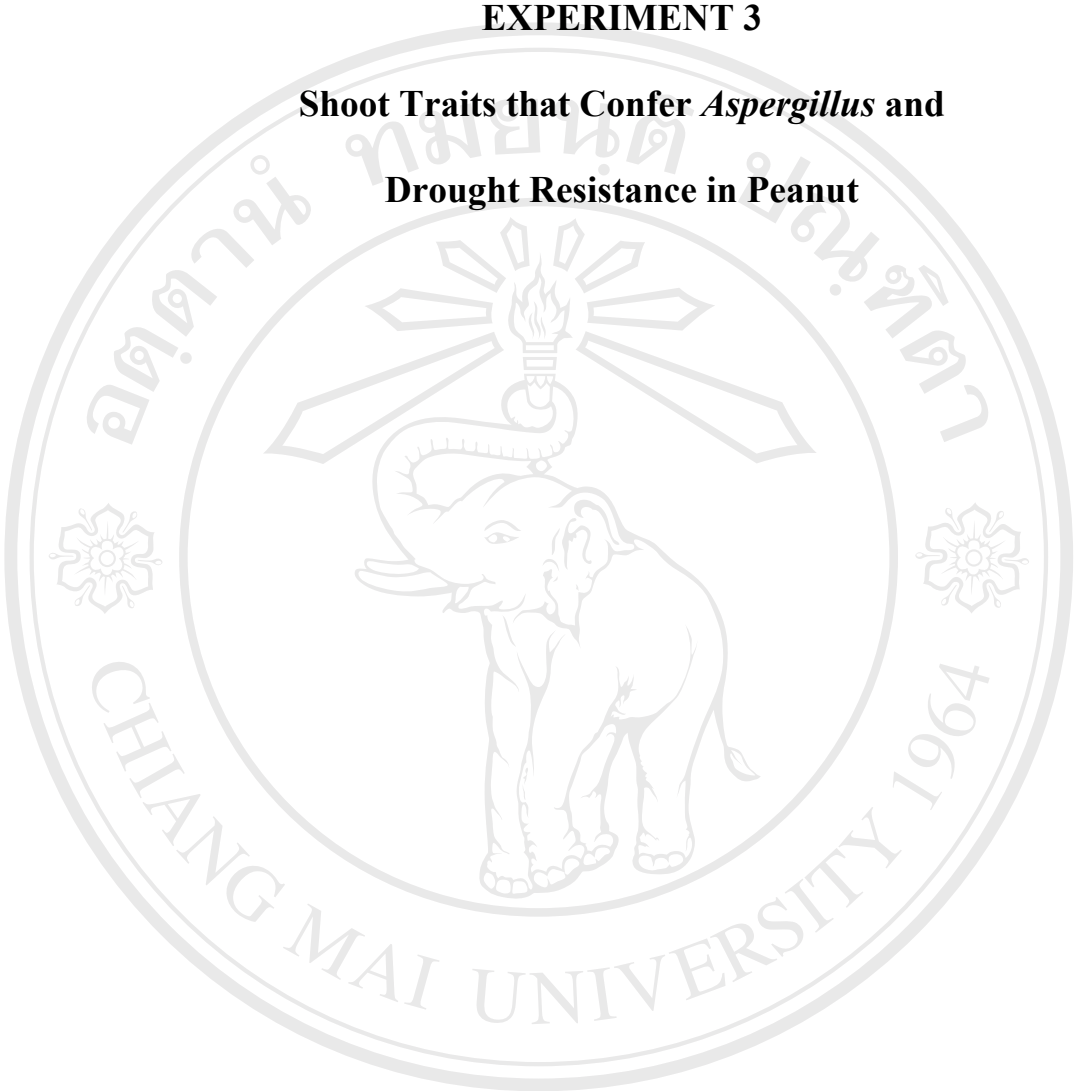
EXPERIMENT 3

Shoot Traits that Confer *Aspergillus* and Drought Resistance in Peanut



INTRODUCTION

Peanut is susceptible to aflatoxin contamination when pods develop under drought. Aflatoxin contamination occurs when peanuts are colonized by aflatoxigenic strains of certain *Aspergillus* spp., especially *A. flavus*, which is common in most countries where peanut is grown. Aflatoxin resistance may result from resistance to *A. flavus* infection, or prevention of aflatoxin production, or both. Because most damaged pods are contaminated with aflatoxin, I restrict my investigation of aflatoxin resistance to whole, sound pods and seeds.

Genetic differences in aflatoxin resistance have been found among peanut cultivars and field methods have been developed to screen peanut germplasm for aflatoxin resistance (Anderson *et al*., 1995). It is difficult to screen germplasm directly for aflatoxin resistance because *A. flavus* infection levels are highly variable and because infection and contamination of less than 1% of pods is sufficient to contaminate a peanut lot to levels exceeding allowable thresholds. Duration and timing of soil moisture stress influences the degree of *A. flavus* invasion and aflatoxin contamination in peanut (Sander *et al*., 1985; Mehan *et al*., 1988; Azaizeh *et al*., 1989). Thus, screening peanut genotypes for aflatoxin resistance will require the use of drought to gain a complete understanding of the genotype's potential defences against infection (Azaizeh *et al*., 1989). Because of the highly variable nature of aflatoxin contamination and the high cost of aflatoxin analysis, researchers have looked into more-easily identified traits that may be related to aflatoxin resistance. One possible alternative to direct screening for aflatoxin resistance is to screen for drought resistance. Holbrook *et al*. (2000) suggested that leaf temperature or visual stress ratings under drought may be used for preliminary screening of germplasm for

preharvest afltoxin resistance and that such screening proxies would greatly reduce the expense of developing aflatoxin-resistant germplasm.

In addition to reducing crop quality and safety through greater aflatoxin contamination, drought also reduces peanut yields. Typically, rainfed peanut yields 50 to 90% that of irrigated peanut (Nageswara *et al*., 1989) and rainfed peanut has 67 % greater aflatoxin contamination than irrigated plants (Davidson *et al*., 1983).

The ability of plant breeders to select genotypes for increased yield and yield stability in drought-prone environments is limited by the variable nature of drought. Because yield is one of the most important agronomic traits, it is necessary to examine the relationship between yield potential and drought resistance. Drought resistance includes traits that confer: 1) drought tolerance, which is the capacity to endure low tissue water potential; 2) drought avoidance, which is the capacity to maintain high tissue water potential, whether by water conservation, as through stomatal closure, or water collection, as through deep or more efficient root systems; 3) drought recovery through prevention of injury or repair damage after relief of water deficit, and 4) drought escape, which allows plants to complete their life cycle, or at least drought sensitive growth stages, during periods when water is available.

The geocarposphere is the top 2.5- to 5.0-cm soil layer where most peanut pods develop (Thai *et al*., 1990). In general, moderate soil temperatures in the geocarposphere (25–30°C) favor *Aspergillus* growth and infection of peanut, whereas higher temperatures (28-35°C) favor aflatoxin contamination (Jackson, 1965). Hill *et al*. (1983) reported that geocarposphere temperature in the 28 to 30°C range increased the probability of aflatoxin contamination when these temperatures occurred with water deficit. Soil temperature and moisture regimes varied with environmental

conditions, and these variables affect the infection of seed by *A. flavus* (Blankenship *et al*., 1984). Ingram *et al*. (1999) showed that a minirhizotron can be used to observe *in situ* root and pod growth and development as well as to observe *A. flavus* populations using an *A. flavus* strain that produces a GFP. *A. flavus* infection levels differed among pegs, pods, tap, and fibrous roots, and seeds of different genotypes (Kisyombe *et al*., 1985).

I hypothesize that drought-resistant peanut genotypes are better able to maintain crop growth and internal moisture content under water deficit, probably through the establishment of a deep root system that allows maximum soil moisture extraction and high yield production. I hypothesize further that under water deficit, drought-resistant peanut genotypes would have less *A. flavus* infection of seed than drought-susceptible genotypes. Thus, objectives of this study were to observe *A. flavus* infection and crop growth of four peanut genotypes in response to water deficit.

MATERIALS AND METHODS

Four peanut genotypes were used, three from the U.S. peanut core collection (Holbrook *et al*., 1993): 511CC, which Holbrook *et al*. (1993) classify as drought and aflatoxin resistant; 419CC, which is drought and aflatoxin susceptible; and 329CC, which is aflatoxin resistant, and a fourth genotype Georgia Green, which is commercial variety from the Southeastern USA. Plants were grown in 214-L containers in a green house of the Georgia Envirotron, the University of Georgia. Half of the containers had moisture blocks and thermocouples installed at 5, 25, and 75 cm depths (Figure 3.1). Each of these environmental parameters was recorded with a CR10X data logger and stored as hourly averages throughout the experiments.

Containers were filled with Tifton loamy sand soil (86% sand, 8% clay, and 6% silt) from the Blackshank Farm, Tifton, Georgia. Seeds of the four genotypes were germinated in moist paper for 3 days. Four healthy seeds of a single genotype were planted in each 214-L container. Containers were placed in green house, set to 80/75° F day/night. All containers were irrigated lightly by hand at 1- to 2-day intervals until seedlings established. After establishment, containers were watered twice a weekly with half strength Hoagland's solution (Table 1.1).

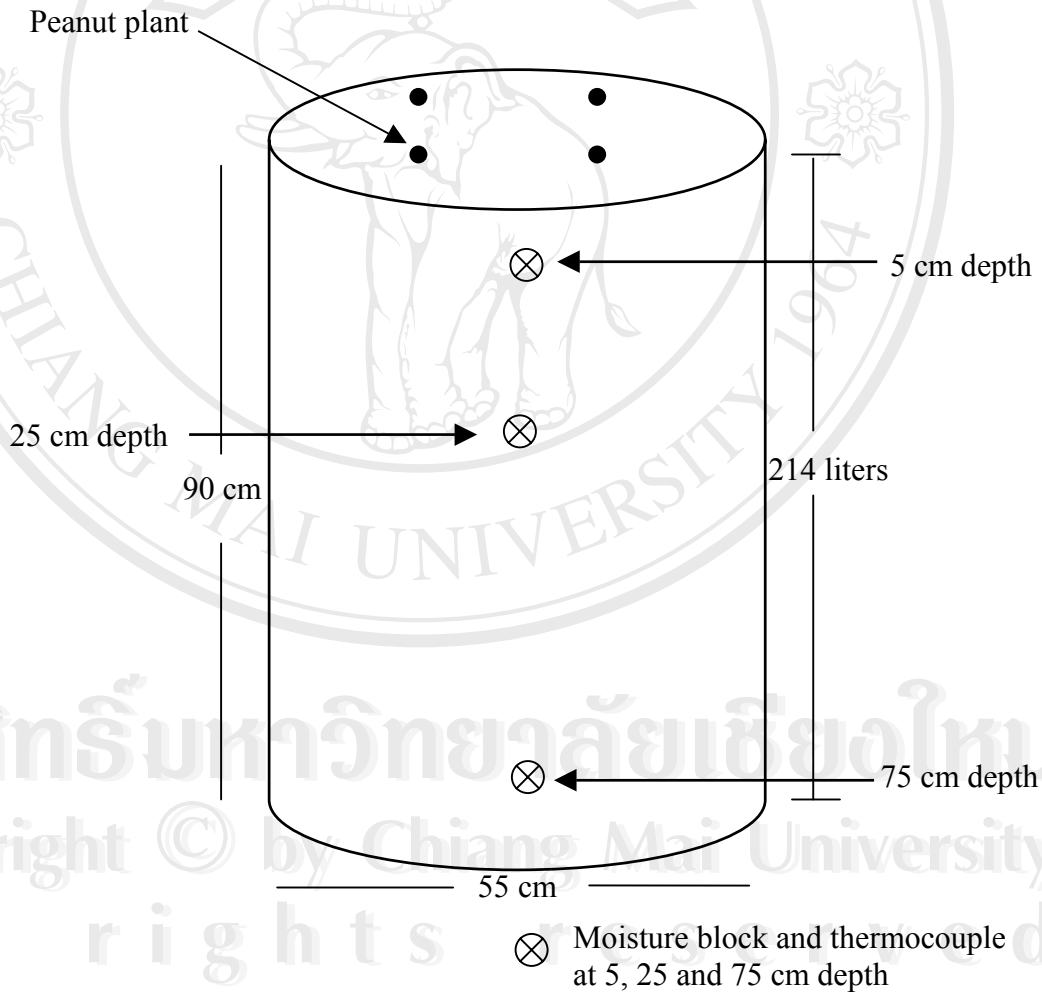


Figure 3.1 Diagram of 214-liter container fitted with four peanut plants, and moisture blocks and thermocouples installed at 5, 25, and 75 cm depths.

The experimental design was a 2 × 4 factorial, two water regimes by four genotypes with 4 replications, each container being one replication.

Water regimes began at 25 DAP. The well-watered treatment was irrigated to field capacity twice weekly. The water deficit treatment was alternately grown without irrigation for 2 weeks then irrigated twice during the week that followed, with four such cycles imposed during the course of the season. All watering was done with half strength Hoagland's solution using an automatic irrigation system to apply solution until drainage appeared from the bottom of each irrigated container. At 76-85 DAP, all containers were double irrigated at 1- to 2-day intervals to allow plants to recover from injury caused by the application of an insecticide for spider mite and white fly.

Inoculum preparation

An *A. flavus* strain modified to produce a GFP was used. The culture was obtained from Jeffery Carey (USDA-ARS, New Orleans, LA). Strains were cultured on Petri dishes containing M3S1B medium, an *A. flavus* selective mediumoriginally developed by Bell and Crawford (1967) and modified by Griffin *et al*. (1974). M3S1B medium had following composition: 5.0 g peptone, 10.0 g glucose, 1.0 g KH_2PO_4, 0.5 g $MgSO_4.7H_2O$, 30.0 g NaCl, 20.0 g agar, 50.0 mg streptomycin sulfate, 50.0 g chlorotetracycline, 1.0 mg 2,6-dichloro-4-nitroaniline (added in 3 ml acetone), and 1 L distilled water. When spores had been formed, they were washed from the mycelia with 50 ml sterile deionized water and stored in a refrigerator at 3 to 5°C.

Corn (*Zea mays* L.) seeds were coarsely ground in a blender to make cracked corn. Then 200 g of cracked corn was placed in each of four stoppered 250 ml flasks and autoclaved twice. After the cracked corn had cooled, a 50 ml aliquot of GFP *A.*

flavus spore strain was added to each flask and incubated at 30°C for 5 days. At 30 and 40 DAP all containers were inoculated with this cracked corn inoculum by spreading it on the soil surface and mixing with upper 1 cm soil over the uppermost minirhizotron tubes.

Crop growth observation

Beginning 2 weeks after starting water regime treatments, main stem length and area of the uppermost fully-expanded leaf (4 leaflets of 1 compound leaf) for each plant were measured at 14-day intervals. Individual leaf area was estimated nondestructively from leaf length (LL) and maximum width (MW) measurements (Liedgens and Richner, 2001):

$$LA = 0.75 \times (LL \times MW)$$

At 125 DAP all containers were harvested by hand. From each container, the area of a 100-leaflet subsample was measured with an area meter (Model Li-3000, Li-Cor, Inc., Lincoln, NE). One shoot from each container was separated into stem and leaves, then weighed fresh. The three remaining plants were combined for whole shoot fresh weight measurement. All samples were dried at 80 °C for 72 hours before measuring dry weigh.

Peanut pods were removed from containers by hand immediately after harvesting shoots. Pods were washed with tap water to remove soil, blotted, and dried at room temperature overnight. Pods harvested from each container were separated into mature and immature pods. Thirty mature fresh pods from each container were processed to determine the extent of GFP *A. flavus* infection. Pods of each replication were surface sterilized by dipping in 10% Clorox for 60 s and then rinsed twice in sterile water. Fifteen pods were shelled by hand, 15 seeds and 15 half shells were

plated on M3S1B medium (5 seeds, 5 shell per plate). Fifteen whole pods were plated on M3S1B medium. Plates were incubated at 27 °C for 5 days. Results were recorded as the percent infection for seed, shell, and whole pod.

Statistical analysis

Data were analyzed by the general linear model procedure of SXW (Statistix For Windows; Analytical Software, Tallahassee, FL) and SAS Version 7 (SAS Institute, Cary, North Carolina, USA). Means were compared by least significant difference (LSD). Unless otherwise stated, all significant differences were tested at $P \leq 0.05$.

RESULTS

Soil Moisture Potential and Soil Temperature

All genotypes extracted more soil moisture at 5 cm than at 25 and 75 cm depths (Figure 1.2). Table 3.1 also shows that 329CC and 419CC generally extracted the most soil moisture at 5 cm depth, whereas 511CC and Georgia Green generally absorbed the most moisture from 25 and 75 cm depths. At 5 cm depth soil, minimum soil moisture potential for 511CC was 64% that of 419CC and 65% that of 329CC at stress period 2, but extracted more moisture at the 25 and 75 cm depths during stress periods 2 through 4. Georgia Green extracted the least soil moisture at 5 cm, yet extracted more moisture than 329CC and 419CC at 25 and 75 cm depths. The absolute values of moisture potentials at 5 cm depth for genotype 329CC and 419CC were at least twice those of Georgia Green during stress periods 1 and 2.

Table 3.1 Minimum soil moisture potential during each of four water deficit periods for four peanut genotypes at three soil depths.

Genotype	Soil depth (cm)											
	Stress period 1			Stress period 2			Stress period 3			Stress period 4		
	5 cm	25 cm	75 cm	5 cm	25 cm	75 cm	5 cm	25 cm	75 cm	5 cm	25 cm	75 cm
	----------Soil moisture potential (MPa)----------											
329CC	-2.175	-0.040	-0.003	-2.807	-0.282	-0.015	-1.247	-0.582	-0.365	-1.151	-0.548	-0.549
419CC	-1.595	-0.045	-0.003	-2.867	-0.347	-0.285	-1.244	-0.335	-0.426	-1.125	-0.362	-0.132
511CC	-1.468	-0.093	-0.008	-1.838	-0.496	-0.283	-1.287	-0.630	-0.599	-1.144	-0.736	-0.667
Georgia Green	-0.830	-0.052	-0.004	-1.457	-0.496	-0.324	-1.106	-0.653	-0.585	-1.007	-0.754	-0.689

Soil temperatures at 5, 25, and 75 cm depths did not differ significantly among peanut genotypes or soil depth. The difference between the daily maximum of soil temperature for the water deficit and well-watered treatment at 5, 25, and 75 cm depths are shown in Figure 3.2. For genotypes 329CC and 419CC, differences in maximum soil temperatures at 5 cm depth were inversely and significantly correlated with soil moisture potential except during stress period 2 (Table 3.2). For 511CC, differences in maximum soil temperatures at 5 cm depth were and significantly correlated with soil moisture only during stress period 2. Georgia Green had no significant correlations between differences in maximum soil moisture potential and soil temperature at 5 cm depth throughout four stress periods. Soil moisture potential and soil temperature of Georgia Green were influenced by temperature and sunshine outside the green house (Figure 3.3).

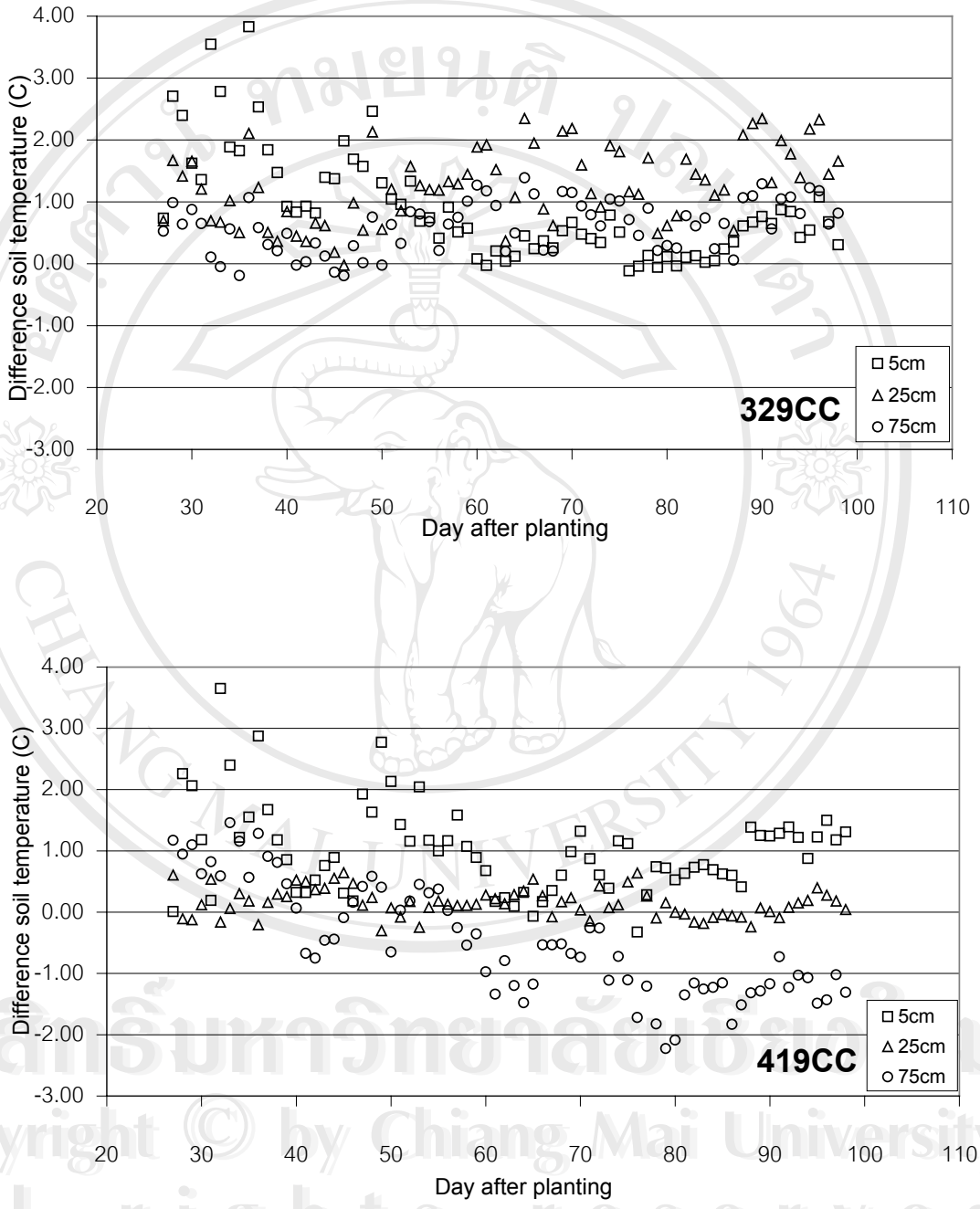


Figure 3.2 The difference between the daily maximum of soil temperature for the water deficit and well-watered treatment at 5, 25, and 75 cm depths of four peanut genotypes.

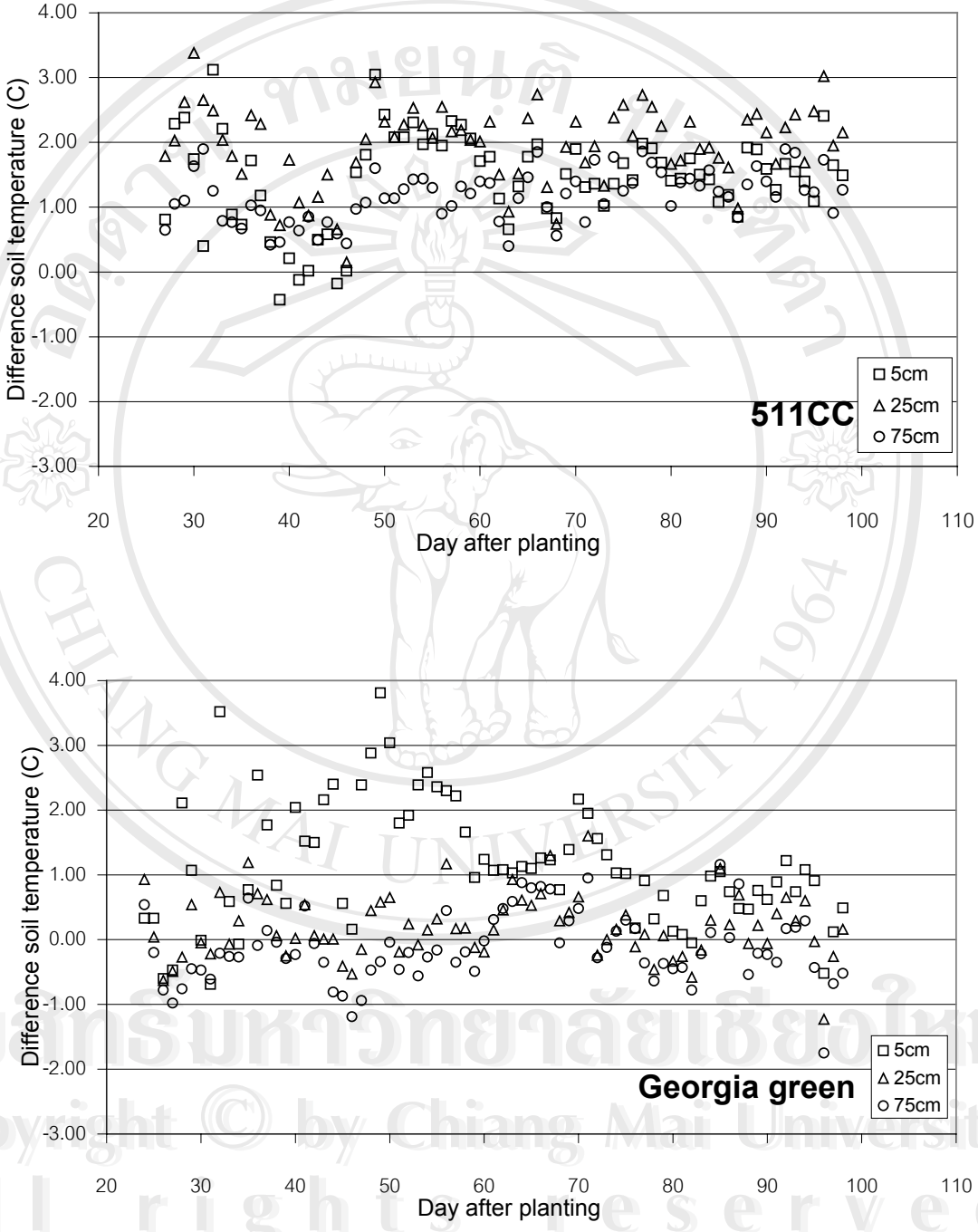


Figure 3.2 continued

Table 3.2 Correlation coefficients (*r* values) for relationship between soil moisture potential and difference in daily maximum soil temperature between water deficit and well-watered condition at 5 cm depth for four stress periods and four peanut genotypes.

Stress period	Genotype			
	329CC	419CC	511CC	Georgia Green
1	0.556*	0.488*	0.104	0.256
2	-0.428	0.116	0.609**	0.124
3	0.664*	0.726**	-0.365	0.553
4	0.696**	0.609*	0.403	-0.018

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

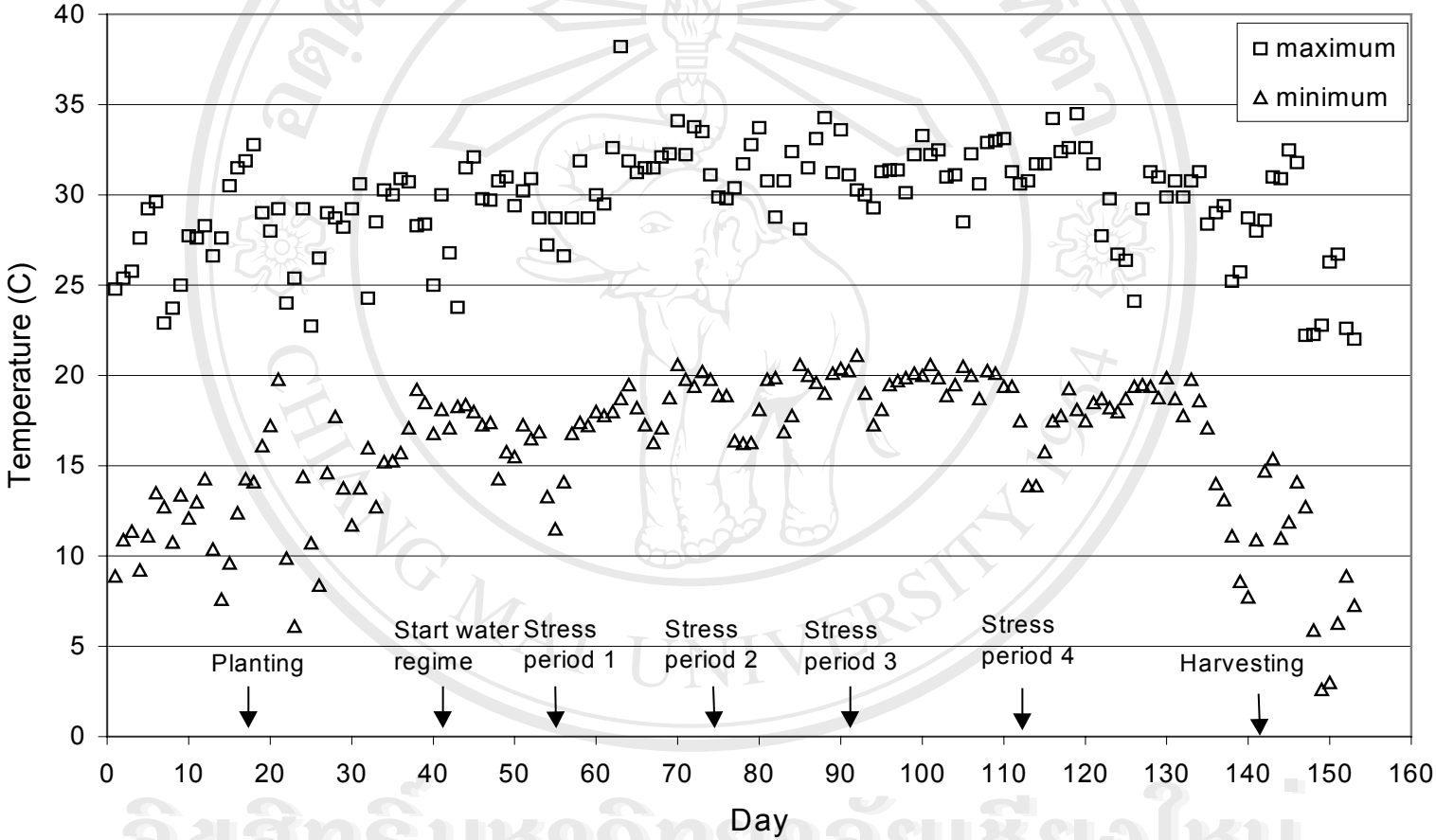


Figure 3.3 The maximum and minimum temperature at Georgia Experiment Station during May to September 2001.

Shoot growth

Main stem elongation. At 50 DAP, water deficit decreased main stem length of all genotypes except that of 329CC (Figure 3.4). Water deficit decreased main stem length of genotype 511CC by 35%, Georgia Green by 32% and 419CC by 24%. Thus, 329CC appeared to have greatest tolerance for this water deficit condition.

Although water deficit did not significantly affect main stem elongation of 329CC genotype, it caused the greatest yield loss for 329CC (Table 3.3). In contrast, water deficit reduced main stem growth of 511CC and Georgia Green but decreased pod yield by only about 30%. Genotype 419CC had the longest main stem among these genotypes, but it appeared to have a shallow root system that extracted moisture mostly from shallow soil layers. Genotype 419 also had a large relative yield loss under water deficit which is to be expected as 419CC identified as a highly drought-susceptible genotype (Holbrook *et al*., 1993).

Individual leaf area. At 60 DAP, water deficit significantly reduced individual leaf area of 419CC (Figure 3.5), causing as much as a 30% reduction in individual leaf area after 77 DAP. However, water deficit did not significantly affect individual leaf area of any other genotype and before harvesting time (115 DAP), there was no effect on individual leaf area of any genotype by irrigation treatment.

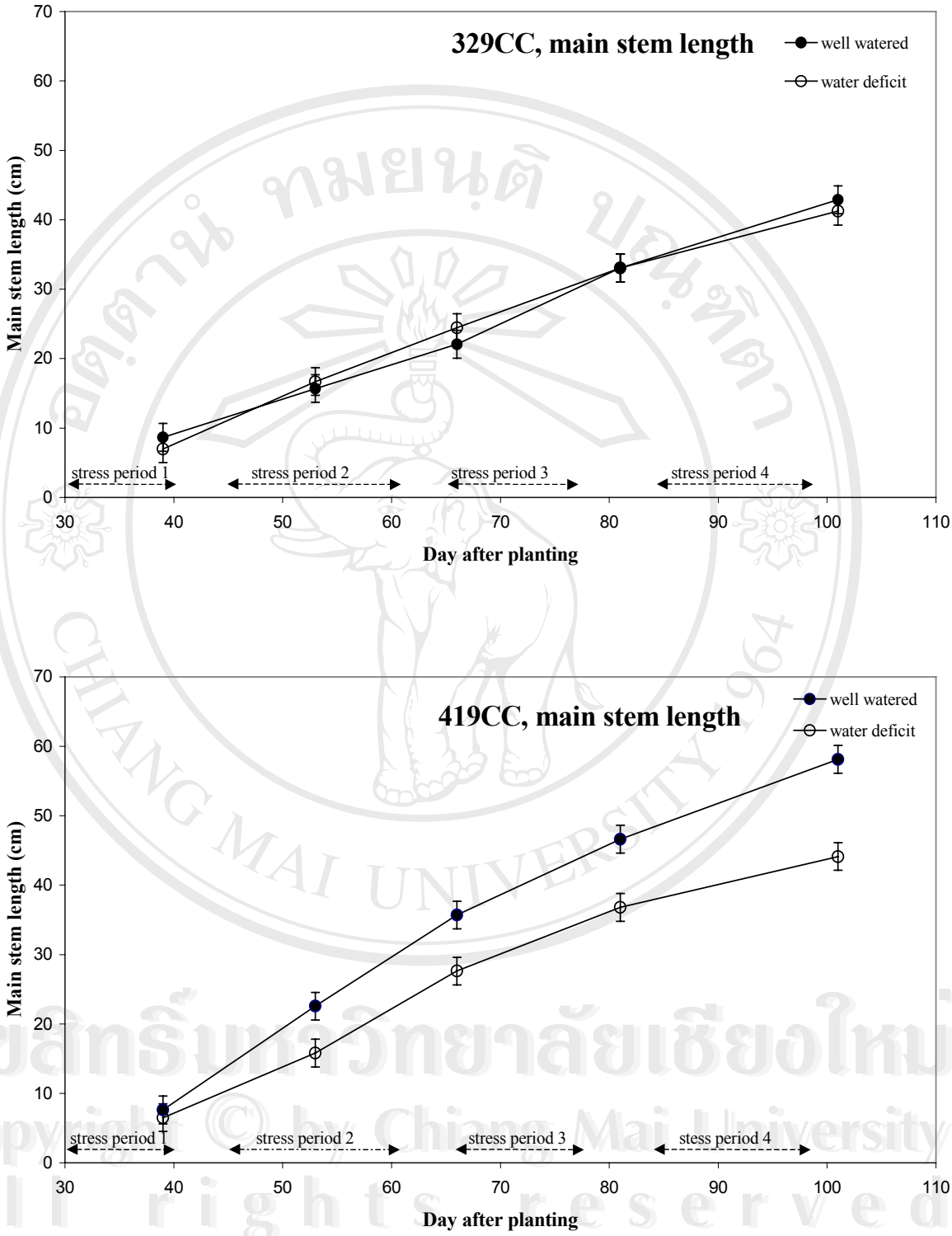
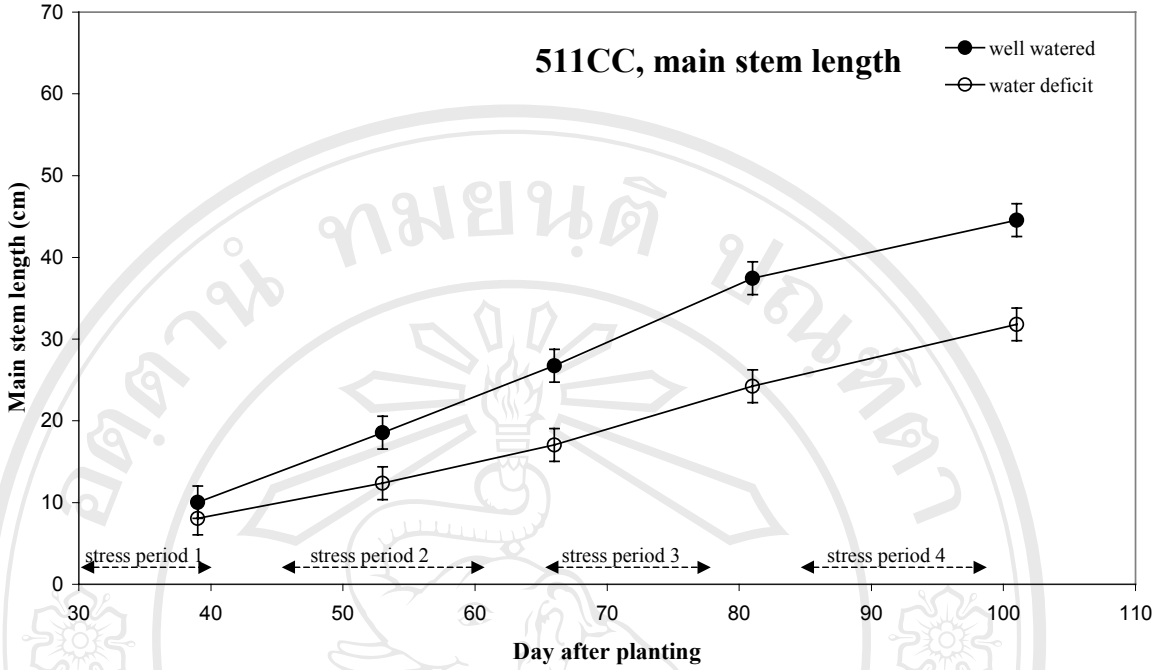


Figure 3.4 Main stem length for four peanut genotypes under well-watered (•) and water deficit (○) treatments.



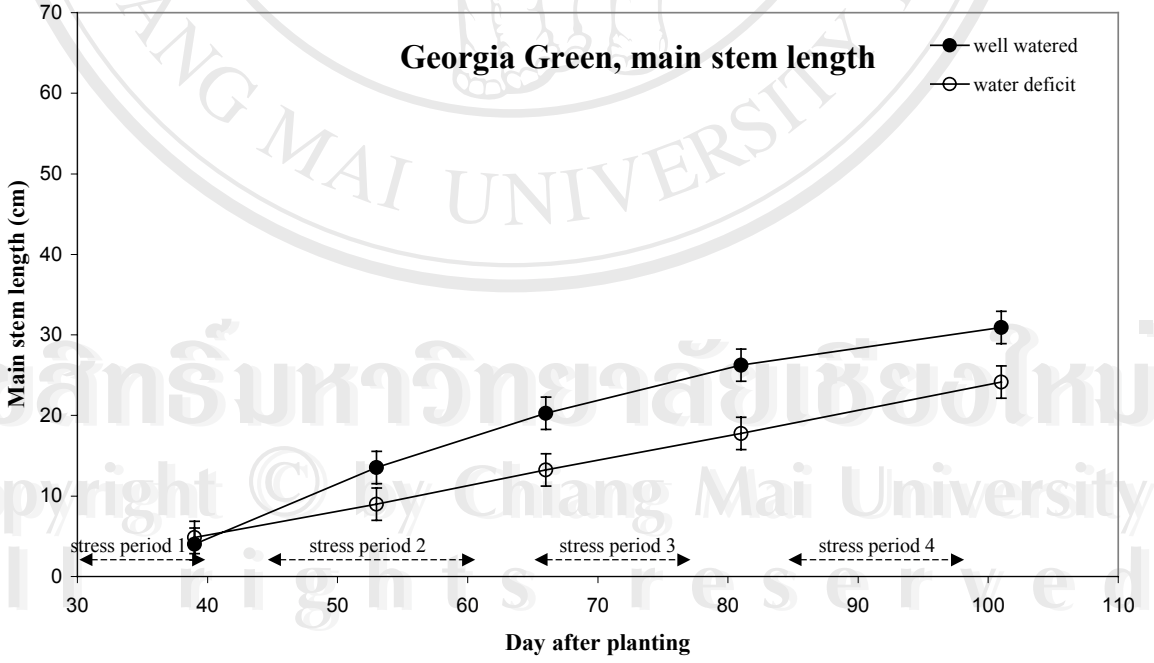


Figure 3.4 continued

Table 3.3 Fresh weight of mature peanut pods grown under drought- stressed and well-watered conditions in the Georgia Envirotron, GA, 2001.

Genotype†	Water regimes‡		Relative yield loss
	Water deficit	Well- watered	%
	Pod weight, g plant $^{-1}$		
Georgia Green	39.4	61.6	36.04
511CC	42.9	67.8	36.72
419CC	32.1	55.4	42.06
329CC	22.6	40.3	43.90

† and ‡ indicate significant difference of mature pod weight at P= 0.05 by LSD. LSD (0.05) genotype = 7.12. LSD (0.05) Water regimes = 8.62.

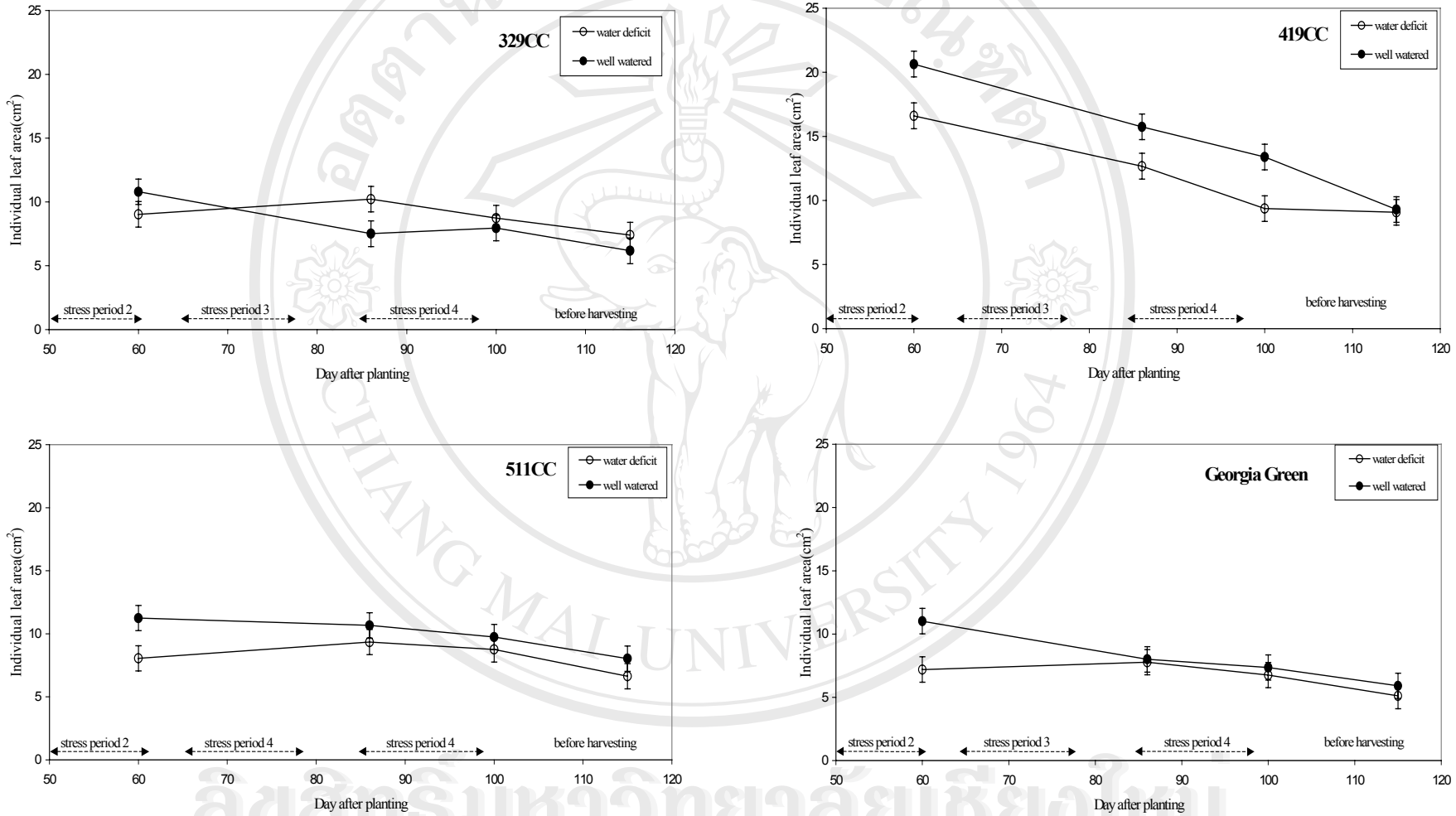


Figure 3.5 Individual leaf area of four peanut genotypes response to well-watered (●) and water deficit (○) treatment.

Harvesting and Post harvest

Plant traits of peanut genotypes at the final sampling are shown in Table 3.4. Water deficit reduced all plant traits, especially pod yield and moisture content of shoot. There was a significant interaction between genotype and water treatment effects on the pod dry weight and seed dry weight. Water deficit decreased pod and seed dry weight of 419CC and Georgia Green, but did not significantly affect pod or seed dry weight of 329CC and 511CC.

Table 3.5 shows the correlations among measured plant traits. Peanut plants with large shoots also had large stems. Moisture content of shoot also correlated with the moisture content of leaf and stem. The specific leaf area was negatively correlated with pod and seed dry weight so that high specific leaf area had produced the small pod and seed.

***Aspergillus flavus* infection**

Effect of soil moisture regimes on *A. flavus* infection of shells and seeds of all genotypes are summarized in Table 3.6. Recovery of *A. flavus* from peanut pods harvested in the containers was relatively high, indicating that soil conditions favored fungal activity. Water regime did not significantly affect *A. flavus* infection for all genotypes. Genotype 511CC had significantly less *A. flavus* infection of pods and shells than the other genotypes, but infection of 511CC seeds was not significantly different from that of 329CC and 419CC. Georgia Green had the greatest *A. flavus* infection of seed. Neither pod (exterior) nor shell (interior) infection levels were correlated with seed infection.

Table 3.4 Levels of significant difference, means, and standard error of selected plant traits.

Plant trait	Source of Variation	Mean	SE
Mature pod weight	Genotype**		
(MAFPW), g plant^{-1}	329CC	32.4	5.4
	419CC	44.3	5.5
	511CC	55.6	5.2
	Georgia Green	51.3	7.6
	Water Regime***		
	Water deficit	34.4	2.7
	Well-watered	56.6	4.2
Immature fresh pod	Genotype*		
weight (IMMAFW), g	329CC	14.3	2.1
plant^{-1}	419CC	11.3	2.6
	511CC	27.0	2.6
	Georgia Green	21.8	4.7
	Water Regime*		
	Water deficit	14.1	1.8
	Well-watered	22.7	2.8
Whole pod dry weight	Genotype ***, Water Regime***		
(PDW), g pod^{-1}	(Genotype × Water Regime) ***		
	329CC water deficit	0.65	0.007
	329CC well-watered	0.69	0.008

Plant trait	Source of Variation	Mean	SE
	419CC water deficit	1.22	0.009
	419CC well-watered	1.42	0.01
	511CC water deficit	0.92	0.01
	511CC well-watered	0.99	0.03
	Georgia Green water deficit	1.05	0.02
	Georgia Green well-watered	1.11	0.01
Seed dry weight (SEDW),	Genotype ***, Water Regime***		
g seed^{-1}	(Genotype × Water Regime) *		
	329CC water deficit	0.29	0.007
	329CC well-watered	0.30	0.009
	419CC water deficit	0.57	0.01
	419CC well-watered	0.64	0.01
	511CC water deficit	0.37	0.01
	511CC well-watered	0.44	0.009
	Georgia Green water deficit	0.46	0.01
	Georgia Green well-watered	0.51	0.01
Specific leaf area (SLA),	Genotype ^{Ns}		
cm^2 g^{-1}	329CC	302	11.1
	419CC	264	10.6
	511CC	304	9.9
	Georgia Green	275	19.2
	Water Regime ^{Ns}		

Plant traits	Source of Variation	Mean	SE
	Water deficit	282	11.3
	Well-watered	292	7.3

*, **, *** Significant at the 0.05, 0.01, and 0.001 probability levels, respectively: Ns, no significant difference, at 0.05 probability level.

Table 3.5 Correlation coefficients (*r* value) among plant traits grown under water deficit and well-watered condition for the four peanut genotypes.

PDW	-0.218	-0.246	-0.078	0.548	0.740*	-0.373	-0.293	-0.265	-0.038	0.438	-0.035		
SEDW	-0.220	-0.270	-0.033	0.566	0.749*	-0.348	-0.273	-0.247	-0.011	0.428	-0.053	0.992**	
SLA	0.721*	0.755**	0.527	-0.187	-0.558	0.769*	0.643	0.648	0.445	0.189	-0.578	-0.728*	-0.728*
	SFW	SDW	SMC	LFW	LDW	LMC	STFW	STDW	STMC	MPFW	IPFW	PDW	SEDW

Shoot fresh weight, SFW (g plnat^{-1}); shoot dry weight, SDW (g plant^{-1}); shoot moisture content, SMC (% plant^{-1}); 100 leaflets fresh weight, LFW (g 100 leaflets^{-1}); 100 leaflets dry weight, LDW (g 100 leaflets^{-1}); 100 leaflets moisture content, LMC (% 100 leaflets^{-1}); stem fresh weight, STFW (g stem^{-1}); stem dry weight, STDW (g stem^{-1}); stem moisture content, STMC (% stem^{-1}); mature pod fresh weight, MPFW (g plant^{-1}); immature pod fresh weight, IPFW (g plant^{-1}); pod dry weight, PDW (g pod^{-1}); seed dry weight, SEDW (g seed^{-1}); and specific leaf area, SLA (cm^2 g^{-1}).

Table 3.6 Peanut infection by *Aspergillus flavus* grown under water deficit and well-watered conditions in the Georgia Envirotron, GA, 2001.

Genotype	Water regimes	Seed	Shell	Pod
		----------%----------		
329CC	Water deficit	2.9	100	93
	Well-watered	23.2	98	96
	mean	13.0 b	99 a	94 a
419CC	Water deficit	8.1	96	100
	Well-watered	6.6	100	100
	mean	7.35 b	98 a	100 a
511CC	Water deficit	14.1	71	78
	Well-watered	16.2	74	71
	mean	15.2 b	72 b	73 b
Georgia Green	Water deficit	45.6	97	100
	Well-watered	25.7	100	100
	mean	35.6 a	98 a	100 a

* Means followed by the same letter are not significantly different at P = 0.05 by LSD. Letters are used for simple means of genotype. LSD (0.05) pod = 8.99. LSD (0.05) shell = 9.14. LSD (0.05) seed = 8.26.

DISCUSSION

Soil environment

Georgia Green had the smallest main stem length and individual leaf area, the plant canopy probably did not fully cover the soil surface. Thus external temperature and solar radiation probably explain the high soil temperature at 5 cm and the fact that differences in maximum temperatures of well-watered and water deficit treatments were not correlated with soil moisture under water deficit in this genotype. During stress period 2, soil moistures of genotypes 329CC and 419CC were inversely related with soil temperatures, indicating that even though the surface of soil layer was dried the plant canopy intercepted sufficient light to prevent increases in soil temperature. On the other hand, low soil moisture and high soil temperature decreased main stem elongation of 511CC, but did not decrease individual leaf area whereas high soil temperature had no overall effect on vegetative growth of peanut.

Plant traits confering drought resistance

In general, drought-tolerant genotypes had a large individual leaf area, more leaves, more stems or branches, and heavier dry matter than drought susceptible genotypes under water deficit. In this experiment, water deficit did not decrease main stem elongation or individual leaf area of 329CC until harvest, indicating that 329CC either was able to maintain shoot and leaf growth during water deficit or recovered quickly when water was available. Under water deficit, 329CC extracted the most soil moisture at 5 cm depth, and had high capability to use the moisture for yield production (Table 3.3). Rucker *et al*. (1995) found that peanut genotypes with low visual stress ratings often have large root systems which can utilize moisture from the

soil, and also found that some genotypes with small root systems had low stress ratings (Rucker *et al*., 1995). Genotype 329CC may fall into this category by avoiding stress as through stomatal closure which can conserve its water status but the photosynthesis will be reduced and causes yield loss.

Water deficit reduced main stem length of 511CC more than the other genotypes (Figure 3.4). However 511CC had small individual leaf area and had high leaf moisture content, probably through the development of the branches and new leaves. The root system of 511CC extracted the most moisture throughout the soil profile, suggesting that under water deficit, it was able to maintain sufficient internal water status to continue its growth processes. Passioura (1983) stated that under water deficit, many plants leave large amounts of available water in the deeper soil layers, and the plants which can utilize this water would have yielded more in a water-limited situation. Genotype 511CC appears to be such a plant.

The root system of 419CC generally extracted the least soil moisture from 25 and 75 cm depths, indicating a relatively shallow root system. Genotype 419CC had a large main stem and large individual leaf area but the leaf moisture content was low. Genotype 419CC might have a few leaves or wilted under water deficit condition that related to the reduction in the specific leaf area. Rucker *et al*. (1995) reported that plant with large shoots also had large root systems. Although 419CC has a large root system, the root system may be too shallow which explains the drought susceptibility rating of this genotype.

Water deficit decreased main stem elongation of Georgia Green, but did not affect individual leaf area. Georgia Green had the lowest moisture content of the shoot, leaf, and stem, indicating that leaves of Georgia Green probably wilted and

rolled that also related to decrease in specific leaf area (Appendix H). The root system of Georgia Green extracted more soil moisture from 25 and 75 cm depth than 329CC and 419CC, which explains the greater pod yield of Georgia Green under water deficit.

Genotypes differed in their responses and adaptations to water deficit condition. Drought-tolerant genotypes might include 329CC and 511CC, for which water deficit did not affect the moisture content of the shoots or stems. The root system of 511CC allowed moisture uptake from deeper soil layers that improved drought tolerance avoidance by utilizing deeper soil water. However the root system of 329CC also maintained water balance into the plant under water deficit condition that may extract more soil water from the upper soil horizons but not able to reduce the relative yield loss. On the other hand, the root system of Georgia Green was low distributed at shallow soil but large root at deep soil might be able to supply the moisture to reduce relative yield loss.

Plant traits conferring resistance to infection by *A. flavus*

Low soil moisture and high soil temperature of pod zone led to high levels of *A. flavus* colonization of whole pods, shells and seeds for all genotypes. Azaizeh *et al*. (1989) also reported that low soil moisture under both long and short drought stress conditions enhanced colonization of peanut shell and seed when compared to non-stressed conditions.

Genotype 329CC might be drought-tolerant but this genotype was greatly infected by *A. flavus* fungi on the pods, shells and seeds. Thus this finding can indicate that the peanut genotypes which are drought resistant may not be tolerant to

A. flavus invasion. Contrary to expectation, shells and seeds from 511CC and 329CC genotypes subjected to prolonged well waters were most highly infected by *A. flavus* and the presence of fungi probably had no aflatoxin contamination (Will *et al*., 1994), except for Georgia Green, which also had highest levels of seed infection under water deficit. More aflatoxin contamination was found in peanut that grew under drought than irrigated peanut (Pettit *et al*., 1971) and peanut seed was more susceptible to *A. flavus* infection when soil moisture levels in the pod zone were low enough to reduce seed moisture below 31%. Although the drought-resistant genotype was susceptible to *A. flavus* infection on the pod, seed infection was not enhanced by water deficit.

In this experiment, shallow soil layer conditions under water deficit condition of each peanut genotypes differed and only had increased the seed infection by *A. flavus* for Georgia Green. Georgia Green were frequently infected with *A. flavus* on seeds under water deficit, indicating that soil temperature was related to water activity of peanut seed; when due to drought the seed water activity was low, it decreased and eventually lost its capacity to produce phytoalexin which was its natural resistance mechanism against fungal growth (Dorner *et al*., 1989).

This experiment showed that yield and *A. flavus* infection of peanut genotypes differed in their responses to water deficit. Care should be taken in additional screening and evaluations to ensure the stability of the resistance response over differing level of environmental stress, i.e., drought and extreme temperature. Shallow roots are essential for extraction of water from light rains, but cannot confer to the ability to extract enough soil moisture to sustain growth, or prevent yield loss. Root systems of drought-resistant genotypes can extract soil moisture from both shallow

and deep soil layers, thereby maintaining moisture in the plant, and having less relative yield loss.