**Genetic variability, Heritability and Genetic advance in Analysis of Seed Quality Parameters in Wheat (*Triticum aestivum* L.) Germplasm**

**ABSTRACT**

The present investigation was carried out using twenty wheat genotypes in a laboratory setting to assess genetic variability, heritability, and genetic advance for seed quality traits. The experiment followed a Completely Randomized Design (CRD) with three replications during 2024–25 at the Department of Seed Science and Technology, Bundelkhand University, Jhansi. Significant genotypic and phenotypic variation was observed for vigour index-I, shoot length, seed width, root length, and seedling length. High heritability coupled with high genetic advance was recorded for shoot length, root length, seed width, and seedling dry weight, indicating additive gene action and suitability of these traits for selection. Vigour index-I ranged from 1540.00 (JK-7254) to 2349.60 (WH-1402), with a mean of 2106.44. The results underline the importance of these traits for breeding high-quality seed varieties in wheat.

Keywords: Wheat, heritability, genetic advance, seed quality, vigour index, germplasm

**INTRODUCTION**

Wheat (Triticum aestivum L.) is one of the most widely cultivated and consumed cereal crops globally, accounting for a significant proportion of caloric intake. Among the species, bread wheat is the most dominant, occupying nearly 90% of the global wheat cultivation area (Prasad et al., 2020). Enhancing wheat productivity and seed quality through genetic improvement is vital for meeting the growing food demand.

Seed quality defined by attributes like germination, vigour, and purity is fundamental to agricultural success. High-quality seed ensures uniform crop establishment and resilience under stress conditions. Conversely, seeds with low vigour can severely impact field emergence and productivity (Akshitha et al., 2020). Seedling vigour, in particular, plays a critical role in early plant development, especially in suboptimal environments.

The current study aims to quantify genetic variability among wheat genotypes for seed quality parameters and identify traits with high heritability and genetic advance. This will support the development of high-performing wheat varieties through informed selection.

**MATERIALS AND METHODS**

The present study was conducted during 2024–25 in the Seed Testing Laboratory of the Department of Seed Science and Technology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), India. The experiment involved twenty wheat (Triticum aestivum L.) germplasm lines, evaluated for seed quality traits using a Completely Randomized Design (CRD) with three replications.

Seeds were placed on germination paper and kept under optimum conditions as per ISTA rules (2021). Shoot and root length were measured after 7 days of germination. Seedling dry weight was measured after drying the seedlings at 80°C for 24 hours. Germination counts were taken at first count (4th day) and final count (8th day).

**Statistical Analysis**

1. Germination Percentage

Germination Percentage = (Number of seeds germinated / Total seeds sown) × 100

2. Speed of Germination (Maguire's Index)

Speed of Germination = Σ (n\_i / d\_i)

Where:

- n\_i = number of seeds germinated on the i-th day

- d\_i = number of days from sowing

3. Seedling Length (cm)

Seedling Length = Root Length + Shoot Length

4. Seedling Vigour Index-I (SVI-I)

Vigour Index-I = Germination Percentage × Seedling Length (cm)

5. Seedling Vigour Index-II (SVI-II)

Vigour Index-II = Germination Percentage × Seedling Dry Weight (mg)

Genetic Parameters

6. Phenotypic and Genotypic Coefficient of Variation (PCV and GCV)

GCV (%) = (√σ²g / X̄) × 100

PCV (%) = (√σ²p / X̄) × 100

Where:

- σ²g = genotypic variance

- σ²p = phenotypic variance

- X̄ = general mean

7. Heritability in Broad Sense (h²bs)

h²bs = (σ²g / σ²p) × 100

8. Genetic Advance (GA) and Genetic Advance as % of Mean (GAM)

GA = K × σp × h²bs

GAM (%) = (GA / X̄) × 100

Where:

- K = selection differential (usually 2.06 at 5% selection intensity)

- σp = phenotypic standard deviation

Analysis of Variance (ANOVA) for each character was performed using CRD layout. Standard Error (SE) and Critical Difference (CD) at 5% were calculated. All calculations were done using Microsoft Excel and statistical software packages.

**RESULTS AND DISCUSSION**

**Analysis of Variance (ANOVA)**

The analysis of variance (ANOVA) revealed highly significant differences (**p < 0.01**) among the twenty wheat genotypes for all thirteen seed quality traits evaluated (Table 1). This statistically significant variation among genotypes highlights the presence of substantial genetic diversity within the studied material. Such diversity is essential for the success of any crop improvement program, as it provides the foundational basis for the selection of superior genotypes. The observed differences affirm the potential for genetic improvement through targeted selection and breeding strategies (Kumari et al., 2019; Yadav et al., 2021).

**Performance of Genotypes**

The mean performance of genotypes across various traits indicated notable differences, particularly for seed vigour and seedling growth traits. Among all genotypes, **WH-1402** recorded the highest value for **vigour index-I** (**2349.60**), reflecting robust early seedling vigour. Similarly, **PBW-502** excelled in **vigour index-II**, with the highest value (**14378.00**), suggesting its superiority in sustaining seedling development under laboratory conditions. High vigour indices are associated with better field emergence and seedling establishment, which are crucial under both optimal and stress-prone environments (Maguire, 1962; Sharma et al., 2018).

Significant variability was also evident in other traits such as **seedling length**, **shoot length**, and **seed width**, which are directly associated with early growth and seedling performance. The genotypes **HI-8751**, **PBW-502**, **WH-1402**, and **RAJ-3077** emerged as promising candidates based on their superior performance across multiple traits. These lines could serve as potential parental sources for improving seed quality traits in wheat.

**Genetic Parameters**

The estimation of genetic parameters provided deeper insights into the inheritance pattern and variability among genotypes. The **Genotypic Coefficient of Variation (GCV)** and **Phenotypic Coefficient of Variation (PCV)** were highest for **vigour index-I** (GCV: **17.24%**, PCV: **17.36%**), followed by **shoot length** and **seed width**. The minimal difference between GCV and PCV for these traits indicates that environmental factors had a limited effect, and the observed variability is largely genetic in nature (Roychowdhury & Tah, 2016; Das et al., 2020).

High **heritability** combined with high **genetic advance** was recorded for vigour index-I, shoot length, and seed width, indicating the predominance of additive gene action. This implies that selection based on these traits in early generations would likely be effective and heritable. Such a scenario is highly desirable in plant breeding programs as it ensures consistent trait improvement (Singh et al., 2020; Raut et al., 2022).

The findings of this study are consistent with earlier reports in wheat and other cereals. For example, **Akshitha et al. (2020)** reported similar trends of high GCV, PCV, and heritability for seed vigour traits in wheat. Likewise, **Sudeepthi et al. (2020)** found that seedling vigour and seed width were reliable indicators of field emergence and early establishment in rice. Studies by **Kumari et al. (2019)** and **Chaudhary et al. (2021)** further corroborate the importance of genetic variability and its utilization for improving seed and seedling characteristics.

The identification of high-performing genotypes like **WH-1402** and **PBW-502**, which combine favourable seed quality traits and vigour, provides valuable germplasm for use in breeding programs. These genotypes could be exploited to develop varieties with enhanced seedling vigour and better establishment under field conditions. Moreover, the observed genetic variability and high heritability offer ample opportunity for **phenotypic selection** to improve these traits.

Considering the increasing emphasis on sustainable agriculture and resilience to abiotic stresses, seed quality enhancement assumes critical importance. Breeding for improved vigour not only boosts initial growth but also helps mitigate the impact of delayed sowing, poor soils, or erratic rainfall—conditions increasingly common due to climate variability (Rana et al., 2017; Patel et al., 2021)

**Table 1: Analysis of variance of completely randomized design for 13 characters of wheat genotypes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Characters** | **Source of variation** | | |
| **Treatments** | **Error** | **Total** |
| **19**  **(Degree of freedom)** | **40**  **(Degree of freedom)** | **59**  **(Degree of freedom)** |
| 1000 Seed Weight (g) | 36.30\*\* | 0.74 | 12.35 |
| Seed Length (mm) | 00.88\*\* | 0.03 | 0.30 |
| Seed Width (mm) | 00.82\*\* | 0.01 | 0.27 |
| Shoot Length (cm) | 7.10\*\* | 0.06 | 2.36 |
| Root Length (cm) | 9.26\*\* | 0.08 | 3.08 |
| Seedling Length (cm) | 22.05\*\* | 0.21 | 7.34 |
| Speed of germination | 5.24\*\* | 0.18 | 1.83 |
| Seedling Dry Weight (mg) | 287.15\*\* | 10.12 | 100.58 |
| First Count (No.) | 37.75\*\* | 3.07 | 14.39 |
| Final Count (No.) | 28.15\*\* | 3.70 | 11.68 |
| Germination Percentage (%) | 20.57\*\* | 3.05 | 8.77 |
| Vigour Index – I | 397376.22\*\* | 1836.00 | 130991.99 |
| Vigour Index – II | 2498481.95\*\* | 86019.27 | 873762.19 |

\*\* Significant at 1% probability level

**Table 2. Adjusted means of twenty germplasm/varieties, range and least significant differences for 13 characters in wheat**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.  N. | | Genotypes | 1000  Seed Weight (g) | Seed Length (mm) | | Seed Width (mm) | | | Shoot Length (cm) | Root Length (cm) | | Seedlin g Length (cm) | | | Speed of germi nation | Seedlin g Dry Weight (mg) | | | First Count (No.) | Final Count (No.) | | | Germina tion Percenta ge (%) | | Vigour Index -I | Vigour Index –  II | |
| 1 | | JK-7254 | 35.83 | 5.86 | | 2.78 | | | 5.60 | 11.70 | | 17.50 | | | 20.42 | 123.00 | | | 83.00 | 88.00 | | | 88.37 | | 1540.0 | 10824 | |
| 2 | | JK-5501 | 38.56 | 5.87 | | 2.78 | | | 9.50 | 14.60 | | 24.30 | | | 19.23 | 129.00 | | | 76.00 | 84.00 | | | 89.42 | | 2041.2 | 10836 | |
| 3 | | JK-PITAMBAR | 42.89 | 5.76 | | 2.69 | | | 9.40 | 13.80 | | 23.40 | | | 18.67 | 132.00 | | | 86.00 | 89.00 | | | 89.68 | | 2082.6 | 11748 | |
| 4 | | LOKWAN | 39.59 | 6.25 | | 3.95 | | | 8.50 | 13.60 | | 22.30 | | | 17.85 | 160.00 | | | 80.00 | 86.00 | | | 86.49 | | 1917.8 | 13760 | |
| 5 | | RAJ-4037 | 38.25 | 6.69 | | 3.84 | | | 8.40 | 14.70 | | 23.40 | | | 17.58 | 147.00 | | | 81.00 | 85.00 | | | 85.31 | | 1989.0 | 12495 | |
| 6 | | ATW RAJ- 2052 | 37.57 | 5.62 | | 2.75 | | | 10.50 | 14.90 | | 25.60 | | | 19.79 | 138.00 | | | 85.00 | 89.00 | | | 89.18 | | 2278.4 | 12282 | |
| 7 | | BIO SEED- 3001 | 39.15 | 5.93 | | 2.85 | | | 10.00 | 13.30 | | 23.50 | | | 20.21 | 142.00 | | | 80.00 | 87.00 | | | 87.15 | | 2044.5 | 12354 | |
| 8 | | RAJ-4238 | 40.54 | 5.78 | | 3.17 | | | 8.20 | 16.50 | | 25.00 | | | 21.53 | 150.00 | | | 81.00 | 83.00 | | | 86.27 | | 2075.0 | 12450 | |
| 9 | | RAJ-4220 | 43.67 | 6.26 | | 3.21 | | | 8.00 | 14.50 | | 22.80 | | | 21.64 | 161.00 | | | 84.00 | 94.00 | | | 94.86 | | 2143.2 | 12134 | |
| 10 | | RAJ-3077 | 42.16 | 6.18 | | 2.83 | | | 9.00 | 14.50 | | 23.80 | | | 22.32 | 137.00 | | | 83.00 | 92.00 | | | 92.78 | | 2189.6 | 12604 | |
| 11 | | HD-2967 | 36.26 | 5.78 | | 4.15 | | | 7.50 | 15.70 | | 23.50 | | | 17.93 | 146.00 | | | 82.00 | 83.00 | | | 85.95 | | 1950.5 | 12118 | |
| 12 | | PBW-343 | 42.11 | 6.05 | | 3.86 | | | 7.60 | 15.00 | | 22.90 | | | 18.07 | 153.00 | | | 80.00 | 86.00 | | | 86.29 | | 1960.8 | 13158 | |
| 13 | | PBW-550 | 40.15 | 7.16 | | 2.95 | | | 9.40 | 13.50 | | 23.20 | | | 18.93 | 156.00 | | | 80.00 | 82.00 | | | 87.14 | | 1902.4 | 12792 | |
| 14 | | PBW-502 | 43.16 | 6.23 | | 2.84 | | | 10.10 | 13.30 | | 23.60 | | | 20.21 | 158.00 | | | 77.00 | 91.00 | | | 91.23 | | 2147.6 | 14378 | |
| 15 | | HD-3086 | 40.25 | 6.19 | | 3.85 | | | 10.00 | 11.50 | | 21.70 | | | 17.46 | 145.00 | | | 74.00 | 86.00 | | | 86.52 | | 1866.2 | 12470 | |
| 16 | | WH-1402 | 28.52 | 5.87 | | 3.98 | | | 11.70 | 14.50 | | 26.40 | | | 19.35 | 134.00 | | | 83.00 | 89.00 | | | 89.63 | | 2349.6 | 11926 | |
| 17 | | PB-826 | 44.85 | 6.21 | | 3.83 | | | 9.50 | 11.10 | | 20.80 | | | 18.57 | 136.00 | | | 81.00 | 86.00 | | | 86.79 | | 1788.8 | 11696 | |
| 18 | | HI-1621 | 38.32 | 6.85 | | 3.76 | | | 10.50 | 13.80 | | 24.50 | | | 17.34 | 145.00 | | | 82.00 | 85.00 | | | 85.82 | | 2082.5 | 12325 | |
| 19 | | HI-8751 | 44.29 | 7.23 | | 4.18 | | | 12.10 | 15.60 | | 27.90 | | | 20.52 | 149.00 | | | 85.00 | 93.00 | | | 93.67 | | 2294.7 | 13857 | |
| 20 | | HI-1628 | 43.18 | 6.15 | | 2.75 | | | 10.40 | 17.00 | | 27.60 | | | 19.48 | 140.00 | | | 76.00 | 89.00 | | | 89.39 | | 2263.2 | 11480 | |
|  | **Mean** | | 39.95 | | 6.36 | | 3.43 | 9.72 | | | 13.93 | | 23.87 | 19.59 | | | 145.82 | 80.91 | | | 87.85 | 88.82 | | 2106.44 | | | 12631.  55 |
|  | **Min.** | | 28.52 | | 5.62 | | 2.69 | 5.60 | | | 11.10 | | 17.50 | 17.34 | | | 123.00 | 74.00 | | | 82.00 | 85.31 | | 1540.00 | | | 10824.  00 |
|  | **Max.** | | 44.85 | | 7.23 | | 4.18 | 12.10 | | | 17.00 | | 27.90 | 22.32 | | | 161.00 | 86.00 | | | 93.00 | 94.86 | | 2349.60 | | | 14378.  00 |
|  | **SE(d)** | | 0.70 | | 0.13 | | 0.06 | 0.20 | | | 0.23 | | 0.37 | 0.34 | | | 2.60 | 1.43 | | | 1.57 | 1.43 | | 34.99 | | | 239.47 |
|  | **C.D. at 5%** | | 1.41 | | 0.26 | | 0.12 | 0.39 | | | 0.47 | | 0.74 | 0.69 | | | 5.20 | 2.86 | | | 3.14 | 2.85 | | 70.01 | | | 479.21 |
|  | **C.V. (%)** | | 2.16 | | 2.52 | | 2.16 | 2.46 | | | 2.05 | | 1.90 | 2.14 | | | 2.18 | 2.17 | | | 2.19 | 1.97 | | 2.03 | | | 2.32 |

**Table 3: Estimates of range, grand mean, phenotypic (PCV) and genotypic (GCV) coefficient of variation, heritability in broad sense [h2(bs)%] and genetic advance in per cent of mean (**Ga **%) for thirteen characters in wheat varieties**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Characters** | **Range (Min. – Max.)** | **Mean (**x**)** | **PCV (%)** | **GCV (%)** | **Heritability[h2**  **(bs)%]** | **Genetic advance in per cent of 5% mean (Ga%)** |
| 1000 Seed Weight (g) | 28.52-44.85 | 39.95 | 8.88 | 8.62 | 94.11 | 17.22 |
| Seed Length (mm) | 5.62-7.25 | 6.36 | 8.74 | 8.37 | 91.71 | 16.51 |
| Seed Width (mm) | 2.69-4.18 | 3.43 | 15.35 | 15.19 | 98.02 | 30.99 |
| Shoot Length (cm) | 5.60-12.70 | 9.72 | 15.96 | 15.77 | 97.62 | 32.10 |
| Root Length (cm) | 10.00-17.00 | 13.93 | 12.72 | 12.56 | 97.41 | 25.53 |
| Seedling Length (cm) | 17.50-29.30 | 23.87 | 11.46 | 11.30 | 97.25 | 22.97 |
| Speed of germination | 17.34-22.32 | 19.59 | 6.97 | 6.63 | 90.55 | 13.00 |
| Seedling Dry Weight (mg) | 123.0-163.0 | 145.2 | 6.94 | 6.59 | 90.12 | 12.89 |
| First Count | 72.00-88.00 | 80.91 | 4.73 | 4.20 | 79.02 | 7.70 |
| Final Count | 82.00-94.00 | 87.85 | 3.92 | 3.25 | 68.75 | 5.55 |
| Germination Percentage | 85.31-94.86 | 88.82 | 3.36 | 2.72 | 65.71 | 4.54 |
| Vigour Index -I | 1540.0-3637 | 2106.4 | 17.36 | 17.24 | 98.63 | 35.27 |
| Vigour Index -II | 10824-14507 | 12631 | 7.47 | 7.10 | 90.34 | 13.90 |

# **Conclusion**

The study demonstrated significant variability among wheat genotypes for seed quality parameters. Traits like shoot length, seed width, seedling dry weight, and vigour index-I showed high heritability and genetic advance, suggesting their suitability for selection. These findings provide a foundation for improving seed quality in wheat and support the development of robust, high-yielding varieties tailored to diverse agro-climatic zones.

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