Plant Ideotypes for climate change

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Global climate is changing and rice production will have to adapt to ensure sustainability and survival. Climate change will lead to increased $C0_2$ and ozone concentrations; more and severe frequent droughts, higher temperatures (mainly night temperatures), and reduced solar radiation.

In the near future, climate change might hinder the increase of rice production rates that are needed to meet the demand of rice in 2050 (Ray et al. 2013) and may result in large gaps between rice supply and demand in some regions. Climate change, not only challenges rice yields but also grain quality, since high temperatures might increase grain chalkiness and affect proteins and starch concentrations in grains (Sreenivasulu et al. 2015). This talk will present a framework for ideotypes design showing the importance of the study of climate variability and genotypic characterization in order to suggest candidate traits to design plant ideotypes for climate change.

The impacts of climate changing conditions on rice production have already been observed year to year. Climate variability explains around 33% of rice yield variability globally. In south America 25% to 38% of yield variability in rice crops was mainly explained by precipitation and temperature variation and/or its interaction (Ray et al. 2015). Using empirical modeling, Jimenez et al, demonstrated that in Colombia from 15 to 40% of yield variability can be explained by climate factors variability depending on the region and the cropping system. In China (Liu et al. 2012) used mechanistic and empirical model to study the impact of climate trends on rice production, and found that past warming led to a reduction in the length of the rice growing season and grain yield. Both studies showed either differential responses of varieties to climate variability(Jimenez, personal communication) or the favorable impact on yield trends of the adoption of new varieties better adapted to changing climatic conditions (Liu et al,2012).

Plant breeding is a large component of yield growth in cereals (Fischer & Edmeades 2010). Adapting agriculture to actual global climate variability with emphasis on rice crop improvement could potentially contribute to mitigate the effect of climate change on rice yields. Under abiotic constrains yield has low heritability. Thus, the inclusion of fast assessment and low cost secondary traits (affecting the yield forming process), with higher heritability and genetic variance, can accelerate breeding for new "climate smart" varieties. Besides, new techniques as genotyping by sequencing and complete genome sequence (3K RGP 2014) are now available for rice and can be used for the genetic dissection of traits.

In spite of the improved knowledge on traits conferring adaptation to abiotic stress, there is little evidence on the inclusion of secondary traits in breeding programs. This could be explained by the lack of knowledge on : (i) the compensation among traits, (ii) the genotypic variability and predominant genetic control and (iii) the behavior of traits in different environments.

Under a general physiological framework, yield is the result of resource capture, conversion and partitioning to different organs and final grains. Partitioning between source and sink organs is often regarded in a static way by analyzing harvest index, however partitioning is a dynamic process and is a result of the source-sink relationships in the different growth phases of the crop. All processes

(resource acquisition, conversion and partition) are under genetic control and will interact with the environment determining the final plant type or Ideotype. (Donald 1968) defined an ideotype as a biological model expected to perform or behave in a predictable manner within a defined environment, emphasizing on the importance of understanding both the genotype performance and the environments to define the relevance of a specific combination of traits. Recently, (Martre et al. 2015)extended this definition suggesting that the ideotype is a combination of different types of traits (morphological , physiological) or its genetic basis that confer enhanced performance for a particular (i) biophysical environment, (ii) specific cropping system and (iii) end use of the crop.

An ideotype for climate change can be defined as the combination of traits (genes) that confers the crop a satisfying adaptation to climate variability and extreme climate events in specific environments and under specific cropping systems. First we will illustrate this concept showing the contribution of physiological secondary traits to understand drought tolerance during the vegetative stage (Rebolledo et al. 2013). Secondly, the importance of environment characterization and secondary traits will be illustrated with an example in a rice productive region in Colombia, where secondary traits were measured in multi- environmental trials. Finally, in order to design ideotypes adapted to Latin America cropping systems, modifications in plant partitioning should be considered to reach a satisfying performance under high density stands.

Our studies of genotype performance under climate variability showed that a single trait will not improve plant performance in all climatic scenarios and also that a single genotype will not cope with all the existing climatic variability. Therefore, the impacts of changing climate on rice will depend not only on spatial and temporal patterns of climate change but also on cultivar characteristics under specific environments and for high dense cropping systems. We suggest a framework to design ideotypes for climate change adapted to site specific condition. This includes, (i) the definition of past, present and future environments scenarios and the response of the local material using empirical or mechanistic modelling, (ii) multi environmental trials to dissect and validate candidate traits and finally (iii) the genotypic dissection of traits in rice varieties in order to validate the breeding value of the proposed ideotypes.

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