LPAD: a lysimetery platform to phenotype the temporal transpiration pattern for field crops over the growing cycle.

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Abstract
Future food security will rely on the ability to design crops and systems that make better use of water in traditional and new farming environments. Also, with the potential impact of climate change on temperature and rainfall variability, breeding for water-use efficient cultivars is a great challenge. A lysimetery facility (LPAD) has been developed at UQ Gatton, Queensland, employing the latest technology to study transpiration rate and efficiency throughout the crop cycle. The LPAD has a current capacity to monitor transpiration of plants in 128 large pots (up to 100 kg each). The platform is equipped with automatic weighing and watering systems allowing continuous measurements and fine irrigation controls. Water deficits can be managed for individual pots, and contrasting genotypes can be subjected to water deficits similar in both intensity and timing, independently of genotypic differences in maturity and/or transpiration.

Key Words
Transpiration, water deficit, VPD, roots.

Introduction
In both rain-fed and irrigated environments, efficient use of water is central to maintain food security. Over the last 40-60 years, many cropping areas have experienced increases in average seasonal temperatures which decrease the efficiency of water use. With the potential impacts of climate change on temperature and rainfall variability, this tendency is expected to be accentuated in coming years, making breeding for water-use-efficient cultivars an important challenge for the present and the future (Chenu and Chapman, 2012). The problem to be addressed is the difficulty in studying traits that will convey enhanced transpiration efficiency and to phenotype cultivars for those traits in a breeding program. Of great importance in the ability of a crop to maximise the use of available soil water is the temporal transpiration pattern. In a water limiting environment, the ability to shift water use from before to after anthesis can significantly increase grain production. Current phenotyping facilities concentrate on traits that are observable in early plant growth. The LPAD is designed to allow the investigator to study the canopy growth and water use over the whole growing cycle, and to examine the root system (Manschadi et al., 2006) and biomass production at required intervals. Automatic weighing and watering systems allow continuous measurements and controls of water deficit for each pot. Different stress patterns can be imposed on cultivars so that deficits similar in both intensity and timing, independently of genotypic differences in maturity and/or transpiration can be investigated.

Materials and methods
The current capacity of the LPAD is for 128 pots. The pots are mounted on tables of 8 to allow for movement within a semi-controlled glasshouse environment. Each pot is a 50 litre bin with tapered sides lined with plastic bags to assist in the removal of the soil and root system when required. The soil water holding ability is characterized by overwatering one pot that has drain holes, and allowing it to completely drain. This gives the weight of a pot with soil at the drained upper limit, or field capacity.

Each pot sits on a plate connected to a load cell on the table. Load cells are connected to a multiplexer in the control box on each table and the signal sent to the controlling computer. RS485 serial protocol is used so that each multiplexer can be individually addressed. In this way the computer can query the required table and pot to get a measurement of weight.

The individual watering system will apply water to the watering tube inserted 30cm into the pot. Solenoids switched by a module in the control box on the table control the flow of the water in the tube. The control module is connected by RS485 serial protocol to the management computer which can then apply the required amount of water to each pot.

The tables are designed to connect to each other or to wall outlets so that data, control and water can be connected to each pot.

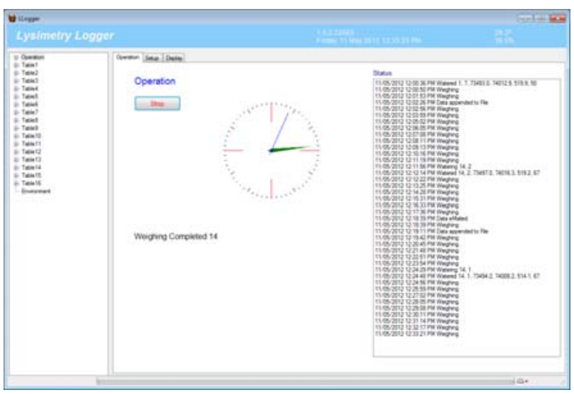
Pots on a table showing blue watering tubes

Control box showing load cell multiplexer and solenoid control.

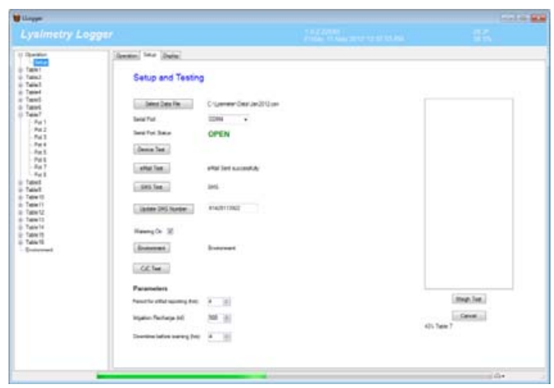
Photo 1. Pots (A) and control box (B).

Temperature, radiation and humidity are also continuously monitored.

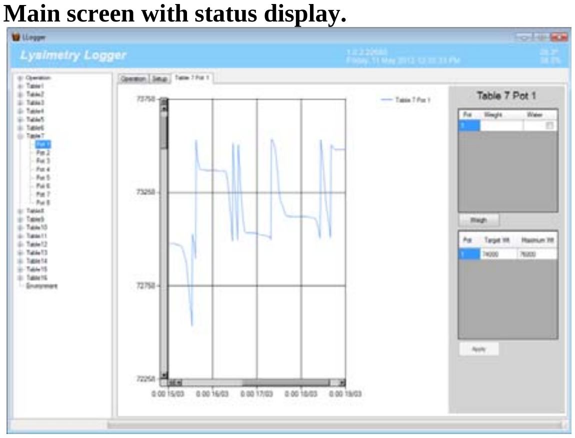
Customized software on the central computer records the weights and controls the LPAD system. The software measures pot weight each minute and records the average weight every 15 minutes. Re-watering weight levels can be set for each pot, and the amount of water applied can also be pre-set. When the weight of a pot is below the re-watering level, the program instructs the solenoid to open and the required amount of water is applied to the pot.



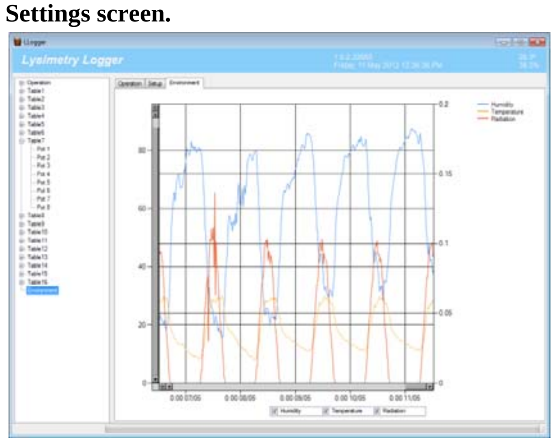
Main screen with status display.



Settings screen.



Individual pot weights and rewatering.



Environment monitoring.

Fig. 1. Software interface and examples of application.

Results

Cumulative water use can be calculated from the raw data.

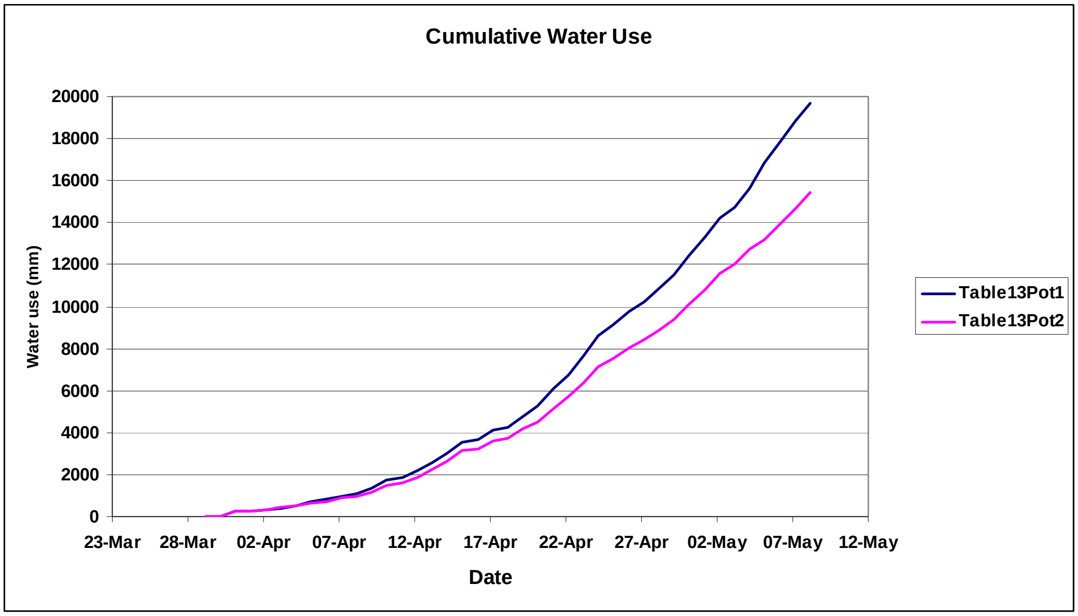


Fig. 2. Accumulated water use (mm) as plant develops

Figure 2 shows contrasting accumulated water use for two different cultivars in two of the 128 pots. This is calculated by summing the irrigations during the period. Other data collected such as canopy measurements and environment measurements are used to calculate and screen for water use efficiency (WUE). Weight measurements at 15 minute intervals provide data to calculate diurnal transpiration cycles.

Conclusion

The ability of the LPAD to provide water use for the whole growing season will be a useful tool for breeders to phenotype material for drought resistance. Imposing different water deficits will allow the study of drought adaptive traits such as stay-green and root architecture in a wide variety of lines, helping to meet the challenge of breeding for water-use efficient cultivars.

References

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