Bangladesh Agron. J. 2025, 28(1): 35-45

GROWTH AND YIELD OF CHIA (*Salvia hispanica)* AS INFLUENCED BY SOWING TIME AND ROW SPACING IN RELATION TO TEMPERATURE AT DIFFERENT AEZS

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(Received: 16 October 2025, **Accepted:** 21 November 2025**)**

Keywords: Chia, different AEZ, leaf area index, row spacing, temperature, total dry matter production, yield

Abstract

A field experiment was conducted at the Agronomy Research Field, Gazipur, RARS, Jamalpur, RARS, Jashore, RARS, Burirhat, HARS, Hathazari, ARS, Rajbari and OFRD, Shyampur of Bangladesh Agricultural Research Institute, during *rabi* season of 2022-23 to study the effect of yield and yield contributing characters of chia seeds as affected by sowing date and spacing at different location. The experiment consisted of four sowing dates viz. (15 Nov., 30 Nov., 15 Dec. and 30 Dec.) and two spacing viz. (30 cm × continuous in solid line and 40 cm × continuous in solid line). Sowing date showed great influence on total dry matter (TDM) production, leaf area index (LAI), yield and yield components of chia. The November sowing produced the maximum TDM and LAI at Gazipur. These parameters finally contributed to higher seed yield in early planting than later sowing date. The days required for the events of maturity (109 days,108 days,106 days, 112 days, 108 days, 110 days and 108 days at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) was obtained from 15 November sowing. It was also found that 15 November sowing with 30 cm row spacing produced the higher yield (1059.41 kg ha^{-1}, 823.80 kg ha^{-1}, 849.42 kg ha^{-1}, 1037. 94 kg ha^{-1} and 828.64 kg ha^{-1} at Gazipur, Jamalpur, Jashore, Burirhat and Hathazari, respectively) but at Rajbari and Shyampur produced the highest yield in 15 November sowing with 40 cm row spacing (1273 kg ha^{-1} and 1327.00 kg ha^{-1}). The results revealed that November sowing produced higher yield might be due to favourable air temperature for growth and development of chia. Late sowing after November 30 produced lower yield due to high temperature prevailed at the later growth stage (March) of chia at all locations. Results revealed that November sowing with 30 cm × continuous in solid line performed better and with the advancement of sowing dates the temperature increased reduced the grain growth duration and decreased the seed yield. The results revealed that November 15 to November 30 sowing would be the optimum sowing date for chia in relation to air temperature. The temperature co-efficient of chia was estimated at 131.81 kg ha^{-1} decreased per increasing 1 °C air temperature. Effect of temperature on the seed yield of chia was estimated at 74-94 %.

Introduction

Chia plant is botanically known as *Salvia hispanica* belong to mint family Lamiaceae (Cahill, 2004). Chia seeds contain high amount of omega-3 fatty acids, proteins, minerals and vitamins therefore they can serve as a potential ingredient for both human food and livestock feeds. Agronomic management is one of the most important aspects for the success of any crop with efficient use of all the resources. Studies on agronomic management of chia crop are limited as it is a newly introduced crop to Bangladesh. For a farmer to get maximum profit from any crop, study about its growth and responses towards inputs is very much essential. As chia being a new crop, different aspects of sowing time and plant population of this crop are to be studied to harness

potential yield of this crop. Standardization of suitable location specific agronomic practices with respect to spacing and sowing time is essentially required to popularize this crop in Bangladesh. The sowing date is an extremely relevant variable, since it determines the duration of the development period of the crop due to variations in environmental temperature and day length to which it is exposed (Lobo *et al.*, 2011). It is intolerant to freezing in all development stages (Lobo *et al.*, 2011). Its minimum and maximum growth temperatures are 11 and 36 °C, respectively, with an optimum range of 16-26 °C (Ayerza and Coates, 2009). It is considered to be a short-day plant with a threshold of 12-13 h (Busilacchi *et al.*, 2013), and as such, its period of growth and fruiting depend on the latitude where it grows. Temperature is the single most important climatic factor that affects the growth and development of crop plant (Mian *et al.*, 2013). It also influences the other different physiological process of the crop plant. Temperature affects root and shoot growth, nutrient uptake, water absorption, photosynthesis, respiration, transpiration, translocation of photosynthate and other metabolic functions in the plant system (Ali and Sarker, 2016). Some studies have shown that the best row spacing range for the culture would be between 30 and 50 cm, with an amount of 5 kilograms of seed per hectare (Ayerza and Coates, 2011). Appropriate sowing time and row spacing are very effective to increase yield of chia. But information under this aspect is unavailable in Bangladesh condition. The objective of this study was to determine the effect of climatic conditions in different regions on the growth and yield of chia in different regions. This study also proposes to determine the most promising sowing date and row spacing in terms of growth and yield in chia in the different study areas.

Materials and Methods

A field experiment was conducted at the Agronomy Research Field, Gazipur, Jamalpur RARS, Jashore RARS, Burirhat RARS, Hathazari RARS, Rajbari ARS and OFRD Shyampur of Bangladesh Agricultural Research Institute, during *rabi* season of 2022-23.

Gazipur

The experimental site was located at Chhiata Series under Agro-Ecological Zone-28 (AEZ-28) latitude 23°59 N and longitude 90°24 E. The meteorological data of the experimental site revealed that the highest temperature prevails in March-April and the lowest in December to January. Maximum rainfall was received during the months of March. The crop received 133 mm rain showers from November to March in 2022-23 years. The average maximum temperature (32.08 °C) was found in the month of March during the crop growing season (Fig. 1 and Fig. 2) and minimum (12.77 °C) temperature in the month of January during the crop growing season.

Jamalpur

It is a city of 2031.98 km^2 with a population density of 1200 km^{-2}. The warmer weather started in March (35 °C). The coldest month (7.0 °C) is January. The heavy rainfall from May to September ranges from 318 to 436 mm. Wheat, maize, potato, tomato, mustard, eggplant, bitter gourd, cauliflower, and other vegetables are cultivated in this area during the arid season (Fig. 1 and Fig. 2).

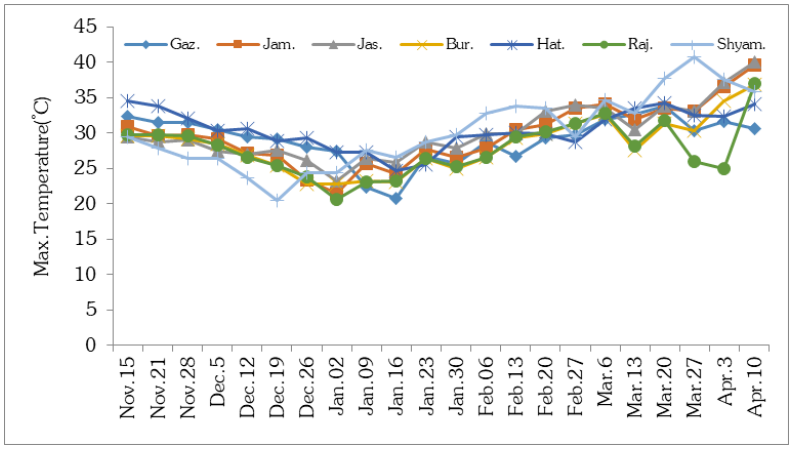

Fig. 1. Weekly maximum air temperature of Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur during crop growing period in 2022-2023

Jashore

The area of the city is 2,606.94 km^2 and it has a population of approximately 2,98,000. The hottest month is April (35.6 °C); however, warmer weather commences in March (33 °C) and remains at 30 °C until November. December and January are the coldest months, with a minimum average temperature of 11–12 °C. This region occupies most of the country's dry zone where the annual rainfall is the lowest. The maximum amount of rainfall is 304 mm, which occurs during July. Beans, cabbage, cauliflower, radish, spinach and gourd are cultivated in this region throughout the dry season (Fig. 1 and Fig. 2).

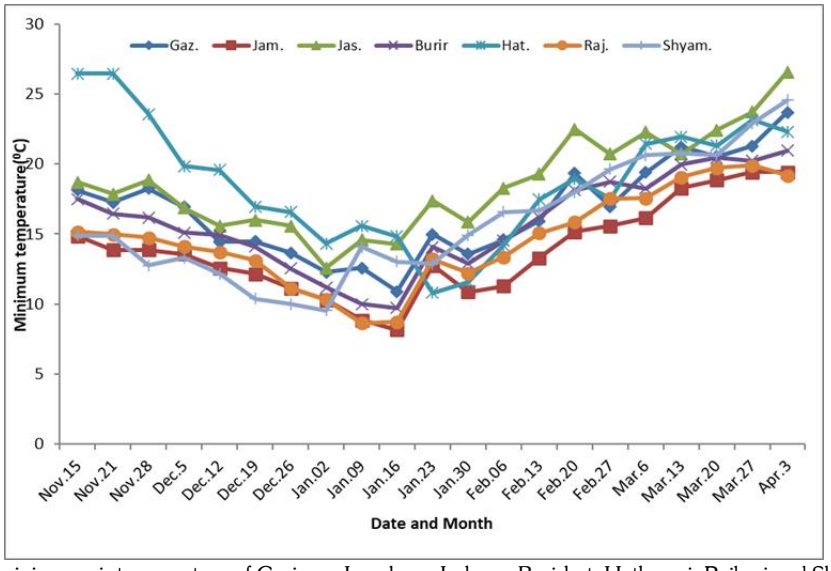

Fig. 2. Weekly minimum air temperature of Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur during crop growing period in 2022-2023

Hathazari

It is located at latitude 22.50° N and longitude 91.80° E. The primary crops grown in the area include rice, wheat, maize, pulses and oilseeds. The maximum temperature range 25-37 °C and the minimum temperature range 10-21°C. The annual average rainfall 2590 mm. The

average maximum (35.08 °C) was found in the month of March during the crop growing season (Fig. 1) and minimum (8.4 °C) temperature in the month of January during the crop growing season (Fig. 1 and Fig. 2).

Burirhat

It is located at latitude 26.70° N and longitude 89.00° E. The primary crops grown in the area include rice (particularly T. *Aman* and *Boro*) vegetables pulse, jute and spices crop. The maximum temperature range 25-37 °C and the minimum temperature range 8-12 °C. The average maximum temperature (33.08 °C) was found in the month of March during the crop growing season and minimum (8.4 °C) temperature in the month of January during the crop growing season (Fig. 1 and Fig. 2).

Rajbari

A district in Bangladesh, has an area of 1,118.80 square kilometers and a population of 1,189,818 according to the 2022 census. The main crops cultivated in this area are rice, jute, wheat, onion, potato and mustard. The warmer weather started in March (35 °C) and continued until October (31.5 °C). The hottest month is April (32.4 °C). The coldest month (6.5 °C) is January (Fig. 1 and Fig. 2).

Shyampur

It is situated within the Barind Tract 23 m above sea level. The area of this metropolis is 120.98 km^2. The average maximum temperature is slightly high in this region, starting in March at 33 °C and continuing to increase until October (~32 °C). During the pre-monsoon and monsoon seasons (March–September), Shyampur receives an average of 24.8–106.4 mm of rain, with July having the highest total of 321 mm. The cultivation of cauliflower, cabbage, radish, carrot, beet, turnip, tomato, green spinach and red spinach is predominantly carried out in this region during the dry season.The experiment consisted of four sowing dates viz. (15 Nov., 30 Nov., 15 Dec. and 30 Dec.) and two spacing viz. (30 cm × continuous in solid line and 40 cm × continuous in solid line) were used in the study. There were 8 treatment combinations as follows: $D_1 \times S_1$, $D_1 \times S_2$, $D_2 \times S_1$, $D_2 \times S_2$, $D_3 \times S_1$, $D_3 \times S_2$, $D_4 \times S_1$ and $D_4 \times S_2$. The experiment was laid out in a RCBD design with three replications. The unit plot size was 3.6 m × 3.0 m. The crop was fertilized with 60-15-30-5 N-P-K-S kg ha^{-1}, respectively (Karim *et al.*, 2015). Half of N and full doses of other fertilizers were applied at the time of final land preparation and the rest urea was top dressed 35 days after sowing (DAS). Seeds were treated with vitavax. Hand weeding was done at 25 DAS. Data on yield and yield contributing characters were taken in all locations and growth parameters like leaf area and dry matter accumulation were measured at different growth stages in Gazipur location. To record dry matter weight and leaf area, five plants were sampled at 30, 45, 60, 75 and 90 days after emergence (DAE) and at harvest. Dry weight of the samples was taken after drying at 80 °C in an oven for 72 h. Leaf area was measured by an automatic leaf area meter (L13100 c, L1COR, USA). The crop was harvested on1 March to 4 April 2023 in Gazipur, 2nd March to 5 April 2023 in Jashore, 7 March to 8 April 2023 and Burirhat, 2 March to 5 April 2023 in Jamalpur, 5 March to 7 April in Shyampur, Rajshahi, 2 March to 3 April 2023 in Rajbari and 2 March to 5 April 2023 in Hathazari. The yield component data was collected from randomly selected ten plants prior to harvest from each plot. At harvest, the yield data was recorded plot wise. Data were analyzed statistically and means were compared using LSD test at 5% level of significance.

Results and Discussion

Days for development events

The numbers of days required for different development events of chia are presented in Table 1. All the development events varied on sowing dates. Chia crop was differed for the events

of 50% flowering and maturity. The days required for 50% flowering was differed by sowing time in chia crop. The highest duration for 50% flowering was recorded in 15 November (71 days, 67 days, 64 days, 72 days, 67 days, 69 days and 67 days at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) sowing.

Table 1. Crop development events, mean temperature and crop duration of chia seed as affected by sowing date and row spacing during *rabi season* of 2022-2023 at different locations

Treatments	Duration (days)							Mean air temperature (°C)						
	Days to 50% flowering							Days to 50% flowering						
	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.
$D_1 \times S_1$	71	67	64	72	67	69	67	21.00	19.43	21.66	19.82	24.90	19.22	18.98
$D_1 \times S_2$	71	67	64	72	67	69	67							
$D_2 \times S_1$	65	62	57	70	62	65	62	20.29	18.72	21.07	19.08	22.48	18.56	18.88
$D_2 \times S_2$	65	62	57	70	62	65	62							
$D_3 \times S_1$	59	59	54	67	59	61	59	19.71	18.20	20.86	18.96	21.34	18.03	18.46
$D_3 \times S_2$	59	59	54	67	59	61	59							
$D_4 \times S_1$	57	55	50	65	55	58	57	20.44	18.55	21.87	19.87	21.06	18.67	18.74
$D_4 \times S_2$	57	55	50	65	55	58	57							

The second highest duration for 50% flowering was recorded in 30 November sowing but all sowing date prevailed lower mean air temperature during flowering stage except Hathazari. On the other hand, 30 December sowing time took minimum days for 50% flowering (57 days, 55 days, 50 days,65 days, 55 days, 52 days and 57 days at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively). Highest crop growth duration was recorded (109 days, 108 days, 106 days, 112 days, 108 days, 110 days and 110 days at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) in 15 November sowing due to prevailing lower mean air temperature (21.58 °C, 19.89 °C, 22.50 °C, 20.61 °C, 23.57 °C, 19.94 °C and 20.45 °C at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) (Table 2).

Table 2. Crop development events, mean temperature and crop duration of chia seed as affected by sowing date and row spacing during *rabi season* of 2022-2023 at different locations

Treatments	Duration (days)							Mean air temperature (°C)						
	Days to harvest							Days to harvest						
	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.
$D_1 \times S_1$	109	108	106	112	108	110	110	21.58	19.89	22.50	20.61	23.57	19.94	20.45
$D_1 \times S_2$	109	108	106	112	108	110	110							
$D_2 \times S_1$	106	104	104	108	107	106	108	21.71	20.06	22.95	20.68	22.95	19.76	20.78
$D_2 \times S_2$	106	104	105	108	107	106	108							
$D_3 \times S_1$	103	100	100	101	99	103	102	21.99	20.45	23.31	20.83	22.87	20.45	21.10
$D_3 \times S_2$	103	100	100	101	99	103	102							
$D_4 \times S_1$	98	97	97	99	97	100	96	22.72	21.38	24.29	22.04	23.68	20.84	21.94
$D_4 \times S_2$	98	97	97	99	97	100	96							

Here, $D_1 \times S_1$=15Nov×30cm, $D_1 \times S_2$=15Nov×40cm, $D_2 \times S_1$=30Nov×30cm, $D_2 \times S_2$=30Nov×40cm, $D_3 \times S_1$=15Dec.×30cm, $D_3 \times S_2$=15Dec.×40cm, $D_3 \times S_1$=30Dec.×30cm, $D_3 \times S_2$=30Dec.×40cm

The second highest crop growth duration was recorded in 30 November sowing in all locations. November sown crop prevailed lower mean air temperature throughout the growing

period. The minimum crop growth duration (98, 97, 97, 99, 97, 100 and 96 days at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) was recorded in 30 December sowing due to prevailing higher mean air temperature (22.72, 21.38, 24.29, 22.04, 23.68, 20.84 and 21.94 °C at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively).The reasons for variation in growth duration might be due to increased day and night temperature at later sowing (Table 1 and Table 2). Similar results also have been reported by Ali and Sarker (2016).

Leaf area index

The leaf area index plays a crucial role in all crop plants because optimum leaf area was required for maximum light interception which results in better photosynthesis. The highest leaf area recorded with the November sowing might had increased due to the presence of more favorable weather conditions for the plant's vegetative growth. It is influenced by genotype and plant population (Murphy *et al.*, 1996). The LAI was influenced by different sowing dates over time (Fig. 1) in 2022-23.

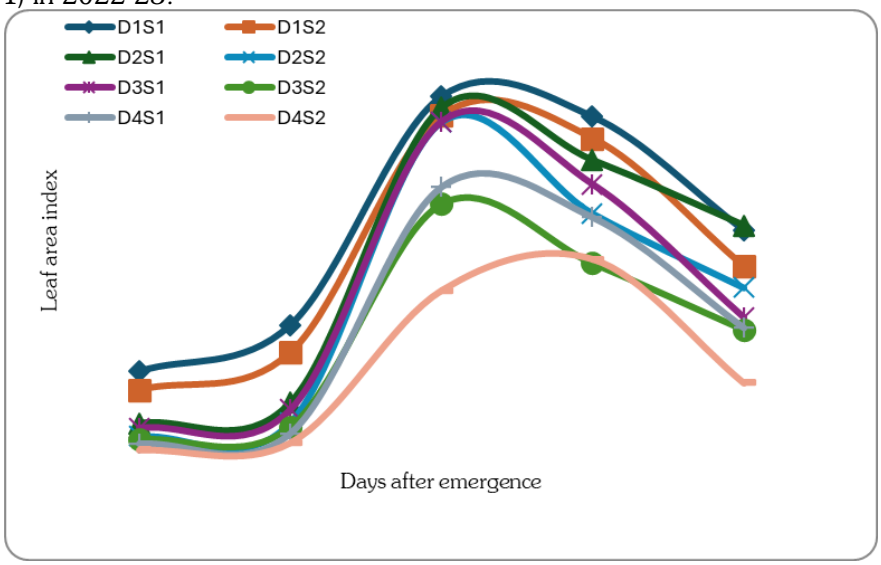

Fig. 3. Leaf area index of chia as influenced by sowing date and row spacing during *rabi* season of 2022-23. Here, D_1×S_1=15Nov×30cm, D_1×S_2=15Nov×40cm, D_2×S_1=30Nov×30cm, D_2×S_2=30Nov×40cm, D_3×S_1=15Dec×30cm, D_3×S_2=15Dec× 40cm

In this study, the variation in plant population greatly influenced LAI. LAI increased with the increase in plant population. Leaf area index increased up to 60 DAE and there after it decrease in all the treatments. The higher LAI was recorded in15 November sowing date with 30 cm × continuous sowing row spacing followed by 30 November sowing date with 30 cm × continuous sowing row spacing in all growth period. Maximum LAI (3.28) was recorded at 60 DAE in 15 November sowing date with 30 cm × continuous sowing (D_1S_1) treatment followed by D_2S_1 treatment. Leaf area index was lower with 40 cm × continuous sowing in all the sowing dates. The result of the present study was also supported by (Karim *et al.*, 2015).

Effect of sowing date and row spacing on total dry matter (TDM) production

The pattern of TDM accumulation in chia over time was influenced by different sowing dates and row spacing (Fig.4). The TDM of chia increased slowly up to 45 DAE when the crop sown on 15 and 30 November. After 45 DAE dry matter accumulation rate increased rapidly up to harvest. Among the sowing dates, 15 November sowing with 30 cm × continuous seeding row

spacing showed the highest TDM (1153 g m^{-2}) at 90 DAE and it was higher throughout the growing period except at 30 and 45 DAE followed by 30 November sowing with 30 cm × continuous seeding and it was higher than 15-30 December sowing throughout the growing period in 2022-23. The crop sown on November got longer duration might be due to favorable temperature for growth and development as compared to other sowing dates and produced the maximum TDM. The results are in agreement with the findings of Karim *et al.* (2015) stated that sowing dates had significant difference on dry matter production. The lowest TDM was observed in 30 December sowing at all over the growing period. Moosavi *et al.* (2012) reported that delay in sowing decreased significantly the plant height, leaf area index, total fresh and dry yield in Maize. Significant differences in plant height of two kenaf genotypes were found between the early and late plantings, throughout the growing period (Danalatos and Archontoulis, 2004).

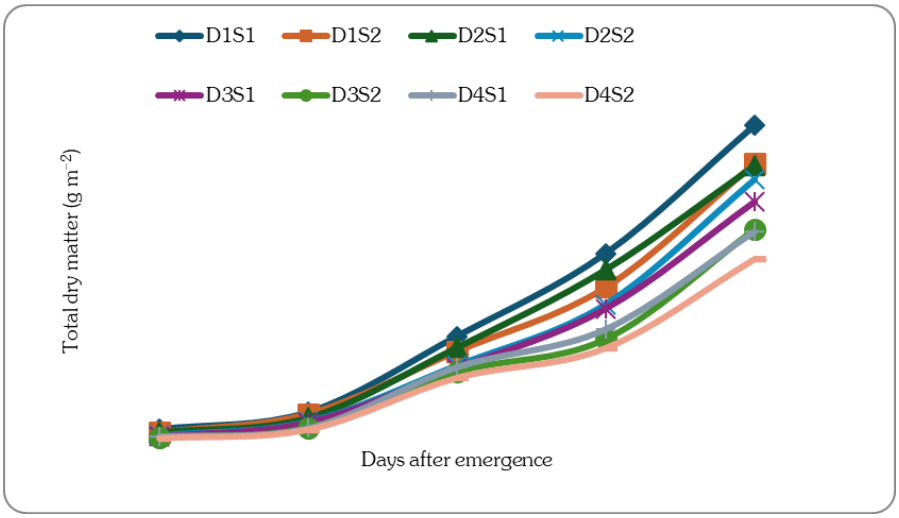

Fig.4.Total dry matter production of chia as influenced by sowing date and row spacing during *rabi* season of 2022-23. Here, $D_1 \times S_1$=15Nov.×30cm, $D_1 \times S_2$=15Nov.×40cm, $D_2 \times S_1$=30Nov.×30cm, $D_2 \times S_2$=30Nov.×40cm, $D_3 \times S_1$=15Dec.×30cm, $D_3 \times S_2$=15Dec.×40cm, $D_3 \times S_1$=30Dec.×30cm, $D_3 \times S_2$=30Dec.×40cm

Yield and yield components

Number of plant population^{-2}, plant height, yield and yield contributing characters of chia were significantly influenced by sowing date and row spacing in all locations (Table 3).

Table 3. Plant population, and plant height at harvest of Chia influenced by spacing and sowing dates

Treatments	Plant population (m^{-2})							Plant height (cm)						
	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.
$D_1 \times S_1$	92	78	79	83	74	119	78	129.33	146.07	106.73	149.53	108.73	98.86	150.7
$D_1 \times S_2$	86	69	67	77	67	101	67	117.33	147.33	112.93	140.07	109.93	98.06	153.3
$D_2 \times S_1$	98	81	73	80	70	96	74	123.20	139.9	108.8	146.93	107.28	96.93	161.9
$D_2 \times S_2$	85	79	69	76	66	84	65	112.37	132.07	109.93	143.73	108.93	95.83	159.9
$D_3 \times S_1$	96	85	79	79	71	94	72	96.00	128.27	98.4	148.00	103.14	94.13	162.9
$D_3 \times S_2$	83	69	68	69	69	84	64	85.56	115.43	80.33	154.20	104.33	92.86	168.33
$D_4 \times S_1$	98	77	76	75	69	90	76	83.37	106.2	88.47	133.53	88.47	90.33	153.8
$D_4 \times S_2$	83	71	67	67	62	77	64	79.93	97.33	106.73	137.00	96.73	88.56	143.5
LSD (0.05)	4.07	10.10	14.10	5.40	3.23	6.9	3.13	3.42	11.7	13.80	NS	13.8	13.07	3.69
CV%	3.89	3.20	10.66	3.66	4.66	10.38	3.66	3.82	5.29	7.77	6.46	7.77	7.90	10.12

Highest (92, 78, 79, 83, 74, 119 and 78) no. of plants were recorded in 15 November sowing with 30 cm row spacing and the lowest was recorded in 30 December sowing with 40 cm

row spacing in all locations. Plant height at harvest varied significantly among sowing date and row spacing in all locations have been presented in Table 3. The highest (129.33 cm, 146.07 cm, 106.73 cm, 149.53 cm, 108.73 cm, 98.86 cm and 150.7 cm at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) plant height was recorded from 15 November sowing with 30 cm row spacing followed by 30 November with 30 cm row spacing in all locations and the lowest from 30 December sowing with 40 cm row spacing all locations.

Significantly the highest number inflorescences plant^{-1} (13, 17, 15, 15, 12, 12 and 14 at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) was obtained from 15 November sowing with 40 cm row spacing whereas 30 December sowing with 40 cm row spacing significantly the lowest number of inflorescences plant^{-1} in all locations (Table 4). The maximum number of seed inflorescences^{-1} (414, 409, 317, 374, 411 and 442 at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari and Rajbari, respectively) was recorded in 15 November sowing with 40 cm row spacing but at Shyampur, maximum number of seed inflorescences^{-1} (442) was recorded in 15 November sowing with 30 cm row spacing whereas the lowest number of seed inflorescences^{-1} was recorded in 30 December sowing with 40 cm row spacing in all locations.

Table 4. Number of inflorescence and seeds inflorescence^{-1}

Treatments	Inflorescence plant^{-1}							Seeds inflorescence^{-1}						
	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.
$D_1 \times S_1$	13	14	14	13	12	14	12	381	358	274	395	360	379	442
$D_1 \times S_2$	15	17	17	15	13	15	13	414	409	317	374	411	442	396
$D_2 \times S_1$	13	13	13	14	12	13	13	359	265	257	342	347	389	397
$D_2 \times S_2$	15	16	15	15	13	14	13	370	274	305	377	368	423	422
$D_3 \times S_1$	10	6	7	12	8	13	15	307	191	231	366	303	377	187
$D_3 \times S_2$	12	7	9	13	9	12	17	325	187	281	352	329	390	173
$D_4 \times S_1$	9	4	5	9	6	12	18	241	91	215	238	242	350	198
$D_4 \times S_2$	9	6	7	9	8	11	21	250	92	254	250	261	365	95
LSD (0.05)	0.63	0.61	0.61	0.93	0.39	2.11	2.76	23.78	65.5	23.5	51.98	20.89	71.60	37.2
CV%	4.09	3.37	3.26	4.23	3.32	9.27	10.46	4.09	3.01	5.24	5.13	3.74	9.42	7.35

The highest 1000-grain weight (1.27, 1.04, 1.23, 1.24, 1.48, 1.27 and 1.3 g at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari and Shyampur, respectively) was recorded in15 November sowing with 40 cm row spacing and the lowest grain weight was recorded in 30 December with 30 cm row spacing in all locations (Table 5). There are reports of thousand seed weight ranging from 1.21 grams to 1.31 grams, in field trials in Argentina (Rovati *et al.*, 2012). Grain yield of a crop is the expression of combined effects of various yield components. All the yield components contributed to the final yield. Significantly the highest yield (1059.41, 823.80, 849.42, 1037.94 and 828.64 kg ha^{-1} at Gazipur, Jamalpur, Jashore, Burirhat and Hathazari, respectively) was obtained from 15 November sowing with 30 cm row spacing which was statistically similar to 30 November with 30 cm row spacing but at Rajbari and Shyampur produced the highest yield in 15 November sowing with 40 cm row spacing (1273 and 1327.00 kg ha^{-1}). The lowest yield (359.57, 448, 420.74, 633.92, 333.43, 273.67 and 508.33 kg ha^{-1} at Gazipur, Jamalpur, Jashore, Burirhat, Hathazari, Rajbari was Shyampur in 30 December sowing with 40 cm row spacing. All the wider row spacing yielded lower at December 30 sowing might be due to high temperature at reproductive stage which caused lower number of inflorescences plant^{-1}, seed inflorescences^{-1} and lower seed size. These findings agree with Wojahn *et al.* (2018) and Busilachi *et al.* (2013). This difference in seed yield among different sowing time difference in adaptation to high temperature, which reduced the yield drastically due to its detrimental effects on metabolism and duration of phonological phases (Ali and Sarker, 2016). The present study revealed that more TDM production in 15 November sowing with 30 cm row spacing and long

crop growth duration increased inflorescences size and seed number per inflorescences that ultimately increased the seed yield. On the other hand, the lowest grain yield was observed in 30 December sowing. It was founded that 30 December sowing crop received cool temperature at early growth stage which produced higher flower and higher temperature at reproductive phase that hastened maturity and reduced TDM production and translocation of less dry matter to the reproductive organ (grain). Yield of chia was found more or less high at Gazipur, Burirhat, Shyampur and Rajbari than Jashore, Hathazari and Jamalpur locations. It might be due to maximum and minimum temperature prevailed during chia growing period at Gazipur, Burirhat, Shyampur and Rajbari was lower than Jashore, Hathazari and Jamalpur location (Fig.1 and 2). Similar findings were also obtained by Ayerza and Coates (2005). Ayerza and Coates (2007) also reported that the yield of chia 2253 kg ha^{-1} and the growth period required 135 days in yungas ecosystem of tropical Argentina.

Table 5. Weight of thousand seeds and yield (kg ha^{-1})

Treatments	1000-seed weight (g)							Yield (kg ha^{-1})						
	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.	Gaz.	Jam.	Jas.	Bur.	Hat.	Raj.	Shyam.
$D_1 \times S_1$	1.24	1.02	1.20	1.23	1.46	1.10	1.13	1059.41	823.80	849.42	1037.94	828.64	1010.00	1280.33
$D_1 \times S_2$	1.27	1.04	1.23	1.24	1.48	1.27	1.30	1001.92	762.40	772.36	998.16	767.79	1273.00	1327
$D_2 \times S_1$	1.21	0.87	1.24	1.21	1.45	1.17	1.14	1010.49	815.73	788.90	1000.2	799.55	1010.67	1132
$D_2 \times S_2$	1.23	0.91	1.22	1.20	1.46	1.21	1.07	895.68	725.33	732.23	973.43	678.56	893.33	1293.66
$D_3 \times S_1$	1.18	0.79	1.25	1.17	1.45	1.07	0.99	684.72	686.13	622.12	763.72	648.18	525.00	726.66
$D_3 \times S_2$	1.20	0.93	1.26	1.17	1.46	1.13	0.77	621.94	566.40	573.30	768.5	542.71	501.00	673.33
$D_4 \times S_1$	0.82	0.90	1.17	1.14	1.44	0.87	0.79	436.32	557.87	560.03	675.29	438.89	318.00	510
$D_4 \times S_2$	0.84	0.89	1.19	1.15	1.40	1.04	1.15	359.57	448.00	420.74	633.92	333.43	273.67	508.33
LSD (0.05)	0.05	0.12	0.04	NS	NS	0.97	0.14	63.32	45.11	50.56	59.29	35.68	16.60	78.84
CV%	3.18	7.39	4.56	4.12	5.44	4.83	7.76	4.72	3.83	4.34	3.95	3.24	4.82	4.83

Here, $D_1 \times S_1$=15Nov×30cm, $D_1 \times S_2$=15Nov×40cm, $D_2 \times S_1$=30Nov×30cm, $D_2 \times S_2$=30Nov×40cm, $D_3 \times S_1$=15Dec×30cm, $D_3 \times S_2$=15Dec×40cm, $D_3 \times S_1$=30Dec×30cm, $D_3 \times S_2$=30Dec×40cm

Relationship between grain yield and air temperature

There was a negative linear relationship between yield (kg ha^{-1}) of chia and air temperature of all locations has been shown in Fig. 5. At Gazipur, the regression line (Y= −191.83x+4984, R^2=0.94) indicated that the regression of co-efficient (x) was 191. This expressed that yield of chia would decrease at the rate of 191 kg ha^{-1} per increase of 1^0C air temperature. The co- efficient of determination (R^2=0.94) value indicated that air temperature had 94% effect on yield of chia. Similar expression was made by the regression line (Y= −98.88x+2694, R^2 =0.90) at Jamalpur, (Y= −84.90x + 2640, R^2=0.96) at Jashore, (Y= −130.90x+3710, R^2 =0.82) at Hathazari, (Y= −57.12x + 2058.1, R^2=0.76) at Burirhat, (Y= −224.9x + 5280, R^2=0.74) at Rajbari and (Y= −134.26x + 3762.4, R^2=0.91) at Shyampur. The results revealed that increasing temperature decreases the yield of chia. Similar results have also been described by Mian *et al.* (2016). Temperature co-efficient (average of seven locations) of chia was estimated at 131.81 kg ha^{-1} decreased per increasing 1 °C air temperature. Effect of temperature on the grain yield of chia was estimated at 74-94%.

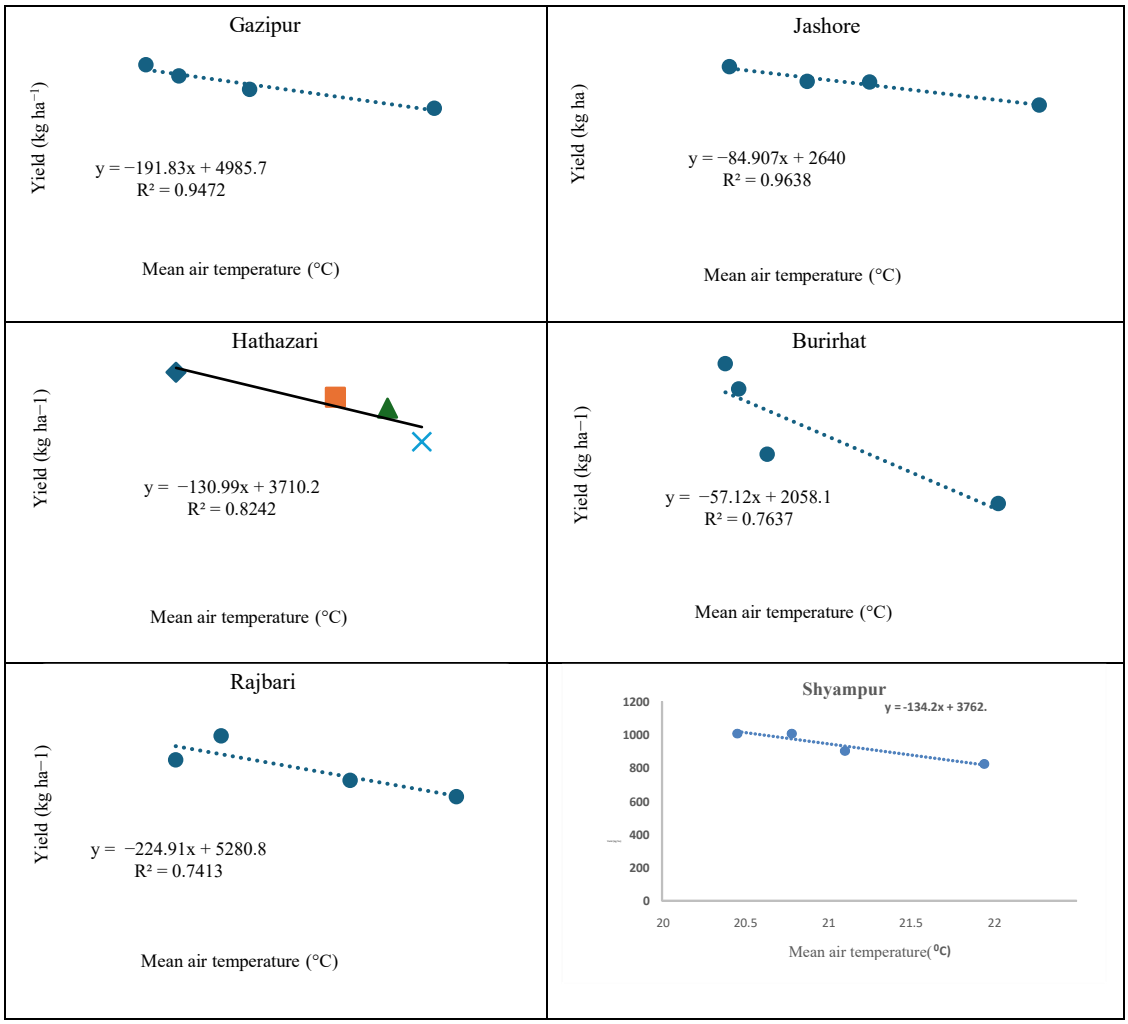

Fig.5. Functional relationship between mean air temperature and grain yield of chia

Conclusion

Results revealed that November 15 to November 30 sowing would be the optimum sowing date for chia in relation to air temperature. Temperature co-efficient of chia was estimated at 131.81 kg ha^{-1} decreased per increasing 1 ^{0}C air temperature and the effect of temperature on grain yield of wheat was estimated at 74-94%.

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