A lysimetric system to simultaneously measure T, TE and HI in peanut (*Arachis hypogeae L.*)

Vincent Vadez, P Ratna Kumar, L Krishnamurthy, Shridar Rao,
Kiran K Sharma, and Pooja Bhatnagar-Mathur
ICRISAT

Introduction

Successful genotypes under water-limited environments need to achieve simultaneously high water uptake for transpiration (T), high conversion of water taken up into biomass (Transpiration Efficiency, TE), and high conversion of biomass into a harvestable product (Harvest Index, HI). Each of these components is a component of the yield hierarchy (Y = T x TE x HI) defined by Passioura (1977).

It is difficult to measure each of these components accurately. Water uptake measurements in the field are difficult and root measurement often show large experimental errors. It is also difficult to measure each of these components precisely. For example, the measurement of TE has often used surrogates of TE that are not always strongly related to gravimetric TE (Krishnamurthy et al., 2007). So, there is a need to develop methods that allow direct and accurate measurements of T, TE, HI.

Objectives of this work were to: (i) set up lysimeters for individual plants, having characteristics close to those in the field (ii) Test the relationship between root dry weight and water uptake; (iii) Assess yield along with T, TE and HI simultaneously in the lysimeters (iv) Compare the relative importance of T, TE, HI towards yield under water stress conditions.

Materials and Methods

Lysimetric system to assess water uptake

Description - Lysimeters used for groundnut are PVC tubes with 20 cm diameter and 1.2 m length. The diameter offer a surface area close to 300 cm^2, equivalent to the surface available to peanut plants under standard sowing densities. Dry and sieved Alfisol was used to fill up the cylinders at an homogenous bulk density of 1.4. Soil was basal fertilized (Muriate of potash and SSP) before filling the tubes. The tubes were saturated with water before planting (20% w/w) and soil level was adjusted to be at 5 cm from the tube's brim. After harvest, lysimeters are kept intact and later on replanted with another crop, or with the same crop after fallowing with a different crop.

a

b

Picture 1 a & b: Design of the lysimeters and weighing principle, using a "S-type" load cell (Mettler-Toledo), with a 10-20 grams precision (for 100 and 200 kg capacity).

A "dynamic" assessment of water uptake by roots – Most work done thus far on roots has used time-consuming methods to extract roots. Virtually no work has been done to test whether differences in rooting relate to differences in water uptake under water deficit. In addition, the destructive measurements of root provided only "static" information on roots at one point in time. Further progress in root research can only be achieved by approaching roots and their role in a dynamic way. For that, cylinder weight is recorded on a regular basis, usually every 3-4 days, and water uptake calculated from weight differences. Water loss in well-watered cylinders is adjusted to about 90% FC. For the drought stress treatment, any regime can be designed. Here we have imposed an intermittent stress, typical for most groundnut growing areas: Plant are grown under well-watered conditions until flowering. The cylinders are then saturated. No water was added for 6-7 weeks (until transpiration fell below 20-30% of control). Then 1 L (equivalent to 30 mm rainfall) was added back to the plants every 3 weeks until harvest.

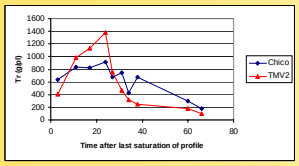


Figure 1. Water transpired (extracted from the soil profile) as a function of time after stress imposition in two genotypes contrasting for pod yield under intermittent drought (Chico with higher pod yield than TMV2, Table 3). **TMV 2 uses water "opportunistically" after stress imposition whereas Chico sustains a smaller water uptake for longer period,**

A system that can be used for other crops and that could combine a range of other uses and measurements - Tubes can be used also for other crops (eg chickpea). Other types of tubes were designed for deeper rooted crops such as pigeonpea, sorghum and pearl millet (2.0 m length, 25 cm dia).

a

b

Pictures 2 a & b: Chickpea growing in the lysimeters under receding moisture (left), in which pods can be seen and polyethylene beads covering the surface of the cylinder to prevent evaporation (right)

Results

Picture 3: High throughput lysimetric setup, allowing the weighing of approximately 500-600 lysimeters/day, with 5 workers. It allows accurate assessment of water uptake in a large range of materials. Current capacity: 2400 cylinders

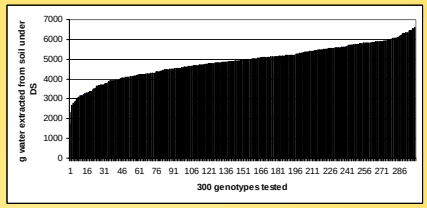
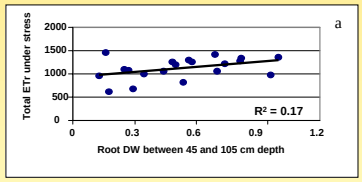


Figure 2. Range of variation in water uptake in the cultivated accessions of the reference germplasm collection of groundnut

Data show over a 2-fold range of variation for water uptake under receding moisture



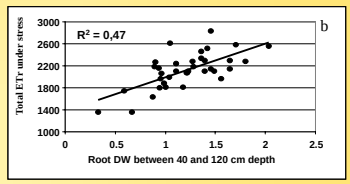


Figure 3 a & b. Relationship between the evapotranspiration (measured over time and under receding moisture) and root dry weight in the deep soil layers of the lysimeters in 5 groundnut genotypes (left) and in 6 transgenics events along with their wild type (right)

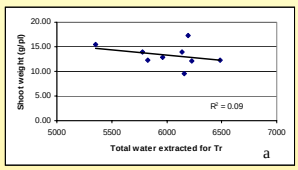
- **Data show a poor relationship between ET and root DW in the experiment using germplasm, where higher dry weight does not directly translate into higher water uptake**
- **There is a fairly close relationship in the experiment using transgenics, where increase root growth led to increased water uptake.**

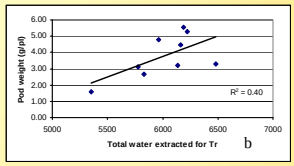
Picture 4. Measurement of the components of yield – The system allows to grow plants up to maturity. Here, the harvest of an experiment comparing peanut genotypes exposed to an intermittent drought stress in the lysimeters

		pod wt	T	TE	HI
Water stress	chico	5.30	6225	2.58	0.29
	ICG S 44	3.27	6483	1.79	0.20
	ICGV-00350	3.20	6138	2.28	0.18
	ICGV-86015	4.79	5963	2.00	0.27
	ICGV-86031	5.53	6190	2.88	0.25
	ICGV-91114	2.68	5830	1.80	0.17
	JL-24	1.59	5350	2.47	0.10
	TAG-24	4.48	6160	1.90	0.31
	TMV-2	3.13	5780	2.48	0.16
Well-watered	chico	20.02	9517	2.39	0.70
	ICG S 44	17.12	11220	2.75	0.49
	ICGV-00350	18.12	13238	2.45	0.46
	ICGV-86015	14.61	12650	1.68	0.47
	ICGV-86031	14.78	10886	2.91	0.39
	ICGV-91114	13.80	14800	1.97	0.42
	JL-24	21.55	13617	2.87	0.50
	TAG-24	6.12	8120	1.47	0.37
	TMV-2	17.55	13840	2.25	0.51

Figure 3. Pod dry weight (g/plant), water uptake (T), transpiration efficiency (TE) and the harvest index (HI) were measured under water stress (intermittent drought) and well-watered conditions in 9 groundnut varieties.

- **Differences in T, TE, HI found under both water regimes**
- **High pod weight under WS in Chico, ICGV 86015, and ICGV 86031 was related to higher HI and higher TE**
- **Poor pod yield in JL 24 and TMV 2 was due to poor HI, likely to be explained by lower water extraction**





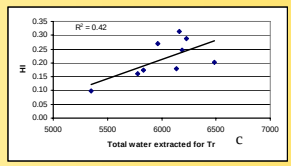


Figure 5. Relationship between water extracted from the lysimeters and the shoot dry weight (a, left), the pod weight (b, center) and the harvest index (c, right).

- **Higher water uptake did not lead to higher shoot weight**
- **High water uptake was related to high pod weight under intermittent drought conditions**
- **High water uptake was related to high harvest index**

Conclusions

- The lysimetric system developed allows high throughput and precise measurements of water uptake of plants exposed to water stress
- Large variations exist for water extraction across germplasm of groundnut
- Root dry weight and water uptake under stress don't always show a very close correlation, thereby the need to measure water uptake rather than rooting characteristics
- The lysimetric system allows the evaluation of yield and its components T, TE, and HI
- Better pod yield under stress was related both to higher TE and higher water extraction, the latter leading to higher HI

Prospects:

- Assess the putative role of root across crop species
- Compare several legumes and cereals
- Add leaf canopy temperature measurement to the system (under WW) to understand shoot water loss
- Test the importance of water extraction at key time