ï The rainfall during vegetative to pegging stages played a determining role under timely-sown condition and contributed to high yields.

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Variation in Transpiration Efficiency and Related Traits in a Groundnut Mapping Population

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Previous research to enhance the drought tolerance of groundnut (*Arachis hypogaea*) has led to the selection of transpiration efficiency (TE) as an important component trait of water-use efficiency (WUE) and a major source of yield variation under drought stress (Nageswara Rao and Wright 1994). The need to find non-destructive methods of selection for drought tolerant progenies and to breed for improved TE has subsequently led to the identification of surrogate traits that are closely related to TE such as carbon discrimination ($\Delta\ ^{13}C$), specific leaf area (SLA), SPAD Chlorophyll Meter Readings (SCMR) and leaf nitrogen status (Nageswara Rao et al. 2001). Low SLA has been incorporated into genotypes with high transpiration and/or harvest index through subsequent trait-based breeding approaches, with a parallel development of progenies through empirical breeding approach. Comparison of the progenies developed through trait-based and empirical breeding approaches, for enhanced drought tolerance and WUE across environments, have shown that the trait-based groundnut selections failed to demonstrate any clear superiority over the empirical selections for yield under drought (Nigam et al. 2003). This failure has necessitated reexamining the adequacy of the physiological model for fully explaining the yield and WUE variations, the reliability of the surrogate traits as a proxy for TE and the perfection of selection indices and genotype × environment analysis. These recent findings have also prompted the need for the development of a component-trait approach using molecular markers to characterize the parents precisely for the WUE related physiological traits and to identify relevant quantitative trait loci (QTLs) for subsequent marker-assisted selections (Nigam et al. 2003).

The dry-down experimental method, which consists of exposing plants to progressive and controlled drought stress, offers an adequate way to quantify the response of transpiration and TE traits to drought (Sinclair and Ludlow 1986). The first objective of this work was to characterize a set of genotypes including the two extensively used parents, ICGV 86031 and TAG 24, using the dry-down methodology for confirming the extent of contrast in their TE. The second objective was to characterize a set of mapping populations derived from a cross between these two parents for assessing the extent of TE variation among progenies and its suitability for further genotyping and phenotyping.

Seven genotypes (JUG 26, ICGS 76, CSMG 84-1, ICGS 44, ICGV 86031, TAG 24 and ICG 2773), known from previous studies to possess various combinations of transpiration, TE and harvest index, were subjected to a dry-down experiment following the methodology described by several authors (Sinclair and Ludlow 1986, Serraj et al. 1999). Single plants were grown in 20-cm diameter pots with 4.5 kg of Alfisol mixed with 4 g of single super phosphate. Rhizobial inoculation was carried out immediately after sowing. The design of the experiment was randomized complete block design (RCBD) with 8 replications per treatment and the treatments included well-watered control and gradual stress imposition. Five plants (replications) per genotype were grown separately and harvested at 28 days after sowing (DAS) to estimate the pre-stress leaf area and dry matter accumulation of the plant components. The pots

Table 1. Trial means, range of best linear unbiased predicted (BLUP) means and analysis of variance of transpiration efficiency (on the basis of total biomass) and its related characteristics at stages related to stress imposition and harvest of 318 groundnut RILs and their parents TAG 24 and ICGV 86031 during MarchñApril 2004.

Trait[1]	Trial mean	Range of predicted means	SEd (±)	σ^2_g	CV (%)	Heritability[2] (h^2)
Transpiration (kg)	1.42	1.31ñ1.48	0.053	0.002 (0.0005)[3]	9.0	0.105
Transpiration efficiency (g kg^{-1})	3.08	2.63ñ3.52	0.276	0.06 (0.011)	18.9	0.150
Specific leaf area at the start of stress (cm^2 g^{-1})	151.5	137.3ñ169.7	7.61	52.1 (8.0)	7.2	0.303
Specific leaf area at harvest (cm^2 g^{-1})	147.6	117.1ñ171.3	9.44	103.8 (12.7)	10.7	0.293
SCMR at the start of stress	45.7	40.7ñ50.1	2.18	5.0 (0.66)	8.3	0.258
SCMR at 1 week after stress	49.8	43.1ñ55.2	2.61	6.7 (0.93)	9.4	0.232
SCMR at harvest	49.7	42.9ñ55.8	2.30	5.1 (0.72)	8.4	0.227

1. SCMR = SPAD Chlorophyll Meter Readings.
2. Heritability was estimated as $h^2 = \sigma^2_g/(\sigma^2_g + \sigma^2_e)$.
3. Standard error values are given in parentheses.

were irrigated to 90% field capacity until subjecting them to drought stress. Drought stress was imposed at 28 DAS by irrigating stress treatment pots, with 70% of the water lost during the previous day, as a measure to impose gradual stress while similar number of control pots received all the water lost. Drought stress treatment was considered to be completed when the normalized transpiration of stressed plants was lower than 0.1 of the transpiration of controls. Plants were then harvested and TE calculated as the biomass increase during the drought treatment, divided by the total water transpired during that period.

There were significant differences among the genotypes for TE, with TAG 24 showing the lowest TE values and ICGV 86031 the highest. The important finding in this study was that the soil water content where transpiration begins to decline relative to control, proxied by the fraction of transpirable soil water (FTSW) threshold, varied from one genotype to the other and these threshold values were negatively related to TE (Fig. 1). Although mesophyll efficiency, rather than stomatal factors, has been concluded to mainly contribute to TE in groundnut (Udayakumar et al. 1998), our results indicate the likelihood of involvement of stomatal control also in regulating the TE.

In another set of dry-down experiment, 318 F_8 recombinant inbred lines (RILs) derived from a cross between ICGV 86031 and TAG 24 were characterized for TE along with their parents. Large pots containing 8 kg of Alfisol mixed with 165 g of MultiplexÆ (vermicompost) and 2 g of diammonium phosphate (DAP) were planted with a single seed of each RIL in an alpha lattice (16 × 20) design with 8 replications and regularly irrigated to 90% field capacity until 33 DAS. At 33 DAS, three pots (replications) were harvested to assess the SLA and shoot and root biomass accumulated before the initiation of stress treatment. Soils of the remaining five pots for each RIL were saturated with repeated watering on the day before initiation of drought stress, allowed to drain overnight, and the pots were wrapped with polythene bags to prevent soil evaporation. The pots were weighed after overnight draining and then exposed to progressive drought stress. The SCMR were also recorded on all leaflets of the second fully expanded leaf from the top. Prior to drought imposition the weights of the pots and the SCMR of the parents were recorded everyday while that of the RILs were recorded on seventh day and on tenth day after drought imposition. Plants were harvested when 80% of plants were showing symptoms of permanent wilting. Plants were separated into leaf, stem and roots and SLA was recorded using the leaflets and the weights were recorded after drying the samples in hot air ovens.

Substantial variation among the RILs for transpiration, TE and SLA before and after imposition of drought stress and the SCMR before, during and at the end of imposition of drought stress was observed (Table 1). The parent ICGV 86031 had higher TE than TAG 24 (Fig. 2),

Table 2. Correlation coefficients among various transpiration efficiency (TE)-related traits of 318 groundnut RILs and their parents[1].

Trait	Transpiration (kg)	TE ($g\ kg^{-1}$)	SLA ($cm^2\ g^{-1}$) (pre-treatment)	SLA ($cm^2\ g^{-1}$) (at harvest)	SCMR at the start of stress	SCMR after 7 days of stress
TE ($g\ kg^{-1}$)	0.343***					
SLA ($cm^2\ g^{-1}$) (pre-treatment)	–0.031	–0.030				
SLA ($cm^2\ g^{-1}$) (at harvest)	–0.416***	–0.387***	0.425***			
SCMR at the start of stress	–0.009	0.102	–0.307***	–0.135*		
SCMR after 7 days of stress	0.374***	0.406***	–0.281***	–0.474***	0.515***	
SCMR at harvest	0.076	0.159**	–0.347***	–0.257***	0.644***	0.596***

1. SLA = Specific leaf area; SCMR = SPAD Chlorophyll Meter Readings.
   * = Significant at 5% level; ** = Significant at 1% level; *** = Significant at 0.1% level.

lower SLA and higher SCMR (data not shown). The distribution of TE was normal and there were also RILs with values lower than the lowest parent and values higher than the highest parent indicating that the trait segregates transgressively and is governed by polygenes. Already well-documented relationships such as the negative relationship between TE and SLA, the positive relationship between TE and SCMR and the negative relationship between SLA and SCMR (Bindu Madhava et al. 2003) were exhibited clearly at 7 days after stress imposition (Table 2). However, such relationships of TE could not be seen with SLA or SCMR under well watered conditions before stress imposition (Table 2). Therefore, SLA and SCMR measured under well watered conditions are of little use since surrogate characters (SLA or SCMR) measured are mostly linked to TE after imposition of stress, and particularly at mid-way through stress. The heritability value for SLA was the highest (0.3), followed by that for SCMR (0.23). However, these values were low for TE or transpiration (Table 1) because these values are the plant biomass based estimates and therefore would have the reflections of polygenic control as seen for shoot biomass in chickpea (*Cicer arietinum*) under terminal drought (Serraj et al. 2004). Also TE was estimated from a pre- and post-treatment harvest, then with a different set of plants, and low number of replications, increasing the measurement of TE.

The FTSW threshold value estimated for ICGV 86031 was 0.43 and that of TAG 24 was 0.55. These values were about the same observed in the first experiment confirming

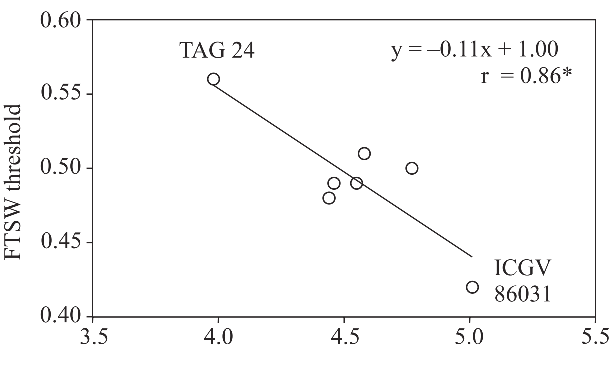

Figure 1. Relationship between transpiration efficiency ($g\ kg^{-1}$) and the fraction of available soil water (FTSW) threshold (at which the stomatal control starts limiting transpiration) in seven groundnut varieties with contrasting transpiration, transpiration efficiency and harvest index characteristics.

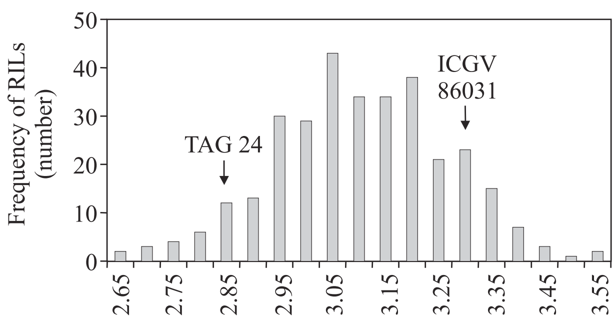

Figure 2. Frequency distribution of transpiration efficiency of 318 groundnut RILs along with their parents, ICGV 86031 and TAG 24, grown in a pot culture and exposed to progressively increasing drought stress till about permanent wilting point during 2004 season.

the varietal differences in the level of drought stress at which the stomatal control starts regulating the water loss.

In conclusion, adequate variation for TE is available among the parents as well as the RILs and considering the poor heritability of TE it is necessary to identify molecular markers for this trait. Although the relationship of SLA and SCMR with TE was significant, R^2 values remained fairly low (0.15ñ0.17). Therefore, SLA and SCMR can be useful surrogates as a proxy for TE, only when direct biomass-based evaluation of TE is not possible, like in field experiments. However, direct measurement of TE remains the best option when the need to estimate TE precisely is required, for example, for a precise physiological characterization of that trait, or to phenotype for TE for further genotyping and identification of molecular markers.

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Effect of Irrigation Regimes, Weed Management and Growth Regulators on Protein and Dry Pod Yields of Groundnut Grown Under Polythene Mulch

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India is the second largest producer of groundnut (*Arachis hypogaea*) accounting for 38% area (7.7 million ha) and 31% production (6.7 million t) of the world. However, the productivity in India is only 1046 kg ha^{-1} (2001ñ02) as compared to the worldís average of 1662 kg ha^{-1}. Use of transparent polythene mulch in groundnut cultivation augments its yield by 20 to 50% (Wenguang et al. 1995). Amongst different inputs, water is of great significance to plants for their physiological and biochemical processes like transpiration, respiration, nutrient absorption, photosynthesis and translocation. Efficient and economical use of water is essential for higher productivity as it is a scarce and expensive input. There is a need to find out optimum water use and irrigation schedule for groundnut crop as high soil moisture results in pod rot, low yield and poor seed quality. Similarly, water stress reduces photosynthesis mainly due to the reduction in photosynthetic area. Application of growth regulators under optimal water supply increases the protein and dry pod yields of groundnut (Patil and More 1991). Hence, this investigation was conducted to study the effect of irrigation regimes, weed management and growth regulators on the protein and dry pod yields of groundnut grown under polythene mulch.