PhD School on Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XXXV cycle, 2019-21)

Project draft

1.Field of interest

AGR/02

2.Project title

Biophysical models to support breeding programs

3.Tutor (membro del Collegio dei Docenti):

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- Eventually: co-tutor/s:

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4.Relevance of the topic and state of the art: mezza pagina

Given their capability of interpreting genotype (G) × environment (E) × management (M) interactions, crop models are increasingly considered as powerful tools to support breeding activities (Martre et al., 2015). Representing genotype features via model parameters, indeed, crop models can be used to answer the "what if" question when the potential impact of varying one or more plant traits is under evaluation (Casadebaig et al., 2016). This kind of analysis can involve current conditions and climate change scenarios as well as entire production districts, thus allowing to effectively exploring both spatial and temporal heterogeneity (Paleari et al., 2015). Moreover, physiologically sound crop models have the potential to integrate the effect of genes or QTLs across different hierarchical levels of organization of biological systems, thus providing insight into their impact at crop scale (Chenu et al., 2009).

Despite this potential, model development in last decades has been mainly driven by the need of defining management strategies and agricultural policies, and this limited – although to a different extent – their suitability for ideotyping studies (Tardieu, 2010). Model parameters do not always have a biological meaning and, even when they have, relationships between model parameters and plant traits are often unclear. This could make the model-based definition of putative ideotypes a speculative exercise (Hammer et al., 2002).

5.Layout of the project (draft)

5.1.Materials & Methods: da mezza pagina ad una pagina massimo

The research will be articulated in three main tasks: (T1) improving crop models to improve the relationships between model parameters and plant traits, (T2) identifying ideotypes targeting climate change scenarios in different production contexts worldwide, (T3) extending GWAS potentialities by using crop models to interpret G × E interaction.

T1 will refer to the substitution of key sub-models for specific physiological processes with new approaches explicitly built around plant traits (Paleari et al., 2017). This will be

carried out by targeting 1:1 relationships between plant traits and model parameters. Data to formalize the new approaches will be collected in dedicated experiments performed in growth chambers and field trials.

Within T2, ideotypes will be defined by (i) measuring trait values on genotypes of interest, (ii) deriving statistical distributions for each traits using measured values, (iii) identifying most relevant traits (those breeders should focus on) using global sensitivity analysis techniques (Casadebaig et al., 2016), (iv) deriving optimal values for most relevant traits under different environment (including climate change) and management scenarios; (v) evaluating in silico the performances of ideotypes (i.e., the potential benefits deriving from their in vivo realization).

T3 will refer to integration of techniques based on crop models and GWAS. In particular, crop models will be used to decompose complex traits in simple ones. Then, crop model parameters will be calibrated for many genotypes using existing data from phenotyping experiments and automatic optimizers. Relationships will then be found between genomic data (SNPs) and calibrated parameters. Those relationships, after being validated, will be used to predict – under different environmental conditions – the behaviour of genotypes for which phenotypic data are not available.

5.2.Schedule and major steps (3 years): mezza pagina max

The activities presented and briefly described in the previous paragraphs will be articulated according to the following GANTT diagram.

		Year		
Task	Description	1	2	3
T1	Improving crop models to improve the relationships between model parameters and plant traits			
T2	Identifying ideotypes targeting climate change scenarios in different production contexts worldwide			
T3	Extending GWAS potentialities by using crop models to interpret G × E interaction			

Major steps will be:

- First set of experimental data collected: end of year 1;
- New modelling approaches developed: end of year 2;
- First version of ideotypes available: end of year 2;
- First version of model-based GWAS performed: end of year 2.

6. Available funds (source and amount)

Different projects from regional, national and European calls, more than 200k euros on this research line.

6. Literature: max 10 citazioni

Casadebaig, P. et al., 2016. Assessment of the potential impacts of wheat plant traits across environments by combining crop modelling and global sensitivity analysis. PLoS ONE 11, e0146385.

Chenu, K. et al., 2009. Simulating the yield impacts of organ-level quantitative trait loci associated with drought response in maize: a “geneto-phenotype” modelling approach. Genetics 183, 1507-1523.

Hammer, G.L., Kropff, M.J., Sinclair, T.R., Porter, J.R., 2002. Future contribution of crop modelling from heuristic and supporting decision making to understanding genetic regulation and aiding crop improvement. Eur. J. Agron. 18, 15-31.

Martre, P., He, J., Le Gouis, J., Semenov, M.A., 2015. In silico system analysis of physiological traits determining grain yield and protein concentration for wheat as influenced by climate and crop management. J. Exp. Bot. 66, 3581-3598.

Paleari, L. et al., 2015. District-specific, in silico evaluation of rice ideotypes improved for resistance/tolerance traits to biotic/abiotic stressors under climate change scenarios. Climatic Change 132, 661-675.

Paleari, L., Movedi, E., Confalonieri, R., 2017. Trait-based model development to support breeding programs. A case study for salt tolerance and rice. Sci. Rep. 7:4352.

Tardieu, F., 2010. Why work and discuss the basic principles of plant modelling 50 years after the first crop models? J. Exp. Bot 61, 2039-2041.