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Seed Vigour Index as a Predictor of Growth Performance in Traditional and High-Yielding Rice (*Oryza sativa* L.) Varieties

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ABSTRACT: Seed vigour is an important determinant of crop establishment and subsequent field performance. The present study evaluated the relationship between seed vigour and growth performance of six rice (*Oryza sativa* L.) varieties, comprising three traditional and three high-yielding cultivars, during the Kharif 2022 season. Laboratory experiments assessed seed germination and seed vigour index (SVI) at 5 and 14 days after sowing, while field observations were recorded at 30, 60, and 90 days after transplanting (DAT) and at harvest under organically managed soil conditions. Significant varietal differences were observed in germination and seed vigour. The traditional variety Nua Chinikamini (V_4) exhibited the highest germination (96%), whereas the high-yielding variety Maudamani (V_1) recorded the highest seed vigour index at both 5 and 14 days, with values of 108.5 and 509.7, respectively. Seed vigour index at 5 days showed a strong positive correlation with total tillers per hill at harvest (r = 0.981, $p < 0.01$), while the correlation at 14 days was also significant but comparatively lower (r = 0.834, $p < 0.05$). Plant height exhibited a moderate positive correlation with seed vigour index at both observation stages. The findings demonstrate that seed vigour index, particularly at the early seedling stage, is a reliable predictor of subsequent field growth, especially tillering ability, and may serve as a useful tool for evaluating seed quality and predicting crop performance in rice.

Keywords: Correlation, Field performance, High Yield, Rice, Seed vigour, Tillers, Traditional

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population, particularly in Asia, Africa, and Latin America [1], and plays a major role in food security. The ever-increasing food demand requires constant crop improvement to feed the expected world population of 8.5 billion by 2030 [2]. Understanding the basic relationships between different crop characteristics is important for improving crop performance. Such knowledge can be useful for increasing breeding efficiency through the early identification of desirable traits and reduction of population size during selection [3].

Yield is primarily influenced by seed quality, which is characterized by seed vigour. This has a significant effect on yield [4]. The term seed vigour indicates the degree of aliveness of the seed, or the effect of seed quality on crop emergence and establishment. It shows a wide range of physiological and biochemical processes that define how quickly and uniformly seeds can germinate in a given set of environmental conditions. The efficiency of crop yield and resource utilization relies on the ability of crops to establish themselves in the field, and the vigour of seeds determines the rate and homogeneity of crop establishment [5]. Seed size and weight are also important characteristics associated with seedling vigour and overall seed quality. This established a uniform crop stand, ultimately leading to higher productivity ensured by high seed vigour [6]. Genotypic differences in the speed of germination under favorable conditions can significantly impact the time it takes for seedlings to emerge in field conditions. This has a substantial effect on early growth and grain yield, particularly in rainfed lowland ecosystems [7]. Rice seed vigour is reflected in the early parameters of seedling growth [8]. According to [9] reported a positive correlation between seed vigour and tillering capacity, leading to high-quality seeds with higher vigour. This resulted in better yield performance. Contemporary rice cultivars perform better than regional cultivars in terms of growth, yield potential, and field adaptability [10].

Seed vigour is also an important factor in breeding programs and crop management practices for uniform field performance. Pre-sowing evaluation of seed quality is important for predicting field performance and assisting breeders and farmers in selecting suitable varieties and management practices for them. The yield of local cultivars is very low and is often affected by biotic and abiotic stresses. Therefore, it is not sufficient to fulfil farmers demands and expectations [11]. Seed vigour tests can help identify seed lots with high emergence potential and storability [12]. It is helpful in the selection of improved seeds, both for crop establishment in the field and improved productivity. Such relationships can be established by conducting correlation studies between seed tests in the laboratory and their performance in the field. This will be useful for designing more effective screening procedures in breeding programs.

MATERIALS AND METHODS

A laboratory experiment was conducted at the Agricultural Research Station, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan Deemed University, Bhubaneswar, Odisha, during Kharif 2023. The experiment was designed using a randomized block design (RBD) with three replicates. The study involved six varieties of rice namely Maudamani (V_1), Kamal (V_2), Poornabhog (V_3), Nua chinikamini (V_4), Naveen (V_5) and Kalinga Dhan 1201 (V_6). These varieties were grouped as traditional (V_2, V_3, and V_4) and high-yielding (V_1, V_5, and V_6). Pure seeds of all six varieties were collected from the respective sites following a proper selection process. The selected seed lot was used for germination analysis using the top of paper method.

The mean weekly temperature during the growing season ranged from a minimum of 15.6°C to a maximum of 34.5°C, reflecting a gradual cooling period. Evaporation recorded from the USWB Class-A open pan evaporimeter showed a mean weekly peak of 45.72 mm/day. Similarly, the relative humidity remained high during the forenoon (exceeding 90%), whereas the afternoon showed greater fluctuations. The bright sunshine hours (BSH) increased significantly toward the end of the season, peaking at 8.0 h per day (Week 50). The study suggested a strong correlation between the withdrawal of precipitation and a transition toward increased solar radiation and enhanced atmospheric stability.

Seed vigour was studied using physical seed properties such as dry single grain weight (g), embedded weight(g), seed moisture content (%), seed length (cm), and seed

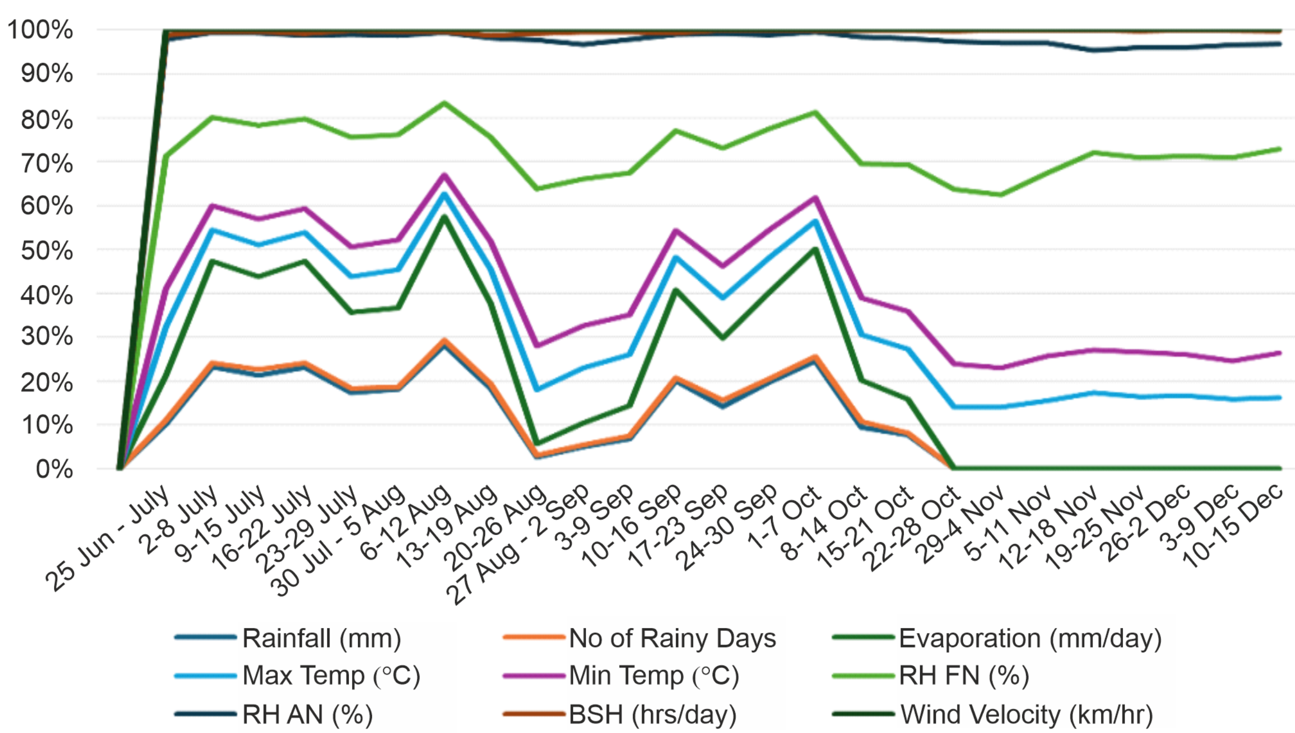

Figure 1. Weekly mean meteorological data during the crop growing period

breadth (cm). Germination tests were performed according to ISTA (International Seed Testing Association) standards, where the seeds were placed on wet filter papers in Petri dishes and incubated under controlled conditions at 25±2ºC with 12-hour photoperiod. The percentage germination was recorded following the recommended time using the formula derived by [14]. Observations were taken at 5 days (SVI 5D) and 14 days (SVI 14D) on randomly selected 10 normal seedlings from each replication to measure root and shoot length.

In the field experiment, the seeds were planted in wet nursery beds, followed by transplanting 2 to 3 seedlings of 21 days old in the main field with a spacing of 20 cm × 15 cm. Field performance was evaluated based on characteristics such as total tillers per hill (TT/hill) and plant height (PH), which were measured at 30, 60, and 90 days after transplanting (DAT) and at harvest. Plant height was measured from the ground level to the apex of the tallest tiller, and the total number of tillers per hill was counted manually at every growth stage from 10 marked hills.

Data analysis was performed using Microsoft Excel. Analysis of variance (ANOVA) was used to evaluate the significance of the differences among varieties. Correlation analysis with different parameters was performed using the Pearson correlation coefficient. The values of critical difference (CD) were computed at 5% level of probability ($p < 0.05$) to determine whether any relationships exist between field performance parameters and laboratory studies on seed vigour indices.

RESULTS AND DISCUSSION

Seed Characteristics

The data obtained from this study indicate that seed vigour traits are positively correlated with the field performance of rice. The assessment of physical seed traits indicated a large degree of variability among the six rice varieties studied (Table 1). Differences in all measured parameters were indicative of genetic diversity in the sampled germplasm. Variety Poornabhog (V_3) had the highest seed length of 0.915 cm and the lowest (0.538cm) was noted in variety Nua chinikamini (V_4), Variety Kalinga Dhan 1201 (V_6) had the widest seed of 0.335 cm while variety Poornabhog (V_3) had the lowest seed breadth (0.220cm). The percent germination difference between varieties varied between 48 percent in Kalinga Dhan 1201 to 96 percent in Nua chinikamini, highlighting the importance of seed quality assessment in rice production systems. These results are consistent with the existing principles of seed science recorded by [14]. The interpretation of the seed weight parameters indicated that both Maudamani (V_1) and Kalinga Dhan 1201 (V_6) had the highest values in terms of dry single grain weights (0.023 g each), and Nua chinikamini (V_4) had the lowest value (0.013 g).

The embedded weight also showed a similar trend, with the majority of the varieties grouped at 0.028-0.031 g, with Kamal (V_2) having the significantly lowest weight (0.020 g). Similarly, the moisture content of the seed varied from 19% to 45%, where Poornabhog (V_3) had the highest moisture content of 45.2% and Kamala (V_2) had the lowest (19.72 %). [6] has reported that heavy grain produces more vigorous seedlings. By integrating the germination rate and seedling growth characteristics, the seed vigour index provides a more complete evaluation of seed quality that better predicts the potential field performance. It has been observed that vigour testing is more predictive than conventional germination tests, as shown in NERICA rice genotypes [3]. A considerable length and breadth ratio was observed, ranging from 1.82 in Kalinga Dhana 1201 (V_6) to 4.16 in Poornabhog (V_3). The higher length and breadth ratio in Poornabhog represents a slender grain, whereas the lower ratio of

Table 1. Seed morphological characters of different rice varieties

Variety code	Variety name	Dry single grain wt. (g)	Embedded wt.(g)	Moisture content (%)	Seed length (cm)	Seed breadth (cm)
V_1	Maudamani	0.023	0.030	30.557	0.700	0.318
V_2	Kamal	0.017	0.020	19.703	0.645	0.230
V_3	Poornabhog	0.020	0.029	45.213	0.915	0.220
V_4	Nua chinikamini	0.013	0.028	35.520	0.538	0.223
V_5	Naveen	0.021	0.031	44.710	0.730	0.315
V_6	Kalinga dhan 1201	0.023	0.031	32.410	0.610	0.335
CD (P= 0.05)	0.003	0.004	0.543	0.032	0.021	-

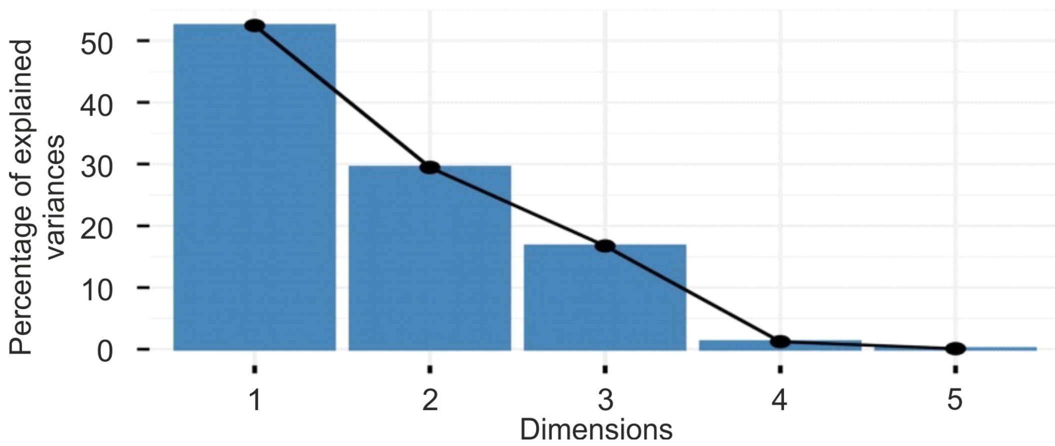

Figure 2. Scree plot indicating the variation explained by different principal components

variety Kalinga Dhana 1201 indicates a bolder grain. The length-to-breadth (L/B) ratio reflects the variation in seed shape among varieties, ranging from slender to bold grains. Varieties with a higher L/B ratio (long and slender seeds) are associated with early seedling growth. Longer and slender seeds tend to produce higher seedling dry weight and improved biomass accumulation during early growth stages [6]. The variations in moisture content, which varied from 19.7% in Kamal (V2) to 45.2% in Poornabhog (V3), were responsible for the observed variations in the embedded ratio. Higher moisture content was observed in certain varieties (e.g., Poornabhog), enhancing imbibition and enzymatic activity by rapid germination and early seedling growth. However, excessive moisture negatively affects the storability and longevity of seeds. Physiological traits of the seed, including moisture percentage, starch mobilization, and enzyme activity, significantly influence seed vigour and germination efficiency [13].

Principal component analysis (PCA) showed variability among the rice varieties. The first principal component (PC1) explained 52.46% of the total variance, whereas the second principal component (PC2) explained 29.46%, together accounting for 81.92% of the total variation. The third principal component (PC3) showed an additional 16.75%, resulting in a cumulative variance of 98.67%, whereas PC4 and PC5 showed negligible variation. The scree plot showed a clear elbow after PC2, indicating that most of the variation among rice varieties could be explained by the first two principal components.

The PCA biplot showed a clear relationship between traits and rice varieties, contributing to varietal differentiation. Among these varieties, Poornabhog, being highly positive on PC2, showed higher expression of traits such as grain length and moisture content compared to other varieties, indicating their important role in separating genotypes along the axis. Maudamani and Kalinga Dhan 1201 were linked to dry weight and breadth, indicating their dominance in these characteristics. Kamal and Nua chinikamini, located on the positive side of PC1 and away from most trait vectors which shows distinct trait combination. However, Naveen, positioned near the origin, showed moderate expression of all traits.

The PCA biplot differentiated the traditional and high-yielding rice varieties. Traditional varieties (V_2, V_3, and V_4) were positioned away from the origin, indicating greater variability and were linked with traits such as grain length and moisture content. High-yielding varieties (V_1, V_5, and V_6) were located closer to the origin or negative axis, which showed moderate variability in traits, particularly linked with dry weight and grain breadth.

Germination Performance and Seed Vigour Assessment

Significant variations in seed viability between varieties were observed, ranging from 48 to 96 percent (Table 2). The highest germination capacity was 96.0% in Nua chinikamini (V_4), followed by Maudamani (V_1) with 92.0%. In contrast, Kalinga Dhan 1201 (V_6) produced the least germination (48.0%). According to [14], the germination percentage was used as a basic measure of viability in a given seed lot. However, the present findings show that a single parameter does not provide a complete picture of seed potential, which is evident from the observations of Nua chinikamini and Maudamani. The former had the highest germination rate, while the latter had better vigour indices, especially on the 14th day of measurement. This

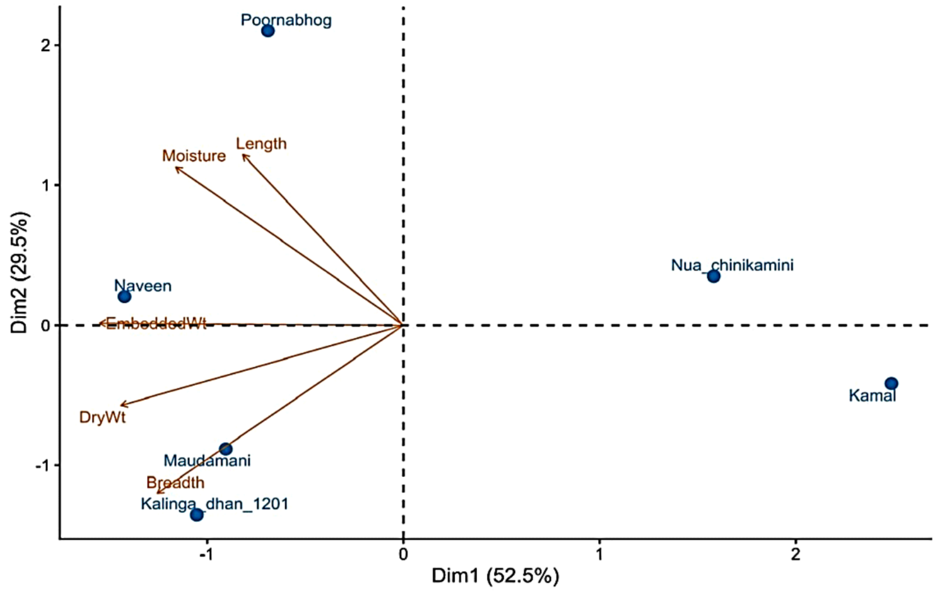

Figure 3. Principal component analysis (PCA) biplot of rice varieties based on seed traits

Table 2. Germination percentage and Seed Vigour Index of rice varieties

Variety code	Germination (%) 5D	Germination (%) 14D	SVI 5D	SVI 14D
V_1	78.00	92.00	167.8	511.55
V_2	54.00	64.00	97.88	356.45
V_3	48.00	58.00	112.48	360.23
V_4	82.00	96.00	116.53	304.3
V_5	58.00	74.00	170.9	289.26
V_6	36.00	48.00	57.65	193
CD (0.05)			3.87	2.86

difference might be due to the difference between viability and the potential for strong seedling growth, as reported by [15].

The seed vigour index is more informative than the percentage of germination. Variety Maudamani (V_1) proved to be the most active variety with the maximum values at both the dates of observation, SVI 5D (167.8) and SVI 14D (511.55). This result further shows that although Nua chinikamini (V_4) has slightly better germination percentages, Maudamani (V_1) had more vigourous seedlings with better early developmental traits. The trend in time change (5 days to 14 days) was congruent with Kalinga Dhan 1201 (V_6), recording the lowest values at the time of observation. The Poornabhog variety (V_3) had the highest seed length (0.915) and breath (0.220).

Correlation analysis between seed vigour and field level performance

Correlation analysis indicated a dynamic relationship between seed vigour and field-level performance. The early stages of growth (30 and 60 DAT) were weakly or negatively correlated with measures of seed vigour in terms of total tillers per hill, indicating that the early stages of field establishment are more driven by transplanting shock than seed quality. However, this trend changed with the progress of the growing season. By the 90th day of transplantation, the parameters showed positive correlations with the maximum degree at the time of harvest. The relationship between the SVI 5D and total tillers per hill at harvest was 0.981 ($p < 0.01$). Similarly, SVI 14D recorded a high positive correlation of 0.834 ($p < 0.05$) with the final tiller counts. These results indicate that seed vigour is more likely to manifest as plants grow and show their complete genetic potential. The highest correlation coefficient between the 5-day seed vigour index and total tillers per hill at harvest ($r = 0.981$) can have significant implications for rice breeding and production strategies. Early seedling vigour traits can also be useful predictors of the ultimate tillering potential and management aspects. The biological justification for this relationship lies in the fact that the early determination of meristematic activity and patterns of resource allocation determines the later tiller initiation and growth, as evidenced by the genome-wide association studies

(GWAS) by [16], which indicated that certain quantitative trait loci are correlated with early vigour traits that relate to plant performance.

Plant height appeared to be more consistent and showed a positive correlation with seed vigour indices at all stages of growth, although the correlations were moderate. SVI 5D showed that correlation value increased from 30 DAT (r = 0.415) to 90 DAT (r = 0.675) and then declined at harvest (r = 0.619). The pattern was similar in the SVI 14D measurements, and the highest correlation was recorded at 90 DAT (r = 0.786). These relationships suggest that vigourous seedlings are likely to produce taller plants during the entire growing season, although the effect is not as conspicuous as that of tiller counts.

High correlations between seed vigour parameters and field performance have been reported in other rice varieties. According to [3], standard germination, seedling vigour indices I and II, speed of germination index, and energy of germination had significant and positive correlations with traits of seedling emergence, seedling establishment, plant height, seedling dry weight, and seed yield per plant among rice genotypes. These results were consistent across different genetic backgrounds, reinforcing the validity of seed vigour as a universal predictor of field performance in rice.

The intermediate correlations found between seed vigour indices and plant height during the growing season show that vigorous seeds always yield stronger plants with better growth. Nevertheless, the lower correlations with tillering indicate that plant height might be more likely to be determined genetically and less liable to changes in the initial seed quality. This pattern of responses is useful in providing an idea of the relative plasticity of different morphological traits in response to different changes in seed vigour, as observed by [17] who showed that different traits respond to seed vigour differently and increase by marker-assisted selection in different ways. The negative correlation between seed quality and early growth traits shows interactions among environmental conditions, transplanting stress, and field establishment challenges, which affect seed vigour in the short term. As plants advance in their stages of growth and increase their tolerance to environmental stresses, seed vigour becomes more evident, a trend aligning with [18], who reported increasing vigour impact over time in direct-seeded rice.

The timing of vigour measurement is a key issue [19] showed that radicle emergence testing 56 h after germination offers the best predictive value of field emergence across rice seed vigour levels. Its practical implications for rice production and improvement programs are also important because the high level of predictive correlation between early seed vigour and field performance means that breeding programs can increase their efficiency by using laboratory-based screening methods, as seen with marker-assisted pedigree selection strategies [17].

Table 3. Correlation between total tillers per hill and SVI 5D and 14D

Parameter	SVI 5D	SVI 14D
TT/hill 30DAT	-0.418	-0.160
TT/hill 60DAT	-0.169	0.349
TT/hill 90DAT	0.558	0.612
TT/hill at harvest	0.981**	0.834*

Table 4. Correlation between Plant Height and SVI 5D and 14D

Parameter	SVI 5D	SVI 14D
PH 30DAT	0.415	0.128
PH 60DAT	0.578	0.412
PH 90DAT	0.675	0.786
PH at harvest	0.619	0.599

CONCLUSIONS

The findings establish a relationship between seed vigour parameters and characteristics of rice varieties at the field level, which is useful in breeding and crop management schemes. The study revealed variations in rice varieties in terms of seed vigour and field performance traits. Positive correlations between seed vigour indices and total tillers per hill, especially at the harvest stage, were observed, where SVI 5D had the highest correlation (r = 0.981). Moderate positive correlations were observed between plant height and seed vigour indices at all growth stages. Early seedling vigour (SVI 5D) was a more accurate indicator of field performance than later measurements (SVI 14D) of tillering capacity. These results clearly suggest that seed vigour evaluation, especially the seed vigour index at 5 days, can be used as effective predictors of field performance in rice, with implications for breeding programs that aim to develop cost-effective early selection tools and farmers who need to make the right variety selections to maximize crop output. The evaluation of traditional varieties (V2, V3, and V4) and high-yielding varieties (V1, V5, and V6) showed differences in seed traits and performance. Traditional varieties exhibited greater variability in grain morphology and moisture content, reflecting their diverse genetic backgrounds. HYVs showed uniform seed characteristics and vigour expression, which were attributed to improved agronomic performance during varietal development. Further research can be conducted in different environments, other varieties, and yield-related parameters.

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