PEANUT CROP RESPONSES TO CLIMATE VARIABILITY IN CORDOBA, ARGENTINA: A SIMULATION STUDY

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SUMMARY

We investigate the effect of changes in the mean and in the daily and interannual variability of temperature on peanut yields simulated by CROPGRO V3.5 model at one location in the Córdoba province, Argentina, under irrigated and rainfed conditions. By applying an stochastic weather generator to 28 years of observed weather data, series of 99 years of simulated weather which include changes in the mean (no mean change, mean + 1.5 °C and mean + 3.5°C) and changes in the variance of temperature from 0.5 to 2.0 in 0.25 increments were generated. Temperature increase alone resulted in shortened crop cycle, slight decreased in yield in the irrigated experiment and decreased yield in the rainfed experiment. Increased variability produced yield decreases and increased crop failure in both experiments. Some complex interactions resulting from the combined mean and variance changes were found.

Key words: peanut, climate variability, crop simulation models

INTRODUCTION

In the coming decades, global agriculture faces the prospect of a changing climate, mainly induced by the increasing concentration of radiatively active greenhouse gases (IPCC, 1990a, 1992, 1996a), as well as the known challenge of continuing to feed a rapid growing world population. Due to the close links between climate and agriculture, concern about potential climate changes has lead, among other things, to efforts to estimate consequences of these changes on agriculture production.

Most climate change agricultural impact studies have analyzed the effects of changes in the mean value of climate variables (mainly temperature and rainfall) on crop production (e.g., Smith and Tirpak, 1989; Santer *et al*., 1990; Rosenzweig and Parry, 1994). Similar studies have been done in Argentina (e.g. Baethgen y Magrin, 1995; Magrin *et al*., 1997). In contrast, the impact of climate

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variability changes have been much less studied (e.g., Wilks, 1992; Mearns *et al*., 1992, 1996, 1997; Riha *et al*., 1996). Climatic variability is the major cause of inability to achieve potential yields in irrigated and dryland production areas and can generate substantial production variability (Parry and Carter, 1985). It is experienced by crops mainly through the occurrence of damaging extreme events, such as droughts, freezes, and heat waves (Mearns *et al*., 1984). Although there is considerable uncertainty regarding how climate variability will change for any given region under perturbed climate conditions, it is important to determine what degree of change in climate variability is significant to the different biophysical systems (IPCC, 1996b).

Argentina is mainly an agro-exporter country. Most of the agricultural production is based in the Pampa region which covers approximately 34 million hectares of agricultural land (Hall *et al*., 1993). The Pampa region lies between 30° and 41° latitude and has a temperate, humid-subhumid climate with occurrence of seasonal droughts. The agricultural productive system is basically extensive rainfed production which is extremely dependent on weather conditions. Peanut production is mainly concentrated (99 %) in the central and southwest area of Cordoba Province (west portion of the Pampa region). Annual yield variability is determined by weather conditions (mostly rainfed production), due to the lack of water in critical crop periods. Although peanut yield and quality has been increasing as the result of better crop management, climate variability is still a key factor in determining crop productivity. The main objective of this study is to assess the effect that changes in daily and interannual climatic variability could exert on peanut crop growth, development and yield under different environmental conditions and crop management practices in Córdoba Province, Argentina.

MATERIAL AND METHODS

Crop Model

To simulate peanut crop growth, development and yield under different climate scenarios, CROPGRO V3.5 model is used. This model was released in 1998 by ICASA (International Consortium for Agricultural Systems Applicationsin) as part of the DSSAT V3.5 (Decision Support System for Agrotechnology Transfer). CROPGRO model is a process-based model for grain legumes that considers crop development, crop carbon balance, crop and soil nitrogen balance, and soil water balance. CROPGRO has a common set of FORTRAN code and all species attributes associated with dry bean, peanut, and soybean are input from species files, plus information contained in eco- type and cultivar files. Climate input variables are daily solar radiation (MJ m^{-2} day^{-1}), minimum and maxi- mum temperatures (°C), and precipitation (mm day^{-1}). Other inputs include soil and cultivar specific parameters and management factors (e.g., plant population, row spacing, sowing depth). Description of the model structure, processes, relationships to climatic factors etc., may be found in Boote *et al*., (1997, 1998). Some assumptions of CROPGRO model as used in this study are that nutrients are not limiting, and weeds, diseases, insect pests and poor management do not constrain yields.

Stochastic weather generator

We used WGEN (Richardson and Wright, 1984) to generate daily weather data. WGEN provides daily values of maximum and minimum temperature, incident solar radiation, and precipitation for and n-year period at a given location. The ocurrence of rain on a given day has an influence on temperature and solar radiation for the day. The frequency of precipitation is generated independently for a given day and it is represented by a two-state first order Markov chain model. Precipitation amount on wet days are generated via the gamma distribution. Maximum temperature, minimum temperature and solar radiation are then generated depending on whether a wet day or dry day was generated. The model is designed to preserve the dependence in time, the correlation between variables, and the seasonal characteristics in actual weather data for the location (Richardson, 1985). The relationship between annual and daily variability is described in Mearns *et al*., 1996. Approaches to changing the variability of stochastically generated climate time series were adumbrated by Mearns (1989) and described in more detail by Wilks (1992)

Study characteristics

CROPGRO V3.5 was calibrated and validated for peanut using data from one location situated in the peanut productive region of Córdoba province (Manfredi, 31° 48’ S Latitude, 63° 46’ W Longitude, 292 m above sea level). Florman INTA, a runner type cultivar commonly used in the region, is sown every year on November 16th, at a plant density of 12.2 plants/m^{-2} and at 0.7 m distance between rows on an Oncativo silty loam soil (Entic Haplustoll). Simulations were done under rainfed and irrigated conditions (automatic irrigation, refilled profile when available soil water is less than 50% in the first 0.3 m of the soil) and soil water content is initialized to the same value every year.

The parameters for the weather generator were estimated from 28 years (1969-1996) observations for the location. Using these parameters, 99 years of daily weather data including changes in the mean and the variance of temperature and the baseline climate were generated. Changes in the mean and variance of precipitation were not considered in this study. Daily temperature variance changed by factors from 0.5 to 2.0 in 0.25 increments. Two mean temperature changes were also applied, 3.5 °C (T_{Mean} + 3.5) and 1.5 °C (T_{Mean} + 1.5). Thus, a total of 24 cases were established: the base case (using the real weather data for the site), the base case altered by the two mean temperature changes, the seven variance changes with no mean change, and then the combined variance and mean changes (14 cases). In discussing the results, we compare changes in the mean and variability of yields and frequency of crop failure using the coefficient of variation of yield.

RESULTS AND DISCUSSION

Comparison between yields simulated using 28 years of observed climate data (BASE) and those simulated using the stochastically generated climate is presented in Table 1, for the irrigated and rainfed experiments. In both cases mean simulated yields were very similar to mean observed yields, when no change in variability is included (Variance change=1) although the Standard Deviation (SD) and the Coefficient of Variation (CV) are much higher under the observed climate. WGEN underestimated the interannual variability of climate, and thus, will likely result in lower variability of crop yields when generated time series are used.

Mean temperature increases alone resulted in slight yield increases for the T_{Mean} + 1.5 case while no change was observed in the T_{Mean} + 3.5 case in the irrigated experiment (Table 1). Temperature increases shortened the growing period by 15 and 21 days for the T_{Mean} + 1.5 and T_{Mean} + 3.5 cases respectively. More reduction ocurred in the period from first flower to maturity. As temperature was increased, mean number of seed per square meter (SEEDN) and total biomass at harvest (TOTB) increased, mean seed weight (SEEDW) decreased and number of seed per pod (SEEDP) remained constant. At higher than optimun temperatures, yield is not enhanced because of the non-optimal conditions for seed growth and the progressively declined of the harvest index (Hammer *et al*., 1995). When the growing period is extended more than normal, crop failure may occur as the crop does not reach maturity due to killing frost. As the growing period is shortened under increased temperatures, crop failures decreased to zero.

In the rainfed experiment, mean temperatures increases resulted in yield and SD decreased d and an increased in CV (Table 1). Compared to the no mean change, T_{Mean} + 1.5 and T_{Mean} + 3.5 cases shortened the growing period was shortened by 16 and 26 days respectively. Also, more reduction in the period from first flower to maturity was observed. Temperature increases reduced SEEDW and increased SEEDN for T_{Mean} + 1.5 and T_{Mean} + 3.5 cases in BASE. SEEDN and TOTB were reduced in the T_{Mean} + 3.5 case for the simulated observed climate while TOTB was increased in the T_{Mean} + 1.5 case Crop failures were reduced to zero due to the shortened cycle.

Change in temperature variance modifies the effect of mean temperature increase (Table 1). As temperature variance increases, mean yield decreases and SD and CV increased in the rainfed and irrigated experiments. The detrimental effect of variance increase was experienced by the crop through a very high incidence of crop failure due to frost, as the growing period is extended. Variability increase exposed the crop to large fluctuations in temperatures, and thus higher frequency of extreme temperatures above the optimal level during the different crop stages. SEEDN and SEEDW decreased in the rainfed experiment for no mean change and increased in the combined variance and temperature change cases. In the irrigated experiment, SEEDW decreased in the three cases while SEEDP do not change and slightly decreased or remained constant in the rainfed experiment. TOTB decreased and their CV increased in both experiments under the different combinations of variance and mean temperature changes. Some complex interactions resulting from the combined mean and variance changes were found.

Table Erro! Argumento de opção desconhecido.: Simulated yield (kg/ha) from observed climate (BASE) and from simulated climate with different changes in the mean and variance of temperature, for the **irrigated** and **rainfed** experiments

Irrigated		**Variance changes**							
		0.5	0.75	1.0	1.25	1.50	1.75	2.0	BASE
No Mean Change	Mean	5593	5495	5380	5243	5091	4916	4701	5320
	SD	241.9	261.8	300.2	374.1	497.5	557.8	713.4	560.9
	CV(%)	4.3	4.8	5.6	7.1	9.8	11.3	15.2	10.5
T_{Mean} + 1.5	Mean	5700	5623	5552	5479	5386	5268	5148	5523
	SD	265.3	247.9	257.9	262.1	282.7	355.7	382.8	563.3
	CV(%)	4.7	4.4	4.6	4.8	5.2	6.8	7.4	10.2
T_{Mean} + 3.5	Mean	5516	5446	5389	5319	5251	5182	5105	5369
	SD	284.7	285.4	291.2	283.2	287.4	311.7	321.9	584.2
	CV(%)	5.2	5.2	5.4	5.3	5.5	6.0	6.3	10.9
Rainfed									
No Mean Change	Mean	1517	1443	1369	1291	1213	1141	1051	1245
	SD	836.9	808.8	781	749.8	722.8	694.4	652.7	1012.6
	CV(%)	55.2	56.1	57.1	58.1	59.6	60.8	62.1	81.3
T_{Mean} + 1.5	Mean	1461	1381	1305	1231	1166	1103	1043	1262
	SD	832.1	802.8	772	739.6	714.7	685.7	655.7	1057.7
	CV(%)	57	58.1	59.2	60.0	61.3	62.2	62.9	83.8
T_{Mean} + 3.5	Mean	1189	1120	1050	990	932	885	840	1070
	SD	732.6	698.9	660.8	630.9	598.6	573.3	549.4	1004.3
	CV(%)	61.6	62.4	62.9	63.8	64.2	64.8	65.4	93.9

Where: Simulated observed climate, Variance change=1; T_{Mean} + 1.5 °C = maximum and minimum temperatures increased by 1.5 °C; T_{Mean} + 3.5 °C = maximum and minimum temperatures increased by 3.5 °C; Mean = mean yield (kg/ha); SD = Standard Deviation (kg/ha); CV = Coefficient of variation (%).

CONCLUSIONS

The effect of changes in mean and daily and interannual variability of temperature on simulated yields were significant. In both experiments, increased temperature variability substantially decreased mean yields and increased their variability mainly due to increased frequency of crop failure, as the growing season is extended. As climate change will bring about changes on both time scales, studies of this type in spite of their shortcomings, provide useful information about crop responses to those mean and variance changes.

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