Response of leaf expansion to water deficit and vapor pressure deficit in different rice genotypes

Leaf expansion is one of the most sensitive processes in response to water deficit. Reduction in leaf expansion rate (LER) under drought stress occurs before changes in other physiological processes such as photosynthesis, transpiration, and metabolism. The control of tissue expansion under water deficit contributes to traits such as early vigor, as well as to maintenance of growth of reproductive organs, which may be important components of crop drought resistance. We are analyzing the genetic basis for tissue growth rate under water-limited conditions, combining new phenotyping approaches, whole plant modeling, quantitative genetics, and comparative genomics to identify processes, QTLs, and genes controlling tissue growth rate under water stress. Here, we present work on the response of leaf elongation to drought stress and environmental conditions.

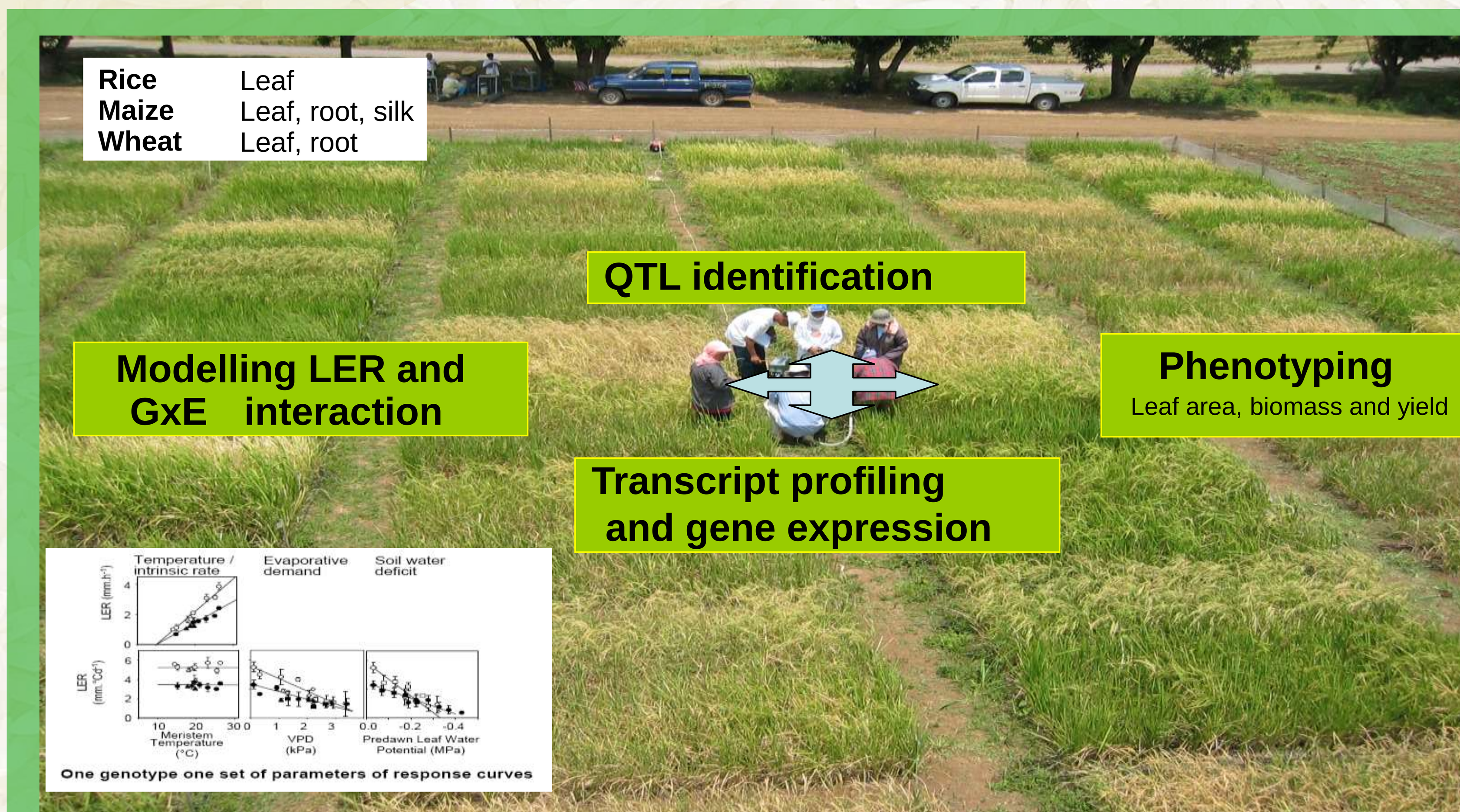

Fig. 1. Comparative dissection of genetic basis of tissue growth under drought stress.

Fig. 2. Growth of rice plants for LER measurement under controlled conditions in growth chamber (a) and phytotron (b)

Dry-down methodology

Two rice varieties, Apo (drought-resistant) and IR72 (drought-sensitive), were used to study the effects of environmental variables on LER (Fig. 2).

Response of LER to environmental variables

Three experiments were conducted at an indoor growth chamber to investigate the effect of drought stress on LER. In the first two experiments, controlled stress was gradually applied after sowing using the dry-down method at 0.1 FTSW (fraction of transpirable soil water). Pot weight was measured daily to determine transpiration rate and FTSW. In the first experiment, leaf length was measured on a daily basis. In the second experiment, leaf length was measured twice a day (6 am and 6 pm). In the third experiment, plants were grown differently 75% field capacity (well-watered) and 50% field capacity (drought stress treatment). When the fifth leaf emerged, LER was measured by placing a dot at the base of the youngest leaf (collar) every 2 h (8 am, 10 am, 12 nn and 2 pm), during three consecutive days with variable vapor pressure deficit (VPD). Air temperature and air relative humidity were used to determine VPD, which directly affect leaf elongation.

Leaf elongation in the field under vegetative drought stress

As part of a QTL mapping study, Apo and IR72 were grown under upland vegetative drought stress alongside a Vandana/Moroberekan BC population. Leaf elongation was determined over a period of 3 d, starting 3 d after irrigation was withheld.

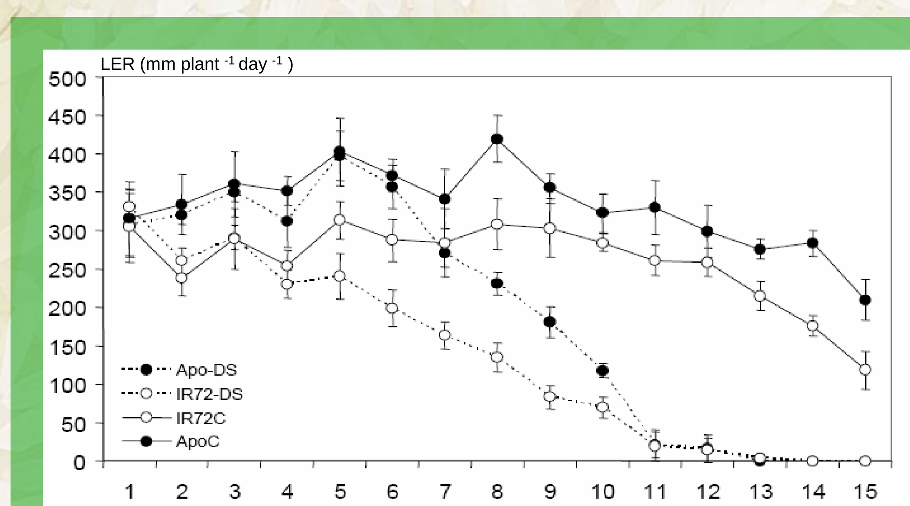

Fig. 3. Evolution of leaf elongation rate against time under well-watered and drought stress conditions.

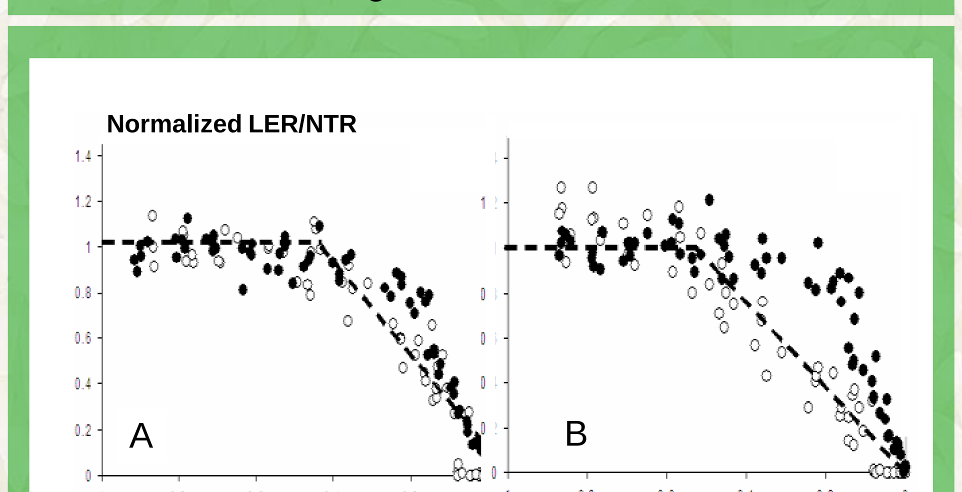

Fig. 4. Plots of normalized LER (black circles) and transpiration rates (open circles) to soil drying (FTSW) in a) Apo (drought-tolerant) and b) IR72 (drought-sensitive).

Results

Response of LER to FTSW

Leaf elongation declined with drought stress in both Apo and IR72 relative to the control. Thus, both cultivars had progressively decreasing leaf elongation rate on the fifth day after treatment (Fig. 3). It showed how leaf elongation rate increased during the day, which was similar to transpiration rate (Fig. 4). Leaf elongation consistently started to decrease at higher available soil water content compared with transpiration. Significant genotypic variation in the FTSW threshold value, at which leaf elongation began to decrease, was also observed.

Effects of temperature and VPD

Diurnal fluctuations

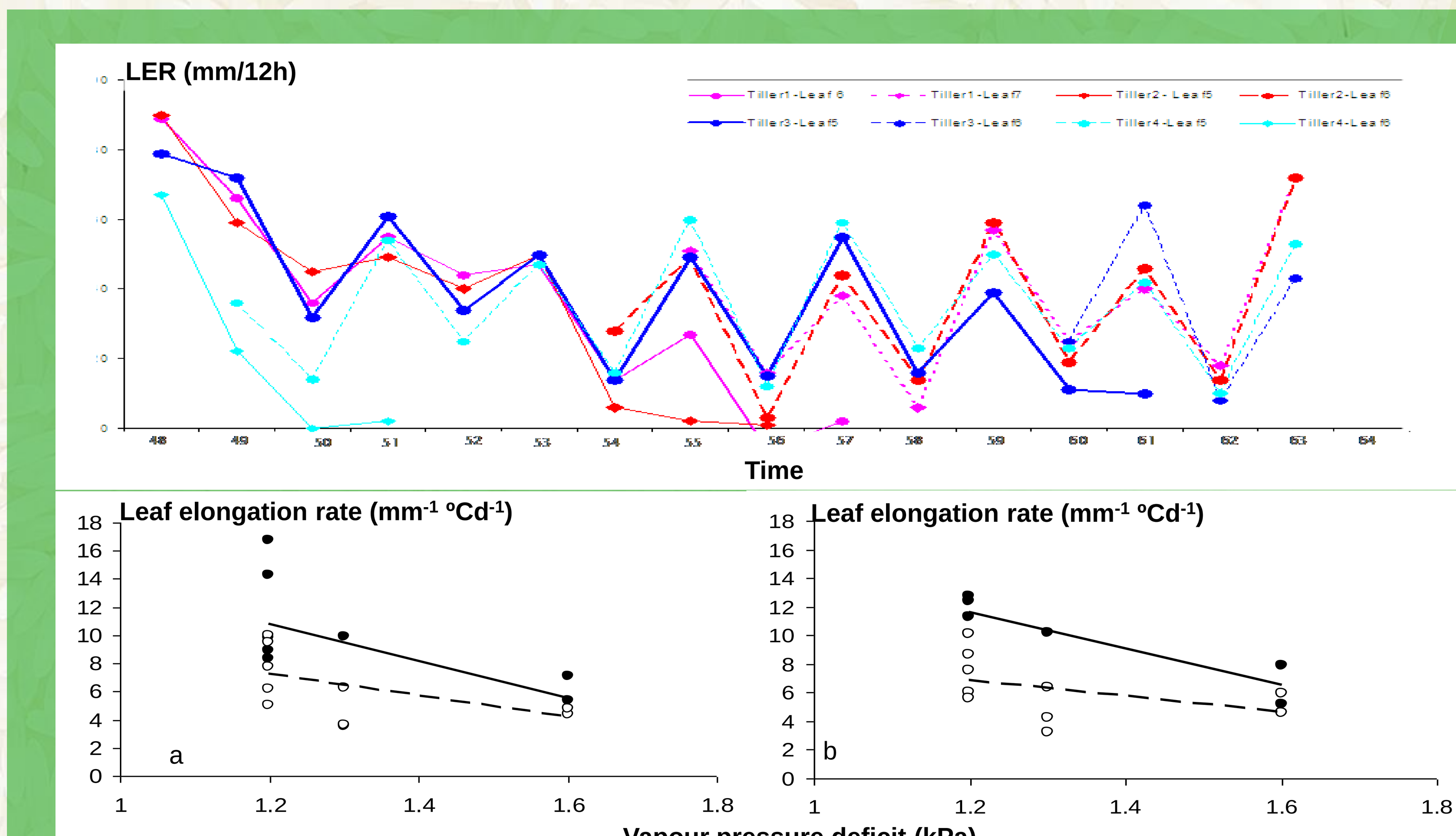

Fig. 5. Response curves of leaf elongation rate to vapour pressure deficit in a) Apo and b; IR72. The black circles represent well-watered (75% field capacity) and the white circles represent drought stressed plants (50% field capacity).

The graph shows the response of leaf elongation rate to VPD (Fig. 5). LER decreased as VPD increased in both well-watered and drought-stressed plants. However, leaf elongation rate was higher under well-watered plants. The declining trend may be attributed to high temperature that affects plant metabolism.

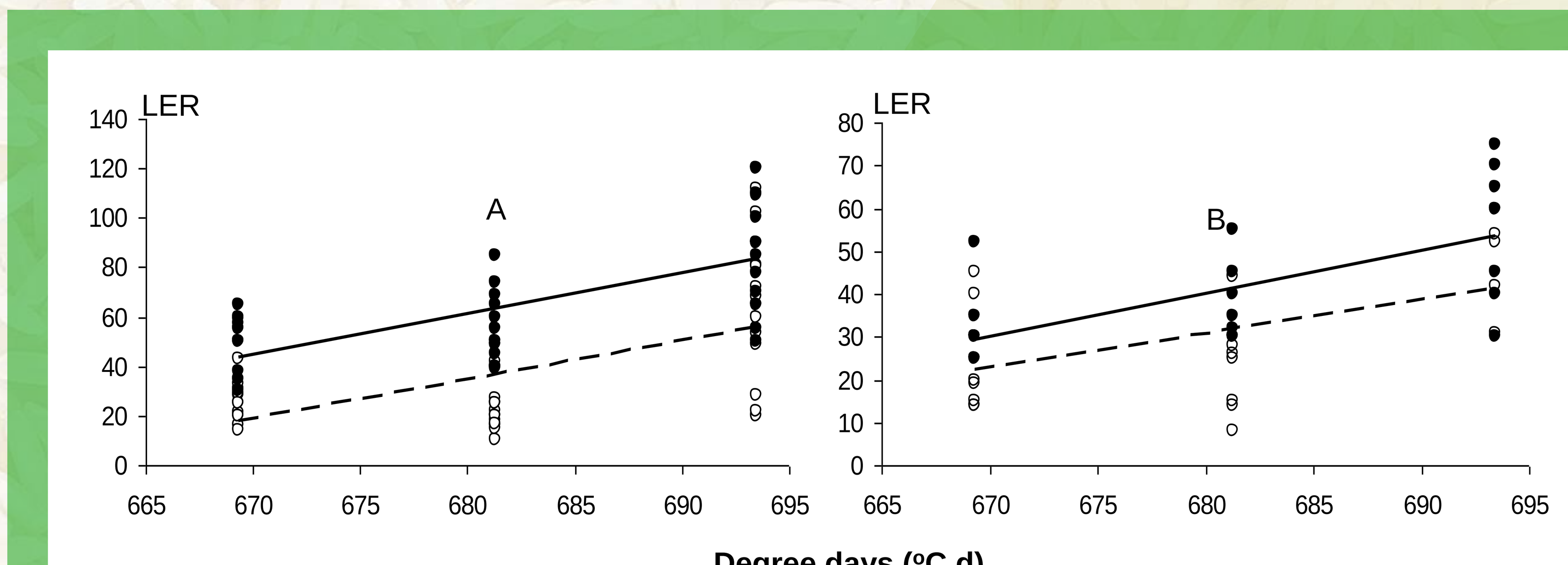

Fig. 6. Leaf elongation of a) Apo and b) IR72 under upland field conditions. The black circles represent well-watered and the white circles represent drought stressed plants.

Leaf length of expanding leaves in the field increased (Fig. 6). Apo significantly showed a faster rate of leaf elongation compared with IR72. It also showed that increase in leaf length was greater under well-watered condition.

Conclusion

Understanding the interactions of leaf expansion in rice genotypes with different environmental parameters leads us to exploit traits/characteristics associated with improved performance under drought in marker-assisted breeding programs. This will also be applied to on going work on the analysis of the genetic basis of growth tissue under water deficit.

R. Mabesa, J.E. Cairns, and R. Serraj

Crop and Environmental Sciences Division, International Rice Research Institute, DAPO Box 7777, Metro Manila, Philippines

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