SAMARA: A crop model for simulating rice phenotypic plasticity

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Introduction

Plant adaptation to variable resources depends on phenotypic plasticity, enabling adjustment of organ deployment and growth to balance source-sink relationships. Plasticity in rice is mostly compensatory and stabilizes harvest index (HI). Since Donald (1968) proposed the concept of ideotype, breeders sought modifying morphology to increase yield, e.g., in green revolution semidwarfs, IRRI's New Plant Type or China's Super Hybrid Rice (Dingkuhn et al., 2015). But effects of modified morphology and partitioning can be absorbed by compensatory plasticity resulting in unchanged yield. Crop models unable to simulate plasticity are not suited to predict ideotype performance. We sought to model compensatory plasticity with the new crop model SAMARA using IR72 rice. Plasticity in organ number and size is driven by an internal competition index (Ic) relating fresh assimilate supply (S) to aggregate demand (D) in growing organs [Ic=S/D]. Low S triggers reserve mobilization, reduced organ size and mortality of leaves or tillers. Ic>1 promotes storage. The objectives were to (1) study experimentally effects of population and environment on morphology and yield, (2) calibrate and validate SAMARA, and (3) evaluate observed and simulated plasticity.

Materials and Methods

A field trial was conducted in 4 environments in the Philippines: 2012 dry season (DS) and wet season (WS) at International Rice Research Institute (IRRI); 2012 and 2013 DS at the Philippine Rice Research Institute (PRRI). Design was split-plot RCB (4 replications) with factors stand density (D1, 25 hills m^{-2}; D2, 100 hill m^{-2}) and genotype (12 cvs., with only IR72 reported). Fourteen or 21 d old seedlings were transplanted at 2 seedlings $hill^{-1}$ and kept flooded thereafter, using local practice for inputs. For growth analysis, samples were taken at panicle initiation (PI), flowering (FL) and physiological maturity (PM). SAMARA was calibrated using PRRI 2013 DS data (25 hill m^{-2}). Validation was done with 14 combinations of seasons, years, stand densities and sites. For model description with source code, parameters, and input/output variables read http://umr-agap.cirad.fr/en/equipes-scientifiques/modele-samara. Data was analyzed with STAR V2.0.1 (IRRI 2014).

Results and Discussion

Calibrated for IR72, SAMARA simulated tiller production and mortality, and organ dw dynamics (Fig.1A); and plant height, leaf number/size, filled/unfilled spikelets $panicle^{-1}$, and stem reserve dynamics (not shown). Validation for 14 environments gave accurate predictions for agdw at FL (R^2=0.64***) and physiological maturity (PM) (R^2=0.62***),

grain yield (R^2=0.77***), culm number hill^{-1} at PI (R^2=0.94***) and PM (R^2=0.84****), and green leaf dw at FL (R^2=0.58***).

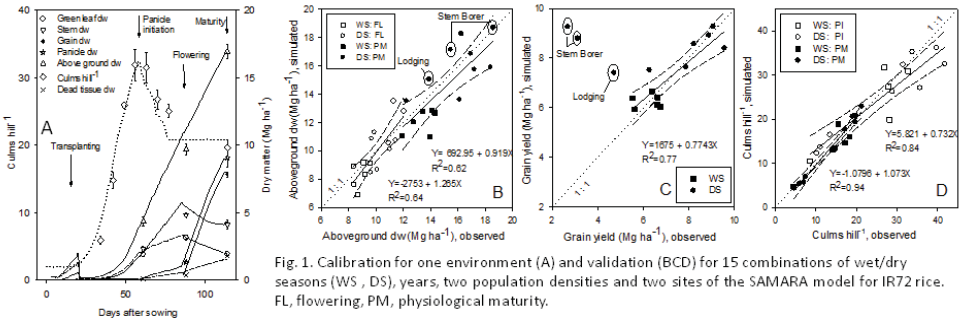

Fig. 1. Calibration for one environment (A) and validation (BCD) for 15 combinations of wet/dry seasons (WS , DS), years, two population densities and two sites of the SAMARA model for IR72 rice. FL, flowering, PM, physiological maturity.

Across the 4 trials, high population reduced tillers hill^{-1}, plant height, flag leaf size, HI and spikelets panicle^{-1}, while increasing LAI, agdw, and tillers and panicles per area (Fig. 2). The model predicted accurately these trends, and also picked up the slight reductions in spikelet fertility and grain yield.

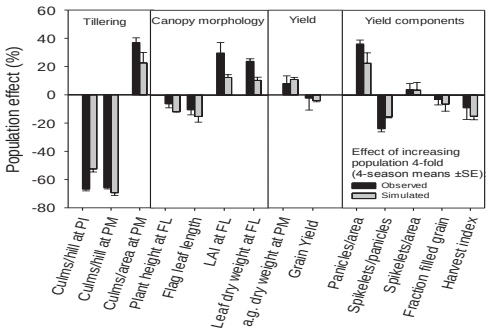

Figure 2. Mean effect (±SE) across 4 environments of 4-fold increased population on observed (black) and simulated (grey) crop variables.

Conclusions

SAMARA captures compensatory plasticity accurately. Next, we will study broader genetic diversity and evaluate yield gains from hypothetical ideotype concepts.

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References

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