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Evaluation of the CROPGRO-Peanut model in simulating appropriate sowing date and phosphorus fertilizer application rate for peanut in a subtropical region of eastern India

Debjani Halder[a,*], *Rabindra Kumar Panda*[b], *Rajiv Kumar Srivastava*[c], *Shyamal Kheroar*[d]

[a]*Department of Agriculture, Government of West Bengal, Mathabhanga, Cooch Behar 736 146, West Bengal, India*
[b]*School of Infrastructure, Indian Institute of Technology, Bhubaneswar 751 013, Odisha, India*
[c]*Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur 721 302, West Bengal, India*
[d]*Department of Agronomy, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar 736 165, West Bengal, India*

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ABSTRACT

Projected changes in weather parameters, mainly temperature and rainfall, have already started to show their effect on agricultural production. To cope with the changing scenarios, adoption of appropriate management strategies is of paramount importance. A study was undertaken to evaluate the most appropriate combination of sowing date and phosphorus fertilization level for peanut crops grown in sandy loam soil in a subhumid region of eastern India. Field experiments were conducted during the summer seasons of 2012 and 2013 on peanut crops at the farm of the Indian Institute of Technology, Kharagpur. The DSSAT v4.5 CROPGRO-Peanut model was used to predict the phenology, growth, and yield of peanut crop under combinations of four sowing dates and four phosphorus fertilization levels. The model was calibrated with a 2012 dataset of growth, phenology, and yield parameters for estimating the genetic coefficients of cultivar TMV-2 and was validated with a 2013 dataset of the same parameters. Simulations of pod yield and other yield parameters using the calibrated model were found to be quite accurate. The model was able to reasonably simulate pod yield and final biomass with low normalized root mean square error ($RMSE_n$), low absolute root mean square error ($RMSE_a$) and high coefficient of determination ($R^2 > 0.7$) over a wide range of sowing dates and different phosphorus fertilization levels sensitivity analysis indicated that sowing from the second week of January to the end of February with 30–50 kg P_2O_5 ha^{-1} would give the highest pod yield.

1. Introduction

Eastern India, which is one of the major contributors to Indian agricultural food production, is facing various challenges owing to weather variation in recent years. Erratic rainfall distribution, particularly during the monsoon season, is causing drought or flooding in alternate years and reduction in yield of major food crops including rainfed rice (*Oryza sativa* L.), and other field crops.

* *Corresponding author.*
E-mail address: debjaniiit@gmail.com (D. Halder).
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Accordingly, contingent crop planning using short-duration and high-value crops should be performed to protect farmers from heavy crop yield and monetary losses. Growing peanut (*Arachis hypogaea* L.), an important oilseed as well as a high-value cash crop, can be considered as an alternative adaptation strategy for poor farmers who depend solely on agriculture. In India, about 75% of the peanut growing area lies in a low- to moderate-rainfall zone with a short growing period (90–120 days). The crop is grown mainly in the rainy (*Kharif*) season (June to September), accounting for about 80% of the total peanut production. But owing to variation in monsoon rains, peanut production fluctuates in major growing areas. In the southern and eastern part of the country, peanut is cultivated during the post-monsoon and pre-monsoon season. However, if irrigation facilities are available, peanut can be planted from January to May as a summer crop. According to Bandyopadhyay et al. [25] peanut cultivation under irrigated conditions during the summer season (March–June) may increase the productivity of the crop by two to three times relative to the monsoon crop. For this reason, studies have been conducted to determine appropriate sowing dates for peanut to obtain potential yield in most peanut-growing countries worldwide [21,23,29]. Significant differences in shelling percent among sowing dates were observed, in the ranges of 66%–80% in the *Kharif* and 66%–73% in the *Rabi* season. Hundred-pod weight ranged from 74 to 107 g in the *Kharif* and 65 to 110 g in the *Rabi* [31]. On the basis of experiments conducted during all seasons, Reddy [22] reported that *Rabi* peanut gave an additional yield of 156% in 1989 and 134% in 1990 over the summer-season crop. In both years the harvest index was considerably higher (39.9% and 48.0%) in *Rabi* than in *Kharif* (32.7% and 37.3%) and summer (24.5% and 18.9%). Sharma and Yaday [1] stated that phosphorus fertilizer plays a beneficial role in legume growth and development. It promotes extensive root development, which improves the supply of other essential nutrients and water to the growing parts of the plants, resulting in increased photosynthetic area and accumulation of more dry matter [14,26,32,34]. In addition, the productivity of peanut is lowered in the highly acidic soil in the tropical region of the country [20,30]. The lower concentration of phosphorus fertilizer as well as the presence of toxic elements such as aluminum and lower concentrations of calcium, potassium, and magnesium reduce peanut yield [3,28].

To assess the scope for increasing peanut production in India, is prerequisite to know the yield potential of and to identify factors limiting the yield of peanut. Such knowledge can be obtained by conducting field trials over several years to evaluate crop management practices in different environments. An alternative approach is to use validated crop growth models and historical climatic data to evaluate various crop management strategies for locations or regions on a long-term basis. To meet these objectives, peanut crop models have been developed in the U.S. [10,11,15,17,18] and in India [24] to quantify growth responses to various management practices. The Cropping System Model (CSM)-CROPGRO-Peanut is a process-oriented model that is part of the Decision Support System for Agrotechnology Transfer (DSSAT) [6,12,16]. The model has been evaluated extensively for investigating multiple environmental conditions and evaluating crop yield, cultivars, cropping practices and genetic coefficient [18]. Accordingly, the validated model can be used to predict growth and yield responses to sowing dates, nutrients, row spacing, and irrigation. The objective of the present study was to evaluate the performance of the model for peanut crops grown in subhumid and subtropical regions of eastern India and to identify appropriate combinations of sowing dates and phosphorus fertilization levels by sensitivity analysis.

2. Materials and methods

2.1. Field experiment

Crop experiments were conducted in summer peanut during 2012 and 2013 at the experimental farm of the Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India (22°19′N latitude and 87°19′E latitude; 48 m above mean sea level). The growth and yield data collected from the experiments were used to calibrate and validate the DSSAT v4.5 CROPGRO-Peanut model. In the field experiments, 16 treatment combinations, including four planting dates (January 14 and 29, February 14 and 28) and four phosphorus fertilization levels (0, 40, 60, and 80 kg P_2O_5 ha^{-1}) respectively, were used and replicated three times, with plot sizes of 20 m^2. The whole experiment was designed following the split-plot technique (main factor: date of sowing; subfactor: fertilizer dose). Peanut seeds of cultivar TMV-2 (Spanish, bunch-type cultivar) were treated with culture (*Rhizobium japonicum*) at 25 kg ha^{-1} and sown at a depth of 5 cm with 30 cm row-to-row and 20 cm plant-to-plant spacing. The soil of the experimental site was red lateritic and sandy loam. The soil contained 14%–28% clay, 19%–26% silt, and 52%–59% sand with bulk density 1.56–1.62 g cm^{-3}. The soil had pH 5.5–5.9 and 0.15%–0.32% organic carbon as well as 0.04% total nitrogen, 0.04% phosphorus and 0.42% potassium [27].

During both years, all the plots were irrigated with measured amounts of water at regular intervals of five days to 45 cm of root zone depth to maintain field capacity and ensure no water stress during the cropping season. Leaf area (cm^2) plant^{-1} was measured with a leaf area meter (AC Mas Technocracy Pvt. Ltd., Sr. no. 1303–1161) 25 days after emergence.

Daily temperature (maximum and minimum), rainfall, solar radiation for the cropping period were recorded with an automatic weather station installed in the experimental field and used as input data for the simulation model. The weather conditions at Kharagpur, expressed as monthly average maximum and minimum temperature (°C) and total rainfall (mm) during the crop growing season (January to May 2012 and 2013), are presented in Fig. 1. The maximum and minimum temperature varied in the ranges 24.5–40.0 °C and 14.4–24.7 °C, respectively, during the 2012 crop season, with total rainfall of 167 mm. During the 2013 cropping season, a total of 104 mm rainfall was received, with maximum and minimum temperatures in the ranges 24.2–33.4 °C and 12.8–28.7 °C, respectively.

2.2. Model description

2.2.1. CROPGRO-Peanut model

The DSSAT CROPGRO-Peanut model v4.5 [6,12] was used to study the effect of sowing date and phosphorus fertilization level on yield and yield parameters of peanut and to identify a