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Response of summer groundnut varieties to the changing climate in Dharwad district of Karnataka using DSSAT model

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Abstract
Groundnut is a protein rich oilseed crop predominately cultivated in Dharwad district of Karnataka and varieties viz., JSP-39, KDG-123, TG-37-A, TGLPS-3 and JL-1085 are adapted to the Northern part of Karnataka as well as the neighbouring state of Maharashtra. Climate change with rising temperature and erratic rainfall patterns is threatening the productivity of this crop. Hence, study was taken up to find the response of summer groundnut varieties to the changing climate in Dharwad district of Karnataka using DSSAT model. Experimental data required to calibrate, validate and run the model were collected from experiments conducted during summer of 2019-2020 and 2020-2021 at AICRP-Groundnut, MARS, UAS, Dharwad. The seasonal analysis was done under current (1991-2020) and projected climate (2021-2050) following recommended package of practices for UAS, Dharwad and for representative black clay and red loam soils of Dharwad district, under irrigated conditions across five dates of sowing from 15, Dec to 15, Feb at 15 days interval. Thirty years average yield simulated on black clay soils under current climate in irrigated conditions was 30 per cent higher than on red loamy soil in irrigated conditions. Under projected climate crop duration was shortened by 5 days, but yield increased by 4 to 19 per cent across varieties compared to yield under current climate, which mostly masked the negative effects of climate change on crop in the projected period. Dharwad district differed in terms of optimum sowing window in irrigated situation under both current and projected climate. Under irrigated condition early sowing i.e., 15, Dec to 30, Dec simulated higher yields for TGLPS-3 variety.

Keywords: DSSAT, climate change, summer groundnut

Introduction
Oilseeds play a significant part in India's agricultural economy. In terms of area, production and value, oilseeds are second only to food grains. Groundnut (*Arachis hypogaea* L.), the world's most significant and supplemental food crop, is also known as the "King of oilseeds" and "poor man's nut". Groundnut kernels are high in riboflavin, thiamine, nicotinic acid and vitamin E, and include 45-50 per cent oil, 26 per cent protein and 18 per cent carbohydrate. It is the third most important source of vegetable protein and the fourth most important source of edible oil. Its high protein, unsaturated fat, carbohydrates, vitamin and mineral content make it a significant nutritional component as well as a nutritious snack and healthy feed or feed supplement. It is commercially grown between the latitudes of 40° N and 40° S. The crop is grown on an area of about 26.4 million hectares around the world, with a gross harvest of 37.1 million tons. Globally the average production per hectare is 1,400 kg. Groundnut exports are over 2 million tonnes per year, with annual all-season coverage of over 70 lakh hectares. India ranks first in terms of area and second in terms of production, with roughly 85 lakh tonnes of shell groundnuts produced. India is now one of the world's biggest exporters, competing for a 20-25 per cent share of global trade with Argentina, the United States and China (Anon., 2017) [1]. Groundnuts are a good source of nutrition at a reasonable cost due to their high calorie value, protein level and mineral content. It is also called "poor man's cashew," and used in urban snacks to replace more costly nuts like almonds, cashews and pistachios. The nuts are high in vitamin E and minerals like Copper, Manganese, Potassium, Calcium, Magnesium and Zinc. Around the world, 50 per cent of groundnuts are used for oil extraction, 38 per cent for confectionery, and 12 per cent for seed production.

In India groundnut crop is grown on an area of around 4.56 million hectares with a total production of 6.77 million tonnes at an average yield of 1486 kg ha^{-1}. Groundnut accounts for around 3.3 per cent of the net planted area in India. As of 2018, China was the World's top producer of peanuts, accounting for an estimated 40 per cent of global production.

India came in second, generating around 15 per cent of the World's peanuts. Gujarat, Tamil Nadu, Andhra Pradesh, Maharashtra, Karnataka and Rajasthan are the primary groundnut-growing states in India. Although groundnut is grown in one or more seasons (*kharif*, *rabi* and summer) in several Indian states, the *kharif* (June-October) crop accounts for roughly 80 per cent of land and production.

Climate change is one of the world's biggest environmental issues. The Earth's climate system has undeniably altered on a global and regional scale since pre-Industrial times, according to the latest scientific assessment studies. Research has shown that the great majority of human activities during the past 50 years have been attributed to warming (averaging 0.1 °C each decade) (Sathaye *et al*., 2006) [7].

The IPCC reports say the global average temperature might increase between 1.4 and 5.8 °C by 2100. This extraordinary increase is likely to have impact on the global hydrological system, ecosystems, crop production, sea level and related activities. In tropical climates covering most developing countries, including India, the impact would be extremely severe (Sathaye *et al*., 2006) [7]. Crop simulation studies in several places across India with dynamic agricultural models suggests a declining trend in crop yield. But this has been somewhat countered by a CO_2 increase at a modest temperature increase, but due to a decline in crop duration, the larger warming negative impact on agricultural output is expected. Crop growth models are useful for assessing the influence of climate change on crop production stability under various management strategies (Hoogenboom *et al*., 1995) [5]. In light of this, the current study, titled "Response of summer groundnut varieties to the changing climates in Dharwad district of Karnataka using DSSAT model," was conducted during the summer seasons of 2019-2020 and 2020-2021, with the following objectives: i) To study the effect of current climate on yield of summer groundnut in Dharwad district of Karnataka. ii) To quantify the effect of future projected climate on the yield of summer groundnut, and iii) To optimize agronomic adaptation strategies in summer groundnut for enhanced yield under future climates.

Material and Methods

A field experiment was carried out at AICRP on Groundnut MARS, Dharwad, Agriculture College, Dharwad during two consecutive summer seasons of 2019-2020 and 2020-2021. The data were used for calibration and validation of the genetic coefficients of five groundnut varieties collected for these experiments JSP-39, KDG-123, TG-37-A, TGLPS-3 and J-1085 by DSSAT CROPGRO model. Five dates of sowing with 15 days interval were taken from 15, Dec to 15, Feb for Dharwad district of Karnataka which lies between coordinates 15.45º N and 75.00º E, with altitude of 750 m above mean sea level (Fig 1). The past weather data (rainfall, minimum and maximum temperature) for Dharwad district was collected from NASA POWER web portal for the period of 30 years from 1991 to 2020 (http://power.larc.nasa.gov) and also the projected data for the period 30 years from 2021-2050 was collected from Copernicus Climate Change Service (IPSL-CM5A model) (http://climate.copernicus.eu), RCP 6.0 scenario) (Table 4). Soil data were collected from ICAR Krishi Geoportal website (http://geoportal.icar.gov.in) and N, P, K (kg/ha) for both black and red loamy soils, and data for initial management was collected from soil health card web portal of the Ministry of Agriculture and Farmers Welfare, Govt. of India (http:soilheath2.dac.gov.in/Health card). The Decision Support System for Agrotechnology Transfer (DSSAT), CROPGRO model is a computer program developed by The International Benchmark Sites for Agrotechnology Transfer (IBSNAT) Initiative, which was funded by the US government.

Results and Discussion

Days to anthesis

Average simulated days taken to reach anthesis across five different dates of sowing for five groundnut varieties JSP-39, KDG-123, TG-37-A, TGLPS-3 and JL-1085 in irrigated conditions on both black clay soil and red loamy soil under current climate (1991-2020) were 35, 35, 29, 29 and 29, whereas under projected climate (2021-2050) it reduced to 32, 32, 26, 27 and 26 days, respectively, was simulated, which on an average three days lesser than that in the current climates. Individually maximum reduction of three days was observed in JSP-39, KDG-123, TG-37-A and JL-1085, and minimum reduction of two days was observed in TGLPS-3 (Table 5)

Days to physiological maturity

Average simulated days taken to reach physiological maturity across five different dates of sowing for groundnut varieties JSP-39, KDG-123, TG-37-A, TGLPS-3 and JL-1085 in irrigated conditions on black clay soil under current climate (1991-2020) were 123, 124, 108, 111 and 108, whereas under projected climate (2021-2050) 115, 117, 101, 104 and 103 days, respectively, has been simulated, which on an average comparatively are six days lesser than that of the current climates, individually maximum reduction of seven days was observed in JSP-39, KDG-123, TG-37-A and TGLPS-3 and minimum reduction of six days was observed in JL-1085. (Table 5)

Average simulated days taken to reach physiological maturity across five different dates of sowing for groundnut JSP-39, KDG-123, TG-37-A, TGLPS-3 and JL-1085 in irrigated conditions on red loamy soil under current climate (1991-2020) were 122, 123, 107, 111 and 107, whereas under projected climate (2021-2050) 116, 117, 101, 104 and 101 days, respectively, has been simulated, which on an average was six days lesser than that of the current climates. Individually maximum reduction of seven days was simulated for JSP-39 and TGLPS-3, and minimum reduction of six days was simulated for KDG-123, TG 37-A, JL-1085. The results are in good agreement with the findings of Guled *et al*. (2012) [3] for days to physiological maturity in groundnut as simulated by PNUTGRO model, (Table 5).

Shortening of groundnut crop duration under projected climate (2021-2050) was due to warmer temperature by 2.1 °C compared to current climate in Dharwad district. Rise in growing season temperature accelerate development rate resulting in shorter vegetative and reproductive phases which directly affects grain yield and biomass levels (Jerry, L. and John, P. 2015)

Grain yield (kg ha^{-1})

Simulated mean grain yield across five different dates of sowing in irrigated conditions in black clay soils under current climates (1991-2020) for groundnut varieties JSP-39, KDG-123, TG-37-A, TGLPS-3 and JL-1085 showed maximum yield for TGLPS-3 (3470) followed by JSP -39 (3362) and the lowest yield for JL-1085 (2091) followed by TG-37-A (2123). Similarly under projected climates (2021-2050) maximum yield was observed for TGLPS 3 (4053) followed by KDG 123 (4000) and the lowest yields was observed for JL-1085 (2404) followed by TG-37-A (2553). Maximum percent yield increase of 22.4 percent was observed in KDG-123 under future climates (2021-2050) comparing the current climates (1991-2020) followed by 20.2 percent of increase in yield was observed in TG-37-A, (Table 6).

Simulated mean grain yield across five different dates of sowing in irrigated conditions in red loamy soils under current climates (1991-2020) for groundnut varieties (JSP-39, KDG-123, TG-37-A, TGLPS-3 and JL-1085) showed maximum yield for JSP-39 (1491) followed by TGLPS-3 (1441) and lowest yield for JL-1085 (872) followed by TG-37-A (884). Similarly under projected climates (2021-2050) maximum yield was observed for JSP-39 (1860) followed by TGLPS-3 (1810) and lowest yields were observed for JL-1085 (1140.2) followed by TG-37-A (1158.8). Maximum percent yield increase of 31 percent was observed in TG-37-A under future climates (2021-2050) comparing the current climates (1991-2020) followed by 27.5 percent of increase in yield was observed in KDG-123. (Table 6)

Boote *et al.* (1989) [2] also reported of this study that the elevated maximum temperature decreased the yield of groundnut significantly. Overall results showed that elevated maximum temperature lower yield significantly and reduced temperature increased the pod yield in all cultivars. Similiarly Kaur and Hundal *et al.* (2006) [6] observed that with an increase in solar radiation by 5% increased the yield of rice, wheat, groundnut, gram and soybean by 6, 3, 8, 4 and 2% respectively.

Performance of groundnut varieties across sowing dates

Five dates of sowing from 15, Dec to 15, Feb were tested for each variety of groundnut to identify the best sowing date for higher yields. The simulated outputs showed that best date of sowing were almost same for all varieties, It was observed that as the date of sowing delayed from 15, Dec to 15, Feb the yields decreased in all the varieties and soils irrespective of current (1991-2020) and projected climates (2021-2050). Sowing on 15, Dec simulated highest yield followed by 30, Dec and the lowest yield was simulated on 15, Feb followed by 30, Jan irrespective of black clay and red loamy soils, current and projected climates. (Table 7 and Fig 2)

Table 1: Description of genetic coefficients for groundnut varieties.

Code	Description
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short-day plants) (hour)
PPSEN	Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour)
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days).
FL-SH	Time between first flower and first pod (R3) (photothermal days)
FL-SD	Time between first flower and first seed (R5) (photothermal days)
SD-PM	Time between first seed (R5) and physiological maturity (R7) stages (photothermal days)
FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)
LFMAX	Maximum leaf photosynthesis rate at 300 C, 350 vpm CO_2, and high light (mg $CO_2/m^2/s$)
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)
XFRT	Maximum fraction of daily growth that is partitioned to seed+shell
WTPSD	Maximum weight per seed (g)
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)
SDPDV	Average seed per pod under standard growing conditions (#/pod)
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
THRSH	The maximum ratio of (seed/ (seed+shell)) at maturity. Causes seed to stop growing as their dry weights increase until shells are filled in a cohort. (Threshing percentage)
SDPRO	Fraction protein (g) per g seed
SDLIP	Fraction oil(g) per g seed

Table 2: Description of calibrated genetic coefficients for groundnut varieties JSP-39, KDG-123, TGLPS-3, TG-37-A, and JL-1085.

		Groundnut varieties				
Sl. No.	**Coefficient's**	**JSP-39**	**KDG-123**	**TG-37A**	**TGLPS-3**	**JL-1085**
1	CSDL*	11.84	11.84	11.84	11.84	11.84
2	PPSEN*	0	0	0	0	0
3	EM-FL	19.56	19.56	1.642	15.22	1.642
4	FL-SH*	7	7	7	7	7
5	FL-SD	31.58	35.99	33.95	24.85	33.95
6	SD-PM	42.19	38.71	31.38	43.46	31.38
7	FL-LF	84.7	77	77	77	77
8	LFMAX	2.263	2.357	2.374	1.728	2.289
9	SLAVR	278.3	269.5	269.5	269.5	269.5
10	SIZLF*	16	16	16	16	16
11	XFRT*	0.84	0.84	0.84	0.84	0.84
12	WTPSD	1.286	0.701	0.701	0.701	0.6924
13	SFDUR	97.79	29.86	31.52	44.77	31.3
14	SDPDV	1.996	1.815	1.815	1.815	1.815
15	PODUR	18.15	16.5	16.5	16.5	16.5
16	THRSH*	78	78	78	78	78
17	SDPRO*	0.27	0.27	0.27	0.27	0.27

18	SDLIP*	0.51	0.51	0.51	0.51	0.51

*not calibrated for lack of data

Table 3: Monthly meteorological data during the year 2019-2020 and 2020-2021, and The average of past 30 years (1989-2018) at the experimental site on Main Agricultural Research Station, University of Agricultural Sciences, Dharwad.

Months	SRAD (MJ m^{-2} day^{-1})			Rainfall (mm)			No. of rainy days			Mean temperature (°C)					
										Maximum			Minimum		
	2019	2020	1989-2018	2019	2020	1989-2018	2019	2020	1989-2018	2019	2020	1989-2018	2019	2020	1989-2018
January	19.5	18.5	20.1	0.0	0.0	1.1	0.00	0.00	0.00	29.5	29.8	28.1	13.0	15.5	19.1
February	22.0	21.4	23.3	0.0	0.0	2	0.00	0.00	0.00	32.8	31.8	30.3	15.9	16.9	20.1
March	24.1	23.2	25.8	0.0	13.6	9.8	0.00	3.00	1.00	35.6	34.0	33.5	18.8	19.4	22
April	23.9	24.3	27.1	54.5	34.6	28.3	2.00	3.00	3.00	37.7	36.2	36.5	21.0	21.2	24.1
May	24.8	23.0	26.6	16.2	40.2	64.4	8.00	10.00	4.00	37.2	35.8	37.2	21.5	22.6	25.1
June	17.2	17.2	25.5	104.7	85.7	237.7	5.00	9.00	9.00	31.5	29.4	35.9	21.5	21.3	24.7
July	13.9	13.8	21.5	230.8	126.6	274.2	10.00	19.00	12.00	27.1	27.5	32.6	20.3	20.8	24.3
August	14.1	13.3	17.5	451.2	323.6	214.9	5.00	7.00	10.00	26.4	26.1	30.4	20.4	20.4	24
September	14.7	15.5	20.1	106.8	186.0	144.2	13.00	4.00	7.00	27.3	28.4	30.5	20.9	20.4	23.8
October	15.9	16.6	21.2	323.2	202.0	115.1	7.00	6.00	6.00	28.8	29.1	30.1	20.3	20.0	23.1
November	17.9	16.8	19.3	21.0	0.6	27.3	1.00	2.00	2.00	29.7	29.4	29.1	18.0	17.0	21.5
December	16.2	17.3	18.6	7.8	0.0	5.3	0.00	1.00	0.00	28.6	28.9	27.8	16.5	14.6	19.8
Total / Average	18.7	18.4	22.2	1316.2	1012.9	951.7	51.00	64.00	54.00	31.0	30.5	31.8	19.0	19.2	22.6

Table 4: Monthly average weather data of Dharwad district for the current climate (1991 - 2020), the projected climate (2021 – 2050) and the difference between the two periods.

Current climate variables (1991 - 2020)					Projected climate variables (2021 – 2050)				Difference			
Months	Rain (mm)	Solar radiation	Mean temperature (˚C)		Rain (mm)	Solar radiation	Mean temperature (˚C)		Rain (mm)	Solar radiation	T max.	T min.
			T max.	T min.			T max.	T min.				
January	1.1	20.1	28.1	19.1	8.8	20.1	28.1	19.1	7.6	0.8	-3.7	3.7
February	2.0	23.3	30.3	20.1	3.8	23.3	30.3	20.1	1.9	1.4	-4.4	3.0
March	9.8	25.8	33.5	22.0	7.8	25.8	33.5	22.0	-2.0	2.1	-3.9	2.0
April	28.3	27.1	36.5	24.1	6.8	27.1	36.5	24.1	-21.6	3.1	-1.7	1.6
May	64.4	26.6	37.2	25.1	19.8	26.6	37.2	25.1	-44.6	3.8	1.0	2.0
June	237.7	25.5	35.9	24.7	33.3	25.5	35.9	24.7	-204.4	9.6	6.1	2.3
July	274.2	21.5	32.6	24.3	128.0	21.5	32.6	24.3	-146.2	8.0	4.8	2.5
August	214.9	17.5	30.4	24.0	257.4	17.5	30.4	24.0	42.4	3.0	2.8	2.7
September	144.2	20.1	30.5	23.8	212.1	20.1	30.5	23.8	67.9	3.3	2.2	3.0
October	115.1	21.2	30.1	23.1	198.1	21.2	30.1	23.1	83.0	3.6	1.3	3.2
November	27.3	19.3	29.1	21.5	60.7	19.3	29.1	21.5	33.3	1.3	0.0	4.0
December	5.3	18.6	27.8	19.8	15.3	18.6	27.8	19.8	9.9	0.6	-1.8	4.4
Total / Average	1125	22.2	31.8	22.6	951.7	22.2	31.8	22.6	-172.7	3.4	0.2	2.9

Table 5: Simulated days to anthesis and maturity of groundnut varieties under current climate (1991-2020) and projected climate (2021-2050) in irrigated conditions on black and red loamy soils of Dharwad district, Karnataka (average of 30 years).

I. Days to Anthesis								
Dharwad	Black clay soils		Red loamy		Diff in days		Diff in %	
	Current	Projected (B)	Current	Projected (D)	B-A	D-C	B-A	D-C
JSP-39	35	32	35	32	-3	-3	-9	-8
KDG-123	35	32	35	32	-3	-3	-9	-9
TG-37-A	29	26	29	26	-2	-2	-8	-8
TGLPS -3	29	27	29	27	-2	-2	-8	-7
JL-1085	29	27	29	26	-1	-2	-5	-8
II. Days to Maturity								
Dharwad	Black clay soils		Red loamy		Diff in days		Diff in %	
	Current	Projected (B)	Current	Projected (D)	B-A	D-C	B-A	D-C
JSP-39	123	115	122	116	-7	-7	-6	-5
KDG-123	124	117	123	117	-7	-6	-5	-5
TG-37-A	108	101	107	101	-7	-6	-6	-6
TGLPS -3	111	104	111	104	-7	-7	-6	-6
JL-1085	108	103	107	101	-5	-6	-4	-6

Table 6: Simulated grain yield (kg/ha) of groundnut varieties under current climate (1991-2020) and projected climate (2021-2050) in irrigated conditions on black clay and red loamy soils of Dharwad district, Karnataka (average of 30 years).

Dharwad	Black		Red		Diff in yield		diff in %	
	Current	Projected	Current	Projected	B-A	D-C	B-A	D-C
JSP-39	3362	3979	1491	1860	617	369	18.4	24.7
KDG-123	3255	4000	1362	1737	745	374	22.9	27.5
TG-37-A	2123	2553	884	1159	430	274	20.2	31
TGLPS -3	3470	4053	1441	1810	583	369	16.8	25.6
JL-1085	2091	2404	872	1140	313	269	15	30.8

Table 7: Simulated optimum sowing date for groundnut varieties under current climate (1991-2020) and projected climate (2021-2050) in irrigated conditions on black clay and red loamy soils of Dharwad district, Karnataka (average of 30 years).

Varieties	Black		Red	
	Current	Projected	Current	Projected
JSP-39	15, Dec	15, Dec	30, Dec	15, Dec
KDG-123	15, Dec	15, Dec	30, Dec	15, Dec
TG-37-A	30, Dec	15, Dec	30, Jan	30, Dec
TGLPS-3	15, Dec	30, Dec	30, Jan	30, Dec
JL-1085	30, Dec	15, Dec	30, Dec	30, Dec

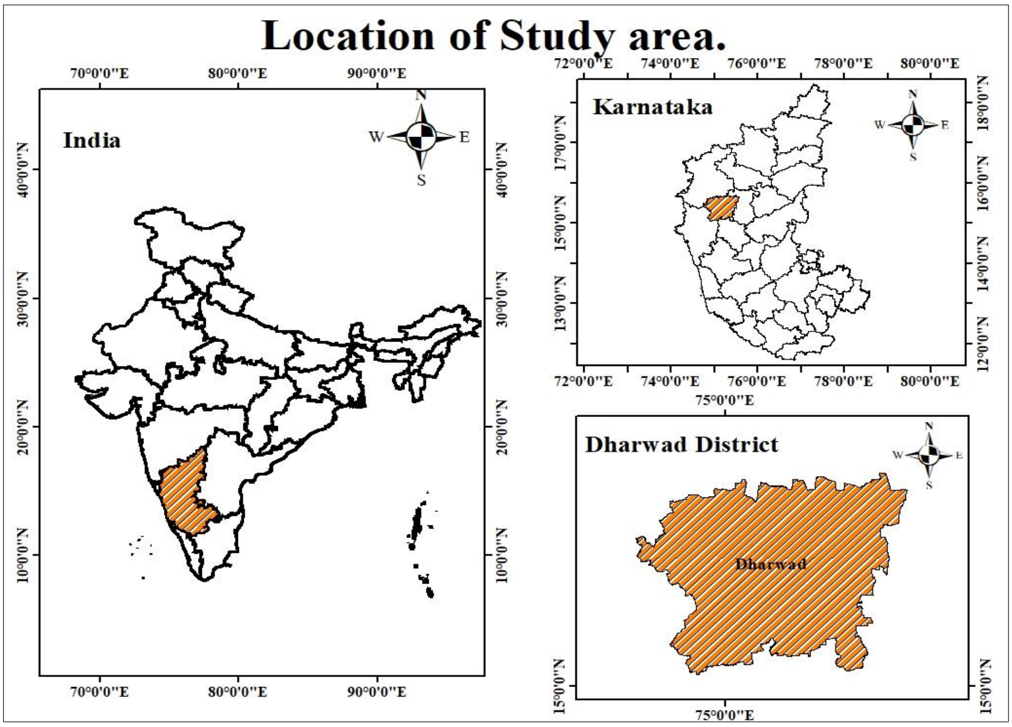

Fig 1: Study area of Dharwad district of in Karnataka state, India.

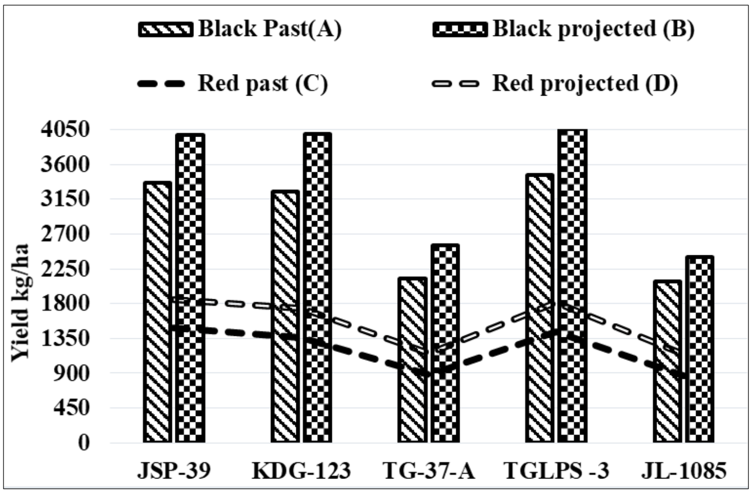

Fig 2: Simulated grain yield of groundnut varieties (kg/ha) under current climate (1991-2020) and projected climate (2021-2050) in irrigated conditions on black clay and red loamy soils of Dharwad district of Karnataka (average of 30 years).

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