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# DETERMINATION OF WATER USE EFFICIENCY IN GROUNDNUT BY GRAVIMETRIC METHOD AND ITS ASSOCIATION WITH PHYSIOLOGICAL PARAMETERS

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## SUMMARY

**Water use efficiency (WUE) and associated physiological parameters were measured in fifteen genotypes of groundnut *(Arachis hypogaea* L) grown in pots. Accurate measurement of WUE is possible by gravimetric approach. In this study there was an inverse relationship between mean transpiration rate (MTR) and WUE. A positive association between net assimilation rate (NAR) and WUE and total dry matter (TDM) and WUE indicated the possibility of identifying genotypes with WUE under mesophyll control. There was a strong correlation between TDM and LAD suggesting the role of leaf surface area in determining the biomass production. WUE was also estimated in field trials utilizing specific leaf area (SLA) values. The results show that, the WUE in the pot culture experiment was significantly correlated with the WUE estimated under field conditions. Among the genotypes, Tir 16 recorded highest WUE compared to all other genotypes.**

***Key words:*** **Gravimetric method, groundnut, water use efficiency.**

## INTRODUCTION

Groundnut *(Arachis hypogaea* L.) is one of the important oil seed and cash crops grown in India accounting for 36 per cent of total oil seeds production. This crop is predominantly grown as a rainfed crop in India (>80 per cent) where drought is a major constraint for crop production. Water is becoming a scarce commodity even in irrigated agriculture. Genetic enhancement to improve crop productivity per unit input of water has been a research priority in crop improvement programmes all over the world. The physiological model proposed by Passioura (1986) explains the importance of WUE in influencing grain yield under water limited situations.

Grain yield = T x TE x HI, where, T = total transpiration by the crop canopy, TE = transpiration efficiency, HI = the ratio of biomass that is partitioned to economically important parts. This relationship provides an analytical basis to explain genotypic performance under water deficit conditions and to select the genotype with high levels of the model parameters (T and TE). Variation in WUE among genotypes of same species was first documented by Briggs and Shantz ( 1913). The possibility of using this as a selection trait in breeding for drought tolerant genotypes has been reported by several workers (Dewit 1958, Fischer and Turner 1978, Tanner and Sinclair 1983). Thus, it is apparent that WUE is one of the most important factor influencing crop productivity, particularly under water-limited conditions (Turner 1986, Uma 1987).

At the canopy level, WUE based on evapotranspiration (Fischer and Turner 1978) is difficult to measure in the field because of the lack of suitable

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techniques for measuring accurately the root mass and water use of the plants (Martin and Thorstenson 1988). WUE is often quantified at whole plant level by adopting gravimetric technique by assessing the accumulation of biomass during a definite growth period and accumulation of water transpired during the same period of growth. With the advent of this rapid technique, significant progress was achieved in establishing the genetic variability in WUE. Measurement of WUE in single leaves using gas exchange techniques requires expensive instrumentation and specific expertise. Despite the inevitable drawbacks of container studies, this approach has been adopted widely in more recent studies on WUE (Hubick and Farquhar 1987, Wright *et al.* 1988 and 1994).

## MATERIALS AND METHODS

Pot culture experiments were conducted during Rabi 2000-2001 at S.V. Agricultural College, dryland farm, Tirupati, Andhra Pradesh, India. Fifteen groundnut *(Arachis hypogaea* L.) genotypes were used to assess differences in WUE and associated physiological parameters by gravimetric approach. Plants were grown in carbonized rubber battery pots of 0.26 x 0.16 x 0.40m filled with potting medium (a mixture of sandy loam soil and farm yard manure) weighing about 17 kg to their capacity leaving top 25 mm. Basal fertilizer (20 kg N, 40 kg $P_2O_s$ and 50 kg $K_2O$ $ha^{-1}$) was mixed into the top soil at sowing. Each genotype was planted in 3 pots and 2 plants were grown in each pot. Plants were watered daily until 30 days after sowing (DAS).

At 30 DAS, all pots were saturated with water and any excess water was allowed to drain through a drainage hole in the base of the container. Treatments were imposed from 30 DAS to 60 DAS. The exposed soil surface was covered with pieces of polythene to minimize soil evaporation. The pots were arranged in a randomized block design. The amount of water loss was determined by weighing the pots daily using a mobile hanging balance. One pot for each replication with soil and plastic mulch, but without plants, was maintained to monitor soil evaporation in the absence of the plants. The experiment was terminated at 60 DAS.

The principle of determining the water use efficiency in this technique is by assessing the increase in biomass during a particular growth stage (30 DAS to 60 DAS) and cumulative water transpired (CWT) during this period as per Udaya Kumar *et at.* (1998).

The observations recorded during pot culture experiment were cumulative water transpired (CWT), leaf area duration (LAD), mean transpiration rate (MTR), net assimilation rate (NAR) and WUE. The biomass accumulated during the treatment period (30 to 60 DAS) was computed as the difference in the initial and final dry matter and expressed as gram per plant. LAD was measured as, LAD = (Ll+L2)/2) x days where, Ll is initial leaf area and L2 is final leaf area at the end of the treatment period. The amount of water added daily to each pot after weighing to bring back to 100 per cent field capacity was summated individually for each pot during the treatment period, and was expressed as cumulative water transpired. The rate of transpiration over the entire experimental period was measured as mean transpiration rate. MTR was arrived at by computing the ratio of CWT to the LAD and expressed as ml of water $dm^{-2}$ leaf area $day^{-1}$. Measurement of WUE by gravimetric approach involves the measurement of dry matter accumulated over a specific period of time and the total water transpired by the plant during the same period. NAR was determined as the ratio of TDM during the treatment period and LAD, and expressed as g $m^{-2}$ $day^{-1}$. Field experiments were conducted during *kharif*, 2000 with the same genotypes used for pot culture experiments. In field experiment WUE at 60 DAS was estimated utilizing actual SLA values as per Wright *et al.* (1995).

## RESULTS AND DISCUSSION

Pot culture experiments were conducted to measure WUE accurately by gravimetric method. WUE was determined by measuring the daily loss of water by transpiration, using an electronic load cell balance. During the course of study, significant genotypic variation was observed for WUE. In the present investigation the variation ranged from 2.67 to 3.99 g $kg^{-1}$. The genotype Tir 16 recorded highest WUE compared to all other genotypes (Table 1). Hebbar *et al.* (1994) reported that

**Table 1.** Total dry matter (TDM), leaf area duration (LAD), mean transpiration rate (MTR), cumulative water transpired (CWT), net assimilation rate (NAR) and water use efficiency (WUE) during the treatment period in fifteen groundnut genotypes

| Genotype | TDM (g plant$^{-1}$) | LAD (dm$^{2}$ days) | MTR (ml dm$^{-2}$ day$^{-1}$) | CWT (litres plant$^{-1}$) | NAR (g m$^{-2}$ day$^{-1}$) | WUE (g litre$^{-1}$) |
|---|---|---|---|---|---|---|
| Tir 7 | 10.5 | 198.8 | 17.2 | 3.42 | 5.29 | 3.08 |
| Tir 8 | 8.0 | 152.0 | 19.7 | 3.00 | 5.27 | 2.67 |
| Tir 12 | 9.0 | 181.9 | 17.7 | 3.22 | 4.95 | 2.80 |
| Tir 10 | 9.0 | 182.7 | 17.6 | 3.21 | 4.93 | 2.80 |
| Tir 11 | 8.5 | 166.4 | 18.7 | 3.12 | 5.12 | 2.72 |
| Tir 13 | 13.0 | 243.7 | 15.2 | 3.71 | 5.34 | 3.50 |
| Tir 14 | 14.0 | 257.9 | 14.7 | 3.80 | 5.44 | 3.68 |
| Tir 15 | 10.5 | 198.4 | 17.2 | 3.41 | 5.30 | 3.08 |
| Tir 16 | 16.0 | 282.1 | 14.2 | 4.02 | 5.68 | 3.99 |
| Tir 17 | 12.0 | 227.3 | 15.4 | 3.51 | 5.29 | 3.42 |
| ICR 1 | 9.0 | 181.3 | 17.6 | 3.20 | 4.97 | 2.81 |
| ICR 3 | 11.0 | 209.1 | 16.7 | 3.51 | 5.27 | 3.14 |
| ICR 7 | 8.5 | 166.5 | 18.7 | 3.11 | 5.12 | 2.73 |
| ICR 8 | 10.5 | 197.8 | ]7.2 | 3.41 | 5.32 | 3.08 |
| ICR 21 | 12.0 | 226.2 | 15.5 | 3.51 | 5.31 | 3.42 |
| **Mean** | **10.7** | **204.8** | **16.91** | **3.41** | **5.24** | **3.13** |
| **SEm** | **0.03** | **0.76** | **0.36** | **0.02** | **0.04** | **0.02** |
| **CD** | **0.07** | **2.13** | **1.01** | **0.05** | **0.11** | **0.05** |

WUE estimated by gravimetric method in the fourteen genotypes used varied from 1.2 to 2.7 g kg$^{-1}$ under irrigated and from 1.6 to 3.5 g kg$^{-1}$ under water deficit conditions. These values are in accordance with the WUE range reported for $C_3$ crops such as groundnut (Shashidhar 1987, Hebbar 1990, Nageswara Rao *et al.* 1993). The physiological basis for variations in WUE between genotypes from the present study and earlier work (Hubick *et al.* 1986) suggests that, in groundnut variation in photosynthetic capacity per unit leaf area might be a factor causing variation in WUE.

The two physiological traits often associated with WUE are transpiration rate and net assimilation rate at a given leaf area. These parameters respectively describe the variations in stomatal conductance ($g_s$) and mesophyll capacity for carbon fixation ($g_m$). Both these parameters were gravimetrically determined for fifteen genotypes of groundnut. Dry matter production in the present study varied significantly among fifteen genotypes which ranged from 8.0 g plant$^{-1}$ (Tir 8) to 16.0 g plant$^{-1}$ (Tir 16) during the treatment period (Table 1). Hebbar *et* al. (1994) showed that more than 92 per cent of the variation in dry matter accumulation was accounted for by the variation in WUE. MTR ranged between 14.2 in Tir 16 and 19.7 ml dm$^{-2}$ day$^{-1}$ in Tir 8 representing a significant genetic variability (Table 1). Similarly, the highest NAR of 5.68 g m$^{-2}$ day$^{-1}$ was recorded, for Tir 16 (Table 1).

A strong inverse relationship between MTR and WUE (r = -0.92, P< 0.05) indicated a considerable stomatal control of WUE in these genotypes (Fig. 1b). However, NAR showed a positive relationship with WUE (r = 0.69, P< 0.05) among these genotypes (Fig 1c). A strong positive correlation between WUE and TDM (r = 0.90, P< 0.05) (Fig. 1a) indicated that groundnut genotypes belong to the capacity type category despite an inverse relationship of WUE and MTR. It is well documented that in groundnut differences in WUE is mainly associated with assimilation efficiency rather than stomatal conductance (Hubick *et al.* 1986, Wright *et al.* 1988, Martin *et al.* 1994).

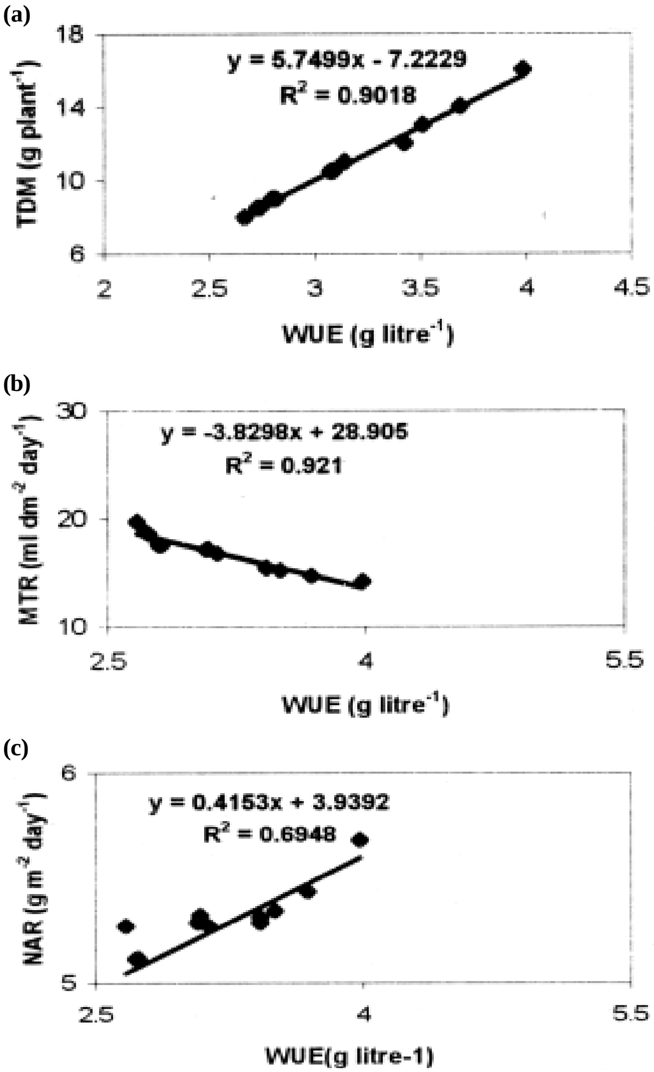

**Fig. 1. Correlation between WUE and associated physiological parameters in pot studies**

WUE values of the pot experiment correlated well with those estimated in the field experiment with the same genotypes utilizing specific leaf area values at 60 DAS as per Wright *et al.* (1995). There was a significant positive correlation (r = 0.90, P< 0.05) between the water use efficiency measured in pots and in field experiments indicating that the genotypic ranking was similar both in pot and field experiments (Fig. 2) (Hebbar *et al.* 1994). Thus pot studies can be utilized to confirm water use efficiency of selected and important genotypes like donor parents in a breeding programme.

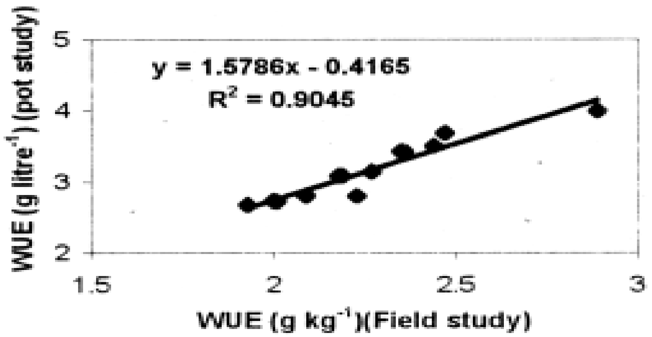

**Fig. 2. Relationship between WUE (pot study) and WUE (field study) in fifteen groundnut genotypes**

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