__Review Article__

Influence of different sowing date on the morphology, phenology and thermal indices of rapeseed: A review

ABSTRACT

India ranks third in the world in the area and production of rapeseed mustard. Rapeseed mustard accounts for approximately 80% of all rabi oilseed production Currently, rapeseed cultivation accounts for less than 1% of the total area of rapeseed mustard in India. Weather is a very important factor among various abiotic stressors that affect crop growth and yield. Therefore, the plant response is greatly influenced by changes in the growing environment such as sowing date, rainfall, and temperature. Weather parameters play an important role in determining plant growth development and yield as the physical expression and various metabolic processes of a plant's genetic potential are strongly influenced by environmental factors. Rape blossoms are usually sown from mid-October to mid-November. Under multiple cropping systems after transplanting winter rice, the sowing time is usually from mid-November onwards. The thermal unit increased up to 120 DAS and decreased slightly upon maturation. Delayed sowing results in stunted growth, premature ripening, and a significant reduction in yield, primarily due to increased temperatures during grain-filling. In addition, late sowing depletes soil moisture, which adversely affects crop performance. Therefore, sowing at different dates is discussed in this review to find the optimum time to harvest more yield.

KEY WORDS: Early sowing, GDD, HTU, PTU and HUE

INTRODUCTION

Rapeseed (*Brassica napus* L.), also known as rape, oilseed rape, or Gobhi sarson, belongs to family Brassicaceae and is cultivated mainly for its seed yield having about 40% oil, which naturally contains erucic acid. Canola are a group of rapeseed cultivars which were bred to have very low levels of erucic acid. Rapeseed and mustard crops are cultivated in 53 countries covering area of 24.2 million hectares with total production of 35.1 million tonnes. India ranks third in the world in the area and production of rapeseed mustard. Rapeseed mustard, which accounts for approximately 80% of all rabi oilseed production, is an important component of the edible oil sector (Kumar *et al.,* 2009). Rapeseed is the second most important crop after groundnut and are grown under rainfed condition with low input during rabi season. Currently, rapeseed cultivation accounts for less than 1% of the total area of rapeseed mustard in India. Despite traditional preferences for qualities such as spiciness, there is a niche market for rapeseed oil among some Indian consumers (Sonvanee and Pathak, 2016). Due to its suitability for both sole cropping and mixed cropping, it is becoming increasingly popular among farmers. In addition, it provides higher returns with minimal production costs and little water usage.

Weather parameters play an important role in determining plant growth development and yield, as weather strongly influences the physical expression of a plant's genetic potential. The goal of national availability of high-quality edible oil can only be achieved by increasing oilseed productivity. Sowing time is the most important non-monetary input for achieving target mustard yields Sowing time affects crop phenological development through temperature and heat units. During rabi season sowing from September- October to February-March is common (Kumar *et al.,* 2009). However, when introducing multiple cultivation systems, especially after winter rice, the sowing time is usually from mid-November onwards. (Das *et al.,* 2021). Pod number, pod length, number of seed siliqua^{-1} and seed maturity are strongly influenced by growth and environmental factors such as sowing date, fertilization, water and temperature conditions, harvest date, etc (Diepenbrock, 2000). Sowing at the optimum time gives higher yields because the right environment prevails at all stages of growth. The production efficiency of rapeseed varies greatly under different planting days. Delayed sowing results in stunted growth, premature ripening, and a significant reduction in yield, primarily due to increased temperatures during grain-filling.

The yield was greatly affected by temperature and radiation during pod and seed germination. The availability of assimilation at this stage determines the number of seeds m^{-2} (sink size). After flowering, only temperature significantly affected winter oilseed rape yield. Temperature is the main parameter that determines the duration of the growth stage. Lower temperatures increase the time for assimilation production and transfer to seed (Weymann *et al.,* 2015).

RESULTS

Effect of date of sowing of rapeseed on growth parameters

Razzaque *et al.* (2007) reported the highest plant height (120 cm) was obtained at sowing on 15 Nov, with 8%, 13.3% and 15% decreased when sown on 23 Nov, 30 Nov and 7 Dec respectively in mustard and rapeseed. Bhuiyan *et al*. (2008) reported the highest plant height of 115 cm was recorded from 10 November sown rapeseed. Kok (2010) observed significantly higher plant heights from early sowing to that of the late sowing plot of the canola. Dinda *et al.* (2015) found that different sowing dates of oilseed rape had a significant impact on growth characteristics. Of the three sowing days, October 20 was found to be superior to the others with the highest values for plant height (156.68 cm) and the number of branches per plant (6.07). Mondal *et al.* (2011) found that November 20 planting had the highest plant height and the November 30 planting had the shortest plant from the average of the 3 years. However, the highest dry weight (4.15 t ha^{-1}) was achieved on October 20 sowing and decreased with later sowing of rapeseed and mustard. Khayat *et al.* (2015) conducted an experiment on four planting dates *viz.* 6 Nov, 21 Nov, 6 Dec and 21 Dec of rapeseed and reported that 6 Nov (22.34 g m^{-2} day^{-1}) showed the highest relative growth rate (RGR) and the 21 Dec (16.5 g^{-2} day^{-1}) the lowest RGR. The total dry matter on 6 Nov (1271.25 g m^{-2}) was superior compared to other planting days. Kaur *et al.* (2022a) found that the maximum plant height, LAI and dry matter accumulation of primary and secondary branches were measured at the 25th of October Gobhi sarson seeding which was on par with the October 10 sowing and outperforming the crop sown on November 15 at all stages of growth.

Bhuiyan *et al.* (2008) observed that out of the five planting dates *viz.* October 20, October 30, November 10, November 20 and November 30 of rapeseed, the highest number of primary branches $plant^{-1}$ (6.85) was found from the plants of October 20 and it was statistically similar with October 30 and November 20. The lowest number of primary branches $plant^{-1}$ was recorded from the plants of November 30 planting, which was 6.20. Singh *et al.* (2014) studied two different dates of sowing *i.e.* 26 October and 26 November and found that the 26 November sown rapeseed was higher in terms of primary and secondary branches. Ranabhat *et al.* (2021) found that the number of branches was maximum (8.09) on November 14th, followed by October 4th (8.03) and minimum on October 24th (5.4), while the overall average of branches $plant^{-1}$ was 7.17 for rapeseed (Table 1). Khatiwada *et al.* (2021) observed the highest number of branches $plant^{-1}$ of rapeseed on October 28th and the lowest on November 27th at 70 DAS.

Effect of date of sowing of rapeseed on number of days to flowering and maturity

Uzan *et al*. (2009) conducted an experiment on canola to investigate the effect of sowing date approximately 20 days apart, from October 1 to January 10 on the growth and flowering patterns during the 2004-05 and 2005-06 growing seasons and reported that growth and flowering decline with late sowings. According to Kok (2010), the number of days to 50% flowering of canola was significantly increased with early sowing and early seeded plants required more days to flower (84.46 in 2005 and 86.29 in 2006) than late seeded plants *i.e* early sown plants extended from 3.62 days to 7.4 number of days to flowering. Shamsi *et al.* (2012), also reported that late planting caused a shortening of the flowering time in oilseed rape and a significant positive correlation between the length of the flowering time and the seed yield component. Similarly, Akhter *et al.* (2015) conducted an experiment on rapeseed to investigate the effect of sowing date on phenology on four different dates on S1- 18 Oct, S2- 2 Nov, S3- 17 Nov and S4- 3 Dec. The results showed that delayed seeding shortened the time to reach various phenological stages. The number of days required to reach different seasonal stages was in the order S1 > S2 > S3 > S4. The S1 plant took the longest, followed by S2, S3, and S4 (Table 2). Devi and Sharma, (2017) found that delayed sowing significantly shortened the flowering period. During 2015, crops sown on 6th October had the longest flowering period (45 days), followed by 23rd October (41 days) and 12th November (35 days). Crops sown on 23rd October had the earliest flowering (106 days) and crops sown on 12th November took up to several days to flower (113 days) followed by 6th October. In 2016, mustard sown on 1st October took the most days to flower (107 days), followed by 7th October (105 days) while 3rd November took the shortest days (98 days) to harvest.

Bhuiyan *et al.* (2008) observed the longest period to mature (80 days) for rapeseed sown on10 November while the shortest period (77 days) by November 20 and November 30 plantings and opined that early plantings required a longer period to mature and delayed sowing reduces time to mature (Fig 1). Mondal *et al.* (2011) laid out a field experiment at the BARI Agricultural Research Station in Bangladesh during the rabi season for three consecutive years (2004-05, 2005-06, 2006-07) to identify the optimal planting time from 5 planting days (October 20th, November 1st, November 10th, November 20th, November 30th) of rapeseed reported that 1st November planting took 29, 28, 29 days to flower and 81, 82, 81 days to maturity for three years respectively. The November 1st planting required the longest ripening time and the shortest grain filling time was 77 days on November 30th. Soleymani and Shahrajabian (2013) also found that reported the maximum number of days from planting to stem elongation (165.5), from 50% flowering to 100% flowering (15.8), from initiation of stem elongation to maturity (29.14), from stem elongation to maturity (62.17) and from sowing to maturity (227.7) were obtained on early sowing brassica. Kaur *et al.* (2018) also reported that rapeseed sown on October 15 took 3.8 days longer and November 15 took 5.8 days longer to reach physiological maturity compared to crops sown on October 30.

Effect of date of sowing of rapeseed on yield and yield attributes

Razzaque *et al.* (2007) reported the maximum number of siliqua plant^{-1} (105.28), number of seed siliqua^{-1} (11.52) was reached on the first sowing (15 Nov) of rapeseed and then decreased significantly. The number of siliqua plant^{-1} decreased significantly by 11.54%, 27.79% and 32.84% when sown on 23rd Nov, 30th Nov and 7th Dec compared to 15th Nov (Table 3). Bhuiyan *et al.* (2008) observed that 30 Oct sowing plants produced the most seeds siliqua^{-1} which was statistically similar to 20 Oct, 10 Nov, and 20 Nov sowing and a decrease in weight of 1000 seeds indicating that the test weight decreases with each successive sowing delay of rapeseed. Dinda *et al.* (2015) also conducted a field trial on three different dates (October 20, November 5 and November 20) of rapeseed and recorded the highest values for siliqua plant^{-1} (125.74), seeds siliqua $^{-1}$ (18.09) and test weight (3.68 g) from sowing on 20 October (Table 4). Khayat *et al.* (2018) reported that the first planting date of rapeseed (Nov 6) had the highest number of pods plant^{-1} and 1000 seed weight.

Butkevičienė *et al.* (2021) reported that the timely sown rapeseed produced the most plant siliqua, averaging 2.8 times more than other sowing times during 2018. During 2019, most pods were formed by the last sown rapeseed with 1.4 to 2.7 times more siliquas. The average number of seeds in a pod was significantly reduced by early sowing. In 2019, the highest 1000 weights were observed at the earliest sowing time, averaging 18.0% higher compared to late sowing. Khatiwada *et al.* (2021) found the shortest siliqua length and the lowest number of seeds siliqua $^{-1}$ when rapeseed was sown on 27th November (table 5). Anuroop *et al.* (2022) reported that plants sown on November 15 recorded the highest siliqua plant^{-1} (137.80), seeds siliqua $^{-1}$ (33.97) and test weight (3.83 g).

Kok (2010) found that early planting resulted in a higher grain yield (2409 kg ha $^{-1}$) and oil content (405 mg g^{-1}) than late planting (1326 kg ha^{-1} and 274 mg g^{-1} respectively) canola. Satter *et al*. (2013) found that rapeseed planted on October 30 achieved higher seed yield, biological yield and HI, whereas on November 15 sown achieved the lowest. Khayat *et al.* (2015) reported that Nov 6 planting rapeseed showed the highest grain yield (2611.6 t ha^{-}

^{1}) and it decreases to 13.74, 31.36 and 41.97% from 21 Nov, 6 Dec and 21 Dec respectively. Similarly, early sowing of rapeseed recorded the highest yield and late sowing significantly reduced yield from 20.7% to 48.2% (Butkevičienė *et al.*, 2021). Khatiwada *et al.* (2021) observed decrease in grain yield @ 17.05%, 40% and 62.18% for 13 Oct, 12 Nov and 27 Nov sown compared to 28 Oct sown rapeseed (Table 5). Kaur *et al.* (2022a) reported that the maximum seed yield, stover yield and biological yield of ghobi sarson were observed on 25th October sowing and were significantly better by 4.18%, 4.23%, 4.23% for October 10 sowing and 11.33%, 12.09%, 11.92% for November 15 sowing respectively.

Mondal *et al.* (2011) observed the highest oil content and oil yield was recorded on November 1^{st} sown rapeseed and the lowest on November 30^{th}. The percentage of rapeseed oil was higher in early planting and decreased with late planting (Fig 2). Fard *et al.* (2018) reported that mean oil content of canola sown on 2^{nd} February decreased by 4.6% compared to the 7^{th} October sown rapeseed autumn crop. Sevgi and Aydin (2021) investigate the effects of two sowing dates (early and late) of rapeseed and the early sowing date resulted in the highest crude oil rate (43.34 to 43.54%) in both years.

Effect of date of sowing of rapeseed on thermal indices

Singh *et al.* (2014) studied two different sowing dates *i.e.* October 26 and November 26 of rapeseed and found that the effects of high temperatures on crops sown on November 26 in terms of primary shoots, secondary shoots, pod length, seeds pod^{-1}, the weight of 1000 seeds, and seed yield plant^{-1}. Weymann *et al.* (2015) reported that nearly 40% inconsistency of rapeseed seed yield is due to weather situations. Temperature and radiation during pod and seed germination greatly affected the yield and yield-response patterns showed that winter oilseed rape yield is p source restricted during the late reproductive period. Patel *et al.* (2017) observed that early sown crop faced good soil moisture, relatively warm temperatures during the vegetable season, and conducive temperatures during the 50% flowering and pod forming stages. However, late sown crops experienced cooler temperatures at emergence and 50% flowering. Singh (2018a) from meteorological data show that both the maximum and minimum temperatures on the first day of sowing (7 October) were high during the early growing stage, but then both the maximum and minimum temperatures on the first day began to decrease while the second and third sowing days rose from 80-100 days to physiological maturity. However, it is reported that the crops sown on October 27 may have been forced to mature due to the high temperatures during the breeding season.

Adak and Chakravarty (2010) found that fewer heat units were absorbed on October 30 than on October 15 sown brassica. Akhter *et al*. (2015) laid out a field experiment of rapeseed on four different dates on S1- 18 Oct, S2- 2 Nov, S3- 17 Nov, S4- 3 Dec and the results showed that the growing degree day (GDD), heliothermal unit (HTU) and heat use efficiency (HUE requirement decreased with delayed sowing to different phenological stages and S1 required the highest followed by S2, S3 and S4 at all phenological stages. S1 plants required 485.77 GDD for bud initiation, 554.90 for flowering initiation, 802.72 for pod filling and 1020.70 GDD for physiological maturity in an average of 2 years (Table 6). Similarly, the highest HTU was recorded in In S1 with 3717.25 for bud initiation, 4282.74 for flowering initiation, 5782.80 for pod filling and 6892.75 for average two years of physiological maturity. Consequently, in S4, the lowest requirements were observed at all phenological stages (Fig 3). Singh (2014) reported that the agrometeorological indices *viz*. GDD, PTU (photothermal unit) and HTU were high at sowing on 10 October and decreased with each later sowing. Singh *et al*. (2015) observed that among the sowing dates, HUE was the highest on October 25, followed by October 10 and November 10 sowings for all growth stages. Also, HUE was higher at 90 DAS for all sowing days. Singh *et al*. (2018b) found that brassica sown on 7 October accumulated more GDD, HTU, PTU and HUE (0.86 gm^{-2}°Cday^{-1}) followed by 17 and 27 October. Djaman *et al*. (2018) observed that the mean daily temperature decreased from 21.6 on September 1 to -7.0°C on January 4 and then increased to 25.4°C. The heating time requirement for oilseed rape was recorded in the GDD with 5°C as the base temperature and found to decreased from 1 to 10 November, and remained virtually zero until 5 March and then increased. The cumulative average total seasonal GDD was 2283°day.

DISCUSSION

According to Kok (2010), the difference in the duration between early and late seeding is related to changes in temperature direction and solar irradiance immediately after seeding. In general, dry matter accumulation occurs at a slow rate until the crop reaches full ground cover, after which it increases at a much faster rate. This is probably due to differences in temperature during the growing season. Cooler temperatures reduced vegetative activity in the early-seeded plots. Stems, pods, and to a lesser extent leaves all contributed to the increase in total dry matter, but only the pods gained weight thereafter There was a negative relationship between planting date and dry matter at both 50% flowering and final harvest. This reflects a shortened vegetative period. Later planting dates may have more cumulative growing degree days, resulting in faster overall crop development due to the late planting of canola (Begna and Angadi, 2016). Early sown crops faced good soil moisture and relatively warm temperatures during the vegetable season and beneficial temperatures during the 50% flowering and pod-forming stages. However, late sown crops experienced cooler temperatures (Anuroop *et al.,* 2022).

The decrease in grain yield with a late sowing date can be largely explained by the decrease in biomass at maturity, while oil content was positively correlated with harvest index and seed size, and negatively correlated with post-flowering temperature conditions of canola and mustard (Robertson *et al*., 2004). According to Shaarghi *et al.* (2011), increased in seed yield in early planting may be due to increased uptake of light, water, and minerals by the plant canopy, thereby increasing photosynthetic capacity. While reduced in rapeseed yield and yield attributes such as primary shoots, number of secondary shoots, seeds pod^{-1}, and 1000 seed weight for late and early sowing may be due to heat stress (Singh *et al.,* 2014). The availability of assimilation determines the number of seeds m^{-2} (sink size). After flowering, only temperature significantly affected winter oilseed rape yield. Lower temperatures increase the time for assimilation production and transfer to seed. Seed weight is determined at this stage of growth and small sink size did not limit yield due to a compensating effect between the yield component number of seeds m^{-2} and 1000 seed weight of rapeseed (Weymann *et al.,* 2015)**.** Rana *et al.* (2017) reported that at 90% pod formation period, plant GDD, HTU and PTU requirements decreased with delay in sowing on different days. More GDD is required in early sowing to reach physiological maturity compared to late sowing and this may be owing to high temperatures during the late growing season, which forced the crop to mature.

CONCLUSION

From the above results, we can conclude that sowing at the optimum time gives better growth and higher yields of rapeseed mustard. To produce higher yields, it required optimal heat and sunlight for different plant processes. Thermal units had positive effects on growth and yield parameters and decreased with successive seeding delays. Sowing too early or delayed sowing results in stunted growth, premature ripening and a significant reduction in yield.

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Table 1. Effect of different sowing dates on plant height and number of branches per plant^{-1} (Ranabhat *et al.* 2021)

Sowing dates	**Plant height (cm)**	**Number of branches plant^{-1}**
Oct 4	84.71	8.025
Oct 24	60.325	5.4

Nov 14	46.762	8.087

Table 2. Mean average values of two seasons of phenology (days after sowing) at different stages as affected by different sowing dates (Akter *et al.*, 2015).

Date of sowing	Bud initiation	Flower initiation	Pod filling	Physiological maturity
S1 (18 October)	33.61	39.78	64.52	93.26
S2 (02 November)	30.6	36.61	60.91	88.85
S3 (17 November)	28.07	33.96	57.37	83.98
S4 (03 December)	25.89	31.82	54.37	80.54

Table 3: Effect of sowing date on yield attributes and yield of rapeseed pooled data (Razzaque *et al.*, 2007)

Sowing date	Siliqua plant^{-1}	Seed siliqua^{-1}	Seed yield (kg ha^{-1})
15 Nov	105.28	11.52	1164.00
23 Nov	93.13	11.06	1001.90
30 Nov	74.33	10.52	700.63
7 Dec.	72.40	9.46	611.90

Table 4: Effect of dates of sowing of rapeseed yield attributes and yield pooled data of two seasons (Dinda *et al.*, 2015)

Sowing date	Siliqua plant^{-1}	Seeds siliqua^{-1}	Test weight (g)	Seed yield (t ha^{-1})	Oil content (%)
Oct 13	125.74	18.09	3.68	1.35	40.65
Oct 28	118.60	16.89	3.62	1.30	40.00
Nov 12	109.46	16.03	3.44	1.22	39.18

Table 5. Effect of different dates of sowing on yield attributes and yield as influenced by (Khatiwada *et al.*, 2021)

Sowing date	**Siliqua plant^{-1}**	**Siliqua length (cm)**	**Seeds siliqua^{-1}**	**Test weight (g)**	**Seed yield (t ha^{-1})**
13 October	54.79	5.57	10.08	2.60	1.06
28 October	59.64	6.09	14.89	2.83	1.27
12 November	50.14	5.26	8.26	2.16	0.76
27 November	45.49	4.19	6.12	1.91	0.48

Table 6. Mean values of GDD at different phenological stages as affected by sowing dates average of two seasons (Akter *et al.*, 2015)

Sowing date	**Bud initiation**	**Flower initiation**	**Pod filling**	**Physiological maturity**
S1 (18 October)	485.77	554.9	802.72	1020.7
S2 (02 November)	383.56	449.95	684.28	896.42
S3 (17 November)	310.4	356.71	545.56	767.63
S4 (03 December)	248.01	292.97	448.35	716.21

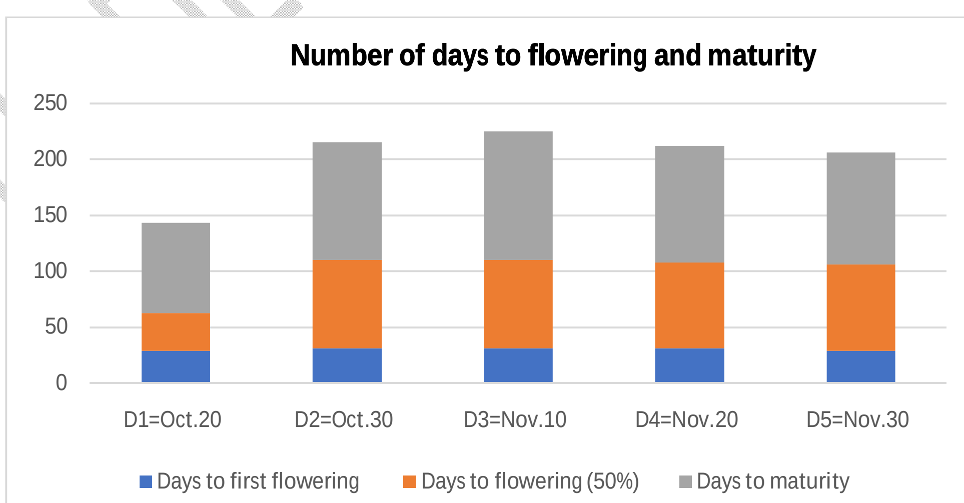

Fig 1: Effect of sowing dates on number of days to flowering and maturity (Bhuiyan *et al*., 2008)

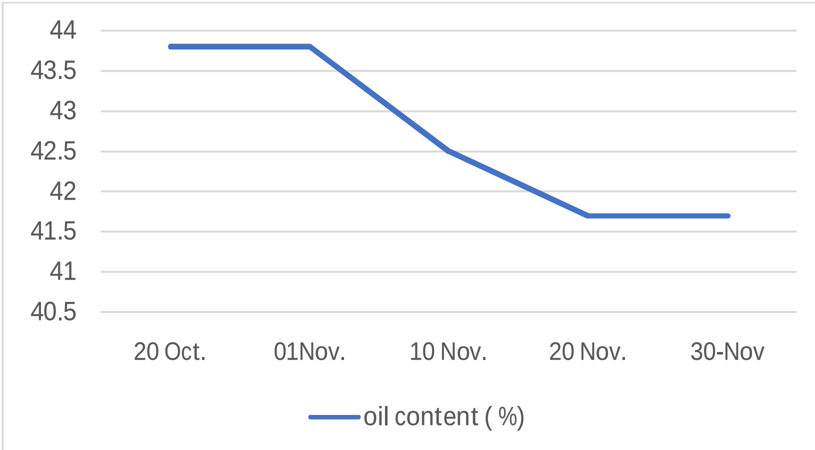

Fig 2. Mean values of rapeseed oil content as influenced by different planting dates (Mondal *et al*., 2011)

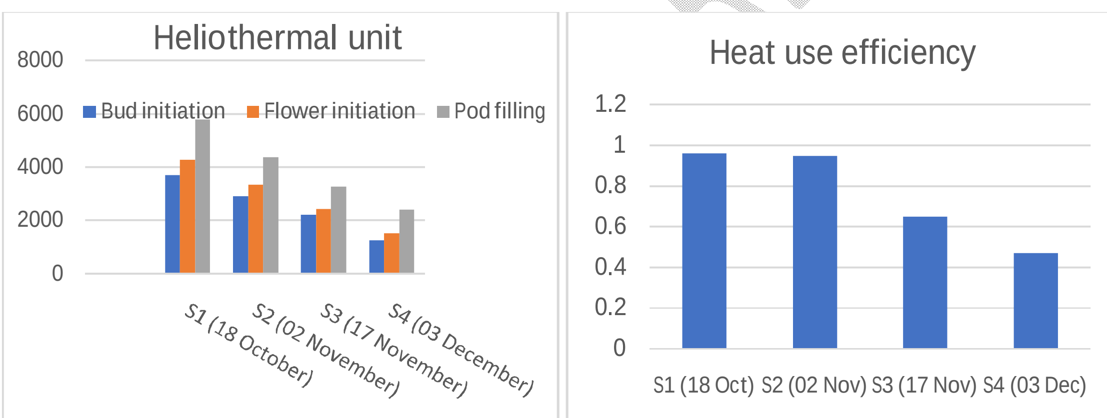

Fig 3. Effect of sowing dates on HTU and HUE at different phenological stages average of two seasons (Akter *et al*., 2015)