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Review paper

Influence of sowing date on growth and productivity of rapeseed-mustard: a review

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Abstract

Sowing date is an important factor that determines the length of growing season affecting yield attributes and yield of any crop. Rapeseed-mustard being a photosensitive crop is significantly influenced by sowing date with respect to growth and productivity has been studied by different research workers. The optimum time for sowing of rapeseed-mustard is important as the phenological (phasic) development in terms of organ appearance and its rate of development is directly associated with prevailing weather conditions and the sowing date depends on the prevailing climatic conditions in the location. Shift in sowing dates directly influences both thermoperiod and photoperiod as temperature regimes affects phenological and physiological parameters of mustard and consequently causes variation in yield. Therefore, results from different studies revealed that the maximum yield potential of rapeseed-mustard crop is usually achieved when the crop is exposed to the most appropriate temperature range, which can be controlled by sowing at the proper time. In this paper an attempt has been made to critically review the research works carried out by the researchers which may contribute in realizing the optimum date of sowing for higher growth and productivity in rapeseed-mustard.

Keywords: *Growth, rapeseed-mustard, sowing dates, weather, yield*

Introduction

Oilseed crops play an important role in Indian agriculture wherein, rapeseed-mustard is one of the major oilseed crops, traditionally grown everywhere in the country due to their high adaptability in conventional farming systems. Among nine oilseeds, soybean (39 %), groundnut (26 %), and rapeseed-mustard (24 %) account for more than 88 % of the total oilseeds production in the country. However, rapeseed-mustard (31 %) contributes the most in edible oil production in the country, followed by soybean (26 %) and groundnut (25 %) (Bhagat *et al.*, 2022a). Rapeseed-mustard is grown in tropical and sub-tropical regions as a cold season crop during 2019-20 (Shekhawat *et al.*, 2012), it was grown on 6.86 million ha in India, with a production of 9.12 million tonnes and a productivity of about 1329 kg/ha (Anonymous, 2021) and. India is the largest importer of edible oils ($10.5 billion) in the world followed by China and USA (Choudhary *et al.*, 2021). Several species within the *Brassica* genus including Indian mustard (*Brassica juncea*), oilseed rape (*B. napus*), Ethiopian mustard (*B. carinata*), Indian rape (*B. rapa* var. Toria), Brown Sarson, (*B. rapa* var. Brown sarson), Yellow Sarson (*B. rapa* var. Yellow Sarson), black mustard (*B. nigra*) and taramira (*Eruca sativa*) are grown as oilseed crops. Among which, *B. napus*, *B. rapa* and *E. sativa* species are classified as "rapeseed", while *B. juncea*, *B. carinata*, and *B. nigra* are classified as "mustard" (Hayward, 2011). The change in crop environmental conditions due to sowing dates is bound to affect the production potential of the crop. Different sowing dates provide variable environmental condition within the same location for growth and development of crop and its yield of *Brassica* species largely depends upon change in environment during crop growth (Panda *et al.*, 2004; Prasad *et al.*, 2018). The physical factors mainly climatic factors cannot be manipulated under field conditions but sowing time can be adjusted to meet the optimum thermal requirements of crop at various phenological stages to avoid any adverse effect on the yield of mustard (Gupta *et al.*, 2017). The growth phase of the crop should synchronize with optimum environmental conditions for better expression of output as yield through the change in environment with many practices including sowing dates. Therefore, sowing at optimum time gives higher yields due to suitable environment that prevails at all the growth stages (Shekhawat *et al.*, 2012). Moreover, optimum sowing time is an important agronomic factor and non-monetary input which plays a key role in achieving the potential yield of a crop in any region by creating suitable environment for optimum growth and development that converts into better yield attributes (Bhagat *et al.,* 2022b). Many authors have reported from experiments carried out to determine the effect of sowing time on rapeseed-mustard, but the results are often contradictory as it is probably subject to variation due to differences in weather at sowing time between seasons and within the range of climates. Due to climate change, it becomes difficult to predict optimum sowing dates for mustard crop. In practice, recommended dates are normally drawn up from the results of long-running series of agronomic experiments, which can give mean sowing dates for higher yield together with realistic estimates of expected yield penalties for each week of delay in planting. However, in accepting such guidelines, several reservations must be appreciated in addition to the fact that use of the recommended date is not a guarantee of highest yield under growing season. First, there can be very large differences in the pattern of response to sowing date among cultivars. Secondly, the interactions between plant diseases and sowing dates are not fully understood. The literature available on effect of sowing date on mustard was reviewed and described as under by using various headings namely phenology, growth parameters (plant height, leaf area index, dry matter accumulation, crop growth rate and relative growth rate), agrometeorological indices, yield attributes (number of branches per plant, number of siliquae per plant, number of seeds per siliqua and test weight) and yield (seed yield, stover yield and biological yield). Hence, the work of previous researchers and scientists relevant to sowing date has been gleaned from the different sources of literature over the years are collected and presented in a systematic way in this paper.

Effect of sowing date on phenology of rapeseed-mustard

To evaluate the development of any crop with respect to prevailing weather conditions, the most important aspect is to study the occurrence of different phenological stages, which determines the phasic development of crop with respect to the prevailing environments. Kumar *et al.* (2004) observed that flower initiation delayed significantly under 7th October planting as compared to crop sown on 14th October and 21st October in mustard crop at Haryana. Kaur *et al.* (2006) stated that the rate of development from emergence to anthesis in most of mustard crop species depends upon photoperiod and the temperature. Khushu *et al.* (2008) found that duration of each phenophase and the number of days to reach physiological maturity was shortened under the delayed sowing of mustard crop at sub-tropical zone of Jammu region. Gomez and Miralles (2011) suggested that length of the reproductive phase can be increased at the expense of a reduction in the duration of the vegetative phase, but without changing the whole duration of the crop cycle in gobhi sarson (*B. napus*). The results showed that oilseed rape evidenced photoperiod responses during vegetative and early reproductive phases that yield could be increased by lengthening the duration of that phase. Akhter *et al.* (2015) studied the effect of date of sowing and varieties on yield of Brown Sarson (*B. rapa*) and reported that the number of days were increased to reach flower bud initiation stage due to delay in sowing. Moreover, early planting on 1st October had taken lesser number of days for seedling emergence and rosette stage as compared to the later dates of sowing. Devi and Sharma (2017) conducted field experiments for two consecutive years (2015 and 2016) to determine the effect of sowing date on flowering in mustard (*B. juncea*) and found that the crop sown on 6th October had the longest flowering duration (45 days) followed by the crop sown on 23rd October (41 days) and 12th November (35 days) during 2015. Likewise, in 2016 the crop sown on 1st October had the longest flowering duration of 42 days and minimum in 3rd November (35 days). Gupta *et al.* (2017) conducted field experiments for two consecutive years *i.e.*, 2010-11 and 2012-13 on two cultivars of mustard (RL-1359 and RSPR-01) with three dates of sowing (9th October, 24th October and 8th November) at Jammu and reported that late sown crop took more number of days to complete early stages *viz.*, fifth true leaf exposure and pod development. Whereas, it took lesser number of days from flower bud initiation stage. Singh *et al*. (2017) found that mustard sown on 25th October took more number of days to attain physiological maturity followed by 5th November and 15th November sown crop. Prasad *et al.* (2018) revealed that the early sown gobhi sarson crop took more number of days to attain different phenological stages due to the maximum mean temperatures during the reproductive phase. Kaur *et al.* (2018) at Ludhiana observed that each successive delay of 15 days in sowing of oilseed rape (*B. napus*) from 15th October to 15th November significantly delayed the initiation and completion of emergence and required significantly more number of days for completion of flowering stage but required lesser number of days to attain physiological maturity.

Effect of sowing date on growth of rapeseed-mustard

Plant height

Plant height is an important index for studying the growth and development of the crop plant. Due to the indeterminate growth habit shown by the *Brassica sp.* leads to the continuous increase in the plant height with the advancement in age of crop. Sharma and Thakur (1993) conducted a field experiment to evaluate the performance of Gobhi Sarson (*B. napus*) under different dates of sowing *viz.*, October 15th, October 30th, November 15th and November 30th and found that the plant height reduced significantly under late sown crop as compared to early sown crop. Dinda *et al.* (2015) studied the effect of sowing dates on growth of rapeseed-mustard varieties at West Bengal and found that 20th October (156.68 cm) sown crop recorded significantly higher plant height as compared to the crop sown on 5th November (151.91 cm) and 20th November (147.04 cm). Gogoi *et al.* (2017) conducted and experiment for two years to study the influence of different sowing dates on toria (*B. rapa)* at Assam and revealed that crop sown on 1st December recorded significantly taller plant height as compared to the crop sown on 8th December, 15th December and 22nd December. Similarly, Patel *et al.* (2017) conducted a field experiment at Faizabad, Uttar Pradesh and assessed the effect of different dates of sowing on the growth, yield and quality of various Indian mustard (*B. juncea*) varieties and reported significantly highest plant height in crop sown on 14th November in comparison to 15th October and 29th November sown crop at 60 DAS, 90 DAS as well as at harvest stage but was at par with 30th October sown crop. Keerthi *et al.* (2017) reported that the Indian mustard (*B. juncea*) sown on 15th October (226.7 cm) recorded significantly highest plant height as compared to 25th October (222.3 cm), 5th November (218.2 cm) and 15th November (208.6 cm) sown crop. Kumar *et al*. (2017) conducted an experiment on Indian mustard genotypes with three different dates of sowing *i.e.*, 26th October, 5th November, and 15th November at Hisar, Haryana and they reported that significantly maximum plant height of 190.5 cm was recorded under crop sown on 26th October followed by the crop sown on other two dates *i.e.* 5th November (188.2 cm) and 15th November (178.1 cm). Singh *et al.* (2017) revealed that the mustard (*B. juncea* L.) crop sown on 25th October produced significantly taller plant (146.3 cm) over 25th September sown crop (111.0) among the four dates of sowing *viz.*, 25th September), 5th October, 15th October and 25th October. Lakra *et al.* (2018) studied the response of Indian mustard (*B. juncea*) with the four dates of sowing (28th October, 07th November 17th November and 27th November and showed that the crop sown on 28th October and 07th November produced significantly taller plant height of about 135 cm and 108 cm, respectively as compared with other two dates of sowing but was at par with each other. They concluded decrease in plant height with progressive delay in sowing from 28th October to 27th November.

Leaf area index

Leaf area index is another most important growth characteristics which determines the amount of solar radiation intercepted by crop canopy which is utilized for various metabolic activities of the plants. Hundal *et al.* (2003) found significantly higher leaf area under early sown *B. juncea* coupled with large sink strength and capacities to accommodate more photosynthesis which resulted in significantly higher yield and yield contributing characteristics as compared to late sown crop. Panda *et al.* (2004) highlighted that leaf area index reduced significantly under delay sowing of *B. juncea* from October 16th to November 15th due to decrease in mean temperature at later dates of sowing which resulted in reduction in expansion and growth of the crop. Kumar *et al.* (2017) stated that leaf area index of Indian mustard reduced significantly with the delay in sowing at all growth intervals and maximum leaf area index was found under 26th October (1.73) sown crop followed by 5th November (1.40) and 15th November (1.17) at harvesting. Patel *et al.* (2017) conducted a field experiment to study the effect of different dates of sowing on the growth of various Indian mustard varieties and revealed that the crop sown on 14th November recorded significantly higher LAI over 15th October and 29th November, but was found at par with 30th October at 60 DAS. Bhagat *et al.* (2022b) studied the growth of *B. napus* cultivars under diverse sowing environment at Jammu and revealed that crop sown under first sowing environment (20th October in 2018-19 and 15th October in 2019-20) recorded significantly higher leaf area index of about 5.14 as compared to the second environment (4.59) and third environment (3.50) sown crop. Kaur *et al* (2022) studied the performance of oilseed rape (*B. napus*) as influenced by different date of sowing under irrigated condition of central Punjab and revealed that crop sown on 25th October (4.3) being at par with crop sown on 10th October (3.9) recorded significantly higher leaf area index over 15th November (2.2) sown crop at 90 DAS.

Dry matter accumulation

Dry matter accumulation is also an important growth parameter affecting the photosynthetic efficiency (sink) of the crop which ultimately influences the crop yield. Dudhade *et al.* (1996) stated that delay in sowing of Indian mustard from October 15th adversely affected the dry matter accumulation/plant. Singh *et al.* (2002) reported that the dry matter accumulation of *Brassica* was significantly reduced with delay in sowing due to the increased temperatures during latter reproductive phase (36.0 to 41.5 °C). Hundal *et al.* (2003) conducted a field experiment at PAU, Ludhiana on *B. juncea* under different dates of sowing during *rabi* seasons of 1999-2000 and

2000-2001 and observed that dry matter accumulation was reduced with delay in sowing from second week of October to first week of December. Keerthi *et al.* (2017) revealed that the total dry matter accumulation decreased significantly with delay in sowing dates at all the growth stages *viz.*, 30, 90, 120 DAS and at harvest during both the years. However, the difference in dry matter accumulation at 60 DAS was statistically at par with October 25th and November 5th sown crop. Kumar *et al.* (2017) revealed that higher biomass accumulation was found under the first date of sowing *i.e.* 25th October (124.1 g/m^2) in comparison to other dates of sowing *i.e.* 5th November, and 15th November. Patel *et al.* (2017) reported that higher dry matter accumulation was recorded under 14th November over 29th November sown crop and was found at par with 15th October and 30th October at 60 and 90 DAS. Tyagi (2017) observed significantly higher dry matter at all the growth stages under 20th October sown crop followed by November 4th and November 19th, respectively Therefore, fifteen-day successive delay in sowing from 20th October to 4th November and 19th November decreased the total dry matter accumulation at maturity by 9.37 per cent and 17.6 per cent, respectively. Singh *et al.* (2017) revealed that the crop sown on 25th October accumulated significantly higher dry mater/plant than 15th October sown crop. Samant *et al.* (2018) conducted an experiment to assess the effect of sowing dates and nutrient management practices on important parameters in toria (*B. rapa*) and reported that dry matter accumulation/plant were significantly higher under the crop sown on 15th October (28.6 g/plant) as compared to 30th October (28.0 g/plant) and 14th November (25.2 g/ plant) sown crop at Angul (Odisha). Kaur *et al.* (2018) reported that oilseed rape (*B. napus*) sown on 15th October (15835 kg/ha) recorded significantly higher dry matter accumulation over crop sown on 30th October (14000 kg/ ha) and 15th November (11807 kg/ha) on 120 DAS.

Crop growth rate (CGR) and relative growth rate (RGR)

CGR and RGR are the growth indices which are calculated from the change in dry matter accumulation to study the growth of the plant within a particular time interval. Rameshwar *et al.* (2000) found that RGR increased with delay in sowing of *B. napus.* Panda *et al.* (2004) evaluated the growth and development of Indian mustard under different dates of sowing and stated that CGR decreased significantly with delay in sowing and the highest values of CGR were calculated in crop sown on 16th October whereas the least values were calculated on 15th November sowing at all the growth stages. Kumari and Rao (2005) emphasized that CGR in *B. juncea* was lowest in crops sown earlier than 1st October whereas it increased under 15th and 30th October sown crop due to higher temperature prevailed during initial stages of the crop growth. They also reported that RGR was lowest in crop sown earlier than 1st October in *B. juncea* due to higher temperature prevailed during initial stages of the crop growth. Alam *et al.* (2014) observed the decreased crop growth rate under 25th December sowing as compared to 25th November and 5th December sown crop due to high temperature at grain filling stage. Kumar *et al.* (2018) found the minimum crop growth rate (2.57 g/m^2/day) in crop sown on 21st November whereas maximum crop growth rate (3.59 g/m^2/day) under 23rd September sown crop at Hisar.

Effect of sowing dates on agrometeorological indices of rapeseed-mustard

Agrometeorological indices *viz.*, growing degree days, photothermal units, heliothermal units, heat use efficiency and radiation use efficiency are useful for assessing the agroclimatic resources for effective crop planning and reflecting the impact of weather variables at different crop developmental stages (Bauer *et al.*, 1985). Tripathi *et al.* (2007) found that the radiation use efficiency was highest in early sown crop *i.e.* [5th October (2.18 g/MJ)] followed by later sown crops *viz.*, [20th October (1.71 g/MJ) and 5th November (1.23 g/MJ)]. Khushu *et al.* (2011) reported that the utilized solar energy was higher in early sown crop as compared to normal and late sowing at all the phenophases except during reproductive stage, where the utilized energy was same in early and normal sowing on 10th October and 25th October. Keerthi *et al.* (2016) stated that the total accumulated thermal unit of the crop decreased from 2288 °C day to 2262 °C day, 2225 °C day and 2125 °C day as sowing was delayed from October 15th to October 25th, November 5th and November 15th, respectively. However, maximum heat use efficiency was recorded for the crop sown on 15th October (1.294 g/m^2 °C day) followed by October 25th (1.177 g/m^2/ °C day), November 5th (1.108 g/m^2 °C day) and November 15th (1.012 g/m^2 °C days) sown crop at maturity. Rana *et al.* (2017) reported that the early sown (10th October) crop took maximum growing degree days for flower initiation (492±1), 50 per cent flowering (682±1), pod initiation (742±1), 90 per cent pod formation (811±4) and maturity (1394±8) which decreased with delay in sowing time and recorded lowest under late sown (9th November) crop. Ahatsham *et al.* (2018) revealed that the growing degree days were higher in 1st fortnight of October sown mustard at every phenophase [Early vegetative phase (379 °C day), 50 per cent flowering (785 °C day), pod initiation (890 °C day), seed development (1231 °C day), physiological maturity (1969 °C day)] as compared to the crop sown on 2nd fortnight of October and 1st fortnight of November. Choudhary *et al.* (2018) observed that the accumulation of heat units to attain crop maturity was higher under the crop sown on 10th October (1582.2 °C day) as compared to the other sowing dates *i.e.*, 25th October (1354.1 °C day) and 10th November (1290.5 °C day). Likewise, 10th October sown crop also accured higher heliothermal units and photothermal units over the crop sown on 25th October and 10th November. Jiotode *et al.* (2017) recorded higher thermal use efficiency (0.45 kg/ha/ D °C) under sowing of mustard on 43rd SMW (22 to 28 October) over other dates of sowing. Singh *et al.* (2018) revealed that the maximum per cent of PAR interception was observed in crop sown on 7th October [Vegetative (62.0 %), flowering (91.3 %) and pod filling (80.9 %)] as compared to 17th October [vegetative (49.6 %), flowering (84.6 %) and pod filling (78.7 %)] and 27th October [Vegetative (25.6 %), flowering (79.5 %) and pod filling (67.5 %)] sown crop. Similarly, the maximum radiation use efficiency was also observed in crop sown on 7th October *viz.*, [Vegetative (2.72 g/MJ), flowering (3.26 g/MJ) and pod filling (3.42 g/MJ)] as compared to 17th [Vegetative (2.27 g/MJ), flowering (2.72 g/MJ) and pod filling (2.86 g/MJ)] and 27th October [vegetative (1.60 g/MJ), flowering (1.92 g/MJ) and pod filling (2.02 g/MJ)] sown crop. Singh *et al.* (2019) at Arunachal Pradesh observed maximum pheno thermal index under 10th October sown crop at 50 per cent flowering (7.6), siliquae filling (8.0), physiological maturity (8.4) sown crop and followed by 20th October and 30th December. Likewise, the highest heat use efficiency for grain yield (1.14 kg/ha °C days) as well as for biological yield (3.73 kg/ha °C days) recorded under 10th October sown crop and the minimum values were observed for late sown crop *i.e.* 30th October crop.

Effect of sowing dates on yield attributes of rapeseed-mustard

Number of branches per plant

Bhuiyan *et al.* (2008) conducted a field experiment to study the yield attributes and yield of rapeseed as influenced by date of planting (October 20th, October 30th, November 10th, November 20th and November 30th) at Bangladesh and revealed that significantly highest number of primary branches/plant (6.85) was recorded under the first the planting date (October 20th) over other planting dates but found at par with 2nd date of planting (October 30th: 6.72). Kumari *et al.* (2012) reported that crop sown on 10th October recorded significantly higher primary (7.8) as well as secondary branches (19.9) /plant over 20th October (7.0 & 17.6) and 30th October sown crop (6.4 & 14.1), respectively. Dinda *et al.* (2015) revealed that 20th October (6.07) sown rapeseed-mustard varieties recorded significantly more number of branches followed by 5th November (5.78) and 20th November (5.32) at West Bengal. Meena *et al.* (2017) at Banswara revealed that the maximum primary branches/plant were recorded under 25th September sown mustard (4.58) and 05th October (4.59) as compared to early sown mustard on 15th September (4.05) and late sown 15th October (4.14). Bhagat *et al.* (2022a) reported significantly higher primary and secondary branches under *B. napus* sown on 20th October (5.2, and 12.9, respectively) over 30th October (4.5 and 11.6, respectively) and 9th November (4.0 and 10.1, respectively) sown crop.

Number of siliquae per plant

Dinda *et al.* (2015) reported that early sown (20th October: 125.7) crop recorded significantly higher number of siliquae per plant as compared to late sown crop (5th October: 118.6 and 5th November: 109.5). Gawariya *et al.* (2015) evaluated the effect of sowing dates on yield attributes of mustard and found that number of siliquae/plant were significantly affected at Karnal. They further reported that the crop sown on 1st October (1391.47 g/plant) recorded significantly higher number of siliquae/plant as compared to 16th October (1227.96 g/per plant) and 31st October (847.41 g/plant) and 15th November (656.75 g/plant) sowing. Keerthi *et al.* (2016) reported that there was decreased number of siliquae/plant by 5.8, 10.2, and 32.6 per cent, when sowing of the crop was delayed from 15th October to 25th October, 5th November and 15th November. Bhagat *et al*. (2022a) reported significantly higher siliquae per plant under *B. napus* sown on 20th October (160.2) followed by 30th October (149.8) and 9th November (130.8) sown crop. Kaur *et al.* (2022) recorded significantly higher siliquae/plant under oilseed rape (*B. napus*) on 25th October (325) as compared to 15th November (321) sown crop but at par with 10th October (294) sown crop sown.

Number of seeds per siliqua

Bhuiyan *et al.* (2008) assessed the yield attributes and yield of rapeseed influenced by date of planting at Bangladesh and recodeded significantly less number of seeds/siliqua (18.8) in the plants sown on 30th November in comparison to all other sowing dates *i.e.* [20th November (21.8), 10th November (22.8), 30th October (24.0) and 20th October (21.3)]. Akhter *et al.* (2015) studied the delayed planting effects on yield of rapeseed (brown sarson) and reported significant decline in no. of seeds/siliqua sown under 1st October (21.4) followed by 15th October (20.6) and 30th October (16.8) sown crop, respectively. Kumar *et al.* (2017) reported that the crop sown on 25th October recorded significantly highest seeds/siliqua (13.4) followed by 15th October (12.5), 5th October (11.21) and 25th September (10.9) sown crop. Bhagat *et al.* (2022) reported significantly higher seeds/siliqua in 20th October (19.2) sown gobhi sarson followed by crop sown on 30th October (18.2) and 9th November (17.1) at Jammu.

Test weight

Bhuyian *et al.* (2008) revealed the lowest test weight with each successive delay in sowing after 30th October (3.80 g) in rapeseed (*B. rapa*) to 30th November (3.24 g). Akhter *et al.* (2015) reported a significant decline in test weight in brown sarson under delayed planting of rapeseed sown on 1st October (2.27 g) followed by 15th October (2.1 g) and 30th October (2.1 g), respectively. Kumar *et al.* (2017) stated that test weight was successively decreased with early sowing of the Indian mustard as crop sown on 25th October recorded highest test weight (4.7 g) followed by 15th October (4.7 g), 5th October (4.4 g) and 25th September (4.4 g) sown crop. Kaur *et al.* (2022) revealed significantly higher test weight under oilseed rape (var. GSC-7) sown on 25th October (4.6 g) over 15th November (4.0 g) but at par with 10th October (4.3 g).

Effect of sowing dates on yield of rapeseed-mustard

Seed yield

Khandey *et al.* (1991) revealed that *B. napus* gave higher seed yield when sown on 15th October, but non-significant differences were found under October 5th and 15th sown crop at Shalimar (Kashmir). Bali *et al.* (1992) found that when *B. juncea* crop sown on 25th September, gave significantly higher seed yield (14.4 q/ha) as compared to the crop sown on 15th October and 4th November as they yielded 12.7 and 5.1 q/ha, respectively. Moreover, *B. juncea* L. crop sown on 25th September gave 13.4 and 18.4 % higher seed yield than 15th October and 4th November sowing under Kashmir conditions. Bhagat *et al.* (1996) reported that dates of sowing had significant effect on seed yield as 5th October sown crop being at par with 15th October sowing recorded significantly highest seed yield than later dates of sowing. Singh *et al.* (2019) also reported transplanting of mustard on 13th October was found highly superior with respect to growth, physiological parameters, yield and yield attributes compared to transplanting done on 22nd October and 01st November. Yadav *et al.* (1996) evaluated the effect of sowing time on performance of Indian mustard at Morena (M.P.) and portrayed that the crop sown on 17th October (22.5 q/ha) being at par with 27th October (21.6 q/ha) sown crop yielded significantly higher seed yield than late sown crop *viz.,* 6th November and 16th November yielding 18.8 q/ha and 16.4 q/ha, respectively. Thakur and Singh (1998) reported that crop sown on October 5th gave significantly higher seed yield than later dates of sowing *viz.,* October 20th, November 4th and November 19th, respectively. Shivani and Kumar (2002) concluded that the maximum seed yield of 18.8 q/ha was obtained when crop was sown on 25th September which was at par with crop sown on 5th October but was significantly higher yielding than crop sown on 4th November. Srivastava *et al.* (2011) evaluated the growth and yield of mustard at IARI, New Delhi and concluded that crop sown on 1st October produced less seed yield than that of crop sown during October 8th to 22nd. Dinda *et al.* (2015) revealed significantly higher seed yield of rapeseed-varieties sown on 20th October (1.35 t/ha) followed by the crop sown 5th November (1.30 t/ha) and 20th November (1.22 t/ha). Gupta *et al.* (2017) recorded significantly higher seed yield of mustard crop sown on 9th October (1136 kg/ha) followed by the crop sown on 24th October (828 kg/ha) and 9th November (610 kg/ha), respectively. Khajuria *et al.* (2017) reported that 25th October sown crop produced highest seed yield of about 1710 kg/ha and remained significant superior to 5th November and 15th November sown crop in Jammu region. Kumar *et al.* (2017) reported that the maximum seed yield was recorded under 26th October (1870 kg/ha) as compared to 5th (1525 kg/ha) and 15th November (1100 kg/ha). Singh *et al.* (2017) concluded that crop sown on 14th November recorded significantly higher seed yield over 15th October and 29th November sowing but at par with 30th October sowing**.** Kaur *et al.* (2018) at Ludhiana revealed that *B. napus* sown on 15th October produced 4.1% more (significantly) seed yield (2476 kg/ha) than 30th October sown crop, while, produced 36.1% more seed yield than 15th November sown crop. Prasad *et al.* (2018) found that every 10 days delay in sowing from 20th October to 10th November resulted in a reduction of 10.1-28.9 and 10.1-45.1%, respectively, in rapeseed (*B. napus*) with an overall reduction of 30.2% from 20th October to 10th November in 20 days delay in sowing at Palampur, Himachal Pradesh. Bhagat *et al.* (2022a) reported that the seed yield of *B. napus* was recorded significantly higher under 20th October sown crop to the extent of 29.91 and 61.45% than delayed sowing on 30th October and 9th November, respectively at Jammu.

Stover yield

Bhuyian *et al.* (2008) from Bangladesh reported that the highest stover yield (6.06 t/ha) was found under first sowing (October 20th) while the lowest stover yield (4.80 t/ha) recorded on November 30th sown crop. Akhter *et al.* (2015) highlighted that significantly maximum stover yield of rapeseed (brown sarson) was obtained with 1st October

(56.73 q/ha) sowing followed by 15th October crop sown (39.93 q/ha) and 30th October (20.85 q/ha), respectively at Kashmir valley. Kumar *et al.* (2017) observed that stover yield of mustard crop was significantly affected as crop sown on 25th October (57.81 q/ha) recorded significantly higher stover yield as compared to 5th October (48.21 q/ha) and 25th September (43.84 q/ha) sown on different dates, respectively. Kaur *et al.* (2018) reported significantly higher stover in the crop (oilseed rape) sown on 15th October (9458 kg/ha) recorded significantly higher stover yield as compared to 30th October (7427 kg/ha) and 15th November (5445 kg/ha) sown crop at Ludhiana. Bhagat *et al.* (2022a) recorded significantly higher stover yield in *B. napus* sown 20th October (6074 kg/ha) sown crop in comparison to the crop sown on 30th October (4694 kg/ha) and 9th November (3801 kg/ha) at sub-tropical conditions of Jammu region.

Biological yield

Panda *et al.* (2004) reported that the biomass yield of crop was significantly influenced by the date of sowing as October 16th sown crop produced the highest biomass (73.5 q/ha), which was higher than about 18 per cent under crop sown on October 31st but there was drastic reduction in total harvested biomass when crop was sown on November 15th. Jiotode *et al.* (2017) found that the mustard crop sown on 43rd SMW (22 to 28 October) recorded significantly higher biomass (2946.6 kg/ha) as compared to the Mustard sown on 44th SMW (29 October to 4 November), 45th SMW (5 to 11 November) and 46th SMW (12 to 18 November) but was found par with 42nd SMW (15 to 21 October) sown crop. Keerthi *et al.* (2017) stated that biological yield decreased significantly with delay in sowing date from 15th October (11828 kg/ha) to 15th November (9311 kg/ha) while Kumar *et al.* (2017) showed that the variety RH 0749 of Indian mustard sown on 26th October (12239 kg/ha) produced significantly higher biological yield as compared 5th November (10881 kg/ha) and 15th November (6242 kg/ha), respectively. Bhagat *et al.* (2022a) recorded significantly higher biological yield in the oilseed rape (*B. napus*) sown on 20th October (7849 kg/ha) in comparison to the crop sown on 30th October (6060 kg/ha) and 9th November (4906 kg/ha) at Jammu region.

Effect of sowing dates on quality of mustard

Angrej *et al.* (2002) observed that oil content and oil yield recorded higher with 10th and 30th October sowing as compared to 20th November and 10th December sowing at PAU, Ludhiana. Shivani and Kumar (2002) reported that oil yield of 25th September (619 kg/ha) and 5th October (583 kg/ha) sown crops were significantly higher than 15th October (425 kg/ha), 25th October (284 kg/ha) and 04th November (197 kg/ha) sown crops, respectively. Srivastava *et al.* (2011) evaluated the quality of *B. juncea* with ten different dates of sowing on weekly intervals starting from 1st October to 3rd December in two seasons at IARI New Delhi. Further, they recorded that the oil content drastically reduced after the optimum sowing window (15th October to 22nd October) in both the cultivars of *B. juncea i.e.*, Pusa Jaikisan and Varuna. Akhter *et al.* (2015) emphasized that oil content of brown sarson varieties had non-significant effect among dates of sowing, but crop sown on 1st October recorded significantly higher oil yield (634 kg/ha). Patel *et al.* (2017) reported that the significantly higher oil yield of 838 kg/ha in crop sown on 14th November as compared to 15th October (723 kg/ha) and 29th November (660 kg/ha) sowing, but was found at par with 30th October (782 kg/ha) sowing whereas, protein content of mustard was not influenced significantly due to different dates of sowing.

Conclusion

The perusal of literature reveals that the sowing dates are the most significant non-monetary input that describe yield of rapeseed-mustard. Early or delayed sowing is associated to a considerable decline in yield-attributing characters due to unfavourable weather conditions leading to declining trend in seed yield. It is agreed upon in the literature that altering the sowing date of the rapeseed-mustard is responsible to achieve the synchronisation of the important phenophases (phasic development) with the favourable weather regime, which ensures a promising productivity. Therefore, in order to increase mustard yield and ensure food security under climate change scenario, it is crucial to choose the ideal sowing date depending upon the prevailing weather conditions of that location.

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