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Effect of sowing windows on biochemical traits, yield and their correlation in indian mustard

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ABSTRACT

Ten Indian mustard (Brassica juncea L.) genotypes viz., ACN-240, SKM-1626, ACN-226, ACN-244, ACN-255, T-9, ACN-237, PM-26 (check) and TAM 108-1 (check) were assessed under four sowing dates i.e. 30th October (timely sowing), 15th November (moderately late sowing), 30th November (late sowing), 15th December (very late sowing) to study the morpho-physiological, biochemical and yield and yield attributing characters during the Rabi 2023 at AICRP on linseed and mustard, College of Agriculture, Nagpur Agriculture, Dr. PDKV, Akola. Three replications in a factorial randomized block design (FRBD) were used to set up the experiment. The two experimental factors were sowing conditions and genotypes. Results revealed that, genotype ACN-237 outperformed other genotypes on October 30, November 15 and November 30 in terms of biochemical parameters including total chlorophyll content, oil content. For genotype ACN-237, the 30th October, 15th November and 30th November sowing dates had no significant percent reduction in yield and yield-attributable characteristics. In Sowing dates, there is a significant yield reduction in very late sown condition (15th December) in comparison with timely sown (30th October) condition in yield and yield-attributable characteristics including number of siliquae plant^{-1}(19.19%), test weight (21.68%), seed yield plant^{-1}(29.05%) and seed yield ha^{-1}(39.35%). The correlation analysis was conducted for 11 traits at phenotypic and genotypic levels. Seed yield ha^{-1} was positively correlated with plant height (cm), leaf area (dm^{2}), relative water content (%), crop growth rate (gm^{-2}day^{-1}), total chlorophyll content (mgg^{-1}), proline content (µmolg^{-1}), oil content (%), number of siliquae plant^{-1}, test weight (g), seed yield plant^{-1} (g) at both genotypic and phenotypic levels. The study revealed significant differences among the mustard genotypes both in their genotypic and phenotypic level. Seed yield ha^{-1} was positively correlated with plant height, leaf area, relative water content, crop growth rate, total chlorophyll content, proline content, oil content, number of siliquae plant^{-1}, test weight, seed yield plant^{-1} at both genotypic and phenotypic levels. However, genotypes ACN-237, ACN-226 and ACN-250 consistently performed well under 30th October, 15th November and 30th November sowing dates.

Keywords: *Indian mustard, genotypes, sowing dates, seed yield and Correlation.*

Introduction

Oilseeds play a vital role in India's economy, coming in second to food grains in terms of significance. They account for around 10% of the area under cultivation and make a substantial contribution to the overall agricultural yield. Among the different oilseed varieties cultivated in India, rapeseed-mustard is notable for its compatibility with traditional farming practices. Soybean has the highest average production share at 38%, with rapeseed-mustard and groundnut following closely behind at 27% each. In terms of edible oil production, rapeseed-mustard leads the way with 31%, while soybean and groundnut account for 26% and 25%, respectively (Bhagat *et al.*, 2022)[1]. Indian mustard, scientifically known as Brassica juncea L., belongs to the Brassicaceae family and is a key Rabi oilseed crop in the country. This plant is thought to have its origins in the Mediterranean area and has been grown for many centuries. Although mustard is mainly grown in temperate climates, it can also be cultivated as a cold-weather crop in certain tropical and subtropical zones. Brown mustard thrives in cool and damp growing environments, usually with an average temperature range of 15–25 °C. Mustard growth is best supported by sandy soils, and the plant can attain a height of 60–70 cm or more (Pradhan, 2014)[2]. India ranks as the second-largest nation in terms of the area allocated for mustard farming, representing 19.81% of the worldwide total, while Canada holds the top spot. In terms of global mustard output, India contributes 10.37%, positioning it fourth in production, following China, the European Union, and Canada (AICRP PC Report 2021, ICAR-DRMR)[3] (Duluri Sowmya *et.al.*, 2024)[4]. Mustard seeds can be crushed to extract mustard oil, which is rich in unsaturated fatty acids and has a concentration of 38 to 46% in the seed oil and the oil is used for various purpose like cooking, medicinal etc (Smooker et al., 2011)[5]. Examining the traits that contribute to yield can assist breeders in identifying desirable genotypes for enhancing yield and other agronomic characteristics.

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By studying the genetic architecture of yield, breeders can select genotypes with high yield potential and desired combinations of traits (Khan and Dar, 2010)[6].

Materials and Methods

A field trial was carried out at the experimental farm of AICRP on linseed and mustard, College of Agriculture, Nagpur, during the rabi season of 2023-24, as part of the research investigation titled "Evaluation of morpho-physiological characters of mustard genotypes under different sowing windows." The study was designed using a factorial randomized block design (FRBD) featuring forty combinations, which included four sowing dates *i.e*. 30th October (timely sowing), 15th November (moderately late sowing), 30th November (late sowing), 15th December (very late sowing) along with ten genotypes *viz.,* ACN-240, SKM-1626, ACN-226, ACN-244, ACN-255, T-9, ACN-237, PM-26 (check), and TAM 108-1 (check). The gross experimental plot measured 3.00 m x 1.20 m, while the net plot size was 2.40 m x 1.20 m, with a planting configuration of 30 cm x 10 cm, utilizing 5-6 kg of seeds per hectare. A total of five plants from each plot were randomly selected, and data on morpho-physiological parameters were collected, including plant height (cm), number of branches plant^{-1} measured 45 DAS, 70 DAS, and at the harvest stage using a measuring scale. The leaf area was assessed in dm^2 with a leaf area meter, leaf area index, relative water content (%), canopy temperature (^{0}C) at both 45 and 70 DAS during the growth stages. Leaf area duration (dm^2 day^{-1}), crop growth rate (gm^{-2}day^{-1}) was recorded during the interval of 45-70 DAS. Days to first flowering, days to 50% flowering and days to maturity was recorded at specified times. At harvest, yield and yield-related parameters, including the number of siliquae plant^{-1}, the number of seeds siliqua^{-1}, seed yield plant^{-1}(g), seed yield plot^{-1}(kg), test weight (g), seed yield hectare^{-1} (q) and harvest index (%) were recorded. Statistical analysis of the data will be carried out according to the method proposed by Singh and Choudhary (1985).

Results and Discussion

Total chlorophyll content

The data recorded about the total chlorophyll content at 70 DAS was subjected to statistically significant. The range of total chlorophyll content was recorded 0.89 mgg^{-1} to 0.22 mgg^{-1}. At 70 DAS, significantly higher total chlorophyll content was recorded on 30th October (0.89 mgg^{-1}) followed by 15th November. These findings are with the conformity with the findings of Kumar *et al.* (2013)[7] who indicated that decrease in chlorophyll content at 1st November and 15th November (late sowing) sowings compared to the 15th October (timely sowing).

The data recorded about the total chlorophyll content at 70 DAS was subjected to statistically significant. The range of total chlorophyll content was recorded 0.34 mgg^{-1} to 0.64 mgg^{-1}. At 70 DAS, significantly higher total chlorophyll content was recorded in ACN-237 (0.34 mgg^{-1} %) followed by ACN-226. Total chlorophyll content of ACN-226 genotype at 70 DAS was found to be at par with ACN-237. Similar results were showed by Uddin et al. (2012)[8] about rapeseed-mustard mutants based on morpho-physiological, biochemical and yield attributes in seven advanced mustard mutants *viz.,* RM01, RM02, RM03, RM04, RM05, RM10 and RM11 along with a cultivar BINA sarisa-4. They found that the variation in chlorophyll content during flowering and fruiting stage was significant among the mutants. The highest chlorophyll content was recorded in RM05 and the lower was recorded in Rm01.

This might be due to genetic makeup of mutants.

At 70 DAS, interaction effect between different sowing dates and genotypes for total chlorophyll content in leaves found significantly highest total chlorophyll content in leaves at 70 DAS was found higher in ACN-237 on 30th October (1.12 mgg^{-1}) among all other interactions and significantly lowest total chlorophyll content in leaves was found in interaction on 15th December in genotype ACN-240 (0.34 mgg^{-1}). Findings of this study has similarity with the findings of Gopale *et al.* (2022) [9] who revealed that genotypes ACN-250, ACN-237 and ACN-226 performed better under 30th October sowing as compared to 30th November sowing over two checks (PM 26 and TAM 108-1) and remaining genotypes in respect of chlorophyll.

Proline content

The data recorded about the proline content (µmolg^{-1}) of fresh weight at 70 DAS was found statistically significant among different sowing dates. The range of mean proline content was recorded 7.33 µmolg^{-1} to 13.81 µmolg^{-1}. Significantly higher proline content was recorded on 15th December *i.e.* very late sowing (13.81 µmolg^{-1}) followed by 30th November *i.e*. late sowing (13.81 µmolg^{-1}) and lowest proline content was recorded on 30th October *i.e*. timely sowing (7.33 µmolg^{-1}) compared with all other sowing dates under study. An increase in proline content was observed from 30th October to 15th December (very late sowing), as the sowing delays which can be attributed to the rise in temperature during this period, leading to stress conditions in the plants. Findings of this experiment is in correlation with Kumar *et al.* (2018) [7] who showed that maximum proline content in leaf was recorded in crop sown on 21st November (delayed sowing) and minimum was observed in 16th October (timely) sowing.

The data recorded about the proline content (12.02 µmolg^{-1}) in different mustard genotypes at harvest was found statistically and significantly different. Significantly maximum mean proline content was recorded in genotype ACN-237 (12.02 µmolg^{-1}) followed by ACN-226 and significantly lowest mean proline content was recorded in genotype ACN-240 (12.02 µmolg^{-1}) and found at par among themselves. Similar result revealed by Kumar *et al.* (2018) [7] who showed that the maximum proline content in leaf was recorded in genotype RH-0116 and minimum was observed in RH-1019.

Most of the Indian mustard recorded lower proline content in timely sowing condition *i.e*. 30th October which ranged from 6.80 µmolg^{-1} in PM-26 to 8.44 µmolg^{-1} in ACN-237 genotypes. This increase in proline content as sowing delays from 15th November to 15th December was seen and ACN-237 (15.42µmolg^{-1}) recorded highest proline content followed by ACN-226 (15.42 µmolg^{-1}) however found at par with each other and SKM-1626 (11.71 µmolg^{-1}) and ACN-240 (12.32 µmolg^{-1}) recorded lowest proline content when sown very late (15th December). This shows the interaction effect of different genotypes over different sowing dates. These results are in the agreement with findings of Kumar *et al.* (2018)[7] who stated that the maximum proline content in leaf was recorded in genotype RH-0116 on 21st November of sowing date and minimum was observed in RH-1019 on 16th October of sowing date.

Oil content

The data recorded about the oil content (%) in seed at harvest was found statistically significant among different sowing dates. The range of mean oil content in seed was recorded 30.91% to 37.61%.

Significantly higher oil content in seed was recorded on 30th October *i.e.* timely sowing (37.61%) followed by 30th November *i.e.* moderately late sowing (35.15%). The results are in line with the findings of Singh *et al.* (2017) [10] who indicated that the oil content was significantly higher under 25th October (timely sowing) sown crop as compared to 05th October and 25th September sown crop. The data recorded about the oil content (%) in seed in different mustard genotypes at harvest was found statistically significant. Significantly higher oil content in seed (%) was recorded in genotype ACN-237 (37.20%) followed by ACN-226 (36.37%) and found significantly at par with each other. Deotale *et al.* (2019) [11] revealed that among these twenty mutants, the highest oil content after harvesting was obtained from ACM_{18}, ACM_{12}, ACM_6, ACM_8 and ACM_4. In case of proximate analysis, the highest chlorophyll and oil were recorded from ACM_{18}. The oil content of different mutants of mustard varied from 33.30-42.67%.

Table 01: Biochemical parameters (total chlorophyll content, proline content, oil content) of Indian mustard as affected by growing environment and genotypes

Treatments		Total chlorophyll content (mgg^{-1})	Proline content (µmolg^{-1})	Oil content (%)
	Sowing dates (A)			
A_1	30th October	0.89	7.33	37.61
A_2	15th November	0.60	8.88	35.15
A_3	30th November	0.28	11.02	32.82
A_4	15th December	0.22	13.81	30.91
	SEm±	0.011	0.147	0.197
	CD at 5%	0.032	0.415	0.556
	Genotypes (B)			
B_1	ACN-240	0.34	9.57	32.33
B_2	SKM 1626	0.42	9.62	34.53
B_3	ACN-226	0.59	11.22	36.37
B_4	ACN-244	0.50	9.90	33.93
B_5	ACN-250	0.55	10.60	34.64
B_6	ACN-255	0.51	10.03	32.06
B_7	T-9	0.41	9.63	32.34
B_8	ACN-237	0.64	12.02	37.20
B_9	PM 26	0.48	9.93	32.14
B_{10}	TAM-108-1	0.53	10.10	35.68
	SEm±	0.018	0.233	0.312
	CD at 5%	0.051	0.656	0.879
	Interaction (A×B)			
	SEm±	0.044	0.570	0.765
	CD at 5%	0.125	1.606	NS

Note: A:-Sowing dates, B:-Genotypes and NS:-Non-significant

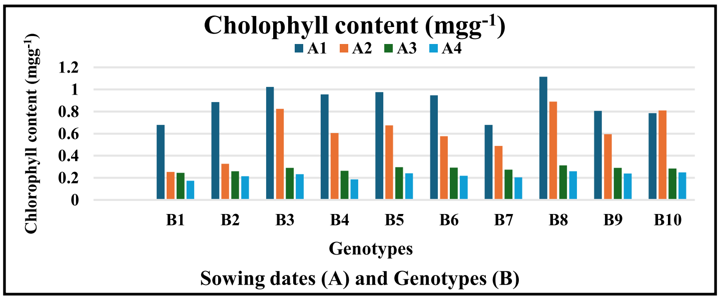

Fig. 1. Total chlorophyll content of different Indian mustard genotypes as affected by different sowing dates

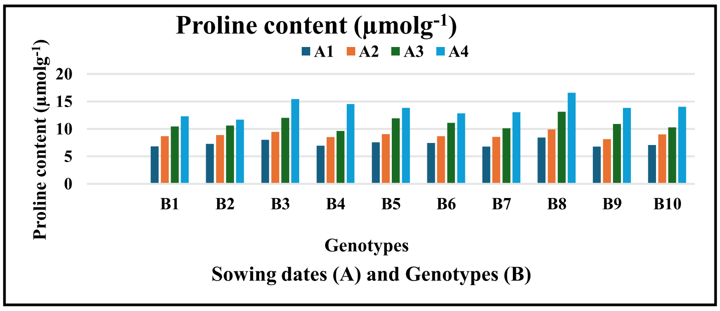

Fig. 2. Proline content of different Indian mustard genotypes as affected by different sowing dates

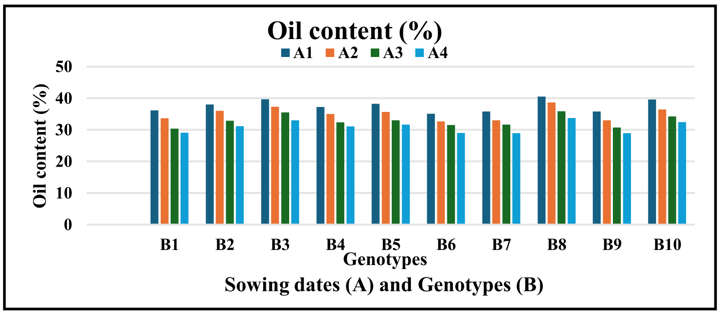

Fig. 3. Oil content of different Indian mustard genotypes as affected by different sowing dates

Number of silique plant^{-1}

The maximum number of siliquae per plant (251.41) was observed on October 30th, followed by November 15th, whereas the minimum (203.16) was recorded on December 15th. The decline in siliquae with delayed sowing is likely attributed to suboptimal temperature conditions, which may have adversely affected seed yield. Pandey et al. (2024) [12] similarly found higher yield traits in mustard sown late September compared to mid-October.

At harvest, ACN-237 recorded the highest number of siliquae per plant (250.25), closely followed by ACN-226, with no significant statistical difference between them. In contrast, the lowest number was observed in T-9 (210.31), likely due to genetic variation. Similarly, Sowjanya et al. (2021)[13] reported that among the varieties tested, PUSA Mehak had the highest siliquae count (174.1).

Test weight

The highest test weight (4.38 g) was observed in the 30th October sowing, followed by the 15th November sowing, while the lowest (3.43 g) occurred on 15th December, likely due to a more favourable source-sink balance in earlier sowings. Sowjanya et al. (2021) [13] also reported increased test weight with mid-October sowing.

ACN-237 recorded the highest test weight (4.76 g), likely attributed to its genetic characteristics and efficient source-sink relationship. Genotypes such as ACN-226, ACN-250, and TAM-108-1 showed comparable results to ACN-237. Similarly, Samota *et al.* (2022) [14] also reported the highest test weight (5.13 g) in crops sown on 15th November, identifying this sowing date along with the Md Rani Super Gold variety as the most profitable combination for Indian mustard cultivation.

Seed yield plant^{-1}, ha^{-1}

The highest seed yield plant $^{-1}$(13.70 g) and seed yield hectare^{-1} (22.49 q) was achieved with the 30th October sowing, followed by the 15th November sowing, while the lowest yield was recorded on 15th December. Early sowing promoted improved growth attributes, resulting in greater yield, whereas delayed sowing exposed the crop to heat stress, negatively impacting yield components. Similarly, Tripathi et al. (2021) [15] reported that sowing the Varuna variety on 10th November produced the highest yield (18.50 q ha^{-1}).

Genotype ACN-237 achieved the highest seed yield both plant-1 (14.30 g) and hectare^{-1} (23.22 q), with ACN-226 ranking next, while T-9 recorded the lowest yield. This superior performance is likely attributed to favourable genetic traits that support enhanced growth and photosynthetic efficiency. Similarly, Bhagat et al. (2022)[1] reported that among the cultivars studied, GSL-1 produced the highest seed yield.

Genotype ACN-237 sown on 30th October produced the highest seed yield plant^{-1}(16.69 g) and seed yield hectare^{-1} (27.55 q), whereas the lowest yield was observed in genotype T-9 sown on 15th December. Gopale et al. (2022) [9] also reported that ACN-237, ACN-250, and ACN-226 performed optimally with 30th October sowing, demonstrating a strong positive correlation with yield.

Table 02: Yield and yield attributing characters of Indian mustard as affected by growing environment and genotypes

Treatments		Number of siliquae plant^{-1}	Test weight (g)	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (q)
	Sowing dates (A)				
A_1	30th October	251.41	4.38	13.70	22.49
A_2	15th November	235.57	3.96	12.54	22.26
A_3	30th November	218.30	3.65	10.74	18.94
A_4	15th December	203.16	3.43	9.72	13.64
	SEm±	2.24	0.072	0.90	0.32
	CD at 5%	6.31	0.20	0.25	0.90
	Genotypes (B)				
B_1	ACN-240	214.77	3.47	10.79	17.01
B_2	SKM 1626	216.88	3.24	10.45	18.29
B_3	ACN-226	242.00	4.58	13.09	21.75
B_4	ACN-244	225.58	3.10	11.55	18.55
B_5	ACN-250	231.99	4.50	12.57	21.59
B_6	ACN-255	217.42	2.96	11.29	18.13
B_7	T-9	210.31	3.08	8.00	15.75
B_8	ACN-237	250.25	4.76	14.30	23.22
B_9	PM 26	229.29	4.40	12.14	19.02
B_{10}	TAM-108-1	232.64	4.46	12.58	20.00
	SEm±	3.55	0.11	0.14	0.508
	CD at 5%	9.98	0.32	0.98	1.431
	Interaction (A×B)				
	SEm±	8.69	0.27	0.35	1.245
	CD at 5%	NS	NS	0.98	3.506

Note: A:-Sowing dates, B:-Genotypes and NS:-Non-significant

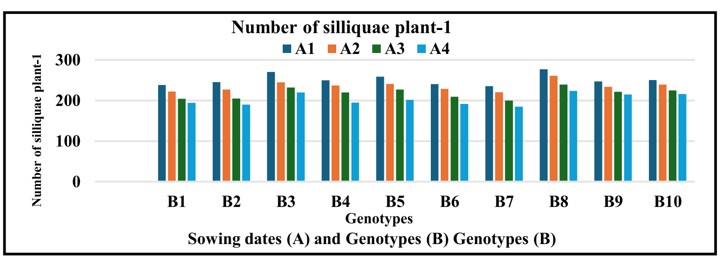

Fig. 4. Number of silliquae plant^{-1} of different Indian mustard genotypes as affected by different sowing dates

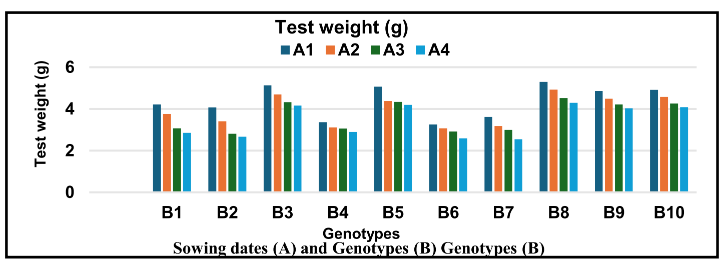

Fig. 5. Test weight of different Indian mustard genotypes as affected by different sowing date

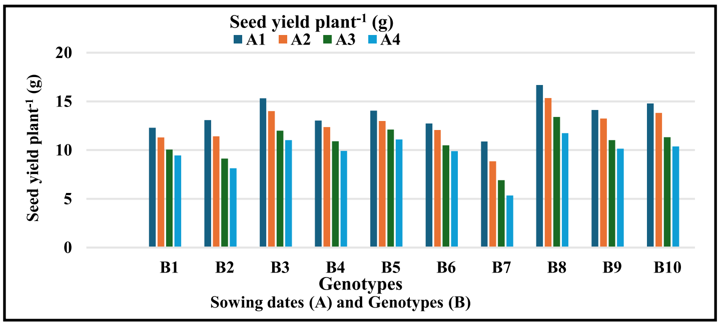

Fig. 6. Seed yield plant^{-1} of different Indian mustard genotypes as affected by different sowing dates

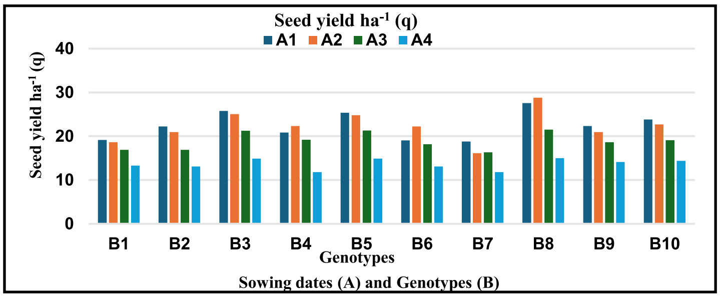

Fig. 7. Seed yield heactare^{-1} of different Indian mustard genotypes as affected by different sowing dates

Correlation

Correlation illustrates the relationship between various traits, which are typically interconnected in any biological system. To determine the extent to which different traits are associated with yield under different sowing dates, genotypic and phenotypic correlation coefficients were calculated.

The genotypic and phenotypic correlation coefficients (r_g and r_p, respectively) between various traits and seed yield hectare^{-1} were evaluated under 30th October, 15th November, 30th November, 15th December sowing dates as shown in table 1 and 2 respectively.

Genotypic Correlation:

Under **30th October** (timely sowing) date of sowing, seed yield hectare^{-1} showed a highly significant positive correlation with plant height ($r_g = 0.829$) and the leaf area ($r_g = 0.868$). It also had a positive and significant correlation with the relative water content ($r_g = 1.042$), crop growth rate ($r_g = 0.999$), total chlorophyll content ($r_g = 0.759$), proline content ($r_g = 0.999$), oil content ($r_g = 0.998$), number of siliquae plant^{-1} ($r_g = 0.999$), test weight ($r_g = 0.981$), seed yield plant^{-1} ($r_g = 0.998$).

Under the sowing date of **15th November** (moderately late sowing), the seed yield hectare^{-1}exhibited a highly significant positive correlation with plant height ($r_g = 0.512$) and leaf area ($r_g = 0.991$). Additionally, it demonstrated a positive and significant correlation with relative water content ($r_g = 0.998$), crop growth rate ($r_g = 0.996$), total chlorophyll content ($r_g = 0.827$), proline content ($r_g = 0.999$), oil content ($r_g = 0.894$), number of siliquae plant^{-1} ($r_g = 0.998$), test weight ($r_g = 0.720$), and seed yield plant^{-1} ($r_g = 0.970$).

Under the sowing date of **30th November** (late sowing), the seed yield hectare^{-1} exhibited a highly significant positive correlation with plant height ($r_g = 0.999$) and leaf area ($r_g = 0.995$). Furthermore, it also showed a positive and significant correlation with relative water content ($r_g = 1.032$), crop growth rate ($r_g = 0.999$), total chlorophyll content ($r_g = 0.921$), proline content ($r_g = 0.951$), oil content ($r_g = 0.909$), number of siliquae plant^{-1} ($r_g = 0.999$), test weight ($r_g = 0.930$), and seed yield plant^{-1} ($r_g = 0.999$).

The seed yield hectare^{-1} showed a highly significant positive connection with both plant height ($r_g = 0.721$) and leaf area ($r_g = 0.989$) under the very late sowing date of November 30. Additionally, it demonstrated a strong and positive association with the following: relative water content ($r_g = 1.045$), crop growth rate ($r_g = 0.926$), total chlorophyll content ($r_g = 0.897$), proline content ($r_g = 0.666$), oil content ($r_g = 0.789$), number of siliquae plant^{-1} ($r_g = 0.999$), test weight ($r_g = 1.062$), and seed yield plant^{-1} ($r_g = 0.853$). These findings are broadly in agreement with some earlier reports (Choudhary et al., 2003; Sirohi et al., 2004 and Kumar and Pandey, 2014 and Anuj Gupta et.al., 2018)[16],[17],[18],[19].

Table 03: Genotypic (G) correlation coefficients with seed yield hectare^{-1} for different characters in Indian mustard under different sowing dates

Characters	30th October	15th November	30th November	15th December
Plant height	0.829**	0.512**	0.999**	0.721**
Leaf area	0.868**	0.991**	0.995**	0.989**
RWC	1.042**	0.998**	1.032**	1.045**
CGR	0.999**	0.996**	0.999**	0.926**
Chlorophyll	0.759**	0.827**	0.921**	0.897**
Proline	0.999**	0.999**	0.951**	0.666**
Oil	0.998**	0.894**	0.909**	0.789**
No. of sillique plant^{-1}	0.999 **	0.998**	0.999**	0.999**
Test weight	0.981**	0.720**	0.930**	1.062**
Yield plant^{-1}	0.998**	0.970**	0.999**	0.853**

*Note: ** (Significance at 1%), NS (Non-significant)*

Phenotypic Correlation:

Under **30th October** (timely sowing) date of sowing, seed yield hectare^{-1} showed a highly significant positive correlation with plant height ($r_p = 0.599$) and the leaf area ($r_p = 0.581$). It also had a positive and significant correlation with the relative water content ($r_p = 0.489$), crop growth rate ($r_p = 0.619$), total chlorophyll content ($r_p = 0.623$), proline content ($r_p = 0.611$), oil content ($r_p = 0.697$), number of siliquae plant^{-1} ($r_p = 0.672$), test weight ($r_p = 0.712$), seed yield plant^{-1} ($r_p = 0.810$).

Under the sowing date of **15th November** (moderately late sowing), the seed yield hectare^{-1}exhibited a non-significant and positive correlation with plant height ($r_p = 0.306$). Additionally, it demonstrated a positive and significant correlation with leaf area ($r_p = 0.742$), relative water content ($r_p = 0.567$), crop growth rate ($r_p = 0.842$), total chlorophyll content ($r_p = 0.684$), proline content ($r_p = 0.524$), oil content ($r_p = 0.653$), number of siliquae plant^{-1} ($r_p = 0.748$), test weight ($r_p = 0.568$), and seed yield plant^{-1} ($r_p = 0.814$).

Under the sowing date of **30th November** (late sowing), the seed yield hectare^{-1}exhibited a non-significant and positive correlation with plant height ($r_p = 0.358$) and relative water content ($r_p = 0.303$).

Furthermore, it also showed a positive and significant correlation with leaf area (r_p = 0.624), crop growth rate (r_p = 0.577), total chlorophyll content (r_p = 0.558), proline content (r_p = 0.557), oil content (r_p = 0.536), number of siliquae plant^{-1} (r_p = 0.676), test weight (r_p = 0.702), and seed yield plant^{-1} (r_p = 0.782).

The seed yield hectare^{-1} exhibited a non-significant and positive correlation with plant height (r_p = 0.349) and proline content (r_p = 0.342) under the very late sowing date of November 30. Additionally, it demonstrated a strong and positive association with the following: leaf area (r_p = 0.577), relative water content (r_p = 0.466), crop growth rate (r_p = 0.525), total chlorophyll content (r_p = 0.577), oil content (r_p = 0.404), number of siliquae plant^{-1} (r_p = 0.502), test weight (r_p = 0.680), and seed yield plant^{-1} (r_p = 0.668). These findings are broadly in agreement with some earlier reports (Choudhary et al., 2003; Sirohi et al., 2004 and Kumar and Pandey, 2014 and Anuj Gupta et.al., 2018)[16],[17],[18],[19].

Table 04: Phenotypic (P) correlation coefficients with seed yield hectare^{-1} for different characters in Indian mustard under different sowing dates

Characters	30th October	15th November	30th November	15th December
Plant height	0.599**	0.306NS	0.358NS	0.349NS
Leaf area	0.581**	0.742**	0.624**	0.577**
RWC	0.489**	0.567**	0.303NS	0.466**
CGR	0.619**	0.842**	0.577**	0.525**
Chlorophyll	0.623**	0.684**	0.558**	0.577**
Proline	0.611**	0.524**	0.557**	0.342NS
Oil	0.697**	0.653**	0.536**	0.404*
No. of sillique plant^{-1}	0.672**	0.748**	0.676**	0.502**
Test weight	0.712**	0.568**	0.702**	0.680**
Yield plant^{-1}	0.810**	0.814**	0.782**	0.668**

*Note: ** (Significance at 1%), NS (Non-significant)*

Conclusion

Indian mustard exhibited no notable reduction in biochemical traits, yield, or yield-related attributes when sown between 30th October and 30th November, especially with genotype ACN-237, followed by ACN-226 under delayed sowing. However, sowing beyond this period resulted in lower total chlorophyll and oil content, and higher proline accumulation, likely due to moisture stress. Strong positive correlations between seed yield hectare^{-1} and traits like plant height(r_g= 0.829 and 0.721), leaf area (r_g= 0.868 and 0.989), relative water content (r_g= 1.042 and 1.045), crop growth rate (r_g= 0.999 and 0.926), total chlorophyll content (r_g= 0.759 and 0.897), proline content (r_g= 0.999 and 0.666), oil content (r_g= 0.998 and 0.789), number of siliquae plant^{-1} (r_g= 0.999 and 0.999), test weight (r_g= 0.981 and 1.062) and seed yield plant^{-1} (r_g= 0.998 and 0.853) under timely sowing (30th October) and very late sowing (15th December) respectively reinforce their importance as selection criteria in breeding under timely sowing conditions (30th October) to late sowing conditions (30th November). Therefore, ACN-237, ACN-226 and ACN-250 genotypes can be suitable for timely (30th October) as well as late sowing conditions (30th November) for high yield.

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References

1. Bhagat, R., M. Singh, B. C. Sharma and Uma Shankar, 2022. Effect of sowing environments on yield attributes and yield of Gobhi Sarson (Brassica napus L.) cultivars under sub-tropics of Jammu region. J. Oilseeds Res., 13(1): 7-10.
2. Pradhan, A. 2014. Mustard: A potential cash crop. Journal of Pharmacognosy and Phytochemistry, 3(5): 13-15. Project Coordinator. (2020-21).
3. Project Coordinator's Report for AICRP-RM (2020-21). In 28th Annual AICRP (R and M) Group Meeting, ICAR-Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, Rajasthan.
4. Duluri Sowmya, I. R. Delvadiya and A. V. Ginoya, 2024. Genetic variability, correlation, path coefficient and cluster analysis in Indian mustard (Brassica juncea L.). Electronic Journal of Plant Breeding, Vol 15(1): 201 – 208. https://doi.org/10.37992/2024.1501.019
5. Smooker, A.M., Wells, R., Morgan, C., Beaudoin, F., Cho, K. and Fraser, F. 2011. The identification and mapping of candidate genes and QTL involved in the fatty acid desaturation pathway in Brassica napus. Theortical and Applied Genetics, 122(6): 1075 1090.
6. Khan, S. A. and Dar, Z. A. 2010. Genetic variability, heritability and genetic advance for seed yield and other quantitative traits in Indian mustard (Brassica juncea L. Czern & Coss). Electronic Journal of Plant Breeding, 1(4): 906-910.
7. Kumar, A., M. Kumar, P. Gill and K. N. Dharamvir, 2018. Physiological and biochemical responses of Indian mustard (Brassica juncea L.) genotypes to different sowing dates. Int. J. Curr. Microbiol. App. Sci., 7(12): 2794-2801.
8. Uddin M. A., M. A. Ullah, F. Sultana, K. M. Rahman and M. Z. Rahman, 2012. Evaluation of Some Rapeseed Mutants Based on Morpho-Physiological, Biochemical and Yield Attributes. J. Environ. Sci. & Natural Resources, 5(2): 281 – 285.
9. Gopale R, Deotale RD, Raut A, Kamdi SR, Baviskar SB, Aade A. Effectivity of different sowing dates on chemical, biochemical, yield and yield traits in mustard genotypes. J Soils Crops. 2022;32(1):171-179.
10. Singh, A. K., H. Singh, O. P. Rai, G. Singh, V. P. Singh, N. P. Singh and R. Singh, 2017. Effect of sowing dates and varieties for higher productivity of Indian mustard (Brassica juncea L.). J. Appl. & Nat. Sci., 9(2): 883-887.

11. Deotale, R. D., A. P. Dhongade, S. R. Kamdi, V. S. Madke, M. P. Meshram and V. B. Kalamkar, 2019. Experimental study on biochemical parameters and yield of M4 Indian mustard mutants. J. Soils and Crops, 29(2): 297-301.

12. Pandey B, Yadav R, Ramawat N, Vishwakarma H, Pandey S. Optimization of sowing dates in Indian mustard (Brassica juncea L.) to combat yield losses caused by high temperature at reproductive stage. Plant Sci Today. 2024;11(1):81-92.

13. Sowjanya M, Reddy GS, Revathi P, Chandrashaker K. Effect of sowing dates and varieties on productivity of mustard under northern Telangana zone. J Plant Interact. 2021;10(9):183-187.

14. Samota, F. S. K., R. Sharma and H. B. Paliwal, 2022. Effect of Different Sowing Dates and Varieties on Mustard Growth and Yield in Prayagraj Conditions. Int. J. Environ. Clim., 12(11):2316-2322.

15. Tripathi KBM, Gaur T, Pandey L, Singh A, Tiwari A, Prakash V, Rathore US, Singh RK. Effect of sowing dates on growth and yield of Indian mustard (Brassica juncea L.). Int J Curr Microbiology App Sci. 2021;10(1):3046-3057.

16. Choudhary VK, Kumar R, Sah JN. 2003. Path analysis in Indian mustard. J Applied Biol.; 13(1, 2):6-8.

17. Sirohi SPS, Malik S, Kumar A. Correlation and path analysis of Indian mustard (Brassica juncea L. Czern and Coss.). Ann. Agri. Res. 2004; 25(4):491-494.

18. Kumar B, Pandey A. 2014. Association analysis of yield and its components in Indian mustard (Brassica juncea L. Czern and Coss). Environment and Ecology, 32(4B):1778-1783.

19. Anuj Gupta, Naveen Chandra Pant, Upendra Dwivedi, Shailendra Tiwari, CS Pandey, Rakesh Dhoundiyal, KN Maurya and OP Verma. 2018. Studies on correlation and path coefficient analysis for yield and yield related traits in Indian mustard (Brassica juncea L. Czern & Coss.) under timely and late sown conditions. Journal of Pharmacognosy and Phytochemistry; 7(2): 2545-2551