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Research paper

Assessment of potato response to climate change and adaptation strategies

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ABSTRACT

This study was conducted to simulate the climate change impacts on potato production and evaluate the planting date and variety management as possible climate change adaptation strategies in Isfahan province, Iran. Two types of General Circulation Models (HadCM3 and IPCM4) and three scenarios (A1B, A2 and B1) were employed. Daily climatic parameters were generated by Long Ashton Research Station-Weather Generator (LARS − WG). The SUBSTOR-Potato model was used to simulate the baseline and future potato growth and development. Results indicated that LARS-WG and SUBSTOR-Potato had an appropriate accuracy to simulate climatic and growth parameters of potato. Simulated results showed that the maximum leaf area index (LAI), days to tuber initiation (DTTI), days to harvest (DTH) and fresh tuber yield of evaluated variety will be declined as affected by future climate change. Based on the simulation results, delayed planting date (31 May) would increase tuber yield under future climatic conditions. In the contrary, early planting (30 April) would accelerate harmful effects of climate change on potato yield. The medium and early maturing varieties showed a better tuber yield under climate change conditions than common (delayed maturing) variety. In essence, early maturing variety and delayed planting date are reported as the most efficient agronomical approaches for mitigating harmful effects of climate change and proposed to be considered in designing and managing potato ecosystems of the region for future climatic conditions. Generally, our results highlight the importance of considering early maturing variety and delayed planting date as the efficient agronomical approaches for mitigating harmful effects of climate change on potato production.

1. Introduction

Total field crops production in Iran is estimated at about 94 million tons on 13,500,000 ha in 2013. Potato (*Solanum tuberosum* L.) is one of the important crops grown in Iran. It is grown almost all over the country under varied soil and climatic conditions. Total potato production area is approximately 191,000 ha with total production of 4.05 million tons in 2013 (MAJ, 2014).

The historic trend of mean annual temperature of Iran indicates an increase of 0.05 °C per year (Moradi et al., 2013). Based on this fact, it is expected that the emissions of greenhouse gases will continue and as it has been seen in the recent years in scientific experiments and real conditions, combined effects of these two parameters will cause some predictable and unpredictable climatic changes (IPCC, 2007). This environmental change will consequently have serious impacts on growth and development of different processes. For example, elevation of temperature could affect physiological processes such as photosynthesis, respiration and partitioning of photoassimilate (Chartzoulakis and Psarras, 2005; Yang and Zhang, 2006). The final effect of climatic change will depend on local conditions. So, in regions with cold spring and summer seasons that the growing season length is limited, warmer conditions might be beneficial for crop yields. But, locations with warmer climate will see yield reductions if temperature increase (Meza et al., 2008). Increasing temperature can lead to shorten growth and grain-filling duration of crops (Boote, 2011). Additionally, various cultivars of crops may show different responses to future climate changes due to different lengths of seasons.

The negative impacts of climate change on potato productivity have been extensively reported in the literature (Rosenzweig et al., 1996; Hijmans, 2003; Holden et al., 2003; Daccache et al., 2011; Van der Waals et al., 2013; Sparks et al., 2014; Kumar et al., 2015). Although, farmers are not able to change or manage the climatic conditions but

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some factors such as soil, water, cultivars type and agricultural practices can be managed to reduce the adverse impacts of climate change (Ozkan and Akcaoz, 2002; Moradi et al., 2013). Adaptation is a known way for reducing the negative impacts of climate change on crop productions (Moradi et al., 2014). The aim of adaptation is minimizing the potential negative impacts of climate change while maximizing opportunities for adjustment (Rosenzweig and Tubiello, 2007; Moradi et al., 2013). In IPCC (2007) reports, various adaptation strategies for moderating the projected climatic changes including changing planting date, altered crop rotations, changing cultivars, more efficient water use; altering the timing or location of cropping activities; development of new agricultural areas, improving the effectiveness of pest, disease and weed management practices were suggested. Without adaptation and mitigation strategies, climate change is generally problematic for agricultural production and economies (Smit and Skinner, 2002).

The crop models such as SUBSTOR-Potato can be used for crop growth and development estimating in climate change conditions. The model has been used previously for potato and climate change impact assessments (Han et al., 1995; Travasso et al., 1996; Hodges 1998; Holden et al., 2003; Stastna et al., 2010; Daccache et al., 2011 ; Arora et al., 2013; Martre et al., 2017; Raymundo et al., 2017).

The present study was undertaken with the aims of quantifying the potential impacts of climate change on phenology, growth and tuber yield of potato and to evaluate the effectiveness of planting date and variety management strategies for minimizing climate change impact on potato production in Iran. To achieve these objects, the experiment was performed during 2011, 2012 and 2013 growing seasons in Fereydoon-Shar region, Isfahan province, Iran.

2. Material and methods

2.1. Study area

The study was conducted in Fereydoon-Shahr region, Isfahan province, Iran. The province is located in the center of Iran, within 30° 43′ and 34° 27′ north latitude and 49° 36′ and 55°31′ east longitude and covers an area of about 107,027 Km^2. This area is inhabited by more than 5 million people and agriculture plays the main economic role. Fereydoon-Shahr region with minimum temperature −17.6 °C, maximum temperature 34.6 °C, cumulative annual radiation 7781 MJ m^{-2} and annual precipitation 600 mm, has a suitable condition for potato growth and cultivation. Cultivated area of the region including field and horticultural crops is 440,743 ha (MAJ, 2014). Potato is grown during spring-summer season (May to October) under irrigated conditions with a fairly intensive use of chemical fertilizers. Minimum temperature, maximum temperature, cumulative annual radiation and annual precipitation of the region during the potato growing season (May to October) were 3.6 °C, 34.6 °C, 4076 MJ m^{-2} and 34.8 mm, respectively.

2.2. Data set and climate model

We used climate projections from the Hadley Centre Coupled Model version 3 (HadCM3) and France and Institute Pierre Simon Laplace (IPCM4), United Kingdom. The HadCM3 model is a coupled atmosphere-ocean global circulation model (GCM) developed at the Hadley Centre has stable control climatology and does not use flux adjustment (Meza et al., 2008). The scenarios used were SRES (Special Report on Emissions Scenarios) − A2, SRES − B1 and SRES − A1B. The SRES − A2 indicated very heterogeneous world conditions with high population growth rate, slight economic development and slow technological change (IPCC, 2000; Prudhomme et al., 2010). The SRES − B1 defines a convergent world with a global population that peaks in mid-century and rapid changes in economic structures towards a service and information economy with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity but without additional climate initiatives (Prudhomme et al., 2010; Wetterhall et al., 2009) and the SRES − A1 B scenario describes a world of rapid economic growth, a global population that peaks in mid-century and declines thereafter, and more efficient technologies based on a balanced energy mix (IPCC, 2000).

Daily climate data including solar radiation (Mj m^{-2} day^{-1}), maximum and minimum air temperature (°C) and precipitation (mm) were obtained for the period of 1982–2012 for Fereydoon-Shahr meteorological station.

LARS − WG (Long Ashton Research Station-Weather Generator) was used to generate daily climatic parameters as one stochastic growing season for each projection period. These data included radiation, maximum and minimum air temperature and precipitation for four projection time (1982–2012 (baseline), 2015–2045, 2046–2075 and 2076–2105). LARS-WG is a stochastic weather generator based on the time series approach (Semenov and Stratonovitch, 2010). LARS-WG produces synthetic daily time series of solar radiation, maximum and minimum temperature and precipitation. LARS-WG applies observed daily weather data for a given site to compute a set of parameters for probability distributions of weather variables as well as correlations between them (Semenov and Brooks, 1999).

2.3. Weather generator uncertainty

Climate model uncertainty analysis was performed by two methods. First of all, uncertainty of solar radiation, maximum and minimum temperatures and precipitation has been evaluated by comparison between mean observed values and simulation results assuming normal distributions of the variables (Khan et al., 2006). In addition, uncertainty was evaluated by Wilcoxon rank sum method. This test is a nonparametric alternative to the two-sample *t*-test which is based solely on the order in which the observations from the two samples fall (Conover, 1980). Based on the Wilcoxon rank sum method, if the *P*-value is more than 0.05, there is no significant differences between populations and vice versa.

2.4. Potato growth model

The SUBSTOR-Potato model was used for simulating the baseline and future yield and growth characteristics of potato. This is one of sixteen models embedded within the DSSAT (v4.5) program (Jones et al., 2003). The SUBSTOR-Potato model was completely described by Griffin et al. (1993). The SUBSTOR-Potato model simulates on a daily basis the growth and development of the potato crop using information on climate, soil, management and cultivar. The model is divided into four main sub models simulating simultaneously the phenological development, the biomass formation and partitioning, soil water and nitrogen balances to provide a realistic description of the plant–soil–atmosphere system (Ritchie et al., 1995; Jones et al., 2003). The SUBSTOR-Potato model has been used more recently for climate change impact assessments (Holden et al., 2003; Daccache et al., 2011; Arora et al., 2013; Martre et al., 2017; Raymundo et al., 2017). Weather and soil data, agronomic practices and genetic coefficients of potato are the main inputs to run the SUBSTOR-Potato model.

2.4.1. Crop model calibration

It is important that the crop model can accurately predict observed variations in historical yield, before modelling climate impacts on future yield. For calibration and validation the SUBSTOR-Potato model, an experiment was performed in three years (2011, 2012 and 2013), that two years data were used for calibrating and one year for validating the model. So, the SUBSTOR-Potato was calibrated by two years experiment as spilt-plot based on the randomized complete block design with three replications, which was conducted in 2011 and repeated