CLIMATE CHANGE IMPACT ON RAINFED COMMON BEAN PRODUCTION SYSTEMS

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ABSTRACT: Reductions in agricultural productivity with consequences for food security associated to climate change are expected in the absence of adaptation. For common beans, across South America, is projected a decrease in the climatic suitability, with heat and drought stresses being the key drivers for such suitability reduction. This study hypothesize that climatic and atmospheric changes for common beans growing period at rainfed wet growing season in Goiás State are likely to alter the yield by 2030. We considered as historic period from 1980 to 2005 and four representative concentration pathways (RCP - 2.6 and 8.5) for the near future from 2020 to 2045. For assessing the common bean yields we applied the CSM-CROPGRO-DRY BEAN model, calibrated and validated for cultivar Pérola. The climate change impacts on average simulated yield ranged from -267 to 272 and -439 to 314.2 kg ha-1 for RCP 2.6 and 8.5.

PALAVRAS-CHAVE: simulation modeling; global circular models; *Phaseolus vulgaris* L.

IMPACTO DAS MUDANÇAS CLIMÁTICAS NO FEIJÃO DAS ÁGUAS

RESUMO: Devido às mudanças climáticas espera-se uma redução da produtividade agrícola com consequências para a segurança alimentar na ausência de adaptação. Para o feijoeiro, na América do Sul, é projetada uma diminuição da adequabilidade climática, com o calor e o déficit hídrico como os principais causadores dessa redução. Este estudo sugere que as mudanças climáticas e atmosféricas para o período de crescimento do feijoeiro na estação das águas no estado de Goiás provavelmente alterarão a produtividade até 2030. Considerou-se o período histórico de 1980 a 2005 e dois cenários de concentração representativos (RCP), 2,6 e 8,5, para um futuro próximo, de 2020 a 2045. Para a avaliação da produtividade de grãos, aplicou-se o modelo de simulação do feijoeiro, CSM-CROPGRO-DRY BEAN, calibrado e validado para a cultivar Pérola. Os impactos da mudança climática sobre a produtividade média simulada sem mudanças climáticas variaram de -267 a 272 e -439 a 314,2 kg ha^{-1} para os RCPs 2,6 e 8,5, respectivamente.

KEY-WORDS: modelos de simulação, modelos de circulação global; *Phaseolus vulgaris* L.

INTRODUCTION

Brazil is the largest world edible bean producer and consumer (~2.5 million ton in 2013 - IBGE, 2015). Beans constitute a primary source of protein in the diet of the Brazilian population (per capita consumption estimated at 17.8 kg year-1). Rainfed systems represent 93% (2.8 million ha) of common bean Brazilian production area (IBGE, 2015). In the State of Goiás, one of the main bean-producing states in Brazil and the focus of this paper, crop production is concentrated in the same geographic area, but spread across three distinct growing seasons, namely wet (sowing from 1 Nov to 31 Dec), dry (sowing from 01 Jan to 28 Feb) and winter (sowing from 1 May to 30 Jun). In the wet and dry seasons, common beans are grown under rainfed conditions, whereas the winter sowing is fully irrigated. Due to environmental variability, the performance of cultivars varies substantially across seasons, with average yield being 1,700, 1,500 and 2,700 kg ha- 1 for the wet, dry and winter seasons, respectively (IBGE, 2015). The differences in yield between the winter and the two rainfed (wet and dry) seasons imply the occurrence of stresses that limit crop productivity.

Concerns have been raised as to how rainfed bean production systems will be able to sustainably satisfy increasing demand in the context of climate change (Challinor et al., 2014; Ramirez-Cabral et al., 2016). It has been estimated that changes in climate have already been reducing global agricultural production by 1–5% per decade over the last 30 years (Challinor et al., 2014). Reductions in agricultural productivity with consequences for food security associated to climate change are expected in the absence of adaptation in many parts of South America. Specifically for beans, modelling studies have projected a systematic decrease in the climatic suitability for common bean cultivation across most of South America, with heat and drought stresses being the key drivers for such suitability reductions (Ramirez-Cabral et al., 2016).

In this study, we assessed changes in the yields as a result of climate change for rainfed common beans growth at wet season in Goiás State.

MATERIAL AND METHODS

We used observed historical (1980-2005) weather from 26 weather stations in the Goiás State in central Brazil (Fig.1). Future climate data used here are from the CMIP5 (Coupled Model Intercomparison Project Phase 5) ensemble for two representative concentration pathways (RCPs 2.6 and 8.5) and for the four variables needed for simulating common bean growth with the CSM-CROPGRO-DRYBEAN model, namely, daily precipitation, solar radiation, and maximum and minimum temperatures. We downloaded 12 GCMs that presented data for all four variables and RCPs. Since GCM data at daily scale have inherent errors, bias correction (BC) was necessary before the future data was used into the crop model (Ramirez-Villegas et al., 2013). We corrected the data bias using two different methods: (a) the delta method (DEL, hereafter), which applies a correction on the means, and (b) the change factor method (CF, hereafter), which corrects both the means and the variability of the GCM output (Hawkins et al., 2013). A total of 12 [GCMs] x 2 [RCPs] x 2 [BC methods] = 48 individual climate scenarios for the period 2020-2045 were used. The CSM-CROPGRO-DRYBEAN model was calibrated and validate for cultivar Pérola (Heinemann et al., 2016). A total of three soil classes, namely, Oxisols, Ultisols and Inceptisols, which represent 64, 19 and 6% of the agricultural area in the Goiás State, respectively, were finally selected for all model runs. In order to perform spatially explicit crop simulations, we first divided the study area into 26 sub-areas using the Thiessen polygons method. For each sub-area, common bean growth and development was simulated with the crop model CSM-CROPGRO-DRYBEAN, which is included in the Decision Support System for Agrotechnology Transfer (DSSAT). Here, for both historical and future climate conditions, we ran simulations for all soil (n=3) and management scenarios (n=7 sowing dates (from 1/11 to 30/12), respectively). Historical simulations used observed weather data from each of the 26 sub-regions (each containing one weather station), whereas future simulations were conducted for the 48 individual future climate projections (12 GCMs x 2 RCPs x 2 BC methods) for the period 2020-2045 at each sub-region. The CO_2 concentration set for the model in the historical (1980–2005) run was 380 ppm and for the RCPs 2.6, and 8.5 were 446.5 and 501.8 ppm, respectively, which represent the mean value for each RCP for the period 2020–2045.

RESULTS AND DISCUSSIONS

In this study, the climate change impacts on average simulated yield ranged from -267 to 272 and -439 to 314.2 kg ha^{-1} for RCP 2.6 and 8.5 (Fig.1). As expected, the highest variation was at RCP 8.5. The climatic change yield impact was not so high for both RCPs because it was applied the near future (2020 to 2045). However, there was a marked difference of yield gain between RCPs. RCP 2.6 showed a geographic yield gain distribution at the southeast, middlewest, midlle and northeast Goiás region, while RCP 8.5 showed a yield gain in a few areas of Goiás State (Fig. 1B).

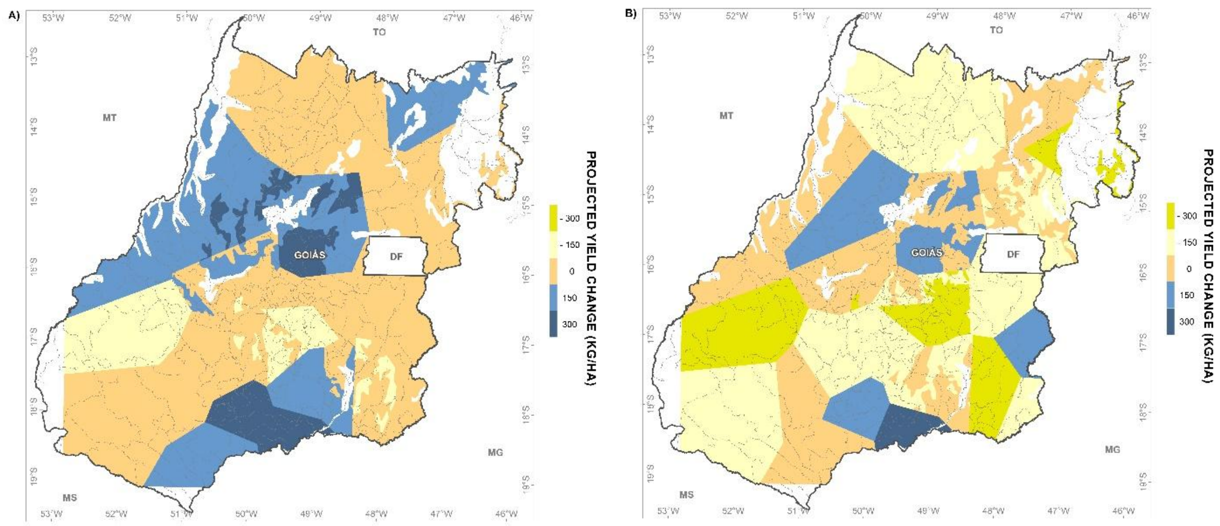

Figure 1. Median projected change in average yield by 2030s for wet season and RCPs 2.5 and 8.5, expressed as difference (in kg ha^{-1}) with respect to the historical average yield for cultivar Pérola.

In Latin America, studies that investigate common bean yield responses to climate change are scarce, but these generally indicate negative effects from climate change. Eitzinger et al. (2016) showed that yields, on average, are projected to reduce in Central America by 2020s and 2050s. Yield reductions were spatially heterogeneous, and mainly driven by temperatures. Similar findings are reported by Ramirez-Cabral et al. (2016), who used a crop suitability approach to map changes in common bean suitable areas by 2050s. However, in both studies did not simulate direct CO_2 effects. This study found an important role for the interactions between temperature-driven duration reductions (acting to reduce yield) and CO_2 response (acting to increase yield and ameliorate drought); these result in changing yield distributions mainly for RCP8.5.

CONCLUSION

This study showed that there is an interaction between temperature and CO_2 for common bean and it is changing the yield distribution for the wet common bean season at Goiás State.

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