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Durum wheat and climate change: simulation models as a tool to support decisions in targeting genotypes and crop breeding

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Abstract. The CERES-Wheat crop model, included in DSSAT v. 4.0, was used to simulate the grain yields of three Italian durum varieties--Creso, Duilio and Simeto-- grown in two sites, Benatzu (high-fertility soil) and Ussana (low-fertility soil), in Southern Sardinia (Italy). The model was cal brated and validated using long-term weather and agronomic data-sets over the period 1973 to 2004. To assess the responses of durum wheat varieties to increasing temperatures and decreasing rainfall, 48 scenarios were used: 6 scenarios with increasing maximum air temperature from 1 to 6 °C incremented by 1 °C steps; 6 with decreasing rainfall from 5 to 30% of the annual measured amount reduced by 5% steps; 36 combining increasing temperature and decreasing rainfall scenarios. The simulated impact of increasing temperatures and decreasing rainfall scenarios on the grain yields of Creso, Duilio and Simeto were evaluated at both sites and resulted in grain yield reduction for all varieties and sites. The late variety Creso proved to be the most sensitive to the effects of the simulated scenarios. In contrast, the early genotypes Duilio and Simeto showed the lowest grain yield reduction. Compared to results from real experiments in different pedoclimatic conditions, CERES-Wheat model responses effectively express reality. Hence, CERES-Wheat can be reliably used to evaluate plant responses to projected climate change conditions and used successfully to support mitigation strategies such as choice and selection of adapted genotypes to tackle the negative impact of climate change.

Keywords. Durum wheat – Climate change – Simulation models.

Blé dur et changement climatique : les modèles de simulation comme outil d'aide aux décisions de sélection des génotypes et à l'amélioration des cultures

Résumé. *Le modèle de culture CERES-Blé, inclus dans DSSAT version 4.0, a été utilisé pour simuler les rendements en grain de trois variétés de blé dur italien - Creso, Duilio et Simeto-- cultivées dans deux sites, Benatzu (sol à haute fertilité) et Ussana (sol à faible fertilité), dans le sud de la Sardaigne (Italie). Le modèle a été étalonné et validé en utilisant des séries de données météorologiques et agronomiques de long terme couvrant la période 1973-2004. Pour évaluer les réponses des variétés de blé dur à la hausse des températures et à la baisse des précipitations, 48 scénarios ont été élaborés : 6 scénarios avec augmentation de la température maximale de l'air de 1 à 6°C incrémentée par paliers de 1°C ; 6 avec la diminution de la pluviométrie de 5 à 30% de la quantité mesurée annuelle réduite par paliers de 5% ; 36 scénarios combinant température croissante et précipitations décroissantes. L'impact simulé des scénarios envisageant une hausse des températures et une diminution des précipitations sur les rendements en grains de Creso, Duilio et Simeto a été évalué sur les deux sites, révélant une réduction du rendement en grain pour toutes les variétés et les sites. La variété tardive Creso s'est avérée être la plus sensible aux effets des scénarios simulés. En revanche, les génotypes précoces Duilio et Simeto ont montré la plus faible réduction du rendement en grain. Par rapport aux résultats des expériences réelles dans différentes conditions pédoclimatiques, les réponses du modèle CERES-Blé traduisent bien la réalité. Par conséquent, CERES-blé peut être utilisé de manière fiable pour évaluer les réponses des plantes aux conditions du changement climatique prévu et appliqué avec succès pour soutenir les stratégies d'atténuation telles le choix et la sélection de génotypes adaptés pour lutter contre l'impact négatif du changement climatique.*

Mots-clés. *Blé dur – Changement climatique – Modèles de simulation.*

I – Introduction

Crop simulation models are useful tools to determine the potential impact of climate change on production and to define adaptation strategies in order to analyse the most appropriate actions to mitigate the potential negative effects as well as to propose guidelines for plant breeding and agricultural policies. In this study the CERES-Wheat crop model included in DSSAT v. 4.0 (Godwin *et al.*, 1990; Jones *et al.*, 2003) was applied to assess the simulated impact of increasing temperatures and decreasing rainfall on grain production of three durum wheat varieties grown at two different sites in Southern Sardinia (Italy). In addition, the simulated responses of the three varieties to increasingly harsh growing conditions was evaluated.

II – Material and methods

The Italian varieties Creso, Duilio and Simeto were used to test the model performances. The CERES-Wheat model had been calibrated and validated in the test area for the same varieties in a previous study (Dettori *et al.* 2011). Two sites were considered: Benatzu (clay soil with high-yielding potential) and Ussana (sandy-clay soil with low-yielding potential). Experimental data of both sites came from the Italian Durum Wheat Variety Trials. The following study periods were considered: 1974-2004 and 1975-2004 for Creso at Benatzu and Ussana, respectively; 1985-2004 and 1986-2004 for Duilio at Benatzu and Ussana, respectively; 1989-2004 for Simeto both at Benatzu and Ussana. To assess the simulated effects of increasing temperatures and decreasing rainfall on the grain yields of the three durum wheat varieties, 48 scenarios were used to represent paths of possible future climate: 6 scenarios with increasing maximum air temperature from 1 to 6 °C incremented by 1 °C steps; 6 scenarios with decreasing rainfall from 5 to 30% of the annual measured amount reduced by 5% steps; 36 scenarios obtained by combining increasing temperature and decreasing rainfall. The simulated impacts of increasing temperatures and decreasing rainfall on grain yields of the three varieties at Benatzu site were compared over the study period 1990 to 2004, when field trial tests were conducted simultaneously for the three varieties.

III – Results and discussion

Figure 1 shows the predicted effects of simulated scenarios on the three varieties in comparison with the observed values. The increasing negative impact on grain yields when passing from the mildest (temperature increase: +1 °C; rainfall reduction: 5%) to the worst scenario (temperature increase: +6 °C; rainfall reduction: 30%) is clear, especially in the low fertility soil of Ussana. Figure 2 shows the simulated reduction of grain yield over the period 1990-2004 at Benatzu for the same climate change scenarios T1_R5 and T6_R30. Creso (late genotype) seems to be the most prone to the negative impact of climate change when compared to the early varieties Duilio and Simeto. These preliminary results confirm the plausibility of the CERES-Wheat model in evaluating the impact of climate change on wheat production and its possible use to support decisions in targeting genotypes and crop breeding.

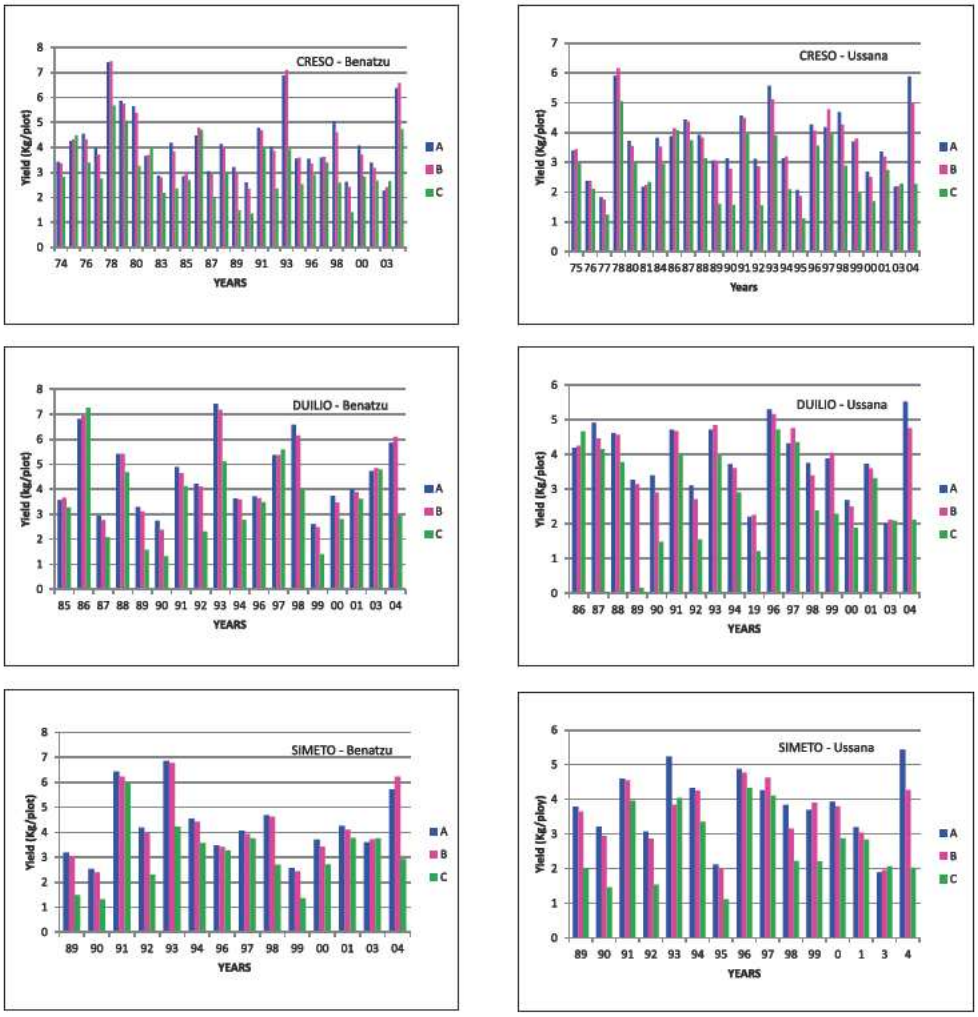

Figure 1. Effects of climate change scenarios on grain yield of durum wheat varieties Creso, Duilio, and Simeto, at Benatzu and Ussana sites. Observed yield data (A), and simulation results from scenarios T1_R5 (temperature increase: +1 °C); rainfall reduction: 5% (B), and T6_R30 (temperature increase: +6 °C; rainfall reduction: 30%) (C).

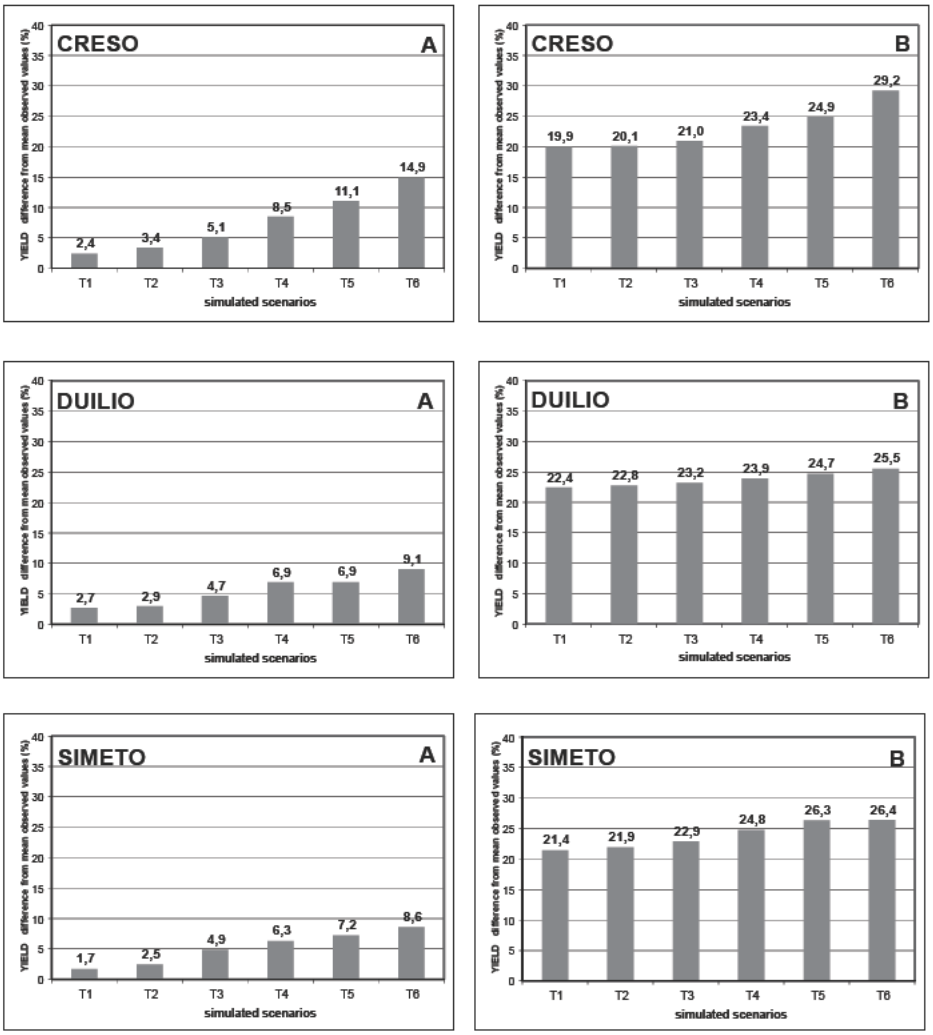

Figure 2. Percentage decline of grain yield over the period 1990-2004 at the experimental site of Benatzu for climate change scenarios characterized by increasing temperature (from +1 °C to +6 °C) and decreasing rainfall by 5% (A) and 30% (B).

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