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Effect of two different water regimes on growth and yield of different groundnut (*Arachis hypogaea* L.) genotypes in Sri Lanka

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ABSTRACT

Drought resistance is an important character for increasing groundnut (*Arachis hypogaea* L.) yields in the sub-humid, dry zone of Sri Lanka. Therefore, the objective of this study was to determine the effect of soil water deficit on vegetative growth and seed yield, and to determine the physiological basis of yield of groundnut under water stress. Seven genotypes of groundnut (Tissa, ANKG-2, Red Spanish, N-45, ICGV86015, ICGV86143 and ICGV86149) were grown under well-watered (90% available water) and water-stressed (30% available water) conditions in pots (12 kg) in a glasshouse at Maha Illuppallama, Sri Lanka. In all genotypes, water stress significantly reduced leaf area, final total dry weight and seed yield. Final total dry weight and yield showed significant genotypic variation under both water regimes but did not show significant genotype x water regime interaction. Under water-stressed conditions, the highest seed yield was produced by ICGV86015 whereas ICGV86149 had the highest yield under well-watered conditions. A greater partitioning of dry matter to seeds (i.e. greater harvest index) was required to achieve high groundnut yields under water stress. On the other hand, dry matter partitioning was not a yield-determining parameter under well-watered conditions where a greater capacity for total biomass production was required to achieve high yields. Under water-stressed conditions, groundnut yields were positively correlated with pod number per plant, seed weight and the number of primary roots per plant.

Key words: *Arachis hypogaea,* water stress, root growth, yield, yield components, harvest index

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important legumes in the world (Bunting *et al.* 1985). It provides edible seeds rich in both protein and lipid (Ashley 1984). In Sri Lanka, groundnut cultivation is confined to the well-drained soils of the sub-humid dry zone. This agroclimatic zone has a distinctly bi-modal rainfall pattern with a major rainy season (locally known as *maha)* from October to December and a minor rainy season *(yala)* from April to June. Therefore, a major portion of the annual rainfall of about 900 mm falls during the *maha* season (Panabokke 1996). Consequently, during the *yala* season, most of the groundnut crops planted during mid-April or early-May experience a prolonged period of drought during the second half of their life cycle. Accordingly, water stress is one of the major causes of low groundnut yields in Sri Lanka (600 kg ha^{-1} as compared to the world average of 1000 kg ha^{-1}) (Virmani and Singh 1986). Therefore, breeding for drought resistance is a major objective in groundnut yield improvement programmes in Sri Lanka.

Effects of water stress on growth and yield of groundnut have been examined previously by Chapman *et al.* (1993a), who observed reductions in the total biomass, seed yield and harvest index. They also observed significant variation between different cultivars in their response to water deficit. Ability to partition more assimilates to growing pods rather than to canopy growth was identified by Chapman *et al.* (1993a) as a key character required to achieve higher groundnut yields under drought conditions. A drought resistant variety can be defined as one which produces a higher yield, as compared to other varieties when grown under soil water deficits. Breeding a drought resistant variety requires the identification of relatively more resistant genotypes which could be used as parents in crossing programmes (Blum 1989). Moreover, such resistant genotypes could be used to identify physiological mechanisms and traits which confer drought resistance (Ludlow and Muchow 1990).

Therefore, the objective of the present experiment was to screen a selected set of groundnut genotypes to determine the effect of soil water deficit on vegetative growth, seed yield and harvest index. This would enable identification of genotypes with

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Abbreviations: DAS- Days after sowing; HI- Harvest index; LA- Leaf area; NOP- Number of pods; NOPR- Number of Primary roots; RDW- Root dry weight; RSR- Root-shoot ratio; SPP- Number of seed per pod; SWT- Mean seed weight; W- Total plant dry weight; W_f- Final total dry weight; Y-Seed yield relative drought resistance which could be used for future breeding programmes.

Seed yield (Y) of groundnut can be expressed as the product of final total plant biomass (W_f) and harvest index (HI). A high seed yield under soil water deficits can be achieved either with a higher W_f or HI or both. Investigation of the variation of Y, W_f and HI under different soil water deficits would enable the determination of the relative importance of mechanisms of biomass production (which are responsible for high W_f) and biomass partitioning (which are responsible for high HI) under drought.

MATERIALS AND METHODS

Experimental site and environmental conditions

The experiment was carried out in a rain-sheltered plant house at the Field Crops Research and Development Centre, Maha Illuppallama, Sri Lanka (7-8°N & 80-81°E) during the period of October, 1996 to February, 1997. Plants were grown in polybags with a height of 45 cm and a diameter of 12 cm. The soil used in the experiment belonged to Rhodustalfs (Panabokke 1996) which is the major soil type found in groundnut-growing areas in Sri Lanka.

The daily incident radiation was measured at a weather station about 100 m away from the plant house. The daily incident short-wave radiation during experimental period varied from 18.6 to 25.5 MJ m^{-2} d^{-1}. Maximum and minimum temperatures inside the plant house were recorded daily. The daily mean temperature, calculated as the mean of maximum and minimum temperatures, during the experimental period ranged from 27.6 to 34.8°C. The relative humidity in the plant house was measured by a thermohydrograph and ranged from 76 - 84%.

Treatments and experimental design

The treatment structure was a two-factor factorial with groundnut genotypes and water regimes as the two factors. Seven genotypes which included four released varieties (Tissa, ANKG-2, Red Spanish and N-45) and three promising breeding lines (ICGV86015, ICGV86143 and ICGV86149) were used. Two water regimes were used to represent a well-watered (90% of available water) and a water-stressed (30% of available water) situation. The 14 treatment combinations (7 genotypes x 2 water regimes) were laid out in a randomized complete block design. Each treatment combination had 15 replicate plants making a total of 210 pots which were arranged in five blocks.

Plant establishment and management

All pots were filled with 12 kg of air-dried and sieved soil. The initial soil moisture content was determined gravimetrically from samples taken at the time of filling the pots. This enabled the determination of the exact weight of soil contained in each pot. A basal fertilizer mixture containing 35 kg ha^{-1} of urea, 140 kg ha^{-1} of triple super phosphate and 75 kg ha^{-1} of muriate of potash was incorporated at the time of filling pots. Soil moisture contents at field capacity and permanent wilting point, which were required to determine available water range, were obtained from previous work done on the same soil type (Mapa and Pathmarajah 1995).

Before sowing, each pot was irrigated upto field capacity. Seeds were obtained from the Research Station of the Department of Agriculture, Angunakolapalassa, Sri Lanka. Three seeds per pot were sown on 9 October 1996. These were thinned out to one plant per pot 10 days after sowing. Seeds were soaked overnight before sowing. Soon after thinning out, the soil surface in each pot was covered with polythene to minimize evaporation. From this point onwards, the two water treatments were imposed. The well-watered treatment was maintained at 90% available water by daily weighing and adding measured amounts of water. Soil water content in the water-stressed treatment was allowed to decrease from field capacity at sowing down to 30% available water which was maintained thereafter by daily weighing and adding water. A top-dressing of 30 kg ha^{-1} of urea was applied with the onset of flowering which occurred one month after sowing. The plants were maintained free of pests and diseases by recommended control measures (Anon. 1990).

Measurements

Plant growth was measured by destructive sampling at 20, 45, 70, 95 and 120 days after sowing (DAS). Each sample consisted of three plants per treatment. The plants were removed from polybags and soil washed off carefully. Leaves, stems, roots, pegs and pods were separated in harvested plants and their dry weights determined by oven-drying at 80°C to a constant weight. Total leaf area of the harvested plants was measured by automatic leaf area measuring system (Delta-T Devices, UK). In addition, the number of leaves, branches and primary roots per plant were counted at each harvest.

Pod and seed yields were measured at the final harvest 120 DAS. In addition, the number of seeds per pod and the mean seed weight were measured. Harvest index was calculated as the ratio between seed dry weight and total plant dry weight.

Significance of treatment effects was tested by analysis of variance using the SAS statistical package. Mean separation was done using standard error of treatment means. Linear correlation analysis was used to examine the inter-relationships between total dry weight, seed yield and yield components.

RESULTS

Leaf area per plant (LA)

LA showed significant variation between the 7 genotypes under both water regimes (Figs. 1 a & b) on all dates of sampling. Except at 20 DAS, LA was significantly reduced in all genotypes under 30% available water (i.e. lower water regime) as compared to 90% available water (i.e. higher water regime) (Figs. 1 a & b). The genotype x water regime interaction was not significant at p=0.05. The seasonal variation pattern of LA differed with the genotype under both water regimes. N-45 had faster early leaf growth, irrespective of the water regime, as shown by its significantly greater LA at 70 DAS (Fig. 1). LA expansion slowed down in many genotypes after 70 DAS. However, ICGV86149 was able to continue LA expansion during the latter part of the life cycle under both water regimes. This was shown by its significantly greater (p<0.05) LA at 120 DAS.

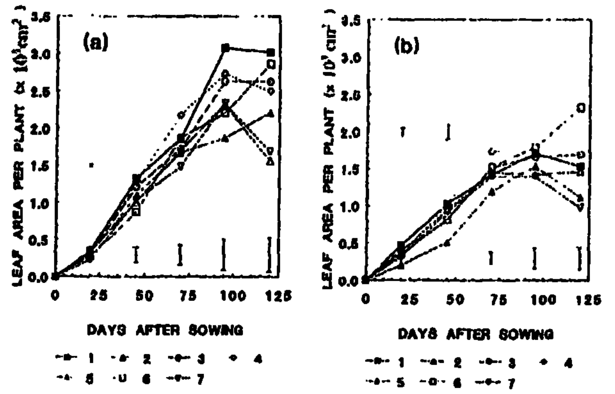

Figure 1. Variation of leaf area per plant with time in different groundnut varieties under 90% (a) and 30% (b) of available water regimes. 1 - Tissa; 2 - ANKG-2; 3 - Red Spanish; 4 - N-45; 5 - ICGV86015; 6 - ICGV86149; 7 - ICGV86143. Vertical bars represent standard errors with d.f.=12

Total plant dry weight (W)

Variation of W with time for different genotypes under the two water regimes is shown in Fig. 2. Genotypic differences in W were statistically significant (p<0.01) on all dates of sampling. However, in practical terms, the genotypic differences became significant only during the second half of life cycle under both water regimes (Fig. 2). Except at 20 DAS, the lower water regime significantly reduced W on all dates of sampling. The greatest increase of W occurred during the period between 95 and 120 DAS in all treatments. Highest increase in W was shown by ICGV86149 under both water regimes (Figs. 2 a & b). Consequently, ICGV86149 had the highest final W (W_f) under both water regimes. In contrast, ANKG-2 had the lowest increase in W and hence the lowest W_f under the higher water regime. Under the lower water regime, W_f was lowest in N-45 while ANKG-2 also had a very low value.

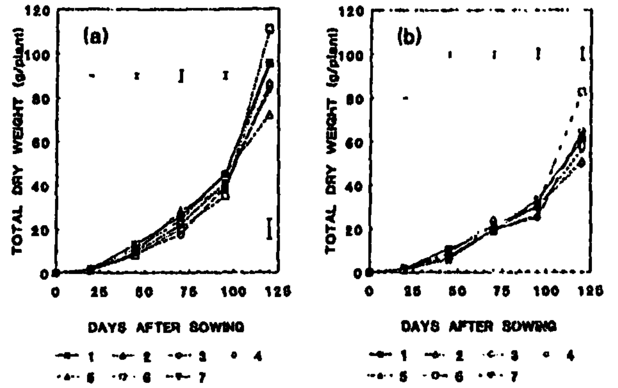

Figure 2. Variation of total dry weight per plant with time in different groundnut varieties under 90% (a) and 30% (b) of available water regimes. 1 - Tissa; 2 - ANKG-2; 3 - Red Spanish; 4 - N-45; 5 - ICGV86015; 6 - ICGV86149; 7 - ICGV86143. Vertical bars represent standard errors with d.f.= 12

Root growth

There was significant (p<0.01) genotypic variation in root dry weight per plant at final harvest (RDW) under both water regimes. The genotype x water regime interaction on RDW was also significant at p=0.05. ANKG-2 and Red Spanish showed increases in RDW with decreasing water availability (Table 1) whereas the rest showed the opposite trend. Under the higher water regime, ICGV86149 had the highest RDW whereas ANKG-2 had the lowest. In contrast, under the lower water regime, Red Spanish had the highest RDW and ICGV86143 had the lowest. Decreasing water availability increased the root:shoot ratio (RSR) in all genotypes (Table 1). Under both water regimes, significant genotypic variation was observed in both RSR and the number of primary roots at final harvest (NOPR). Moreover, there was a highly significant (p< 0.001) genotype x water level interaction on NOPR. Decreasing water availability increased NOPR in Tissa, ANKG-2 and ICGV86143 (Table 1), but decreased NOPR in N-45. In the rest of the genotypes, NOPR did not vary significantly with decreasing water availability. Under both water regimes, ICGV86149 had the highest NOPR while Red Spanish had the lowest.

Table 1. Variation of final total dry weight (Wf), seed yield (Y) and harvest index (HI) of different groundnut genotypes under 90% of available soil water regimes.

Genotype	W (g/plant)		Y (g/plant)		HI (%)	
	WW	WS	WW	WS	WW	WS
Tissa	95.76	60.64	31.27	21.99	32.94	36.21
ANKG-2	72.08	51 05	28.87	16.86	39.80	33.29
Red Spanish	85.22	64.61	28.34	14.97	33.26	23.64
N-45	86.48	49.64	26.07	12.43	30.13	25.29
ICGV86015	95.70	63.37	32.37	24.57	33.96	38.98
ICGV86149	110.88	82.63	36.50	22.00	32.95	26.53
ICGV86143	83.52	56.38	31.09	22 07	37.79	39.01
S.E.(df=12)	9.18	5.49	2.89	1.88	3.75	4.42

Final biomass (W_f), seed yield (Y) and harvest index (HI)

Both W_f and Y varied significantly ($p<0.0001$) with different genotypes and water regimes. The genotype x water regime interaction was not significant at $p=0.05$. Decreasing water availability reduced both W_f and Y significantly in all genotypes (Table 2). Under the higher level of water availability, the greatest W_f and Y were shown by ICGV86149 which also had the highest W_f under the lower water regime. The highest Y under the lower level of water availability was shown by ICGV86015 which had the second highest Y under the higher level of water availability. The yield of ICGV86149 under the lower level of water availability was only slightly lower than that of ICGV86015. In contrast, N-45 showed the lowest Y under both water regimes. N-45 also had the lowest W_f under the lower water regime whereas ANKG-2 had the lowest well-watered W_f (Table 2). Out of the rest of the genotypes, Tissa and ICGV86143 had intermediately higher Y under both water regimes whereas Red Spanish had intermediately lower Y. The absence of any significant interaction between genotypes and water regimes meant that there were no genotypes which performed comparatively better in any one water regime as compared to the other. In terms of yield stability under varying water regimes, ICGV86015 had the narrowest difference in yields between higher and lower water regims(Table 2).

In contrast to W_f and Y, the effect of genotype x water regime interaction on HI was significant ($p<0.05$). Under the higher water regime, ANKG-2 had the highest HI whereas ICGV86143 had the highest HI under the lower water regime (Table 2). On the other hand, N-45 had the lowest HI under both water regimes. HI of Tissa, ICGV86015 and ICGV86143 increased with decreasing water availability whereas the opposite was true in other varieties. Red Spanish showed the highest decline in HI in response to decreasing water availability whereas ICGV86015 showed the highest increase.

Table 2. Variation of root dry weight (RDW), root:shoot ratio (RSR) and the number of primary roots (NOPR) per plant at final harvest of different groundnut genotypes under 90% (WW) and 30% (WS) of available soil water regimes.

Genotype	RDW (g/plant)		RSR		NOPR (plant^{-1})	
	WW	WS	WW	WS	WW	WS
Tissa	4.31	3.31	0 047	0.059	82.00	88.00
ANKG-2	3.10	4.43	0.045	0.082	88.67	125.67
Red Spanish	4.31	5.37	0.053	0.092	70.00	68.00
N-45	5.09	4.21	0.062	0.092	89.00	82.67
ICGV86015	4.68	3.62	0.052	0.060	123.67	124.33
ICGV86149	6.17	4.54	0.055	0.058	129 00	127.83
ICGV86143	4.04	3.02	0.051	0.058	99 67	105.67
S.E.(df=12)	0.62	0.68	0.006	0.008	5.55	8.10

Yield components

The number of pods per plant (NOP) and mean seed weight (SWT) were significantly ($p<0.0001$) affected by both genotypes and water regimes. The number of seeds per pod (SPP) was significantly ($p<0.001$) affected by genotypes, but not by water regimes at $p=0.05$. The genotype x water regime interaction had a significant ($p<0.001$) effect on SWT, but not on NOP and SPP.

Decreasing water availability decreased NOP in all genotypes (Table 3). Under well-watered conditions, ICGV86015 had the highest NOP and also had second highest NOP behind ICGV86143 under the lower level of water availability. In contrast, Red Spanish had the lowest NOP under both water regimes. However, Red Spanish had significantly greater SPP under both water regimes as compared to the rest of the genotypes which did not show significant variation within the group (Table 3). Decreasing water availability reduced SWT in all genotypes except in ICGV86015 which showed a slight increase. ICGV86149 had the highest SWT and Red Spanish had the lowest SWT under both water regimes.

Table 3. Variation of the number of pods per plant (NOP), the number of seeds per pods (SPP) and mean seed weight (SWT) of different groundnut genotypes under 90% (WW) and 30% (WS) of available soil water regimes.

Genotype	NOP		SPP		SWT (mg)	
	WW	WS	WW	WS	WW	WS
Tissa	42.00	36.33	2.12	2.07	352	293
ANKG-2	41.33	34.33	2.13	2.09	326	235
Red Spanish	29.00	23.67	3.24	4.77	302	158
N-45	37.33	27.00	2.19	2.26	319	207
ICGV86015	50.33	36.33	2.16	2.16	301	314
ICGV86149	42.50	35.50	2.16	2.18	397	283
ICGV86143	42.00	38.33	2.29	2.18	322	263
S.E.(df=12)	4.67	2.56	0.02	0.98	0.01	0.02

Correlation analysis

Correlation coefficients between Y, W_f, HI and yield components are shown in Table 4, separately for the two water regimes. Under the higher level of water availability, Y showed significant positive correlations with W_f, NOP and SWT, but not with HI.

On the other hand, under the lower level of water availability, Y showed only a weak positive correlation with W_f, but had highly significant positive correlations with NOP, SWT and HI. Under both water regimes, Y had weak negative correlations with SPP which were not significant at p=0.05. Under the higher water regime, SPP had a strong negative correlation with NOP and a weak negative correlation with SWT. There was no correlation between SPP and HI. In contrast, under the lower water regime, SPP had strong negative correlations with NOP, SWT and HI. Under the higher level of water availability, SWT was not significantly correlated with NOP or HI, but was positively correlated with W_f. In contrast, under the lower level of water availability, SWT was not correlated with W_f, but showed strong positive correlations with NOP and HI. Under the higher water regime, NOP did not show significant correlations with either W_f or HI. However, under the lower water regime, NOP had a strong positive correlation with HI, but not with W_f.

Table 4. Correlation coefficients between final total dry weight (W), seed yield (Y), harvest index (HI), number of pods per plant (NOP), number of seeds per pod (SPP) and mean seed dry weight (SWT) under 90% (below the diagonal and 30% (above the diagonal) of available soil water regimes.

	Y	W	HI	NOP	SPP	SWT
Y	-	0.44^{*}	0.74^{***}	0.85^{***}	-0.36^{ns}	0.81^{***}
W	0.71^{***}	-	-0.27^{ns}	0.19^{ns}	0.25^{ns}	0.16^{ns}
HI	0.23^{ns}	-0.53^{**}	-	0.77^{***}	-0.52^{**}	0.71^{***}
NOP	0.62^{**}	0.35^{ns}	0.28^{ns}	-	-0.55^{**}	0.74^{***}
SPP	-0.24^{ns}	-0.16^{ns}	-0.10^{ns}	-0.70^{***}	-	-0.77^{***}
SWT	0.64^{**}	0.58^{**}	-0.03^{ns}	0.12^{ns}	-0.36^{ns}	-

Note: ns-non-significant at p=0.05; * - significant at p=0.05; ** - significant at p=0.01, *** -significant at p=0.001

Table 5 shows linear correlation coefficients between yield and root characteristics for the two water regimes separately. NOPR showed strong positive correlations with Y under both water regimes. RDW showed a positive correlation with Y under the higher level of water availability, but not under the lower level of water availability. In contrast, RSR had a strong negative correlation with Y in the lower water regime, but only a weak negative correlation with Y in the higher water regime. Both RDW and RSR had negative correlations with HI under both water regimes.

Table 5. Linear correlation coefficients between root characteristics, seed yield, final total dry weight and harvest index under 90% (WW) and 30% (WS) of available soil water regimes.

	WW			WS		
	RDW	RSR	NOPR	RDW	RSR	NOPR
Y	0.42^{*}	-0.22^{ns}	0.59^{**}	-0.37^{ns}	-0.67^{***}	0.55^{**}
W_f	0.80^{***}	0.14^{ns}	0.57^{**}	0.21^{ns}	-0.34^{ns}	0.29^{ns}
HI	-0.59^{**}	-0.47^{*}	-0.09^{ns}	-0.53^{**}	-0.47^{*}	0.37^{ns}

RDW - Root dry weigth; RSR - Root:shoot ratio; NOPR - Number of primary roots
Note: ns-non-significant at p=0.05; * - significant at p=0.05; ** - significant at p=0.01; *** -significant at p=0.001

DISCUSSION

The present experiment quantified the growth and yield responses of several groundnut genotypes to a significant reduction in soil water availability (i.e. from 90% to 30% of soil available water). A wide body of research literature has shown that many physiological processes responsible for growth and yield formation of annual crops are affected adversely when the available water in the soil decreases below a threshold value (Turner and Kramer 1980; Taylor *et al.* 1983; Jones 1992; Smith and Griffiths 1993). For example, Gollan *et al.* (1985) showed that leaf stomatal conductance decreases rapidly when the available soil water decreases below 60%. The exact value of this threshold varies with crop species and the physiological process concerned. Despite this variation, it is widely accepted that yields of all annual crops are reduced when the available soil water decreases below 50%. Therefore, it could be assumed beyond any reasonable doubt that the water regime of 30% available water level in the present experiment imposed a significant water stress in plants. This was clearly shown by the significant reductions in growth and yield observed in all the genotypes which were grown continuously at the 30% available water regime. Except for the difference in soil water availability, plants under both water regimes grew under similar environmental and management conditions. Therefore, it is clear that the observed reductions in all growth and yield parameters were primarily due to the water stress experienced by the plants growing under the continuously maintained level of 30% of soil available water.

Water stress can be quantified either by measuring soil water availability or plant water availability. In both cases (i.e. soil or plant), water potential is the measure of water availability. However, whether soil or plant water potential is the most appropriate parameter indicating plant water stress, has often been a contentious issue (Kramer 1988; Passioura 1988). The appropriateness of any measurement of water stress depends on how closely it follows an observed plant response to decreasing water availability. Through a well-designed experiment where soil water potential could be varied while the plant water potential was being kept at zero (i.e. at its maximum value), Gollan *et al.* (1986) clearly showed that leaf stomatal conductance (which is a universally recognized response to water stress) responds to a reduction in soil water potential rather than plant water potential. Moreover, as compared to soil water potential, plant water potential is a highly variable parameter varying with genotype, time of the day, the leaf on which it is measured and the prevailing atmospheric conditions (Turner 1988). Therefore, soil water availability (which is defined on the basis of soil water potentials at field capacity and permanent wilting point) was used to quantify a specific level of water stress in the present experiment.

Results of the present experiment enabled the identification of drought resistant groundnut genotypes among those tested. There are several criteria in selecting genotypes either to be grown in drought-prone environments or to be used in breeding programmes for drought-resistance. Of prime importance would be the higher yielding ability under soil water deficits and on this basis, ICGV86015 could be selected (Table 2). A second criterion of importance would be a combination of higher yielding ability under both well-watered and water-stressed conditions. A genotype such as ICGV86149 would be able to take advantage of seasons with adequate rainfall and therefore would be most suitable for variable environments in which droughts are interspersed with seasons of adequate water availability. A third criterion to be considered is the stability of yield under varying levels of water availability. Such a variety could be used across a range of environments with a wide variety of seasonal water regimes. On this basis also, ICGV86015 is a suitable genotype because it had the narrowest difference between well-watered and water-stressed yields (Table 2).

Correlation analysis between Y, W_t, HI and yield components enabled the identification of physiological mechanisms that determine groundnut yield under different water regimes. The strong positive correlation between water-stressed Y and HI showed that greater partitioning of assimilates to reproductive structures is important to achieve a higher yield under water deficits. This agrees with the findings of Chapman *et al.* (1993a & b) and Williams *et al.* (1986). In contrast, under well-watered conditions, a higher biomass production capacity, rather than a greater ability of assimilate partitioning, is required to maximize yield. Under both water regimes, maximizing the pod number per plant and individual seed weight were essential to achieve higher seed yields. Hence, these can be used as additional selection criteria in breeding programmes. In contrast, breeding for larger pods (i.e. higher seeds per pod) would not result in groundnut yield increases as illustrated by Red Spanish (Tables 2 and 3).

Several root characters were measured with the objective of finding additional selection criteria which could be used in breeding programmes for drought resistance in groundnut. It is widely suggested in literature that greater rooting ability confers drought resistance (Jordan *et al.* 1983; O'Toole and Bland 1987; Blum 1989; Ingram *et al.* 1994). Out of the root characters measured in the present experiment, the number of primary roots per plant had the strongest correlation with seed yield under both water regimes. This was probably because NOPR was the most valid indicator of rooting ability in the restricted soil environment in the pots used in the present experiment. However, interestingly both root dry weight and root:shoot ratio showed negative correlations with seed yield under water deficits. This may be an indication that greater assimilate partitioning to roots occur at the expense of assimilate partitioning to seeds. This is supported by the observed negative correlations of the harvest index with both RDW and RSR. However, this finding needs to be confirmed by further experimentation under field conditions where unrestricted root growth can occur.

CONCLUSION

It is concluded that out of the genotypes tested in the present experiment, ICGV86015 and ICGV86149 can be used in breeding for drought resistance in groundnut or as cultivars in drought-prone environments. Greater groundnut yield under water deficits can be achieved by increasing the harvest index, the number of pods per plant, individual seed weight and the number of primary roots.

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