. 141, PETO-76, and five pepper cultivars, Coronado, Papri Mild, California Mild, El Paso, and PS 1008, were used for the experiment.

The water stress was maintained in all laboratory experiments with polyethylene glycol (PEG) 8000. The equation derived by Michel and Kaufmann (13) was used to obtain the desired osmotic potential of the solution.

$$\psi_s = -(1.18 \times 10^{-2})C - (1.18 \times 10^{-4})C^2 + (2.67 \times 10^{-4})CT + (8.39 \times 10^{-7})C^2T$$

ψ_s = osmotic potential
C = concentration of PEG 8000 g/kg H_2O
T = temperature in degrees C

POLYETHYLENE GLYCOL (PEG) 8000

Stress (bars)	grams PEG/1000 ml H_2O 25°C
0	0.0
-1	78.5
-2	119.6
-3	151.4
-4	178.3
-5	202.1
-6	223.7
-7	243.5
-8	261.9
-9	279.3
-10	295.7

Eleven different water potentials were prepared at 1 bar increments, ranging from 0 to -10 bars.

Experiment I

Twenty-five dry seeds of the tomato and pepper cultivars were placed in petri dishes fitted with one Whatman #3 filter paper. Water deficits ranged from 0 to -10 bars in 1 bar increments. Ten ml of PEG 8000 solution was placed in each dish. The petri dishes were placed in white plastic containers with a tight lid to control relative humidity and evaporation, then transferred to an incubator. The experiment was conducted for six days in darkness. A continuous temperature of 25°C was maintained throughout the experiment.

The percent germination and radicle length was measured for each seed treatment at the end of two, four, and six day periods.

Experiment II

Seed of the tomato and pepper cultivars were pre-germinated using well aerated germinating columns. After three days, seeds with radicles just emerging were selected for uniformity and 25 seeds of each tomato and pepper cultivar were transferred into petri dishes containing water potentials ranging from 0 to -10 bars at 1 bar increments. Seedlings for water potential treatments of -2 to -10 bars were preconditioned for one hour in each successive water potential before reaching its final water potential. Otherwise, seeds were exposed to the same conditions as in Experiment I. Pepper seeds were allowed to grow for nine days. Percent survival and radicle elongation was taken for both tomato and pepper cultivars.

Each experiment was conducted in a randomized complete block design with five replications per treatment. Data was analyzed using analysis of variance and trend analysis. Means were compared using Duncan's Multiple Range Test.

CHAPTER III

RESULTS AND DISCUSSION

Results

Table I: PEG Germination Tests for Tomato Cultivars

Two days after commencement of the experiment, Red Rock showed significantly greater radicle elongation than Campbell 38, PETO-76, and U.S. 141 at osmotic potentials as low as -2 bars, Campbell 28 and Chico III were intermediate. At Day four, Red Rock and Chico III showed significantly greater radicle elongation from -1 to -7 bars than all other cultivars tested, followed by Campbell 28 and 38, while U.S. 141 and PETO-76 showed the least radicle elongation. At Day six, Red Rock and Chico III appeared to be the most tolerant of the cultivars tested exhibiting significantly greater radicle elongation between 0 and -6 bars.

Red Rock and Chico III appear to be the most tolerant, Campbell 28 and 38 intermediate, while U.S. 141 and PETO-76 appear susceptible to osmotic stress.

TABLE I

PEG GERMINATION TESTS FOR TOMATO CULTIVARS
RADICLE LENGTH (MM)

Cultivar	Bar 0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
						Day 2							
Campbell 38	2.2b[z]	0.4ab	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	4.4c	1.4bc	0.6ab	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	4.0c	1.5c	1.0ab	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
PETO-76	2.4b	0.4ab	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	5.8d	2.4c	1.2b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
U.S. 141	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 4							
Campbell 38	47.6b	37.2b	22.8b	15.6b	3.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	53.8c	47.2c	38.0c	26.2c	4.20a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	58.0c	54.2d	47.2d	41.4d	30.2b	24.0b	11.0b	6.0b	0.6a	0.0a	0.0a	**	**
PETO-76	10.6a	5.4a	1.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	58.2c	56.0d	49.6d	40.8d	30.6b	20.4b	15.2b	4.8b	0.4a	0.0a	0.0a	**	**
U.S. 141	9.2a	6.4a	2.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 6							
Campbell 38	58.0b	45.2c	32.8b	21.8b	5.8b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	65.4bc	55.4d	47.0c	33.2c	20.2c	3.8a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	67.6c	62.6e	51.6c	44.4d	32.8d	21.4b	13.2b	4.2a	1.4a	0.0a	0.0a	**	**
PETO-76	23.4a	12.0a	5.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	80.2d	79.2f	67.8d	54.8e	42.8e	22.0b	14.0b	0.0a	0.0a	0.0a	0.0a	**	**
U.S. 141	25.4a	21.4b	10.4a	3.0a	0.6a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**

[z]Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level for linear (L) or quadratic (Q) response.

Table II: PEG Germination Tests for Tomato Cultivars

After two days, Chico III showed the highest percent germination followed by Campbell 28 and Red Rock. After four and six days, Red Rock and Chico III showed the highest percent germination from -1 to -6 bars. From 0 to -3 bars, Red Rock, Chico III, and Campbell 28 showed to be the most significant. This indicates that Red Rock and Chico III are the most tolerant, Campbell 28 and 38 are intermediate, while U.S. 141 and PETO-76 are the susceptible cultivars.

All cultivars showed significance at the 1% level for both linear and quadratic responses after two, four, and six days, indicating that as the water potential decreases, there is a decrease in radicle elongation and percent germination.

Table III: PEG Germination Tests for Pepper Cultivars

After two days, El Paso and PS 1008 showed significantly greater radicle length at -1 bars than the other cultivars tested. After four days, El Paso grew best from 0 to -3 bars, followed by PS 1008. After six days, El Paso showed the best radicle elongation from 0 to -3 bars. In this experiment, El Paso and PS 1008 showed to be the tolerant cultivars while other cultivars tested appear susceptible.

Table IV: PEG Germination Tests for Pepper Cultivars

Percent germination was very low for all the cultivars tested. This may be due to slow germination rates of the cultivars. In spite

TABLE II

PEG GERMINATION TESTS FOR TOMATO CULTIVARS
PERCENT GERMINATION

Cultivar	Bar											L	Q
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10		
						Day 2							
Campbell 38	3.2a	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	10.4c	4.8b	1.6b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	88.0e	32.0d	4.0c	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
PFTO-76	8.0b	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	11.2d	6.4c	1.6b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
U.S. 141	3.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 4							
Campbell 38	47.2c	45.6b	25.6b	16.8b	3.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	74.4d	61.6c	52.0c	33.0c	8.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	73.6a	68.8c	58.4cd	44.0d	28.0b	24.0b	8.0ab	5.6a	0.8a	0.0a	0.0a	**	**
PETO-76	26.4b	15.2a	2.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	84.0e	81.6d	63.2d	54.4e	40.0c	35.2c	14.4b	5.6a	0.8a	0.0a	0.0a	**	**
U.S. 141	8.0a	6.4a	2.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 6							
Campbell 38	48.0b	46.4c	26.4b	16.8b	4.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	75.2c	61.6d	52.8c	39.2c	14.4b	3.2a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	73.6c	68.8d	58.4cd	45.6c	28.0c	26.4b	9.6b	4.0a	0.8a	0.0a	0.0a	**	**
PETO-76	44.8b	26.4b	8.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	84.0d	81.6e	63.2d	54.4d	40.0d	30.4b	14.4b	5.6a	0.8a	0.0a	0.0a	**	**
U.S. 141	16.8a	12.8a	10.4a	4.8a	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a		

[z]Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level from linear (L) or quadratic (Q) response.

TABLE III

PEG GERMINATION TESTS FOR PEPPER CULTIVARS
RADICLE LENGTH (MM)

Cultivar	Bar												
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
						Day 2							
Coronado	0.6a[z]	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	*	**
California Mild	1.0a	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	*	**
Papri Mild	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	4.6c	2.4c	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
PS 1008	2.2d	1.0b	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 4							
Coronado	4.0a	1.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
California Mild	4.0a	1.8a	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Papri Mild	4.8a	1.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	9.8c	6.6c	6.2c	4.0b	1.4a	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
PS 1008	6.4b	4.2b	1.2b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 6							
Coronado	7.8a	4.2a	1.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
California Mild	10.0b	6.8bc	2.8bc	0.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Papri Mild	9.0ab	5.6ab	2.0ab	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	15.2c	11.2d	8.4d	4.4b	2.4b	1.2a	0.2a	0.0a	0.0a	0.0a	0.0a	**	**
PS 1008	9.4b	7.4c	4.2c	1.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**

[z]Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiple Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level from linear (L) or quadratic (Q) response.

TABLE IV

PEG GERMINATION TESTS FOR PEPPER CULTIVARS
PERCENT GERMINATION

Cultivar	Bar											L	Q
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10		
					Day 2								
Coronado	2.4ab[z]	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	*	**
California Mild	1.2a	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Papri Mild	3.2b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	6.4c	4.0b	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
PS 1008	5.6c	3.2b	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
					Day 4								
Coronado	8.0b	2.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
California Mild	8.8b	4.0ab	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Papri Mild	10.4a	4.0ab	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	24.8c	22.4c	16.0b	8.6b	2.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
PS 1008	10.4a	6.4b	1.6a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
					Day 6								
Coronado	16.0ab	8.2a	3.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
California Mild	26.4c	20.8c	0.8b	0.8a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Papri Mild	18.4b	8.8a	4.0ab	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	24.8c	29.6d	20.0c	12.8b	5.6b	2.4a	0.8a	0.0a	0.0a	0.0a	0.0a	**	**
PS 1008	12.8a	12.0b	4.4ab	1.6a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**

[z]Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level from linear (L) or quadratic (Q) response.

of this, El Paso showed the highest percent germination at water potentials from 0 to -4 bars, PS 1008 is next. California Mild, Papri Mild, and Coronado appear to be susceptible between 0 to -3 bars.

All cultivars showed significance at the 1% level for linear and quadratic response after two, four, and six days, except for Coronado which was significant at 5% level for linear and quadratic responses after two days. This showed that radicle length and percent germination decreases as the water potential decreases.

Table V: Growth of Pregerminated Seedlings of Tomato Cultivars in PEG Solutions

After two, four, and six days, Red Rock showed significantly better radicle elongation than all other cultivars tested at water potentials between -3 and -9 bars. Chico III follows Red Rock exhibiting significantly greater radicle elongation than Campbell 28 and 38 after two days at water potentials between -1 to -9 bars. After Day 6, Chico III, with values very close to Red Rock, exhibits significantly better radicle elongation than Campbell 28 and 38 at water potentials between -3 to -6 bars. Red Rock and Chico III appear to be the most tolerant, Campbell 28 and 38 intermediate, while U.S. 141 and PETO-76 appear susceptible to osmotic stress.

Table VI: Growth of Pregerminated Seedlings of Tomato Cultivars in PEG Solutions

After two days, Red Rock and Chico III appear to be the most tolerant at water potentials ranging from -3 to -10 bars. Campbell 28 and 38 appear to be intermediate exhibiting a significantly

TABLE V

GROWTH OF PREGERMINATED SEEDLINGS OF TOMATO
CULTIVARS IN PEG SOLUTIONS
RADICLE LENGTH (MM)

Cultivar	Bar												
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
						Day 2							
Campbell 38	18.4a[z]	16.0b	13.6ab	11.6b	9.0a	6.8b	4.8b	2.8b	1.0a	0.6a	0.2a	**	**
Campbell 28	18.2a	13.6a	11.4a	8.6a	7.2a	3.0a	1.4a	1.0ab	0.6a	0.2a	0.2a	**	NS
Chico III	19.2a	20.0c	18.8c	16.6c	13.8b	11.6c	9.6c	8.0c	5.0b	3.8b	2.0a	**	NS
PETO-76	20.6ab	16.6b	14.8b	12.2b	9.6a	7.0b	2.2a	0.6ab	0.0a	0.0a	0.0a	**	**
Red Rock	22.0b	21.4c	20.4c	19.2d	17.2c	15.2d	12.6d	11.4d	9.6c	7.2c	6.0b	**	**
U.S. 141	19.4a	16.2b	14.2b	11.4b	8.4a	4.0a	0.2a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 4							
Campbell 38	47.8bc	42.6b	34.8ab	27.0ab	22.0ab	16.6a	12.6b	4.2ab	0.0a	0.0a	0.0a	**	**
Campbell 28	53.8d	48.0bc	40.2b	31.4b	24.6ab	13.6a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	33.8a	32.6a	31.4a	24.2a	19.4a	15.4a	10.6b	8.2b	5.8b	4.2a	2.0a	**	**
PETO-76	44.4b	36.6a	29. a	23.4a	19.8a	14.6a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	52.4cd	49.8c	47.8c	45.8d	44.6c	41.8b	36.6c	28.4c	21.2c	13.2b	8.8b	**	**
U.S. 141	51.2cd	48.0bc	43.2bc	37.8c	26.8b	13.2a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 6							
Campbell 38	57.0a	45.2a	39.8a	31.8a	26.4b	12.4b	3.6a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	62.8a	56.4b	49.4b	37.8ab	29.4bc	12.4b	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	69.4a	63.4b	57.6b	48.8c	37.0c	25.2c	18.4b	14.0b	11.2b	5.8ab	0.0a	**	**
PETO-76	60.6a	47.6a	35.8a	32.4a	9.2a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	93.0b	89.4c	84.2c	79.2d	71.4d	64.2d	55.2c	42.8c	27.0c	12.8b	0.0a	**	**
U.S. 141	62.4a	57.2b	51.6b	42.8bc	29.0bc	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**

[z]Means within columes followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level for linear (L) or quadratic (Q) response.

TABLE VI

GROWTH OF PREGERMINATED SEEDLINGS OF TOMATO CULTIVARS IN PEG SOLUTIONS PERCENT SURVIVAL

Cultivar	Bar												
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
						Day 2							
Campbell 38	100.0a	100.0b	100.0c	92.8c	76.8c	56.0b	24.8b	13.6a	5.6a	3.2a	0.8a	**	**
Campbell 28	100.0a	94.4a	90.4b	84.0b	67.2b	44.8b	21.6b	10.4a	4.8a	0.4a	0.4a	**	**
Chico III	100.0a	100.0b	100.0c	100.0d	100.0d	100.0c	100.0c	100.0b	100.0b	100.0b	100.0b	NS	NS
PETO-76	97.6a	90.4a	72.0a	54.4a	37.6a	25.6a	8.0ab	3.2a	0.0a	0.0a	0.0a	**	**
Red Rock	100.0a	100.0b	100.0c	100.0d	100.0d	100.0c	100.0c	100.0b	100.0b	100.0b	100.0b	NS	NS
U.S. 141	100.0a	100.0b	80.0ab	52.8a	32.8a	16.0a	0.6a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 4							
Campbell 38	100.0a	98.4c	88.0b	61.6c	42.4b	21.6b	4.8b	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	97.6a	80.8a	76.8b	56.8ab	40.8b	16.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	100.0a	100.0c	100.0c	88.8c	85.6c	72.8c	68.0c	56.8b	45.6b	23.2b	8.8a	**	**
PETO-76	92.8a	82.4a	55.2a	39.2a	19.2a	10.4a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	100.0a	100.0c	100.0c	100.0d	100.0d	100.0d	100.0d	81.6c	65.6c	43.2c	16.8a	**	**
U.S. 141	100.0a	92.8b	68.8b	44.0a	18.4a	4.8a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
						Day 6							
Campbell 38	96.8c	82.4d	65.6b	51.2b	24.8c	6.4b	0.8a	0.0a	0.0a	0.0a	0.0a	**	**
Campbell 28	96.0c	78.4c	76.0c	56.8c	39.2d	12.8c	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Chico III	100.0d	100.0e	92.0d	84.8d	80.8e	75.2e	64.8c	41.6b	32.0b	13.6b	0.0a	**	**
PETO-76	86.4a	65.6a	44.8a	23.2a	6.4a	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**
Red Rock	100.0d	100.0e	100.0e	100.0e	88.0f	68.0d	56.8b	48.0c	35.2b	13.6b	0.0a	**	**
U.S. 141	92.0b	71.2b	47.2a	28.8a	13.6b	0.0a	0.0a	0.0a	0.0a	0.0a	0.0a	**	**

[z]Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,**non-significant (NS) or significant at 5% (*), or 1% (**) level for linear (L) or quadratic (Q) response.

greater percent survival at water potentials between -3 to -6 bars than U.S. 141 and PETO-76. After Day four, Red Rock and Chico III showed greater percent survival at water potentials between -1 to -9 bars. After Day six, Red Rock and Chico III exhibited significantly greater percent survival at water potentials between 0 to -9 bars than Campbell 28 and 38. U.S. 141 and PETO-76 are the most susceptible.

All cultivars are significant at the 1% level for linear and quadratic responses for radicle length and percent survival showing that as the water potential decreases, radicle length and percent survival decreases. Red Rock and Chico III on Day two, showed no significance for percent survival as all seeds survived all treatments. Also, on Day two, Chico III and Campbell 28 showed no significance quadratic response for radicle length.

Table VII: Growth of Pregerminated Seedlings of Pepper Cultivars in PEG Solutions

After two days, El Paso, Papri Mild, California Mild, and Coronado showed greater radicle elongation than PS 1008 at osmotic potentials between -3 to -6 bars, although only El Paso was significant. After Day four, PS 1008 and El Paso showed significantly greater radicle elongation than Coronado, California Mild, and Papri Mild at osmotic potentials between -7 to -10 bars. After Days six and nine, El Paso and PS 1008 appear to be the most tolerant by showing a significantly greater radicle elongation at water potentials between -7 to -10 bars than Coronado, Papri Mild, and California Mild.

TABLE VII

GROWTH OF PREGERMINATED SEEDLINGS OF PEPPER
CULTIVARS IN PEG SOLUTIONS
RADICLE LENGTH (MM)

	Bar												
Cultivar	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
					Day 2								
Coronado	19.2a[z]	17.0a	15.4a	13.8b	11.4ab	9.2ab	7.6ab	5.2ab	2.6a	1.4ab	0.2a	**	*
California Mild	19.2a	17.2a	15.0a	12.8ab	10.2ab	8.6ab	6.2ab	3.8a	2.4a	0.8a	0.0a	**	**
Papri Mild	18.0a	16.0a	14.0a	12.6ab	10.6ab	8.8ab	6.6ab	5.4ab	3.8ab	2.0ab	1.4a	**	*
El Paso	18.6a	17.4a	15.4a	14.2b	12.2b	10.6b	8.4b	7.2b	5.4b	3.4b	2.0a	**	NS
PS 1008	19.0a	16.4a	13.8a	11.2a	9.8a	7.2a	5.8a	4.8a	3.6ab	2.4ab	1.4a	**	**
					Day 4								
Coronado	41.2a	38.4a	35.2a	32.6ab	29.4ab	26.6b	24.2b	17.0b	12.0b	6.2b	2.4a	**	**
California Mild	49.0b	44.2b	40.6b	36.0b	32.6b	27.6b	24.2ab	12.0a	7.6a	0.0a	0.0a	**	NS
Papri Mild	41.0a	36.6a	32.6a	29.6a	24.8a	21.0a	15.4a	10.0a	2.8a	2.2ab	0.0a	**	NS
El Paso	41.6a	38.4a	35.6ab	33.0ab	30.8b	28.0b	25.6b	22.8c	19.0c	15.6c	13.2b	**	NS
PS 1008	38.8a	35.8a	33.8a	31.8ab	29.6ab	25.8ab	23.8b	21.0bc	16.8bc	13.6c	10.4b	**	**
					Day 6								
Coronado	58.2a	54.0ab	48.8ab	45.6ab	41.2b	37.0b	32.8b	24.4bc	16.8b	10.2b	4.2a	**	*
California Mild	60.8a	55.0ab	52.2b	47.2b	43.6b	33.6b	33.4b	16.6b	9.2b	0.0a	0.0a	**	*
Papri Mild	53.6a	47.0a	41.4a	38.2a	31.8a	20.2a	14.4a	3.8a	0.0a	0.0a	0.0a	**	*
El Paso	55.0a	52.2ab	40.2ab	44.4ab	42.0b	38.4b	34.8b	32.0c	27.6c	24.4c	21.8b	**	NS
PS 1008	59.6a	56.0b	51.6b	55.8c	42.8b	40.0b	35.6b	33.0c	28.0c	23.2c	20.2b	**	NS

TABLE VII (CONTINUED)

Cultivar	Bar 0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
						Day 9							
Coronado	79.8a	74.4a	68.4a	62.0ab	55.6b	50.8b	45.0b	32.8b	22.0b	13.2b	5.8a	**	**
California Mild	80.6a	75.0a	69.4a	64.4a	55.8b	51.0b	44.4b	25.2b	15.2b	0.0a	0.0a	**	**
Papri Mild	82.0ab	76.0ab	66.0a	58.6a	45.0a	29.6a	¿8.6a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	84.0ab	79.4ab	75.0b	69.8b	63.8b	59.8b	55.6c	49.8c	43.8c	39.6c	35.0b	**	NS
PS 1008	91.2b	85.4b	76.4b	70.6b	63.8b	60.0b	52.4bc	46.0c	40.0c	37.0c	32.2b	**	*

^{z}Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level for linear (L) or quadratic (Q) response.

Table VIII: Growth of Pregerminated Seedlings of Pepper Cultivars in PEG Solutions

After two days, El Paso showed significantly greater percent survival than PS 1008 at osmotic potentials between -4 to -10 bars, Coronado, Papri Mild, and California Mild were more susceptible. After four days, El Paso still showed greater percent survival between -3 to -10 bars better than PS 1008. After six days, El Paso continued exhibiting greater percent survival than PS 1008 at osmotic potentials between -2 to -10 bars while other cultivars tested are less tolerant than PS 1008. After Day nine, El Paso and PS 1008 appear to be the most tolerant by exhibiting a greater percent survival at water potentials between -2 to -9 bars than the other cultivars tested.

After two days, all cultivars except El Paso showed significance at the 1% level for linear response showing a decrease in radicle length and percent survival as water potential decreases. El Paso showed no decrease for percent survival. PS 1008 showed significance at the 1% level for quadratic response, also Papri Mild and California Mild for percent survival and radicle length, respectively. Coronado and Papri Mild showed significance at the 5% level for quadratic response, while El Paso showed no significance for quadratic response for radicle length or percent survival. Coronado and California Mild showed no significance for quadratic response for percent survival.

After four days, El Paso showed no significance decrease for linear response for percent survival while other cultivars showed significance at the 1% level for linear response. California Mild, Papri Mild, and El Paso showed no signficance for quadratic response for radicle length and percent survival while Coronado and PS 1008

TABLE VIII

GROWTH OF PREGERMINATED SEEDLINGS OF PEPPER
CULTIVARS IN PEG SOLUTIONS
PERCENT SURVIVAL

Cultivar	Bar												
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	L	Q
						Day 2							
Coronado	97.6a[z]	87.2a	78.4a	70.4a	64.0a	59.2a	44.0a	25.6a	13.6a	8.0a	2.4a	**	NS
California Mild	100.0a	97.6b	90.8b	80.0a	67.2a	60.0a	48.0a	36.0a	24.8a	8.0a	0.0a	**	NS
Papri Mild	100.0a	100.0b	96.0c	88.8b	80.0b	72.8a	65.5b	52.8b	41.6b	29.6b	16.8a	**	**
El Paso	100.0a	100.0b	100.0d	100.0c	100.0d	100.0c	100.0c	100.0c	100.0c	100.oc	100.0c	NS	NS
PS 1008	100.0a	100.0b	97.3cd	100.0c	91.2c	84.0b	75.2b	55.2b	45.6b	34.4b	22.4b	**	**
						Day 4							
Coronado	97.6a	87.2a	78.4ab	70.4a	64.0a	58.4a	40.0a	23.2a	12.0a	6.4ab	1.6a	**	*
California Mild	99.2a	91.2a	84.0b	76.8ab	62.4a	50.4a	36.8a	18.4a	8.0a	0.0a	0.0a	**	NS
Papri Mild	97.6a	83.2a	72.8a	66.4a	56.0a	44.8a	32.0a	18.4a	4.0a	2.4a	0.0a	**	NS
El Paso	100.0a	100.0c	100.0c	100.0c	100.0c	100.0c	100.0c	100.0c	100.0c	100.0c	100.0b	NS	NS
PS 1008	100.0a	98.4b	96.8c	88.0b	79.2b	75.2b	61.6b	45.6b	34.4b	20.8b	14.4a	**	**
						Day 6							
Coronado	97.6b	87.2ab	76.0ab	70.4b	64.0b	56.8b	39.2b	23.2b	12.0a	6.4ab	1.6a	**	**
California Mild	99.2b	92.4b	84.0b	77.6b	62.4b	50.4b	36.8b	18.4ab	8.0a	0.0a	0.0a	**	*
Papri Mild	93.6a	83.2a	70.4a	55.2a	45.6a	27.2a	15.4a	3.2a	0.0a	0.0a	0.0a	**	**
El Paso	100.0b	100.0c	100.0d	100.0c	100.0d	100.0d	100.0d	100.0d	99.2c	95.2c	93.6b	**	**
PS 1008	100.0b	98.4c	93.6c	78.2b	78.2c	73.6c	61.6c	45.6c	34.4b	20.8b	13.2a	**	**

TABLE VIII (CONTINUED)

Cultivar	Bar											L	Q
	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10		
						Day 9							
Coronado	97.6b	87.2ab	76.0ab	70.5b	64.0b	56.8b	39.2b	23.2b	12.0bc	6.4a	1.6a	**	*
California Mild	99.2b	91.2b	84.0b	77.5bc	62.4b	50.4b	26.8b	18.4b	8.0a	0.0a	0.0a	**	NS
Papri Mild	92.8a	81.6a	69.6a	54.4a	43.2a	23.2a	13.6a	0.0a	0.0a	0.0a	0.0a	**	**
El Paso	100.0b	100.0c	100.0c	100.0d	100.0d	100.0d	100.0d	100.0d	99.2d	99.2c	93.6b	**	**
PS 1008	100.0b	96.8c	92.8c	78.3c	77.6c	71.2c	60.8c	44.0c	34.0c	20.4b	14.4a	**	**

^{z}Means within columns followed by the same letter are not significantly different at the 5% level by Duncan's Multiply Range Test.

NS,*,** non-significant (NS) or significant at 5% (*), or 1% (**) level for linear (L) or quadratic (Q) response.

are significant at the 1% level for quadratic response for radicle length and percent survival except for Coronado which is significant at the 5% level for percent survival.

After six days, all cultivars are significant at the 1% level for linear response for both radicle length and percent survival. Coronado, Papri Mild, El Paso, and PS 1008 are significant at the 1% level for quadratic response for percent survival, while Coronado, California Mild, and Papri Mild are significant at the 5% level for quadratic response for radicle length and El Paso and PS 1008 showed no significance.

After nine days, all cultivars are significant at the 1% level for linear and quadratic response for both radicle length and percent survival, except for El Paso which showed no significance for quadratic response for radicle length and California Mild for percent survival.

Discussion

Drought avoidance and drought tolerance as the two factors of drought resistance in plants have to be investigated separately because they depend on different morphological and physiological principles (20), which require individual analysis. Under field conditions, plants may avoid water stress by expanding their root systems into the moist subsoil, while some plants may tolerate water stress by being able to withstand very low moisture availability.

Taylor et al. (19) compared the responses of three tomato species to water deficits. Lycopersicon chilense, a drought tolerant species, and Solanum pennellii, a drought avoider species, did not germinate when subjected to a water potential of -7 bars for four days. When transfered to water for 24 hours, they both had a higher percent germination than *Lycopersicon esculentum*, 'Campbell 1327', a commercial tomato which did germinate at -7 bars. When transferred back to a water potential of -7 bars, the two wild species, *L. chilense* and *S. pennillii*, exhibited a similar radicle elongation as did *L. esculentum*, the commercial tomato.

Our experiments were designed to study drought tolerance only. Artificial means were used to bring tomato and pepper seeds and seedlings under uniform osmotic stress by dissolving polyethylene glycol in distilled deionized water and growing the seeds and seedlings therein. Individual PEG treatments induced equal water stress for each cultivar tested.

In PEG germination experiments, Chico III performed better than any other tomato cultivar tested in respect to radicle length and percent germination after the sixth day of the experiment. Red Rock showed similar results. This indicates that Chico III and Red Rock are more tolerant than the other tomato cultivars tested at the various water potentials tested. Campbell 28 and 38 were intermediate, while U.S. 141 and PETO-76 were susceptible tomato cultivars.

In the same experiment, El Paso performed better than any of the pepper cultivars tested. It showed better radicle length and percent germination at lower water potentials. This indicates El Paso is a more tolerant cultivar, PS 1008 intermediate, and the other cultivars tested were susceptible.

U.S. 141 and PETO-76, which were two of the tomato cultivars tested, and all of the pepper cultivars showed very low percent germination. This may be due to the following:

1. Low viability of the seeds used.

2. Natural variability in percent germination.

3. Slow germination rate of the cultivars.

This problem is overcome in the second experiment by starting off with 100 percent germinated seedlings.

In the growth of pregerminated seedlings in PEG solution, Red Rock and Chico III produced greater radicle elongation and percent survival after the sixth day, than other tomato cultivars tested. This confirms the results in the first experiment for Red Rock and Chico III being tolerant cultivars, Campbell 28 and 38 were intermediate, while U.S. 141 and PETO-76 were susceptible cultivars. In the same experiment, El Paso performed better than any other pepper cultivar tested by showing the greater radicle length and an exceptional percent survival after the sixth day of the experiment. El Paso, thus, is tolerant, PS 1008 is intermediate, Coronado, California Mild, and Papri Mild are susceptible cultivars.

All tomato and pepper cultivars showed decreasing radicle length, percent germination, and percent survival as the water potential decreased, unless otherwise noted. At high water potential, the tolerant cultivars demonstrated greater radicle elongation, higher percent germination, and higher percent survival. At very low water potential, the tolerant cultivars produced superior results in all aspects measured.

The polyethylene glycol method used is apparently the best that is available for obtaining uniform and prolonged water stress in growing plants. Despite observations of some workers, immediate toxic effects of PEG were not observed when the compound was carefully refined before use. The solvation effect of PEG on sodium and potassium ions (11) may have some minor influence on plants, and this point needs further investigation. Death of seedlings occurred with time, and whether this is a primary effect of PEG due to plugging of the radicles or a secondary one caused by the water stress is not known.

The results of the two experiments made this rapid screening method valid for determining resistant cultivars in vegetable crops. This will help researchers to provide information to growers in different areas on suitable cultivars for their particular region. To confirm the validity of this method, a third experiment is underway. The same cultivars are actually grown and allowed to stay in PEG plus nutrient solution from the seedling stage until maturity, six weeks in the final PEG solution. The responses of the cultivars would then be compared to responses obtained from the experiments in this thesis to see if they correspond.

In the preliminary work done on the growth in PEG + nutrient solution, Chico III survived in all the different water potentials of 0 to -10 bars at 1 bar intervals while Campbell 38 survived in only 0 to -4 bars. As the water potential becomes greater than -4 bars, Campbell 38 wilted within one week of transfer into PEG + nutrient solution. This response corresponds with the response in the first experiment which further strengthens the validity of this method.

The first experiment, which is the germination of seeds in PEG solution and measurement of percent germination and radicle elongation, thus becomes a simple, fast method for determining drought tolerance of vegetable cultivars.

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VITA 2

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