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# DEVELOPMENT OF A MULTI-TRAIT SELECTION INDEX FOR IMPROVING GRAIN YIELD, SEED VIGOUR AND FLOUR SHELF LIFE IN PEARL MILLET (*PENNISETUM GLAUCUM* L.)

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## SUMMARY

The present investigation was undertaken to develop an efficient multi-trait selection index for identifying superior pearl millet genotypes combining high grain yield, enhanced seed vigour and improved flour shelf life through reduced rancidity progression. Sixty diverse pearl millet genotypes were evaluated under field conditions for grain yield, vigour index-II, comprehensive acid value difference (CAV diff) and comprehensive peroxide value difference (CPV diff). Rancidity-related traits were measured as the change between initial and stored values (1st to 10th day), reflecting deterioration during storage. Standardization of traits was performed using Z-score transformation and rancidity-related traits were direction-adjusted during index construction so that lower rancidity progression contributed positively towards overall index value. A weighted selection index was developed assigning greater weight to grain yield followed by vigour index-II, while equal weights were assigned to rancidity-related traits. Selection index values ranged from -1.42 to 2.02, indicating substantial variability among genotypes. HMS 57B recorded the highest index value followed by ICMB 92777 and HMS 47B. Spearman's rank correlation between grain yield and selection index was high (rs = 0.80), indicating strong association while also revealing meaningful genotype re-ranking. Genotypes with lower CAV and CPV differences exhibited improved storage stability, confirming that reduced biochemical changes over time are reliable indicators of extended flour shelf life. The study demonstrates the effectiveness of multi-trait selection in identifying pearl millet genotypes with balanced performance for productivity, seed quality and post-harvest storage stability.

**Key words:** Pearl millet, selection index, grain yield, seed vigour, rancidity, shelf life

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is an important cereal crop cultivated extensively in arid and semi-arid regions because of its remarkable adaptability to drought, high temperature and low soil fertility conditions. The crop serves as a staple food for millions of people in marginal environments and plays an important role in sustaining food and nutritional security under changing climatic conditions (Yadav *et al.*, 2012). In addition to its resilience, pearl millet is nutritionally superior to several major cereals due to its high content of protein, dietary fibre, iron and zinc. Because of its nutritional value and climate resilience, pearl millet has gained importance in sustainable agriculture and nutritional security programmes (Govindaraj & Pujar, 2024). Despite these advantages, the wider utilization and commercialization of pearl millet-based products remain limited because of poor flour shelf life caused by rapid rancidity development during storage.

Rancidity in pearl millet flour primarily results from lipid hydrolysis and oxidation, leading to the accumulation of free fatty acids and peroxide compounds responsible for undesirable flavour and odour (Bhargavi *et al.*, 2024; Goswami *et al.*, 2020). The relatively high proportion of unsaturated fatty acids in pearl millet accelerates oxidative deterioration under ambient storage conditions. Earlier studies have generally emphasized absolute acid and peroxide values; however, the rate of increase in these parameters during storage provides a more meaningful assessment of flour stability. Genotypes exhibiting lower increases in comprehensive acid value (CAV) and comprehensive peroxide value (CPV) during storage tend to possess improved flour shelf life and delayed rancidity development. Therefore, evaluating the differences in CAV and CPV between initial and stored samples may provide a practical indicator of rancidity progression and storage stability in pearl millet flour.

In plant breeding programmes, simultaneous improvement of multiple traits is essential for developing genotypes with balanced agronomic and quality performance. Grain yield is the primary breeding objective in pearl millet; however, it is a complex quantitative trait strongly influenced by environmental conditions (Falconer and Mackay, 1996). Selection based solely on grain yield may overlook important traits related to seed quality and post-harvest stability. Seed vigour is an important component of seed quality and contributes to rapid germination, uniform crop establishment and improved field performance (Abdul-Baki and Anderson, 1973). Similarly, post-harvest quality traits such as flour shelf life are important for consumer acceptance and marketability of pearl millet products.

Selection index methods combine information from multiple traits into a single selection criterion for identifying superior genotypes (Smith, 1936; Hazel, 1943). These approaches are useful when several important traits need to be improved simultaneously. Recent studies in pearl millet have demonstrated the usefulness of multi-trait selection approaches for identifying superior and stable genotypes under different breeding objectives (Kalagare *et al*., 2021; Jha *et al*., 2022; Khandelwal *et al*., 2024; Singhal *et al*., 2024). However, most studies have mainly focused on yield stability and stress tolerance traits, whereas limited attention has been given to integrating post-harvest quality traits associated with flour rancidity into selection strategies. Considering the importance of shelf life in the utilization and commercialization of pearl millet products, incorporation of storage stability traits along with grain yield and seed vigour may improve the efficiency of breeding programmes aimed at developing superior and consumer-acceptable cultivars. Therefore, the present investigation was undertaken to develop and validate a multi-trait selection index integrating grain yield, seed vigour and rancidity-related traits for identification of pearl millet genotypes with balanced performance for productivity and flour shelf life.

## MATERIALS AND METHODS

The present investigation was conducted during the kharif season of 2021 at the research area of the Bajra Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, India (29°102 N, 75°462 E; 215.52 m above mean sea level). The experimental material comprised sixty genetically diverse pearl millet [*Pennisetum glaucum* (L.) R. Br.] genotypes, including maintainer lines and hybrids. The genotypes were evaluated in a randomized block design with two replications under recommended agronomic practices. Each genotype was grown in a single-row plot of 4 m length with 45 cm inter-row and 10-12 cm intra-row spacing.

Observations were recorded for grain yield per plant (g), vigour index-II (VI-II), comprehensive acid value difference (CAV diff) and comprehensive peroxide value difference (CPV diff). Grain yield per plant (GY) was recorded at physiological maturity from randomly selected competitive plants. Vigour index-II was computed as the product of germination percentage and seedling dry weight following the method of Abdul-Baki and Anderson (1973).

Rancidity-related traits were estimated using standard AOAC (1990) procedures. Comprehensive acid value (CAV) and peroxide value (CPV) were calculated using the following equations:

$$CAV = \frac{40 \times A \times N}{W}$$

$$CPV = \frac{(A - B) \times N \times 1000}{W}$$

where *A* represents the titre value of the sample, *B* the blank titre value, *N* the normality of the titrant and *W* the sample weight (g). The differences in CAV and CPV were calculated as the change between initial and stored values under ambient storage conditions (1st to 10th day). Lower values of these parameters indicated slower rancidity progression and better flour storage stability.

Mean values across replications were used for statistical analysis. Data for all traits were standardized using Z-score transformation to minimize scale-related bias among variables differing in magnitude and units of measurement.

$$Z = \frac{X - X}{\sigma}$$

where X is the observed value, X is the trait mean and σ is the standard deviation.

Rancidity-related traits (CAV diff and CPV diff) were treated as negatively associated traits during index construction because lower values are desirable for improved storage stability. A weighted selection index was developed by assigning weights of 0.40 to grain yield, 0.30 to vigour index-II and 0.15 each to CAV diff and CPV diff. Greater weight was assigned to grain yield considering its primary importance in pearl millet improvement programmes, while vigour and rancidity-related traits were included to ensure balanced selection for seed quality and flour storage stability.

The selection index was computed as:

$$I=0.4Z(GY)+0.3Z(VI\text{-}II)-0.15Z(CAV\ diff)-0.15Z(CPV\ diff)$$

Genotypes were ranked based on selection index values, with higher values indicating superior overall performance. Spearman's rank correlation analysis was performed to assess the relationship between grain yield ranking and selection index ranking. Linear regression analysis was also carried out to study the association between grain yield and selection index values. All statistical analyses and graphical visualizations were performed using Microsoft Excel following standard statistical procedures.

## RESULTS AND DISCUSSION

The selection index values among the sixty pearl millet genotypes ranged from -1.42 to 2.02, indicating substantial variability for the combined expression of grain yield, seed vigour and rancidity-related traits. This wide range reflects the presence of considerable genetic diversity among the evaluated genotypes, providing strong scope for effective multi-trait selection. The top ten genotypes identified based on selection index values (Table 1) exhibited desirable combinations of high grain yield, enhanced seed vigour and reduced rancidity. These genotypes represent promising candidates for direct selection and can serve as potential parental lines in breeding programmes aimed at simultaneous improvement of productivity and post-harvest quality. The superiority of these genotypes reflects the effectiveness of the selection index in integrating multiple traits with differing biological functions into a single selection criterion.

Based on the selection index, HMS 57B recorded the highest value (2.02), followed by ICMB 92777 (1.19) and HMS 47B (1.04), indicating their superior overall performance. Although ICMB 92777 exhibited the highest grain yield, it ranked second in the selection index due to comparatively higher rancidity values. In contrast, HMS 57B emerged as the top-ranking genotype, indicating that combined improvement of grain yield, seed vigour and reduced lipid degradation is achievable, reflecting favourable genetic control of both productivity and storage stability traits. This observation further confirms that selection based solely on grain yield may be inadequate for identifying superior genotypes, as it fails to account for traits related to seed vigour and storage stability.

TABLE 1
Top ten pearl millet genotypes based on selection index

| Rank | Genotype | Selection index |
|---|---|---|
| 1 | HMS 57B | 2.02 |
| 2 | ICMB 92777 | 1.19 |
| 3 | HMS 47B | 1.04 |
| 4 | HMS 30B | 0.97 |
| 5 | HMS 71B | 0.95 |
| 6 | HMS 64B | 0.83 |
| 7 | HMS 58B | 0.83 |
| 8 | HMS 38B | 0.81 |
| 9 | HMS 29B | 0.74 |
| 10 | HMS 36B | 0.73 |

A comparison between grain yield ranks and selection index ranks revealed noticeable re-ranking of genotypes, highlighting the differential contribution of individual traits in determining overall performance. This is supported by the high but imperfect Spearman's rank correlation ($r_s = 0.80$), indicating a strong association along with meaningful rank shifts. This partial association indicates that grain yield alone cannot fully explain overall genetic merit, thereby reinforcing the importance of multi-trait selection approaches for capturing comprehensive genotype performance. The deviation from unity ($r_s \neq 1$) suggests that reliance on grain yield alone may overlook genotypes with superior seed vigour and storage stability, thereby emphasizing the importance of multi-trait selection.

The relationship between grain yield and selection index exhibited a positive trend, with a coefficient of determination ($R^2 = 0.6737$), indicating that grain yield contributed substantially to the index. However, the moderate magnitude of $R^2$ suggests that a considerable proportion of variation in the selection index was governed by seed vigour and rancidity-related traits. This highlights the advantage of index-based selection in capturing overall genotype performance, particularly when component traits differ in their biological roles and directions of

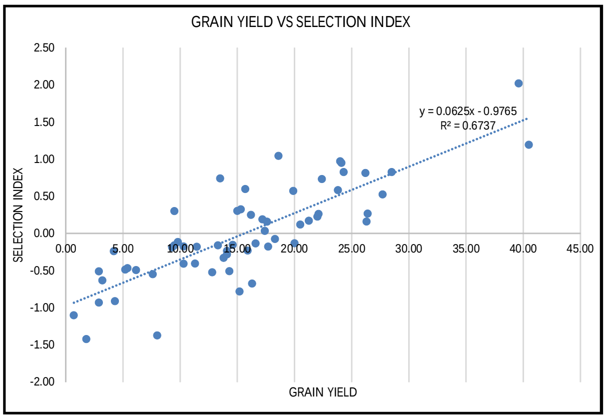


Fig. 1. Relationship between grain yield and selection index in pearl millet genotypes ($R^2$ = 0.6737).

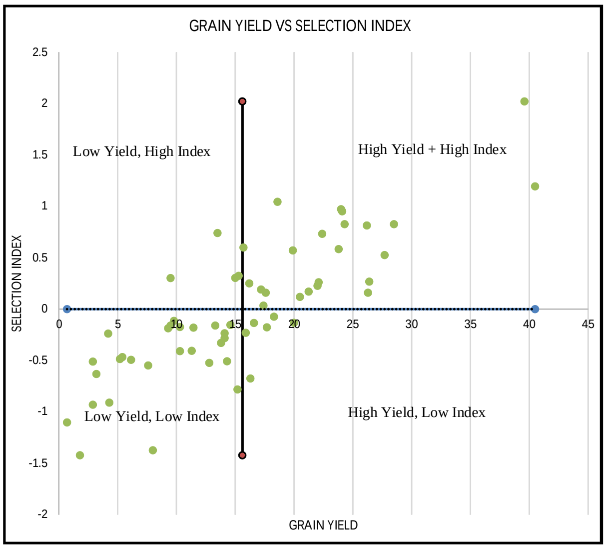


Fig. 2. Selection map of pearl millet genotypes based on grain yield and selection index illustrating classification into four performance categories.

desirability. To further interpret the distribution of genotypes, a quadrant-based classification was performed (Fig. 2).

Further classification of genotypes based on grain yield and selection index revealed four distinct categories. Genotypes grouped under the high yield-high index quadrant were identified as the most desirable, combining superior productivity with favourable quality traits. Genotypes with high yield but low index indicated poor performance for vigour or rancidity traits, whereas those with low yield but high index may serve as potential donors for improving quality attributes. This classification provides a practical framework for targeted selection and breeding strategies, enabling breeders to identify genotypes suited for specific improvement objectives such as yield enhancement or shelf-life stability.

The radar plot illustrated the comparative trait profiles of selected genotypes based on normalized values (Fig. 3). Superior genotypes exhibited balanced expression across all traits, characterized by high grain yield and vigour index-II along with lower CAV and CPV differences. In contrast, genotypes with imbalanced profiles showed either high yield coupled with poor storage stability or vice versa. This visualization further validates the effectiveness of the selection index in identifying genotypes with balanced expression of multiple traits.

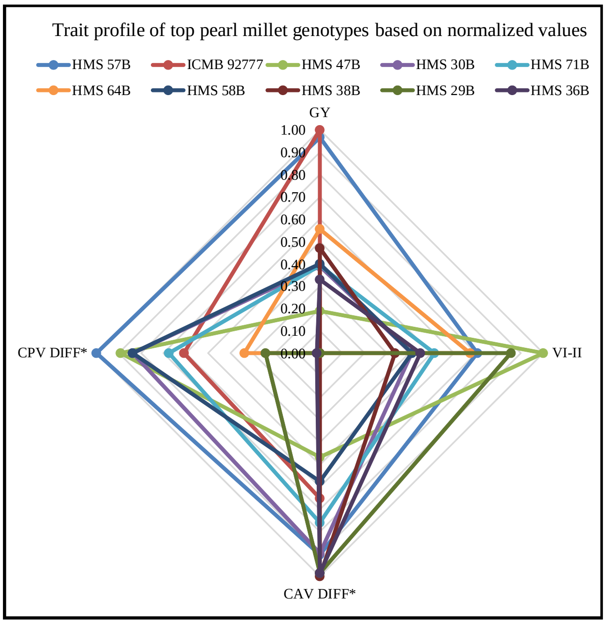


Fig. 3. Radar plot illustrating comparative trait profiles of selected pearl millet genotypes based on normalized and direction-adjusted values.

Rancidity-related traits, measured as the difference in comprehensive acid value (CAV) and peroxide value (CPV) between day 1 and day 10, provided a dynamic assessment of lipid degradation during storage. Lower differences in these parameters indicate reduced lipid hydrolysis and oxidation rates, thereby contributing to improved flour shelf life and delayed onset of rancidity. This suggests that genotypes exhibiting minimal biochemical changes over time possess enhanced storage stability, making them desirable for post-harvest quality improvement. These findings are consistent with earlier reports (Goswami *et al.*, 2020), highlighting the importance of incorporating dynamic biochemical traits in selection strategies.

Overall, the results demonstrate that the multi-trait selection index effectively integrates grain yield, seed vigour and rancidity-related traits into a single criterion, enabling identification of genotypes with balanced performance. The observed rank shifts and moderate association between grain yield and selection index further emphasize the limitations of single-trait selection and highlight the importance of incorporating post-harvest quality traits in breeding programmes. These findings are consistent with classical selection index theory (Smith, 1936; Hazel, 1943) and reinforce the utility of index-based approaches for improving complex quantitative traits in pearl millet breeding.

## CONCLUSION

The present investigation demonstrated that a multi-trait selection index is an effective and robust approach for identifying superior pearl millet genotypes with balanced performance for grain yield, seed vigour and flour shelf life. The observed variability in selection index values and the noticeable re-ranking of genotypes relative to grain yield alone highlight the limitations of single-trait selection. The high but imperfect association between grain yield and selection index (rs = 0.80) further emphasizes that reliance on yield alone may overlook genotypes with desirable quality attributes.

The integration of dynamic rancidity parameters, namely comprehensive acid value (CAV) and peroxide value (CPV) differences, provided a more realistic and biologically meaningful assessment of storage stability. Genotypes exhibiting lower changes in these parameters demonstrated reduced lipid degradation and improved shelf life, confirming the utility of incorporating post-harvest quality traits into selection strategies. The identification of superior genotypes such as HMS 57B, ICMB 92777 and HMS 47B indicates that simultaneous improvement of productivity, seed vigour and storage stability is achievable.

From a breeding perspective, the developed selection index offers a practical and efficient tool for multi-trait selection, enabling breeders to enhance both agronomic performance and post-harvest quality in pearl millet. The approach can be effectively utilized in varietal development programmes aimed at improving shelf life along with yield potential, thereby addressing key constraints in the large-scale adoption and commercialization of pearl millet.

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