Dissecting the role of root traits in water uptake, maintenance of plant growth, and dehydration avoidance mechanisms in rice

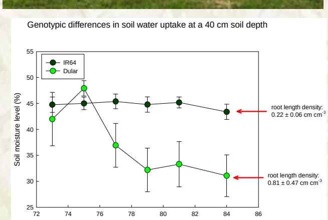
Rachid Serraj, Amelia Henry, Veeresh Gowda, Ken McNally, Arvind Kumar, Adam Price, Akira Yamauchi*

** International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines; e-mail: r.serraj@cgiar.org*

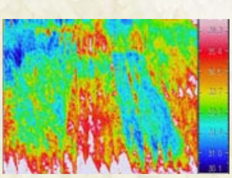
Root architecture is a key trait for dissecting the genotypic differences in rice responses to water deficit. In the first year of this project implementation, we have developed root phenotyping methods both under field and controlled conditions, to investigate the relationships between root architecture and the dynamics of plant water uptake during progressive soil drying. This has also allowed precise phenotyping of advanced breeding lines, genetic stocks, and NILs, for identifying the genetic basis of dehydration avoidance.

OryzaSNP phenotyping: field performance under drought is related to root length density

In the 2009 dry season at IRRI, we conducted a root phenotyping study using the OryzaSNP panel, which consists of 20 genotypes representing genetic diversity in rice that have been completely mapped for SNP markers.



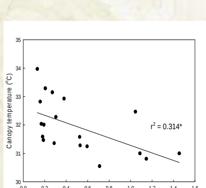
Soil moisture profiles were monitored for two genotypes, IR64 (drought-sensitive) and Dular (drought-resistant). At a depth of 40 cm, soil moisture differed between genotypes. The genotype with greater root length density (Dular) had greater water uptake.



Infrared thermography

Genotypes were assessed for drought resistance based on mid-day canopy temperature, since higher canopy temperatures indicate stomatal closure due to reduced water uptake.

Genotypes with deeper root systems showed a general tendency toward lower mid-day canopy temperature in the drought treatment.



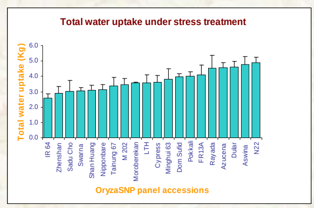
	Yield	Total Biomass	Harvest Index	Days to Flowering	Canopy Temperature	RLD 0-15 cm	RLD 15-30 cm	RLD 30-45 cm	NDVI	SAVI
Yield	1									
Total Biomass	**0.53****	1								
Harvest Index	**0.62****	**-0.29***	1							
Days to Flowering	0.22	**0.63****	**-0.39****	1						
Canopy Temperature	**-0.47****	**-0.60****	0.08	-0.15	1					
RLD 0-15 cm	**0.51****	**0.55****	0.00	**0.52****	**-0.28***	1				
RLD 15-30 cm	0.07	0.15	-0.07	0.19	-0.17	0.13	1			
RLD 30-45 cm	0.08	0.25	-0.20	0.22	-0.16	**0.31***	-0.06	1		
NDVI	**0.3***	**0.6****	-0.22	0.21	**-0.62****	0.22	0.11	-0.03	1	
SAVI	0.02	0.004	-0.02	**-0.46****	**-0.35****	-0.23	-0.08	-0.01	**0.43***	1

A correlation matrix shows that yield, canopy temperature, and root growth were interrelated in the OryzaSNP panel grown under drought in the 2009 dry season at IRRI.

Genotypic differences in water uptake confirm the role of root traits in performance under drought

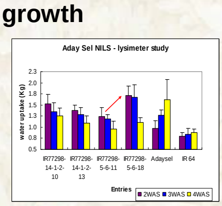
Greenhouse lysimeter facility at IRRI

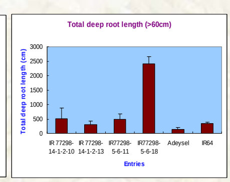
We have developed a high-throughput lysimeter facility to precisely monitor the dynamics of plant water uptake under water deficit, in order to analyze the interaction between root architecture, water uptake kinetics, and drought resistance traits.



We observed large differences in root water uptake among genotypes in the OryzaSNP panel over time. Initial results showed that genotypes that are able to take up more water under drought in these conditions are likely to have improved drought resistance in the field.

Drought QTL NILs differ for root growth





Two pairs of AdaySel x IR64 NILs showed significant differences for yield under drought in field conditions and large genetic variation in root growth at depth, associated with higher water uptake. These lines were investigated in the field for soil water uptake and root architecture parameters under water deficit, in relation to biomass accumulation and partitioning.

These differences in root growth and water uptake under drought between NILs, together with detailed transcript profiling experiments (Kikushi et al., unpublished) are leading the way for rapid progress toward dissecting the genetic basis of drought avoidance responses in rice, and developing improved varieties for drought-prone rainfed environments.

Role of root hydraulics under drought

Although root depth was found to be a key trait for plant water uptake, genetic variation in root hydraulic conductance (Lpr) may be critical for plant response to water deficits.

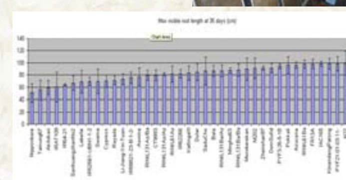
Ongoing research at IRRI and Nagoya University is investigating the role of Lpr in water uptake under drought by developing in-situ measurement techniques under variable soil moisture regimes.

Collaborations

Researchers at partner institutions are also progressing with phenotyping root traits for drought resistance as part of this GCP project.

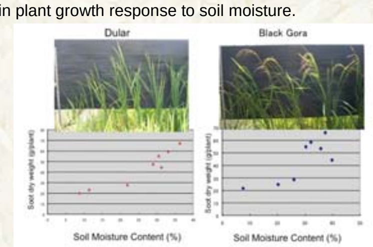
- ***University of Aberdeen (U.K.)*** - Adam Price

Rhizotron screening for root length and architecture showing large variation in root traits among OryzaSNP accessions



• ***Nagoya University (Japan)*** – Akira Yamauchi

Line source study to assess the genetic variability of drought avoidance traits and root growth plasticity over a soil moisture gradient. Results showed genotypic variation in plant growth response to soil moisture.



Effect of soil moisture contents on dry matter production of Dular and Black Gora evaluated by using line source sprinkler system.

• ***Sokoine University of Agriculture (Tanzania),*** A. Kijoji & Z. Kanyeka

A field-managed drought screening trial was conducted during the 2009 under lowland conditions, to standardize drought screening protocols and identify promising drought-resistant breeding lines for ESA.

Initial data confirmed large variability in drought response among *O.Glaberrima x Sativa* IR64 introgression lines.

• ***DRR and Barwale Foundation (India),*** HE Shashidhar, T. Ram & V. Vadez

Advanced breeding lines from the **India Drought Breeding Network** were evaluated for water uptake in lysimeters at ICRISAT, to analyze root traits for drought resistance. Results confirmed the relationship between plant water uptake and performance under drought.

Conclusions

- The OryzaSNP root phenotyping confirms the importance of genetic variation in root growth at depth for conferring drought avoidance through improved water uptake under water deficit.
- Integration of root architecture, plasticity, and hydraulic properties will allow dissection of dehydration avoidance mechanisms in rice.
- The use of advanced breeding lines, drought resistance NILs and field-proven genetic stocks in root phenotyping studies contributes to filling the gap between breeding for yield under drought and functional analysis of underlying traits.

IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE

Acknowledgement: Funding was provided through GCP project (1): SP2 (**G3008.06**) *Targeting Drought-Avoidance Root Traits to Enhance Rice Productivity under Water-Limited Environments* (PI: R. Serraj)