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Praveen Singh

Assistant Professor of
 Agrometerology, Sant Baba
 Bhag Singh University Khiala,
 Jalandhar (Punjab) India

Nalini Singh

Assistant Professor of Plant
 pathology, Sant Baba Bhag
 Singh University Khiala,
 Jalandhar (Punjab) India

Ram Prakash

Assistant Professor of
 Agronomy, Sant Baba Bhag
 Singh University Khiala,
 Jalandhar (Punjab) India

Prabhdeep Singh

(Ph.D Research scholar) Sant
 Baba Bhag Singh University
 Khiala, Jalandhar (Punjab)
 India

Chamkaur Singh

(Ph.D Research scholar) Sant
 Baba Bhag Singh University
 Khiala, Jalandhar (Punjab)
 India

Corresponding Author: Nalini Singh

Assistant Professor of Plant
 pathology, Sant Baba Bhag
 Singh University Khiala,
 Jalandhar (Punjab) India

Influence of different growing environments on yield attributes and yield of rapeseed and mustard (*Brassica Juncea* L.)

Praveen Singh¹, Nalini Singh², Ram Prakash³, Prabhdeep Singh⁴, Chamkaur Singh⁵

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ABSTRACT

A field experiment was conducted at the Agricultural Research Farm, Sant Baba Bhag Singh University, Khiala, Jalandhar (Punjab), during the Rabi season of 2023–24 to evaluate the influence of different crop-growing environments on yield-attributing traits and yield of mustard (*Brassica juncea* L.) cultivars. The experiment comprised nine treatment combinations involving three sowing dates, viz. 15 October, 30 October, and 14 November, and three cultivars, namely PGSH 170, PHR-126, and PBR-357. The treatments were evaluated in a split-plot design with four replications. The results indicated that sowing date had a significant influence on major yield-attributing characters and yield parameters, including the number of siliquae plant⁻¹, silique length, number of seeds silique⁻¹, test weight, seed yield, stover yield, biological yield, and harvest index. In general, the crop sown on 15 October recorded higher values for most yield-attributing traits and yield, followed by the crop sown on 30 October, whereas the lowest values were generally observed with 14 November sowing. Among the cultivars, PHR-126 recorded comparatively higher values for most of the yield attributes and yield parameters. PHR-126 also exhibited a relatively longer crop duration under the 15 October sowing environment and matured approximately two days later than PGSH 170. The findings indicate that appropriate selection of sowing time and cultivar can play an important role in improving mustard productivity under the agro-climatic conditions of Punjab.

Keywords: Mustard, Growing environment, Growth, Phenophase, Silique, Seed weight

Introduction

Rapeseed and mustard are among the major Rabi-season oilseed crops cultivated in India and occupy an important position in the country's oilseed economy, ranking next to groundnut in terms of importance. These crops belong to the family Brassicaceae and are widely cultivated under diverse agro-climatic conditions. Rapeseed and mustard contribute substantially to the edible oil requirement of the population, particularly in states such as Uttar Pradesh, Punjab, Rajasthan, and Assam. The crop is predominantly self-pollinated, although honey bees also play an important role in pollination. The genus *Brassica* comprises six major species, namely *B. nigra*, *B. oleracea*, *B. rapa*, *B. carinata*, *B. juncea*, and *B. napus*. Among these, *B. nigra*, *B. oleracea*, and *B. rapa* are diploid species with chromosome numbers of $2n = 16, 18$, and 20 , respectively, whereas *B. carinata*, *B. juncea*, and *B. napus* are tetraploid species with chromosome numbers of $2n = 34, 36$, and 38 , respectively. These species are cultivated across a wide range of agro-climatic environments. Brown mustard (*Brassica juncea* L.), also known as Indian mustard or leaf mustard, is a highly variable species that has been cultivated for centuries as an oilseed and vegetable crop. It is also found as a common weed in some regions. In eastern Uttar Pradesh, particularly in low-lying areas, rice is commonly cultivated and is generally harvested during the last week of October or, in some cases, the first week of November. Farmers often consider growing mustard after rice harvest in these areas; however, information regarding the suitability of mustard genotypes and appropriate nitrogen management under such conditions remains limited. Therefore, identification of suitable genotypes and nutrient requirements is important for improving the profitability of mustard cultivation under these production systems (Raghuvanshi *et al.*, 2018) [1]. The ecotypes of brown sarson (*B. rapa* ssp. *sarson*) include Lotni and Toria. Yellow sarson (*B. rapa* var. *trilocularis*) is primarily cultivated as a Rabi crop in Assam, Bihar, Odisha, and West Bengal. It is also grown as a catch crop in Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, and Madhya Pradesh (Shekhawat *et al.*, 2012) [2]. Oilseed crops are economically important, particularly in regions where they provide a comparatively profitable cropping option. Rapeseed and mustard are versatile crops with multiple uses. In addition to their importance as sources of edible oil, their seeds are widely used as condiments, particularly in pickling and in the preparation and flavouring of curries and vegetables. Mustard oil is extensively used for cooking and frying in India. Young leaves of the plant are also consumed as green vegetables and contribute minerals to the diet. The oil cake obtained after oil extraction is used as livestock feed as well as organic manure. Traditional rapeseed and mustard varieties may contain relatively high levels of erucic

acid in their oil and glucosinolates in their meal, which have raised nutritional and health-related concerns. The composition of mustard seed oil includes substantial proportions of fatty acids such as erucic, linoleic, and oleic acids. In contrast, canola oil is characterized by a low erucic acid content ($< 2\%$), low glucosinolate levels in the meal ($< 20 \mu\text{mol g}^{-1}$), and a relatively low proportion of saturated fatty acids. Its favourable balance of monounsaturated and polyunsaturated fatty acids has contributed to its importance as an edible vegetable oil. A substantial proportion of the irrigated area under oilseed crops is occupied by rapeseed and mustard. However, the average productivity of mustard in India remains comparatively low. Several factors contribute to this yield gap, including dependence on rainfed cultivation and insect-pest pressure, particularly aphid infestation. Mustard is also sensitive to deficiencies of micronutrients, especially sulphur, zinc, and boron. Application of zinc has been reported to improve seed yield, with an increase of approximately 8.5% at $12.5 \text{ kg ZnSO}_4 \text{ ha}^{-1}$. Zinc application has also been reported to influence harvest index, although increasing ZnSO_4 application beyond an optimum level may result in diminishing returns in seed yield. Mustard is highly sensitive to weather conditions and exhibits considerable variation in growth and productivity in response to sowing time (Singh *et al.*, 2002; Kar *et al.*, 2000; Kumar *et al.*, 2007) [4, 3, 5]. A delay of one month in sowing from mid-October has been reported to reduce seed yield by 40.6% (Lallu *et al.*, 2010) [6]. In general, mustard is adversely affected by low temperatures during the vegetative and early pod-filling stages, whereas comparatively higher temperatures during grain filling and maturity can also influence crop performance. Thus, appropriate adjustment of sowing time is an important agronomic consideration for achieving optimum yield. Rapeseed and mustard (*Brassica* spp.) constitute an important component of India's edible oilseed production. The crop occupies a significant share of the country's cultivated area and contributes substantially to the oilseed economy. At the global level, rapeseed and mustard also represent important oilseed crops, with India being a major producer. The crop therefore has considerable importance in meeting domestic edible oil requirements and contributing to the global oilseed sector (IPCC, 2012) [7]. Considering the sensitivity of mustard to environmental conditions, particularly temperature and sowing time, evaluation of suitable crop-growing environments and cultivars is essential for improving productivity. Therefore, the present study was undertaken to assess the influence of different growing environments on yield-attributing characters and yield of selected mustard cultivars under the agro-climatic conditions of Punjab.

Materials and Methods

The experiment was conducted at the Agricultural Research Farm, Sant Baba Bhag Singh University, Khiala, Jalandhar, Punjab, India. The experimental site is geographically located at $31^{\circ}33' \text{ N}$ latitude and $75^{\circ}58' \text{ E}$ longitude, with an elevation of 229 m above mean sea level. The site falls under a humid subtropical climatic region and is situated between the intensively irrigated and fertile agricultural plains of the Beas and Sutlej rivers. The area receives an average annual precipitation of approximately 703 mm, of which about 85–90% occurs during the monsoon season. To assess the physico-chemical properties and fertility status of the experimental soil, soil samples were collected randomly from a depth of 0–15 cm using a soil auger before sowing. The collected samples were thoroughly mixed to obtain a representative composite sample of the experimental field, which was subsequently analyzed. The experiment was laid out in a split-plot design with four replications. Nine treatment combinations were evaluated using three crop-growing environments and three mustard cultivars. The crop-growing environments comprised 15 October (D_1 ; 33°C), 30 October (D_2 ; 31.75°C), and 14 November (D_3 ; 30.5°C). The cultivars used were PGSH 170 (V_1), PHR-126 (V_2), and PBR-357 (V_3). The experimental field was prepared by one ploughing with a tractor-drawn mouldboard plough, followed by two operations with a cultivator. Each tillage operation was followed by

planking to obtain a smooth and clod-free seedbed. The experimental plots were subsequently laid out according to the prescribed experimental plan. Seeds were sown according to the respective treatments in conventionally tilled soil on flat beds to achieve the desired plant population. Excess plants were removed periodically to ensure uniform crop establishment, plant geometry, and population. The recommended fertilizer dose of $120:60:40 \text{ kg ha}^{-1} \text{ N}_2\text{O}_{52}\text{O}$ was applied to the mustard crop. The full doses of phosphorus and potassium, along with half of the recommended nitrogen, were applied as basal fertilizer. The remaining nitrogen was applied as top dressing in two equal applications, with the first application at 35 days after sowing (DAS) and the remaining dose at the pre-flowering stage. Urea, diammonium phosphate (DAP), and muriate of potash (MOP) were used as the respective sources of nitrogen, phosphorus, and potassium.

Plant protection measures were undertaken according to the occurrence of pests and diseases during the crop season. *Alternaria blight* caused by *Alternaria brassicae* was observed on the crop. Following the appearance of disease symptoms, Mancozeb 75 WP was applied at the specified rate of $2.0 \text{ kg active ingredient in } 1000 \text{ L of water ha}^{-1}$ at 10-day intervals. Mustard sawfly larvae were observed on the crop during October and November. Mustard aphid infestation was also recorded, with both nymphs and adults feeding on tender leaves, twigs, stems, inflorescences, and pods. Malathion-50 EC at 0.05% was sprayed twice during the crop season for aphid management. Weed management was carried out manually through hand weeding and hoeing. The first weeding was performed with a *khurpi* at 22 DAS, while the second weeding was carried out after the first irrigation to improve soil aeration and facilitate proper root development. Irrigation was provided according to the crop requirement during the Rabi season. The crop was harvested manually using sickles at maturity. The harvested produce from each plot was kept separately and allowed to dry in the field under sunlight. Individual bundles were labelled to prevent mixing among treatments. After complete drying, the bundles were threshed manually using wooden sticks. The threshed material was cleaned, and grain yield was recorded as kg plot^{-1} and subsequently converted into q ha^{-1} .

Number of siliquae per plant

At harvest, the total number of siliquae on the selected sample plants from each plot was counted, and the average number was calculated. The siliquae were counted separately on primary, secondary, and tertiary branches. The total number of siliquae per plant was calculated by summing the number of siliquae borne on all types of branches.

Length of siliquae (cm)

Ten siliquae were randomly selected from each plot. The length of each silique was measured from the base to the beak using a suitable measuring scale, and the average length was calculated and expressed in centimetres (cm).

Number of seeds per silique

The number of seeds per silique was recorded at harvest by counting the seeds present in ten randomly selected siliquae from three sample plants in each plot. The average number of seeds per silique was calculated.

1000-seed weight (g)

A sample of seeds obtained from each net plot was used for determining 1000-seed weight. One thousand seeds were counted using an electronic seed counter and weighed separately on an electronic balance. The weight was recorded in grams (g) for each plot.

Seed yield (q ha^{-1})

The crop from the net plot area of each experimental plot was harvested separately and sun-dried. After proper drying, the produce was threshed and cleaned separately for each net plot. The final seed weight was recorded in kilograms (kg) per net plot and subsequently converted into quintals per hectare (q ha^{-1}).

Stover yield ($q\ ha^{-1}$)

Stover yield was calculated by subtracting the seed yield from the total biological produce on a net plot basis. The stover weight was recorded in kilograms per net plot and subsequently converted into quintals per hectare ($q\ ha^{-1}$).

Biological yield ($q\ ha^{-1}$)

The above-ground plant biomass from each net plot was harvested at physiological maturity and weighed after proper drying. The total above-ground biomass, including seed and stover, was considered as biological yield and expressed in quintals per hectare ($q\ ha^{-1}$).

Harvest index (%)

Harvest index represents the ratio of economic yield (seed yield) to biological yield and was calculated using the following formula:

$$\text{Harvest Index (\%)} = (\text{Seed Yield/Biological Yield}) \times 100$$

Results and Discussions

Number of seeds siliqua⁻¹

The data pertaining to the number of seeds siliqua⁻¹ as influenced by different cultivars and sowing dates are presented in Table 1. Among the cultivars, PHR-126 recorded the highest number of seeds siliqua⁻¹ and was significantly superior to PGSH 170 and PBR-357. The number of seeds siliqua⁻¹ was also significantly influenced by sowing date. The highest number of seeds siliqua⁻¹ was recorded in the crop sown on 15 October, which was significantly superior to the crops sown on 30 October and 14 November. These results are in

close agreement with the findings of Dhaliwal *et al.* (2007) [8] and Roy *et al.* (2007) [9].

Length of siliqua

Data pertaining to length of siliqua presented in Table-1 revealed that the different varieties significantly affected the length of siliqua. The maximum length of siliqua plant⁻¹ was recorded for NDR- 2001 which was significantly superior to PGSH 170 and PBR-357. The length of siliqua was also significantly affected by different sowing dates. The maximum length of siliqua was recorded with 1st date of sowing (15 October) which was significantly superior over 2nd date of sowing (30 October) and 3rd date of sowing (14 November). These findings are in agreement with Singh *et al.* (2008) [10].

Table 1. Effect of varieties and Sowing dates on number of siliquae plant⁻¹, length of siliqua, Seeds/ Siliqua and 1000 grain wt. (g.) of mustard crop at different growth stages

Treatment Combination	Siliquae plant ⁻¹	Seeds siliqua ⁻¹	Length of siliqua (cm)	Test weight (g)
Date of sowing				
D ₁ (15 Oct.)	294.5	16.1	7.5	4.52
D ₂ (30 Oct.)	283.5	12.97	7.23	4.27
D ₃ (14 Nov.)	254.5	12.2	6.47	4.17
SEM	6.497	0.398	0.232	0.118
CD (0.5%)	20.474	1.254	0.73	NS
Varieties				
V ₁ (PGSH 170)	279.5	13.87	7.14	4.42
V ₂ (PHR-126)	304.5	15.1	7.75	4.92
V ₃ (PBR-357)	248.5	12.3	6.32	3.62
SEM	4.384	0.277	0.146	0.084
CD (0.5%)	12.795	0.809	0.425	0.245

Test weight (1000-seed weight)

The data regarding test weight as influenced by cultivars and sowing dates are presented in Table 1. Sowing date significantly influenced test weight. The maximum test weight of 4.52 g was recorded with the 15 October sowing, which was significantly higher than the values recorded with sowing on 30 October and 14 November. The minimum test weight of 4.17 g was observed when the crop was sown on 14 November. Significant variation in test weight was also observed among the cultivars. PHR-126 recorded the highest test weight (4.92 g), followed by PGSH 170 (4.42 g) and PBR-357. These findings are in close agreement with the results reported by Khan *et al.* (2008) [11] and Nihalani *et al.* (2008) [12].

Seed yield

The data on seed yield as influenced by cultivars and sowing dates are presented in Table 2. Among the cultivars, PHR-126 recorded significantly higher seed yield than PGSH 170 and PBR-357. The superior seed yield of PHR-126 indicates better yield performance under the experimental conditions. Similar results were reported by Singh *et al.* (2008) [10]. Sowing date also exerted a significant influence on mustard seed yield. The highest seed yield was obtained from the crop sown on 15 October, which was significantly superior to sowing on

30 October and 14 November. The reduction in yield with delayed sowing may be associated with exposure of the crop to less favourable environmental conditions during critical growth and reproductive stages. Similar findings were reported by Panda *et al.* (2004) [13], Lallu *et al.* (2010) [6], and Kumari *et al.* (2012) [14].

Stover yield

The data pertaining to stover yield as influenced by cultivars and sowing dates are presented in Table 2. Among the cultivars, PHR-126 recorded significantly higher stover yield than PGSH 170 and PBR-357. Similar results were reported by Singh *et al.* (2008) [10] and Singh *et al.* (2019) [15]. Sowing date also significantly affected stover yield. The highest stover yield was recorded with the 15 October sowing, which was significantly superior to the yields obtained with sowing on 30 October and 14 November. The findings are in agreement with those reported by Sharma *et al.* (2023) [16] and Kumar *et al.* (2017) [17].

Biological yield

The data concerning biological yield as influenced by cultivars and sowing dates are presented in Table 2. Biological yield differed significantly among the cultivars, with PHR-126 recording a significantly higher biological yield than PGSH 170 and PBR-357. Sowing

date also had a significant effect on biological yield. The maximum biological yield was recorded with the 15 October sowing, which was significantly superior to sowing on 30 October and 14 November. The higher biological yield under the earlier sowing environment may be attributed to more favourable conditions for crop growth and biomass

accumulation. Similar findings were reported by Khan *et al.* (2008) [11] and Nihalani *et al.* (2008) [12]. Overall, the results demonstrated a significant effect of the evaluated treatments on the biological yield of mustard.

Table 2. Yields and Harvest Index of mustard as influenced by varieties and date of sowing

Treatment Combination	Grain yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)	Biological yield(q ha ⁻¹)	Harvest index (%)
Date of sowing				
D ₁ (15 Oct.)	21.01	74.33	95.34	22.27
D ₂ (30 Oct.)	18.62	65.43	84.05	22.61
D ₃ (14 Nov.)	15.92	57.49	73.41	22.06
SEM	0.609	1.831	2.386	0.521
CD(0.5%)	1.918	5.771	7.518	NS
Varieties				
V ₁ (PGSH 170)	18.78	66.36	85.14	22.35
V ₂ (PHR-126)	20.32	70.43	90.75	22.99
V ₃ (PBR-357)	16.44	60.47	76.91	21.6
SEM	0.391	1.274	1.571	0.381
CD (0.5%)	1.141	3.718	4.585	NS

Harvest index (%)

The data pertaining to harvest index (%) as influenced by different sowing dates and cultivars are presented in Table 4.8. The results indicated that sowing date did not have a significant effect on harvest index. Numerically, the highest harvest index (22.61%) was recorded with the crop sown on 30 October, followed by 15 October (22.27%) and 14 November (22.06%). Since the critical difference (CD) at the 5% level was non-significant, the differences among sowing dates were statistically non-significant. Cultivars also showed variation in harvest index. PHR-126 recorded the highest harvest index (22.99%), followed by PGSH 170 (22.35%) and PBR-357 (21.60%). However, the statistical analysis indicated that the effect of cultivar on harvest index was also non-significant. Similar findings were reported by Singh *et al.* (2019) [18].

Conclusion

The results of the present investigation demonstrated that sowing date had a significant influence on most of the yield-attributing characters and yield components of mustard. The crop sown on 15 October (D₁) generally recorded higher values for number of siliqua plant⁻¹, siliqua length, number of seeds siliqua⁻¹, test weight, seed yield, stover yield, and biological yield compared with the later sowing dates of 30 October (D₂) and 14 November (D₃). Among the cultivars, PHR-126 (V₂) exhibited comparatively higher values for the major yield-attributing traits and yield parameters than PGSH 170 (V₁) and PBR-357 (V₃). The highest seed yield, stover yield, and biological yield were recorded with PHR-126. The cultivar also recorded the highest numerical harvest index (22.99%), although the effect of cultivar on harvest index was statistically non-significant. Overall, the findings indicate that appropriate selection of sowing time and cultivar can contribute to improved mustard productivity under the agro-climatic conditions of Punjab. Based on the yield performance observed in this experiment, 15 October represented the sowing environment associated with higher productivity, while PHR-126 exhibited comparatively better performance among the evaluated cultivars.

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