

# Breeding for Yield Stability for Sustainable Production of Wheat (*Triticum aestivum* L.) in Nigeria

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## ABSTRACT

Stability analysis is a major constraint to the identification and deployment of wheat genotypes with consistently high performance across contrasting production environments. This study evaluated the yield performance and stability of 67 wheat genotypes comprising 15 parental lines, three testers, four checks and 45 F<sub>1</sub> hybrids across three locations in Nigeria. The genotypes were evaluated in a randomized complete block design with three replications, and stability was assessed using the Eberhart and Russell model based on genotype mean performance, regression coefficient ( $b_i$ ) and deviation from regression ( $S^2d_i$ ). The evaluated traits included biomass yield, harvest index, grain yield per plant, and grain weight per spike, 1000-grain weight, spike length, number of grains per spike, chlorophyll content, and number of productive tillers, grain-filling period and number of spikelets per spike. Marked genotypic differences in mean performance and stability parameters were observed across traits. For grain yield per plant, DH-3086 × PBW-343 and DBW-222 × PBW ZN1 combined relatively high mean performance with comparatively favorable stability parameters. DBW-173 and PBW ZN1 showed comparatively low environmental responsiveness and relatively good stability, although their mean grain yields were moderate. For chlorophyll content, several hybrids, particularly HD-3721 × PBW-343 and PBW-550 × PBW-343, showed high mean performance with comparatively favorable stability. Overall, no single genotype was consistently superior and stable for all evaluated traits, emphasizing the importance of trait-specific selection and multi-environment testing in wheat breeding for Nigeria. The identified high-performing and comparatively stable genotypes provide useful breeding material for developing wheat cultivars with improved adaptability and yield stability.

**Keywords:** Bread wheat; stability analysis; grain yield; wheat breeding.

## INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is an allohexaploid species with  $2n = 6x = 42$  chromosomes and an AABBDD genomic constitution. It originated through successive hybridization and polyploidization involving tetraploid wheat and the D-genome donor *Aegilops tauschii*. Wheat is predominantly self-pollinated and produces a spike inflorescence, with the grain developing as a caryopsis enclosed by the lemma and palea (Dhiwar et al., 2020; Gami et al., 2010; Gulzar et al., 2015). Its broad adaptation and importance as a staple cereal make it a major target of genetic improvement programmes.

Wheat productivity is strongly influenced by environmental variability, including temperature stress, salinity, pests and diseases, water availability and other site-specific production constraints. Consequently, a genotype that performs well in one environment may not necessarily maintain the same level of performance elsewhere. The assessment of genotype × environment interaction is therefore essential for identifying genotypes with broad adaptation or specific adaptation to favorable or unfavorable environments (Uresh and Bishnoi, 2020; Bouchareb and Guendouz, 2022). In plant breeding, stability analysis complements mean performance by quantifying the response of a genotype to changes in environmental productivity.

The Eberhart and Russell (1966) model remains a useful approach for characterizing phenotypic stability. The model uses the regression coefficient ( $b_i$ ) to describe the responsiveness of a genotype to environmental changes and the deviation from regression ( $S^2d_i$ ) to indicate the predictability of its performance. A genotype with high mean performance,  $b_i$  close to unity and a small deviation from regression is generally regarded as broadly adapted and predictable, whereas  $b_i$  values above or below unity indicate greater responsiveness to favorable or unfavorable environments, respectively.

Although stability studies have been reported in wheat-growing regions, information on the performance and stability of diverse parental lines and their hybrids under Nigerian environments remains limited. Multi-location evaluation in Nigeria can therefore provide breeding information needed to distinguish broadly adapted materials from genotypes that respond preferentially to particular environments. The present study was undertaken to evaluate the performance and stability of 67 wheat genotypes across three Nigerian locations and to identify promising materials for use in breeding programmes aimed at improving yield and yield-related traits.

## MATERIALS AND METHODS

### Plant Materials

The experimental materials comprised 67 wheat genotypes: 15 parental lines, three testers, four check varieties and 45  $F_1$  hybrids. The 15 lines were BHU-25, WB-02, BHU-31, HD-3721, PBW-725, CRD GEHNU1, PBW-550, PBW-677, PBW-822, HD-3117, DBW-173, DH-3086, DBW-222, CSW-18 and PBW-757. The testers were PBW ZN1, PBW-343 and HD-3326, while the checks were HD-2967, DBW-187, NORMAN and BORLAUG-100. The 45 hybrids were generated from crosses between the 15 female lines and three male testers using a line  $\times$  tester mating scheme.

### Experimental Sites and Environmental Conditions

The multi-location evaluation was conducted at three sites: the Teaching and Research Farm of Kebbi State University of Science and Technology, Aliero, Kebbi State; Yauri, Kebbi State; and Lake Chad Wheat Research Institute, Borno State. The source manuscript reports environmental observations for the 2025–2026 period, including temperature, rainfall and relative humidity. The cleaned environmental dataset is presented in Table 1.

Table 1. Environmental conditions recorded at the three experimental locations.

| Month    | Borno Temp (°C) | Borno Rainfall (mm) | Borno RH (%) | Aliero Temp (°C) | Aliero Rainfall (mm) | Aliero RH (%) | Yauri Temp (°C) | Yauri RH (%) | Yauri Rainfall (mm) |
|----------|-----------------|---------------------|--------------|------------------|----------------------|---------------|-----------------|--------------|---------------------|
| October  | 23              | 15                  | 45           | 25.5             | 36.3                 | 58            | 20              | 54           | 14                  |
| November | 18              | 0                   | 25           | 22.4             | 0                    | 29            | 15              | 52           | 0                   |
| December | 15              | 0                   | 20           | 18.1             | 0                    | 20            | 17              | 58           | 0                   |
| January  | 14              | 0                   | 15           | 17.1             | 0                    | 20            | 16              | 60           | 0                   |
| February | 17              | 0.2                 | 14           | 19.8             | 0.53                 | 18            | 17              | 57           | 2                   |
| March    | 20              | 1                   | 17           | 23.3             | 4.9                  | 24            | 18              | 52           | 4                   |
| April    | 24              | 3                   | 21           | 27               | 24.2                 | 36            | 21              | 45           | 8                   |
| May      | 27              | 13.5                | 35           | 29.8             | 75.5                 | 49            | 26              | 38           | 27                  |

|      |    |     |    |      |       |    |    |    |     |
|------|----|-----|----|------|-------|----|----|----|-----|
| June | 26 | 63  | 50 | 28.8 | 94.9  | 58 | 29 | 50 | 50  |
| July | 24 | 115 | 65 | 26.3 | 170.2 | 70 | 28 | 73 | 140 |

Source: Nigerian Meteorological Agency (NIMET) and source data reported in the original manuscript.

## Experimental Design and Crop Management

The 67 genotypes were evaluated in a randomized complete block design with three replications during the 2026 cropping season. Each plot consisted of three rows, each 3 m long, with 22.5 cm spacing between rows. Crop management practices were applied according to the agronomic recommendations used at the respective experimental sites. Emasculation and pollination were undertaken at the appropriate floral stage during hybrid development.

## Data Collection

Quantitative observations were collected using descriptors and procedures reported in the source study, while chlorophyll content was assessed using a Soil Plant Analysis Development (SPAD) meter. Grain protein determination was reported in the source manuscript as being conducted by the micro-Kjeldahl method; however, no corresponding protein-content dataset or table was provided in the submitted manuscript and the trait is therefore not interpreted quantitatively in the present revision.

## Statistical and Stability Analysis

Data were subjected to stability analysis following Eberhart and Russell (1966). For each genotype and trait, the mean performance, regression coefficient ( $b_i$ ) and deviation from regression ( $S^2d_i$ ) were estimated. Mean performance describes the average value across environments;  $b_i$  describes the response of a genotype to environmental productivity, with values near 1.0 indicating average responsiveness, values greater than 1.0 indicating greater responsiveness to favorable environments, and values below 1.0 indicating relatively greater performance in less favorable environments. A small  $S^2d_i$  indicates greater predictability of genotype performance across environments. Interpretation of stability therefore considered the three parameters jointly rather than relying on any single statistic.

# RESULTS AND DISCUSSION

## Biomass Yield, Harvest Index and Grain Yield per Plant

Substantial variation was observed among the 67 genotypes for biomass yield, harvest index and grain yield per plant (Table 2). The grand means were 56.78, 49.17 and 40.24, respectively. DBW-173 × HD-3326 recorded the highest biomass mean (65.61) among the genotypes, with  $b_i = 1.36$  and  $S^2d_i = 1.68$ . Its above-average mean and relatively moderate environmental responsiveness suggest useful performance under favorable environments, although the regression coefficient is not close enough to unity to classify it as broadly stable. BORLAUG-100 also combined a relatively high biomass mean (56.06) with a low deviation from regression (3.71), although its  $b_i$  of 0.55 indicates comparatively lower responsiveness to environmental improvement.

Harvest index showed considerable genotype-to-genotype variation. The highest mean harvest index was recorded for CSW-18 × PBW ZN1 (59.45), followed closely by CSW-18 × PBW-343 (59.03) and PBW-757 × HD-3326 (58.97). In contrast, CSW-18 had the lowest mean harvest index (44.23). These differences indicate that the genotypes differed in the proportion of accumulated biomass partitioned to grain. Similar variation in harvest index and stability among wheat genotypes has been reported by Siddhi et al. (2019) and related studies cited in the source manuscript.

Grain yield per plant ranged widely among the entries. PBW-822 × PBW ZN1 recorded the highest mean grain yield (53.00), but its relatively large  $S^2d_i$  (30.78) indicates substantial unpredictability across environments. DH-3086 × PBW-343 combined a high mean grain yield (51.32) with  $b_i = 1.07$  and  $S^2d_i = 1.04$ , representing a more

desirable combination of high productivity, average environmental responsiveness and comparatively good predictability. DBW-222  $\times$  PBW ZN1 also performed well, with a mean of 50.04,  $b_i = 0.99$  and  $S^2d_i = 1.69$ . These results illustrate the breeding importance of considering stability parameters alongside mean yield: the genotype with the highest mean yield is not necessarily the most predictable across environments. This pattern agrees with earlier reports that genotype  $\times$  environment interaction can substantially influence yield expression and stability in wheat (Madariya et al., 2001; Meena et al., 2014; Fellahi et al., 2019).

Table 2: Stability analysis on biomass yield, harvest index and Grain yield per plant from three locations using 67 wheat genotypes during 2026 rainy season

| S/N | Genotypes        | Biomass yield |       |          | harvest index |       |          | Grain yield per plant |       |          |
|-----|------------------|---------------|-------|----------|---------------|-------|----------|-----------------------|-------|----------|
|     |                  | *             |       | *        | *             |       | *        | *                     |       | *        |
|     | Genotypes        | Mean          | $b_i$ | $S^2d_i$ | Mean          | $b_i$ | $S^2d_i$ | Mean                  | $b_i$ | $S^2d_i$ |
| 1   | HD-2967          | 51.08         | 0.15  | 23.14    | 47.53         | 1.47  | 32.74    | 34.67                 | -2.03 | 0.84     |
| 2   | DBW-187          | 52.45         | 0.55  | 31.5     | 48.87         | 0.62  | -0.15    | 37.38                 | 7.08  | 4.99     |
| 3   | NORMAN           | 52.13         | 0.68  | 19.04    | 46.1          | 1.44  | 10.35    | 33.96                 | -2.38 | -0.4     |
| 4   | BORLAUG-100      | 56.06         | 0.55  | 3.71     | 48.99         | 1.04  | 17.61    | 39.65                 | 7.75  | 3.38     |
| 5   | BHU-25           | 51.07         | 0.86  | 23.66    | 47            | 1.56  | 1.32     | 33.31                 | 0.9   | 1.59     |
| 6   | HD-3117          | 49.96         | 1.18  | 23.38    | 44.58         | 0.78  | 31.84    | 34.88                 | 4.92  | 16.58    |
| 7   | BHU-25 X PBW ZN1 | 61.24         | 1.56  | 20.29    | 52.74         | -0.77 | 5.42     | 42.83                 | -1.94 | 3.41     |
| 8   | BHU-25 X PBW-343 | 63.1          | 1.09  | 19.72    | 55.87         | -0.25 | 23.53    | 44.14                 | -3.06 | 7.1      |
| 9   | BHU-25 X HD-3326 | 63.38         | 0.1   | 0.84     | 56.33         | 1.13  | 5.59     | 44.13                 | -4.52 | 20.8     |
| 10  | DBW-173          | 52.71         | 1.2   | 2.31     | 46.74         | 1.39  | 4.54     | 32.63                 | 0.24  | 1.81     |
| 11  | DBW-173X PBW ZN1 | 62.71         | 1.13  | 1.21     | 57.62         | 0.07  | 4.44     | 43.28                 | -0.93 | -0.71    |
| 12  | DBW-173X PBW-343 | 63.62         | 1.26  | 6.29     | 57.65         | 0.54  | 10.98    | 48.7                  | 8.8   | 16.24    |
| 13  | DBW-173X HD-3326 | 65.61         | 1.36  | 1.68     | 58.84         | 0.35  | 0.9      | 49.85                 | 4.71  | 7.85     |
| 14  | DH-3086          | 54.16         | 1.09  | 8.08     | 46.79         | 1.47  | 7.28     | 35.86                 | 7.02  | 11.11    |
| 15  | DH-3086X PBW ZN1 | 64.66         | 1.26  | 2.09     | 56.34         | 1.61  | 4.6      | 49.38                 | 5.54  | 9.8      |
| 16  | DH-3086X PBW-343 | 64.14         | 1.05  | 3.36     | 58.78         | 1.12  | -1.29    | 51.32                 | 1.07  | 1.04     |
| 17  | DH-3086X HD-3326 | 63.55         | 0.61  | 7.77     | 54.38         | 0.94  | 14.26    | 44.13                 | -2.69 | 4.59     |
| 18  | DBW-222          | 60.42         | 2.22  | 21.64    | 48.51         | 1.81  | 7.59     | 41.42                 | 5.84  | 26.55    |
| 19  | DBW-222X PBW ZN1 | 65.43         | 1.12  | -1.26    | 57.55         | 0.05  | 8.75     | 50.04                 | 0.99  | 1.69     |
| 20  | DBW-222X PBW-343 | 64.15         | 2.07  | 18.52    | 57.52         | 0.8   | -0.61    | 47.82                 | 0.08  | 1.19     |
| 21  | DBW-222X HD-3326 | 64.72         | 1.07  | 2.34     | 53.83         | -0.88 | 7.52     | 43.73                 | -2.86 | 15.12    |
| 22  | CSW-18           | 55.33         | 1.44  | -1.41    | 44.23         | 1.59  | 1.67     | 35.7                  | 8.85  | 2.82     |
| 23  | CSW-18XPBW ZN1   | 62.81         | 0.42  | 21.1     | 59.45         | 0.76  | -1.52    | 46.99                 | -0.61 | -0.51    |
| 24  | CSW-18XPBW-343   | 64.27         | 0.84  | 0.31     | 59.03         | 0.53  | 0.16     | 48.95                 | 3.05  | 38.74    |
| 25  | CSW-18XHD-3326   | 64.77         | 0.65  | 16.34    | 56.52         | 1.05  | 9.67     | 44.05                 | -4.84 | 8.93     |
| 26  | PBW-757          | 52.3          | 1.07  | 5.78     | 48.38         | 1.71  | 3.02     | 35.93                 | 0.24  | 1.81     |
| 27  | PBW-757X PBW ZN1 | 64.41         | 1.06  | 13.97    | 57.14         | 1.59  | 3.79     | 49.17                 | 3.09  | 19.83    |
| 28  | PBW-757X PBW-343 | 62.88         | 1.12  | 1.42     | 58.02         | 1.07  | 3.79     | 48.81                 | 1.35  | 28.84    |
| 29  | PBW-757X HD-3326 | 60.85         | 0.45  | 25.67    | 58.97         | 0.84  | -0.32    | 44.35                 | 1.33  | 8.56     |
| 30  | BHU-31 X PBW ZN1 | 57.47         | 1.59  | 5.24     | 50.87         | 1.98  | 2.39     | 41.8                  | -3.77 | 13.93    |
| 31  | BHU-31 X PBW-343 | 59.33         | 0.13  | -1.6     | 53.43         | 0.62  | 5.56     | 39.58                 | -3.72 | 12.72    |
| 32  | BHU-31 X HD-3326 | 63.14         | 1.3   | -0.55    | 53.51         | 1.53  | 27.12    | 41.66                 | -0.19 | -0.24    |
| 33  | WB-02            | 55.35         | 0.8   | -0.75    | 46.68         | 1.25  | 16.98    | 34.21                 | 0.24  | 1.81     |
| 34  | WB-02 X PBW ZN1  | 65.56         | 1.03  | 1.56     | 54.81         | 1.57  | 19.93    | 45.21                 | -0.23 | 0.19     |

|    |                         |              |      |       |              |       |       |              |       |       |
|----|-------------------------|--------------|------|-------|--------------|-------|-------|--------------|-------|-------|
| 35 | WB-02 X PBW-343         | 60.18        | 1.11 | 48.93 | 54.75        | 0.77  | 26.98 | 42.16        | 0.22  | 20.99 |
| 36 | WB-02 X HD-3326         | 63.55        | 0.13 | 11.12 | 51.17        | -0.12 | 3.6   | 40.58        | 5.12  | 17.63 |
| 37 | BHU-31                  | 53.38        | 0.92 | 19.07 | 48.55        | 1.39  | 4.5   | 35.27        | 0.24  | 1.81  |
| 38 | BHU-31 X PBW ZN1        | 59.33        | 0.73 | 23.95 | 55.5         | 0.82  | 11.06 | 43.32        | 0.04  | 0.76  |
| 39 | BHU-31 X PBW-343        | 58.38        | 0.89 | 18.32 | 55.83        | 2.29  | 4.25  | 41.55        | -1.12 | -1.42 |
| 40 | BHU-31 X HD-3326        | 58.91        | 0.83 | 96.03 | 55.99        | 0.58  | 9.45  | 44.84        | 4.48  | 16.34 |
| 41 | HD-3721                 | 53.63        | 0.01 | 33.39 | 46.99        | 1.81  | 8.06  | 33.38        | 0.24  | 1.81  |
| 42 | HD-3721 X PBW ZN1       | 64.66        | 0.72 | 7.44  | 55.56        | 2.39  | 7.28  | 44.85        | 4.41  | -0.19 |
| 43 | HD-3721 X PBW-343       | 62.54        | 1.16 | -1.85 | 54.23        | 0.02  | 0.25  | 42.24        | -0.85 | -0.57 |
| 44 | HD-3721 X HD-3326       | 63.92        | 1.23 | 1.81  | 54.05        | 1.46  | 39.02 | 47.11        | -0.64 | -0.54 |
| 45 | PWB-725                 | 53.2         | 0.91 | 24.26 | 47.4         | 0.93  | 6.7   | 34.24        | 1.41  | 1.41  |
| 46 | PWB-725 X PBW ZN1       | 62.04        | 1.34 | 34.89 | 55.2         | 0.38  | 42.57 | 43.69        | 4.86  | 21.91 |
| 47 | PWB-725 X PBW-343       | 64.24        | 0.13 | 23.83 | 53.89        | 1.03  | 9.23  | 42.37        | -3.27 | 8.76  |
| 48 | PWB-725 X HD-3326       | 61.7         | 1.15 | 23.71 | 57.58        | 1.48  | -1.53 | 45.95        | -2.27 | 1.81  |
| 49 | CRD GEHNU1              | 57.29        | 2.49 | 93.12 | 46.79        | 1.56  | 19.03 | 40.98        | 8.46  | 20.84 |
| 50 | CRDGEHNU1 X<br>PBWZN1   | 65.15        | 0.6  | 0.07  | 55.66        | 0.72  | 1.49  | 44.76        | -2.79 | 5.22  |
| 51 | CRDGEHNU1 X<br>PBW343   | 61.45        | 0.97 | 20.01 | 56.54        | 0.85  | 6.72  | 44.88        | -0.37 | -0.37 |
| 52 | CRDGEHNU1 X HD-<br>3326 | 60.67        | 0.26 | 45.22 | 55.31        | 1.43  | 27.22 | 41.93        | -3.7  | 12.56 |
| 53 | PBW-550                 | 56.49        | 0.8  | 0.55  | 49.96        | 1.69  | 4.28  | 36.36        | 0.24  | 1.81  |
| 54 | PBW-550X PBW ZN1        | 61.85        | 0.99 | 32.08 | 57.49        | 1.43  | 1.7   | 46.52        | 8.6   | 2.24  |
| 55 | PBW-550X PBW-343        | 64.36        | 1.39 | 0.4   | 55.05        | 0.94  | 2.52  | 46.23        | -0.53 | -0.4  |
| 56 | PBW-550X HD-3326        | 64.01        | 1.2  | 27.31 | 56.29        | 1.04  | 1.62  | 46.8         | 0.5   | 2.87  |
| 57 | PBW-677                 | 55.09        | 0.89 | 42.87 | 46.78        | 1.52  | 1.95  | 34.53        | 0.24  | 1.81  |
| 58 | PBW-677XPBW ZN1         | 59.81        | 0.68 | 37.8  | 56.75        | 0.43  | 8.25  | 40.76        | -3.2  | 16.24 |
| 59 | PBW-677XPBW-343         | 60.41        | 0.2  | 32.34 | 58.93        | 1.19  | -0.37 | 48.07        | 4.17  | -0.72 |
| 60 | PBW-677XPBW-343         | 61.78        | 1.51 | 1.24  | 55.28        | 0.56  | 13.1  | 42.92        | -2.34 | 2.7   |
| 61 | PBW-822                 | 50.38        | 0.86 | 41.59 | 44.75        | 0.96  | 4.34  | 35.17        | 4.81  | 19.94 |
| 62 | PBW-822X PBW ZN1        | 65.25        | 1.54 | 2.43  | 59.43        | 0.94  | -1.33 | 53           | 3.05  | 30.78 |
| 63 | PBW-822X PBW-343        | 64.24        | 0.61 | 6.28  | 55.79        | 0.18  | 16.49 | 45.53        | -3.15 | 2.42  |
| 64 | PBW-822X HD-3326        | 64.24        | 1.31 | 6.83  | 57.77        | -0.35 | 1.74  | 46.47        | 0.38  | 2.41  |
| 65 | PBW ZN1                 | 53.74        | 1.92 | 20.54 | 45.55        | 1.81  | 9.48  | 35.58        | 0.24  | 1.81  |
| 66 | PBW-343                 | 55.79        | 1.63 | 94.81 | 45.64        | 0.49  | 11.61 | 35.69        | -0.14 | 0.45  |
| 67 | HD-3326                 | 54.8         | 1.71 | 5.07  | 48.79        | 1.74  | 7.14  | 38.95        | 0.24  | 1.81  |
|    | <b>Grand Mean:</b>      | <b>56.78</b> |      |       | <b>49.17</b> |       |       | <b>40.24</b> |       |       |
|    | <b>SE±</b>              | <b>1.17</b>  |      |       | <b>0.48</b>  |       |       | <b>0.32</b>  |       |       |
|    | <b>C.D.1%:</b>          | <b>2.97</b>  |      |       | <b>1.25</b>  |       |       | <b>0.83</b>  |       |       |

### Grain Weight per Spike, 1000-Grain Weight, Spike Length and Number of Grains per Spike

The evaluated genotypes also differed in grain weight per spike, 1000-grain weight, spike length and number of grains per spike (Table 3). Grain weight per spike had a grand mean of 3.15 g. Among the hybrids, DBW-222 × PBW ZN1 and DBW-222 × PBW-343 each recorded a mean of 3.87 g, the highest value in the dataset. DBW-173 × PBW-343 also showed a high mean (3.63 g) with  $b_i$  below unity (0.68), suggesting comparatively lower responsiveness to favorable environments.

For 1000-grain weight, the overall mean was 44.12 g. Several hybrids exceeded the grand mean, including CRD GEHNU1  $\times$  PBW ZN1 (47.99 g), BHU-25  $\times$  PBW ZN1 (47.80 g), DBW-173  $\times$  PBW ZN1 (47.45 g) and PBW-822  $\times$  PBW-343 (47.15 g). HD-3117  $\times$  HD-3326 recorded 46.14 g with  $b_i = 0.20$  and  $S^2d_i = -0.80$  in the source dataset, indicating low environmental responsiveness. Because some reported  $S^2d_i$  estimates in the source tables are negative, these values should be checked against the original statistical output before journal submission.

Spike length had a grand mean of 13.39 cm. PBW-757  $\times$  PBW ZN1 recorded the longest mean spike (14.40 cm), followed by CRD GEHNU1  $\times$  PBW ZN1 (14.58 cm) and other high-performing hybrids. BHU-25 had a relatively low mean (12.47 cm) but a small deviation from regression ( $-0.11$  in the source dataset), suggesting comparatively predictable performance according to the reported estimates. For number of grains per spike, DBW-222  $\times$  PBW-343 recorded the highest mean (48.15), followed by CSW-18  $\times$  PBW-343 (49.47) and other hybrids exceeding the overall mean of 42.08. These findings indicate that the hybrid materials generated substantial variation for major yield components, providing useful selection opportunities in breeding.

Table 3. Stability parameters for grain weight per spike, 1000-grain weight, spike length and number of grains per spike.

| SN | Genotypes             | Grain weight per spike (g) |       |                               | 1000 grain weight (g) |       |                               | Spike length (cm) |       |                               | Number of grain per spike |       |                               |
|----|-----------------------|----------------------------|-------|-------------------------------|-----------------------|-------|-------------------------------|-------------------|-------|-------------------------------|---------------------------|-------|-------------------------------|
|    |                       | *                          |       | *                             | *                     |       | *                             | *                 |       | *                             | *                         |       | *                             |
| SN | Genotypes             | Mean                       | bi    | S <sup>2</sup> d <sub>i</sub> | Mean                  | bi    | S <sup>2</sup> d <sub>i</sub> | Mean              | bi    | S <sup>2</sup> d <sub>i</sub> | Mean                      | bi    | S <sup>2</sup> d <sub>i</sub> |
| 1  | BHU-25 (L1)           | 2.41                       | 1.58  | -0.04                         | 38.03                 | 1     | 0.33                          | 12.47             | 4.08  | 0.27                          | 36.25                     | -1.02 | 10.46                         |
| 2  | WB-02 (L2)            | 2.39                       | 1.72  | -0.04                         | 36.54                 | 1.07  | 0.79                          | 12.36             | 1.94  | 0.56                          | 36.24                     | -1.27 | 0.83                          |
| 3  | BHU-31 (L3)           | 2.52                       | 2.14  | -0.02                         | 37.28                 | 1.76  | 3.53                          | 12.72             | -0.35 | 1.02                          | 34.46                     | 0.23  | 0.28                          |
| 4  | HD-3721 (L4)          | 2.35                       | -0.38 | -0.02                         | 37.43                 | 1.69  | 15.27                         | 11.81             | 0.82  | -0.1                          | 33.17                     | -0.49 | 4.33                          |
| 5  | PWB-725 (L5)          | 2.4                        | 1.83  | -0.04                         | 36.35                 | 1.89  | 40.83                         | 11.71             | -0.76 | 0.21                          | 35.12                     | -0.32 | 1.05                          |
| 6  | CRD GEHNU1 (L6)       | 2.86                       | -1.81 | 0.29                          | 39.88                 | 2.76  | -0.19                         | 13.29             | -1.63 | 0.33                          | 35.72                     | 1.43  | 1.94                          |
| 7  | PBW-550 (L7)          | 2.42                       | 1.48  | 0                             | 38.93                 | 1.24  | 2.26                          | 12.36             | -1.42 | 0.63                          | 34.95                     | 1.95  | 1.96                          |
| 8  | PBW-677 (L8)          | 2.49                       | -1.03 | -0.04                         | 37.46                 | 2.08  | 2.61                          | 12.25             | 2.97  | 0.22                          | 33.66                     | 0.53  | 0.31                          |
| 9  | PBW-822 (L9)          | 2.43                       | 1.34  | 0.06                          | 39.83                 | 2.31  | 2.02                          | 12.31             | -1.98 | -0.15                         | 36.63                     | 0.72  | 14.5                          |
| 10 | HD-3117 (L10)         | 2.42                       | 2.4   | 0.04                          | 36.64                 | 1.25  | 33.2                          | 12.38             | -0.79 | -0.11                         | 35.24                     | -0.41 | 31.99                         |
| 11 | DBW-173 (L11)         | 2.47                       | 0.2   | 0.21                          | 37.5                  | 1.53  | -0.46                         | 12.17             | -1.05 | 0                             | 38.7                      | -0.1  | 0.14                          |
| 12 | DH-3086 (L12)         | 2.83                       | 0.14  | 0.08                          | 39.02                 | 2.04  | 0.51                          | 12.13             | 1.68  | 0.16                          | 38.11                     | 0.45  | -0.31                         |
| 13 | DBW-222 (L13)         | 2.6                        | -0.7  | 0.02                          | 39.05                 | 2.49  | -0.62                         | 12.44             | 3.48  | 0.36                          | 37.24                     | 0.4   | 10.34                         |
| 14 | CSW-18 (L14)          | 2.37                       | -1.04 | -0.04                         | 38.22                 | 3.74  | -0.46                         | 12.29             | 0.43  | -0.01                         | 36.51                     | 1.1   | 4.76                          |
| 15 | PBW-757 (L15)         | 2.35                       | -0.79 | 0.03                          | 40.16                 | 1.55  | 1.14                          | 12.33             | 0.82  | -0.06                         | 35.54                     | 1.57  | 2.19                          |
| 16 | PBW ZN1 (Tester 1)    | 2.58                       | -0.6  | 0.05                          | 37.68                 | 1.59  | -0.6                          | 12.53             | -0.34 | 0.45                          | 37.72                     | -0.65 | 2.27                          |
| 17 | PBW-343 (Tester 2)    | 2.32                       | 0.69  | 0.06                          | 39.84                 | 1.88  | -0.76                         | 11.76             | 0.7   | 0.32                          | 37.99                     | 0.32  | -1.37                         |
| 18 | HD-3326 (Tester 3)    | 2.7                        | -1    | -0.04                         | 37.85                 | 2.56  | -0.79                         | 12.56             | 1.54  | 0.58                          | 36.29                     | -1.76 | 0.23                          |
| 19 | HD-2967 (Check 1)     | 2.66                       | 2.1   | -0.01                         | 38.82                 | 0.61  | -0.74                         | 12.39             | -3.11 | 0.06                          | 39.01                     | -0.15 | 0.02                          |
| 20 | DBW-187 (Check 2)     | 2.6                        | 1.43  | -0.02                         | 40.94                 | 1.07  | -0.88                         | 12.54             | -1.5  | 0.04                          | 34.87                     | 1.97  | 3.95                          |
| 21 | NORMAN (Check 3)      | 2.68                       | 1.65  | 0.06                          | 39.09                 | -0.39 | 0.67                          | 12.95             | -0.96 | 0.3                           | 37.55                     | -1.18 | 0.69                          |
| 22 | BORLAUG-100 (Check 4) | 2.87                       | -0.46 | -0.04                         | 40.99                 | 0.7   | -0.53                         | 12.27             | -0.35 | 0.36                          | 37.28                     | -0.79 | 5.74                          |
| 23 | BHU-25 X PBW ZN1      | 3.39                       | 2.01  | 0                             | 47.8                  | 0.77  | 0.99                          | 13.66             | 1.47  | -0.12                         | 47.32                     | 1.49  | 5.84                          |
| 24 | BHU-25 X PBW-343      | 3.37                       | 0.55  | -0.05                         | 47.09                 | 0.7   | -0.03                         | 13.58             | 2.25  | -0.1                          | 46.7                      | 2.36  | 20.35                         |
| 25 | BHU-25 X HD-3326      | 3.53                       | 2.84  | -0.04                         | 46.15                 | 0.2   | -0.81                         | 13.67             | 2.44  | -0.1                          | 45.53                     | -0.72 | 12.78                         |
| 26 | DBW-173X PBW ZN1      | 3.56                       | 1.98  | 0.05                          | 47.45                 | -0.08 | -0.49                         | 13.63             | 2.63  | -0.11                         | 43.3                      | 0.53  | 6.05                          |
| 27 | DBW-173X PBW-         | 3.63                       | -0.68 | 0.04                          | 46.32                 | 0.65  | 3.46                          | 14.15             | 3.06  | 0.36                          | 45.36                     | -0.52 | 10.66                         |

|    |                        |      |       |       |       |       |       |       |       |       |       |       |       |
|----|------------------------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|    | 343                    |      |       |       |       |       |       |       |       |       |       |       |       |
| 28 | DBW-173X HD-3326       | 3.32 | 0.75  | 0.05  | 46.3  | 0.5   | -0.71 | 14.28 | 1.24  | 0.14  | 47.23 | 0.45  | 14.58 |
| 29 | DH-3086X PBW<br>ZN1    | 3.43 | 2.44  | -0.04 | 45.28 | 0.02  | 1.73  | 13.91 | 2.99  | 0.34  | 44.01 | 0.24  | 4.64  |
| 30 | DH-3086X PBW-343       | 3.56 | 1.41  | -0.04 | 46.92 | 0.69  | 0.67  | 13.87 | 5.7   | 0.07  | 47.35 | -0.7  | 2.54  |
| 31 | DH-3086X HD-3326       | 3.61 | 1.72  | 0     | 45.76 | 0.36  | 1.87  | 13.75 | 2.56  | 0.12  | 47.13 | 1.99  | 1.56  |
| 32 | DBW-222X PBW<br>ZN1    | 3.87 | 0.76  | 0.12  | 46.21 | 0.61  | -0.37 | 14.05 | 3.01  | -0.14 | 47.8  | 2.72  | 2.88  |
| 33 | DBW-222X PBW-<br>343   | 3.87 | 2.12  | -0.01 | 46.45 | 0.68  | -0.61 | 13.68 | 0.87  | -0.14 | 48.15 | 3.42  | -1.07 |
| 34 | DBW-222X HD-3326       | 3.51 | 2.5   | -0.05 | 46.96 | 0.72  | 3.89  | 13.47 | 0.13  | -0.13 | 47.15 | 4.08  | 7.9   |
| 35 | CSW-18XPBW ZN1         | 3.73 | -0.29 | -0.03 | 46.81 | 0.68  | -0.78 | 13.63 | 1.02  | -0.04 | 45.51 | 1.02  | 7.39  |
| 36 | CSW-18XPBW-343         | 3.52 | 0.45  | 0.07  | 46.88 | 0.54  | 0.87  | 14.21 | -1.74 | -0.02 | 49.47 | 2.11  | 0.95  |
| 37 | CSW-18XHD-3326         | 3.38 | 1.19  | 0.1   | 46.5  | 1.65  | 0.43  | 13.9  | 3.15  | -0.03 | 47.61 | 3.52  | 2.86  |
| 38 | PBW-757X PBW<br>ZN1    | 3.5  | 0.04  | 0.08  | 46.69 | 0.62  | 0.72  | 14.4  | 2.46  | 0.85  | 46.84 | 3.06  | 8.33  |
| 39 | PBW-757X PBW-<br>343   | 3.55 | 0.08  | 0.22  | 46.94 | 1.42  | 0.06  | 14.08 | 1.01  | 0.22  | 45.03 | 0.06  | -1.29 |
| 40 | PBW-757X HD-3326       | 3.6  | -0.62 | 0     | 46.88 | 0.88  | -0.76 | 13.57 | 0.89  | -0.06 | 44.25 | 2.06  | 0.71  |
| 41 | BHU-31 X PBW ZN1       | 3.38 | 1.72  | -0.01 | 46.79 | 0.99  | -0.71 | 13.78 | 0.47  | 0.17  | 46    | 2.74  | -0.85 |
| 42 | BHU-31 X PBW-343       | 3.71 | 1.01  | 0.26  | 46.94 | 0.94  | -0.17 | 13.85 | -0.36 | 0.31  | 46.12 | 4.26  | -0.81 |
| 43 | BHU-31 X HD-3326       | 3.57 | 2.21  | -0.03 | 46.48 | 0.99  | 2.25  | 13.08 | -0.87 | 0.23  | 46.68 | 3.56  | 1.21  |
| 44 | WB-02 X PBW ZN1        | 3.61 | 0.46  | 0.08  | 46.16 | 1.3   | 0.82  | 13.41 | 0.08  | -0.13 | 47.92 | 3.14  | -1.61 |
| 45 | WB-02 X PBW-343        | 3.5  | 0.31  | 0.03  | 46.36 | 0.43  | 4.32  | 13.52 | -2.95 | 1     | 47.52 | 4.15  | 2.11  |
| 46 | WB-02 X HD-3326        | 3.68 | 1.38  | 0.15  | 46.8  | 0.24  | -0.54 | 13.89 | -0.76 | -0.02 | 47.48 | 4.04  | 2.62  |
| 47 | BHU-31 X PBW ZN1       | 3.7  | 1.62  | 0.11  | 46.38 | 0.84  | 1.02  | 14.16 | 2.42  | -0.07 | 45.06 | -2.16 | -1.34 |
| 48 | BHU-31 X PBW-343       | 3.67 | 2.34  | 0.05  | 46.63 | 0.37  | 0.8   | 13.61 | 1.74  | 0.13  | 45.22 | -1.52 | 2.95  |
| 49 | BHU-31 X HD-3326       | 3.39 | 2.01  | 0.09  | 46.3  | 1.41  | -0.93 | 14.26 | 2.97  | 0.07  | 45.98 | 2.26  | 2.4   |
| 50 | HD-3721 X PBW<br>ZN1   | 3.7  | 0.99  | 0.05  | 45.65 | 0.65  | -0.62 | 13.94 | 4.05  | 0.58  | 44.56 | 1.22  | 8.62  |
| 51 | HD-3721 X PBW-<br>343  | 3.56 | 0.6   | 0.15  | 46.52 | 0.43  | -0.16 | 13.9  | 0.32  | 0.28  | 46.95 | 0.89  | 11.22 |
| 52 | HD-3721 X HD-3326      | 3.38 | 0.97  | 0.03  | 45.87 | 0.38  | -0.72 | 14.12 | -0.93 | 0.47  | 44.91 | 1.88  | 12.55 |
| 53 | PWB-725 X PBW<br>ZN1   | 3.69 | 1.44  | -0.04 | 46.96 | 0.7   | 1.62  | 12.96 | 1.22  | 0.51  | 47.23 | 1.9   | 1.06  |
| 54 | PWB-725 X PBW-<br>343  | 3.33 | 1.12  | 0.01  | 45.9  | 1.29  | 0.99  | 13.62 | 1.62  | -0.05 | 44.46 | 5.41  | 8.18  |
| 55 | PWB-725 X HD-<br>3326  | 3.52 | 1.9   | 0.06  | 46.16 | -0.09 | -0.52 | 13.68 | 0.39  | 0.73  | 45.45 | -1.98 | 9.01  |
| 56 | CRDGEHNU1 X<br>PBWZN1  | 3.45 | 2     | 0     | 47.99 | -0.86 | 0.04  | 14.58 | -0.81 | 0.59  | 47.11 | 3.77  | -1.65 |
| 57 | CRDGEHNU1 X<br>PBW343  | 3.61 | 0.72  | 0.09  | 46.98 | 1.27  | 0.15  | 14.47 | -1.33 | 1.04  | 45.37 | -1.7  | 7.28  |
| 58 | CRDGEHNU1 X<br>HD-3326 | 3.5  | 2.49  | -0.03 | 46.79 | 0.96  | -0.76 | 13.49 | 2.12  | 0.1   | 42.61 | -1.17 | -0.5  |
| 59 | PBW-550X PBW<br>ZN1    | 3.5  | 2.17  | -0.03 | 45.62 | 0.17  | -0.55 | 14.21 | 2.8   | 0.19  | 44.43 | 0.09  | 3.43  |
| 60 | PBW-550X PBW-<br>343   | 3.56 | 1.87  | 0.02  | 47.08 | 1.52  | -0.57 | 14.15 | 2.1   | -0.11 | 45.89 | 2.12  | 2.58  |
| 61 | PBW-550X HD-3326       | 3.6  | 1.92  | 0.02  | 46.53 | 0.8   | 0.6   | 14.29 | 0.82  | -0.08 | 45.13 | 2.32  | 0.64  |
| 62 | PBW-677XPBW<br>ZN1     | 3.36 | 2.45  | -0.04 | 46.47 | 0.63  | -0.3  | 13.19 | -0.21 | 0.42  | 47.85 | 0.51  | 5.29  |

|    |                    |      |       |       |       |      |       |       |       |       |       |       |       |
|----|--------------------|------|-------|-------|-------|------|-------|-------|-------|-------|-------|-------|-------|
| 63 | PBW-677XPBW-343    | 3.41 | 0.86  | -0.04 | 47.08 | 0.88 | -0.64 | 14.21 | 1.55  | -0.11 | 43.77 | -1.21 | 1.16  |
| 64 | PBW-677XPBW-343    | 3.42 | 1.17  | -0.01 | 46.25 | 0.63 | -0.23 | 13.85 | 3.19  | 0.08  | 44.87 | 0.57  | 7.4   |
| 65 | PBW-822X PBW ZN1   | 3.68 | -0.62 | -0.02 | 44.12 | 1.08 | 9.6   | 14.25 | 5.71  | 0.51  | 43.01 | -0.49 | -0.51 |
| 66 | PBW-822X PBW-343   | 3.67 | 0.96  | -0.04 | 47.15 | 0.17 | -0.84 | 14.46 | -1.19 | 0.04  | 45.48 | 4.13  | 0.16  |
| 67 | PBW-822X HD-3326   | 3.64 | 0.81  | -0.01 | 46.55 | 0.86 | 0.21  | 13.85 | 3.52  | 0.03  | 44.46 | -1.43 | 13.26 |
|    | <b>Grand Mean:</b> | 3.15 |       |       | 44.12 |      |       | 13.39 |       |       | 42.08 |       |       |
|    | <b>SE±</b>         | 0.09 |       |       | 0.59  |      |       | 0.07  |       |       | 0.49  |       |       |
|    | <b>C.D.1%:</b>     | 0.23 |       |       | 1.55  |      |       | 0.18  |       |       | 1.27  |       |       |

### Chlorophyll Content, Productive Tillers, Grain-Filling Period and Spikelets per Spike

The four traits summarized in Table 4 also exhibited substantial variation in mean performance and environmental response. Chlorophyll content had a grand mean of 45.99. DH-3086 × PBW-343 recorded the highest mean chlorophyll content (57.15) with  $b_i = 0.88$  and  $S^2d_i = -0.30$  in the source dataset. CSW-18 × PBW-343 (57.16) and CRD GEHNU1 × PBW-343 (57.70) also showed high mean values. These genotypes may therefore be useful where sustained leaf greenness and associated photosynthetic capacity are important breeding targets. The source manuscript similarly identified HD-3721 × PBW-343 and PBW-550 × PBW-343 as promising materials for chlorophyll content.

Number of productive tillers had a grand mean of 6.25. DBW-222 × PBW ZN1 recorded the highest mean (9.49), followed by PBW-822 × PBW ZN1 (9.08) and several other hybrids with means above the grand mean. Because productive tillers contribute directly to spike number and consequently grain yield, genotypes combining high tillering with favorable stability parameters are of particular interest in wheat improvement (Siddhi et al., 2019). The relatively low deviation values reported for some entries, including BHU-31 × PBW-343, suggest potentially predictable tiller production.

The grand mean for grain-filling period was 40.53 days. DBW-187 showed a mean of 43.50 days,  $b_i = 0.13$  and  $S^2d_i = 1.19$ , indicating low environmental responsiveness and comparatively good predictability. HD-2967 also showed a relatively long grain-filling period (43.17 days) with  $b_i = 0.39$ . Several hybrids expressed higher or lower responsiveness, indicating differences in their sensitivity to environmental conditions. Such variation can be useful for breeding programmes targeting adaptation to environments where the duration of grain filling is an important component of yield.

The number of Spikelets per spike had a grand mean of 24.20. Several hybrids exceeded the grand mean, including DBW-222 × PBW ZN1 (25.53), CSW-18 × HD-3326 (25.58), PBW-757 × PBW ZN1 (25.82) and DBW-222 × PBW-343 (25.94). The comparatively low  $S^2d_i$  values of several hybrids indicate relatively predictable performance for this component, although high mean performance and stability did not occur in exactly the same genotype for every trait. This reinforces the need for trait-specific selection and simultaneous consideration of yield and stability.

Table 4. Stability parameters for chlorophyll content, number of productive tillers, grain-filling period and number of spikelets per spike.

| SN | Genotypes    | Chlorophyll content |       |          | Number of productive tiller |       |          | Grain filling period |       |          | Number of spikelet per spike |       |          |
|----|--------------|---------------------|-------|----------|-----------------------------|-------|----------|----------------------|-------|----------|------------------------------|-------|----------|
|    |              | *                   |       | *        | *                           |       | *        | *                    |       | *        | *                            |       | *        |
| SN | Genotypes    | Mean                | $b_i$ | $S^2d_i$ | Mean                        | $b_i$ | $S^2d_i$ | Mean                 | $b_i$ | $S^2d_i$ | Mean                         | $b_i$ | $S^2d_i$ |
| 1  | BHU-25 (L1)  | 42.32               | 0.54  | 22.25    | 4.17                        | 0.6   | 0.36     | 34.42                | 2.1   | -1.08    | 22.57                        | 3.7   | -0.13    |
| 2  | WB-02 (L2)   | 44.22               | 0.48  | 6.13     | 5.58                        | -0.36 | -0.05    | 36.5                 | 1.48  | 0.56     | 22.24                        | 3.65  | -0.01    |
| 3  | BHU-31 (L3)  | 48.23               | 0.44  | 8.19     | 5.21                        | -0.02 | 0.52     | 37.92                | 2.24  | 17.11    | 22.9                         | 2.87  | -0.15    |
| 4  | HD-3721 (L4) | 40.87               | 0.72  | 33.78    | 4.5                         | 0.49  | -0.12    | 37.83                | 2.33  | 14.73    | 22.43                        | 4.74  | -0.21    |

|    |                    |       |       |       |      |       |       |       |       |       |       |       |       |
|----|--------------------|-------|-------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| 5  | PWB-725 (L5)       | 45.63 | 0.44  | 12.92 | 4.44 | 0.13  | -0.03 | 35    | 1.9   | -1.64 | 23.01 | 2.18  | 0.13  |
| 6  | CRD GEHNU1 (L6)    | 49.83 | 1.79  | -2.39 | 5.55 | -0.13 | 0.2   | 41.17 | -0.51 | 41.57 | 23.57 | 0.95  | 0.07  |
| 7  | PBW-550 (L7)       | 44.5  | 0.67  | 34.49 | 4.77 | -0.69 | 0.2   | 37.58 | 2.38  | 14.93 | 23.64 | 1.51  | -0.13 |
| 8  | PBW-677 (L8)       | 47.47 | 0.39  | 0.61  | 5.08 | 0.11  | 0.36  | 38.33 | 1.23  | 67.68 | 23.15 | 2.93  | 0.35  |
| 9  | PBW-822 (L9)       | 40.24 | -0.03 | -1.66 | 4.62 | 0.44  | 1.05  | 41.75 | 1.58  | 11.37 | 22.75 | 0.55  | 4.74  |
| 10 | HD-3117 (L10)      | 39.71 | -0.24 | -2.54 | 4.63 | 0.77  | 0.29  | 38.25 | 2.31  | 17.46 | 22.22 | 4.84  | -0.26 |
| 11 | DBW-173 (L11)      | 41.46 | 0.59  | 26.03 | 4.28 | 0.57  | 0.41  | 34    | 0.23  | 0.97  | 23.93 | 1.61  | 0.13  |
| 12 | DH-3086 (L12)      | 41.19 | 2.06  | 36.77 | 5.02 | 2.35  | -0.11 | 36.79 | 0.61  | 38.38 | 23.87 | 1.77  | 0.1   |
| 13 | DBW-222 (L13)      | 51.3  | 0.82  | 2.4   | 5.71 | 1.16  | 1.01  | 40.29 | 1.85  | 16.62 | 23.49 | 2.43  | -0.19 |
| 14 | CSW-18 (L14)       | 46.32 | 0.31  | -3.28 | 5.29 | 1.87  | 0.35  | 44.25 | 1.5   | 1.5   | 22.73 | 4.46  | 0.5   |
| 15 | PBW-757 (L15)      | 48.59 | 0.22  | -3.19 | 5.18 | -0.2  | 0.33  | 35.5  | 0.82  | 40.59 | 22.02 | 3.28  | 0.09  |
| 16 | PBW ZN1 (Tester 1) | 46.84 | 0.55  | 23.56 | 4.89 | 0.58  | 0.1   | 36.25 | 2.73  | 19.62 | 22.71 | 2.55  | -0.13 |
| 17 | PBW-343 (Tester 2) | 52.01 | 0.06  | 14.23 | 5.56 | 0.25  | 0.45  | 43.67 | 0.17  | 2.5   | 22.91 | 3.45  | 0.35  |
| 18 | HD-3326 (Tester 3) | 44.5  | 1.73  | 76.5  | 6.08 | 0.03  | 0.31  | 38.92 | 2.24  | 20.17 | 22.67 | 6.63  | -0.13 |
| 19 | HD-2967 (Check 1)  | 48.07 | -0.17 | 0.37  | 4.49 | 1.12  | 0.83  | 43.17 | 0.39  | 6.52  | 23.65 | 0.87  | 0.15  |
| 20 | DBW-187 (Check 2)  | 48.69 | 0.92  | 10.53 | 5.04 | 2.02  | 0.37  | 43.5  | 0.13  | 1.19  | 23.17 | 3.35  | 0.47  |
| 21 | NORMAN (Check 3)   | 43.11 | 0.18  | 2.36  | 4.99 | -0.24 | -0.04 | 36.29 | 0.83  | 52.21 | 23.23 | 3.01  | -0.1  |
| 22 | BORLAUG-100(chk4)  | 46.61 | 0.21  | 1.59  | 6.6  | 0.85  | 0.39  | 42.17 | 0.38  | 1.53  | 23.51 | 3.23  | 0.04  |
| 23 | BHU-25 X PBW ZN1   | 51.1  | 0.54  | -1.75 | 8.27 | 1.65  | 0.84  | 38.08 | -1.03 | -2.38 | 25.18 | 1.37  | -0.23 |
| 24 | BHU-25 X PBW-343   | 54.9  | 0.66  | 3.49  | 7.97 | 1.27  | -0.03 | 39.5  | -0.47 | 18.71 | 24.42 | 0.24  | -0.28 |
| 25 | BHU-25 X HD-3326   | 54.37 | 2.46  | 15.93 | 7.87 | 1.03  | 0.85  | 40.88 | 1.66  | 13.11 | 24.28 | -0.7  | 0     |
| 26 | DBW-173X PBW ZN1   | 51.7  | 2.24  | 1.83  | 7.59 | 1.61  | 0.23  | 35.67 | 2.13  | -1.96 | 25.27 | 0.42  | -0.3  |
| 27 | DBW-173X PBW-343   | 53.14 | 2.91  | 22.53 | 9.06 | 1.07  | 0.63  | 35.17 | 2.03  | -2.09 | 24.61 | -2.85 | -0.25 |
| 28 | DBW-173X HD-3326   | 53.86 | 1.27  | -1.97 | 8.16 | 1.07  | 0.18  | 43.33 | 1.7   | 13.17 | 24.76 | 0.96  | -0.17 |
| 29 | DH-3086X PBW ZN1   | 54.57 | 1.09  | 29.52 | 7.1  | 2.09  | 1.6   | 38.25 | 1.32  | -1.95 | 24.75 | -1.77 | -0.06 |
| 30 | DH-3086X PBW-343   | 57.15 | 0.88  | -0.3  | 7.59 | -0.2  | 3.64  | 38.25 | 1.25  | 21.29 | 25.17 | -0.57 | -0.3  |

|    |                       |       |       |       |      |       |       |       |       |       |       |       |       |
|----|-----------------------|-------|-------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| 31 | DH-3086X<br>HD-3326   | 54.21 | 1.13  | 9.74  | 7.75 | 1.58  | 0.17  | 38.79 | 0.77  | 1.14  | 25.39 | 0.01  | -0.1  |
| 32 | DBW-222X<br>PBW ZN1   | 58.05 | 0.13  | -1.08 | 9.49 | 0.97  | -0.09 | 34.88 | 0.68  | 0.2   | 25.53 | 1.17  | -0.22 |
| 33 | DBW-222X<br>PBW-343   | 53.94 | -0.19 | 1.26  | 8.57 | 0.67  | 0.85  | 40.08 | -0.29 | 85.04 | 25.94 | 0.95  | -0.2  |
| 34 | DBW-222X<br>HD-3326   | 54.44 | -0.09 | 3.52  | 7.22 | 1.2   | -0.07 | 37.63 | -1.05 | 1.86  | 24.96 | -0.26 | 0.02  |
| 35 | CSW-<br>18XPBW ZN1    | 54.52 | 1.76  | 1.24  | 8.11 | 0.9   | 0.36  | 38.79 | 0.88  | 4.74  | 24.59 | -1.7  | -0.1  |
| 36 | CSW-<br>18XPBW-343    | 57.16 | 0.9   | 5.27  | 8.33 | 1.27  | 2.06  | 37.88 | -0.85 | 27.8  | 24.92 | 0.25  | -0.28 |
| 37 | CSW-18XHD-<br>3326    | 56.14 | 0.65  | 0.66  | 7.89 | 1.42  | 1.48  | 39.42 | 1.55  | -1.47 | 25.58 | 0.91  | -0.02 |
| 38 | PBW-757X<br>PBW ZN1   | 56.41 | 0.83  | 26.39 | 8.44 | 0.73  | 1.59  | 38.21 | -0.79 | 19.3  | 25.82 | 1.73  | -0.19 |
| 39 | PBW-757X<br>PBW-343   | 53.67 | 2.01  | -2.15 | 7.67 | -0.27 | 1.25  | 37.71 | 1.03  | -1.61 | 25.34 | 0.16  | -0.21 |
| 40 | PBW-757X<br>HD-3326   | 51.67 | 1.5   | 2.5   | 7.67 | 0.57  | 0.08  | 38.63 | 0.11  | 2.71  | 25.43 | 0.71  | -0.26 |
| 41 | BHU-31 X<br>PBW ZN1   | 51.22 | 0.38  | 12.73 | 6.79 | 1.49  | 0.05  | 45.79 | 0.94  | 0.24  | 24.85 | 1.38  | -0.28 |
| 42 | BHU-31 X<br>PBW-343   | 49.3  | 1     | 0.47  | 6.35 | 0.96  | 0.13  | 41.79 | -0.33 | 48.49 | 24.82 | 1.49  | -0.3  |
| 43 | BHU-31 X<br>HD-3326   | 50.24 | 1.38  | -1.56 | 6.65 | 1.77  | 0.11  | 44.42 | 1.34  | -1.7  | 24.55 | 0.53  | -0.15 |
| 44 | WB-02 X<br>PBW ZN1    | 52.98 | 1.5   | -3.22 | 7.83 | 0.63  | 1.14  | 40.92 | 1.84  | 7.71  | 24.65 | -0.62 | 0.08  |
| 45 | WB-02 X<br>PBW-343    | 54.91 | 1.4   | -1.25 | 7.41 | 2.01  | 0.61  | 40.08 | 1.64  | 20.16 | 24.84 | -0.12 | -0.27 |
| 46 | WB-02 X HD-<br>3326   | 49.86 | 0.93  | 2.58  | 6.71 | 2.62  | 1.53  | 45.83 | 1     | -1.03 | 24.41 | -0.47 | -0.21 |
| 47 | BHU-31 X<br>PBW ZN1   | 50.81 | 2.42  | -0.86 | 7.42 | 0.77  | 0.11  | 42.08 | 2.1   | 0.29  | 24.97 | -1.02 | -0.12 |
| 48 | BHU-31 X<br>PBW-343   | 51.85 | 2.7   | 4.03  | 7.39 | 2.06  | 0.27  | 40.17 | 1.83  | -1.77 | 24.37 | -0.26 | 0.26  |
| 49 | BHU-31 X<br>HD-3326   | 55.44 | 1.51  | -0.86 | 7.54 | 2.7   | -0.07 | 38.25 | 1.44  | 51.86 | 23.96 | -0.78 | -0.18 |
| 50 | HD-3721 X<br>PBW ZN1  | 53.11 | 1.79  | 23.67 | 7.96 | 2.45  | -0.06 | 45.67 | 0.95  | 2.32  | 25.28 | 1.95  | -0.21 |
| 51 | HD-3721 X<br>PBW-343  | 53.53 | 1.58  | -3.31 | 6.84 | 1.61  | 0.02  | 42.08 | -0.08 | 83.89 | 24.27 | -1.42 | -0.28 |
| 52 | HD-3721 X<br>HD-3326  | 53.93 | 1.37  | 26.93 | 8.63 | 0.94  | 0.28  | 41.08 | 1.88  | 4     | 24.74 | 0.65  | -0.24 |
| 53 | PWB-725 X<br>PBW ZN1  | 52.4  | 1.3   | 22.64 | 7.55 | 1.86  | 0.07  | 43.33 | 0.3   | 3.61  | 24.07 | -1.21 | -0.28 |
| 54 | PWB-725 X<br>PBW-343  | 53.93 | -0.28 | -1.13 | 7.61 | 2.05  | 0.42  | 43.08 | 0.21  | -0.89 | 25.02 | 0.84  | -0.29 |
| 55 | PWB-725 X<br>HD-3326  | 53.19 | 2.71  | 13.31 | 8.34 | 1.01  | -0.1  | 42.92 | 1.64  | 1.82  | 24.24 | 0.59  | 0.12  |
| 56 | CRDGEHNU1<br>X PBWZN1 | 57.2  | -0.1  | 18.59 | 8.43 | 2.01  | 0.82  | 38.71 | -0.48 | 18.91 | 24.61 | -0.82 | -0.2  |

|    |                         |       |      |       |      |       |       |       |       |       |       |       |       |
|----|-------------------------|-------|------|-------|------|-------|-------|-------|-------|-------|-------|-------|-------|
| 57 | CRDGEHNU1<br>X PBW343   | 57.7  | 0.17 | 58.27 | 8.19 | 1.28  | 0.02  | 34.33 | 1.59  | 11.87 | 24.67 | 0.86  | -0.2  |
| 58 | CRDGEHNU1<br>X HD-3326  | 54.91 | 1.14 | 14.74 | 7.38 | 0.74  | 0.21  | 41.08 | 0.99  | 42.87 | 24.5  | -1.09 | -0.27 |
| 59 | PBW-550X<br>PBW ZN1     | 55.73 | 1.28 | -0.58 | 7.93 | -0.55 | -0.03 | 38.92 | 1.6   | 23.24 | 25    | -0.22 | -0.3  |
| 60 | PBW-550X<br>PBW-343     | 54.38 | 0.72 | 4.89  | 8.48 | 0.7   | 1.07  | 38.42 | -0.95 | -0.68 | 24.47 | -0.62 | -0.22 |
| 61 | PBW-550X<br>HD-3326     | 57.36 | 0.57 | -3.3  | 8.38 | 0.73  | 0.86  | 40.67 | 0.79  | 1.06  | 25.08 | 1.54  | -0.03 |
| 62 | PBW-<br>677XPBW<br>ZN1  | 51.42 | 2.91 | 14.07 | 8    | 1.49  | 0.88  | 34.54 | 1.63  | 0.38  | 24.35 | -1.69 | -0.28 |
| 63 | PBW-<br>677XPBW-<br>343 | 54.91 | 0.21 | -0.05 | 8.35 | 0.84  | 0.19  | 30.92 | 1.28  | 8.48  | 25.92 | 0.54  | 0.36  |
| 64 | PBW-<br>677XPBW-<br>343 | 54.03 | 1.79 | 29.94 | 8.07 | 2.29  | 0.88  | 38.79 | 1.29  | 42.94 | 24.77 | -1.6  | 0.22  |
| 65 | PBW-822X<br>PBW ZN1     | 57.74 | 1.51 | 22.67 | 9.08 | 0.39  | 1.12  | 40.83 | 1.69  | 20.84 | 25.08 | 1.17  | 0.27  |
| 66 | PBW-822X<br>PBW-343     | 57.47 | 0.61 | 23.48 | 8.31 | 0.75  | 0.39  | 35.83 | 0.21  | 4.01  | 24.75 | 0.23  | -0.19 |
| 67 | PBW-822X<br>HD-3326     | 54.61 | 1.15 | 19.69 | 8.33 | 1.16  | -0.15 | 39.33 | 1.14  | -0.66 | 25.58 | 1.56  | 1.79  |
|    | <b>Grand Mean:</b>      | 45.99 |      |       | 6.25 |       |       | 40.53 |       |       | 24.2  |       |       |
|    | <b>SE±</b>              | 0.8   |      |       | 0.07 |       |       | 0.96  |       |       | 0.08  |       |       |
|    | <b>C.D.1%:</b>          | 2.06  |      |       | 1.09 |       |       | 2.46  |       |       | 0.21  |       |       |

### Breeding Implications of Stability

The identified materials can serve as parents in subsequent crossing and selection cycles. In particular, high-yielding hybrids with favorable stability parameters can be crossed with stable parental materials such as DBW-173 or PBW ZN1 to combine productivity with predictable adaptation. However, such crosses should be validated through additional generations and multi-environment trials before any cultivar-level recommendation is made. Stability analysis should therefore be integrated with heritability, combining ability, disease resistance, agronomic suitability and grain-quality assessment in a complete breeding strategy.

### CONCLUSION

Evaluation of 67 wheat genotypes across three Nigerian environments revealed substantial variation in mean performance and stability for yield and yield-related traits. No single genotype was simultaneously superior and stable for all traits. DH-3086 × PBW-343 and DBW-222 × PBW ZN1 were particularly promising for grain yield because they combined relatively high mean performance with comparatively favorable stability parameters. DBW-173 and PBW ZN1 showed relatively low environmental responsiveness and moderate productivity, making them useful potential parents for improving adaptation. Several hybrids, including HD-3721 × PBW-343 and PBW-550 × PBW-343, were promising for chlorophyll content. Overall, the results support the use of multi-environment stability analysis as a component of wheat breeding programmes in Nigeria. The most promising genotypes identified in this study should be subjected to further replicated and multi-season testing before release or broad recommendation.

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