J. Farm Sci., 34(4): (457-459) 2021

RESEARCH NOTE

Assessment of sowing windows for soybean under current climate and projected climate across North Interior Karnataka

P. LAVANYA, R. H. PATIL, K. G. SUMESH AND B. SANGSHETTY

Department of Agricultural Meteorology
University of Agricultural Sciences
Dharwad - 580 005, Karnataka, India
E-mail: patilravi@uasd.in/ravipatil2005@gmail.com

(Received: July, 2021 ; Accepted: December, 2021)

Abstract: The experimental data on soybean variety JS-335 to calibrate and validate CSM CROPGRO were collected from the experiment of AICRP on soybean scheme during *Kharif* season of 2006, 2012 and 2019 under rainfed conditions on deep black soils at Main Agricultural Research Station (MARS) of the University of Agricultural Sciences, Dharwad. The simulation study revealed that under rainfed conditions on clay and sandy soils under both current (1988-2018) and projected climate (2020-2050) no particular pattern was observed and found that the best date of sowing for each district was different. Further, when the crop was simulated under the potential conditions (fully irrigated) under both current (1988-2018) and projected climate (2020-2050) on clay and sandy soils sowing late *i.e.*, on 2nd fortnight of June simulated higher soybean grain yields across 12 districts of north interior Karnataka.

Key words: Climate change, Sowing date, Soybean

Soybean [*Glycine max* (L.) Merrill] crop native to China is also referred to as 'Chinese pea' or 'Manchurian bean'. Globally, it is grown in an area of 125.4 million ha with a production of 347.6 million tons and 2,490 kg ha^{-1} of productivity (Anon., 2020). Production in India is 13.79 million tones from an area of 11.39 million hectares with a productivity of over 1.2 ton ha^{-1} which is less than half of global average production. In India Karnataka ranks seventh in production grown on an area of 2.71 lakh hectares producing 1.73 million metric tones with a productivity of 745 kg ha^{-1} (Anon., 2018), which is lower than national average. The reasons for lower yields of soybean in Karnataka are untimely sowing due to highly unpredictable monsoons.

Future climate projections by IPCC using newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project (CMIP5) for India state that, under the business-as-usual scenario (between RCP 6 and RCP 8.5), mean rise in temperature are likely to be in the range 1.7–2 ºC by 2030s and 3.3–4.8 ºC by 2080s compared to pre-industrial times. Precipitation is projected to increase from 4 to 5 per cent by 2030s and from 6 to 14 per cent by 2080s compared with 1961–1990 baseline period, and there is a consistent increasing trend in the frequency of extreme precipitation days (e.g. > 40 mm/day) by 2060s and beyond (Chaturvedi *et al.,* 2012) Agriculture is climate-dependent and thus vulnerable to climate change, hence it is very important to devise adaptation measures against climate change. Among the various agro-techniques, selection of suitable cultivars and optimizing sowing date would go a long way in maximizing or maintaining higher productivity of all crops including soybean under future climates.

North Interior Karnataka (NIK) is a region with semi-arid climate in the northern part of the South Indian state of Karnataka. It includes 12 districts namely Bagalakote, Belagavi, Ballari, Bidar, Dharwad, Gadag, Haveri, Kalaburagi, Koppal, Raichur, Vijayapura and Yadagiri with a total geographical area of 88,361 km^2.The existence of regional variations in climate, soil, topography and the crop management conditions in each of the 12 districts of NIK make both potential (irrigated) and rainfed yields vary a lot. Considering this, not only understanding the magnitude of the climate change effects on crops has become mandatory, but to choose the right agronomic practices (e. g., sowing time) for the given local climate, soil and targeted yield by the farmer. Hence, this study was undertaken using DSSAT-CROPGRO model to assess the performance of soybean variety JS-335 across nine dates of sowing from 15-May to 15-July at weekly interval in each of 12 districts of NIK under both current and projected climate to identify and propose the optimum sowing date for each district as a climate adaptation strategy which is essential for regional food security.

The experimental data on soybean variety JS-335 to calibrate and validate CSM CROPGRO were collected from the experiment of AICRP on soybean scheme during *Kharif* season of 2006, 2012 and 2019 under rainfed condition on deep black soils at Main Agricultural Research Station (MARS) of University of Agricultural Sciences, Dharwad, located at 15° 26' N latitude, 75° 07' E longitude and at an altitude of 678 m above mean sea level. The data on weather parameters such as daily rainfall (mm), mean maximum and minimum temperature (°C) and solar radiation (MJ m^{-2} day^{-1}) required to build weather file within the DSSAT model were recorded from the Meteorological Observatory, MARS, University of Agricultural Sciences, Dharwad for the experimental years. Historic daily weather of 31 years (1988-2018) for each of 12 districts of NIK were downloaded from NASA power web portal (www.power.larc.nasa.gov) for solar radiation, temperature and rainfall for subsequent seasonal analysis. These files were used to run the model for calibration (2006) followed by validation (2012 & 2019) and also for sequential analysis over 31 years (1988-2018) to estimate yield. The model was calibrated using GenCalc software application within DSSAT model with a satisfactory accuracy of 90 per cent for both phenology and yield parameters, and the genetic coefficients optimized for JS-335 are published elsewhere (Lavanya and Patil, 2021). Further the same historic weather data (1988-2018) were used to create future climate scenarios by altering the daily maximum and minimum temperature and rainfall according to the projections given by the Karnataka Climate Change Action Report of 2011 for the period from 2020 to 2050 for each of 12 districts of NIK and projected weather files for each district were created.

Table 1. Best sowing date and soybean grain yield (kg ha^{-1}) across 12 districts of NIK under current (1988-2018) and projected climates (2020-2050) in rainfed and potential conditions on clay soil.

District	Current climate (1988-2018)		Projected climate (2020-2050)	
	Rainfed	Potential	Rainfed	Potential
Bagalakote	30-Jun (1716)	22-May (2609)	30-Jun (1677)	15-May (2540)
Ballari	15-May (1886)	15-May (2980)	15-May (1789)	30-Jun (2875)
Belagavi	15-Jul (2449)	15-July (2487)	15-July (2730)	15-July (2791)
Bidar	30-Jun (2335)	15-May (2886)	15-Jun (2575)	15-May (2879)
Vijayapura	15-Jul (1373)	08-July (2563)	08-Jul (1586)	15-May (2388)
Dharwad	22-Jun (2107)	15-May (2863)	22-Jun (2142)	15-May (2747)
Gadag	22-Jun (1905)	15-May (2600)	15-Jun (1121)	08-Jul (2856)
Kalaburagi	30-Jun (2094)	22-Jun (2868)	15-Jul (2129)	08-Jul (2731)
Haveri	08-Jul (2227)	15-May (2978)	15-Jun (2321)	22-May (2213)
Koppal	15-Jul (717)	15-May (1839)	08-Jul (1269)	22-May (1810)
Raichur	08-Jul (1233)	08-Jun (2386)	15-Jul (1114)	22-Jun (2326)
Yadagiri	15-Jul (1497)	15-Jun (2559)	30-Jun (1343)	15-Jun (2458)

Figures in parenthesis are Soybean grain yield (kg ha^{-1}), average of 31 years.

Table 2. Best sowing date and soybean grain yield (kg ha^{-1}) across 12 districts of NIK under current (1988-2018) and projected climates (2020-2050) in rainfed and potential conditions on sandy soil.

District	Current climate (1988-2018)		Projected climate (2020-2050)	
	Rainfed	Potential	Rainfed	Potential
Bagalakote	22-Jun (2418)	22-Jun (2784)	15-Jun (2336)	22-Jun (2445)
Ballari	08-Jul (1455)	22-Jun (2440)	08-Jun (1385)	15-Jun (2372)
Belagavi	15-May (1712)	15-May (1607)	15-May (2085)	15-May (1988)
Bidar	22-May (2202)	22-May (2009)	15-May (1845)	15-May (1468)
Vijayapura	15-Jul (1886)	22-Jun (2659)	08-Jun (1900)	22-Jun (2188)
Dharwad	01-Jun (2306)	22-Jun (2254)	22-May (2263)	30-Jun (2164)
Gadag	22-Jun (2273)	22-Jun (2383)	30-Jun (958)	30-Jun (1686)
Kalaburagi	22-Jun (2250)	22-Jun (2492)	22-Jun (2159)	15-Jun (2340)
Haveri	15-May (1165)	15-May (1700)	15-May (1999)	15-May (1610)
Koppal	15-Jul (1608)	22-Jun (2373)	15-Jul (1608)	30-Jun (2276)
Raichur	30-Jun (1777)	22-Jun (2406)	15-Jul (1777)	15-Jul (2385)
Yadagiri	22-Jun (2062)	22-Jun (2591)	22-Jun (2062)	22-Jun (2482)

Figures in parenthesis are Soybean grain yield (kg ha^{-1}), average of 31 years

In order to simulate the yield levels across the 12 districts of NIK, soil profile data of both black and red soils up to a depth of 125 cm and 35 cm, respectively, of all 12 districts were collected from ICAR Krishi Geoportal website (http://geoportal.icar.gov.in). The N, P, K (kg ha^{-1}) data of all the 12 districts for initial management was collected from soil health card web portal of the Ministry of Agriculture and Farmers Welfare, Govt. of India (https:soilhealth2.dac.gov.in/Health Card). Soil profile for each district was built within soil module of DSSAT. The seasonal analysis simulations were ran for each of 12 districts of NIK both under current climate (1988-2018) and projected climate (2020-2050) to generate average yields of soybean variety JS-335 for each district both under current and projected climate on two predominant representative black clay and red loamy soils across nine dates of sowing from 15-May to 15-July at weekly interval.

Nine dates of sowing from 15-May to 15-July at weekly interval were simulated in each of the 12 districts of NIK to identify the best sowing date with the highest yield under both current (1988-2018) and projected climate (2020-2050). The best sowing window found for 12 districts are presented in the (Tables 1 and 2). Under current climate on clay soils in rainfed conditions early sowing (15-May) simulated higher yield only in Ballari district. Sowing in the month of June (22-June and 30-June) gave higher yields in five districts *viz.* Dharwad, Gadag Bidar and Bagalkote districts. Whereas sowing in July (08-July and 15-July) gave higher yields in six districts namely Haveri, Raichur, Yadagiri, Koppal, Vijayapur and Belagavi districts.

Under current climate on clay soil in potential conditions early sowing (15-May, and 22-May) gave higher yield in seven districts *viz.* Bagalkot, Ballari, Bidar, Dharwad, Gadag, Haveri, and Koppal, while June and July sowing (08-Jun, 15-June, 22-June, 08-July and 15-July) gave higher yields in five remaining districts *viz.*, Belagavi, Kalaburgi, Raichur, Vijayapura, and Yadgiri (Table 1).

Under current climate (1988-2018) on sandy soils in rainfed conditions model simulated early sowing (15-May, 22-May, 01-June and 08-June) with higher yield only in three districts *viz.* Belagavi, Bidar and Haveri district whereas, sowing in second fortnight of June (22-June and 30-June) gave higher yield in five districts *viz.,* Dharwad, Bagalkot, Gadag, Kalaburgi, Yadagiri and Raichur. Sowing late (08-July and 15-July) gave higher yields in remaining three districts *viz.* Ballari, Vijayapura Koppal. However, on red soils in current climate under potential conditions soybean gave higher yield in 10 districts of NIK when sown late (30-June, 08-July and 15-July) except for Belagavi and Bidar which showed early sowing (15-May and 22-May) better (Table 2).

Under projected climate (2020-2050) on clay soils in rainfed conditions early sowing (15- May) with higher yield was found only in Ballari district. Sowing in June (8-June 15-June, and 30-June) gave higher yields in six districts *viz.* Bagalkote, Bidar, Dharwad, Gadag ,Yadagiri and Haveri. Late sowing (08-July and 15-July) gave higher yields in Belagavi, Vijayapur, Kalaburgi, Koppal and Raichur. Under potential conditions early sowing (15-May, 22-May) resulted in higher yield in six districts *viz.* Bagalkote, Bidar, Vijayapura, Dharwad, Haveri and Koppal. Sowing in 2nd fortnight (15-June, 22-June) gave higher yields in Raichur and Yadagiri districts. Sowing late (30-June, 8-July and 15-July) gave higher yields in four districts *viz.* Ballari, Belagavi, Gadag and Kalaburgi (Table 1).

Under projected climate (2020-2050) on sandy soils in rainfed conditions early sowing (15-May and 22-May, 01-June and 08-June) resulted in higher yield in six districts *viz.* Ballari, Belagavi, Bidar, Dharwad, Haveri and Vijayapura. Sowing in 2nd fortnight of June (15-June and 22-June) gave higher yields in Bagalkote, Kalaburgi and Yadagiri. Sowing late (30-June, 8-July and 15-July) gave higher yields in three districts *viz.* Gadag, Koppal and Raichur. Under potential conditions early sowing date 15-May gave higher yields in Bealagavi, Bidar and Haveri districts. Sowing in 2nd fortnight of June (15-June and 22-June) gave higher yields in Bagalkote, Ballari, Kalaburgi, Vijayapura and Yadagiri districts. Late sowing date (30 June, 08-July and 15-July) gave higher yields in Dharwad, Gadag, Koppal and Raichur (Table 2).

In this simulation study it was observed that under rainfed conditions on clay and sandy soils under both current (1988-2018) and projected climate (2020-2050) no particular pattern was observed and the best date of sowing for each district was different, but when the crop was simulated under the potential conditions under both current (1988-2018) and projected climate (2020-2050) on clay and sandy soils sowing late *i.e.,* on 2nd fortnight of June simulated much higher yields across 12 districts of NIK.

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