Method for selection of superior lines with combined stay-green and stem reserve mobilisation traits in wheat under multi-environment stress conditions

Abstract

To meet the ever-increasing demand for food, there is a huge concern about the selection of superior genotypes with enhanced resilience to abiotic stress. However, choice/selection of suitable genotype/line is sensitive due to significant interaction of genotypes with environmental factors. Here, one method has been proposed to select superior genotype using combined approach of fourselection indexes such as, multi-trait genotype-ideotype distance index (MGIDI), factor analysis and genotype-ideotype distance (FAI-BLUP), Smith-Hazel index (SHI) and multi-trait stability index (MTSI) under multi-environment stress conditionsby using R programming. Twenty random recombinant inbred wheat lines among the 220 lines developed by crossing HD3086 and HI1500 has been taken for analysis. The selection intensity (SI) was 15% for all the indexes. The lines were tested for stay-green and stem reserve mobilisation traits under control, drought, heat and combined stress conditions.Result found that RIL-10 was common to these fourindexes and was considered to be superior among the lines, which can perform better under multi-environment stress conditions. Thus, we recommend that combined approach of several indexes can be used for robust selection of ideal genotypes in wheat and other crop as well.

Keywords-FAI-BLUP, MGIDI, MTSI, SH index, Selection, Wheat

Introduction

Statistical analysts, geneticists, and plant breeders, all havean enduring fascination with exploring and incorporating Genotype (G) and Genotype× Environment (E) to choose better genotypes for use in breeding trials (Yan *et al*., 2007). Several selection indexes have been used commonly for selection of genotypes namely, Smith-Hazel index, multi-trait stability index (MTSI) and factor analysis and genotype-ideotype distance (FAI-BLUP).However, on account of multicollinearity issues amongst various traits, it is crucial to select superior genotypes or parents for use in future breeding programmes (Olivoto and Nardino, 2021). Several innovative data analysis techniques like principal component analysis (PCA), clustering has been used to remove data analysis bottleneck (Arya *et al*., 2024).Currently, multi-trait stability index (MTSI and the multi-trait genotype–ideotype distance index (MGIDI) is used for genotype selection in multi-environment trials based on desired idiotypes free from weighting coefficients and multicollinearity issues (Olivoto *et al*., 2019; Olivoto & Nardino, 2021). However, use of single selection index may bias the selection of superior genotypes.

Considering above facts in mind, we hypothesized that combined use of various indexes for selection will be a robust method for selection of genotypes. Here, we proposed combined use of multi-trait genotype-ideotype distance index (MGIDI), factor analysis and genotype-ideotype distance (FAI-BLUP), Smith-Hazel index (SHI), multi-trait stability index (MTSI)for selection of superior genotypes using R programming.

Methods

Twenty recombinant inbred lines (RILs) have been taken for selection of superior genotypes. Here, random 20 lines out of 220 RILs have been taken for further analysis. The recombinant inbred lines had been developed by crossing two contrasting wheat genotypes namely, HD3086 and HI1500. The lines were tested for its stay-green (SG) and stem reserve mobilisation (SRM) traits during rabi season 2021-22 (Taria *et al*., 2023) under control, drought, heat and combined stress conditions.

Under normal sown condition, drought stress was imposed during anthesis stage by withholding irrigation after booting stage. Heat stress was imposed by one-month late sowing as compared to normal sown condition to expose terminal heat stress. Combined heat and drought stress (H+D) was imposed by one-month delayed sowing to normal sown condition along with withholding of irrigation after booting stage to impose drought stress. In all the stress conditions, stress was imposed from anthesis stage to physiological maturity. The populations were evaluated using an alpha lattice design with two replications. Each genotype (3 rows of 1 m each) was maintained with 22.5 cm distance between rows and 10 cm distance between plants. Under field conditions, proper agronomic measures were followed for uniform plant establishment. For stay-green traits, we recorded leaf senescence rate (LSR), soil plant analysis development (SPAD) value, 1000 grain weight (TGW). For stem reserve mobilisation, we recorded stem reserve mobilisation efficiency along with ear weight difference (EWD) as a proportion of mobilisation of stored carbon to grain under stress conditions.

Selection of superior high performance RILs

Selection of superior RILs across all the environments were accomplished by computing multi-trait genotype-ideotype distance index (MGIDI), factor analysis and genotype-ideotype distance (FAI-BLUP), Smith Hazel index (SHI) and multi-trait stability index (MTSI). Computation of multi-trait genotype-ideotype distance index (MGIDI) was based on ideotypes input (Olivoto & Nardino, 2021). MGIDI was calculated as follows-

$$\text{MGIDI} = \sqrt{\sum_{j=1}^{f}\left(F_{ij} - F_j\right)^2}$$

Where MGIDI is the multi-trait genotype-ideotype distance index, F_{ij} is the score of the i^{th}genotype in the j^{th} factor (i = 1, 2, ..., g; j = 1, 2, ..., f), being g and f are the number of genotypes and factors, respectively, and F_j is the j^{th} score of the ideotype. For the ideotype plan, all the traits were given higher for the selection of genotypes/lines.

For FAI-BLUP index, the desired ideotypes were defined by setting vector for minimum and maximum values of traits (Rocha *et al.*, 2018). Then, distance of each genotype from ideotype was calculated and converted into spatial probabilities as follows

$$P_{ij} = \frac{\frac{1}{d_{ij}}}{\sum_{i=1;j=1}^{i=n;j=m}\frac{1}{d_{ij}}}$$

Where P_{ij} is the probabilities of the ith genotype (i =1, 2…. n) to be similar to jth ideotypes (j = 1,2…m); d_{ij} is the genotype-ideotype distance from the ith genotype to the jth ideotype based on standardized mean Euclidean distance.

Smith Hazel (SH) index (Smith, 1936; Hazel, 1943) was calculated according to the formulae given below

$$b = \mathrm{P}^{-1}\mathrm{Gw}$$

Where P and G represent phenotypic and genetic variance-covariance matrices, respectively. b and w represent vectors of index coefficients and economic weightings, respectively.Selection intensity (SI) of 15% was used for selection of superior lines using MGIDI, FAI-BLUP and SH index.

Multi-trait stability index (MTSI) based on stability only was calculated by the method described by Olivoto *et al.*, 2019. For selection using all the selection indexes, Metan package in R programming has been used.

Results

Usingmulti-trait genotype-ideotype distance index, it was found that RIL-12, RIL-10 and RIL-9 has been found to be superior among the twenty lines (Fig.1). In-addition, same lines (RIL-12, RIL-10 and RIL-9) were found to be superior using FAI-BLUP (Fig.2). However, lines such as RIL-12, RIL-20 and RIL-10 were found to be superior among the lines using Smith-Hazel index (Fig.3). Based of multi-trait stability index (MTSI) based on stability only, RIL-17, RIL-8 and RIL-10 were found to be superior (Fig.4).

Using Venn diagram, it was found RIL-10 was common to these indexes (Fig.5). Hence, it was concluded that RIL-10 was superior and can perform better under adverse climatic conditions without any yield penalty.

Discussion

Selecting superior genotypes is complex due to the quantitative nature of important agronomic traits (Nogueira *et al.*, 2012). For this, breeders use selection indexes to select high performance and superior genotypes (Harikrishna *et al.*, 2016; Céron-Rojas & Crossa, 2018). MGIDI (Taria *et al.*, 2023; Debnath *et al.*, 2024), FAI-BLUP (Santana *et al.*, 2023; Das *et al.*, 2024) and SH index (Hannachi & Fellahi, 2023) has been used for genetic diversity study and selection of genotypes. In addition, multi-trait stability index (MTSI) has been by various workers based on multiple traits (Lima *et al.*, 2022; Padmaja *et al.*, 2022). Thus, selected line, RIL-10 was can be used as a donor for both SG and SRM traits in wheat. Moreover, these selection indexes can be used for selection of high-performance lines in any crop varieties for better yield.

Conclusion

Under the scenarios of global climate change, there is urgent need to develop crop varieties with capability to withstand multiple abiotic stress conditions. For development of superior genotypes, breeders need to transfer traits of interest from donor parents to elite cultivars. However, G×E interaction impose severe limitation on selection of high-performance lines. We have used several selection indexes under multi-environment condition to select superior lines. From our study, it was concluded that, combined approach of MGIDI, FAI-BLUP, SHI and MTSI can be used as robust method for selection of superior high-performance lines under multi-environment conditions.

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Figures legend

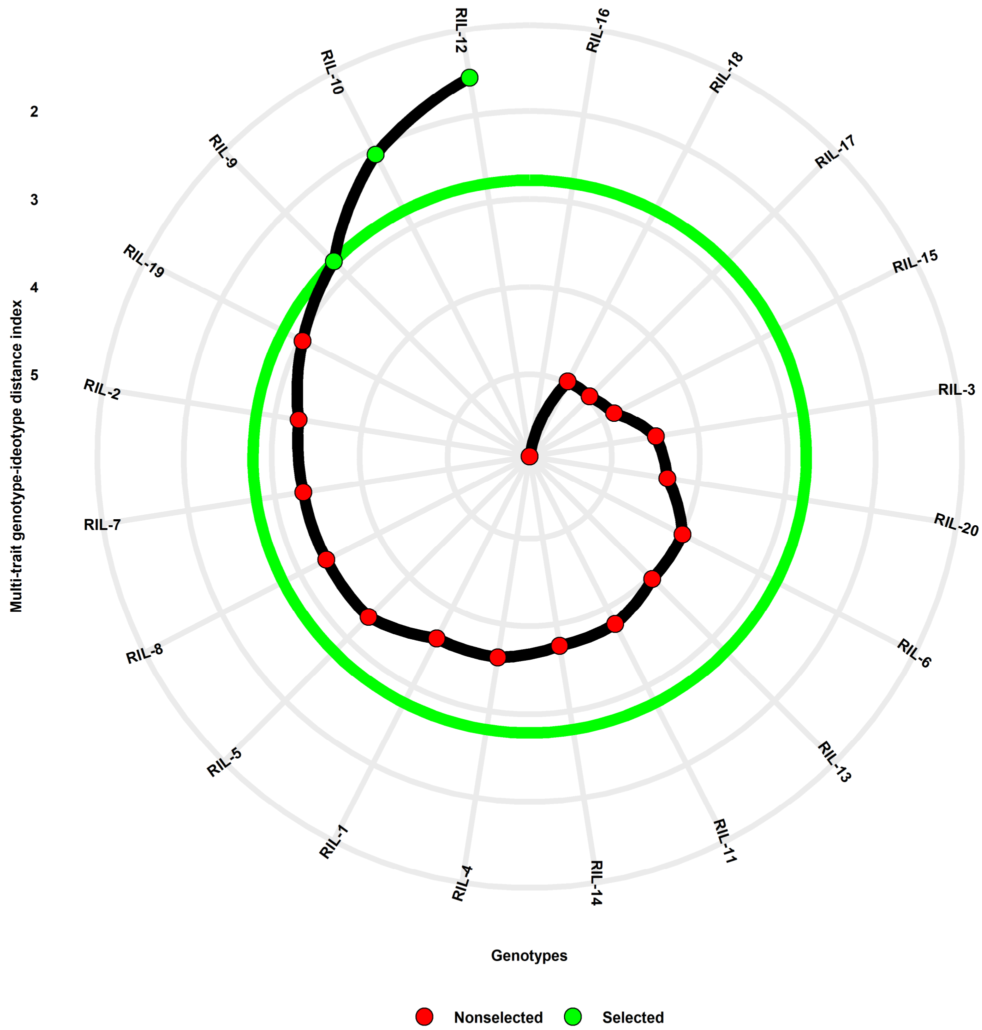

Fig. 1 Ranking of RILs based on multi-trait genotype-ideotype distance index (MGIDI). Red and green dots represent non-selected and selected lines respectively.

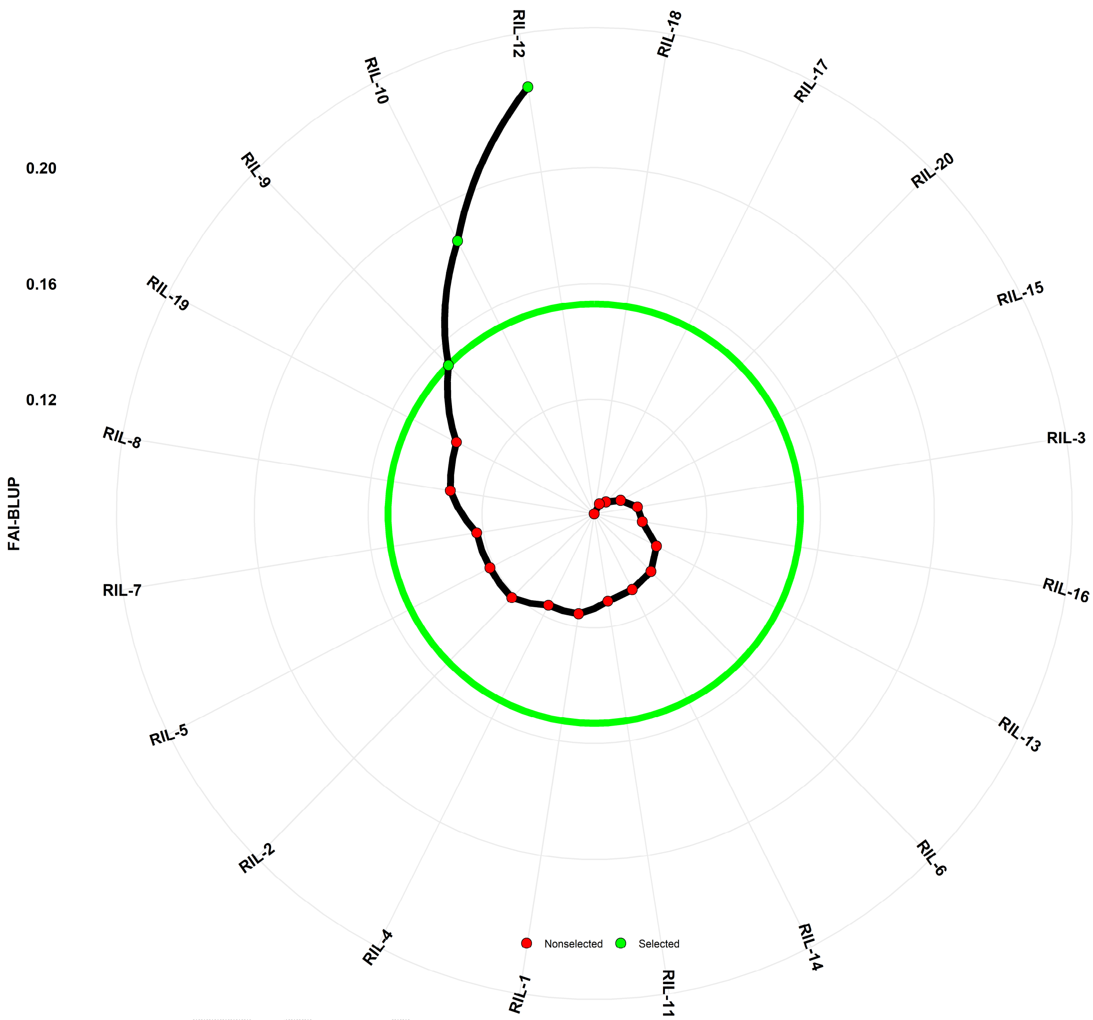

Fig. 2 Ranking of RILs based on factor analysis and genotype-ideotype distance (FAI-BLUP). Red and green dots represent non-selected and selected lines respectively.

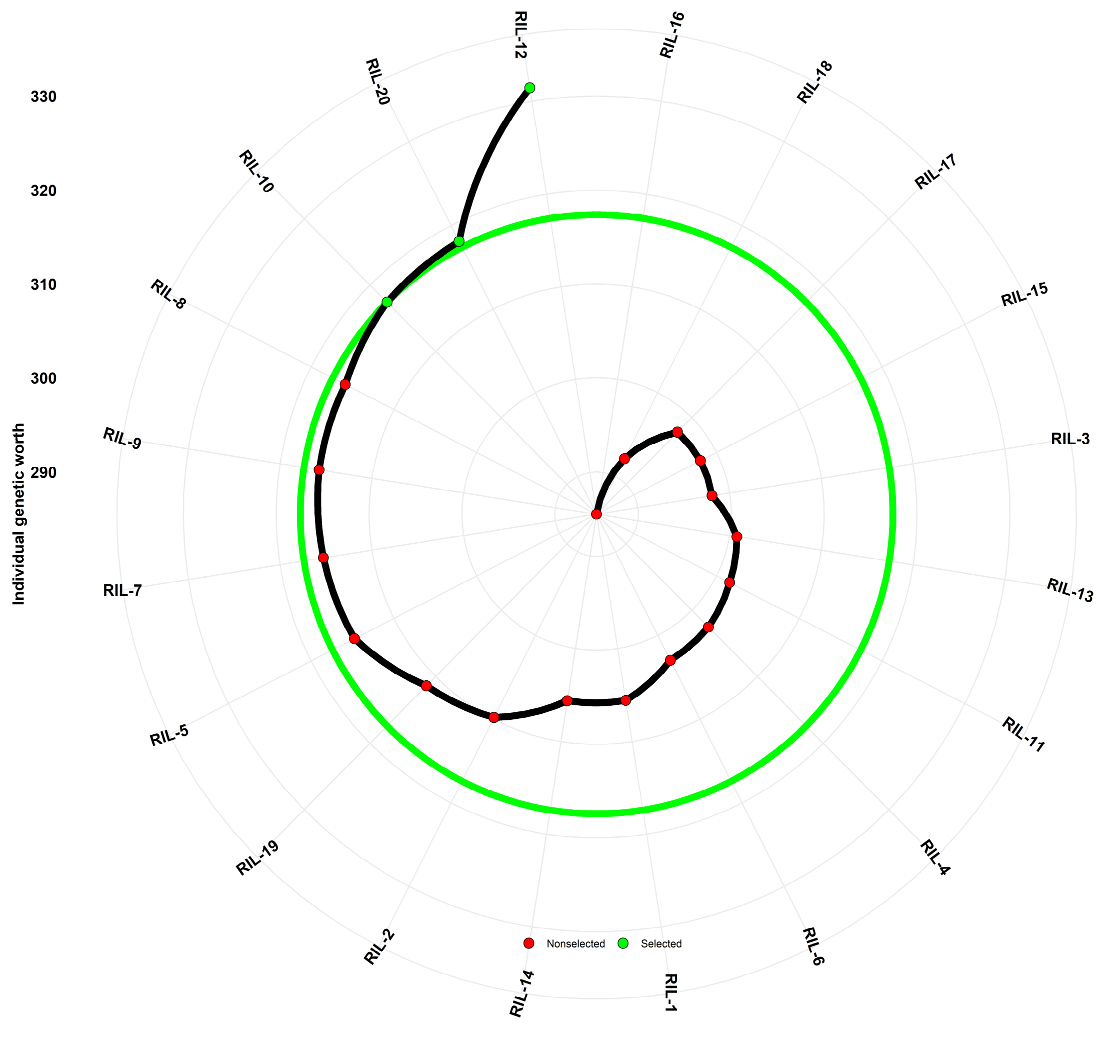

Fig. 3 Ranking of RILs based on Smith and Hazel index (SHI). Red and green dots represent non-selected and selected lines respectively.

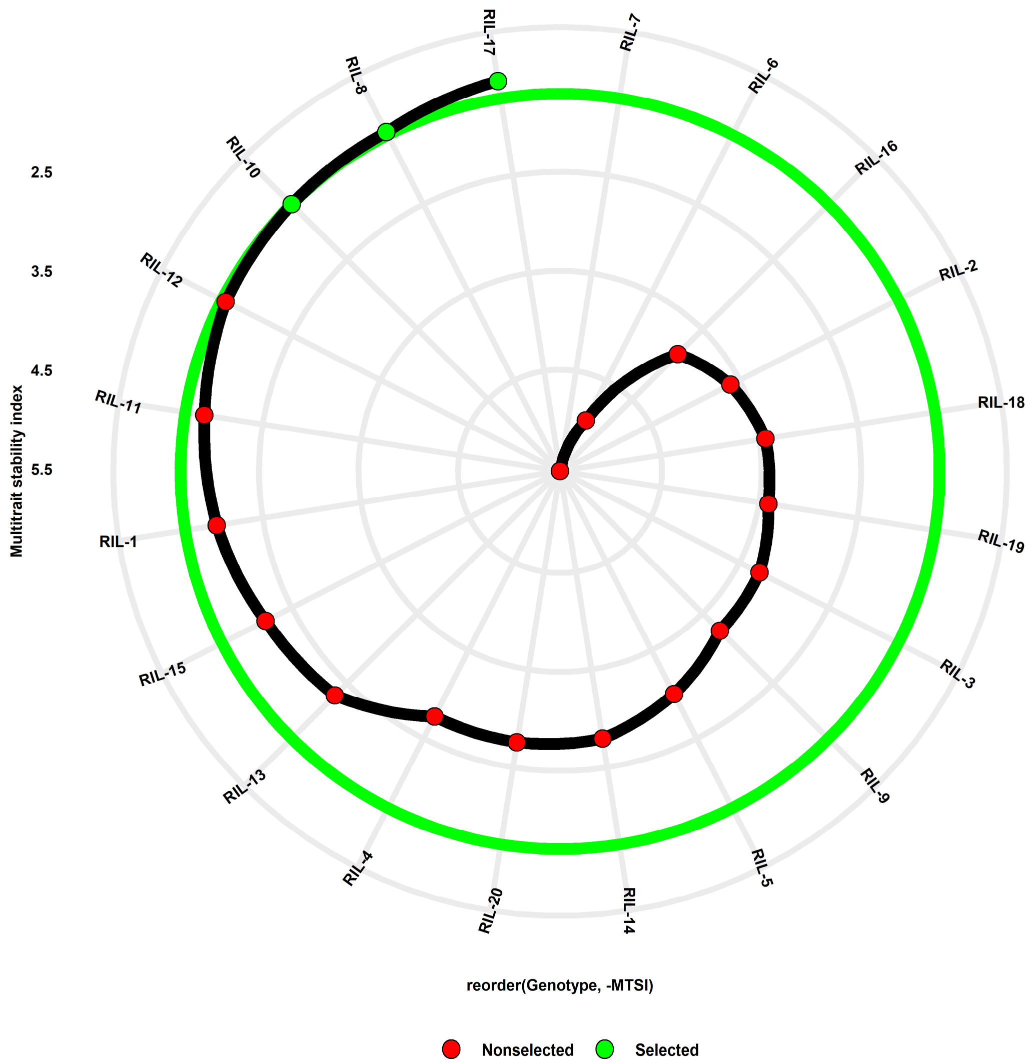

Fig. 4 Ranking of RILs based on multi-trait stability index (MTSI). Red and green dots represent non-selected and selected lines respectively.

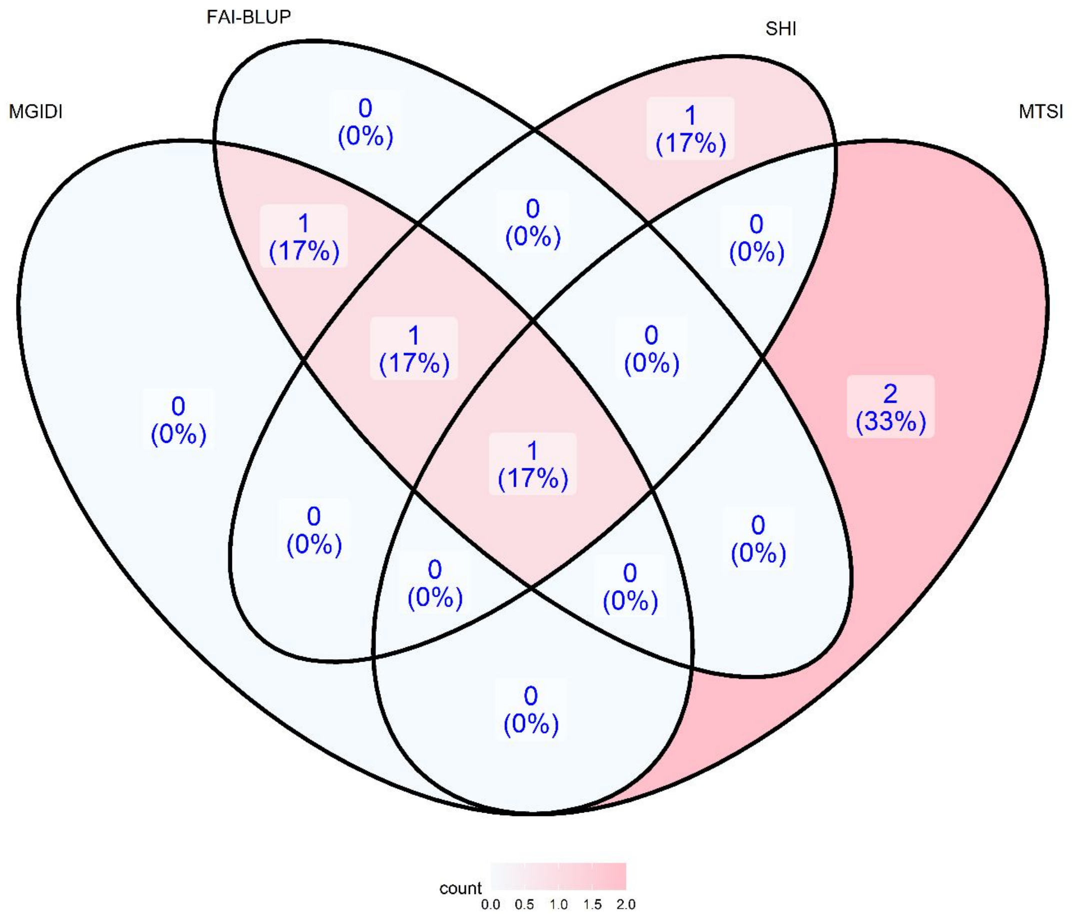

Fig. 5 Venn diagram depicting four best performing lines by employing MGIDI, FAI-BLUP, SHI and MTSI under multi-environment stress conditions.