



RESEARCH ARTICLE

PHENOLOGY, GROWTH, AND YIELD OF CHICKPEA UNDER DIFFERENT SOWING WINDOWS AT CENTRAL REGION OF BANGLADESH

A.H.M. Motiur Rahman Talukder^{a*}, Faruque Ahmed^a, Lutfun Nahar^b^aPlant Physiology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701^bAgricultural Botany Division, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207*Corresponding author email: motiurbari@yahoo.com

This is an open access article distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:

Received 01 January 2025
Revised 05 January 2025
Accepted 09 January 2025
Available online 24 January 2025

ABSTRACT

The phenology, growth, and yield of a crop are primarily governed by its genetic traits, yet they are profoundly affected by environmental factors such as temperature cycles, day length, and soil moisture availability. However, a field experiment was conducted to assess the phenology, growth, and yield of chickpea varieties under different sowing windows and to provide the essential data for initializing DSSAT/APSIM crop model for future research. The chickpea varieties viz. BARI Chola-5 and BARI Chola-11 were sown scheduling at 10-days intervals on 20 November, 30 November, and 10 December, 2021 respectively. The three sowing windows represented different chickpea-growing micro-environments within the sowing window. In this study, a split-plot design with three replications was used, with sowing windows were assigned to the sub-plots and varieties to the main plots. In this study, different phenological stages were influenced by the sowing windows throughout the growing cycle, right up to harvest. The first two sowing windows required a longer period to complete the vegetative and reproductive stages, while the latest window completed these stages in the shortest time. The present investigation revealed that, crops that were planted earlier, took 7-18 days longer to mature than that were planted later. There was a significant difference among the sowing window regarding the growth and yield qualities traits viz. plant height, leaf area index (LAI), dry matter (DM) production. Early sowing (20 November) maximized seed and stover yields for both varieties due to extended growth duration and favorable temperatures. Late sowing (10 December) reduced yields significantly, likely due to higher temperatures during critical growth stages. BARI Chola-11 demonstrated greater resilience under adverse sowing conditions, while BARI Chola-5 performed better under optimal conditions. Earlier first two sowing windows accumulated maximum growing degree days (GDD) ~2407 °C and later sowing accumulated minimum GDD ~1910.5 °C.

KEYWORDS

Chickpea, Sowing windows, Phenology, Growing degree days, Growth and yield

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.), a resilient cool-season crop, thrives across diverse climates, mainly in the arid and semi-arid regions, where it often faces the challenge of harsh weather conditions. Chickpeas are a powerhouse in human diets, offering vital proteins and essential amino acids (Jukanti et al., 2012). Moreover, chickpeas serve as a nutrient-rich energy boost in animal feed, providing essential calories and nutrients (Bampidis and Christodoulou, 2011).

Chickpea is typically grown at the transition between the end of the rainfed transplanted Aman rice and the start of the irrigated cropping season in Bangladesh, a South-Asian country. In Bangladesh, particularly in the central region, chickpea cultivation holds significant potential to enhance food security, diversify cropping systems, and improve soil fertility. Crop production hinges on numerous factors, with weather being the ultimate game-changer that determines a crop's success or failure. However, the success of chickpea production is influenced by various agronomic practices, among which the sowing window is a critical determinant. The sowing window directly impacts the crop's phenological development, growth, and yield. Optimal sowing ensures synchronization of crop development stages with favorable environmental conditions, such as temperature, photoperiod, and rainfall. Conversely, delayed or early sowing can expose the crop to abiotic stresses, including high temperatures during flowering and grain-filling stages or moisture stress

during seedling establishment.

Global warming is disrupting nature's rhythm, with rising temperatures and extended rainy seasons spilling into November, reshaping our world. With winter growing shorter, optimizing sowing windows and selecting the right chickpea cultivars is crucial for maximizing yields. Chickpea yield losses can soar between 30% and 60%, hinging on genotype, sowing timing, location, and the whims of climate during the sowing season (Kabir et al., 2009). Crop plants adopt diverse avoidance and tolerance strategies to thrive under harsh condition (Shunmugam et al., 2018). Early phenology is a widely adopted strategy in crops to mitigate late-season stresses and ensure adaptability to short-season conditions. The growth period must be well-suited to the production environment and agricultural practices.

Determining the ideal sowing time is pivotal for maximizing chickpea productivity. Delayed sowing can expose the crops in Bangladesh to harsh conditions during critical growth stages, creating a major hurdle for their success in the rabi season after rainfed rice (*Oryza sativa* L.) harvest. Sowing time has a noticeable effect on the productivity as it decides the biotic and abiotic conditions to which various phenological stages of the plant is subjected to. Window of sowing can be used as a strategy to improve the yield through avoidance of cold temperature during flowering and to reduce the incidence of disease (Ray et al., 2017). Early and late sowing limit plant growth and development, resulting in lower yield potential, whereas optimal sowing time allows more time for plant growth

Quick Response Code



Access this article online

Website:
www.ppsc.org.my

DOI:
10.26480/ppsc.01.2025.15.20

and development, resulting in higher yield. To reduce yield losses of chickpea seed should be sown as early as possible but sometimes delay sowing reduces epidemics of diseases.

Some researcher observed that early chickpea sowing risks low yields due to disease and cold-sensitive flowering, while later sowing optimizes pod development by aligning flowering with favorable temperatures (OujiA and Mouelhi, 2017). Despite its importance, there is limited research specific to the central region of Bangladesh to determine the most suitable sowing periods for chickpea cultivation. This region's unique agro-climatic conditions necessitate localized studies to optimize sowing time for maximizing yield and ensuring stable production. Understanding how different sowing windows affect phenology, growth, and yield will provide critical insights for farmers and policymakers to enhance productivity and mitigate risks associated with climate variability. Still now, a lot of research work related to sowing windows has been done but, current changing environment condition at central region of Bangladesh is limited to predict the yield reductions. So, the present study was therefore undertaken to find out (i) the suitable sowing window of chickpea specially in *rabi* season at central region of Bangladesh (ii) growing degree days (GDD) required for each phenological growth stages of individual chickpea varieties (iii) to provide the essential phenological data for initializing DSSAT/APSIM crop model for future research (iv) yield performance of chickpea varieties with different the sowing windows.

2. MATERIALS AND METHODS

2.1 Study location

The study was conducted at the research field of Plant Physiology Division, BARI, Gazipur-1701 (in between 23°53' and 24°21' N latitudes and 90°09' and 92°39' E longitudes) a central region of Bangladesh, which was 35 kilometers north of capital city Dhaka.

2.2 Climate and soil

The experimental site was belonged to the agro-ecological zone of Madhupur Tract (AEZ#28). Texturally the soil of the cultivated land was silty clay loam with pH 5.8, organic matter 0.95%, total nitrogen 0.07%, available phosphorus 13.55 ppm, available sulphur 8.45 ppm and exchangeable potassium 0.20 me 100 g⁻¹ soil. The region enjoys a tropical monsoon climate. It has four main seasons: pre-monsoon (March-May), monsoon (June-August), post-monsoon (September-November), and winter (December-February). The average temperatures typically range from 15°C to 34°C year-round, with an overall average of 25.71°C (CCKP, 2021). The months with the highest temperatures align with the period of rainfall (April-September), whereas colder and less humid conditions distinguish the winter season (December-February). The temperature drops significantly starting in November, reaching its lowest point in January. The period from October 15 to March 15 is locally referred to as the *rabi* season, when important irrigated crops such as wheat, maize, potato, mustard, cauliflower, cabbage, and chickpea are grown.

2.3 Methodology

2.3.1 Collection of planting materials:

The seeds of chickpea varieties were collected from Pulses Research Centre (PRC), (24.15°N, latitude and 89.0°E longitude), Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna.

2.3.2 Treatments, experimental design and planting procedure:

The experiment was conducted during the *rabi* (winter) season of 2021-2022. The experiment was designed in randomized complete block (RCB), arrangement with three replications. Two chickpea cultivars named BARI Chola-5 & BARI Chola-11 were sown on three different windows viz. 20 November, 30 November, and 10 December, 2021. The experimental unit was 3.2 m×4 m along with 8 rows maintain 40 cm spacing from each other. Before sowing, seeds and soils were treated with Povax 200-EC (2.5 g powder kg⁻¹ seed) and furadan 3G (@ 5 kg ha⁻¹) to prevent seed and soil borne diseases.

2.3.3 Fertilizer dose, application methods and intercultural operations

As part of the fertilization program, 90-40-55-10 kg ha⁻¹ N-P-K-S- in the form of urea, triple super phosphate, muriate of potash, and gypsum were

applied to the soil (Ahmed et al., 2018). Before seeds were sown, all fertilizers were applied during the final land preparation. Following sowing, seeds were covered with soil and lightly pressed by hand after being sown continuously in rows. Following the establishment of seedlings, proper agronomic practices such as thinning, weeding and other intercultural activities were performed as needed.

2.3.4 Measurement of phenological, growth and yield qualities of chickpea varieties

After sowing, the days to germination are counted once the radicle and shoot emerge from the seeds beneath the soil. When 80% plant populations emerged out of soil surface and just initiate the first trifoliolate leaf then days of emergence and two leaf stage was counted correspondingly. Moreover, window of basic vegetative stage ending was fixed when a single plant starts to bear a bud then counted the days. After the bud transforms into a flower in a single plant, the plant then counts the days of floral development and 50% of floral initiation. Total dry matter (TDM) (gm⁻²) and leaf area (cm²) were measured at 20-day intervals starting at 30 days after seeding to harvest to assess the progress of the crop. Total plants of (0.5m×0.4m) = 0.20 m² area were uprooted and separated into leaves, stems, roots and pods (when available).

Leaf area was measured by an automatic area meter (LI 3100 C, LI-COR, USA). Leaf area index was calculated by the following formula. Leaf area index (LAI) = leaf area/ ground area. For total dry matter (TDM) measurement plants were kept in an oven at 80°C for constant 72 hours. The cumulative dry weight of leaves, stems, roots and pods were considered as total dry matter (TDM) gm⁻². Ten plants were chosen at randomly for counting the yield contributing parameters that will finally support the total yield. Economic yield is the grain yield of the crop and it was calculated from each plot measuring (1.2m×3.0 m) = 3.6 m² area. Seeds were dried in sun to reach the constant 12.0% moisture and converted in (t ha⁻¹). Harvest index (%) is reported as the grain yield of crop varieties versus the total biological yield (grain yield + biomass yield). Finally, Harvest Index (HI) (%) was computed by utilizing the following formula.

$$\text{Harvest Index (HI) (\%)} = (\text{Economic yield})/(\text{Biological yield}) \times 100$$

2.3.5 Accumulated growing degree days (GDD)

Calculation of growing degree days (GDD) was done by employing heat value of each day. This value helps to generate a rough estimation of the total of seasonal growth of plants.

$GDD = \sum [(T_x + T_n) / 2 - \text{Base temperature}]$, $T_{\max}$ =Daily maximum temperature, $T_{\min}$ =Daily minimum temperature. The base temperature (minimum temperature) is the cool temperature at which a plant does not develop.

2.4 Statistical analysis

An analysis of variance (ANOVA) was performed on the acquired data. Least significant difference values were computed at 5°C probability level. Data analysis was performed using computer-based software "R" developed by R core team (2019) for the interpretation.

3. RESULT AND DISCUSSION

The warm temperatures and lack of rainfall in the second fortnight of November 2021, had stressed for young chickpea plants, potentially affecting early vegetative growth. The moderate temperatures and 4.91 mm of rainfall in the first fortnight of December 2021, provided ideal conditions for chickpea growth, supporting root and shoot development. The drop-in temperature to 26.46°C with no rainfall in the second fortnight of December 2021, required supplemental irrigation for chickpeas during flowering and pod formation. The moderate temperatures during the month of January was beneficial for the growth of chickpeas, but the absence of rainfall may cause some stress. At this stage, chickpeas are likely transitioning into reproductive stages (flowering/pod formation), which required careful water management. Ideal temperatures prevailed during the first fortnight of February 2022, creating favorable conditions for pod development, while a small amount of rainfall further supported optimal grain filling. Warm temperatures in the second fortnight of February 2022, reaching a maximum of 28.93°C, may accelerate the maturity process, although the crop could face water stress from limited rainfall.

Table 1: Meteorological information's during growth period of chickpea sown under different sowing window

Month	Durations	Temperature (°C)			Total rainfall (mm)
		Maximum	Minimum	Mean	
November, 2021	1 st fortnight	30.21	20.14	25.17	0.71
	2 nd fortnight	30.43	17.65	24.04	0.00

Table 1 (cont): Meteorological information's during growth period of chickpea sown under different sowing window

December, 2021	1 st fortnight	27.73	17.77	22.75	4.91
	2 nd fortnight	26.46	14.55	20.50	0.00
January, 2022	1 st fortnight	26.77	15.21	20.99	0.00
	2 nd fortnight	24.67	13.83	19.25	0.24
February, 2022	1 st fortnight	25.29	13.57	19.43	2.31
	2 nd fortnight	28.93	15.60	22.26	0.22
March, 2022	1 st fortnight	33.52	18.64	26.08	0.00
	2 nd fortnight	34.87	23.37	29.12	1.61

3.1 Impact of different sowing window on growth and development of both chickpea varieties

3.1.1 Plant height

Both chickpea varieties plant height differed considerably across sowing windows in all sampling windows, with the exception at 30 and 70 DAS (Table 2). The plant height showed an increasing tendency from the early sampling through harvest and increased rapidly from the commencement of sampling up to 90 DAS followed by a slow increasing pattern till harvest. The variety BARI Chola-5 exhibited moderate growth compared to BARI Chola-11 across most sowing windows but reached a similar, though slightly shorter, height at harvest. Varieties exhibited distinct plant heights due to their inherent characteristics. Various chickpea varieties have different plant height that earlier mentioned (Golldani and Moghaddam, 2006). The variety BARI Chola-11 showed higher growth rates than BARI Chola-5, especially at later stages, with a peak harvest height of 78.1 cm when sown on 20 November. The variety BARI Chola-5 showed 8.93% and 3.40% taller plants on 30 November and 10 December sowings,

respectively, compared to 20 November.

In contrast, BARI Chola-11 had 4.70% and 8.92% taller plants on 20 November and 30 November, respectively, compared to 10 December. Across the sowing windows, both varieties showed moderate growth on 20 November, with BARI Chola-11 consistently exhibiting greater plant height than BARI Chola-5. The 30 November sowing improved growth for both varieties, with BARI Chola-11 maintaining a taller height than BARI Chola-5. As per line with the current study, a group researchers found that greater plant heights in early sowing conditions compared to later sowing conditions (Eshan et al., 2023). On 10 December, BARI Chola-11 showed strong growth at 70 and 90 DAS but had a slightly lower harvest height than on 30 November, while BARI Chola-5 showed consistently shorter heights across stages. The interaction between sowing window and variety is evident in the differences in growth patterns over time. The variety BARI Chola-11 exhibited superior growth overall, with sowing on 30 November yielding the tallest plants at later stages. On the other hand, BARI Chola-5 tends to show more consistent but slightly lower growth, with some improvement when sowed earlier (20 November) (Table 2).

Table 2: Effects of sowing window on plant height of Chickpea varieties at different days after sowing

Sowing window	Variety	Plant height at different days after sowing (DAS)				
		30	50	70	90	at harvest
20 November	BARI Chola-5	12.2 a	17.3 b	28.6 a	41.3 a	46.4 ab
30 November		12.7 a	23.7 a	30.1 a	45.4 a	48.2 a
10 December		11.1 a	21.0 ab	32.3 a	45.0 a	41.5 b
CV (%)		10.4	8.80	9.87	6.02	5.06
LSD _{0.05}		2.82	4.11	6.79	5.99	5.21
20 November	BARI Chola-11	18.5 a	31.3 b	48.9 a	62.1 b	78.1 a
30 November		22.2 a	41.6 a	51.7 a	63.5 ab	71.0 ab
10 December		17.9 a	31.2 b	45.9 a	72.4 a	60.3 b
CV (%)		10.1	7.69	9.68	6.01	7.16
LSD _(0.05)		4.48	6.05	10.7	9.00	11.32

3.2 Leaf Area Index (LAI) of Chickpea varieties

Notable differences of leaf area indices (LAI's) of studied varieties were observed among sowing windows (Table 3). With time, the LAI improved, peaking at 90 days after sampling. However, BARI Chola-5 produced the maximum LAI viz. 0.037, 0.41, 0.60, 1.54 at 30, 50, 70, 90 DAS sown on 30 November. The early sown of BARI Chola-5 crop at 20 November produced the minimum LAI such as 0.018, 0.10, 0.54, 1.18 at 30, 50, 70, 90 DAS. Likewise, BARI Chola-11 followed the similar trends of BARI Chola-5 in terms of LAI. Among the sowing windows, BARI Chola-5 and BARI Chola-11 produced 41.1% and 21.7% & 32.8% and 23.9% higher LAI at 30

November than 20 November and 10 December sown respectively. This genotype variation may stem from their remarkable resilience to temperature stress. Moreover, earlier planting showed a superior LAI in later growth stages, which could be related to the crops' longer growth phase, which assures better light-harvesting. The variation in leaf area index can be attributed to the optimal conditions for chickpea growth in the crop sown on November 30th, which promoted robust root and shoot development, leading to an increased leaf area. In contrast, the elevated temperatures during the 50% flowering stage (80-90 DAS) in the December 10th sowing resulted in a reduced leaf area index.

Table 3: Effects of sowing window on Leaf Area Index (LAI) of Chickpea varieties at different days after sowing

Sowing window	Varieties	Leaf Area Index at different days after sowing (DAS)			
		30	50	70	90
20 November	BARI Chola-5	0.018 c	0.10 b	0.54ab	1.18 b
30 November		0.037 a	0.41 a	0.60 a	1.54 a
10 December		0.027 b	0.15 b	0.49 b	1.28 b
CV (%)		9.70	15.3	8.28	5.16
LSD _{0.05}		0.006	0.077	0.102	0.155

Table 3 (cont): Effects of sowing window on Leaf Area Index (LAI) of Chickpea varieties at different days after sowing

20 November	BARI Chola-11	0.034 c	0.180 b	0.782 b	1.39 c
30 November		0.065 a	0.590 a	1.163 a	1.87 a
10 December		0.044 b	0.217 b	0.536 c	1.66 b
CV (%)		9.23	9.34	3.25	4.51
LSD (0.05)		0.0099	0.069	0.061	0.168

3.3 Effect on total dry matter (TDM; g m⁻²) accumulations of Chickpea varieties

The sowing windows significantly impacted TDM accumulation for both varieties across all DAS and at harvest. BARI Chola-11 consistently outperformed BARI Chola-5 in TDM accumulation, particularly at later stages and harvest. The variety BARI Chola-11 produced the 47.8% higher TDM than the BARI Chola-5. The early sowing window (20 November) was more beneficial for BARI Chola-11, resulting in the highest overall TDM at harvest. The 30 November sowing provided superior early and mid-stage TDM accumulation for both varieties, indicating it as an optimal sowing time. Similarly, a study conducted in southern region of Bangladesh who revealed that considerable dry matter was produced from 20 November followed by 30 November sown crop and lowest was produced from 10 November sown (Sikdar et al., 2015). However, 20 November sowing resulted in slightly higher TDM at harvest for both varieties, especially for BARI Chola-11.

Late sowing (10 December) led to reduced TDM accumulation for both varieties at all stages, demonstrating the negative impact of delayed sowing. BARI Chola-5 sown on 20 November showed moderate early TDM and peaked at harvest (785.8 gm⁻²), outperforming later sowings. On 30 November, it achieved the highest early TDM (e.g., 30 DAS: 9.12 gm⁻², 90 DAS: 319.50 gm⁻²) but slightly lower harvest TDM (775.3 gm⁻²). Late sowing (10 December) resulted in the lowest TDM at all stages, with a sharp decline at harvest (319.65 gm⁻²). BARI Chola-11 sown on 20 November showed consistent TDM, reaching the highest harvest TDM (1011.1 gm⁻²). On 30 November, it recorded the highest early TDM (e.g., 30 DAS: 12.55 gm⁻², 70 DAS: 268.38 gm⁻²) and high harvest TDM (988.9 gm⁻²). Late sowing (10 December) significantly reduced TDM at all stages, with a harvest TDM of 536.6 gm⁻². The result was in validation with the conclusions of who observed that early sowing significantly increased total dry matter production over late sowing (Biscoc and Gallge, 2005).

Table 4: Effects of sowing window on TDM (gm⁻²) of Chickpea varieties at different days after sowing

Sowing window	Varieties	Total dry matter (gm ⁻²) accumulations at different days after sowing (DAS)				
		30	50	70	90	At harvest
20 November	BARI Chola-5	5.15 b	23.07 b	78.50 b	242.40 b	785.8 a
30 November		9.12 a	63.56 a	104.78 a	319.50 a	775.3 a
10 December		4.28 b	22.05 b	74.58 b	303.60 a b	319.65 c
CV (%)		8.97	11.39	9.46	11.54	2.60
LSD (0.05)		1.25	9.35	18.43	75.5	36.3
20 November	BARI Chola-11	7.60 b	25.76 c	131.0 b	700.8 a	1011.1 a
30 November		12.55 a	90.43 a	268.38 a	457.6 b	988.9 a
10 December		6.75 c	36.91 b	117.28 b	238.3 c	536.6 b
CV (%)		2.43	3.66	7.10	9.55	4.36
LSD (0.05)		0.494	4.24	27.73	100.87	83.63

3.4 Impact of various sowing windows on the phenological traits and yield performance of Chickpea varieties

The two significant steps in the life cycle of a crop are seed germination and emergence. Temperature, light, pH and soil moisture are the climatic factor changes with the different sowing windows. Under different sowing windows, chickpea variety BARI Chola-5 showed non-significant variations in days required for germinations while BARI Chola-11 showed considerable variations (Table 5). In addition, BARI Chola-11 sown on earliest and latest window took the maximum periods for appearance of radicle and shoot that indicated the germinations. There were no significant differences in days required for emergence and two leaf stages among chickpea varieties (Table 5). However, durations for the completion of vegetative stage were comparatively shortened for both varieties with the delayed sowing (Table 5). The both varieties took the maximum durations for completion of vegetative stage when sown on November 30. On an average seven days was shortened for both varieties for completion of vegetative stage under latest sown condition (Table 5).

The variety BARI Chola-5 sown on November 20 and December 14 took the minimum 65.0 days to initiate flower while November 30 sown took the maximum 66.0 days. Conversely, BARI Chola-11 sown on earlier 30 November took the maximum 45.0 days to initiate flower that was almost similar with 20 November sown (Table 5). The variety BARI Chola-5 and BARI Chola-11 took the maximum 84.0 days and 50.0 days respectively, to reach the 50% floral initiation when sown on November 30. Under latest sown conditions, both varieties took the minimum durations to reach the 50% flower initiations stage. For BARI Chola-5 and BARI Chola-11, reaching pod filling took a maximum of 108.0 days and 75.0 days, respectively. Both varieties sown at latest window took the minimum durations to reach the pod filling stage (Table 5). Days taken to maturity were notably curtailed with the delay in sowing of chickpea. More number of days was taken to maturity in case of 20 November as compared to late sown chickpea.

Field durations were shortened 7-18 days by the later sown crop than the earlier sown might be due to prevailing higher temperature at maturity stage (Table 5). The displayed ANOVA revealed notable variations for number of pod plant⁻¹, 500-seeds weight and seed yield parameters (Table 6). The maximum number of pod plant⁻¹ 128.0 and 85.0 was produced by the variety BARI Chola-5 and BARI Chola-11 respectively, sown on November 20. Whereas both cultivars equally produced the minimum number of pod plant⁻¹ at the latest sown condition. Equally 500-seed weight and seed yield were significantly reduced at the latest planting compared to the earliest planting. The BARI Chola-5 crop produced maximum 71.0 g; 500-seed weight sowing on 20 November followed by 10 December. The 500-seed weight was reduced by 16.30% at the latest planting than maximum value (Table 6). Both seed and stover yields of the varieties dropped steadily with delayed sowing. This decline in grain and stover production was mainly driven by temperature variations linked to the sowing windows.

BARI Chola-5 and BARI Chola-11 both varieties flourished with peak seed and stover yields when sown on 20 November, reaching 1.70 t ha⁻¹ and 1.85 t ha⁻¹ for Chola-5, and 1.80 t ha⁻¹ and 1.97 t ha⁻¹ for Chola-11, while sowing on 10 December led to the lowest yields for both varieties (Table 5). Sowing chickpeas on 20 November resulted in higher seed yields compared to later sowing windows, likely due to the moderate temperatures during the grain filling stage. This finding aligns with the results of Ali et al. (2018), who also observed that chickpeas sown on 20 November produced the highest grain yield.

The harvest index of chickpea varieties exhibited notable variation across sowing windows. For BARI Chola-5, the highest harvest index of 56.3% was observed with 10 December sowing, reflecting an efficient allocation of resources towards grain production despite lower yields. In contrast, 20 November sowing produced a relatively lower harvest index of 47.3%, although seed and stover yields were higher. For BARI Chola-11, 30 November sowing resulted in the highest harvest index of 51.2%, indicating a more favorable balance between grain yield and total biomass,

while 10 December sowing again showed a lower harvest index of 47.8%. These results highlight the complex relationship between sowing window and the efficiency of resource utilization in chickpeas (Table 6).

3.5 Accumulated Growing Degree Days

The table 7. Presented data on Growing Degree Days (GDD) accumulated at different growth stages of chickpea varieties (BARI Chola-5 and BARI Chola-11) sown on three different windows (20 November 2021, 30 November 2021, and 10 December 2021). Earlier sowing windows (20 November) resulted in higher GDD accumulation for most growth stages compared to later sowing windows (30 November and 10 December). A group researcher demonstrated that early sowing (November 5) benefited from a higher accumulation of growing degree days (GDD) from sowing to harvest, while late sowing (December 20) experienced a significantly reduced GDD, underscoring the critical role of planting time in crop development (Eshan et al., 2023). Late sowing (10 December) required fewer GDD and days for field maturity and harvest. BARI Chola-5 showed

higher GDD accumulation across growth stages compared to BARI Chola-11, especially for early sowing windows. The days to reach physiological maturity and harvest were longer for BARI Chola-5 under earlier sowing.

GDD values gradually increased as the plants progressed from germination to physiological maturity. The number of days to each stage decreased with delayed sowing. The variety BARI Chola-5 sown on 20 November had the highest GDD accumulation (2664.7 °C days) by physiological maturity and longest duration (129 days to maturity, 131 days to harvest). While in 30 November deduced GDD (2149 °C days) and days to maturity (122 days) and 10 December had the lowest GDD (1923.2 °C days) and shortest duration (109 days to maturity). The variety BARI Chola-11 sown on 20 November had the GDD accumulation peaked at 2142.9 °C days with a duration of 124 days to maturity. The 30 November sown had the lower GDD (2051.65 °C days) and duration (118 days) and 10 December had Minimal GDD (1897.8 °C days) with the shortest duration (108 days).

Table 5: Phenological performance of Chickpea varieties under different sowing window

Sowing window	Variety	Days to germination	Days to emergence	Days to two leaf stage	End of basic vegetative stage	Floral Initiation	50% floral initiation	Start of pod filling
20 November	BARI Chola-5	4.00 a	6.00 a	8.0 a	62.0 a	65.0 a	77.0 b	108.0 a
30 November		4.00 a	8.00 a	9.0 a	64.0 a	66.0 a	84.0 a	90.0 b
10 December		5.00 a	8.00 a	9.0 a	57.0 b	65.0 a	70.0 c	76.0 c
LSD _{0.05}		1.51	1.99	1.31	1.99	1.51	1.19	1.50
20 November	BARI Chola-11	6.00 a	8.00 a	11.0 a	41.0 a	43.0 b	48.0 b	75.0 a
30 November		5.00 b	9.00 a	11.0 a	43.0 a	45.0 a	50.0 a	61.0 b
10 December		6.00 a	8.00 a	11.0 a	36.3 b	38.0 c	45.0 b	51.0 c
LSD _{0.05}		0.756	1.60	1.60	3.42	1.85	2.39	3.99

Table 6: Field duration and yield of Chickpea varieties under different sowing windows

Sowing window	Variety	Physiological maturity	Field maturity	Pod plant ⁻¹ (no.)	500-seed wt.	Seed Yield (t ha ⁻¹)	Stover Yield (t ha ⁻¹)	Harvest index (%)
20 November	BARI Chola-5	129.0 a	131.0 a	128.0 a	71.0 a	1.70 a	1.85 a	47.3 b
30 November		122.0 b	127.0 b	104.0 b	63.0 b	1.55 b	1.59 b	49.2 b
10 December		109.0 c	111.0 c	45.0 c	69.3 ab	1.51 b	1.25 c	56.3 a
LSD _{0.05}		1.31	0.751	14.48017	7.14	0.074	0.148	3.50
20 November	BARI Chola-11	124.0 a	130.0 a	85.0 a	118.3 a	1.80 a	1.97 a	47.8 b
30 November		118.0 b	123.0 b	86.0 a	118.3 a	1.72 a	1.64 b	51.2 a
10 December		108.0 c	111.0 c	48.0 b	113.7 a	1.49 b	1.63 b	47.8 b
LSD _{0.05}		1.31	0.0226	13.23212	5.28	0.193	0.1476	2.517

Table 7: Growing degree days (GDD) at different growth stage of Chickpea varieties under different sowing windows

Sowing window	Variety	Growing degree days (GDD) at different growth stage								
		Germination	Emergence	Two leaf stage	End of basic vegetative stage	Floral initiation	50% floral initiation	start of pod filling	Field maturity	Days to harvest
20 November	BARI Chola-5	79.4 (4.00)	119.5 (6.00)	154.6 (8.00)	1039.2 (62.0)	1081.65 (65.0)	1254.3 (77.0)	1775.95 (108.0)	2664.7 (129.0)	2315.5 (131.0)
30 November		75.4 (4.00)	144.0 (8.00)	162.4 (9.00)	1017.55 (64)	1051.5 (66.0)	1317.35 (84.0)	1428.55 (90.0)	2149.0 (122.0)	2274.0 (127.0)
10 December		84.1 (5.00)	129.3 (8.00)	143.6 (9.00)	864.7 (57.0)	984.6 (65.0)	1065.7 (70.0)	1176.9 (76.0)	1923.2 (109.0)	1972.8 (111.0)
20 November	BARI Chola-11	119.5 (6.00)	154.6 (8.00)	208.5 (11.0)	708.35 (41.0)	740.25 (43.00)	813.45 (48.0)	1224.95 (75.0)	2142.9 (124.0)	2288.4 (130.0)
30 November		119.6 (5.00)	162.4 (9.00)	201.3 (11.0)	710.45 (43.0)	743.75 (45.0)	837.1 (50.0)	978.8 (61.0)	2051.65 (118.0)	2174.8 (123.0)
10 December		100.1 (6.00)	129.3 (8.00)	174.2 (11.0)	569.09 (36.0)	597.95 (38.00)	702.9 (45.0)	783.7 (51.0)	1897.8 (108.0)	1972.8 (111.0)

4. CONCLUSION

Sowing window played a pivotal role in shaping chickpea seed yields. The

early sowing (20 November) proved to be the yield-boosting champion, delivering maximum productivity for both BARI Chola-5 and BARI Chola-11. Sowing by 30 November still held strong, particularly for BARI Chola-11, maintaining near-optimal yields. In contrast, the delayed sowing (10 December) spelled a significant decline in yields and is best avoided. However, to achieve the best harvest, the golden sowing window between 20th and 30th November would be suitable for chickpea cultivation. The findings of this study provide a solid roadmap for thriving chickpea cultivation in the central region of Bangladesh.

ACKNOWLEDGEMENT

The authors extend their gratitude to Krishi Gobeshona Foundation (KGF) through Modeling Climate Change Impact on Agriculture and Developing Mitigation and Adaptation Strategies for Sustaining Agricultural Production in Bangladesh (CRP-II) Project.

CONFLICT OF INTEREST STATEMENT:

The authors declare that there is no conflict of interest regarding the publication of this manuscript. The research was conducted independently, and the outcomes represent the genuine work of the authors. The authors have no financial, personal, or professional affiliations that could be perceived as influencing the research outcomes or interpretations presented in this study.

AUTHOR CONTRIBUTION

This work was carried out in collaboration between all authors. Conceptualization and methodology, A.H.M. Motiur Rahman Talukder and Faruque Ahmed; Writing-original draft preparation, formal and statistical analysis, A.H.M. Motiur Rahman Talukder; Editing, Lutfun

REFERENCES

- Ahmed, S., Jajiruddin, M., Razia, S., Begum, R.A., and Biswas, J.C., 2018. *Fertilizer Recommendation Guide-2018*. Bangladesh Agricultural Research Council, Dhaka, Bangladesh. ISBN: 984-500-029-1, Pp. 223.
- Ali, Y., Biswas, P.K., Shahriar, S.A., Nasif, S.O., and Raihan, R.R., 2018. Yield and quality response of chickpea to different sowing windows. *Asian Journal of Research in Crop Science*, 1 (4), Pp. 1-8. <https://doi.org/10.9734/AJRCS/2018/41731>
- Bampidis, V.A., and Christodoulou, V., 2011. Chickpeas (*Cicer arietinum* L.) in animal nutrition: A review. *Animal Feed Science and Technology*,

168, Pp. 1-20.

- Biscoc, P.V., and Gallge, J.N., 2005. Physiological analysis of cereal yield production of dry matter. *Agricultural Progress*, 53, Pp. 34.
- Eshan, S.S., Hossen, S., Islam, A., and Islam, A., 2023. Chickpea phenology and yield related to agrometeorological indices under different temperature regimes. *Journal of Agroforestry and Environment*, 16 (1), Pp. 1-8.
- Golldani, A., and Moghaddam, P.R., 2006. Effect of different irrigation levels on phenology, physiology characteristics, and yield components of three chickpea (*Cicer arietinum* L.) cultivars in Mashhad. *Agricultural Science and Technology*, 20 (3), Pp. 21-32.
- Jukanti, A.K., Gaur, P.M., Gowda, C.L.L., and Chibbar, R.N., 2012. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): A review. *British Journal of Nutrition*, 108, Pp. 11-26.
- Kabir, A.H.M.F., BARI, M.N., Karim, M.A., Khaliq, Q.A., and Ahmed, J.U., 2009. Effect of sowing time and cultivars on the growth and yield of chickpea under rainfed conditions. *Bangladesh Journal of Agricultural Research*, 34 (2), Pp. 335-342.
- Ouji, A., and Mouelhi, M., 2017. Influence of sowing windows on yield and yield components of lentil under semi-arid region of Tunisia. *Journal of New Sciences, Agriculture and Biotechnology*, 38 (2), Pp. 2077-2082.
- R Core Team. 2021. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. Retrieved from <https://www.R-project.org/>
- Ray, K., Singh, D., and Jat, B.L., 2017. Effect of sowing time and seed rate on growth and yield of chickpea cultivars. *Advances in Research Journal of Crop Improvement*, 8 (1), Pp. 1-16.
- Shunmugam, A.S.K., Kannan, U., Jiang, Y., Daba, K.A., and Gorim, L.Y., 2018. Physiology-based approaches for breeding of next-generation food legumes. *Plants*, 7 (3), Pp. 72. <https://doi.org/10.3390/plants7030072>
- Sikdar, S., Abuyusuf, M., Ahmed, S., and Tazmin. 2015. Variety and sowing time on the growth and yield of chickpea (*Cicer arietinum* L.) in southern region of Bangladesh. *International Journal of Research in Agricultural Sciences*, 2 (5), Pp. 236-244.

