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SuMoQuality: a crop growth model to predict seed yield and quality under recurring heat waves

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Introduction

Modelling approaches to predict and to help anticipating risks of heat stress over crop sensitive stages could be reliable decision-making tools. However, these approaches are reliable in stressful contexts that were initially used for model calibration and evaluation.

Among the on going climate change's characteristics, the **recurrence of spring heat waves** has become an increasing threat to winter crops that complete their reproductive phase over the spring and early summer period such as winter oilseed rape (WOSR) (IPCC, 2021).

Successive heat stresses can either amplify the negative effects of late stresses or alleviate these late effects (the so-called 'priming effect' of first stress exposure) as a consequence of stress memory (Magno et al. 2022a, Hilker et al., 2019), thus meaning that the effects of the stresses are not additive.

In this work, we used the **SuMoToRI** crop model that was initially designed to predict the effects of sulfur (S) availability in WOSR which is a high S-demanding crop.

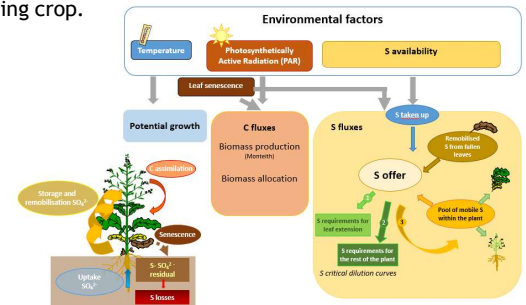


Fig. 1 : Overview of processes and flux in SuMoToRI crop model (Brunel-Muguet et al., 2015)

The objective is to test whether crop models -such as SuMoToRI -are able to predict such non-additive effects of recurring heat stresses

Material and methods

The initial SuMoToRI was implemented to predict seed yield and quality.

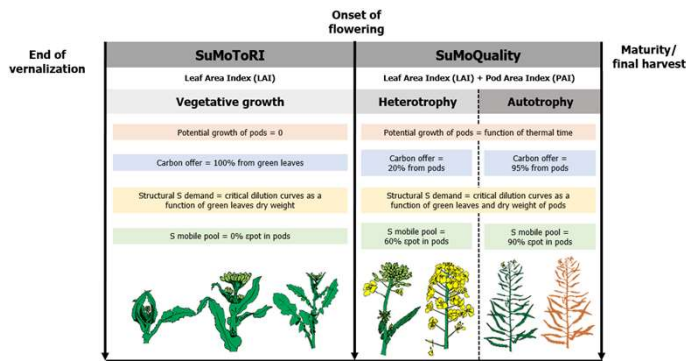


Fig. 2 : Main modifications on SuMoToRI to extend the period of prediction: (i) the pods were added to the photosynthetic surface to be considered for light interception and carbon assimilation, (ii) two periods (in thermal time) were defined to distinguish the pod's heterotrophy from pods' autotrophy and (iii) seed oil content was estimated as a function of the post flowering intercepted PAR (Aguirrezabal et al. 2015) and the seed protein content was negatively correlated to the seed oil content (Hammac 2017).

The **SuMoQuality** model was tested with different heat stress sequences previously used in an in a greenhouse assay. These sequences were initially designed to observe any effect of an early mild stress (EMS) on the magnitude of the effect of later heat peaks (LHP). Two situations were expected: either EMS helps alleviate the negative effects of LHP or the exposure to EMS amplifies the negative effects of LHP in a non additive way.

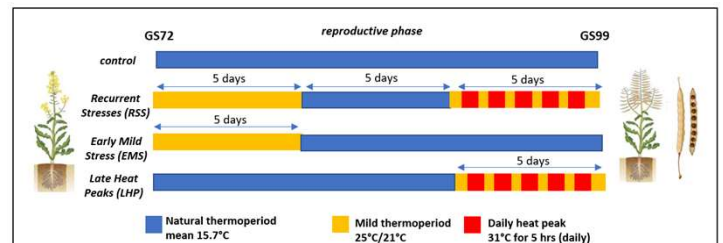


Fig. 3 : Heat stress sequences tested in a greenhouse experiment (Magno et al. 2022b). The stress sequences started at GS72 which corresponds to 20% of the pods that reach final size.

Results

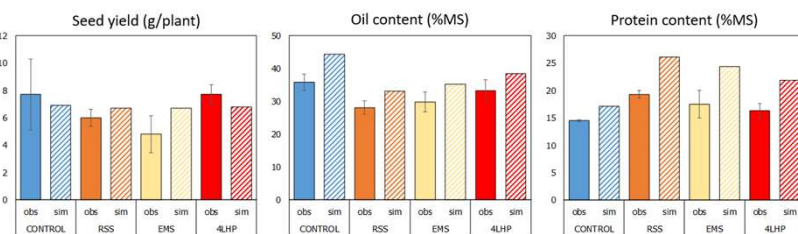


Fig. 4 : Comparisons between observation and simulations performed with SuMoQuality under each heat stress sequence for seed yield, seed oil and proteins contents. Plain and dashed bars present observations and simulation respectively.

- The simulation values were of the same order of magnitude as the observations' values (Fig. 4).
- While seed yield was over estimated for sequences with EMS and under estimated under control and 4LHP, oil and proteins contents were systematically overestimated.
- The model was able to predict the non-additive effects.

Example on seed yield

Observed data indicate that the reduction under RSS was -22.1%, while under EMS and 4LHP, it was respectively -37.7% and null (similar value to the control). Simulated data indicate that the reduction under RSS was -2.9%, while it was -2.9% and -1.4% under EMS and 4LHP respectively.

For both observed and simulated data:
RSS effect = EMS effect + 4LHP effect

Conclusions

These exploratory results indicated that the **SuMoQuality** model was able to predict seed yield and main quality criteria in oilseed rape although the seed oil content was slightly overestimated in the control condition. Under heat stress, trends (increase or decrease) were nicely represented but the model tend to fail simulating correct increase in protein content under repeated heat stresses.

These conclusions indicate that **no additional equations nor structural changes were needed to predict the effects of repeated heat stresses**. The prediction quality is likely to be improved with additional datasets to better calibrate oil and protein content related-parameters.

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