Adapting to heat

The example of rice

Anthesis of a rice panicle, IRRI, Philippines. © T. Lafarge/CIRAD

When growing rice, increased temperatures are a source of sterility. To maintain yields, it is vitally important to adapt flowering processes to heat. Researchers from CIRAD are contributing to develop varieties capable, at the time of flowering: of escaping the heat (anthesis occurs early in the day), avoiding it (the panicle is cooled through transpiration) or tolerating it (presence of genes of interest). Using models, they have shown that the main genetic improvement pathways relate to avoidance and tolerance, whereas ensuring escape would mean adjusting cropping practices, primarily sowing date. This integrative approach is a good example of the strategies adopted in ecophysiology.

Contacts

Tanguy Lafarge
CIRAD, UMR AGAP
Montpellier, France
tanguy.lafarge@cirad.fr
http://umr-agap.cirad.fr

The risks of sterility: changes in the climate and cropping practices

In the Senegal River valley, high air temperatures during flowering can adversely affect plant fertility. As long ago as 1995, optimum sowing windows that minimized the climatic risks were determined using the RIDEV model developed by AfricaRice. However, a recent analysis of weather data showed that temperatures had increased and that the climate (2001-2012) was different from the reference period. The need to update recommendations meant revising the model. To this end, CIRAD has set up a trial network (in Senegal, the Philippines and Camargue) ensuring distinct combinations of climatic factors and contrasting types of planting material in terms of size, plant architecture and crop duration, level of tolerance and yield potential.

Survey in Seriballi, Office du Niger, Mali.
© A-B. Baldé/AfricaRice

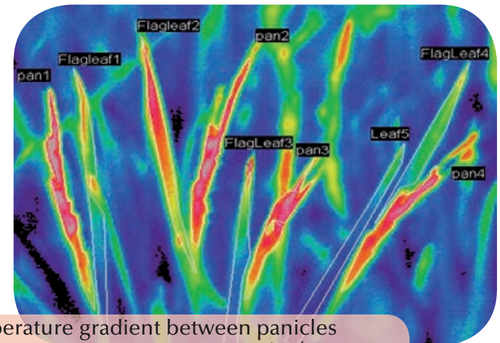
Adaptation through escape: anthesis early in the day

Anthesis is the development stage most sensitive to high temperatures. For a given spikelet, it occurs only in the morning and does not last more than two hours. Through their trial network, researchers have been able to show that anthesis is primarily correlated to the mean of two climate variables, calculated over the seven days that precede flowering: minimum ambient temperature and relative humidity. High air temperatures and relative humidity bring anthesis forward to the early hours of the morning. Conversely, anthesis occurs later in the event of cool, dry conditions. This behaviour is the result of adaptation through escape with respect to high temperatures.

Adaptation through avoidance: panicle cooling through transpiration

When the panicle transpires, it cools itself by consuming energy. At the same time, absorption of solar radiation heats it. The researchers measured panicle temperatures using infrared imaging, and showed that panicle temperature may be several degrees higher or lower than that of the air, depending on the climate conditions. An analysis over the trial network revealed that panicle temperature was primarily correlated to the relative humidity of the air. The rate of spikelet sterility is thus correlated to panicle temperature at the time of flowering, and not to that of the air. The relations established mean that it is possible to predict a degree of sterility once the temperature tops 30°C, with the sterility rate reaching 50% for temperatures of between 33 and 34°C.

Taking an infrared photo, IRRI, Philippines. © T. Lafarge/CIRAD



Temperature gradient between panicles and leaves, IRRI, Philippines. © C. Julia/CIRAD

Adaptation through tolerance: genes that maintain fertility despite the heat

The search for genes involved in heat tolerance at the time of flowering was conducted by studying the statistical correlations between the variations in the genotype and those in the phenotype of 167 traditional to modern varieties. A statistical analysis of the genetic determinism of the sterility rate of the varieties at 37°C detected 91 significant associations concentrated in 12 independent regions of eight chromosomes. The highest heat tolerance was found in two varieties, one originating from India, the other from Taiwan. The genome segments detected pave the way for cloning of the genes involved and implementation of a molecular marker-assisted breeding programme for heat tolerance.

Mature rice cover, Changsha, China. © T. Lafarge/CIRAD

A tool for predicting yields

CIRAD has developed a new version of the model, RIDEV_V2, in partnership with AfricaRice: it simulates the changes in the sterility rate of the cover depending on the sowing date, integrating the variables identified for escape and avoidance. This improved version allows for simulation exercises in order to develop better phenotypes with a high yield potential and high heat tolerance capacity. These steps forward will also make it possible to validate new sowing windows that would avoid climate periods that pose the greatest risk for the fertility of this major food crop.

Partners

Africa Rice (CGIAR), Benin; **IRRI,** International Rice Research Institute (CGIAR), Philippines; **CFR,** Centre français du riz, France. **CGIAR Research Programmes**: **CRP GRISP,** Global Rice Science Partnership; **CRP CCAFS,** Climate Change for Food Security.

› For further information

Lafarge T., Julia C., Baldé A., Ahmadi N., Muller B., Dingkuhn M., 2015. Rice adaptation strategies in response to heat stress at flowering. *In:* Torquebiau E. (ed.). Climate change and agriculture worldwide. Springer (in press)

See also: http://publications.cirad.fr