PHYSIOLOGICAL ASPECTS OF DROUGHT AND HEAT TOLERANCE OF PEANUT (*ARACHIS HYPOGAEA* L.)

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 1985

PHYSIOLOGICAL ASPECTS OF DROUGHT AND HEAT TOLERANCE OF PEANUT (ARACHIS HYPOGAEA L.)

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PREFACE

Drought and high temperature are two main environmental factors which limit peanut production in arid and semiarid areas throughout the world. Since peanut is one of the most important edible oil and food crops, prevention of yield and/or quality losses is necessary. Before variety improvement can occur, physiological studies involving the responses and adaptation of peanut under prolonged drought and heat stress conditions are required. In order to provide information for future breeding needs, this study was carried out during 1983 and 1984. Plant root and shoot growth, soil water extraction, water relations, leaf membrane thermostability, and yield were studied among peanut genotypes under rainfed and irrigated conditions. Genotypic differences in these characteristics have been found and these findings can provide useful information for drought- and heat-resistant breeding uses.

First, I wish to express my deepest appreciation to my major advisor, Dr. Darold L. Ketring, Plant Physiologist, Agricultural Research Service, United States Department of Agriculture, and Associate Professor of Agronomy Department, Oklahoma State University for his patience, guidance, assistance, encouragement, and friendship

throughout the course work and preparation of this thesis.

I am also thankful to the other members of my committee, Dr. Donald J. Banks, Dr. James S. Kirby, Dr. Lawrence G. Morrill, and Dr. Michael W. Smith for their excellent advice in the course of this work.

Special thanks are due to Dr. Jack F. Stone for his help in providing the irrigation system for this study in 1984.

Acknowledgements are also extended to Dr. David C. H. Hsi, Professor of New Mexico State University, Dr. Paul I. Erickson, Dr. Roy N. Pittman, Mr. Harold R. Gray, Doug G. Glasgow, and Ben A. Bittle for their assistance in many ways and unforgettable friendship.

The help of Mr. Joe R. Williams in using computer programs for soil water calculations is appreciated.

Gratitude and appreciation are extended to Dr. Hsiung Wan, Director of Taiwan Agricultural research Institute for his assistance and granting my three-year leave for studying at Oklahoma State University.

The financial support for two-year of my graduate study, provided by the National Science Council, Republic of China, is gratefully acknowledged.

Finally, I wish to express my appreciation and love to my parents, my wife, Tao Liao, my two sons, Hong-jen and Hong-wen for their constant support, understanding, and encouragement during the lonely study duration.

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DAP	- Days after planting
DW	- Dry weight
GC	- Ground cover (%)
IR	- Irrigated treatment
ns	- Nonsignificant at 5 % level
OP	- Osmotic potential (MPa)
r	- Simple linear correlation coefficient
RF	- Rainfed treatment
Rs	- Stomatal resistance (sec/cm)
R/S	- Root/shoot ratio
RWC	- Relative water content (%)
SMK	- Sound mature kernel (%)
SS	- Sound split (%)
Tc	- Canopy temperature (C)
Td	- Temperature difference between leaf and ambient
TP	- Turgor potential (MPa)
TSMK	- Total sound mature kernel (=SMK+SS)
Vol	- Volume
WP	- Water potential (MPa)
Wt	- Weight

CHAPTER I

INTRODUCTION

Crop yield is a primary concern of both agricultural scientists and farmers. After planting, farmers always hope for good weather during the growing season. Because farmers know that even if they plant potentially high yielding varieties in good soil and use the best cultural methods, their actual crop yields usually depend on weather - the amount and distribution of rainfall and occurrence of favorable temperature. They realize that bad weather conditions, especially drought and high temperature, can cause crop yield reductions or even worse, crop failure with no return on their investment. The severe drought during 1983 in the United States resulted in total crop yield losses of ten billion dollars which included 48 and 38 % corn and soybean yield losses, respectively (Le Rudulier et al., 1984). Obviously, among environmental factors, drought and high temperature stress are two of the most important limiting factors which are responsible for yield reduction.

Originally, the term drought described a meteorological time period when the amount of rainfall was less than a given quantity (Swindale and Bidinger, 1981;

Decker, 1983). An agricultural drought, on the other hand, can be defined as the absence of rainfall for a period of time long enough to deplete soil moisture. This results in insufficient available water for crop use for normal growth and development, which then leads to a decrease in yield and/or quality. Whatever the definition, drought occurs frequently in arid, semiarid, and subhumid areas of tropical and temperate regions throughout the world (Swindale and Bidinger, 1981; Dale, 1983; Decker, 1983). High temperature (a temperature that is higher than optimum for normal growth and development of a given crop) usually, but not always occurs with drought to reduce crop productivity.

Peanut (Arachis hypogaea L.), which originated in South America, is an important oil and edible food crop widely grown in arid and semiarid areas as a major cash crop. In arid areas, drought and high temperature frequently occur and decrease yields of peanut. In temperate areas, drought and high temperature are also common. According to Jordan et al. (1983), the average yield reduction due to lack of soil water during the growing seasons of 1976 to 1980 in Texas was about 59.2 %. In 1980, the loss of dryland peanut production due to reduced yield and crop failure was 198 million pounds in Texas alone. The total production for Texas in that year was only 293 million pounds. This meant about a 67.6 % yield loss caused by drought. On the other hand, yield

losses due to high temperature stress are not easily independently estimated because of accompanying drought stress. By comparing environmental data of 1980 with the good peanut production years of 1979 and 1981 for the southwest area (Oklahoma and Texas), Ketring (1984b) indicated that peanut suffered about 5 C higher temperature than optimum. Also a longer duration of exposure to temperature above 35 C probably contributed to yield reduction in 1980 in these areas. Evidenced by these examples, it is very important in peanut production to stabilize yield potential and prevent yield loss caused by drought and/or high temperature stress. Since crops frequently face drought and high temperature stress under natural field conditions, changing cultural practices and peanut genetic components to fit these stress environments seems most promising with regard to preventing yield loss caused by these stresses.

Physiologically, water is an essential component for plant life. It comprises approximately 85 to 90 % of the total fresh weight in physiologically active herbaceous plants. If the water content in most crop species falls much below this level, many physiological activities of the plant are impaired. This can result in yield loss in many important agronomic crops including peanut (Hsiao, 1973; Fischer, 1980; Boote et al., 1982; Mederski, 1983; Shaw, 1983). High temperature stress also affects many important physiological and biochemical processes such as

respiration, protein synthesis, carbohydrate metabolism, and photosynthesis, which also can lead to yield reduction (Lawer, 1979; Levitt, 1980a). As proposed by Swindale and Bidinger (1981), a better understanding of plant water status and response under stress is needed. How stress affects crop growth and development processes is important in order to solve the problems caused by drought and high temperature stresses. Basic research can provide useful information for crop and cultural practice improvements.

Many physiological studies on mechanisms of adaptation and genotypic variation in plant responses to drought and high temperature stress have been done with many important crops such as rice (O'Toole and Chang, 1979; Steponkus et al., 1980), and wheat (Townley-Smith and Hurd, 1979). Although some researches on physiological responses of peanut plants under drought conditions have been conducted (Allen et al., 1975; Bhagsari et al., 1976; Stansell et al., 1976 Pallas et al., 1979; Robertson et al., 1980; Bennett et al., 1984; Pandey et al., 1984a,b,c; Erickson and Ketring, 1985), more detailed research under natural field conditions at different growth stages is still needed to understand the mechanism(s) of adaptation and responses of peanut under long-term drought conditions. Besides, research on high temperature stress in relation to peanut responses is very limited. Therefore, in order to provide valuable information for peanut breeding for drought and/or high temperature resistance, the objectives of this study

were: (1) to examine genotypical variation in growth and development responses of the shoot and root, (2) determine leaf water potential components, stomatal resistances, leaf canopy temperature, heat injury, vegetative growth, and soil water extraction characteristics at different growth stages under rainfed and irrigated conditions, and (3) measure final yield and grade of the peanuts produced.

CHAPTER II

LITERATURE REVIEW

Crop plants rarely attain their full genetic potential for yield because of the limitations imposed by the environment, especially lack of available water caused by drought and unfavorable high temperature. These environmental factors can affect plant growth, development, and yield by adversely affecting physiological processes. As indicated by Hsiao (1973), Begg and Turner (1976), and Eastin et al. (1983), physiological processes such as cell expansion, cell division, protein synthesis, hormone balance, respiration, nitrogen fixation, and photosynthesis can be altered. The interaction between plant hereditary potentials and environmental factors then leads to physiological changes and results in qualitative and quantitative changes of growth, development, and yield. The physiology and biochemistry of plant responses to drought and high temperature have proved to be very complex, involving not one or several physiological processes but rather nearly every major function of plant growth (Paleg and Aspinall, 1981; Kaufmann, 1981). Also, since plant responses to drought and heat stresses involve the whole plant, integrated studies involving root, shoot,

and leaf characteristics are more meaningful.

Roots are the major organs for water and nutrient absorption. Variation in root characteristics within plant species has been shown for many important crops. Results from wheat (Hurd, 1974), barley (Hackett, 1968), and sorghum (Jordan and Miller, 1980) indicated that rooting patterns were related to drought resistance. Studies with dicotyledonous species such as soybean, cotton, and peanut have shown genotypic differences in rooting traits such as taproot length, root growth rate, number of lateral roots, root weight, root/shoot weight ratio, root density, root volumes, etc. (Bhan, 1973; Taylor and Klepper, 1978; Nour and Weibel, 1978; Robertson et al., 1980; Ketring et al., 1982; Ketring, 1984a). Since root studies are more difficult to manipulate than above-ground plant parts and many environmental factors such as soil texture, depth, moisture content, aeration, kind and concentration of solutes and competition with other roots can affect them (Kramer, 1983), more detailed studies on root growth characteristics are still needed.

In sorghum, Jordan and Miller (1980) found that a range of diversity in root characteristics existed among sorghum genotypes. They indicated that sorghums with the highest levels of drought tolerance had consistently higher root weights, greater root volumes, and lower shoot/root (S/R) ratios. Kaspar et al. (1984) reported that taproot-elongation rates initially determined soybean

rooting depth, therefore soybean genotypes with a dominant, rapidly elongating taproot may have a deeper root system and better water availability than a genotype with a weak, slow-growing taproot. They found that taproot-elongation rates of soybean differed significantly. Taproot-elongation rates within a maturity group differed among cultivars by as much as 1.3 cm/day. Cultivars with faster elongation also depleted soil water more than those with slower growth when root growth extended below 120 cm depth. They suggested that cultivars selected for faster taproot-elongation rates had more roots deeper in the soil profile than cultivars with slower elongation rates. Robertson et al. (1980) reported that corn, soybean, and peanut varied in rooting response to plant water and irrigation. Ketring et al. (1982), based on studies of genetic variability in root and shoot growth characteristics of peanut, indicated that peanut genotypes differed in root length and number of downward-growing lateral roots. They found that shoot growth differences also occurred among genotypes, and statistical correlations (r) showed strong positive association between shoot and root growth parameters. Ketring (1984a) also pointed out that peanut genotypes differed in root volume, root dry weight, shoot height, shoot dry weight, leaf area, and leaf number. Root volume and dry weight were highly correlated among genotypes tested. Shoot dry weight, leaf area, and number of leaves were significantly correlated in most

tests. Root dry weight and volume were positively correlated with shoot dry weight, leaf area, and leaf numbers, but not necessarily with all of these parameters in every test. He indicated that there was strong coordination between aerial and subterranean growth. Based on these studies of peanut root characteristics, Ketring (1984a) suggested that selection for more extensive rooting traits is feasible for peanut and may prove useful for developing more drought tolerant peanut cultivars. Recently, Pandey et al. (1984c) pointed out that peanut roots with greater ability to extract deeper soil water and continuously maintain an adequate water uptake was an important mechanism of drought avoidance. They concluded that peanut appeared to have a more balanced root and shoot adaptative mechanism than mungbean. Peanut also exhibited better shoot adjustment (reduced leaf area and slow growth) and an extensive deep root system which led to greater drought resistance.

Soil is a growth medium providing plants with support, nutrients, and water from a dynamic, three-phase, exceedingly complex system. In terms of water relations, soil has been considered as a water reservior and the relation between soil water and plant water status are closely related (Thien, 1983). Recently, the neutron probe has proven to be an useful and rapid method for determining soil water content (Thien, 1983; Kramer, 1983). This method is based on the fact that hydrogen atoms have a much

greater ability to slow down and scatter fast neutrons than most other atoms, so that counting slow neutrons in the vicinity of a source of fast neutrons provides a means of estimated hydrogen (water) content. Recently Bennett et al. (1984) measured volumetric soil water content during a drying cycle at three depths down to 90 cm. They found that when the volumetric soil water content dropped to about 0.04 (cubic meter per cubic meter) in the upper soil profile, water extraction from those depths by the nonirrigated plants was reduced.

Leaf water status affects numerous physiological processes which contribute to plant growth and yield. It is believed that changes of leaf water status under drought conditions may provide information for understanding the mechanism(s) of adaptation and drought tolerance of peanut. The water relation components also may be used to differentiate genotype differences in drought tolerance. According to Kramer (1983), a satisfactory method of monitoring plant water status should meet the following criteria: (1) There should be a good correlation between rates of physiological processes and the degree of water stress measured by the method. (2) A given degree of water stress measured by the selected method should have similar physiological significance in a wide range of plant materials. (3) The units employed to express water status should be applicable to plant material, soil, and solutions. (4) The method should be as simple, rapid, and

inexpensive as possible. And (5) it should require a very small amount of plant material for a measurement. Based on this suggestion, several parameters have been used for measurement of water status. Many parameters such as water potential, osmotic potential, turgor potential, stomatal resistance, relative water content, canopy temperature and the temperature difference between leaf and ambient have been proposed as good water stress measurement methods (Turner, 1981; Jackson et al., 1981; Keener and Kircher, 1983; Bennett et al., 1984). Recently, O'Toole et al. (1984) also suggested that "Crop water stress index" (CWSI) can be used effectively in measurement of water stress.

Relative water content (RWC), defined as the ratio between fresh weight minus dry weight and the saturated weight minus dry weight of leaf tissue, has been suggested as another good indicator of plant water status (Hewlett and Kramer, 1963; Hsiao, 1973; Kramer, 1983). Hsiao (1973) indicated that RWC is related to water potential of plant tissue, although the relationship is dependent on species and stages of growth, on long-term alterations induced by environment, and possibly even on the short-term water history of the plant. He also pointed out that a major shortcoming is that RWC is a rather insensitive indicator of water status when water deficit is not severe. According to Turner et al. (1978), when relative water content reached about 82, 90, and 84 % then the turgor potential of soybean, corn, and sorghum approached zero,

respectively. In peanut, Allen et al. (1976) showed that RWC varied during the day and decreased under induced-drought conditions. Bennett et al. (1981) found that turgor potential of Florunner was 1.2 MPa at 100 % RWC and decreased to zero turgor potential at 86 % RWC. A linear correlation coefficient of 0.625 between leaf turgor potential and RWC was found when turgor potential was greater than zero. Recently, Erickson and Ketring (1985) showed peanut genotypes differed when RWC was expressed as a ratio between rainfed and irrigated treatments. They also used RWC with osmotic potential to estimate the apoplastic water fraction of leaf tissue. Thus, RWC has potential for estimating the water status of peanut plants.

Data have given a more quantitative basis to relationships between stomatal opening and leaf water status. Stomatal closure in response to water stress is a powerful mechanism for regulating water loss and reducing the development of further stress (Begg and Turner, 1976; Jarvis, 1980; Singh et al., 1983). Hsiao (1973) stated that stomatal opening and closing is related to turgor. In many plant species stomates are unaffected by leaf water status until the water potential decreases below a threshold level. This level varies with species and may vary with growing conditions. Reduction of water potential below this threshold level will cause stomatal closure even at 0.2 to 0.3 MPa. O'Toole and Cruz (1980) reported that

rice leaf diffusive resistance and degree of leaf rolling were linearly related to leaf water potential. Based on the relation between stomatal resistance and leaf water potential, Henzell et al. (1975) also suggested stomatal resistance can be used to screen sorghum genotypes for stomatal sensitivity to water deficit. In peanut, under field conditions, Allen et al. (1976) measured stomatal resistance under increasing water stress conditions over a 21-day period and found stomatal resistance was significantly higher in the stressed plants. They concluded that drastic stomatal closure occurred in peanuts only when most soil water was depleted. At that time, the plants reduced further water loss by folding their leaflets. This reduced exposed evaporative surface area and placed leaf laminae parallel to direct-sunbeam radiation. Pallas et al. (1979) found that early 35-day drought had little effect on peanut leaf stomatal resistance and they recovered stomatal function quickly following relief of water stress. Similar results were also shown by Black and Squire (1979). However, they found that the stomatal response was greatly reduced or absent in nonirrigated plants in which stomatal conductances were reduced. In addition to regulating transpiration, stomates also control carbon dioxide uptake, which is required for photosynthesis and dry matter production. Therefore, many investigations have concentrated on the behavior of stomata in relation to the amount of carbon dioxide fixed per unit

water transpired, i.e. water use efficiency (Hsiao, 1973; Begg and Turner, 1976; Ludlow, 1980; Mansfield and Davies 1981). Also other environmental factors such as crop geometry (row spacing and directional orientation of rows) can affect stomatal behavior and hence affect water use efficiency and yield. Abdul-Jabbar (1978) suggested that the physiological characteristics of irrigated peanut plants grown in narrow north-south rows interact with environmental demand to cause the stomates in leaves to close earlier in the day than stomates of leaves of plants grown in wide north-south rows. The effect on stomates was evident only on days with high evaporative demand, i.e., bright full sunshine, strong southerly wind, and high air temperature. Recently, Stone et al. (1985) further indicated that in both narrow and wide row treatments, the relationship between stomatal resistance and leaf water potential was generally linear. They reported that stomatal resistance of peanut plants grown in narrow-rows became higher at mid to late day than the stomatal resistance of plants grown in wide-rows. They suggested that stomatal behavior was under complex control by leaf water potential and environmental evaporative demand, and highly influenced by row spacing.

Water potential seems to be the best single measurement of plant water status because it is a measure of chemical potential of water. It controls water movement in the soil-plant-atmosphere system. The most reliable

measurements of water (also solute) potentials are made by thermocouple psychrometers (Begg and Turner, 1976; Kramer, 1983). Responses and adaptation of plants to drought stress in relation to changes in water relation components such as water, osmotic, and turgor potential, relative water content, and stomatal resistance has been studied and reviewed in many papers and publications (Hsiao, 1973; Begg and Turner, 1976; Bewley, 1979; Levitt, 1980b; Turner and Kramer, 1980; Raper and Kramer, 1983; Teare and Peet, 1983; Kramer, 1983). These data indicated that variations in these parameters are species and genotype specific and are influenced by many environmental factors. Under water deficit conditions, changes in these water parameters can affect many important processes including photosynthesis, dark respiration, translocation, partitioning of metabolites, and ultimately plant growth, development, and yield. In peanut, water potential of water-stressed plants decreased to -3.0 to -4.0 MPa (Allen et al., 1976; Pallas et al., 1979). Gautreau (1977) found that peanut water potential, measured by the Chardakov dye method, was -1.2 and -1.7 MPa for irrigated and nonirrigated peanut plants, respectively. He concluded that peanut genotypes differd in water potential and lower water potentials were correlated with higher yield under nonirrigated conditions, indicating drought tolerance mechanisms in the higher yielding varieties. Bennett et al. (1981) showed that turgor potential of Early Bunch and Florunner peanut leaves

decreased to zero at leaf water potential of -1.2 and -1.3 MPa and relative water content of 87 %. They said there were no cultivar differences in leaf water potential at which turgor potential approached zero. Water potential and relative water content were positively correlated when tugor potential was greater than zero. In their recent studies (1984), they found that plant water content was positively associated with soil water content. Leaf diffusive resistance also was negatively associated with leaf water and turgor potential, respectively. They concluded that osmotic potentials measured at 100 % relative water content were similar for irrigated and nonirrigated peanut plants. Thus, there was little or no osmotic adjustment of peanut under drought conditions. Other research conducted by Pandey et al. (1984b) found peanut plants exhibited leaf water potentials of -0.67 MPa (measured by pressure chamber method) between 1300 and 1400 h in dry regimes 60 days after emergence. Leaf water potential decreased with increased severity of water stress and the seasonal cumulative leaf water potential was negatively correlated with yield. They declared that cumulative water potential may be useful for selection of peanut genotypes for drought prone areas. By using the ratio between rainfed and irrigated peanut, Erickson and Ketring (1985) reported that peanut genotypes differed in water, osmotic potentials, and relative water content. Maximum water potential and relative water content ratios

were found for all genotypes at 63 and 50 days after planting, respectively, whereas the maximum ratio of osmotic potential was significantly different among genotypes at 56 and 63 days after planting. Apoplastic water content differed among peanut genotypes and may be genotype specific. They concluded that the lower water potential, greater change in osmotic potential, higher apoplastic water content, and yield of Comet under rainfed conditions indicated Comet had greater resistance to dehydration when high soil moisture deficits and evaporative demand conditions occur.

Significant growth and yield reductions are almost always found under drought conditions and the mechanism(s) for these reductions are complex. Diversity in drought-induced growth and yield reductions among plant species and genotypes also occurs. The severity of reduction depends on the plant growth stage, duration of stress, and intensity of drought (Hsiao, 1973, Begg and Turner, 1976; Fischer, 1980; Kramer, 1983). Vegetative growth, in general, and leaf expansion, in particular, are severely inhibited by relatively moderate water stress, which inhibits cell division, cell expansion, and differentiation. Physiologically, the causes of growth and yield reductions are associated with inhibition of photosynthesis, dark respiration, translocation, ion uptake, nitrogen fixation in legumes, and biomolecular synthesis (Levitt, 1980b; Paleg and Aspinall, 1981; Kramer,

1983). In peanut, Dashiell (1979) reported that spanish yielded better than virginia type genotypes under rainfed conditions when seasonal rainfall was less than 35 cm. Pandey et al. (1984c), based on their studies on legumes, indicated that drought adversely affected total shoot dry weight. Water stress reduced the total shoot dry weight by 78 % in mungbean, 52 % in soybean, and 60 % in cowpea. They found that crop growth rate, leaf area expansion rate, leaf area duration, leaf area index, and specific leaf weight were also significantly reduced. These reductions in vegetative growth were related to yield loss in these crops. Effects of water deficit on growth, development, and yield in peanut was extensively reviewed by Boote et al. (1982). They indicated that drought stress inhibited leaf expansion, crop growth rate, stem elongation, and rate of dry metter accumulation. The water deficit during pod formation (50 to 80 days) reduced flowering, pod formation, and final yield more than water deficit at any other growth stage. Also seed quality (such as percent of sound mature kernels, and germination of sound mature seed) was also significantly reduced under drought conditions. Pandey et al. (1984a) also found yield reductions under drought conditions. Yields were higher for soybean and cowpea than for peanut with comparable stress (66, 65, and 46 %, respectively). Yield reductions were mainly due to reduced numbers of pods per square meter, followed by number of seeds per pod, while seed weight was not affected. Harvest

index decreased with increasing levels of drought for all legumes tested. Recently, Erickson and Ketring (1985) found peanut yield and seed quality (% sound mature kernel (SMK) plus sound split (SS)) were significantly reduced under rainfed situations. A significant difference in yield and grade was found between Comet and Florunner in 1982 under rainfed conditions. Spanish type peanut genotypes showed better quality under rainfed conditions in both 1982 and 1983.

The potential for infrared thermometry (IRT) measurements of crop temperatures for crop water deficit assessments was recognized by Tanner (1963). This potential occurs because leaf temperature rises as stomates close and transpiration is reduced. Three basic approaches, have been employed for IRT-determination of crop temperature to assess the severity of water deficits. The first used differences in crop temperature (Tc) between various experimental treatments, with a well-watered treatment usually providing the reference Tc (Fuchs and Tanner, 1966). In the second method, suggested by Aston and van Bavel (1972), the variability of replicate Tc measurements was used to indicate the level of water deficit. The third approach ultilized the crop-air temperature difference (Tc-Ta), which has been shown to be negatively correlated with leaf relative water content (Wiegand and Namken, 1966) and with plant water potential (Ehrler et al., 1978). The theory for relating canopy-air

temperature differences to crop drought stress has a sound basis (Jackson et al., 1981). When a leaf is freely transpiring, the cooling properties of evaporating water keep the leaf temperature relatively cool. When water becomes limited, the heat load on the leaf builds up and only convection and thermal radiation emission can dissipate the heat. Thus, leaf temperature will approach air temperature and often rise above it under severe drought stress conditions. Temperature difference has been related to crop yield in wheat (Idso et al., 1977), barley, sorghum and soybean (Isdo et al. 1980), corn (Keener and Kircher, 1983), and beans (Walker and Hatfield, 1983). These investigations indicated IRT can be a good drought stress indicator if proper position and veiwing angle of the instrument are used (Nielson et al., 1984).

High temperature stress usually, but not always, accompanies drought stress. The effects of heat stress are often confounded with those of drought stress (Levitt, 1980a; Eastin et al., 1983). Unfavorably high temperature during the crop season can affect plant growth and development by altering physiological processes. Increased transpiration rate, and respiration, reduced photosynthesis, protein and enzyme activity, cell divison and elongation, and altered membrane integrity, etc. contribute to lower plant productivity (Bjorkman et al, 1980; Levitt, 1980a; Terri, 1980; McDaniel, 1982). In addition to direct injury by heat stress, a secondary

stress (dehydration stress) also is superimposed on the crop and leads to growth and yield reductions. Therefore, many investigations have emphasized adaptation and response of crop plants to high temperature stress. Sorghum (Sullivan et al., 1977), wheat (Blum and Ebercon, 1981), corn (Mederski, 1983), and soybean (Martineau et al., 1979; Shaw, 1983; Bouslama and Schapaugh, 1984) have been studied. These studies showed that genotypes differed in heat tolerance and the severity of yield and growth reduction depended on duration of heat stress, crop growth stage, and temperature level. The mechanism of heat injury is due to damage of cell membranes by high temperature (Levitt, 1980a; Raison et al., 1980; McDaniel, 1982). Hence, measurement of membrane thermostability by conductance of electroyte leakage from injured cells was considered a useful indicator for heat tolerance of crops and for selection among genotypes in a crop breeding program (Blum and Ebercon, 1981; Bouslama and Schapaugh, 1984).

Evidenced by the above literature, we realized that water deficits and high temperature are among the most important environmental factors that limit crop productivity in many areas of the world. The lack of yield stability of peanut because of variable climatic conditions has indicated a need to develop methods to evaluate peanut responses and adaptation to drought and high temperature stresses conditions.

CHAPTER III

ROOT GROWTH CHARACTERISTICS OF PEANUT GENOTYPES

Introduction

Plant roots are one of the major organs for water and nutrient uptake from soil. Root development and amount of water absorption from the soil are closely related (Hurd, 1975; Turner and Burch, 1983; Kramer, 1983). Under drought conditions the success of crop plants, such as wheat (Hurd, 1974, 1975), rice (Steponkus et al., 1980), sorghum (Jordan and Miller, 1980), and soybean (Taylor, 1980, Kaspar et al., 1984), is often dependent on the growth characteristics of roots (root length, growth rate, number, length density, volume, and distribution), especially the development of deep and widely-distributed root systems when the soil water content falls much below field capacity. Generally, studies have shown that as the depth, width, and branching of the root system increases, plant water stress decreases.

Diveristy in root growth and development characteristics among genotypes within species has been found in many crops. Cotton genotypes differed in root length, and number of downward-growing roots, and relative

root weight (Quizenberry et al., 1981; Eissa et al., 1983). Taylor et al. (1980) also pointed out that taproot growth rate and root lenght were different among soybean genotypes. Furthermore, Kaspar et al. (1984) found taproot-elongation rates that differed among soybean cultivars screened under greenhouse conditions also differed under field conditions. Higher taproot growth rates were positively associated with deeper roots. In peanut, Bhan (1973) indicated that differences in rooting depth, number of primary and secondary roots, and root weight occurred among peanut botanical types and genotypes. He also found that the number of primary roots at 25 cm depth, number of secondary roots at both 25 and 50 cm depth, and total dry weight were significantly correlated with shoot weight. Robertson et al. (1980) reported that 84 % of peanut total rooting length was in the top 15 to 30 cm. They also showed that rooting length density of the Florunner cultivar decreased with increasing soil depth. Ketring et al. (1982) measured root and shoot characteristics of peanut genotypes and found that considerable diversity in root length and number of strong downward-growing lateral roots existed among genotypes. Correlations between shoot and root parameters indicated strong positive association between aerial and subterranean growth. Root length and numbers were highly correlated for spanish, but not for virginia genotypes. Jordan et al. (1983) evaluated root systems of exotic peanut lines and

found that genetic variation existed in root number at 1 m depth, hypocotyl diameter, tap root dominance, lateral root density, number of fine roots, and number of nodules. Recently, Ketring (1984a) indicated peanut genotypes differed in both root (volume and dry weight) and shoot (height, dry weight, leaf area, and leaf number) characteristics. Root volume and dry weight were highly correlated among entries tested. Shoot dry weight, leaf area, and number of leaves were significantly correlated in most tests. Root dry weight and volume were positively associated with shoot dry weight, leaf area, and number of leaves. Based on his results, he suggested that selections for extensive rooting traits is feasible to develop more drought tolerant peanut cultivars.

As indicated by Quizenberry (1983), cultivar evaluations and breeding for root development have been carried out in several crop species and this approach proved to be effective in increasing crop water use efficiency and drought tolerance. Evidenced from the above studies, improvement of rooting traits through selection of useful root growth characteristics may enhance the resistance of peanut to drought stress. In order to achieve this goal of breeding peanut for drought tolerance, more detailed studies in root growth are still needed. Therefore, the objectives of this study were to evaluate genotypic variations in root growth characteristics and the intercorrelation among these parameters under greenhouse

conditions.

Materials and Methods

Two sets of experiments, each with two tests, were conducted in the greenhouse located at the Plant Science Research Laboratory, Agricultural Research Service, USDA, Stillwater, Oklahoma during 1983 and 1984. Six and seven peanut (Tamnut 74 was included as a check cultivar in root volume trials only) genotypes were tested in randomized complete block designs with six replications for root length and root volume studies. The genotypes examined in this study were OK-FH-13 and OK-FH-14 (selection lines from the cross combination of Spanhoma x Florunner), and Florunner that belong to the virginia botanical type (Arachis hypogaea L. ssp. hypogaea var. hypogaea), and Comet, Pronto, and Spanhoma which are spanish botanical type (A. hypogaea L. ssp. fastigiata var. vulgaris). These genotypes were also used throughout the studies described in subsequent chapters.

Seeds of each genotypes were imbibed with distilled water in petri dishes and were incubated at 30 C for 16 h. Imbibed seeds then were wrapped in wet paper towel, sealed upright in glass germination chambers so that the root will grow straight vertically, and incubated at 30 C again for 24 h. At 40 h, germinating seeds with uniform radicle lengths were used for root length and root volume studies.

In root length studies, two tests were conducted from

May 26, 1983 to July 1, 1983 (Test 1) and from January 5, 1984 to February 10, 1984 (Test 2), respectively. For each test, seeds were planted in 5 cm (inside diameter) clear PVC tubes 2.1 m in length containing a mixture of potting soil, and fine and coarse vermiculites in a 0.5:1:1 (v/v) ratio as the growth mixture. A total of 36 tubes were arranged according to designs and put in slanted root growth chambers for root growth determinations. Plants were watered twice daily for 2 minutes with an automatic drip irrigation system. A modified Hoagland nutrient solution (200 ml) was applied to each tube once a week starting at 2 weeks after planting. Growth length of the downward-growing taproot was measured 3 times per week (a 2 or 3 day interval) until the end of the test. Number of main lateral roots and total root length per each 30 cm depth were also counted and measured for estimating root length density. At the end of the test, the total root length and shoot dry weight were recorded.

In root volume studies, two tests were conducted from January 5 to February 16 (Test 1) and from March 2 to April 12, 1984 (Test 2), respectively. Uniform, pre-germinated seeds of each genotype were planted in PVC tube (10.2 cm inside diameter and 76.2 cm in length) which contained fritted clay as potting material. A total of 42 tubes in each experiment were arranged according to experimental design. Water was applied as in the root length test and the plants received 200 ml of modified Hoagland nutrient

solution twice weekly. Plants were harvested 42 days after planting (DAP) for root volume determination by water displacement. Root and shoot dry weight were then determined.

Analysis of variance of the data was accomplished with Microstat using the North Star Horizon computer located in the Department of Agronomy, Oklahoma State University.

Results and Discussion

1. Root Length Studies

Significant differences in the amount of taproot growth among genotypes was found in both tests except at 28 and 30 DAP in Test 1 (Table 1) and 5 and 33 days DAP in Test 2 (Table 2). Peanut genotypes with different growth habits (virginia vs spanish) also showed significant differences in amount of taproot growth at most growth stages (Table 1). Significant differences in root growth rate were also found between botanical types. Virginia types had higher rates of root growth (in length) than that of spanish type (except at 5 to 9 DAP and 30 DAP in Test 1, and 5 DAP and 33 to 37 DAP in Test 2). Within each botanical type, Florunner and Pronto had the highest taproot growth rate. Examination of the data on taproot growth rates at different peanut growth stages (2 to 5 week after planting) showed significant differences among genotypes (Table 3). Significant interaction effects between genotypes and growth stages in growth rate were

also found in Test 1, but not in Test 2. The relationship between growth rate and growth stages (DAP) best fit a quadratic polynomial ($y = 2.56 + 1.72\ x - 0.322\ x^2$, $r=0.614^{**}$ in Test 1; $y = 3.10 + 1.12\ x - 0.193\ x^2$, $r=0.584^{**}$ in Test 2). The data showed that all peanut genotypes had maximum taproot growth rates at 21-28 DAP. The average taproot growth rates ranged from 4.57 to 4.61 cm/day depending on genotype. Virginia types had higher growth rates than spanish at 21-28 DAP. At this period, OK-FH-13 had the highest taproot growth rate of 5.5 and 5.4 cm/day in Test 1 and Test 2, respectively. Taproot growth rates increased with DAP until 21-28 days then declined at 28-35 DAP. According to Kramer (1983) and Kaspar et al. (1984), root growth rate is an important factor related to drought resistance. Taproot growth rate determined soybean rooting depth, and a soybean genotype with a dominant, rapidly elongating taproot will have a deeper root system and better water availability than a genotype with a weak, slow-growing taproot. But, they did not point out that genotypes differ in growth rate at different growth stages, which may be important in avoiding water deficit under drought conditions. However, Robertson et al. (1980) showed that peanut root growth progressed at rates of 2.2 to 2.8 cm/day in a sandy soil and had a lag until 30 days. In this study, higher growth rates, no lag in growth but relatively slower growth at later stages indicates the root growth potential of the genotypes.

Root number is also important in water absorption, especially under drought conditions (Jordan and Miller, 1980; Kramer, 1983). Genotypic differences in number of downward-growing lateral branches of roots at the 30 and 120 cm depths in Test 1, and at 30 cm depth in Test 2 were found (Table 4). In Test 1, virginia genotypes had more roots numbers (1.9 to 3.1) in the 120 cm profile than spanish genotypes. Pronto and Comet had the lowest root numbers at 30 and 120 cm depths. In Test 2, the opposite occurred. Spanish types had significantly higher root numbers (4.9 more) than virgina types at 30 cm, but not at lower depths. These results may be due to environmental effects because Test 1 and Test 2 were at different times, one was at early summer, the other at late winter. Different light intensity and photoperiod may alter shoot growth, which may affect root growth and development because of shoot-root relatioships. According to Kramer (1983), root growth depends on the supply of photosynthates from the shoots. Shading and reduction in leaf area will usually reduce root growth. Also, Ketring et al. (1982) mentioned that different photoperiod requirements for shoot growth and for partitioning photosynthates might affect root and shoot growth. Based on their assumptions, the above results might be due to different photoperiod and different responses between these two botanical types to photoperiod, which affected shoot growth and hence altered root growth. However, the results of Test 1 are probably

most representative since the environmental conditions were nearest those to which peanuts are adapted.

Another parameter of root growth is root length density, which is defined as the total root length in centimeter per cubic centimeter of soil. Significant differences in root length density among genotypes were found at 60 through 120 cm in Test 1, but not in Test 2 (Table 5). The lowest root length density was found for Pronto and Comet. Virginia types had 0.09 to 0.11 cm per cubic centimeter higher root length density in the 120 cm profile than spanish types. Higher root length densities found by Robertson et al. (1980) and Pandey et al. (1984c) occurred under field conditions with longer growth duration. Rooting depths to 120 cm have been observed for peanut under field conditions by Robertson et al. (1980). Final taproot length at 39 DAP was different among genotypes and also between botanical types in both tests (Table 6). Virginia types had 13.1 and 19.3 cm longer taproot length than spanish types in Test 1 and Test 2, respectively. Statistically, Florunner, OK-FH-14, and Pronto had the longest taproots in Test 1 and Spanhoma had the shortest taproots in both tests. The selections OK-FH-13 and OK-FH-14 had the longest roots in Test 2 (Table 6). The taproot length of the selections was most similar to the Florunner parent. Florunner taproot length in Test 2 was less than expected from previous results (Ketring et al., 1982) and from the results in Test 1.

There may have some planting date effect on taproot length, but this was not as notable as the effect on root length density (Table 5 and 6).

Shoot-root relationships are complex because the shoot can affect root growth and vice versa (Kramer, 1983). In our tests, significant differences in shoot dry weight between botanical types and among genotypes was obtained in Test 1, but not in Test 2 (Table 6). Mean shoot dry weight of spanish was higher than virginia types. Florunner, Comet, and Spanhoma had more shoot weight while OK-FH-13 and OK-FH-14 had less shoot dry weight (Test 1, Table 6). Linear correlation coefficients between shoot dry weight and taproot length was significant ($r=0.943$) in Test 2, but not in Test 1. Results in Test 2 were consistent with those obtained by Ketring et al. (1982) who reported high correlation between shoot dry weight and root length in experiments done during October and November.

2. Root Volume Studies

No significant differences in root volume and root dry weight were found among genotypes and between botanical types for both tests. However, significant differences in shoot dry weight, total plant dry weight, and root/shoot ratio between types and among genotypes were obtained (Table 7 and 8). Virginia type peanuts tended to have higher shoot and total dry weight, but lower root/shoot ratios than spanish types. Within virginia types, no

genotypic differences in these parameters were found. However, within spanish types, Pronto had the highest shoot, total dry weight, and root/shoot ratio in Test 1. This occurred for Comet in Test 2. The selections (OK-FH-13 and 14) from the Spanhoma x Florunner cross were similar to the Florunner parent.

In both tests, highly positive linear correlation coefficients were found between root volume and root dry weight (r=0.923 and r=0.884), shoot dry weight (r=0.766 and r=0.693), and total dry weight (r=0.843 and r=0.750) (Table 9). Root dry weight also was positively correlated with shoot (r=0.881 and 0.920) and total dry weight (r=0.948 and 0.959). No significant linear correlation coefficients occurred between root/shoot ratio, root volume and root dry weight except for root dry weight in Test 2. Similar trends in intercorrelation among these parameters obtained from combined data were also found. Similar results were obtained by Ketring (1984a) in his root studies. However, there were no differences in root volume and root dry weight among the genotypes selected for the present study.

Summary and Conclusions

As reported for several crops, peanut shows differences in root growth characteristics which have implications for drought resistance. Many researchers have suggested that peanuts with longer taproot, rapid root growth rate, and more root numbers may increase crop water

use efficiency, delay occurrence of drought stress and hence growth and yield reductions should be lowered (Bhan, 1973; Robertson, 1980; Ketring et al., 1982; Boote et al., 1983; Jordan et al., 1983; Ketring, 1984a; pandey et al., 1984c). To evaluate the potential of peanut root development in relation to drought resistance, peanut root growth characteristics such as taproot growth rate at different periods of growth, taproot length, root number, root length density at different depths and the relationship between taproot length and shoot dry weight were examined under greenhouse conditions. Separated studies on root volume, root dry weight, shoot dry weight, root/shoot ratio, and their interrelationship were also conducted. Data obtained showed that peanut genotypes and botanical types differed in taproot growth rate, root number and lenght density in the first 30 cm of soil profile. However, perhaps due to the different times during the year when the tests were conducted, several characteristics such as root length density, number of roots at different depths, and correlation between taproot length and shoot dry weight varied between tests. This suggested that environmental factors, especially photoperiod and/or light intensity may affect shoot and root growth and their development. In root length studies, the fastest taproot elongation was found during 21 to 28 days after planting and virginia type peanuts had longer taproot and faster root growth rate than spanish types.

The correlation bewteen taproot length and shoot dry weight was significant in one test held during late winter. In root volume studies, no significant differences in root volume and root dry weight were found among genotypes. However, peanut genotypes and botanical types differed in shoot dry weight, total dry weight, and root/shoot ratio. Virginia types tended to have heavier shoot, total dry weight, and lower root/shoot ratios than spanish types. Significant positive linear correlations were found between root volume and shoot, root, and total dry weights. Also root dry weight was positively associated with shoot, and total dry weights. Root volume and root dry weight did not show linear relationships with the root/shoot ratio in this study.

Studies of root growth and development are difficult even under rhizotron and greenhouse conditions. Improved methodology will be important in crop production improvement because information obtained can aid in understanding root growth and development physiology under natural field conditions.

TABLE 1

LENGTH (CM) OF ROOT GROWTH AT CONSECUTIVE DAYS AFTER PLANTING (DAP), 1983

DAP	Florunner	OK-FH-13	OK-FH-14	Comet	Pronto	Spanhoma
5	7.5a+	1.6c	5.0b	5.3b	6.7ab	1.7c
7	6.9a	2.6c	4.7b	6.1a	6.4a	2.6c
9	8.8a	4.7d	6.7bc	8.0ab	8.2a	5.2cd
12	15.1a	10.4c	13.4ab	13.1ab	13.1ab	11.3bc
14	9.4ab	7.4cd	9.7a	8.1bcd	8.7abc	7.1d
16	10.1a	9.1ab	10.2a	8.4b	8.8b	7.8b
19	16.1a	13.2bc	14.7ab	13.1bc	13.8bc	12.2c
21	10.0a	10.2a	9.1ab	8.5b	8.5b	8.4b
23	10.5a	9.7ab	9.7ab	8.5bc	8.4bc	8.0c
26	16.4a	17.2a	16.1ab	13.6bc	14.5abc	13.1c
28	10.5a	11.7a	10.7a	9.3a	9.9a	9.9a
30	9.5a	9.9a	9.9a	8.7a	9.3a	9.4a
33	13.0ab	14.2a	12.7abc	11.1bc	12.3abc	10.8c
35	8.1ab	8.6a	8.3a	6.7c	6.9bc	7.3abc
37	9.2ab	9.7ab	10.2a	8.1b	8.4b	8.2b

+ Mean values with the same letter within rows were not significantly different ($P<0.05$) according to Duncan's Multiple Range Test (DMRT).

TABLE 2

LENGTH (CM) OF ROOT GROWTH AT CONSECUTIVE DAYS AFTER PLANTING (DAP), 1984

DAP	Florunner	OK-FH-13	OK-FH-14	Comet	Pronto	Spanhoma
5	9.6a+	9.5a	11.6a	9.9a	8.2a	8.1a
7	8.3b	9.7a	9.6a	8.0b	7.9b	7.8b
9	8.9abc	9.7ab	9.9ab	8.0bc	7.5c	8.0bc
12	12.7a	13.4a	13.5a	9.7b	10.5b	10.3b
14	8.7ab	8.9a	9.1a	7.4b	7.9ab	7.8ab
16	7.8bc	8.8ab	9.1a	7.0c	7.6c	7.5c
19	13.4b	14.5a	14.7a	11.7c	12.6bc	12.6bc
21	9.7b	10.7a	10.7a	8.8c	9.1bc	9.0bc
23	9.5b	11.2a	10.8ab	9.0b	8.8b	9.2b
26	14.6bc	16.0a	15.4ab	13.6c	14.2bc	13.5c
28	9.8b	10.9a	11.1a	9.4b	9.9b	9.6b
30	8.9c	10.1ab	10.5a	9.0c	9.0c	9.4bc
33	12.3a	12.6a	12.7a	12.7a	12.2a	11.7a
35	9.2a	9.9a	9.7a	9.1a	9.3a	9.2a
37	7.5a	8.7a	9.0a	8.2a	8.1a	8.5a

+ Mean values with the same letter withinin rows were not significantly different ($P<0.05$) according to Duncan's Multiple Range Test (DMRT).

TABLE 3

TAPROOT GROWTH RATE (CM/DAY)
AT VARIOUS PERIODS

DAP	Florunner	OK-FH-13	OK-FH-14	Comet	Pronto	Spanhoma
			Test 1			
8-14	4.8a x+	3.2c y	4.2b x	4.2a x	4.3a x	3.4b y
15-21	5.2a x	4.6b xyz	4.9ab xy	4.3a yz	4.5a yz	4.1ab z
22-28	5.4a xy	5.5a x	5.2a xy	4.5a y	4.7a xy	4.4a y
29-35	4.4b x	4.8b x	4.4b x	3.8a x	4.1b x	3.9ab x
			Test 2			
8-14	4.3b xy	4.6b x	4.7b x	3.8b z	3.7c yz	3.7b yz
15-21	4.4ab y	4.9ab x	4.9ab x	3.9b z	4.2b yz	4.2b yz
22-28	4.9a y	5.4a x	5.3a x	4.6a y	4.7a y	4.6a y
29-35	4.3b x	4.7b x	4.7b x	4.4a x	4.4ab x	4.3a x

+ Mean values with the same letters (a,b,c within columns; x,y,z within rows) in the same test indicated no significant difference ($P<0.05$) according to DMRT.

TABLE 4

ROOT NUMBER AT DIFFERENT DEPTHS

Depth	Florunner	OK-FH-13	OK-FH-14	Comet	Pronto	Spanhoma
			Test 1			
30 cm	8.3a+	6.3a	7.0a	2.3b	2.5b	7.5a
60 cm	6.0a	4.5a	4.5a	2.5a	2.3a	4.5a
90 cm	5.5a	4.0a	4.3a	2.0a	1.8a	3.3a
120cm	3.0a	2.5abc	3.5a	1.0c	0.8c	1.3bc
150cm	1.3a	0.25a	1.3a	0.3a	0.5a	0.5a
			Test 2			
30 cm	3.3c	4.7bc	3.0c	5.3bc	11.0a	9.3ab
60 cm	2.3a	2.3a	2.0a	3.0a	4.0a	1.8a
90 cm	1.3a	1.3a	1.5a	1.5a	2.3a	1.0a
120cm	1.3a	1.0a	1.2a	1.0a	1.7a	1.0a
150cm	1.0a	1.0a	1.0a	1.0a	1.0a	1.0a

+ Mean values with the same letter within rows in the same test were not significantly different ($P<0.05$) according to DMRT.

TABLE 5

ROOT LENGTH DENSITY (CM/CUBIC CM)
AT DIFFERENT DEPTHS

Depth	Florunner	OK-FH-13	OK-FH-14	Comet	Pronto	Spanhoma
			Test 1			
30 cm	.30a [+]	.24a	.25a	.14a	.09a	.27a
60 cm	.34a	.25ab	.23ab	.11b	.11b	.29a
90 cm	.29a	.23ab	.18abc	.11bc	.10c	.18abc
120cm	.21a	.13bc	.16ab	.05c	.04c	.07bc
150cm	.07a	.01a	.07a	.01a	.01a	.02a
			Test 2			
30 cm	.08a	.12a	.08a	.11a	.17a	.13a
60 cm	.07a	.08a	.08a	.07a	.11a	.06a
90 cm	.06a	.06a	.06a	.06a	.09a	.05a
120cm	.05a	.05a	.05a	.04a	.04a	.04a
150cm	.05a	.05a	.05a	.04a	.04a	.04a

[+] Mean values with the same letter within rows in the same test were not significantly different ($P<0.05$) according to DMRT.

TABLE 6

VARIATIONS IN TAPROOT LENGTH AND SHOOT DRY WEIGHT

Genotype	Test 1		Test 2	
	Taproot Length (cm)	Shoot Dry Weight (g)	Taproot Length (cm)	Shoot Dry Weight (g)
	Virginia Type			
Florunner	171.7a+	7.62abc	158.8b	2.80 a
OK-FH-13	149.4bc	4.94d	173.5a	3.03 a
OK-FH-14	162.8ab	5.15cd	175.7a	3.26 a
Mean	161.3x	5.90x	169.3x	3.03x
	Spanish Type			
Comet	150.2bc	8.91a	150.0b	2.63 a
Pronto	158.6ab	6.17bcd	151.4b	2.51 a
Spanhoma	135.8c	7.95ab	148.7b	2.28 a
Mean	148.2y	7.68y	150.0y	2.47x

+ Mean values with the same letter within columns and tests indicated no significant difference ($P<0.05$) according to DMRT.

TABLE 7

ROOT VOLUME (RV), DRY WEIGHT (DW), SHOOT DRY WEIGHT, TOTAL DRY WEIGHT, AND ROOT/SHOOT RATIO OF PEANUT TESTED DURING JANUARY AND FEBRUARY, 1984 (TEST 1)

Genotype	Root Vol. (cc)	Root DW (g)	Shoot DW (g)	R/S	Total DW (g)
		Virginia Type			
Florunner	12.8a[+]	1.2a	2.2ab	.55c	3.4a
OK-FH-13	11.1a	1.0a	1.8ab	.55c	2.8ab
OK-FH-14	12.7a	1.2a	2.3a	.51c	3.5a
Mean	12.2x	1.1x	2.1x	.54x	3.2x
		Spanish Type			
Comet	13.4a	1.1a	1.6bc	.66b	2.7ab
Pronto	14.5a	1.3a	1.8ab	.72a	3.1a
Spanhoma	8.9a	0.8a	1.1c	.68ab	1.9b
Tamnut 74	14.6a	1.2a	1.7abc	.68ab	2.8ab
Mean	12.9x	1.1x	1.6y	.69y	2.6y

[+] Mean values with the same letter within columns indicated no significant difference ($P<0.05$) according to DMRT.

TABLE 8

ROOT VOLUME (RV), DRY WEIGHT (DW), SHOOT DRY WEIGHT, TOTAL DRY WEIGHT, AND ROOT/SHOOT RATIO OF PEANUT TESTED DURING MARCH AND APRIL, 1984 (TEST 2)

Genotype	Root Vol. (cc)	Root DW (g)	Shoot DW (g)	R/S	Total DW (g)
		Virginia Type			
Florunner	12.7a[+]	1.1a	2.2ab	.53cd	3.3ab
OK-FH-13	14.4a	1.3a	2.7a	.49d	4.1a
OK-FH-14	14.7a	1.3a	2.7a	.48d	3.9a
Mean	13.9x	1.2x	2.5x	.50x	3.8x
		Spanish Type			
Comet	15.4a	1.2a	2.0ab	.61bc	3.2ab
Pronto	12.1a	1.0a	1.4b	.71a	2.4b
Spanhoma	11.1a	1.0a	1.6b	.65ab	2.5b
Tamnut 74	11.8a	1.0a	1.5b	.65ab	2.5ba
Mean	12.6x	1.1x	1.6y	.66y	2.7y

[+] Mean values with the same letter within columns indicated no significant difference ($P<0.05$) according to DMRT.

TABLE 9

CORRELATION MATRIX FOR ROOT AND SHOOT CHARACTERISTICS OF PEANUT TESTED IN 1984

	Root Vol.	Root DW	Shoot DW	R/S
		Test 1		
Root DW	.923**			
Shoot DW	.766**	.881**		
R/S	.014	-.087	-.529**	
Total DW	.843**	.948**	.986**	-.387*
		Test 2		
Root DW	.844**			
Shoot DW	.693**	.920**		
R/S	-.187	.459*	-.737**	
Total DW	.750**	.959**	.993**	-.666**
		Combined Data		
Root DW	.884**			
Shoot DW	.722**	.893**		
R/S	-.110	-.297	-.666**	
Total DW	.791**	.949**	.989**	-.563**

*, ** Significant at the 0.05 and 0.01 probability levels, respectively.

CHAPTER IV

SOIL WATER EXTRACTED BY PEANUT UNDER RAINFED AND IRRIGATED CONDITIONS

Introduction

Soil not only provides plant support but also supplies water and nutrients for growth and development. In soil plant-water relations, soil serves as the water reservior. Plant roots extract water from soil for metabolism and transpiration. It was proposed that plants which have deep and well-developed root systems can extract soil water more efficiently and may delay or tolerate drought stress (Jordan and Miller, 1980; Passioura, 1981; Kramer, 1983; Taylor, 1983; Ketring, 1984a). Based on this hypothesis, several breeding programs have been initiated for improving crop rooting characteristcs for high water use efficiency and drought tolerance, such as soybean and cotton (Kaspar et al., 1984; Eissa et al., 1983).

Soil water content can affect root growth. Severe deficiency in soil water will cause the cessation of root growth. Newman (1966) found a reduction in flax root growth at soil water potential of -0.7 MPa. The growth rate was only 80 % of the control at -1.5 MPa, but some growth occurred in soil drier than -2.0 MPa. It also

appeared that root growth at any depth was independent of the water potential at other depths because at a stage when root growth was much reduced in the upper, drier layer, it was not yet reduced in the deepest, wettest layer of soil. On the other hand, plant root growth through the soil can cause the depletion of soil water. Studies on soil water extraction patterns of many crops such as soybean (Reicosky et al., 1972; Allmaras et al., 1975) showed that starting with a uniformly wet soil profile, water is initially extracted from the region nearest the surface with the zone of extraction progressing downward through the profile. Also, with prolonged drought, soil water was further depleted. Upper soil layers showed a rapid depletion of water. In peanut, Allen et al. (1976) measured soil water content profiles at different depths by soil tensiometers. They found that water had been extracted significantly to a 180-cm depth in the dry plot and was being extracted below this depth. Peanut roots were found to a depth of 193 cm under these conditions. Stansell et al. (1976) also found that roots of Florunner peanut extended to 30, 60, 90, and 120 cm depths in a Tifton loamy sand by 30, 42, 72, and 87 days after planting. Recently, Bennett et al. (1984) determined gravimetric soil water content at three depth intervals. They converted these data into volumetric water content and found that both irrigated and nonirrigated plants showed appreciable water uptake deep in the soil profile. It appears that the relation between soil

volumetric water content and leaf water potential was a quadratic polynomial. They then suggested that deep penetration of peanut roots and water extraction from deeper, heavier textured subsoils, which were capable of providing larger amounts of available soil water, may offer drought-avoidant capabilities to the peanut crop. However, they indicated that the upper layers of the profile must be moist to avoid plant water deficits.

Soil water content, which is related to root growth and plant water status, can be measured by many direct and indirect methods (Kramer, 1983). One commonly used indirect method for measuring soil water content is the neutron scattering method. By examining the change of soil water content and comparing neutron readings obtained at different depths between bare and planted plots, root growth might be estimated during various growth stages. Genotypic variation in root growth and amount of soil water extracted under rainfed and irrigated field conditions might also be obtained. Therefore, the objectives of this study were to examine the possible differences in soil water extraction and rooting depth of peanut genotypes under rainfed and irrigated conditions.

Materials and Methods

Experiments were conducted at the Agronomy Research Station, Perkins, Oklahoma during the summer growth seasons of 1983 and 1984. Peanuts were planted on May 25 and 26 in

1983 and 1984, respectively. The soil type is a Teller sandy loam (fine-loamy, mixed, thermic Udic Agriustolls). Rainfed (RF) and irrigated (IR) treatments, with five and six peanut genotypes were arranged in randomized complete block designs with two replications for testing soil water extraction in 1983 and 1984, respectively. Included with each replication was a 152 cm x 152 cm bare area (no plants) with a neutron tube covered with black plastic, suspended about 15 cm above the soil surface to block direct sunlight. The cover was removed and then replaced after irrigation. This cover prevented direct soil heating that would enhance excessive evaporation, but did not prevent evaporation due to wind or other factors that also influence evaporation within the plant canopy. Peanut genotypes examined were as described on page 25. The bare plot (control, CK) was used for comparison. Plots were two and four rows (6.1 m long and 0.9 m wide) in 1983 and 1984, respectively. Between two plants near the middle of one row of each plot (the two center rows were used in 1984), a 150 cm long access tube (3.8 cm inside diameter) was vertically driven for soil water measurement. About 5 cm of water was applied to irrigated plots weekly starting at 26 and 41 days after planting (DAP) in 1983 and 1984, respectively. Weeds were controlled by a pre-emergence herbicide (Balan). Hand-weeding was also done when necessary during the season. Soil water was measured by the neutron scattering technique. Troxler Soil Moisture

Meters (Model No. 3223, Troxler Electronic Laboratories, Inc., Research Triangle Park, NC) were used to measure the soil water content at 15, 30, 45, 60, 75, 90, 105, and 120 cm depth at weekly intervals. Neutron probe readings were converted into soil water water content (cc/cc) from standard curves for each instrument. A separate curve was used for the 15 cm depth. The curves were an integral part of the neutron probe data management software developed by J. R. Williams, Department of Agronomy, Oklahoma State University, for the North Star Horizon computer.

Results and Discussion

Significant differences in soil water extraction from 15 to 120 cm depths due to time (DAP) effects were found (Table 1). No significant genotype x treatment interactions in soil water extraction at all depths were observed. Treatment x time interactions were significant at all depths except at 105-120 cm depth in 1984 (Table 1). In 1983, significant genotypic and treatment effects on soil water extraction from 45 to 120 cm depths were found. However, in 1984, significant differences in soil water extraction due to genotypes and treatments were only found at 30-60, 75-90, and 60-90 cm depth, respectively. Genotype x time (DAP) interactions were also significant for all depths in 1983. In 1984, genotype x time interactions were significant only at 15 to 60 cm depths.

Changes in soil water content with time at 75 cm depth

under rainfed (RF) and irrigated (IR) conditions in 1983 and 1984 were shown in Fig. 1 and 2. Soil water content at 75 cm depth of RF plots were significantly lower than IR plots. Differences in soil water content between bare plot (control, CK) and planted plots at 75 cm depth became significant after 63 and 69 DAP in 1983 and 1984, respectively. Also, soil water content at the 75 cm depth under RF at 69 and subsequent DAPs was significantly lower than that of control. Under IR, all peanut genotypes, except OK-FH-14, were significantly lower in soil water content at 75 cm depth than the control (Fig. 1).

As indicated by Bohm (1979), measurement of root growth under field conditions with nondestructive methods is difficult. Although Upchurch and Ritchie (1984) have developed mini-rhizotrons equipped with a video camera, which can measure root growth in the field, more economic methods are still needed. The soil water depletion monitored by neutron scattering techniques can provide an indirect way to estimate root growth under natural field conditions (Bohm, 1979). Based on the soil water depletion of planted and control plots as a function of time (DAP) in this study, the effective root length can be estimated. The significant differences in soil water content at given depths between planted and control plots were used to estimate peanut roots at that depth. In 1983, peanut roots reached the 30-45 cm depth at 41 DAP (Table 2). Root length increased with time from 30-45 cm at 41 DAP to 120

cm (the maximum measuring depth) at 76 DAP. In 1984, root length at 49 DAP was about 45-60 cm. At 56 to 63 DAP, peanut roots reached 60-75 cm in depth. Roots at 90-105 cm were found at 77 DAP. After 84 DAP, peanut roots extended to 120 cm (Table 2). Similar reports on soil water extraction and peanut roots at 120 cm depth were also found by Allen et al. (1976), Stansell et al. (1976), and Robertson et al. (1980) by using similar approaches.

Total water extracted at different soil depths by peanut roots over the entire growing season in 1983 and 1984 is shown in Table 3 and 4, respectively. Significant differences in soil water extraction between RF and IR treatments, except at 15-30 and 15-30 and 105-120 cm depths in 1983 and 1984 were found, respectively. Peanut under RF conditions extracted more soil water than under IR conditions. This was exclusive of water loss from the control plots. However, the IR plots were receiving 5 cm of water per week in addition to the amount that was being extracted from the soil. Also, more soil water at shallow depths (15 to 60 cm) than deeper depths were extracted by peanut. In 1983, peanut genotypes showed significant differences in soil water uptake at 15-30, 30-45, and 105-120 cm depths under RF, and at 45-75 cm depth under IR (Table 3). At these depths, Comet extracted more water, while OK-FH-14 extracted less water than other genotypes under IR conditions.

Soil water content at different soil depths at 76 and

77 DAP in 1983 and 1984 are shown in Fig. 3 and 4. The water content at shallow depths (15 to 75 cm) is less than at deeper depths (75 to 120 cm). More soil water at deeper depths (75 to 120 cm) was extracted by RF than IR peanuts. Bennett et al. (1984) also found that soil water declined quite rapidly at shallow depths in the nonirrigated treatment. They also showed that water extraction by nonirrigated peanuts (Florunner) after 11 days of drying was primarily from the deeper soil profile (40-90 cm). Genotypic differnces in soil water uptake might be due to rooting characteristics, root resistances to soil water transport, maturity factors, and physiolgical status of the plants (Jordan and Miller 1980; Kramer, 1983).

Regarding total soil water extraction from the entire soil profile at different peanut growth stages, results obtained in 1983 showed that more water was extracted by peanuts under RF conditions at earlier stages (41-48, 56-62, and 70-76 DAP), and less water extraction occurred during later stages (77-103 DAP) (Table 5 and Fig. 5). A similar tendency was also found in 1984. Significantly higher soil water extraction occurred at earlier stages (33-49, 57-63, and 78-84 DAP) under RF conditions (Table 6 and Fig. 6). Higher soil water extraction was found at later stages (92-105 DAP) under IR conditions (Table 6). It seems that peanut under RF conditions extracted more water at earlier times but less water uptake at later times because of the depletion of available soil water. On the

other hand, IR peanuts extracted more soil water to meet growth requirements at later stages (Tables 5 and 6). Under RF conditions, peanut genotypes also showed significant differences in total water uptake at 63-69 and 97-103, and 33-49 DAP in 1983 and 1984, respectively. Comet had significantly lower total soil water extraction at 63-69 and 97-103 DAP under RF conditions in 1983 (Table 5). In 1984, only at 33-49 DAP were genotypic differences in total soil water extraction found. At this stage, Spanhoma extracted more water than Pronto, OK-FH-14, and Florunner under RF conditions (Table 6). However, no differences were found among genotypes in soil water extraction at different growth stages under IR conditions. Differences in soil water extraction among plant growth stages under RF might be caused by physiological stage differences, root extension, crop evapotranspiration, ground cover, and LAI (Boote, et al., 1982; Kramer, 1983).

Significant differences between RF and IR treatments in total soil water extraction over the entire growth season were found in both years (Table 7). More soil water was extracted under RF conditions (11.00 and 9.74 cc/cc) than under IR conditions (9.15 and 7.96 cc/cc), respectively. It should be remembered that 5 cm of irrigation water per week was received by IR plots. No significant differences among peanut genotypes in soil extraction were found under RF and IR conditions in 1983. However, peanut genotypes differed in total soil water

uptake under RF and IR conditions in 1984. Under RF, Spanhoma extracted more soil water than Pronto and Florunner. The least soil water was extracted by Pronto and Florunner under RF. Under IR, Spanhoma had the lowest soil water extraction. These differences might be due to differences in peanut rooting systems and morphological characteristics of the shoot (Kramer, 1983).

Summary and Conclusions

Among several soil water determination methods, the neutron scattering technique is one of the most effective approaches in monitoring soil water content (Kramer, 1983; Thien, 1983). By using this technique, root growth of plants can also be estimated (Bohm, 1979). Since soil water content is related to peanut growth and yield, neutron probes were used to monitor the changes of soil water content and to calculate soil water extraction by peanut roots at different growth stages.

Based on the data obtained from two years of study, there were no significant interactions between peanut genotypes and treatments (RF and IR) in soil water extraction. Peanut roots extended to 120 cm depth at 76 and 84 DAP in 1983 and 1984, respectively. Soil water depletion increased with time, especially under RF conditions. At 75 cm depth, soil water content was different between planted and control plots after 69 and 63 DAP under RF conditions in 1983 and 1984, respectively

(Fig. 1 and 2). More soil water was extracted by RF peanuts at shallow depths. Peanut genotypes showed differences in soil water uptake at different soil depths. Comet extracted less water than other genotypes at the 15-45 cm depth under RF, while OK-FH-14 extracted the least soil water under IR conditions in 1983 (Table 3). However, Spanhoma extracted most soil water from the 15-75 cm profile under RF conditions in 1984 (Table 4).

Amount of soil water extracted also differed at different growth stages. More soil water was extracted at earlier growth stages of peanuts. After 77 DAP, less soil water was extracted by peanut roots under RF conditions. Genotypic differences in water extraction at various stages were also found at 56-62 and 97-103, and 33-49 DAP in 1983 and 1984, respectively. Under RF conditions, Comet extracted the least soil water in 1983, while Spanhoma extracted more soil water at the stages mentioned above. Total water extracted during the entire growth season was different between RF and IR treatments. RF peanut plants extracted more soil water than IR plants. Variation among genotypes in total soil water extraction under RF conditions was only found in 1984. Nonirrigated Spanhoma peanuts extracted more and Florunner and Pronto extracted the least soil water in 1984. Peanut genotypes also showed differences in soil water extraction under IR conditions in 1984. Spanhoma extracted the least soil water under IR conditions in 1984.

Root growth is significantly affected by soil environments such as soil water content, soil oxygen, etc. Plant root growth characteristics, which differ genetically, are related to drought tolerance (Bohm, 1979; Passioura, 1981; Kramer, 1983; Ketring, 1984a). In this study, neutron scattering techniques were efficiently used for estimating root growth and calculating soil water extracted by different peanut genotypes at different times and soil depths under RF and IR conditions, which will aid in understanding water relations of peanuts.

TABLE 1

SOURCE OF VARIATION OF SOIL WATER EXTRACTION OF PEANUT GENOTYPES

Source	15-30	30-45	45-60	60-75	75-90	90-105	105-120
			1983				
Genotype(G)	ns	**	**	**	**	**	**
Treatment(T)	ns	ns	**	**	**	**	**
Time(Ti)	**	**	**	**	**	**	**
G x T	ns	ns	ns	ns	ns	ns	ns
G x Ti	**	**	**	**	**	**	**
T x Ti	**	**	**	**	**	**	**
G x T x Ti	ns	ns	**	**	**	**	**
			1984				
Genotype(G)	ns	**	*	ns	*	ns	ns
Treatment(T)	ns	ns	ns	**	*	ns	ns
Time(Ti)	**	**	**	**	**	**	**
G x T	ns	ns	ns	ns	ns	ns	ns
G x Ti	**	**	**	ns	ns	ns	ns
T x Ti	**	**	**	**	**	**	ns
G x T x Ti	**	**	ns	ns	ns	ns	ns

ns, *, and ** indicated not significant, significant at 0.05 and 0.01 probability levels, respectively.

TABLE 2

ROOT LENGTH OF PEANUT ESIMATED
FROM SOIL WATER EXTRACTION

DAP	Root Length (cm)	
	1983	1984
41-42	30-45	-
48-49	45-60	45-60
55-56	60-75	60-75
62-63	75-90	60-75
69-70	90-105	75-90
76-77	> 120	90-105
83-84	> 120	> 120

TABLE 3

TOTAL SOIL WATER EXTRACTED (CC/CC)
BY PEANUT GENOTYPES AT DIFFERENT
SOIL DEPTHS, 1983

	Depth (cm)						
Genotype	15-30	30-45	45-60	60-75	75-90	90-105	105-120
			Rainfed				
Florunner	1.71a[+]	2.07a	1.92a	1.71a	1.60a	1.39a	1.05a
OK-FH-13	1.78a	2.10a	1.92a	1.72a	1.55a	1.30a	.96a
OK-FH-14	1.73a	2.06a	1.93a	1.75a	1.59a	1.33a	1.00a
Comet	1.33b	1.77b	1.84a	1.70a	1.52a	1.23a	.89ab
Pronto	1.55ab	1.86ab	1.87a	1.67a	1.44a	1.21a	.94a
Control	1.12b	.91c	.71b	.63b	.59b	.60b	.60b
Mean	1.53x	1.80x	1.70x	1.53x	1.38x	1.18x	.91x
			Irrigated[‡]				
Florunner	1.50a	1.68a	1.53ab	1.35ab	1.21a	.99a	.72a
OK-FH-13	1.74a	1.89a	1.63ab	1.41ab	1.23a	1.01a	.73a
OK-FH-14	1.74a	1.83a	1.51b	1.21b	.96a	.71a	.52a
Comet	1.46a	1.78a	1.72a	1.54a	1.26a	.90a	.66a
Pronto	1.56a	1.86a	1.69ab	1.40ab	1.13a	.91a	.78a
Control	.49b	.26c	.16c	.12c	.08b	.12b	.11b
Mean	1.42x	1.55y	1.37y	1.17y	.99y	.77y	.57Y

[+] Values within columns not followed by the same letter were significantly different ($P<.05$) according to Duncan's Multipe Range test (DMRT).

[‡] Irrigated plots received 5 cm irrigation water weekly during the growing season.

TABLE 4

TOTAL SOIL WATER EXTRACTED (CC/CC)
BY PEANUT GENOTYPES AT DIFFERENT
SOIL DEPTHS, 1984

	Depth (cm)						
Genotype	15-30	30-45	45-60	60-75	75-90	90-105	105-120
				Rainfed			
Florunner	1.57abc[+]	1.61bc	1.45b	1.45ab	1.39a	.95a	.39a
OK-FH-13	1.54abc	1.73bc	1.74ab	1.77ab	1.67a	1.27a	.61a
OK-FH-14	1.83a	1.75bc	1.48b	1.42b	1.32a	.89a	.50a
Comet	1.78ab	1.78ab	1.66ab	1.63ab	1.58a	1.18a	.64a
Pronto	1.36bc	1.50c	1.45b	1.49ab	1.47a	1.01a	.52a
Spanhoma	1.93a	2.06a	1.93a	1.82a	1.64a	1.09a	.58a
Control	1.13c	.94d	.72c	.56c	.51b	.45b	.36a
Mean	1.59x	1.62x	1.49x	1.45x	1.37x	.98x	.52x
				Irrigated[‡]			
Florunner	1.88a	1.70a	1.19a	1.02a	1.08ab	.71ab	.35a
OK-FH-13	1.71a	1.54ab	1.15a	1.15a	1.33a	1.04a	.63a
OK-FH-14	1.73a	1.62ab	1.28a	1.18a	1.32a	.98ab	.54a
Comet	1.77a	1.63ab	1.32a	1.14a	1.06ab	.76ab	.45a
Pronto	1.63a	1.52ab	1.20a	1.14a	1.12ab	.79ab	.56a
Spanhoma	1.45a	1.37b	1.03a	.84a	.85b	.60b	.39a
Control	.43b	-.12c	-.22b	-.04b	.20c	.12c	-.06b
Mean	1.51x	1.32y	.99y	.92y	.99y	.71y	.41x

[+] Values within columns not followed by the same letter were significantly different ($P<.05$) according to Duncan's Multipe Range Test (DMRT).

[‡] Irrigated plots received 5 cm irrigation water weekly during the growing season.

TABLE 5

TOTAL SOIL WATER EXTRACTED (CC/CC) BY PEANUT GENOTYPES AT DIFFERENT GROWTH STAGES, 1983

DAP		Genotype+ F	#13	#14	C	P	Mean‡
41-48	RF	2.01a§	2.01a	2.28a	2.49a	2.25a	2.31x
	IR¶	1.28a	.91a	.62a	1.90a	.71a	.95y
49-55	RF	1.94a	2.04a	1.75a	1.52a	1.25a	1.43x
	IR	1.32bc	1.86ab	.92bc	1.87ab	2.51a	1.49x
56-62	RF	1.95a	1.40a	1.70a	1.55a	1.54a	1.42x
	IR	1.03a	1.34a	1.29a	.53ab	1.05a	.88y
63-69	RF	1.41ab	1.91a	1.75a	.98b	1.65a	1.28x
	IR	1.00b	1.59a	1.29ab	1.29ab	1.34ab	1.04y
70-76	RF	1.28a	1.24a	1.14a	.97a	1.02a	.97x
	IR	.60a	.24a	.71a	.22a	.37a	.42y
77-83	RF	1.11a	1.12a	1.12a	1.27a	1.15a	1.03x
	IR	1.07a	1.05a	1.36a	1.17a	1.24a	1.36y
84-89	RF	.34a	.40a	.35a	-.02a	.26a	.30x
	IR	-1.11a	-.85a	-1.28a	-.70a	-1.20a	-1.29y
90-96	RF	.68a	.56a	.66a	1.35a	.71	.58x
	IR	1.36a	1.46a	.99a	1.51a	.99a	1.26y
97-103	RF	.74b	.65b	.64b	.18c	.72b	.71x
	IR	2.42a	2.03ab	2.11ab	2.05ab	1.80b	1.74y

+ F=Florunner; #13=OK-FH-13; #14=OK-FH-14; C=Comet; P=Pronto.

‡ Mean values include control.

§ Values within each row not followed by the same letter were significantly different (P<.05) according to DMRT.

¶ Irrigated plots received 5 cm irrigation water weekly during the growing season.

TABLE 6

TOTAL SOIL WATER EXTRACTED (CC/CC)
BY PEANUT GENOTYPES AT DIFFERENT
GROWTH STAGES, 1984

		Genotype[+]						
DAP		F	#13	#14	C	P	S	Mean[‡]
33-49	RF	3.87b[§]	4.65ab	3.52b	4.88ab	3.74b	6.05a	3.90x
	IR[¶]	2.21a	2.68a	3.58a	2.46a	2.84a	1.84a	1.97y
50-56	RF	.15a	.51a	1.52a	1.31a	.28a	.95a	.67x
	IR	.60a	.05a	-.55a	.82a	.03a	.34a	.17x
57-63	RF	1.37a	1.46a	.86a	.38a	2.04a	1.72a	1.16x
	IR	.41a	.18a	.19a	.34a	-.54a	-.26a	-.02y
64-77	RF	1.64a	1.08a	2.92a	1.98a	1.41a	1.36a	1.64x
	IR	1.65a	2.32a	2.70a	1.92a	2.91a	2.05a	2.05x
78-84	RF	2.22a	1.85a	.93a	.93a	.50a	.68a	1.10x
	IR	-.39a	.18a	.14a	.39a	.35a	.10a	.01y
85-91	RF	-1.02a	-.13a	-1.32a	.25a	-.20a	-.16a	-.23x
	IR	-.01a	-.69a	-.72a	-.17a	-.29a	-.88a	-.32x
92-105	RF	.58a	.91a	.78a	.53a	.63a	.47a	.78x
	IR	3.46a	3.84a	3.30a	2.37a	2.67a	3.32a	3.02y

[+] F=Florunner; #13=OK-FH-13; #14=OK-FH-14; C=Comet; P=Pronto; S=Spanhoma.

‡ Mean values include control.

§ Values within each row not followed by the same letter were significantly different (P<.05) according to DMRT.

¶ Irrigated plots received 5 cm irrigation water weekly.

TABLE 7

TOTAL SOIL WATER EXTRACTED (CC/CC)
BY PEANUT GENOTYPES OVER THE
ENTIRE SEASON

	1983		1984	
Genotype	Rainfed	Irrigated[+]	Rainfed	Irrigated
Florunner	11.45a[‡]	8.98a	8.81b	7.92a
OK-FH-13	11.33a	9.63a	10.33a	8.56a
OK-FH-14	11.39a	8.48a	9.20ab	8.65a
Comet	10.28a	9.32a	10.25a	8.12a
Pronto	10.55a	9.32a	8.80b	7.96a
Spanhoma	-	-	11.06a	6.52b
Mean[§]	11.00x	9.15y	9.74x	7.96y
Control	5.16b	1.35b	4.67c	.31c

+ Irrigated plots received 5 cm irrigation water weekly.

‡ Values within each column under the same year and same treatment not followed by the same letter were significantly different ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

§ Exclusive of control; Values within this row under same year not followed by the same letter were significantly different ($P<.05$) according to DMRT.

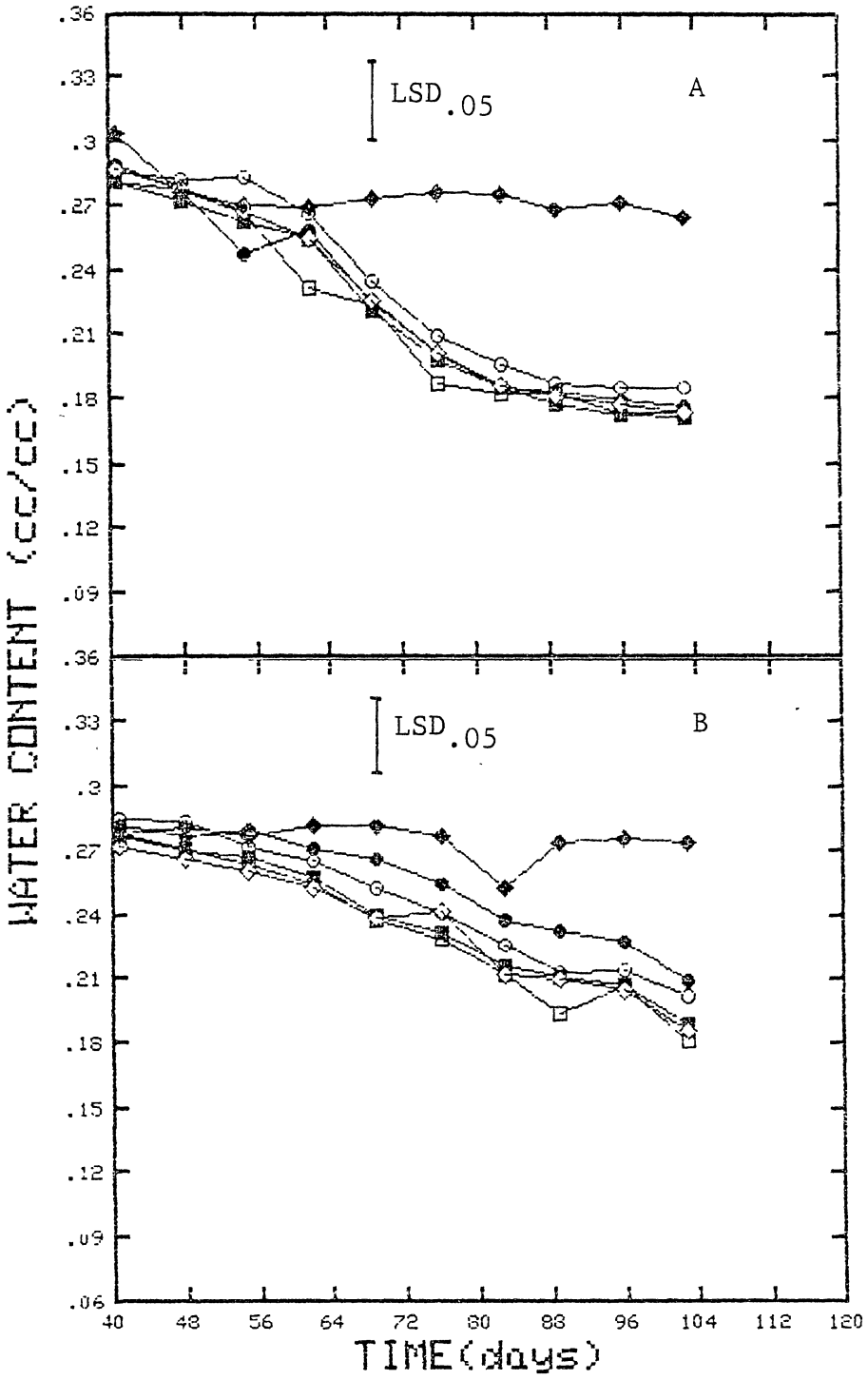

Fig. 1. Change in soil water content at 75 cm depth under (A) rainfed and (B) irrigated conditions in 1983. (o=Pronto; ●=OK-FH-13; ■=OK-FH-14; ◊=Florunner; □=Comet; ◆=CK)

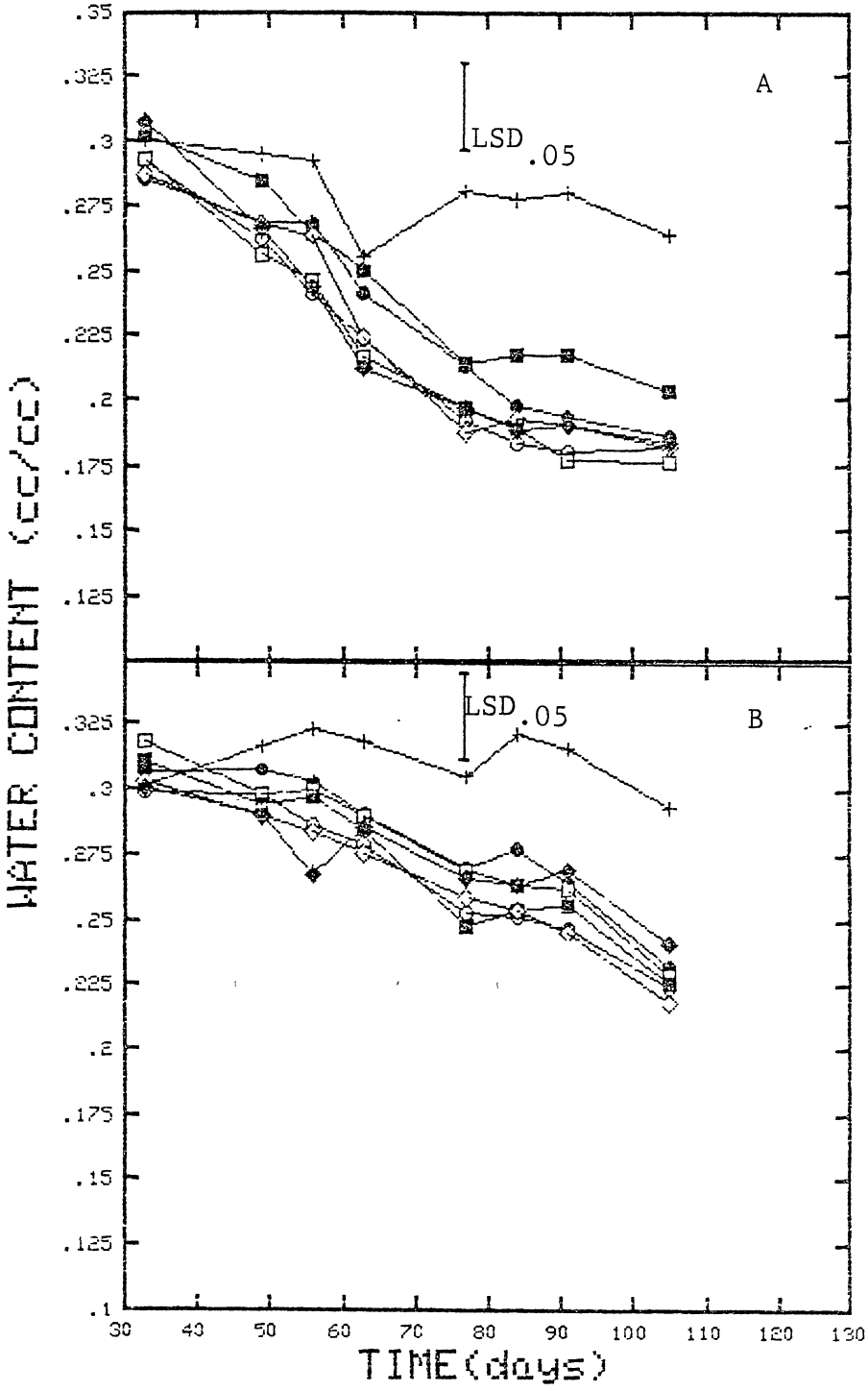

Fig. 2. Change in soil water content at 75 cm depth under (A) rainfed and (B) irrigated conditions in 1984. (o=Comet; ●=Florunner; □=OK-FH-13; ■=OK-FH-14; ◇=Pronto; ◆=Spanhoma; +=CK)

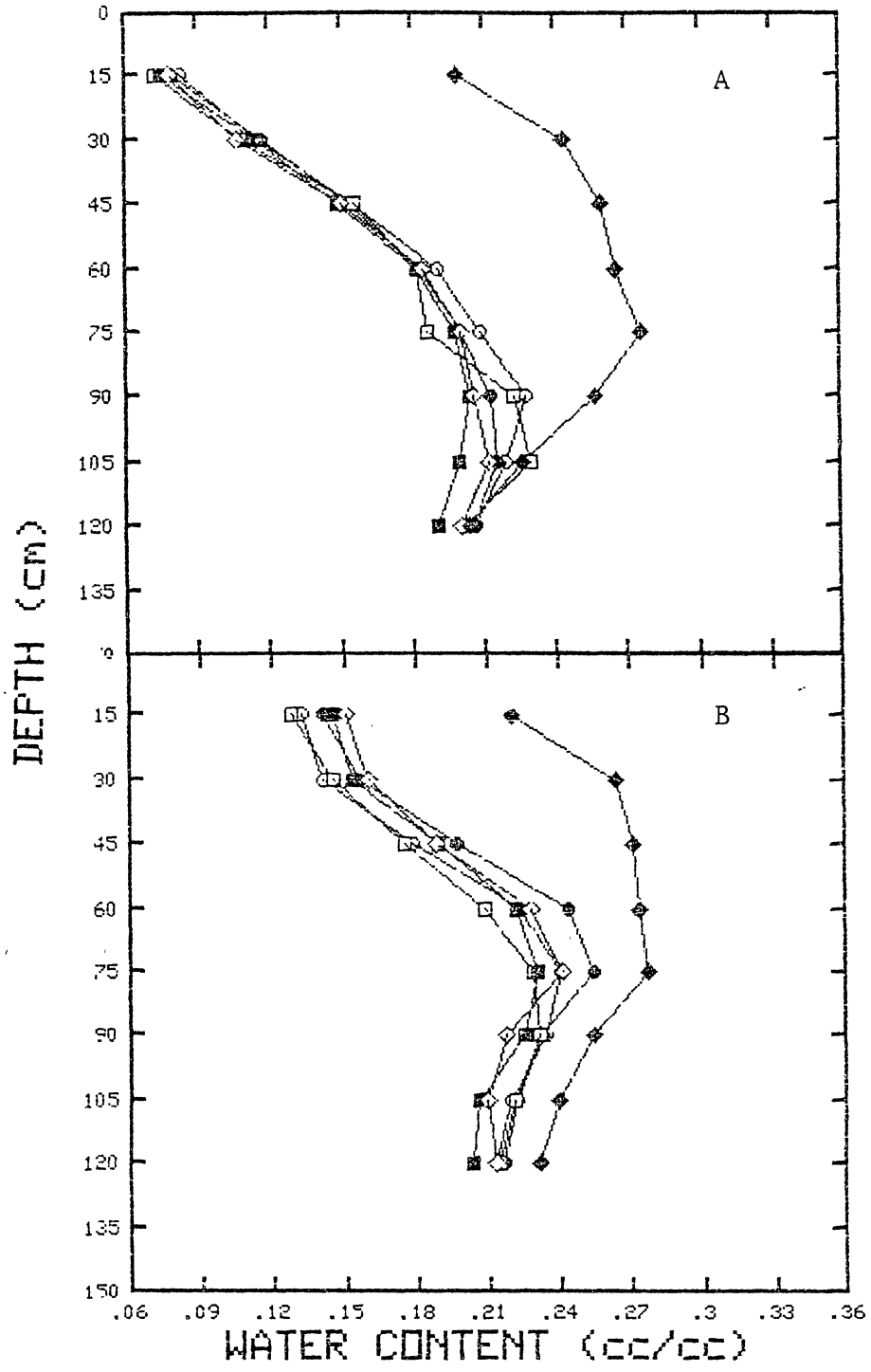

Fig. 3. Soil water content at 76 DAP under (A) rainfed and (B) irrigated conditions in 1983 (legend same as in Fig. 1).

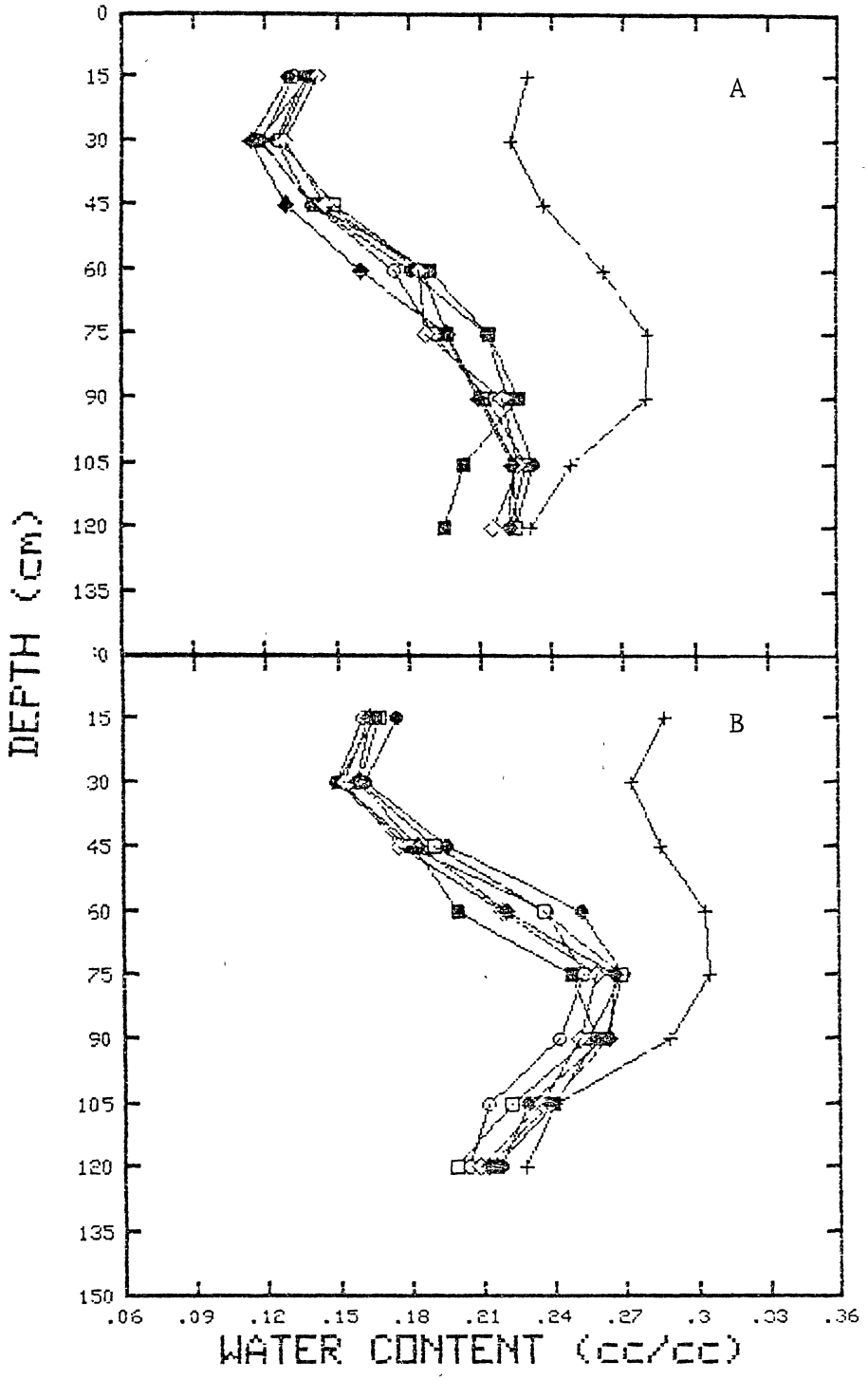

Fig. 4. Soil water content at 77 DAP under (A) rainfed and (B) irrigated conditions in 1984 (legend same as Fig. 2).

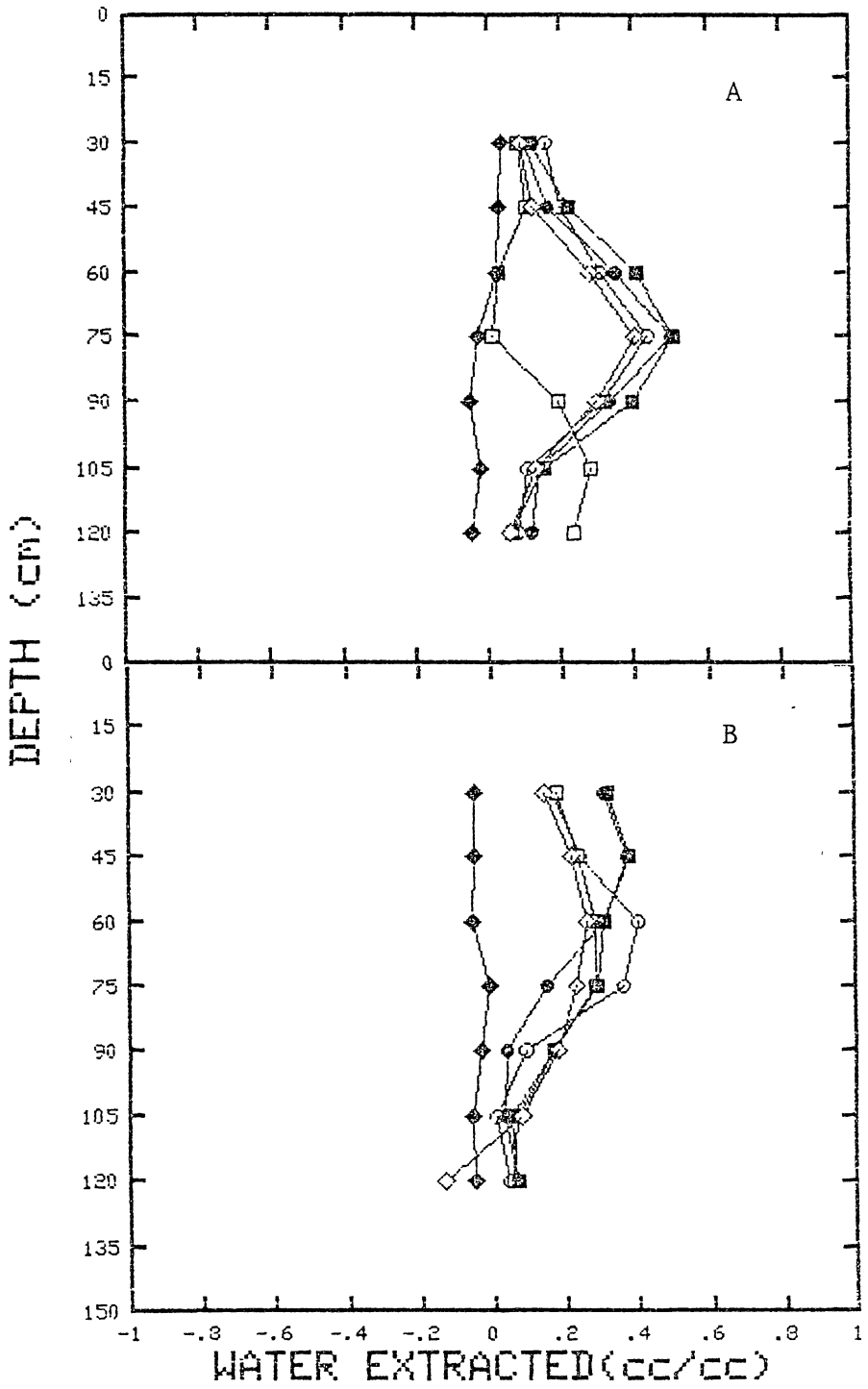

Fig. 5. Soil water extracted at 63-69 DAP under (A) rainfed and (B) irrigated conditions in 1983 (legend same as in Fig. 1).

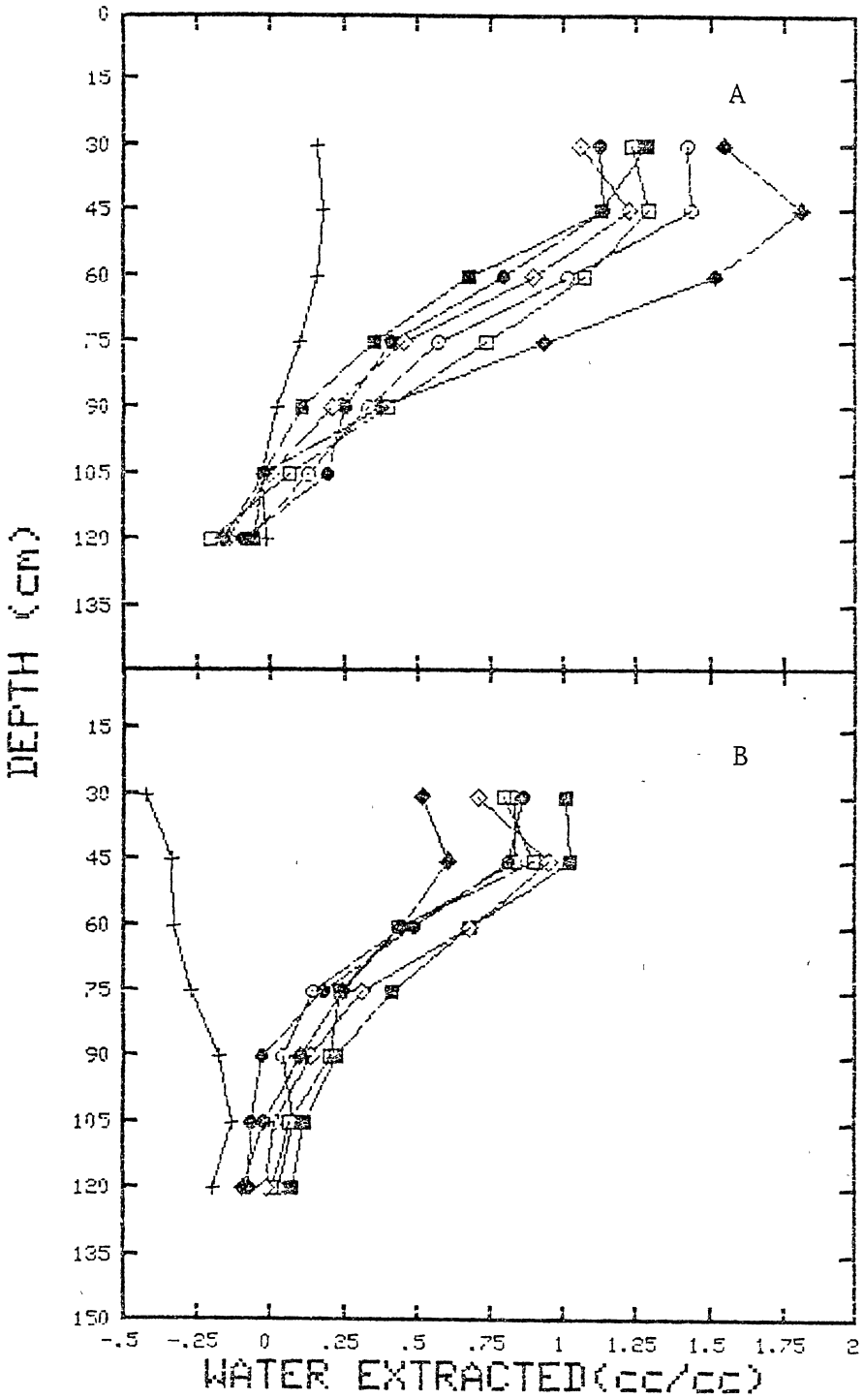

Fig. 6. Soil water extracted at 33-49 DAP under (A) rainfed and (B) irrigated conditions in 1984 (legend same as in Fig. 2).

CHAPTER V

WATER RELATIONS OF PEANUT UNDER RAINFED AND IRRIGATED CONDITIONS

Introduction

Water is one of the essential components for plant life. It comprises about 85 to 90 % of total fresh weight in physiologically active plants. If the water content of most crop plants falls below this level, many physiological processes, such as photosynthesis, protein synthesis, cell expansion, respiration, etc., will be impaired. Then growth, development, and yield will be adversely affected by the water deficit (Hsiao, 1973; Begg and Turner, 1976; Levitt, 1980b). Hence the water status of leaves, which can quantify the water content within the plant, has been related to crop yield and quality (Begg and Turner, 1976; Shaw, 1983). Understanding the adaptation and mechanism(s) of plant responses under drought conditions is one step toward success in preventing yield and quality losses caused by drought stress. Leaf water status affects almost all physiological processes which contribute to plant growth and yield (Hsiao, 1973; Begg and Turner, 1976). It is believed that studying changes of leaf water relation components under water deficit conditions may provide

useful information for differentiating genotypic differences in drought resistance for plant breeding programs (Begg and Turner, 1976; Quizenberry, 1983).

In peanut, Allen et al. (1976) reported that higher stomatal resistance (Rs), lower relative water content (RWC), and water potential occurred under dry soil conditions. Similar results were also found by Pallas et al. (1979). They recorded water potentials of -3.0 to -4.0 MPa for the Florunner cultivar for several treatments during midseason under dry conditions. The effects of atmospheric water vapor saturation on peanut stomatal conductance was noted by Black and Squire (1979). They found that stomatal response to atmospheric saturation and stomatal conductance of nonirrigated peanuts were decreased. Stone et al. (1985) indicated that Rs was affected by row spacing under field conditions. Bennett et al. (1981) pointed out that positive correlations existed between turgor potential and water potential and between RWC of peanut leaves when turgor potential was greater than zero. They said that no unique drought resistance mechanism could be attributed to peanut. Furthermore, they (1984) found that water potential of nonirrigated peanut only decreased to -2.0 MPa. Increasing Rs with decreasing leaf water and turgor potentials were also observed. They showed that the leaf-air temperature difference was increased with increasing Rs. Pandey et al. (1984b) found that peanut leaf water potential was -0.67

MPa in dry regimes 60 days after emergence. Increasing water stress decreased leaf water potential and increased canopy-air temperature differences (Td). They (1984a) indicated that the seasonal cumulative leaf water potential and Td during peanut growth were negatively correlated with yield and may be useful in a genotype selection procedure. They (1984c) concluded that peanut had a higher leaf water potential and maintained a lower canopy temperatre than the other legume species tested. Recently, Erickson and Ketring (1985) found that peanut genotypes differed in the rainfed (RF)/irrigated (IR) ratio for water and osmotic potentials and relative water content. They also reported differences in apoplastic water content among genotypes. The lower water potential, greater change in osmotic potential, higher apoplastic water content, and yield of the nonirrigated Comet cultivar suggested greater resistance to dehydration when soil water deficits and high evaporative demand occur.

Evidenced from the above results, it seems that choosing the best indicator of water status for evaluating peanut genotypes for drought tolerance is complicated because physiological responses of peanut under drought conditions are complex. This indicates that more detailed studies on peanut responses and adaptation to water stress are still needed. Therefore, the objectives of this study were: (1) to investigate the variation in water relation components (water and osmotic potential and relative water

content), stomatal resistance, and canopy temperature among peanut genotypes at different growth stages under RF and IR conditions; and (2) to examine the interrelationships among these water status parameters.

Materials and Methods

Five and six genotypes including Florunner, OK-FH-13, OK-FH-14, Comet, Spanhoma (1984 only), and Pronto were grown at the Agronomy Research Station, Perkins, Oklahoma during the summer seasons in 1983 and 1984, respectively. The soil at the experimental site was a Teller sandy loam soil (fine-loamy, mixed, thermic Udic Argiustolls). A split-plot arrangement in randomized complete block design with four and two replications was used in 1983 and 1984, respectively. Two- and four-row plots were used 1983 and 1984, respectively. Main plots were irrigation treatments §rainfed (RF) and irrigated (IR)£ and subplots were peanut genotypes. A total of 40 and 24 plots (6.1 m long, 0.91 m wide) were used for sampling in 1983 and 1984, respectively. About 5 cm of water was applied weekly to IR plots while RF plots received no supplemental water during the season. Weeds were controlled by pre-emergence herbicide (Balan), application followed seed bed preparation, and hand-weeding during the growth season as necessary.

Plants near the center of the row of each plot and the two middle rows of 1984 were used for the following weekly

measurements. Percentage ground cover (GC) was obtained by measuring canopy ground coverage and dividing by row width. All water status parameters were measured from randomly chosen peanut plants on the same day between 13:30 and 15:00 h, CDT. Samples were obtained from fully developed terminal leaflets of the first fully-expanded leaf below the terminal primodia on a secondary branch (the third node if the terminal is counted first). Stomatal resistance was measured by porometery using the LI-700 Transient State Porometer (LI-COR, Inc., Lincoln, NE). It was calibrated in the field using the accompanying polypropylene calibration plate. Transient times were obtained from adaxial leaflet surfaces then converted into stomatal resistance (Rs) in sec/cm using the standard calibration curve.

Punched leaf discs of 0.97 square centimeter were sampled from the middle portion of leaflets and immediately sealed in pre-weighed vials for relative water content (RWC) determination. After the fresh weight was determined, the saturated weight of the leaf disc was obtained after floating in demineralized water for 24 h in the light. Dry weight of the disc was obtained after it was oven-dried at 90 C for 24 h. RWC was calculated as the ratio between fresh weight minus dry weight and saturated weight minus dry weight.

The leaf cutter thermocouple psychrometer (J.R.D. Merrill Specialty Equipment, Logan, UT) was used for

determining water and osmotic potentials of 0.24 square centimeter leaf discs sampled from the middle portion of the same leaflet. After sampling, psychrometers were transported to the laboratory and put into a 30 C water bath for equilibration for at least 2 hours. Microvolt readings were obtained with a thermocouple psychrometer micrometer (Model No. 82-22, J.R.D. Merrill Specialty Co., Logan, UT). Microvolts were converted into potentials based on calibration equations for each psychrometer. The psychrometers were calibrated with molal KCl solutions. After water potential (WP) was obtained, the psychrometers were put into a freezer (-15 C) for 24 hour. After thawing, the same procedure as for water potential measurement were followed for determining osmotic potential (OP). Turgor potential (TP) was calculated as the difference between water potential and osmotic potential.

Canopy temperature (Tc) and temperature difference (Td) between the leaf and ambient air were measured in each plot using a tripod-held Everest Infrared Thermometer (Everest Intercience, Tustin, CA). It was poised at a 22 degree angle parallel with the row direction when the sun was at or near its zenith in 1983.

Weather data taken at each measurement time were photosynthetically active radiation, total radiation, wind direction and speed, and the dry and wet bulb air temperatures (Appendix). Data obtained from these measurements were analyzed by analysis of variance using

Microstat software with the North Star Horizon computer.

Results and Discussion

By statistical analysis of pooled data for peanut percent ground cover (GC), stomatal resistance (Rs) in sec/cm, relative water content (RWC), water potential (WP), osmotic potential (OP), and turgor potential (TP) obtained at six different days after planting (DAP) in each year, it was found that variations due to RF vs IR treatments (T), time of measurement (Ti), and their interaction (T x Ti) were highly significant ($P<0.01$) for all six parameters (Tables 1 and 2). Variation due to peanut genotype (G) was also significant for GC, WP, and OP, but not for Rs, TP, and RWC in 1983. However, variation for all six parameters due to genotype was significant in 1984. G x T effects for GC, Rs, and RWC were significant in both years. No significant G x T effects on WP and TP in 1983, and WP and OP in 1984 were found, respectively. G x Ti interactions for RWC, WP, and OP were not significant in both years. These combined analysis of variance suggested that water relations varied in response to different sources of variation and separate analyses are required for examining these effects in detail (Gomez and Gomez, 1984).

Growth reduction as indicated by a lower percentage GC was observed under RF conditions (Table 3 and 4). Significant differences in GC were found between RF and IR treatments in 1983 and 1984. Ground cover of RF peanut at

all six DAPs was significantly reduced. Peanut botanical types were signficantly different in ground cover at 53 and 68 DAP in 1983 and 1984, respectively. Virginia types generally had more GC than spanish types under RF conditions. However under IR, all of the genotypes attained nearly 100 % GC by 91 and 82 DAP in 1983 and 1984, respectively. Variation in GC under RF was probably due to the different growth habit (erect vs prostrate) between the virginia and spanish types. Reduction in GC was due to an overall reduction in plant growth (stem length, and leaf area). Pandey et al. (1984c) indicated that leaf expansion rate and reduced leaf area resulted in less GC.

Significant differences in mean Rs between RF and IR treatments were found in 1983 and 1984 (except at 54 DAP in 1984, Table 5 and 6). At 61, 81 and 91 DAP in 1983 (Table 5), genotypes were significantly different in Rs. The highest Rs value was for OK-FH-14 at 91 DAP under RF conditions. Significantly lower Rs values were observed for Florunner and Pronto at 61 DAP and for Pronto at 81 DAP under RF. Under IR in 1983, differences in Rs between virginia and spanish genotypes were observed at 61 DAP. Contrast comparison §Q(s-v)£ showed that spanish types had higher Rs at 61 DAP under IR conditions. Other comparisons showed that spanish types had lower Rs at 91 DAP under RF (Table 5). At 91 DAP, higher Rs of virginia types was mainly due to the high Rs of OK-FH-14. In 1984, virginia types showed higher Rs than spanish types at 61 and 75 DAP,

but lower at 89 DAP (Table 6). Genotypic differences in Rs were observed at 61, 75, 82, and 89 DAP. The lowest Rs values under RF were for Pronto at 61, 75, and 82 DAP, and OK-FH-14 at 89 DAP. Under IR, the highest Rs values were found for Comet and Spanhoma at 61 and 82 DAP, respectively. The stomatal response of plants is sensitive to environmental conditions (Hsiao, 1973; Begg and Turner, 1976; Mansfield and Davies, 1981, Stone et al., 1985). Variation in values of peanut Rs also have been obtained by other researchers (Allen et al, 1976; Pallas et al., 1979; Black and Squire, 1979). Higher Rs under RF found by these researchers are in agreement with this study. However, genotypic differences in Rs also were found in this study.

Significant differences in RWC were found between treatments (Table 7 and 8). RWC of RF peanuts was significantly lower than that of IR plants at all DAPs. In 1983, no significant differences among peanut genotypes in RWC in both years were found (Table 7). However, significant G x T interactions were observed at 82 and 89 DAP in 1984 (Table 8). The lowest RWC was found for Comet; while highest RWC was observed for OK-FH-13 and Spanhoma under RF conditions at both DAPs. Comet may be able to withstand a lower RWC because of its high apoplastic water fraction (Erickson and Ketring, 1985). Botanical types did not show differences in RWC. Similar results were also observed by Bhagsari et al. (1976) and Allen et al. (1976). However, RWC values obtained in our study was lower than

that reported by Allen et al. (1976) and Bennett et al. (1984), especially under RF conditions.

Decreases in WP with increasing duration of drought stress under RF conditions were observed in both years. Leaf WP differed between treatments. Significantly lower WP was found in peanut leaves under RF compared to IR except at 53 DAP in 1983 (Table 9). Genotypic differences in WP were found at 61 and 82 DAP in 1983 and 1984, respectively. In 1983, higher WP was shown for Florunner and OK-FH-14 under RF and OK-FH-13 under IR at 61 DAP (Table 9). In 1984, higher WP for Florunner was observed in both treatments and Spanhoma under IR at 82 DAP (Table 10). Botanical type comparisons showed that virginia types had higher WP than spanish types at 61 and 67 DAP in 1983 and at 82 DAP in 1984, respectively. Many reports have indicated that peanut WP decreased when drought stress increased. Also values of leaf WP in this study and others are similar (Allen, et al., 1976; Pallas et al., 1979; Bennett et al., 1981 and 1984; Pandey et al., 1984b). Genotypic differences in WP were found only at 61 and 81 DAP in 1983 and 1984, respectively. However, Erickson and Ketring (1985) found that peanut genotypes differed when the RF/IR ratio was used to make comparisons. Virginia type ratios were closest to 1.0 in their study. Gautreau (1977) and Turner (1979) have indicated that those plants exhibiting more negative leaf WP are more drought tolerant. The spanish types tend to have more negative WP in this

study.

Peanuts grown under RF and IR conditions also differed in OP. Except at 53 DAP in 1983, more negative OP occurred for RF peanuts. Significant genotypic effects for OP were observed at 61 through 74 DAP in 1983 and at 54 and 75 DAP in 1984, respectively (Table 11 and 12). OK-FH-14 had the highest (-1.56 to -1.83 MPa), while Pronto had the lowest OP (-2.08 to -1.72 MPa) in 1983. Virginia type peanuts grown under RF at 61 and 67 DAP had higher OP than spanish types (Table 11). In 1984, genotypic differences in OP were found under RF at 75 and 82 DAP (Table 12). Spanhoma had less while Pronto and Comet had more negative OP. Under IR, significant differences among genotypes were observed at 54 and 75 DAP (Table 12). OK-FH-13, OK-FH-14, and Spanhoma had the highest osmotic potential, respectively. At 82 DAP in 1984, Florunner had the highest, and Comet the lowest OP under RF situations. Bennett et al. (1981) reported OP values of -1.31 to -1.68 MPa and Erickson and Ketring (1985) reported more negative values of -1.76 to -1.86 MPa as zero turgor was approached. Also Erickson and Ketring (1985) indicated that peanut genotypes differed in OP as was found here on given DAP's.

Peanuts differed significanly in TP between RF and IR treatments, except at 53 DAP in 1983 (Table 13). Both negative and positive TP were observed under RF and IR, but RF peanuts showed mostly negative and IR peanuts showed positive turgor. No significant differences in TP were

found among peanut genotypes. Similar results were obtained in 1984 (Table 14). However, peanut genotypes also showed significant differences in TP at 54 and 89 DAP under RF. Florunner, Comet, and Spanhoma at 54 DAP, and Florunner and Spanhoma at 89 DAP had the highest TP.

Negative TP is not uncommon for peanuts (Bennett et al., 1981, 1984). The negative values of TP probably represent zero turgor and presumably arise as a result of dilution of the osmotic cell sap by extracellular water after freezing and thawing of the tissue (Boyer and Potter, 1973). This dilution effect would result in a slight underestimation of OP and would give a calculated negative TP when using frozen material (Boote et al., 1976). However, according to Bennett et al. (1981), the error due to dilution is small.

Peanut canopy temperature (Tc) and temperature difference (Td) between leaves and ambient temperature were measured by infrared thermometer at 53 to 81 DAP only in 1983. Td was not measured at 67 DAP due to instrument failure (Table 15 and 16). Canopy temperature of peanuts differed between RF and IR treatments (Table 15). Higher canopy temperature occurred for peanuts grown under RF conditions. Peanut genotypes also showed significant differences in Tc at 53 to 67 DAP. OK-FH-13 had the lowest (36.8 C) at 53 DAP and Comet the lowest (39.0 and 37.9 C) canopy temperature at 61 and 67 DAP under RF. Pronto had the most consistently high Tc under IR. Canopy temperature

of spanish types were higher than virginia types under IR at 53 and 61 DAP. However, virginia types had higher canopy temperature at 67 DAP under RF. Except at 53 DAP, genotypes grown under RF had lower temperature differences (Td, leaf temperature minus ambient) between leaves and air temperature, i. e. canopy temperature of RF peanut was near ambient temperature (Table 16). The Td of IR was higher than RF peanuts. Significant differences among genotypes in Td were found at 61 DAP. However, differences were only found under IR. Virginia type leaves were about 1.4 C cooler than spanish type leaves under IR. Similar results were found by Bennett et al. (1984) and Pandey et al. (1984c). Diurnal variations in Tc and Td were also reported by Erickson and Ketring (1985). The lower temperature difference under water deficit conditions is due to stomate closure which reduces transpiration (Tanner, 1963; Jackson et al., 1981). Hence, canopy temperature increases. Temperature differences have been proposed as an indicator of plant leaf water status, which when related to yield, can be used in screening procedures for drought resistance (Idso et al., 1980; Keener and Kircher, 1983; Pandey et al., 1984a). However, Nielson et al. (1984) suggested that measuring techniques are important in order to use Tc and Td as selection criteria for screening purposes.

Combined data analysis from the six DAPs showed significant linear correlations among water status

parameters (Table 17 and 18). High RWC, WP, OP, TP, and lower RS will result in higher ground cover of peanuts. Rs was highly negatively correlated with RWC, and water potential components. Lower RWC, and water potential components led to higher Rs. RWC was positively associated with WP, OP, and TP. OP was strongly correlated with WP and TP. Similar trends were also found between these parameters when linear correlation coefficients were calculated based on single DAP data (Table 19 and 20). Based on data obtained at 81 DAP in 1983, Tc and Td were negatively associated with GC, Rs, RWC, WP, OP, and TP. Significant positive correlation was found between Tc and Td (Table 19). The positive linear correlation coefficients between TP (greater than zero) and WP and RWC were also found by Bennett et al. (1981). Later, they (1984) also found positive correlation between leaf WP and TP, and between leaf Rs and Td. In our study, RWC was found positively associated with WP, OP, and TP, respectively. Pandey et al. (1984c) also showed similar results. They found that leaf WP was positively associated with Tc and Td. They proposed that cumulative temperature differences during the entire growing season can be used as a selection index for drought resistance in peanut.

Summary and Conclusions

Plant responses to prolonged drought are complicated because under drought conditions almost all phyiological

processes and their interaction are affected by water deficits, which result in reduced growth and yield (Hsiao, 1973, Begg and Turner, 1976; Paleg and Aspinall, 1981). Based on this two-year study, data showed that irrigation treatment (RF and IR), and time (DAP) were two main sources which caused variation in GC, Rs, RWC, WP, OP, and TP. Also, significant effects of T x G and T x Ti interactions on GC, Rs, and RWC were observed. No significant G x T interactions were observed for WP in either year. T x G interaction occurred for OP in 1983, but not in 1984. However, the opposite occurred for TP (Table 1 and 2). These results may be due to different seasonal environments.

Ground cover of peanut genotypes was significantly reduced under RF and virginia types had higher GC under RF conditions (Table 3 and 4). Genotypic differences were generally found at later stages (81 to 91 DAP).

Stomatal resistance was different for plants grown under RF and IR. Rainfed genotypes had higher Rs. Genotypic differences were only found at 61 DAP and later stages (81 to 98 DAP) (Table 5 and 6).

The RF treatment caused a decrease of RWC. No genotypic differences were found at earlier stages (53 to 75 DAP) but G x T interactions were observed at 82 and 89 DAP in 1984 (Table 7 and 8).

Genotypes differed in WP at 61 and 82 DAP in 1983 and 1984, respectively (Table 9 and 10). Under RF, higher WP

was observed for Florunner and OK-FH-14 at 61 DAP in 1983. Florunner also showed higher water potential at 82 DAP in 1984. The selections OK-FH-13 and 14 from Spanhoma x Florunner cross were intermediate or more like the Florunner parent when significant differences were found.

Genotypic differences in OP were also obtained at 61 to 74, and at 54 and 75 DAP in 1983 and 1984, respectively. Under RF, OK-FH-14 and Spanhoma had higher OP in 1983 and 1984, respectively.

Significant differences between RF and IR in OP were also found. Genotypic differences occurred at 54 and 89 DAP in 1984. Under RF Pronto had higher (-.09 MPa) TP at 89 DAP in 1984.

Peanut genotypes differed in canopy temperature at earlier stages (53 to 67 DAP). Virginia types had lower Tc at 53 and 61 DAP under IR and higher Tc under RF at 53 to 67 DAP (Table 15). In general, peanuts grown under RF had higher Tc than those grown under IR. Canopy temperature of IR peanuts was lower and RF peanuts higher than ambient temperature, respectively.

Significant linear correlation coefficients were found among all water status parameters. Ground cover was positively associated with the other parameters except stomatal resistance. On the other hand, stomatal resistance was negatively correlated with all the other parameters. RWC was positively linked with water potential components. Highly significant positive correlations among

water, osmotic, and turgor potential were found (Table 17, 18, 19, and 20). Canopy temperature and temperature difference were negatively correlated with all other parameters. However, Tc was positively correlated with Td.

Observations suggested that spanish types such as Comet are more tolerant of drought than viginia types such as Florunner under severe water stress and high evaporative demand conditions. In our case, more negative water and osmotic potentials, which might contribute to differences in drought tolerance, were observed. Water status parameters of OK-FH-13 and 14, two progeny lines from Spanhoma x Florunner, were more or less close to their viriginia-type parent, Florunner. Studies on the genetic behavior of these water status parameters will aid in understanding drought tolerance traits of peanut.

Studies on plant responses to water stress is essential for developing a stress index which might be used for screening procedures in breeding programs. Parameters such as Tc and Td, and cumulative water potential have been suggested as selection critera (Keener and Kircher, 1983; Pandey et al., 1984a). However, due to environmental variations, more detailed studies on evaluation of all possible parameters related to physiological responses and yield are required.

TABLE 1

SOURCE OF VARIATION OF WATER RELATION COMPONENTS, 1983

Source of Variation	%GC	Rs	RWC	WP	OP	TP
Treatment(T)	**	**	**	**	**	**
Genotype (G)	**	ns	ns	**	**	ns
Time (Ti)	**	**	**	**	**	**
G x T	**	*	**	ns	**	ns
T x Ti	**	**	**	**	ns	**
G x Ti	*	**	ns	ns	ns	ns
T x G x Ti	*	**	ns	ns	ns	ns

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference in F-test, respectively.

TABLE 2

SOURCE OF VARIATION OF WATER RELATION COMPONENTS, 1984

Source of Variation	%GC	Rs	RWC	WP	OP	TP
Treatment(T)	**	**	**	**	**	**
Genotype (G)	**	**	*	**	**	*
Time (Ti)	**	**	**	**	**	**
G x T	**	*	**	ns	ns	*
T x Ti	**	**	**	**	**	**
G x Ti	ns	**	ns	ns	ns	*
T x G x Ti	ns	**	*	ns	ns	**

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference in F-test, respectively.

TABLE 3

PERCENT GROUND COVER OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Ground Cover (%)					
	53 DAP		61 DAP		67 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	32.2a [+]	41.3a	44.5a	50.0a	45.8a	66.3a
OK-FH-13	36.8a	42.0a	43.4a	54.9a	45.1a	68.8a
OK-FH-14	37.5ab	42.4a	44.5a	53.1a	46.5a	68.1a
Comet	35.8b	38.6a	36.8a	47.9a	38.9a	60.8a
Pronto	35.4b	38.7a	37.2a	45.9a	37.5a	55.9a
Mean	36.7x	40.6y	41.2x	50.4y	42.8x	64.0y
Q(v-s) [‡]	1.9*	3.3**	7.1**	5.8**	7.6**	9.4**

	74 DAP		81 DAP		91 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	46.5a	68.4a	47.2a	87.2a	50.0a	96.9a
OK-FH-13	47.9a	71.9a	46.5a	88.9a	49.3a	99.7a
OK-FH-14	48.3a	71.5a	48.3a	87.2a	50.4a	96.3a
Comet	36.8a	62.9a	38.6a	85.4a	38.6a	100.0a
Pronto	37.9a	62.5a	37.9a	88.6a	40.0a	96.9a
Mean	43.5x	67.4y	43.7x	87.4y	45.6x	97.9y
Q(v-s)	10.2**	7.9**	9.1**	ns	10.6**	ns

[+] Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 4

PERCENT GROUND COVER OF PEANUT GENOTYPES GROWN IN 1984

Genotype	Ground Cover (%)					
	54 DAP		61 DAP		68 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	37.5a[+]	62.5a	50.0a	73.6a	50.0b	80.6b
OK-FH-13	40.3a	62.5a	48.6a	79.2a	50.0b	88.9b
OK-FH-14	40.3a	62.5a	54.2a	75.0a	54.2b	88.9b
Comet	33.4a	63.9a	37.5a	80.6a	40.3a	87.5b
Pronto	37.4a	62.5a	41.7a	90.3a	41.7a	95.8a
Spanhoma	37.5a	63.9a	37.5a	87.5a	38.9a	95.8a
Mean	37.3x	63.0y	44.9x	81.0y	45.8x	89.6y
Q(v-s)[‡]	4.2*	ns	12.1*	-10.2*	11.1*	-6.9**
	75 DAP		82 DAP		89 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	50.0a	88.9a	48.6a	93.1a	51.3a	95.5a
OK-FH-13	52.8a	95.8a	54.2a	100.0a	56.8a	100.0a
OK-FH-14	52.8a	95.8a	52.8a	100.0a	53.8a	100.0a
Comet	41.7a	93.0a	44.4a	98.6a	45.5a	100.0a
Pronto	41.6a	97.2a	41.7a	100.0a	45.4a	100.0a
Spanhoma	41.7a	97.2a	43.1a	100.0a	45.4a	100.0a
Mean	46.8x	94.6y	47.4x	98.6y	49.7x	99.3y
Q(v-s)	10.2**	ns	8.8**	ns	8.5**	ns

[+] Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significant at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 5

STOMATAL RESISTANCE (Rs, SEC/CM) OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Stomatal Resistance (sec/cm)					
	53 DAP		61 DAP		67 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	3.7a[+]	3.9a	5.1b	2.5a	6.0a	3.2a
OK-FH-13	6.6a	2.7a	6.1ab	4.7a	6.1a	3.1a
OK-FH-14	5.8a	2.6a	6.1ab	2.4a	8.0a	3.0a
Comet	7.1a	4.8a	7.2a	4.3a	7.3a	3.7a
Pronto	8.1a	3.2a	5.8ab	4.4a	6.3a	3.2a
Mean	6.3x	3.4y	6.0x	3.6y	6.7x	3.2y
Q(s-v)[‡]	ns	ns	ns	1.2*	ns	ns

	74 DAP		81 DAP		91 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	13.6a	4.5a	17.6a	4.0a	18.4a	6.5a
OK-FH-13	15.6a	3.4a	14.8a	4.2a	22.1a	8.5a
OK-FH-14	10.0a	3.8a	15.1a	3.4a	43.1b	8.7a
Comet	11.2a	3.4a	16.7a	5.6a	15.2a	8.1a
Pronto	10.7a	3.0a	11.0b	4.1a	15.7a	7.3a
Mean	12.2x	3.6y	15.0x	4.3y	22.9x	8.2y
Q(s-v)	ns	ns	ns	ns	-12.4**	ns

[+] Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(s-v) represents contrast comparison between mean values of spanish minus virginia types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 6

STOMATAL RESISTANCE (Rs, SEC/CM) OF PEANUT GENOTYPES GROWN IN 1984

Genotype	Stomatal Resistance (sec/cm)					
	54 DAP		61 DAP		68 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	9.3a[+]	2.9a	16.3a	8.0a	18.0a	3.2a
OK-FH-13	7.1a	3.3a	11.4b	4.0b	15.0a	12.0a
OK-FH-14	10.4a	3.5a	18.9a	5.0b	12.3a	7.1a
Comet	9.1a	4.1a	11.0b	8.5a	18.2a	4.3a
Pronto	7.6a	3.8a	7.2c	3.0b	13.3a	7.5a
Spanhoma	9.5a	3.6a	12.8b	4.9b	9.2a	7.9a
Mean [‡]	8.8x	3.5y	12.9x	5.5y	14.3x	7.0y
Q(s-v) [‡]	ns	ns	-5.2**	ns	ns	ns
	75 DAP		82 DAP		89 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	13.9a	4.4a	8.3b	3.6b	23.2b	5.7a
OK-FH-13	16.6a	3.1a	7.3b	3.2b	14.7c	5.2a
OK-FH-14	7.8b	3.3a	11.5a	2.9b	8.5d	4.3a
Comet	10.7b	3.3a	11.7a	3.1b	15.6c	4.4a
Pronto	7.6b	4.1a	8.3b	3.1b	15.5c	3.7a
Spanhoma	8.5b	3.5a	10.7a	6.1a	26.1a	5.1a
Mean	10.8x	3.6y	9.7x	3.7y	17.2x	6.7y
Q(s-v)	-3.9*	ns	ns	ns	3.6**	ns

[+] Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(s-v) represents contrast comparison between mean values of spanish minus virginia types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 7

RELATIVE WATER CONTENT (RWC, %) OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Relative Water Content (%)					
	53 DAP		61 DAP		67 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	74.6a+	78.1a	62.6a	82.6a	56.2a	77.9a
OK-FH-13	77.2a	83.2a	62.1a	84.6a	53.8a	78.3a
OK-FH-14	76.1a	79.0a	61.1a	76.4a	58.4a	75.9a
Comet	74.7a	73.7a	72.4a	70.5a	58.0a	75.3a
Pronto	82.0a	76.3a	70.0a	74.6a	62.3a	70.9a
Mean	76.9x	78.1y	65.6x	77.7y	57.7x	75.7y
	74 DAP		81 DAP		91 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	57.4a	87.8a	51.9a	82.4a	58.2a	84.3a
OK-FH-13	54.8a	89.4a	51.1a	84.8a	56.5a	83.2a
OK-FH-14	56.5a	85.7a	53.3a	78.8a	50.7a	77.8a
Comet	64.2a	84.5a	58.5a	78.4a	60.3a	74.0a
Pronto	59.0a	78.9a	54.6a	80.0a	61.4a	77.2a
Mean	58.4x	85.2y	53.9x	80.9y	57.4x	79.3y

+ Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

TABLE 8

RELATIVE WATER CONTENT (RWC, %) OF PEANUT GENOTYPES GROWN IN 1984

Genotype	Relative Water Content (%)					
	54 DAP		61 DAP		68 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	86.5a+	95.1a	79.2a	91.9a	79.2a	91.9a
OK-FH-13	77.4a	87.9a	79.7a	94.3a	67.4a	87.5a
OK-FH-14	83.5a	84.4a	78.2a	85.4a	69.2a	92.3a
Comet	82.7a	97.6a	70.2a	91.1a	65.3a	87.6a
Pronto	81.5a	91.1a	74.8a	89.9a	69.4a	96.4a
Spanhoma	76.9a	94.6a	78.8a	88.9a	73.1a	81.9a
Mean	81.4x	91.7y	76.8x	90.2y	69.9x	89.6y
	75 DAP		82 DAP		89 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	75.0a	91.8a	67.6d	90.8a	64.0cd	93.0a
OK-FH-13	76.3a	80.5a	70.7cd	78.4c	81.2b	80.3b
OK-FH-14	69.2a	92.9a	64.8de	90.1a	64.6cd	97.7a
Comet	65.8a	83.5a	57.4e	89.7a	61.3d	94.0a
Pronto	85.7a	90.8a	62.7de	84.0ab	66.6cd	93.7a
Spanhoma	77.0a	86.6a	69.2cd	92.0a	72.8bc	95.2a
Mean	74.3x	87.6y	65.4x	87.5y	68.4x	92.3y

+ Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

TABLE 9

WATER POTENTIAL (WP, MPa) OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Water Potential (MPa)					
	53 DAP		61 DAP		67 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-1.35a[+]	- .89a	-1.80b	-1.28ab	-1.98	-1.17a
OK-FH-13	-1.20a	- .80a	-1.95ab	-1.24b	-1.97a	-1.15a
OK-FH-14	-1.12a	-1.06a	-1.80b	-1.40ab	-1.72a	-1.10a
Comet	-1.44a	- .92a	-2.13ab	-1.59a	-2.12a	-1.45a
Pronto	-1.38a	-1.33a	-2.25a	-1.59a	-2.11a	-1.38a
Mean	-1.30x	-1.00x	-1.99x	-1.42y	-1.98x	-1.25y
Q(v-s)[‡]	ns	ns	.34**	.28**	.27*	ns

	74 DAP		81 DAP		91 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-2.33a	-1.07a	-2.57a	-1.16a	-1.74a	- .96a
OK-FH-13	-2.33a	- .89a	-2.55a	-1.22a	-1.91a	-1.06a
OK-FH-14	-2.01a	-1.26a	-2.63a	-1.49a	-1.85a	- .93a
Comet	-2.22a	-1.15a	-2.42a	-1.44a	-1.86a	-1.08a
Pronto	-2.42a	-1.40a	-2.70a	-1.54a	-1.99a	-1.34a
Mean	-2.26x	-1.15y	-2.57x	-1.37y	-1.87x	-1.07y
Q(v-s)	ns	ns	ns	ns	ns	ns

[+] Values not followed by the same letter within column or mean comparison within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively

TABLE 10

WATER POTENTIAL (WP, MPa) OF PEANUT GENOTYPES GROWN IN 1984

Genotype	Water Potential (MPa)					
	54 DAP		61 DAP		68 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-1.47a+	- .61a	-1.99a	- .50a	-2.12a	- .79a
OK-FH-13	-1.63a	- .79a	-1.72a	- .32a	-2.10a	-1.08a
OK-FH-14	-1.43a	- .93a	-1.68a	- .63a	-1.60a	-1.45a
Comet	-1.62a	- .76a	-1.82a	- .72a	-2.04a	-1.34a
Pronto	-1.68a	- .66a	-1.80a	- .69a	-2.21a	-1.17a
Spanhoma	-1.37a	- .60a	-1.72a	- .70a	-1.95a	-1.33a
Mean	-1.53x	- .72y	-1.79x	- .59y	-2.00x	-1.19y
Q(v-s)‡	ns	ns	ns	.22**	ns	ns

	75 DAP		82 DAP		89 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-2.08a	-1.98a	-1.99b	- .72b	-2.33a	-1.07a
OK-FH-13	-1.97a	-1.37a	-2.33ab	- .85b	-2.25a	-1.62a
OK-FH-14	-1.98a	-1.32a	-2.43ab	-1.05ab	-2.37a	-1.22a
Comet	-2.18a	-1.46a	-2.88a	-1.05ab	-2.18a	-1.81a
Pronto	-2.18a	-1.69a	-2.56ab	-1.39a	-2.68a	-1.72a
Spanhoma	-1.93a	- .94a	-2.38ab	- .70b	-2.39a	- .72a
Mean	-2.01x	-1.46y	-2.42x	- .96y	-2.37x	-1.36y
Q(v-s)	ns	ns	.36*	ns	ns	ns

+ Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

‡ Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 11

OSMOTIC POTENTIAL (OP, MPa) OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Osmotic Potential (MPa)					
	53 DAP		61 DAP		67 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-1.18a[+]	- .90a	-1.63b	-1.25b	-1.88ab	-1.38a
OK-FH-13	-1.20a	- .93a	-1.79ab	-1.17b	-1.83ab	-1.30a
OK-FH-14	-1.34a	-1.36a	-1.56b	-1.33ab	-1.64b	-1.33a
Comet	-1.31a	-1.17a	-1.93a	-1.47a	-2.02a	-1.40a
Pronto	-1.33a	-1.59a	-2.07a	-1.57a	-2.08a	-1.66a
Mean	-1.27x	-1.19x	-1.80x	-1.36y	-1.89x	-1.41y
Q(v-s)[‡]	ns	ns	.34**	.27*	.27*	ns
	74 DAP		81 DAP		91 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-2.11ab	-1.60ab	-2.32a	-1.42a	-1.67a	-1.26a
OK-FH-13	-2.15ab	-1.32b	-2.37a	-1.56a	-1.78a	-1.28a
OK-FH-14	-1.83b	-1.50ab	-2.42a	-1.63a	-1.73a	-1.21a
Comet	-2.00ab	-1.26b	-2.24a	-1.65a	-1.57a	-1.25a
Pronto	-2.26a	-1.72a	-2.54a	-1.71a	-1.91a	-1.52a
Mean	-2.07x	-1.48y	-2.38x	-1.59y	-1.73x	-1.30y
Q(v-s)	ns	ns	ns	ns	ns	ns

+ Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

‡ Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 12

OSMOTIC POTENTIAL (OP, MPa) OF PEANUT GENOTYPES GROWN IN 1984

Genotype	Osmotic Potential (MPa)					
	54 DAP		61 DAP		68 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-1.56a[+]	-1.15ab	-2.04a	-1.16a	-2.08a	-1.61a
OK-FH-13	-1.59a	- .98b	-1.66a	-1.37a	-2.01a	-1.47a
OK-FH-14	-1.51a	- .86b	-1.67a	-1.30a	-1.68a	-1.82a
Comet	-1.60a	-1.37a	-1.90a	-1.44a	-1.98a	-1.60a
Pronto	-1.82a	-1.19ab	-2.01a	-1.66a	-2.23a	-1.58a
Spanhoma	-1.64a	-1.37a	-1.88a	-1.32a	-1.97a	-1.47a
Mean	-1.62x	-1.15y	-1.86x	-1.39y	-1.99x	-1.59y
Q(v-s)[‡]	ns	.32**	ns	.22**	ns	ns
	75 DAP		82 DAP		89 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-2.06ab	-2.00a	-1.93bc	-1.51b	-2.19a	-1.79a
OK-FH-13	-1.87ab	-1.42bc	-2.12cd	-1.50b	-2.07a	-1.87a
OK-FH-14	-1.87ab	-1.64abc	-2.27cd	-1.53b	-2.20a	-1.50a
Comet	-1.96ab	-1.48bc	-2.78e	-1.43b	-2.13a	-1.74a
Pronto	-2.22a	-1.86ab	-2.50de	-1.53b	-2.59a	-1.78a
Spanhoma	-1.65b	-1.37c	-2.30cde	- .95a	-2.26a	-1.09a
Mean	-1.94x	-1.63y	-2.31x	-1.41y	-2.24x	-1.63y
Q(v-s)	ns	ns	.42**	ns	ns	ns

[+] Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 13

TURGOR POTENTIAL (TP, MPa) OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Turgor Potential (MPa)					
	53 DAP		61 DAP		67 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-.17a[+]	-.01a	-.17a	-.03a	-.11a	.21a
OK-FH-13	-.01a	.13a	-.16a	-.07a	-.14a	.15a
OK-FH-14	.23a	.30a	-.24a	-.06a	-.09a	.23a
Comet	-.13a	.25a	-.21a	-.12a	-.07a	-.05a
Pronto	-.05a	.26a	-.18a	-.02a	-.03a	.28a
Mean	-.03x	.19x	-.19x	-.06y	-.09x	.16y
Q(v-s)[‡]	ns	ns	ns	ns	ns	ns
	74 DAP		81 DAP		91 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-.22a	.54a	-.25a	.27a	-.08a	.30a
OK-FH-13	-.18a	.43a	-.18a	.34a	-.14a	.23a
OK-FH-14	-.18a	.24a	-.21a	.14a	-.12a	.29a
Comet	-.22a	.11a	-.18a	.21a	-.28a	.17a
Pronto	-.16a	.33a	-.16a	.15a	-.08a	.18a
Mean	-.19x	.33y	-.20x	.22y	-.14x	.23y
Q(v-s)	ns	ns	ns	ns	ns	ns

+ Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

‡ Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 14

TURGOR POTENTIAL (TP, MPa) OF PEANUT GENOTYPES GROWN IN 1984

Genotype	Turgor Potential (MPa)					
	54 DAP		61 DAP		68 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	.09a[+]	.55ab	.05a	.66a	-.04a	.82a
OK-FH-13	-.04a	.20bc	-.07a	1.05a	-.09a	.39a
OK-FH-14	.08a	-.07c	.00a	.76a	.08a	.38a
Comet	-.01a	.61a	.08a	.72a	-.06a	.26a
Pronto	.15a	.53ab	.20a	.10a	.02a	.41a
Spanhoma	.28a	.77a	.17a	.63a	.02a	.14a
Mean	.09x	.43y	.07x	.08y	-.01x	.40y
Q(v-s)[‡]	ns	-.41**	ns	ns	ns	ns
	75 DAP		82 DAP		89 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	-.02a	.02a	-.07a	.80a	-.14d	.72a
OK-FH-13	-.10a	.05a	-.21a	.65a	-.18d	.25bc
OK-FH-14	-.08a	.32a	-.16a	.48a	-.18d	.29bc
Comet	-.02a	.02a	-.10a	.37a	-.06cd	-.16d
Pronto	.05a	.18a	-.06a	.14a	-.09d	.06bcd
Spanhoma	-.03a	.43a	-.09a	.25a	-.12d	.38b
Mean	-.04x	.17y	-.11x	.45y	-.12x	.25y
Q(v-s)	ns	ns	ns	.39**	ns	.33**

+ Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

‡ Q(v-s) represents contrast comparison between mean values of virginia minus spanish types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 15

CANOPY TEMPERATURE (Tc, C) OF PEANUT GENOTYPES GROWN IN 1983

Genotype	Canopy Temperature (C)			
	53 DAP		61 DAP	
	RF	IR	RF	IR
Florunner	37.0b[+]	36.0b	39.3ab	34.9bc
OK-FH-13	36.8b	36.2b	39.7ab	34.1c
OK-FH-14	37.1b	36.0b	40.2a	34.9bc
Comet	37.1b	36.7a	39.0b	35.4b
Pronto	37.7a	36.7a	39.8ab	36.6a
Mean [‡]	37.1x	36.3y	39.6x	35.2y
Q(s-v)	.4*	.6**	ns	1.4**

	67 DAP		74 DAP		81 DAP	
	RF	IR	RF	IR	RF	IR
Florunner	39.4ab	31.9ab	36.8a	31.0a	44.4a	36.6a
OK-FH-13	39.0ab	30.7b	36.8a	31.3a	44.0a	36.4a
OK-FH-14	39.6a	32.5a	38.5a	30.9a	44.3a	37.5a
Comet	37.9b	31.1ab	36.7a	30.0a	43.3a	37.3a
Pronto	38.9ab	32.5a	37.8a	31.8a	43.3a	38.0a
Mean	38.9x	31.7y	37.3x	31.0y	43.8x	37.1y
Q(s-v)	-.9*	ns	ns	ns	ns	ns

[+] Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference ($P<.05$) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(s-v) represents contrast comparison between mean values of spanish minus virginia types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 16

CANOPY TEMPERATURE DIFFERENCE (Td, C)
FROM AMBIENT OF PEANUT GENOTYPES
GROWN IN 1983

Genotype	Canopy Temperature Difference (C)			
	53 DAP		61 DAP	
	RF	IR	RF	IR
Florunner	3.7a[+]	3.6a	-1.3a	-6.9ab
OK-FH-13	2.6a	3.2a	- .8a	-7.9a
OK-FH-14	3.6a	3.5a	- .2a	-6.8ab
Comet	3.2a	3.6a	-1.0a	-6.4b
Pronto	4.0a	3.8a	- .6a	-5.2c
Mean	3.4x	3.5x	- .8x	-6.6y
Q(s-v)[‡]	ns	ns	ns	1.4**

	74 DAP		81 DAP	
	RF	IR	RF	IR
Florunner	.1a	-4.4a	3.1a	-3.0a
OK-FH-13	.1a	-4.6a	1.7a	-3.2a
OK-FH-14	1.3a	-4.5a	3.0a	-2.0a
Comet	-.3a	-4.5a	2.0a	-2.3a
Pronto	.5a	-3.5a	1.9a	-1.9a
Mean	.3x	-4.3y	2.3x	-2.5y
Q(s-v)	ns	ns	ns	ns

[+] Values not followed by the same letter within column or mean comparision within same DAP indicate significant difference (P<.05) according to Duncan's Multiple Range Test (DMRT).

[‡] Q(s-v) represents contrast comparison between mean values of spanish minus virginia types.

**, *, and ns represent significance at the 0.01, 0.05 probability levels, and not significant difference, respectively.

TABLE 17

SIMPLE LINEAR CORRELATION COEFFICIENTS (r) AMONG WATER RELATION PARAMETERS, 1983

	Rs	RWC	WP	OP	TP
GC	-.146+	.430	.423	.249	.489
Rs		-.463	-.426	-.387	-.270
RWC			.731	.584	.595
WP				.392	.662
OP					.252

+ r values greater than .138 and .181 were significant at the .05 and .01 probability levels (n=240), respectively.

TABLE 18

SIMPLE LINEAR CORRELATION COEFFICIENTS (r) AMONG WATER RELATION PARAMETERS, 1984

	Rs	RWC	WP	OP	TP
GC	-.586+	.638	.544	.455	.471
Rs		-.577	-.594	-.531	-.489
RWC			.730	.643	.602
WP				.885	.826
OP					.476

+ r values greater than .159 and .208 were significant at the .05 and .01 probability levels (n=144), respectively.

TABLE 19

SIMPLE LINEAR CORRELATION COEFFICIENTS
AMONG WATER RELATION PARAMETERS
AT 81 DAP, 1983

	Rs	RWC	WP	OP	TP	Tc	Td
GC	-.871[+]	.888	.824	.753	.755	-.920	-.869
Rs		-.836	-.752	-.698	-.673	.867	.833
RWC			.889	.837	.774	-.924	-.885
WP				.954	.853	-.856	-.827
OP					.659	-.783	-.744
TP						-.789	-.785
Tc							.964

[+] r values greater than .312 and .403 were significant at the .05 and .01 probability levels (n=40), respectively.

TABLE 20

SIMPLE LINEAR CORRELATION COEFFICIENTS
AMONG WATER RELATION PARAMETERS
AT 81 DAP, 1984

	Rs	RWC	WP	OP	TP
GC	-.863[+]	.879	.889	.838	.758
Rs		-.821	-.851	-.788	-.749
RWC			.909	.880	.738
WP				.944	.851
OP					.630

[+] r values greater than .404 and .515 were significant at the .05 and .01 probability levels (n=24), respectively.

CHAPTER VI

YIELD RESPONSES OF PEANUT UNDER RAINFED AND IRRIGATED CONDITIONS

Introduction

Crop yield reductions caused by water deficts are a frequent occurrence. For example, the severe drought during 1983 in the United States resulted in 48 and 38 % yield reduction of corn and soybean, respectively (Le Rudulier et al., 1984). For peanut, the average yield reduction due to lack of soil water during the growing season from 1976 to 1980 in Texas was about 59.2 % (Jordan et al., 1983). Also, water stress influences not only yield but quality. Peanut seed grade and germination were lowered (Pallas et al., 1977; Boote et al., 1982). Hence, preventing yield and/or quality losses due to drought is considered one of the main challenges in crop research.

Pallas et al. (1979) reported that drought progressively decreased peanut yields as duration and lateness of occurrence in the season increased. They found that a 70-day extended early season drought caused the greatest reduction in sound mature kernel (SMK), while a late season 35-day and extended midseason 70-day drought lowered subsequent germination 5 and 9 %, respectively.

Other yield components of peanut such as pod number, weight, seed number, seed weight, and quality etc., were also influenced by drought (Pallas et al., 1979; Boote et al., 1982). Pandey et al. (1984a) indicated that drought caused about 46 % yield reduction in peanut. The number of pods per square meter, number of seeds per pod, and 100-seed weight were 53, 26, and 16 % reduced when compared with the wettest treatment. They also showed that yield, yield components, and harvest index were positively correlated with water application. Based on the relationships between yield, water potential, and canopy temperature difference, they furthermore proposed that cumulative leaf water potential and stress degree days were good indices which can be used for determination of crop drought tolerance. Erickson and Ketring (1985) also found that peanut yield was reduced under RF. Peanut genotypes differed in yield and total SMK+SS (TSMK).

As mentioned by Begg and Turner (1976), the degree of yield reduction by water deficit depends on duration and timing of the deficit. However, studies on yield responses under rainfed (RF) and irrigated (IR) conditions during the entire season and the relationships between water relation components, yield, and yield components are limited. Since final yield is the integration of all plant responses to water deficit, studies on the influence of water stress on yield based on entire seasons of water status might be more meaningful. The correlation between water status and yield

might also provide a way for selecting a useful stress index. Therefore, this study was conducted to examine yield responses of peanut genotypes under RF and IR conditions, and to investigate the relationships among yield responses and cumulative water status parameters.

Materials and Methods

The genotypes, experimental designs, and measurements of water status parameters including percent groun cover (GC), stomatal resistance (Rs), relative water content (RWC), water potential (WP), osmotic potential (OP), turgor potential (TP), canopy temperature (Tc), and Leaf-ambient temperature difference (Td) were as described in Chapter Five. Cumulative water status parameters were calculated from the sum of water relation components measured from 53 to 91 DAP in 1983 and from 54 to 89 DAP in 1984, respectively. Before harvest, both two rows in 1983 and the two center rows of each plot in 1984 were trimmed to eliminate the end plants. Peanuts were harvested at 149 days after planting (DAP). After harvest, pod yield and pod and seed characteristics were measured. In both years, yield determinations on a land area basis (kg/ha) were made. Also in 1984, plant samples were taken for determination of yield components (pod number, pod weight, pod weight per plant, seed weight, seed number, and seed weight per plant). Yields in 1984 under RF were so low that there was insufficient pod weight for official grade

analysis. Otherwise official grade analyses were performed by the Federal State Inspection Service at Anadarko, Oklahoma. Simple linear correlation coefficients between yield and pod and seed characteristics, and cumulative water relation parameters were then calculated.

Results and Discussion

Peanut pod yield was significantly reduced under RF. However, no significant difference in pod yield among genotypes was found in 1983 (Table 1). Although the two spanish-type genotypes, Comet and Pronto, had higher pod yield than the others, no difference between botanical types was shown. Under RF conditions, spanish-type genotypes had higher percentage of sound mature kernels (SMK) and total sound mature kernel (TSMK) than virginia types (Table 1). RF-treated Pronto followed by Comet, had the highest SMK and TSMK among the genotypes. Under IR conditions, OK-FH-14 had the highest % SMK and TSMK. Since SMK and TSMK are the important seed quality factors in determination of dollar returns of peanut, Pronto and Comet will have the highest dollar return under RF conditions. Over-all SMK and TSMK of RF peanuts were significantly lower than IR peanuts. Pallas et al. (1977), Stansell et al. (1979), and Erickson and Ketring (1985) also found that SMK was reduced under drought stress conditions. As in 1983, peanut genotypes in 1984 did not show differences in pod yield under RF conditions (Table 2). Yields under RF

in 1984 were even less than 1983. Genotypic differences in pod yield were found under IR conditions, which indicates yield potential when water is available. Significant differences between RF and IR treatments in pod weight per plant, pod number, pod weight, seed weight per plant, seed number, seed weight, and shelling percentage were found (Table 2 and 3). Under RF conditions, all yield components were significantly reduced. Genotypes did not significantly differ in these components, except in pod weight. Pronto had the heaviest pod weight under RF conditions. By using contrast comparisons, Pronto had significantly higher pod weight per plant, seed weight per plant, seed number per plant, and shelling percentage than the mean values of other genotypes under RF conditions (Table 2 and 3).

It has been reported that soil water deficits during pegging and pod development primaily reduced pod number while prolonged water deficit during seed growth and maturation can lead to decreased seed weight and seed number (Boote et al., 1976; Pallas et al., 1979). Data from this study shows similar results, but also indicates genotypic differences. No significant differences among peanut genotypes in pod yield and yield components under RF conditions might be due to the prolonged severe drought environments which eliminated varietal yield responses.

Correlations between pod yield, SMK, TSMK, and water relation parameters in 1983 are shown in Table 4. Highly

significant linear correlation coefficients were found. Pod yield, SMK, and TSMK were positively correlated with cumulative GC, RWC, WP, OP, and TP. But were negatively associated with cumulative leaf Rs, Tc, and Td. In 1984, highly positive linear correlation coefficients among yield and yield components were found (Table 5). Pod yield was positively correlated with pod and seed weight per plant, pod and seed number per plant, weights of pod and seed, and shelling percentage. Also, all linear correlation coefficients between cumulative water relation components and yield and yield components were highly significant (Table 6). Pod yield and its components were positively associated with GC (r=.935 to .616), RWC (r=.899 to .674), WP (r=.936 to .533), OP (r=.845 to .463), and TP (r=.922 to The higher the cumulative RWC, WP, OP, and TP, the higher the pod yield. Similar results have been reported by Pandey et al. (1984a). They summed the leaf water potential and stress degree day (temperature difference between leaf and air) and found that total dry matter and yield were significantly associated with cumulative leaf water potential and stress degree day. In our study, which was based on several genotypes, not only highly significant, positive correlations between pod yield and cumulative WP occurred. But positive correlations with other water status parameters such as RWC were obtained. Since the measurement of cumulative RWC is much easier and more economic than WP determinations, RWC may serve as a

more practical stress indicator. Also, our data indicated that highly negative correlation coefficients existed between pod yield and Tc (r=-.932) and Td (r=-.914). Td was defined as stress degree days by O'Toole et al. (1984) and Pandey et al. (1984a). If Td was a good stress indicator as proposed by Pandey et al. (1984a), then cumulative Tc might also serve as another good stress index (Table 4).

Summary and Conclusions

Prolonged drought caused significant pod yield reduction (Table 1 and 2). Under RF conditions, no significant differences among genotypes in pod yield, pod number per plant, or seed weight were found. However, peanut genotypes did show significant differences in some yield components such as SMK, etc. Pronto and Comet had higher SMK and TSMK, with higher pod yield (although not significant at 5 % level) under RF conditions. This will result in higher dollar return. Pronto had higher pod weight per plant, heavier pods, more seed weight per plant, more seeds per plant, and more shelling percentage under RF environments (Table 2 and 3).

Since pod yield and its components are a result of integrated responses of peanut to water stress during the growing season, the use of cumulative water status parameters from seed emergence to maturity, or most important, during physiological sensitive stages (53 DAP to

91 DAP) may be a better indicator of drought tolerance than an individual measurement. Cumulative water status parameters were significantly correlated to yield. Pod yield, SMK, TSMK, and seed and pod components were positively correlated with GC, RWC, WP, OP, and TP, but negatively associated with Rs, Tc, and Td (leaf minus ambient). These cumulative water status parameters, especially leaf WP, RWC, Tc, and Td with highly significant correlation coefficients, may serve as stress indices for evaluation of drought tolerance of peanut.

TABLE 1

POD YIELD (KG/HA), SOUND MATURE KERNEL (SMK, %), AND TOTAL SMK (TSMK, %) OF PEANUT, 1983

Genotype	Pod Yield		SMK		TSMK	
	RF	IR	RF	IR	RF	IR
Florunner	559a[+]	3090a	7.8e	63.3b	7.8e	65.3b
OK-FH-13	550a	3767a	4.8e	68.5ab	4.8e	73.8a
OK-FH-14	541a	2947a	7.5e	71.0a	7.5e	74.0a
Comet	680a	3691a	23.5d	62.5b	23.5d	66.0b
Pronto	607a	3305a	33.5c	65.8ab	33.8c	68.0ab
Mean	587x	3360y	15.4x	66.2y	15.5x	69.4y

[+] Values within the same column and means between treatments followed by same letter were not significantly different ($P<.05$) according to Duncan's Multiple Range Test, respectively.

TABLE 2

POD YIELD AND CHARACTERISTICS OF PEANUT UNDER RF AND IR CONDITIONS, 1984

Genotype	Pod Yield (Kg/Ha)		Pod Wt. Per Plant (g)		Pod No.		Wt. Per Pod (g)	
	RF	IR	RF	IR	RF	IR	RF	IR
Florunner	58e[+]	3311bc	3.3a	29.2a	13.9a	27.6a	.24b	1.06a
OK-FH-13	112e	3457ab	6.8a	20.5a	14.9a	18.5a	.38ab	1.12a
OK-FH-14	49e	3854a	3.8a	30.1a	11.5a	30.5a	.35ab	.98ab
Comet	99e	3014bc	3.5a	29.5a	17.1a	38.5a	.21b	.76b
Pronto	229e	2377d	15.9a	25.5a	25.5a	27.6a	.58a	.92ab
Spanhoma	101e	2860cd	3.1a	27.4a	16.0a	33.8a	.19ba	.87ab
Mean	108x	3146y	6.1x	27.1y	16.5x	29.4y	.32x	.95y

[+] Values within the same column and means between treatments followed by the same letter were not significantly different ($P<.05$) according to Duncan's Multiple Range Test, respectively.

TABLE 3

SEED CHARACTERISTICS OF PEANUT UNDER RF AND IR CONDITIONS, 1984

Genotype	Seed Wt.(g) Per Plant		Seed No.		Wt. Per Seed (g)		Shelling (%)	
	RF	IR	RF	IR	RF	IR	RF	IR
Florunner	1.0a[+]	22.9a	8.5a	46.3a	.12a	.49a	.29a	.78a
OK-FH-13	3.9a	16.4a	13.8a	30.6a	.20a	.54a	.42a	.80a
OK-FH-14	1.8a	23.2a	8.8a	52.4a	.21a	.44a	.49a	.76a
Comet	1.0a	21.3a	8.1a	61.4a	.12a	.34a	.27a	.72a
Pronto	9.7a	19.0a	33.6a	45.4a	.26a	.42a	.56a	.75a
Spanhoma	.8a	21.1a	7.0a	56.6a	.08a	.40a	.20a	.77a
Mean	3.0x	20.7y	13.3x	48.8y	.16x	.44y	.37x	.76y

[+] Values within the same column and means between treatments followed by the same letter were not significantly different ($P<.05$) according to Duncan's Multiple Range Test (DMRT), respectively.

TABLE 4

SIMPLE LINEAR CORRELATION COEFFICIENT (r) AMONG YIELD AND WATER STATUS PARAMETERS OF PEANUT, 1983

	Pod Yield	SMK	TSMK
Ground Cover	.898 +	.853	.860
Stomatal Resistance	-.805	-.838	-.840
Relative Water Content	.823	.854	.851
Water Potential	.852	.793	.794
Osmotic Potential	.770	.677	.685
Turgor Potential	.801	.810	.799
Canopy Temperature	-.932	-.907	-.911
Temperature Difference	-.914	-.883	-.888

+ r values greater than .403 (n=40) are significant at .01 probability level.

TABLE 5

SIMPLE LINEAR CORRELATION COEFFICIENT (r)
AMONG PEANUT YIELD CHARACTERISTICS
UNDER RF AND IR CONDITIONS, 1984

	PW	PN	WP	SW	SN	WS	S+
Pod Yield	.851‡	.616	.890	.876	.780	.849	.837
Pod Wt. Per Plant (PW)		.862	.878	.996	.965	.834	.879
Pod No. Per Plant (PN)			.554	.827	.939	.528	.662
Wt. Per Pod (WP)				.974	.757	.900	.930
Seed Wt. Per Plant (SW)					.947	.859	.889
Seed No. Per Plant (SN)						.705	.817
Wt. Per Seed (WS)							.955

+ Shelling %.

‡ r values greater than .404 and .515 (n=24) are significant at .05 and .01 probabilit levels, respectively.

TABLE 6

SIMPLE LINEAR CORRELATION COEFFICIENT (r) BETWEEN YIELD AND WATER STATUS PARAMETERS OF PEANUT UNDER RF AND IR CONDITIONS, 1984

	GC	Rs	RWC	WP	OP	TP
Pod Yield	.935 +	-.929	.899	.936	.845	.922
Pod Wt. Per Plant	.851	-.892	.870	.791	.707	.797
Pod No. Per Plant	.616	-.671	.674	.533	.463	.555
Wt. Per Pod	.884	-.910	.926	.867	.785	.860
Seed Wt. Per Plant	.875	-.905	.883	.824	.743	.822
Seed No. Per Plant	.794	-.832	.816	.706	.629	.712
Wt. Per Seed	.854	-.880	.770	.828	.763	.808

+ r values greater than .515 (n=24) are significant at .01 probability level.

CHAPTER VII

HEAT TOLERANCE OF PEANUT GENOTYPES UNDER RAINFED AND IRRIGATED CONDITIONS

Introduction

Among the environmental stresses, drought and high temperature are two main factors which can significanly affect growth, development, and yield of crop plants. Heat stress usually, but not always accompanies drought stress. The effects of heat stress are often confounded with those of drought stress. However, adverse effects of high temperature, one which is higher than optimal for normal crop growth, on many physiological processes such as photosynthesis, photorespiration, dark respiration, nitrogen fixation, enzymatic reactions, diffusion, and transpiration in plants have been shown (Levitt, 1980a; McDaniel, 1982; Eastin et al., 1983). This has been demonstrated for many important crops such as soybean (Mederki, 1983; Bouslama and Schapaugh, 1984), corn (Shaw, 1983), sorghum (Sullivan and Ross, 1977), wheat (Blum and Ebercon, 1981), grasses (Minner et al., 1983), and cowpea (Warrag and Hall, 1983). They concluded that genotypes differed in heat tolerance and the integration of these altered physiological processes finally caused yield and/or

quality reduction. However, reports on the amount of yield and/or quality losses caused by heat stress are limited.

As in soybean (Mederki, 1983), the influence of temperature on peanut is complex because the optimal temperature for vegetative and reproductive growth (flowering, pegging, pod formation, and kernel filling) are different. The optimum mean air temperatures for vegetative growth of peanut are in the range of 25 C to 30 C. Optimum temperature for reproductive growth may be similar or somewhat lower (20 to 25 C) (Ketring, 1984b). Apparently, air temperatures higher than optimal will cause yield reduction. By comparing environmental data, especially temperature, and examining peanut yield throughout the peanut belt, Ketring (1984b) reported that the 40 to 50 % yield reductions in peanut in 1980 might be partially due to high air temperature. The average air temperature in 1980 was about 5 C higher than the average in 1979 and 1981. Length of exposure to 35 C, also may have contributed to peanut yield reduction in 1980. Temperatures of 35 C had inhibitory effects on peanut development such as reduction of leaf area, stem elongation, number of pegs, and mature seed weights (Ketring, 1984b).

One of the earliest and most universal measures of plant temperature injury is electrolyte leakage caused by membrane damage due to high temperature (Raison et al., 1980; Levitt, 1980a; McDaniel, 1982). Therefore, the

thermostability of leaves was used for evaluation of heat stress resistance in many crops such as sorghum (Sullivan and Ross, 1979;) and soybean (Martineau et al., 1979; Bouslama and Schapaugh, 1984). Research on heat tolerance of peaunt is limited. Therefore, the objective of this study was to examine peanut genotypes for differences in leaf membrane thermostability.

Materials and Methods

The experimental design was the same as described in Chapter Five.

Leaf samples were collected at 54, 75, and 96 days after planting (DAP) for determination of leaf membrane thermostability. Five or six leaves were collected from both sides of the row of each plot. The first fully expanded leaf (third node if the apical tip is counted as number one) was collected. The leaves were placed in plastic bags and moistened with water before transporting back to the laboratory. The leaves were kept cool in styrofoam chest during transport. The leaves were briefly washed with tap water and ten distal leaflets (peanut leaves are tetrafoliate) were stacked. The stacked leaflets were punched twice with a No. 3 cork borer to obtain a paired set (control and treatment) of ten leaf discs each. The ten discs were transferred to a 105 mm x 16 mm polycarbonate tube with one end covered by nylon mesh held in place with an elastic band. The tubes with leaf

discs were placed in test-tube racks within pans containing tap water to wash the leaf discs. The nylon mesh retained the discs within individual sample tubes, yet allowed entry of water to wash discs free of exogenous contaminants adhering to tissue surfaces and endogenous electrolytes released from cut cell surfaces. From the time that the last set of discs were cut, the discs were washed for 0.5 hr in tap water followed by two changes of distilled water for a minimum of 1.5 hr of washing. After the final wash, the 16-mm sample tubes were then put into 50-ml graduated, conical polycarbonate test tubes held in racks. Six ml of demineralized water was added to float and separate the discs during heat treatment. The racks of tubes were covered with aluminum foil to prevent moisture loss during temperature treatment. Treatment discs were put into a 50 C water bath for one hour while the other 10 leaf discs (control) were kept at room temperature (Ketring, 1985). After treatment the discs were immediately cooled by immersing the tubes in cold tap water. Control discs remained at room temperature. The leaf discs plus water were than transferred from the 16-mm tubes into 50-ml tubes and brought to 25 ml volume with demineralized water. Tubes were covered with aluminum foil, and both control and treatment leaf discs were then incubated in a refrigerator at 5 C overnight to allow diffusion of electrolytes from the discs. Conductivity of the solution was measured with a Markson Electromark analyzer (Markson Science Inc.) at a

constant temperature of 27 C. After the initial conductivity measurement the tubes were recovered with aluminum foil to prevent moisture loss, and both control and treatment discs were autoclaved at 100 C for 10 minutes to completely kill the leaf tissue. After the tubes were cooled and equilibrated at 27 C, a final conductance measurement was made. Percent membrane injury was calculated according to the following equation:

$$\text{Injury (\%)} = 1 - \frac{1 - (Ti/Tf)}{1 - (Ci/Cf)} \times 100$$

Where Ti and Tf were the conductivity of heat treatment discs obtained from initial and final measurements, respectively. Ci and Cf were the conductivity of control discs obtained from initial and final measurements, respectivity (Martineau et al., 1979).

Results and Discussion

In 1983, no significant genotypic and treatment (RF and IR) differences in % membrane injury at 54 days after planting (DAP) were found (Table 1). However, peanut genotypic and treatment differences in membrane thermostability at 75 and 96 DAP were observed. At 75 DAP, the percentage of membrane injury of Florunner, OK-FH-13, and OK-FH-14 under IR conditions were significantly higher whereas Comet was significantly lower than under RF conditions. No marked difference in membrane thermostability of Pronto between treatments at 75 DAP was

observed. At 96 DAP, the percent membrane injury of Florunner under RF conditions was still lower than IR conditions. But for Comet, less percent injury was found under IR conditions at 96 DAP.

With respect to DAP effects, no significant differences in percent injury of OK-FH-13, OK-FH-14, and Pronto were observed among DAPs under RF. However, Comet, and Florunner had the least percent injury at 54 and 96 DAP, respectively under RF. Under IR conditions, the highest percent injury of virginia types was found at 75 DAP. However, low injury was found at 54 DAP for the two spanish types, Comet and Pronto. It seems that maximum injury of all genotypes occurred at 75 DAP; virginia types under IR and spanish types under RF. Acclimation of all genotypes except Comet seems to have occurred by 96 DAP. Only Comet under RF had a significantly high value compared to the other genotypes. Plants under prolonged high temperature synthesize new proteins (heat-shock proteins) and new fatty acids (longer-chained, saturated fatty acids) which can reduce membrane damage (Raison et al., 1980; Levitt, 1980a; McDaniel, 1982).

In 1984, percent membrane injury was different between treatments and among genotypes at 54 DAP (Table 2). At 54 DAP, the least membrane injury was for Florunner under RF conditions. The membrane injuries of Florunner and OK-FH-13 under IR conditions were significanly higher than under RF conditions. At 75 DAP, only Pronto showed a

significant difference in membrane injury between treatments. Higher injury under RF was observed for Pronto. No genotypic differences in % membrane injury under IR conditions were found at 75 DAP. Under RF conditions at 96 DAP Comet and Pronto had the highest % membrane injury. Under IR conditions, the injury of Comet was higher than OK-FH-13. Only OK-FH-14 had a significant difference in membrane injury among DAPs under RF conditions. Under IR conditions, membrane injury of virginia-type genotypes was significantly higher at 54 DAP than at later stages. Comet had significantly less membrane injury at 75 DAP than 54 DAP under IR conditions. Pronto was unaffected by DAP. Genotypic variation in leaf membrane thermostability of soybean (Matineau et al., 1979; Bouslama and Schapaugh, 1984) and sorghum (Sullivan and Ross, 1979) also have been shown. Differences in membrane thermostability of soybean at different growth stages also have been found (Bouslama and Schapaugh, 1984). Based on the research with soybean, sorghum and ours with peanut, membrane thermostability might be a good index for evaluation of heat tolerance of peanut.

Yearly variations in % membrane injury between treatments and among genotypes are shown in Table 3 and 4. Under RF conditions, differences between years in membrane injury were found only for Pronto at 54 DAP (Table 3). The injury of Pronto was less in 1983 than 1984. However, under IR conditions, significant differences between years

in membrane injury were found for all genotypes at 54 and 75 DAP (except Pronto at 75 DAP), but not at 96 DAP. At 54 DAP under IR, higher membrane damage was found in 1984 than in 1983 (Table 4). But at 75 DAP in 1984, less membrane injury was found for all genotypes except Pronto. The higher % membrane injury at 75 DAP in 1983 (Table 4) might be due to less rainfall in July and August, and more days of temperature greater than 35 C than in 1984 (Table 5). However, this would not explain the higher % membrane injury at 54 DAP in 1984. But yields were less in 1984 than in 1983 (Chapter 6, Table 1 and 2). It appears that the earlier measuring dates 54 and 75 DAP show the largest differences among genotypes and are most sensitive to environmental conditions. It is during this period (July and August) when the plant are subject to the greatest degree of environmental stress (water and temperature) in Oklahoma. However, Bouslama and Schapaugh (1984) found that there were no year x soybean genotype interactions in percent membrane thermostability.

Summary and Conclusions

Membrane leakage caused by heat stress can be measured by electrical conductivity of the cell contents. The percentage of memebrane injury of six peanut genotypes grown under RF and IR conditions in 1983 and 1984 were used to study heat tolerance. Higher membrane damage was found at 75 DAP (Table 1). For the virginia types (Florunner,

OK-FH-13, and OK-FH-14), injury was decreased after 75 DAP, while in spanish types (Comet, and Pronto) similar membrane injury occurred at all DAPs. Genotypic and treatment differences were found at 75 and 96 DAP but not at 54 DAP (Table 1).

Significant differences in % membrane injury between RF and IR treatments were found at 54 DAP for all three virginia-type genotypes, and at 75 DAP for Pronto in 1984 (Table 2). At 54 DAP, the % membrane injury of Florunner, OK-FH-13, and OK-FH-14 under RF was lower than under IR conditions. At 75 DAP, membrane injury of Pronto was higher under RF conditions. At 96 DAP, injury was less or the same as the previous period for all genotypes tested. In 1983 (Table 1), membrane injury increased from 54 DAP to 75 DAP and then decreased at 96 DAP in some virginia types but only Florunner was significant in this trend. For spanish types, injury remained the same at all stages. In 1984 (Table 2) only OK-FH-13 and OK-FH-14 showed differences in membrane injury under IR conditions at different DAPs.

Seasonal variations in membrane injury were also found for some genotypes (Table 3 and 4). Under RF conditions, annual differences were only found at 54 DAP for Pronto. At 96 DAP, Comet had higher % membrane injury than all three virginia-type genotypes under RF conditions.

Heat stress in temperate areas frequently occurs. Yield and/or quality reduction by heat injury alone or

confounded with water deficits also frequently occurs. Severity of yield reduction is determined by the temperature itself, duration of exposure, and critical stages of plant growth (Levitt, 1980a; McDaniel, 1982; Marshall, 1982; Ketring, 1984b). Using membrane injury for evaluating heat tolerance in some crop plants has been demonstrated. It is considered as an effective heat stress index (Sullivan and Ross, 1979; Martineau et al., 1979; Bouslama and Schapaugh, 1984). This could be a means for selecting more heat tolerant peanut germplasm.

TABLE 1

PEANUT LEAF MEMBRANE THERMOSTABILITY
UNDER RAINFED (RF) AND IRRIGATED
(IR) CONDITIONS, 1983

Genotype	Treatment	% Membrane Injury 54 DAP	75 DAP	96 DAP
Florunner	RF	60.54 e-j[+]	65.82 b-f	49.00 h-j
	IR	55.23 f-j	81.68 a	64.73 c-g
OK-FH-13	RF	57.59 f-j	58.60 f-j	54.66 f-j
	IR	55.65 f-j	75.73 a-d	56.35 f-j
OK-FH-14	RF	58.37 f-j	61.34 d-j	49.95 g-j
	IR	57.30 f-j	76.92 a-c	61.01 e-j
Comet	RF	57.23 f-j	79.02 ab	75.26 a-e
	IR	47.42 j	62.82 c-i	59.74 f-j
Pronto	RF	48.93 h-j	63.63 c-h	60.65 e-j
	IR	48.12 ij	60.42 e-j	60.75 e-j

+ Mean values not followed by the same letter were different ($P<.05$) as determined by Duncan's Multiple Range Test.

TABLE 2

PEANUT LEAF MEMBRANE THERMOSTABILITY UNDER RAINFED (RF) AND IRRIGATED (IR) CONDITIONS, 1984

Genotype	Treatment	% Membrane Injury 54 DAP	75 DAP	96 DAP
Florunner	RF	54.20 ij[+]	59.75 d-j	49.89 j
	IR	74.22 a-c	56.50 h-j	56.95 g-j
OK-FH-13	RF	63.26 c-i	63.00 c-i	53.55 ij
	IR	75.30 ab	61.75 d-j	49.87 j
OK-FH-14	RF	70.43 a-e	61.75 d-j	53.49 ij
	IR	78.54 a	62.50 c-i	58.89 e-j
Comet	RF	69.56 a-f	65.25 b-i	64.65 b-i
	IR	69.24 a-g	55.00 ij	65.04 b-i
Pronto	RF	67.70 a-h	71.50 a-d	68.99 a-g
	IR	64.84 a-h	57.50 f-j	58.31 e-j

+ Mean values not followed by the same letter were different ($P<.05$) as determined by Duncan's Multiple Range Test.

TABLE 3

PEANUT LEAF MEMBRANE THERMOSTABILITY
UNDER RAINFED (RF) CONDITIONS
IN 1983 AND 1984

		% Membrane Injury		
Genotype	Year	54 DAP	75 DAP	96 DAP
Florunner	1983	60.54 b-h	65.82 a-f	49.00 h
	1984	54.20 d-h	59.75 c-h	49.89 gh
OK-FH-13	1983	57.59 c-h	58.60 c-h	54.66 d-h
	1984	63.26 b-h	63.00 b-h	53.55 e-h
OK-FH-14	1983	58.37 c-h	61.34 b-h	49.95 gh
	1984	70.43 a-c	61.75 b-h	53.49 b-h
Comet	1983	57.23 c-h	79.02 a	75.26 ab
	1984	69.56 a-d	65.25 a-g	64.65 a-g
Pronto	1983	48.93 h	63.63 b-h	60.65 b-h
	1984	67.70 a-f	71.50 a-c	68.99 a-e

+ Mean values not followed by the same letter were different ($P<.05$) as determined by Duncan's Multiple Range Test.

TABLE 4

PEANUT LEAF MEMBRANE THERMOSTABILITY
UNDER IRRIGATED (IR) CONDITIONS
IN 1983 AND 1984

		% Membrane Injury		
Genotype	Year	54 DAP	75 DAP	96 DAP
Florunner	1983	55.23 h-j[+]	81.68 a	64.73 d-g
	1984	74.22 a-e	56.50 h-j	56.95 f-j
OK-FH-13	1983	55.65 h-j	75.73 a-d	56.35 h-j
	1984	75.30 a-d	61.75 f-h	49.87 h-j
OK-FH-14	1983	57.30 f-j	76.92 a-c	61.01 f-h
	1984	78.54 ab	62.50 e-h	58.89 f-j
Comet	1983	47.42 j	62.82 e-g	59.74 f-j
	1984	69.24 b-f	55.00 h-j	65.04 c-g
Pronto	1983	48.12 ij	60.42 f-i	60.75 f-i
	1984	64.84 d-g	57.50 f-j	58.31 f-j

[+] Mean values not followed by the same letter were different ($P<.05$) as determined by Duncan's Multiple Range Test.

TABLE 5

PRECIPITATION AND AIR TEMPERATURE
AT AGRONOMY RESEARCH STATION
PERKINS, OKLAHOMA

Month	Rainfall (cm)	Mean Air Temperature Min.(C)	Max. (C)	No. of Day > 35 C
		1983		
June	13.77	16.7	28.9	None
July	.05	20.6	35.6	19
August	2.44	21.7	37.2	28
September	4.88	15.6	30.6	None
		1984		
June	10.36	18.9	32.8	None
July	.13	18.3	35.6	18
August	3.91	18.3	36.1	22
September	3.68	12.8	28.9	None

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Yield and/or quality reductions caused by drought and high temperature stresses are serious in peanut production areas throughout the world. In order to provide useful information for peanut breeding uses, five to seven peanut genotypes involving spanish and virginia botanical types were used for root growth characteristics studies under greenhouse conditions, and soil water extraction, water relations, yield responses, and heat tolerance studies under rainfed and irrigated conditions in the field during 1983 and 1984.

Genotypic variation in taproot length, growth rate, and root number at 30 cm depth were found. Virginia types tended to have longer taproot and higher taproot growth rates than spanish types. The root growth characteristics of OK-FH-13 and 14, selections of Spanhoma x Florunner, were close to Florunner. The maximum taproot growth rate was at 21 to 28 days after planting (DAP). Environmental factors such as photoperiod might affect shoot and root growth and development. No significant genotypic differences in root volume and dry weight were found. However, significant positive correlation coefficients

between root volume and root dry weight, and shoot dry weight were found. Also, root dry weight was positively associated with shoot dry weight.

Soil water extracted by peanut increased with time. Peanuts extracted more soil water from shallow depths than from deeper depths. Also, under rainfed (RF) conditions, peanuts extracted more soil water at earlier growth stages. No significant differences among genotypes in total soil water extraction was found in 1983. However, peanut genotypes showed significant differences in soil water extraction in 1984. Under RF, Spanhoma extracted more, while Florunner and Pronto extracted less soil water in 1984. Significantly less soil water was extracted by Spanhoma under IR conditions.

Peanut plants under RF conditions tended to have less percent ground cover (GC), higher stomatal resistance (Rs), higher canopy temperature (Tc), but lower water potential (WP), osmotic potential (OP), turgor potential (TP), and temperature difference between leaf and ambient (Td) than under IR. Genotyic differences in water status parameters were not observed in all DAPs examined. Virginia types had higher GC under RF and higher WP and OP at 61 DAP under IR. Higher Tc and Td of spanish types were found at 53 DAP in 1983. Positive correlation coefficients among all the water status parameters except Rs, Tc, and Td. Rs, Tc and Td were negatively correlated with GC, RWC, WP, OP, and TP.

Peanut genotypes did not show differences in pod yield under RF conditons. However, under RF, spanish types had higher sound mature kernel (SMK) and total SMK (TSMK) than virginia types. In 1984, Pronto had higher weight per pod, seed weight per plant, more seeds per plant, and higher shelling percentage than any other genotype under RF conditions. Cumulative water status parameters, except Rs, were positively correlatated with yield and yield components. Negative correlations between yield and Rs, Tc, and Td were also found. Cumulative RWC of the entire season can be used as a stress indicator.

Peanut genotypes differed in leaf membrane injury under RF and IR conditions. Higher leaf membrane damages occurred for virginia types under IR, and for spanish types under RF at 75 DAP in 1983. In 1984, IR peanut genotypes had higher leaf membrane injury at 54 DAP, but less injury at later stages. It appears that peanut had acclimated to high temperature conditions. Under IR, higher leaf membrane damages of virginia types occurred at 75 and 54 DAP in 1983 and 1984, respectively. But spanish types had higher leaf membrane damages at 75 DAP under RF conditions in both years.

The mechanism of plant responses and adaptation to drought and heat stresses are complex. Therefore, more detailed studies are still needed to further define the fundamental physiological basis for drought and heat tolerance of peanut.

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APPENDIX

ENVIRONMENTAL DATA AT AGRONOMY RESEARCH STATION, PERKINS, OKLAHOMA

DAP[+]	PAR[‡] (uE/m^2/s)	Sr[§] (W/m^2)	Wind Speed (m/s)	Tdry[¶] (C)	Twet[++] (C)	Pressure (mb)
			1983			
53	2025	950	4	34.7	24.6	-
61	1650	855	3	37.5	25.3	-
67	1945	940	2	36.3	24.6	-
74	1900	940	4	34.0	25.6	-
81	1900	910	2	37.8	24.7	-
91	1575	855	3	34.4	24.2	-
			1984			
54	1450	870	2	29.4	21.1	981
61	2100	1000	2	31.0	19.4	984
68	1941	1075	3	34.6	25.7	981
75	1745	1150	2	31.9	22.6	985
82	1600	986	3	32.8	25.4	980
89	1875	1000	2	36.3	26.9	980

+ Planting dates were May 25, 1983 and May 26, 1984, respectively.

‡ Photosynthetic active radiation.

§ Solar radiation.

¶ Dry bulb temperature.

++ Wet bulb temperature.

VITA 2

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