**Genotypic and Phenotypic Association among Seed Quality Traits in Indian Mustard (Brassica juncea L. Czern & Coss.)**

**Abstract:**

The present investigation was conducted during 2024 in the Department of Seed Science and Technology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), India, using thirty varieties of Indian mustard (Brassica juncea L. Czern & Coss.) to evaluate seed quality parameters. Eleven seed quality traits were assessed, and correlation coefficients were computed at both phenotypic and genotypic levels. The genotypic correlations generally exhibited similar directions but were of greater magnitude than the phenotypic ones. Vigour index showed a highly significant positive correlation with seedling length (0.940) and root length (0.893), but a significant negative correlation with speed of germination (-0.361). Seedling length also displayed a highly significant and positive correlation with root length (0.893), while both traits were negatively correlated with speed of germination at the field level. Shoot length had a significant positive correlation with first count (0.379), and root length correlated significantly with speed of germination (0.387). Speed of germination was highly significantly correlated with germination percentage (0.485, 0.500), and germination percentage had a significant positive relationship with field emergence (0.382). A significant negative correlation was observed between first count and 1000-seed weight (-0.415). The findings suggest that traits such as seedling length, root length, and speed of germination can serve as reliable indicators for seed vigour and quality improvement in Indian mustard breeding programs.

**Keywords:** Indian mustard, seed quality, genotypic correlation, phenotypic correlation, vigour index, seedling traits, germination percentage, speed of germination, field emergence, 1000-seed weight.

**Introduction**

Indian mustard (Brassica juncea L. Czern & Coss.) is one of the most extensively cultivated oilseed crops in India, contributing significantly to the country's total edible oil production. It is primarily grown during the rabi season and is well-adapted to diverse agro-climatic conditions, including arid and semi-arid regions. The crop is valued for its high oil content, early maturity, and relatively good tolerance to abiotic stresses. Major mustard-growing states in India include Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat. The productivity and success of mustard cultivation depend not only on genetic potential and agronomic practices but also critically on seed quality, which determines the initial stand establishment and uniformity in the field.

Although prior research has explored variability in seedling traits (Sharma & Lal, 2019; Patel & Patel, 2020), comprehensive studies integrating genotypic and phenotypic correlation analyses for seed quality traits remain limited. Recent investigations have emphasized the role of physiological traits like seedling length, root length, and vigour indices in improving early establishment and yield potential (Meena et al., 2021; Kumar & Chauhan, 2023). Moreover, identifying such traits is particularly crucial under resource-constrained and moisture-stressed conditions common to Indian mustard production zones (Bhatt & Dagar, 2018).

Seed and seedling quality traits such as germination percentage, speed of germination, seedling length, vigour index, and field emergence are vital parameters influencing crop performance. These traits are often polygenic in nature and influenced by environmental interactions, making their evaluation and improvement complex. However, assessing the relationship among these traits through correlation studies provides useful information for identifying potential selection indices. A deeper understanding of these interrelationships is essential for selecting superior genotypes with enhanced seed vigour and better seedling establishment, particularly under stress-prone or marginal environments.

Correlation analysis at genotypic and phenotypic levels offers insights into the strength and direction of associations among traits, helping to determine whether improvement in one trait could lead to simultaneous gains in others. Genotypic correlations are particularly useful as they reflect the true genetic association, less influenced by environmental variability. Therefore, the present investigation was undertaken to evaluate thirty varieties of Indian mustard for eleven seed quality parameters and to estimate the phenotypic and genotypic correlations among these traits. The findings aim to assist in identifying key traits contributing to seed vigour and provide a basis for selection in breeding and seed improvement programmes.

**Materials and Methods**

The present investigation was carried out during rabi 2024 at the Department of Seed Science and Technology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), India. A total of thirty genotypes of Indian mustard (Brassica juncea L. Czern & Coss.) were evaluated for seed and seedling quality parameters under laboratory and field conditions. The experiment was laid out in a completely randomized design (CRD) with three replications under controlled laboratory conditions.

**Seed Quality Parameters Evaluated**

Germination Percentage (%): Based on the number of normal seedlings on the final count (day 7), as per ISTA (2018) rules:  
Germination (%) = (Number of normal seedlings / Total number of seeds sown) × 100

First Count (%): Percentage of normal seedlings recorded on the fourth day of germination test.

Speed of Germination (Maguire, 1962):

Speed of Germination = (n₁/d₁) + (n₂/d₂) + ... + (nₙ/dₙ)  
Where,  
n₁, n₂, ... nₙ = Number of seeds germinated on day 1, 2,... n  
d₁, d₂, ... dₙ = Days after sowing

Seedling Length (cm): Average length of 10 randomly selected normal seedlings (shoot + root length).

Shoot Length (cm): Measured from the base of the hypocotyl to the tip of the plumule in 10 normal seedlings.

Root Length (cm): Measured from the base of the hypocotyl to the tip of the primary root in 10 normal seedlings.

Seedling Dry Weight (mg): Normal seedlings were dried at 80°C for 24 hours and weighed.

Seedling Vigour Index-I (Abdul-Baki and Anderson, 1973):

SVI-I = Germination (%) × Seedling Length (cm)

Seedling Vigour Index-II:

SVI-II = Germination (%) × Seedling Dry Weight (mg)

Field Emergence (%): Calculated based on the number of seedlings emerged in field conditions after 7–10 days.

1000-Seed Weight (g): Determined by weighing 1000 seeds from each replication using a digital balance.

**Statistical Analysis**

Analysis of variance (ANOVA) was carried out to test the significance of differences among genotypes for various traits. Genotypic and phenotypic correlation coefficients among seed quality parameters were calculated using the method proposed by Johnson et al. (1955). The formulas used are:

Phenotypic Correlation Coefficient (rₚ):

rₚ = Covₚ(X,Y) / √[Vₚ(X) × Vₚ(Y)]

Genotypic Correlation Coefficient (r₉):

r₉ = Cov₉(X,Y) / √[V₉(X) × V₉(Y)]

Where:  
Covₚ and Cov₉ = phenotypic and genotypic covariance between traits X and Y  
Vₚ and V₉ = phenotypic and genotypic variances of respective traits  
  
**Results and Discussion**

**Correlation Analysis of Seed Quality Parameters**

The correlation coefficients among eleven seed quality traits were estimated at both phenotypic and genotypic levels and are presented in Table 1 and 2, respectively. In general, genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic values, though the direction (positive or negative) remained the same. This indicates that the observed associations are primarily controlled by genetic factors, with a lower degree of environmental influence.

The **vigour index** exhibited a highly significant and positive correlation with **seedling length** (r = 0.940) and **root length** (r = 0.893), suggesting that improvement in these traits would directly enhance seedling vigour. Similar findings were reported by Yadav et al. (2011) and Kumari et al. (2020), where seedling traits had a direct influence on seed vigour in *Brassica* species. Conversely, a significant negative correlation of vigour index was observed with **speed of germination** (r = –0.361), indicating that early germination may not always contribute to greater vigour, possibly due to weaker early growth.

**Seedling length** also showed a strong positive correlation with **root length** (r = 0.893), implying that both components grow proportionally and can serve as a combined indicator of seedling vigour. However, it showed a significant negative correlation with **speed of germination** in field conditions (r = –0.374), aligning with the inverse relationship found by Singh et al. (2015), where faster germination did not guarantee longer or healthier seedlings.

**Shoot length** exhibited a significant positive correlation with **first count** (r = 0.379), suggesting that early vigour is linked with enhanced plumule growth. Meanwhile, **root length** was positively correlated with **speed of germination** (r = 0.387), indicating a possible contribution of faster radicle emergence to early seedling establishment.

A highly significant and positive correlation was found between **speed of germination** and **germination percentage** (r = 0.485 and 0.500), consistent with reports by Verma et al. (2018), which emphasize speed as a crucial trait for assessing seed quality. **Germination percentage** also showed a significant positive correlation with **field emergence** (r = 0.382), reaffirming its predictive value for field performance.

Interestingly, **first count** exhibited a significant negative correlation with **1000-seed weight** (r = –0.415), suggesting that smaller seeds may germinate faster, though they may not always contribute to higher vigour or establishment. The rest of the traits showed non-significant correlations, suggesting that their impact on seedling vigour may be indirect or environment-dependent.

Overall, the results highlight the importance of **seedling length**, **root length**, and **germination percentage** as key components of seed vigour. These parameters may be prioritized in breeding programmes aiming at improving seed quality and field establishment in Indian mustard. The correlation coefficients among eleven seed quality traits were estimated... In general, genotypic correlation coefficients were higher than their corresponding phenotypic values, indicating strong genetic control (Meena et al., 2021).

The vigour index showed a strong positive correlation with seedling length and root length, reinforcing findings from Kaur et al. (2022), who reported similar associations in diverse mustard genotypes. The negative correlation observed between vigour index and speed of germination suggests that rapid emergence may sometimes be associated with weaker early growth (Sharma & Lal, 2019). Seedling length and root length had a high positive correlation, confirming results from Patel & Patel (2020), who emphasized their potential as selection criteria under saline stress. The consistency of this association across environments and genetic backgrounds suggests these traits are stable indicators of vigour (Kumar & Chauhan, 2023). Additionally, the positive influence of root length on field emergence highlights the critical role of early radicle growth for crop establishment under moisture stress conditions, as supported by Bhatt & Dagar (2018).

**Table 1: Estimates of phenotypic correlation coefficient between different characters in Indian mustard varieties**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Characters** | **Field emergence (%)** | **Speed of germination (at field)** | **First count** | **Final count** | **Germination (%)** | **Speed of germination (in lab)** | **Root length (cm)** | **Shoot length (cm)** | **Seedling length (cm)** | **Vigour index** |
| 1000-Seed weight (g) | 0.074 | 0.035 | -0.415\* | 0.039 | 0.134 | 0.257 | 0.176 | -0.139 | 0.125 | 0.147 |
| Field emergence (%) |  | 0.296 | 0.057 | 0.101 | 0.382\* | 0.196 | -0.009 | 0.132 | 0.009 | 0.095 |
| Speed of germination (at field) |  |  | 0.313 | 0.147 | 0.124 | 0.500\*\* | 0.387\* | 0.030 | -0.374\* | -0.361\* |
| First count |  |  |  | 0.308 | -0.035 | 0.105 | -0.182 | 0.379\* | 0.034 | -0.058 |
| Final count |  |  |  |  | -0.103 | -0.071 | -0.004 | 0.207 | 0.113 | 0.079 |
| Germination (%) |  |  |  |  |  | 0.485\*\* | 0.091 | -0.039 | 0.071 | 0.208 |
| Speed of germination (in lab) |  |  |  |  |  |  | -0.081 | -0.069 | -0.090 | -0.055 |
| Root length (cm) |  |  |  |  |  |  |  | -0.216 | 0.893\*\* | 0.893\*\* |
| Shoot length (cm) |  |  |  |  |  |  |  |  | 0.169 | 0.148 |
| Seedling length (cm) |  |  |  |  |  |  |  |  |  | 0.940\*\* |

\* and \*\* Significant at 5% and 1% level of probability, respectively.

**Table 2: Estimates of genotypic correlation coefficient between different characters in Indian mustard varieties**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Characters** | **Field emergence**  **(%)** | **Speed of germination**  **(at field)** | **First count** | **Final count** | **Germination (%)** | **Speed of germination**  **(in lab)** | **Root length**  **(cm)** | **Shoot length**  **(cm)** | **Seedling length**  **(cm)** | **Vigour index** |
| 1000-Seed weight (g) | 0.008 | 0.026 | -0.436 | 0.056 | 0.164 | 0.267 | 0.196 | -0.209 | 0.118 | 0.146 |
| Field emergence (%) |  | 0.421 | 0.122 | 0.196 | 0.551 | 0.274 | 0.002 | 0.063 | 0.049 | 0.112 |
| Speed of germination (at field) |  |  | 0.340 | 0.217 | 0.180 | 0.520 | -0.403 | 0.016 | -0.404 | -0.386 |
| First count |  |  |  | 0.426 | -0.051 | 0.115 | -0.197 | 0.406 | -0.047 | -0.070 |
| Final count |  |  |  |  | -0.166 | -0.039 | 0.010 | 0.316 | 0.101 | 0.069 |
| Germination (%) |  |  |  |  |  | 0.601 | 0.113 | -0.043 | 0.102 | 0.257 |
| Speed of germination (in lab) |  |  |  |  |  |  | -0.081 | -0.087 | -0.125 | -0.029 |
| Root length (cm) |  |  |  |  |  |  |  | -0.210 | 0.947 | 0.940 |
| Shoot length (cm) |  |  |  |  |  |  |  |  | 0.166 | 0.142 |
| Seedling length (cm) |  |  |  |  |  |  |  |  |  | 0.978 |

**Conclusion**

The present investigation revealed substantial genotypic and phenotypic variability among Indian mustard (*Brassica juncea* L. Czern & Coss.) varieties for key seed quality traits. Genotypic correlation coefficients were generally higher than phenotypic ones, indicating a strong genetic influence on the expression of seed and seedling traits. Vigour index showed a strong positive association with seedling length and root length, highlighting their importance as reliable indicators of seed vigour. Speed of germination, although beneficial for early emergence, exhibited a negative relationship with vigour index and seedling length, suggesting that faster germination may not always result in more vigorous seedlings.

Traits such as seedling length, root length, and germination percentage emerged as critical contributors to seedling vigour and early field performance. These parameters can serve as effective selection criteria in breeding programmes aimed at enhancing seed quality and improving crop stand establishment. The results underscore the significance of genetic evaluation of seed traits for the development of high-quality, vigorous mustard varieties suitable for diverse agro-climatic conditions.

Future research integrating molecular tools with physiological screening may further refine selection strategies and help identify stable genotypes with superior seed performance under stress and non-stress environments.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models, (ChatGPT, COPILOT, etc) and text- to- image generators have been used during writing or editing of this manuscript.

**Competing Interests**

Authors have declared that no competing interests exist.

**References**

* Abdul-Baki, A. A., & Anderson, J. D. (1973). Vigor determination in soybean seed by multiple criteria. *Crop Science*, 13(6), 630–633. <https://doi.org/10.2135/cropsci1973.0011183X001300060013x>
* Bhatt, R. K., & Dagar, J. C. (2018). Germination behaviour and seedling performance in mustard under variable soil moisture. Indian Journal of Plant Physiology, 23(4), 726–732. <https://doi.org/10.1007/s40502-018-0393-0>
* ISTA. (2018). *International Rules for Seed Testing*. International Seed Testing Association, Bassersdorf, Switzerland.
* Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955). Estimates of genetic and environmental variability in soybeans. *Agronomy Journal*, 47(7), 314–318.
* Kaur, J., Singh, D., & Thakur, P. (2022). Seed vigour traits and early seedling performance in mustard genotypes. South African Journal of Botany, 148, 345–352. <https://doi.org/10.1016/j.sajb.2022.04.016>
* Kumari, M., Yadav, R., & Lal, G. M. (2020). Genetic variability and association analysis for seedling traits in mustard. *Journal of Oilseed Brassica*, 11(1), 45–50.
* Kumar, A., & Chauhan, J. S. (2023). Use of physiological seed quality traits in genetic enhancement of mustard. Seed Science and Technology, 51(1), 127–138. <https://doi.org/10.15258/sst.2023.51.1.13>
* Maguire, J. D. (1962). Speed of germination-aid in selection and evaluation for seedling emergence and vigour. *Crop Science*, 2(2), 176–177.
* Meena, R. K., Verma, A. K., & Singh, S. K. (2021). Genetic analysis of seedling vigour traits in Indian mustard (Brassica juncea). Legume Research, 44(11), 1312–1316. <https://doi.org/10.18805/LR-4367>
* Patel, J., & Patel, D. (2020). Evaluation of seedling parameters and their genetic correlation in Brassica juncea under saline stress. Plant Archives, 20(1), 1031–1034.
* Sharma, V., & Lal, C. R. (2019). Estimation of variability and inter-relationship among seedling traits in mustard. Journal of Oilseed Brassica, 10(2), 145–150.
* Singh, N., Sharma, S., & Saxena, B. (2015). Relationship between germination traits and seedling vigour in *Brassica juncea*. *Seed Research*, 43(2), 125–130.
* Verma, A., & Ram, H. (2018). Assessment of seed vigour and field performance in mustard. *International Journal of Current Microbiology and Applied Sciences*, 7(6), 987–993.
* Yadav, S. S., Singh, B., & Tomar, Y. K. (2011). Evaluation of genotypic variation for seedling vigour traits in mustard. *Indian Journal of Plant Physiology*, 16(2), 170–174