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Assessment of Growth, Yield, Soil Temperature and Dew Deposition in Chickpea under Different Growing Environments and Varietal Conditions

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ABSTRACT

Background: Chickpea is a climate-sensitive legume crop and its growth and yield are influenced by sowing time, variety and microclimatic conditions. With increasing weather variability, understanding the effects of soil temperature and dew deposition is essential. This study aimed to assess growth, yield and environmental interactions across different sowing dates and chickpea varieties under field conditions.

Methods: The field study entitled "Assessment of Growth, Yield, Soil Temperature and Dew Deposition in Chickpea under Different Growing Environments and Varietal Conditions" was conducted in *Rabi* 2021-22 and 2022-23 at Research farm of Department of Agricultural Meteorology, CCS HAU, Hisar (Lat.: 29°10′N; Log.: 75°46′E; Alt.: 215.2 m). The study comprised of four sowing dates as main plot treatments *viz*. D1 (16th November 2021, 15th November 2022), D2 (23rd November 2021, 21st November 2022), D3 (29th November 2021, 29th November 2022) and D4 (8th December 2021, 6th December 2022) comprising five varieties as sub plot treatments *viz*. V1 (HC 1), V2 (HC 3), V3 (HC 5), V4 (HC 6) and V5 (HC 7) in split plot design with three replications.

Result: The crop growth and development were found the highest in early sown crop D1. Among different growing environments D1 sown crop produced maximum yield attributes and yield in 2021-22 and D3 sown crop in 2022-23. Among different varieties, the maximum yield attributes and yield was observed in HC 7 and minimum in HC 3 at harvest during both the crop seasons. Soil temperatures decreased from planting to vegetative phase among different growing environments and highest soil temperature was found in D1 sown crop during both seasons. Among the different growing environments, D3 sown crop had significant maximum accumulated dew amount (65.70 mm, 100.35 mm) at 90 DAS.

Key words: Chickpea, Development, Dew, Growth, Soil temperature.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is one of the most widely cultivated legumes in South Asia and ranks as the third most extensively grown crop globally. It is cultivated in over 50 countries and holds the position of the most important pulse crop in India. During 2023-24, chickpea in India covered an area of 10.47 million hectares, achieving a total production of 11.57 million tonnes and an average productivity of 1224 kg/ha [Directorate of Pulses Development (DPD) and Ministry of Agriculture]. In Haryana, chickpea was grown over 10.58 thousand hectares, producing 12.98 thousand tonnes with a productivity of 1226.84 kg/ha (Department of Agriculture and Farmers Welfare, Haryana). Chickpea is a temperature-sensitive legume whose yield and quality are influenced by temperature, day length and moisture. It can survive temperatures above 37°C and below 15°C, but extremes can affect growth. In semi-arid tropics, unfavorable soil temperatures reduce seed germination, hinder seedling emergence and lead to poor establishment.

Chickpea provides an affordable protein source for those unable to access animal protein and supports nitrogen fixation, enhancing cereal-based cropping systems and contributing to food security in India and Sub-Saharan Africa. Among the agronomic practices influencing chickpea yield, the timing of sowing is considered critical in affecting chickpea yield, with its ideal timing varying by variety and region. Different sowing dates expose the crop to varying temperature regimes, solar radiation and day

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lengths, which in turn influence key phenological stages like germination, vegetative growth and reproduction. Approximately 73% of the world's chickpea cultivation occurs in Asia, where it is predominantly grown under receding soil moisture conditions as a rainfed crop (Sachdeva *et al*., 2022). The optimal sowing time for chickpea results from the interaction between the environment and available varietal germplasm. Selecting the right sowing time often involves balancing maximum yield potential with minimal disease incidence. Typically, chickpeas are sown between mid-October and mid-November. Chickpea holds promising prospects as a crop. It is recognized for its biologically active compounds and is already a dietary staple across several Asian countries. As a low-input, low-water-requirement crop, chickpea is highly suited to sustainable farming.

Soil temperature significantly influences plant water absorption and subsequently affects transpiration rates. Soil temperature and dew deposition also affect photosynthesis and alter canopy reflectance in near-infrared and red bands during growth. As soil moisture content rises, soil temperature decreases because water, having a higher specific heat capacity than soil, heats up more slowly. Thus, moist soils experience smaller temperature increases compared to dry soils. Sowing early in spring, when soil temperatures are low, can result in reduced crop stands, whereas delaying sowing until soil temperatures rise shortens the effective growing season, thereby reducing seed yield. Moreover, soil temperatures below 10°C can severely hinder seed germination and seedling establishment, particularly in *kabuli* chickpea genotypes due to their larger seed size and thinner seed coat. Chickpea performance was favorable, characterized by positive growth rates and low productivity variability, indicating progress toward food and nutritional security Kumari and Malik (2024). Accordingly, an investigation was carried out to investigate the growth and development of chickpea cultivars under different growing environments and to analyse the impact of surface soil temperature and dew patterns on the growth and yield of chickpea.

MATERIALS AND METHODS

The present experimental study "Assessment of Growth, Yield, Soil Temperature and Dew Deposition in Chickpea under Different Growing Environments and Varietal Conditions" was conducted during the *Rabi* season 2021-22 and 2022-23 at the experimental farm, Department of Agricultural Meteorology, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India). The site is in the subtropics at latitude 29°10′N, longitude 75°46′E and an elevation of 215.2 meters above mean sea level. Hisar has semi-arid climate with hot dry and desiccating winds, scanty rainfall with very hot summers and relatively cool winters. Soils were sandy loam in texture. The study was comprised of four sowing dates as main plot treatment *viz*. D1 (16th November 2021, 15th November 2022), D2 (23rd November 2021, 21st November 2022), D3 (29th November 2021, 29th November 2022) and D4 (8th December 2021, 6th December 2022) comprising five varieties as sub plot treatment *viz*. V1(HC 1), V2(HC 3), V3(HC 5), V4(HC 6) and V5(HC 7) in split plot design with three replications. The inter and intra row spacing was 30 × 10 cm and gross plot of size 6.0 m × 5.0 m and net plot of size 5.0 m × 3.6 m.

Three plants were randomly taken from one plot for recording the growth and development at different growth stages (30, 60, 90 DAS and at maturity) of all the genotypes under the different growing environments and then average of these measurements was calculated. Yield attributing characters were recorded at the time of crop maturity. Daily soil temperature observations were recorded with the help of a soil thermometer inside the crop field at 5 cm depth from sowing till crop establishment. Dew pattern data was taken from adjacent observatory. The experimental data for various phenological stages, growth, yield attributing characters, yields and physiological parameters were statistically analyzed by the methods of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985).

The significance of treatment effects was computed with the help of 'F' (variance ratio) test and to judge the significance of differences between means of two treatments. Critical differences (CD) were worked out as described by Gomez and Gomez (1983).

RESULTS AND DISCUSSION

Growth and development

The plant height and number of branches per plant increased progressively with the increase in plant stage of

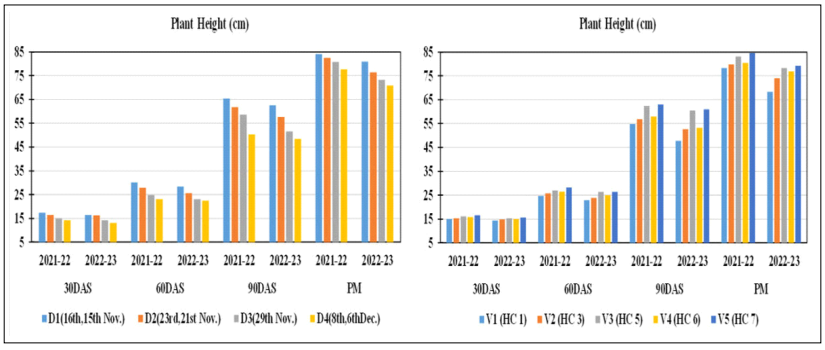


Fig 1: Effect of different growing environments (left) and varieties (right) on plant height (cm) in chickpea.

development from 30 DAS to PM as shown in Fig 1 and Fig 2. The plant height and the number of branches per plant was higher in first crop season 2021-22 as compared to 2022-23, because high soil temperature in first year favorable for plant germination and low soil temperature in second year cause delay in germination (Vashisth *et al*., 2020; Patel *et al*., 2022). Higher plant height was in early sown crop D1 resulted from the crop enhanced vegetative development due to favorable weather conditions (Sandeep *et al*., 2023) and reduced in delay sown crop D4 due to drop in temperature and high thermal stress on crop plant (Tiwari *et al*., 2016). Among varieties, the HC 7 recorded maximum plant height and minimum plant height recorded in HC 1 during both the crop seasons due to variations in genetic framework of varieties. Among different growing environments, higher number of branches per plant in early sown crop due to ideal weather condition for crop vegetative development. The results are in conformity with findings of Khan *et al*. (2021). Among varieties, the HC 7 recorded maximum number of branches per plant and minimum number of branches per plant recorded in HC 3 during both the crop seasons. Leaf area index increased with the advancement of crop growth stage from 30 DAS to 90 DAS as shown in Fig 3. The leaf area index was higher during *Rabi* 2021-22 as compared to 2022-23. Among different growing environments, maximum leaf area index was recorded in early sown crop D1 and minimum in late sown crop D4 during both the crop seasons. High LAI

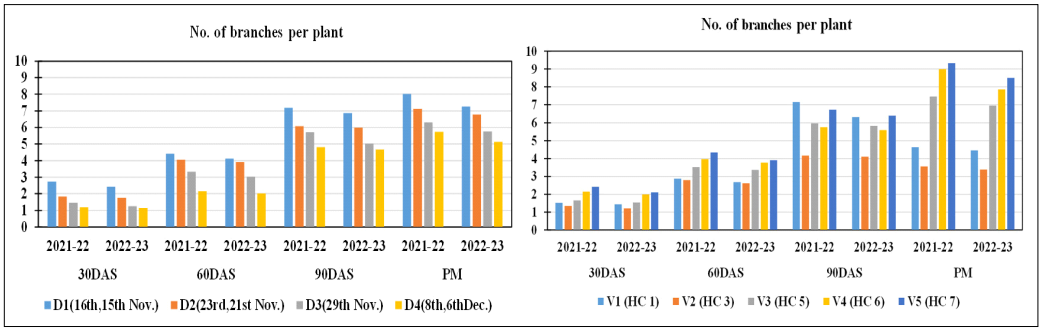


Fig 2: Effect of different growing environments (left) and varieties (right) on number of branches/plants in chickpea.

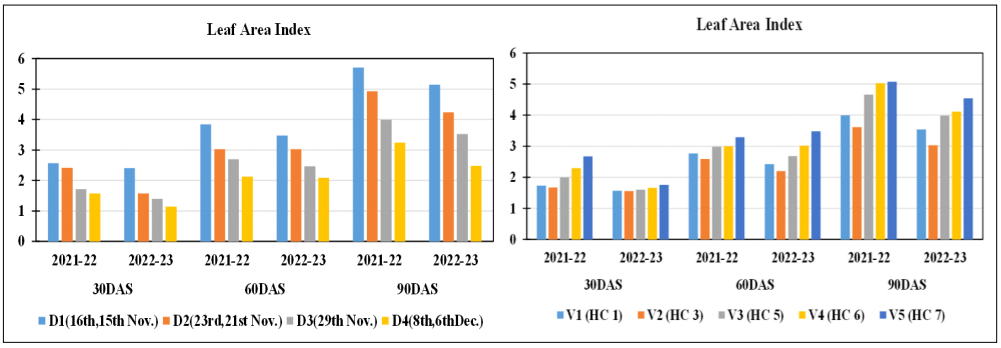


Fig 3: Effect of different growing environments (left) and varieties (right) on leaf area index in chickpea.

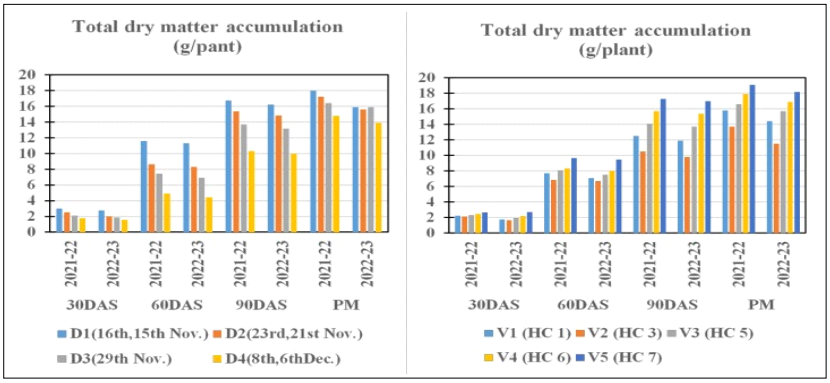


Fig 4: Effect of different growing environments (left) and varieties (right) on total dry matter accumulation in chickpea.

Table 1: Effect of different growing environments on yield attributes and yield in chickpea.

Treatment	No. pods/plant		No. of pods/branch		No. of seeds/pod		Test wt. (g)		Yield/ plant (g)		Biological yield (kg/ha)		Seed yield (kg/ha)		Harvest index (%)	
	2021 -22	2022 -23	2021 -22	2022 -23	2021 -22	2022 -23	2021 -22	2022 -23	2021 -22	2022 -23	2021 -22	2022 -23	2021 -22	2022 -23	2021 -22	2022 -23
Main-plot treatment (A)																
D1 (16^{th},15^{th} Nov.)	164.4	71.9	18.0	13.3	1.74	1.08	17.6	15.7	33.7	20.9	6934.0	5947.4	2889.9	1995.3	41.6	34.2
D2 (23^{rd}, 21^{st} Nov.)	157.2	139.5	17.8	14.9	1.71	1.37	17.4	16.6	31.9	25.7	6873.0	6442.1	2785.6	2289.1	40.2	34.8
D3 (29^{th} Nov.)	155.0	152.2	17.3	17.2	1.69	1.68	17.0	16.9	29.7	28.6	6839.7	6833.0	2717.7	2573.8	39.4	37.7
D4 (8^{th}, 6^{th} Dec.)	146.2	144.5	16.7	16.3	1.62	1.57	16.7	16.7	27.6	26.4	6545.4	6584.2	2515.9	2366.7	38.1	35.6
SE(m) ±	0.77	1.12	0.15	0.17	0.01	0.04	0.18	0.13	0.59	0.48	26.26	41.21	17.78	16.16	0.13	0.37
CD (A) at 5%	2.71	3.95	0.52	0.61	0.04	0.13	0.64	0.46	2.07	1.71	92.63	145.36	62.70	57.00	0.47	1.31
Sub-plot treatment (B)																
V_1 (HC 1)	145.6	122.8	15.0	13.7	1.63	1.32	17.1	16.4	28.7	22.9	6763.6	6712.8	2504.1	2347.1	37.2	35.0
V_2 (HC 3)	135.8	104.0	11.7	10.3	1.59	1.20	15.8	15.7	22.8	20.8	4720.5	3997.6	1698.6	1342.1	36.0	33.6
V_3 (HC 5)	154.4	131.8	18.6	16.8	1.70	1.35	17.3	16.5	30.8	25.2	7314.7	6878.1	3009.1	2424.8	41.2	35.5
V_4 (HC 6)	165.3	137.8	19.4	17.5	1.74	1.54	17.5	16.6	34.7	27.8	7589.1	7189.0	3190.7	2593.3	42.1	36.0
V_5 (HC 7)	177.3	138.9	22.5	18.8	1.80	1.71	18	17.3	36.6	30.2	7602.1	7481.0	3233.8	2824.0	42.6	37.7
SE(m) ±	1.16	0.90	0.29	0.39	0.01	0.05	0.22	0.13	0.50	0.56	52.67	47.49	23.30	18.58	0.42	0.39
CD (B) at 5%	3.35	2.60	0.84	1.57	0.03	0.14	0.63	0.38	1.46	1.61	152.44	137.42	67.50	53.77	1.20	1.13

in early sown due to high vegetative vigour and extended vegetative phase cause more addition to the foliage and lower in late sown due to crop faced higher temperature which causes shortening the crop duration and leads to forced maturity (Khan *et al*., 2021). Among varieties, the HC 7 recorded maximum LAI due to more absorption of PAR and HC 3 recorded minimum LAI during both the crop seasons.

Total dry matter accumulation was higher during *Rabi* 2021-22 as compared to 2022-23 due to shortening of crop duration at vegetative phase result into lower LAI, plant height and no. of branches per plant in 2022-23. Among different growing environments, the maximum total dry matter accumulation was recorded in early sown crop D1 and minimum in late sown crop D4 during both the crop seasons as shown in Fig 4. The highest dry matter accumulated in early sown crop was mainly due to utilization of higher temperature at early vegetative phase as well as more favorable environment during reproductive phase which resulted in higher biomass, whereas in late sown crop D4, due to heat stress resulted into decrease in the reproductive phase and leads to forced maturity. Results revealed that better photosynthesis because of greater leaf area index resulted significantly in higher dry matter production with a greater number of branches per plant in early sown crop (Kumar *et al*., 2023; Renu *et al*., 2023). Among varieties, the HC 7 recorded maximum total dry matter accumulation and minimum total dry matter accumulation recorded in HC 3 during both the crop seasons.The accumulation of root dry matter was increased from 30 DAS to 90 DAS and decreased thereafter up to physiological maturity among the treatments.The accumulation of stem dry matter was increased from 30 DAS to physiological maturity among the treatments. The accumulation of leaf dry matter was increased from 30 DAS to 90 DAS and decreased thereafter up to physiological maturity due to drying of leaves among the treatments. The contribution of pod to the total dry matter biomass accumulation was initiated after 90 DAS. Similar type of findings was supported by Sandeep *et al*. (2023). Also, during the 2022-23 crop season pod weight was lower in early sown crop D1 and D2 due to pod borer attack around 12th SMW due to rainfall.

Yield attributes and yield

Among yield and yield attributing characters *viz.,* number of pods/plant, number of pods/branch, number of seeds/pod, test weight (g), yield/plant (g), seed yield (Kg/ha), biological yield (Kg/ha) and harvest index (%) were found higher in early sown crop D1 and lower in late sown crop D4 during 2021-22 crop season because late sowing cause low air temperature at vegetative phase and high air temperature at reproductive phase, causes shorter duration for pod development. The results are in conformity with findings of Kumar *et al*. (2023) Salih *et al*. (2018) Renu *et al*. (2024). During 2022-23 yield attributes and yield were found higher in D3 and lower in D1 sown crop due to pod borer attack in

Table 2: Variation of soil temperature (°C) at 5 cm depths in chickpea field under different growing environments from sowing to crop establishment.

		2021-22		
Week after sowing	D1 (16th Nov.)	D2 (23rd Nov.)	D3 (29th Nov.)	D4 (08th Dec.)
1st week	22.1	21.2	21.0	20.6
2nd week	21.8	20.8	19.9	19.2
3rd week	21.5	19.4	19.1	17.8
4th week	21.0	19.2	17.7	19.9
5th week	18.6	17.5	19.6	19.0
		2022-23		
Week after sowing	D1 (15th Nov.)	D2 (21st Nov.)	D3 (29th Nov.)	D4 (06th Dec.)
1st week	20.3	20.1	19.2	17.6
2nd week	19.4	19.6	18.0	17.6
3rd week	19.6	17.8	17.5	16.2
4th week	17.8	17.6	16.2	15.2
5th week	17.1	16.2	15.7	14.9

Table 3: Effect of different growing environments on total accumulated amount of dewfall at all heights.

Treatment	30 DAS		60 DAS		90 DAS	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
			Main plot treatment (A)			
D1 (16th,15th Nov.)	8.62	9.12	30.17	74.59	59.96	81.78
D2 (23rd,21st Nov.)	14.77	14.29	30.44	73.09	62.78	88.76
D3 (29th Nov.)	15.77	31.70	36.12	70.94	65.50	100.35
D4 (8th,6thDec.)	18.16	46.59	49.51	72.72	64.85	98.81

early sown crop D1 and D2 lower their yield as shown in Table 1. The maximum seed yield was found in D1 (2889.9 kg/ha) and minimum in D4 (2515.9 kg/ha) during 2021-22 and in D3 (2573.8 kg/ha) and minimum in D1 (1995.3 kg/ha) during 2022-23.

Among different varieties, maximum yield attributes and yield was observed in HC 7 due to better partitioning of biomass to economic sink, increase photosynthetic rate and longer reproduction period resulted in higher yield and yield attributes and minimum in HC 3 at harvest during both the crop seasons. The maximum seed yield was observed in HC 7 (3233.8 kg/ha and 2824.0 kg/ha) and minimum in HC 3 (1698.6 kg/ha and 1342.1 kg/ha) at harvest during 2021-22 and 2022-23, respectively.

Soil temperature and dew pattern

Soil temperature variations (°C)

Soil temperature was higher during *Rabi* 2021-22 as compared to 2022-23 as shown in Table 2. Among the different growing environments, during 2021-22 crop season D1 sown crop had significantly higher soil temperatures at 5 cm (22.1°C) in 1st week and D2 had lower soil temperature at 5 cm (17.5°C) in 5th week. During 2022-23 crop season, D1 sown crop had significantly higher soil temperatures at 5 cm (20.3°C) in 1st week and D4 had lower soil temperature at 5 cm (14.9°C) in 5th week. Soil temperatures decreased from planting to vegetative phase among different growing environments. The low value of soil temperature was responsible for delay in germination under late sowing. Apart from that in late sowing the high value of soil temperature at the time of maturity was responsible for short growing period. Similar type of findings was supported by Vashisth *et al*. (2020; Sharma *et al*. (2023).

Dew pattern variations (mm)

Dewfall amount was higher during *Rabi* 2022-23 as compared to 2021-22 as shown in Table 3. Among the different growing environments, during 2021-22 crop season D4 sown crop had significantly maximum accumulated dew amount (18.16 mm) at 30 DAS and (49.51 mm) at 60 DAS and in D3 (65.70 mm) at 90 DAS. The dewfall amount was found minimum in D1 at all crop growth stages.

Among the different growing environments, during 2022-23 crop season, D4 sown crop had a maximum accumulated dewfall amount (46.59 mm) at 30 DAS and D1 had maximum amount of dewfall (74.59 mm) at 60 DAS and in D3 (100.35 mm) at 90 DAS. Dewfall increased with advancement of crop growth stages during both the crop seasons. The result are in conformity with the findings of Xiao *et al*. (2009).

Correlation studies

During 2021-22 at 30 DAS, dewfall showed significant positive correlation with morning relative humidity (0.965) and significant negative correlation with maximum temperature (-0.959), minimum temperature (-0.999) and grass minimum temperature (-0.997). At 60 DAS dewfall showed significant negative correlation with minimum temperature (-0.961) and at 90 DAS dewfall showed significant positive correlation with evening relative humidity (0.978). During 2022-23, at 30 DAS dewfall showed highly significant positive correlation with morning relative humidity (0.970) and evening relative humidity (0.998) and highly significant negative correlation with maximum temperature (-1.00), grass minimum temperature (-0.970), evening saturated vapor pressure (-0.999) and with bright sunshine hours (-0.992) and at 90 DAS dewfall showed significant positive correlation with maximum temperature (0.951), morning saturated vapour pressure (0.958), evening saturated vapour pressure (0.973), morning relative humidity (0.983) and with evening relative humidity (0.966) as shown in Table 4. The result are in conformity with the findings of Beysens *et al*. (2001); Xiao *et al*. (2013); Chen *et al*. (2013).

During 2021-22, at 30 DAS, dewfall showed significant negative correlation with no. of branches/plant (-0.993) and total dry matter (-0.958) and at 60 DAS dewfall showed significant negative correlation with no. of branches/plant (-0.981). LAI and plant height showed no significant

Table 4: Correlation coefficient of dew with weather parameters.

Growth intervals	Weather parameters								
	Tmax	Tmin	GMIN	SVP(M)	SVP(E)	RH(M)	RH(E)	WS	BSS
					2021-22				
30 DAS	-0.959*	-0.999**	-0.997**	-0.937	0.023	0.965*	0.931	0.853	-0.818
60 DAS	-0.786	-0.961*	-0.895	-0.860	-0.006	0.765	0.708	0.825	-0.361
90 DAS	-0.821	0.883	0.904	0.756	0.948	0.166	0.978*	0.930	0.739
					2022-23				
30 DAS	-1.000**	-0.920	-0.970*	-0.844	-0.999**	0.970*	0.998**	0.933	-0.992**
60 DAS	0.762	0.780	0.541	0.575	0.773	-0.800	-0.780	-0.448	0.774
90 DAS	0.951*	0.888	0.934	0.958*	0.973*	0.983*	0.966*	0.822	-0.994

*Significant at 0.05 p level, ** Significant at 0.01p level, T_{max} = Maximum temperature (°C), T_{min} = Minimum temperature (°C), GMIN = Grass minimum temperature (°C), SVP(M) = Saturated vapour pressure morning, SVP(E) = Saturated vapour pressure evening, RH(M) = Morning relative humidity (%), RH(E) = Evening relative humidity (%), WS = Wind speed (km/h) and BSS = Bright sun shine (hrs) hour.

Table 5: Correlation coefficient of dew with growth parameters.

Growth intervals	Growth parameters			
	LAI	No. of branches/plant	Plant height	Total dry matter
		2021-22		
30 DAS	-0.842	-0.993**	-0.915	-0.958*
60 DAS	-0.859	-0.981*	-0.888	-0.883
90 DAS	-0.909	-0.884	-0.768	-0.782
		2022-23		
30 DAS	-0.851	-0.905	-0.991**	-0.866
60 DAS	0.709	0.519	0.822	0.646
90 DAS	-0.894	-0.976*	-0.961*	-0.833

*Significant at 0.05 p level, **Significant at 0.01 p level.

correlation with dewfall at all growth intervals. During 2022-23, dewfall showed significant negative correlation with plant height (-0.991, -0.961) at 30 DAS and 90 DAS. No of branches/plant (-0.976) showed significant negative correlation with dewfall at 90 DAS as shown in Table 5. LAI and total dry matter showed no significant correlation with dewfall at all growth intervals. The results have been contradicted with the findings of Zhuang and Ratcliff (2012).

CONCLUSION

Growth parameters such as plant height, number of branches per plant, leaf area index and total dry matter accumulation was higher during *Rabi* 2021-22 as compared to 2022-23 due to shortening of crop duration at vegetative phase which resulted into lower LAI, plant height and no. of branches per plant in 2022-23. Among different growing environments, growth parameters were recorded higher in early sown crop D1 and minimum in late sown crop D4 during both the crop seasons. Among the varieties, HC 7 recorded better growth and development, while HC 3 recorded the least during both crop seasons. Yield attributes and yield were found higher in early sown crop D1 and lower in late sown crop D4 during 2021-22 and during 2022-23 yield attributes and yield were found higher in D3 and lower in D1 sown crop, due to pod borer attack in early sown crop D1 and D2 lower their yield. Among different varieties, the maximum yield attributes and yield was observed in HC 7 and minimum in HC 3 at harvest during both the crop seasons. Soil temperatures decreased from planting to vegetative phase among different growing environments and highest soil temperature was found in D1 sown crop during both seasons. Among the different growing environments, D3 sown crop had significant maximum accumulated dew amount (65.70 mm, 100.35 mm) at 90 DAS.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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