Characterization of drought stress environments for upland rice and maize in central Brazil

[1]Alexandre B. Heinemann, [2]Michael Dingkuhn, [2]Delphine Luquet, [2]Jean Claude Combres and [3]Scott Chapman

Introduction

In the Cerrado environments of central Brazil, breeding of rainfed upland rice and maize is based on early screens for agronomic traits such as crop duration, plant vigour, panicle and grain weight, commonly characterized under irrigated conditions on research stations. Only once lines reach advanced testing stages, they are evaluated under natural bio-physical constraints that characterize farmers' fields.

The Cerrado is a complex and extensive biome undergoing rapid changes in land use. The rainfall averages about 1200 mm per year, falling mainly (ca. 1000mm) from November to January (cropping season). Upland rice plays an important role in bringing areas into cultivation because of its comparative tolerance to acid, aluminum-toxic soils (Pinheiro et al., 2006). After two or three years of rice cropping in combination with dolomite and phosphate amendments, cropping systems based on intensified pasture and cash crops such as soybean and maize are established.

Meaningful breeding for drought tolerance requires information on the inter and intra-annual probability of drought occurrence, as well as on the characteristics of prevalent drought types such as duration, intensity (which in turn depends on soil depth) and timing with respect to crop phenology. This information can be captured by defining the target population of environments (TPE) for a given crop (rice and maize).The TPE is defined as the set of environments, including spatial and temporal variability, to which improved crop varieties developed by a breeding program need to be adapted.

This study explores possibilities to adjust regional breeding systems to optimally fit the range of environments they are targeted (TPE), using the example of upland rice and maize in Brazil's Cerrados.

Material and Methods

A crop simulation model, from Ecotrop platform (Dingkuhn et al., 2003), was used to determine drought stress patterns for 12 locations and more than 30 environments (6 years x 5 to 6 planting dates) for short and medium duration rice crops (planted in early summer), and for maize grown either as a first or second crop in the summer cycle. Simulation regression analysis, realized to verify drought stress impact on yield for both crops, confirmed the greater drought impact in both crops (quantified as the ratio of water-limited to potential transpiration) when it occurred around the time of flowering and early grain-filling.

To develop a typology of drought patterns for each rice and maize TPE, a four-dimensional matrix consisting of location, sowing date, year and growth phase (100 °C.d period) was established for the mean *cstr* simulated for the 100 °C.d periods. This classification employed a hierarchical agglomerative clustering. For each TPE, the simulated drought stress scenarios were classified into three main groups based on the similarities in the phenological sequence patterns of *cstr*. Similar drought classification procedures were described previously by Chapman et al. (2000).

---

[1] Embrapa Rice & Bean, Rodovia GO 462, km 12, Santo Antônio de Goiás, GO, 75375-000, Brazil, e-mail: alexbh@cnpaf.embrapa.br, phone (55) 62 3533-2110, fax (55) 62 3533-2100;
2 CIRAD BIOS - UPR Modélisation Intégrative, TA A-59/01, Avenue Agropolis, Montpellier, 34398, Cedex 5, France.
3 CSIRO Plant Industry, Queensland Bioscience Precinct, 306 Carmody Rd, St. Lucia QLD 4067, Australia.

Results

For rice, mild mid-season droughts occurred 40 to 60% of the time in virgin (0.4m deep for rice or 0.5m for maize) soils and improved (0.8m for rice or 1.0m for maize) soils, with a yield reduction of <30%. More severe reproductive and grain-filling stress (yield reductions of 50% for rice to 90% for maize) occurred less frequently in rice (<30% of time) and 1st maize crop (< 10% of time). The 2nd maize crop experienced the greatest proportion (75 to 90%) of drought stresses that reduced yield to <50% of potential, with most of these occasions associated with later planting.

The rice breeding station (CNPAF) experiences the same pattern of different drought types as for the TPE, and is largely suitable for early-stage selection of adapted germplasm based on yield potential. However, selection for virgin soil types could be improved by breeding on some less-improved soils in the slightly drier parts of the TPE region. Similarly, the drought patterns at the maize research station (CNPMS) and the other maize screening locations are better suited to selection of lines for the improved soil types. Development of lines for the 2nd crop and on more virgin (acidic) soils would require more targeted selection at late planting dates in drier sites.

Conclusion

For upland rice, both short and medium-duration, the region can be characterized by three different stress patterns. For upland rice short cycle the stress patterns were low (L), mid-season (M) and terminal (T) stress and for medium cycle low stress (L), vegetative stage stress (V) and mid-season to terminal stress (MT). For the scenario with no physical restrictions on root development, the stress level does not limit breeding for potential yield;

For maize as first crop the region also can be characterized by three different stress patterns, nearly environment free of stress (L), a mild, mid-season stress pattern covering both the reproductive and early grain filling periods (M), and severe drought occurring during the late reproductive period (SR). For the scenario with no physical restrictions on root development, the stress level also does not limit breeding for potential yield;

For maize as second crop, the breeding target should be “escaped” (developing of earlier-season cultivars) and/or development of a drought breeding program specific for terminal stress.

References

Pinheiro, B. da S.; Castro, E. da M. de, Guimaraes, C.M. (2006) Sustainability and profitability of aerobic rice production in Brazil. **Field Crops Research**, 97, 34–42.

Chapman, S.., Cooper, M., Hammer, G. L., Butler, D. G. (2000). Genotype by environment interactions affecting grain sorghum. II. Frequencies of different seasonal patterns of drought stress are related to location effects on hybrid yields. **Aust. J. Agric. Sci**., 51, 209-221.

Dingkuhn, M., Baron, C., Bonnal, V., Maraux, F., Sarr, B., Sultan B, Clopes, A., Forest, F. (2003). Decision support tools for rainfed crops in the Sahel at the plot and regional scales. In ‘Decision Support Tools for Smallholder Agriculture in Sub-Saharan Africa - A practical Guide’. (Eds Struif Bontkes TE, Wopereis MCS), 127-139pp. (CTA Wageningen, The Netherlands).