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**V Koul**
Division of Plant Breeding and Genetics, FoA Sher-e-Kashmir university of Agricultural Sciences and Technology Main Campus, Chatha, Jammu & Kashmir, India

**SK Mondal**
Division of Plant Breeding and Genetics, FoA Sher-e-Kashmir university of Agricultural Sciences and Technology Main Campus, Chatha, Jammu & Kashmir, India

**Corresponding Author:**
**V Koul**
Division of Plant Breeding and Genetics, FoA Sher-e-Kashmir university of Agricultural Sciences and Technology Main Campus, Chatha, Jammu & Kashmir, India

# Stability analysis of heat tolerant bread wheat (*Triticum aestivum* L.) genotypes

**V Koul and SK Mondal**

**Abstract**

The present study entitled, "Stability analysis of heat tolerant bread wheat (Triticum aestivum L.) genotypes" was carried out at Research farm of Sher-e-Kashmir university of Agricultural Sciences and Technology, Jammu during Rabi 2016-17 to evaluate the performance of 20 heat tolerant bread wheat genotypes under three different dates of sowing i.e. Early, Normal and Late in a Randomized Block Design with three replications having a plot size of 0.75 x 1.5 m. The analysis of variance revealed that the mean sum of squares due to environment was found to be significant for twelve traits under study. Mean sum of squares due to genotype was found to be significant for all the traits except for No. of effective tillers/plant, Grain yield/plant, Canopy temperature depression and Chlorophyll content. Environment and Genotype x Environment E + (G x E) component of variance tested against pooled error was found to be significant for all the traits except Grain filling duration and Chlorophyll content. The mean performance for grain yield/plant under early, normal and late sowing conditions which ranged from 12.54-25.44 g, 9.94-21.4 g and 4.13-9.8 g respectively, with an overall mean of 18.98, 15.5 and 6.68 g under early, normal and late sowing respectively.

Stability parameters following joint regression analysis revealed that the genotypes viz., RAJ 3765, RSP 561, J- 07- 47, GW-2008-153 and DPW-621-50 have higher means than general mean and regression coefficient greater than unity are stable and suitable for high performance environments. Genotypes HD 3043, WR 544, NIAW 34, and HW-2012-476 have higher means than general mean and regression coefficient less than unity are stable and suitable for low performance environments. Environmental index and mean performance values indicated that early and normal sowing environments are favorable, whereas late environment is unfavorable for genotypes. The genotypes emerged as stable genotypes could be used as such or to develop new genotypes with combination of stable characters to combat the stress due to terminal heat in wheat.

**Keywords:** Stability, bread wheat, terminal heat, stress, regression

## Introduction

Wheat (*Triticum aestivum* L.) belonging to family *Poaceae* is one of the largest cereal crop of the world, is a most important staple food of about two billion people (36% of the world population), and also it is the second most important source of food and income after rice in India. It is most widely grown crop globally with more than 220 million hectares of crop land producing 715 million tonnes of food grains with a productivity of 3.2 t/ha (FAO,2015). Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally (Breiman and Graur, 1995) [2].

During the last decade, we have witnessed globally a decline in annual growth rate in wheat production associated with an unprecedented increase in the price of food grains. Heat is an important stress that restricts wheat production and productivity, both during germination and grain filling periods because wheat crop is adapted for cultivation in regions with cooler climate conditions.

High temperature (>30 $^0$C) at the time of grain filling is found one of the major causes of yield reduction in wheat in many parts of the world, especially in tropical and sub-tropical countries. This type of stress is called "Terminal heat stress" and it largely refers to a rise in temperature at the time of grain growth (grain filling duration, GFD). Heat stress is a problem in 40% of temperate environments, which covers more than 36 mha (Reynolds *et al.*, 2001, Hays *et al.*, 2007) [16, 6]. Wheat heat stress is more harmful during reproductive phase due to direct effect on grain number and dry weight. Studies conducted in India suggest that with the possible rise of 1 $^0$C temperature throughout the growing period during 2010-2030, there may be a loss of 4-5 million tonnes in wheat production (Aggarwal, 2008) [2]. A brief period of exposure to high ambient (>35 $^0$C) can drastically reduce grain yield in wheat (Hawker and Jenner, 1993) [5] because of induction of early senescence and acceleration of grain filling activities in wheat (Paulsen, 1994) [15] due to shortening of grain filling duration and constriction of carbon

Assimilation (Stone, 2001) [18]. The potential trait for screening wheat for heat tolerance includes depression of canopy temperature, flag-leaf, stomatal conductance and photosynthetic rate (Farooq *et al.*, 2011) [3].
In the state of Jammu and Kashmir, around 70 percent area under wheat in J&K state is rainfed with no dependable source of irrigation the situation worsens when accompanied by heat conditions during grain filling. In Jammu region of J&K state, wheat is also grown in areas with sub-tropical climate and therefore, terminal heat stress is considered as one of the major constraint to wheat production in this area and, also one of the major causes of yield loss. Keeping these things in mind the present study was undertaken to evaluate the stable heat tolerant bread wheat genotypes, which are suitable for the need of the wheat growing areas of Jammu region.

## Material and Methods

The experimental material comprised 16 true breeding lines received from IIWBR, Karnal and 4 check lines maintained in Division of Plant breeding and Genetics, Chatha. The experiment was laid out in Randomized Block Design (RBD) with three replications. Each genotype was planted in a three-row plot having a gross area of 0.75 m x 1.5 m. The sowings were done during Rabi 2016-17 in three different environments created by three different dates of sowing i.e. 5$^{th}$ of November (Early sowing), 21$^{st}$ of November (Normal sowing) and 6$^{th}$ of December (Late sowing).
Recommended standard cultural and agronomic practices were followed to raise the healthy crop. Data was recorded on five randomly selected plants from each replications in each environment for days to heading, days to maturity, plant height, grain filling duration, no. of grains/spike, 1000 grains wt., no. of effective tillers/plant and grain yield/plant. Canopy temperature was recorded on each plot (3 rows) using a handheld infrared thermometer (IMPAC Electronic GmbH, Germany). Chlorophyll content was recorded using chlorophyll meter/SPAD-502 (Soil Plant Analysis Development (SPAD) Section, Minolta Camera Co, Osaka, Japan. The Starch content was estimated by using phenol sulphuric acid method while the Protein content was estimated by Lowry method which is an extension of the biuret method. The G x E interaction was quantified by Eberhart and Russell model (1966). Field was irrigated at regular intervals depending upon the rainfall and recommended standard cultural and agronomic practices were followed to raise the healthy crop.

## Results and Discussion

Joint regression analysis of variance for yield and its components traits is given in Table 1. Mean sum of squares due to genotypes were found to be significant for all the traits except No. of effective tillers/plant, Grain yield/plant, Canopy temperature depression and Chlorophyll content and mean sum of squares due to environment were found to be significant for all the traits. Mean sum of squares due to E + (G x E) were found to be significant for all the traits except Grain filling duration and Chlorophyll content. Genotype and environment interactions were found to be significant for Plant height, 1000 grain wt. and Protein content whereas mean sum of squares due to environment (linear) were significant for all the traits. G x E (linear) was found to be significant for Plant height, 1000 grain wt., Canopy temperature depression, Starch and Protein content. Pooled deviation was found to be significant for Days to maturity and Grain yield/plant. Similar findings were reported by Mahak *et al.*, 2002; Mondal and Khajuria 2002; Kheiralla *et al.*, 2004; Nagarajan, 2005; Mahmoud, 2006; Hamam *et al.*, 2009; Tripura *et al.*, 2011) [11, 12, 9, 14, 10, 4, 19].

**Table 1:** Estimation of mean squares for different Yield and yield contributing traits under different environments in wheat

Mean sum of squares

| Source of Variation | d.f | Days to heading | Days to maturity | Plant height | No. of eff. Tillers/plant | Grain filling duration | No. of grains/spike |
|---|---|---|---|---|---|---|---|
| Genotypes | 19 | 21.996 ** | 7.16 * | 25.29** | 0.30 | 5.23 ** | 15.85 * |
| Env. + (Geno. x Env.) | 40 | 125.99 ** | 130.34 ** | 47.49 ** | 8.60 ** | 2.40 | 30.84 ** |
| Environments | 2 | 2354.54 ** | 2533.38 ** | 802.87 ** | 167.23 ** | 8.42 * | 407.79 ** |
| Geno. x Env. | 38 | 8.701 | 3.871 | 7.74 * | 0.26 | 2.09 | 11.00 |
| Environments (Lin.) | 1 | 4709.08 ** | 5066.75 ** | 1605.74 ** | 334.47** | 16.84 ** | 815.58 ** |
| Geno. x Env.(Lin.) | 19 | 10.04 | 5.17 | 12.29 ** | 0.26 | 2.40 | 14.28 |
| Pooled Deviation | 20 | 6.99 | 2.43 * | 3.02 | 0.24 | 1.68 | 7.38 |
| Pooled Error | 114 | 9.49 | 3.42 | 7.17 | 0.42 | 2.53 | 10.12 |
| Total | 59 | 92.50 | 90.67 | 40.34 | 5.93 | 3.39 | 26.01 |

* = Significant at P = 0.05
** = Significant at P = 0.01

Mean sum of squares

| Source of Variation | d.f | 1000 grain wt. | Grain yield/plant | Canopy temp. depression | Chlorophyll content | Starch content | Protein content |
|---|---|---|---|---|---|---|---|
| Genotypes | 19 | 10.29 ** | 4.88 | 0.11 | 27.00 | 16.09 ** | 0.16** |
| Env. + (Geno. x Env.) | 40 | 15.78 ** | 42.37 ** | 14.71 ** | 53.25 | 39.88 ** | 0.92** |
| Environments | 2 | 260.61 ** | 803.92 ** | 292.63 ** | 505.88 ** | 684.00 ** | 16.36** |
| Geno. x Env. | 38 | 2.90 * | 2.29 | 0.09 | 29.42 | 5.98 | 0.11** |
| Environments (Lin.) | 1 | 521.22 ** | 1607.84 ** | 585.26 ** | 1011.77** | 1368.00 ** | 32.72** |
| Geno. x Env.(Lin.) | 19 | 4.33 ** | 1.76 | 0.12 * | 29.96 | 8.36 * | 0.19** |
| Pooled Deviation | 20 | 1.39 | 2.68* | 0.05 | 27.44 | 3.43 | 0.03 |
| Pooled Error | 114 | 5.46 | 3.69 | 0.14 | 18.86 | 4.82 | 0.16 |
| Total | 59 | 14.01 | 30.30 | 10.01 | 44.79 | 32.22 | 0.67 |

* = Significant at P = 0.05
** = Significant at P = 0.01

Stability analysis helps in characterizing the performance of genotypes in different environments and enable plant breeders in selecting desirable genotypes while, instability is the result of cultivars response in different environments which usually indicates a high interaction between genetic and environmental factors. As per Eberhart and Russell model (1966), three parameters desired mean, regression coefficient ($b_i$ =1), and minimum deviation from the regression line ($S^2d_i$ = 0) exhibit better general adaptability across environments and are considered as a stable ones. Mean performance and stability parameters of various yield and yield attributing traits are depicted in Table 2 and 3 respectively.

**Table 2:** Mean performance of Yield and yield attributing traits in wheat under different sowing environments

| Genotype | Days to heading (No.) DD | | | Days to maturity (No.) | | | Plant height(Cm) | | | No of Eff. Tillers/Plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E | N | L | E | N | L | E | N | L | E | N | L |
| HD 3043 | 118 | 104 | 92 | 151 | 142 | 127 | 88.3 | 85.3 | 76.18 | 12 | 10 | 8 |
| RAJ 3077 | 119 | 107 | 94 | 152 | 145 | 126 | 89.8 | 86.8 | 80.6 | 11 | 13 | 8 |
| DBW 125 | 107 | 104 | 93 | 144 | 142 | 126 | 89.07 | 86.07 | 81.2 | 13 | 11 | 6 |
| WSM 135 | 108 | 105 | 93 | 145 | 143 | 128 | 96.5 | 93.5 | 79.31 | 12 | 12 | 7 |
| WR 544 | 117 | 114 | 91 | 150 | 148 | 128 | 88.4 | 92.52 | 79.82 | 10 | 11 | 7 |
| NWL 9 | 118 | 115 | 96 | 152 | 150 | 128 | 91.4 | 88.81 | 81.1 | 12 | 12 | 6 |
| RAJ 3765 | 105 | 115 | 92 | 142 | 149 | 127 | 98.06 | 91.6 | 78.32 | 12 | 9 | 6 |
| NIAW 34 | 117 | 114 | 95 | 150 | 148 | 130 | 91.2 | 82.6 | 76.89 | 11 | 10 | 7 |
| RSP 561 | 107 | 102 | 95 | 144 | 140 | 130 | 97.52 | 85.4 | 78 | 12 | 11 | 8 |
| NIAW 2477 | 115 | 112 | 95 | 150 | 148 | 129 | 84.3 | 81.3 | 73.91 | 13 | 12 | 6 |
| RAJ 4360 | 112 | 109 | 93 | 148 | 146 | 125 | 83.9 | 80.9 | 73.63 | 12 | 12 | 8 |
| VL 946 | 118 | 115 | 94 | 150 | 148 | 126 | 93.4 | 90.4 | 77.32 | 12 | 10 | 7 |
| J- 07- 47 | 118 | 115 | 93 | 151 | 149 | 128 | 86.4 | 83.4 | 82.22 | 13 | 11 | 6 |
| HW-2012-476 | 111 | 108 | 93 | 149 | 147 | 128 | 84.8 | 81.8 | 79.18 | 12 | 12 | 6 |
| GW-2008-153 | 110 | 116 | 91 | 147 | 150 | 128 | 86.5 | 83.5 | 72.11 | 13 | 13 | 8 |
| AKAW 4702 | 119 | 116 | 94 | 151 | 149 | 127 | 88.7 | 85.7 | 77.6 | 12 | 9 | 6 |
| RWP-2011-17 | 118 | 115 | 92 | 150 | 148 | 128 | 85.21 | 79.2 | 72.94 | 12 | 12 | 7 |
| GW-2013-530 | 117 | 114 | 95 | 150 | 148 | 130 | 81.7 | 78.7 | 73.01 | 12 | 12 | 7 |
| DPW-621-50 | 106 | 103 | 95 | 143 | 141 | 129 | 96.6 | 93.6 | 78.21 | 12 | 11 | 6 |
| HD 2967 | 107 | 104 | 91 | 144 | 142 | 125 | 94.6 | 95.06 | 80.81 | 13 | 12 | 7 |
| Mean | 113 | 110 | 93 | 148 | 146 | 128 | 89.8 | 86.3 | 77.6 | 12 | 1 | 7 |

| Genotype | Grain (No.) Filling Duration | | | No. of Grains//SPIKE | | | 1000 Grains WT. (Gms) | | | Grain Yield/Plant (Gms) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E | N | L | E | N | L | E | N | L | E | N | L |
| HD 3043 | 33 | 38 | 35 | 43 | 49 | 42 | 37.2 | 35.2 | 29.18 | 19.18 | 17.05 | 9.54 |
| RAJ 3077 | 33 | 37 | 32 | 44 | 47 | 41 | 30.1 | 28.1 | 31.13 | 14.89 | 16.88 | 9.8 |
| DBW 125 | 37 | 38 | 33 | 46 | 44 | 45 | 37.58 | 32.5 | 27.61 | 21.69 | 16.13 | 7.42 |
| WSM 135 | 37 | 38 | 35 | 50 | 48 | 42 | 34.5 | 37.91 | 20.3 | 21.49 | 21.4 | 5.94 |
| WR 544 | 33 | 34 | 37 | 41 | 45 | 39 | 30.5 | 28.5 | 23.19 | 12.59 | 14.41 | 6.04 |
| NWL 9 | 34 | 35 | 32 | 49 | 50 | 38 | 32.42 | 30.42 | 26.2 | 19.42 | 17.6 | 6.36 |
| RAJ 3765 | 37 | 33 | 36 | 52 | 47 | 35 | 39.91 | 30.03 | 29.52 | 25.44 | 13.8 | 6.44 |
| NIAW 34 | 33 | 34 | 35 | 42 | 35 | 37 | 27.37 | 25.37 | 27.7 | 12.54 | 9.94 | 6.76 |
| RSP 561 | 37 | 38 | 35 | 50 | 40 | 33 | 34.92 | 30.12 | 22.07 | 20.81 | 14.06 | 5.68 |
| NIAW 2477 | 34 | 35 | 34 | 43 | 48 | 31 | 32.12 | 32.92 | 22.35 | 17.42 | 18.24 | 4.13 |
| RAJ 4360 | 36 | 37 | 32 | 50 | 48 | 36 | 30.1 | 28.1 | 20.12 | 18.47 | 16.12 | 5.56 |
| VL 946 | 32 | 33 | 32 | 43 | 41 | 38 | 32.87 | 30.87 | 23.95 | 16.56 | 13.07 | 6.04 |
| J- 07- 47 | 33 | 34 | 34 | 47 | 39 | 33 | 29.75 | 27.75 | 26.72 | 17.59 | 12.1 | 5.5 |
| HW-2012-476 | 38 | 39 | 35 | 47 | 44 | 40 | 29.76 | 26.76 | 31.23 | 16.77 | 14.04 | 7.09 |
| GW-2008-153 | 36 | 34 | 37 | 51 | 49 | 49 | 33.86 | 31.86 | 21.67 | 22.47 | 20.27 | 8.22 |
| AKAW 4702 | 31 | 32 | 33 | 44 | 41 | 39 | 35.5 | 33.59 | 27.78 | 19.14 | 11.9 | 6.07 |
| RWP-2011-17 | 32 | 33 | 36 | 46 | 42 | 33 | 35.06 | 33.06 | 33.46 | 19.74 | 16.58 | 7.35 |
| GW-2013-530 | 33 | 34 | 35 | 49 | 33 | 33 | 30.63 | 27.96 | 21.81 | 17.9 | 10.94 | 5.01 |
| DPW-621-50 | 37 | 38 | 34 | 52 | 49 | 33 | 35.53 | 33.53 | 28.17 | 21.4 | 17.67 | 6.02 |
| HD 2967 | 37 | 38 | 34 | 51 | 41 | 42 | 36.36 | 35.58 | 31.13 | 24.27 | 17.57 | 8.73 |
| | | | | | | | | | | | | |
| Mean | 35 | 36 | 34 | 47 | 44 | 38 | 33.3 | 31 | 26.26 | 18.98 | 15.5 | 6.68 |

| Genotype | (ºC) Canopy temp. depression | | | (Spad Chlorophyll Units) Content | | | Starch Content (G/100g) | | | Protein Content (G/100g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | E | N | L | E | N | L | E | N | L | E | N | L |
| HD 3043 | 11.3 | 9.3 | 4.06 | 35.17 | 40.89 | 34.74 | 60.2 | 66.2 | 61.2 | 10.9 | 10.9 | 13.7 |
| RAJ 3077 | 11.8 | 10.9 | 5.9 | 38.84 | 39.06 | 37.94 | 62.4 | 68.4 | 63.2 | 10.9 | 10.9 | 13.7 |
| DBW 125 | 12.7 | 10.7 | 3.9 | 45.94 | 30.37 | 33.41 | 70.4 | 67.03 | 59.7 | 11.6 | 11.2 | 13.2 |
| WSM 135 | 12.3 | 10.3 | 5.2 | 44.64 | 41.64 | 36.54 | 66.9 | 64.9 | 55.8 | 11.9 | 11.9 | 13.6 |
| WR 544 | 12.9 | 10.1 | 5.1 | 33.37 | 53.17 | 32.34 | 66.1 | 71.1 | 63.6 | 10.8 | 10.8 | 13.9 |
| NWL 9 | 12.8 | 10.8 | 5.4 | 41.54 | 38.54 | 33.7 | 70.1 | 68.1 | 56.4 | 11.2 | 11.3 | 13.2 |
| RAJ 3765 | 12.9 | 10.9 | 5.4 | 41.14 | 38.14 | 34.54 | 75.1 | 67.2 | 61.2 | 13.2 | 12.7 | 12.9 |
| NIAW 34 | 12.02 | 10.02 | 4.8 | 32.4 | 42.94 | 36.84 | 70.03 | 68.03 | 64.6 | 11.2 | 11.6 | 13.8 |
| RSP 561 | 12.6 | 10.6 | 4.9 | 47.8 | 44.8 | 26.37 | 73.1 | 71 | 60.2 | 13.1 | 12.3 | 12.9 |
| NIAW 2477 | 12.3 | 10.3 | 5.2 | 42.06 | 44.44 | 39.8 | 70.4 | 62.8 | 62.8 | 11.8 | 11.8 | 13.5 |
| RAJ 4360 | 12.9 | 10.9 | 4.1 | 48.37 | 38.34 | 38.37 | 73 | 73.1 | 61.3 | 11.8 | 11.8 | 13.8 |
| VL 946 | 12.6 | 10.6 | 5.03 | 38.84 | 33.5 | 21.4 | 66.4 | 64.4 | 55.8 | 11.7 | 11.7 | 12.8 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| J- 07- 47 | 12.6 | 10.9 | 5.3 | 56.17 | 32.17 | 29.5 | 68.5 | 66.5 | 61.7 | 11.7 | 11.7 | 13.2 |
| HW-2012-476 | 12.3 | 10.3 | 5.4 | 42.34 | 45.37 | 33.47 | 67.5 | 65.5 | 56.8 | 11.6 | 11.6 | 13.6 |
| GW-2008-153 | 12.5 | 9.8 | 4.6 | 44.07 | 41.07 | 28.17 | 68.2 | 64.1 | 55.9 | 11.4 | 11.4 | 13.4 |
| AKAW 4702 | 12.8 | 10.8 | 5.5 | 46.8 | 44.14 | 27.5 | 64.2 | 58.2 | 53.7 | 12.3 | 12.6 | 13.7 |
| RWP-2011-17 | 12.7 | 9.9 | 5.5 | 45.7 | 35.5 | 39.94 | 69.2 | 60.4 | 52.6 | 11.7 | 11.7 | 13.6 |
| GW-2013-530 | 12.02 | 10.02 | 5.1 | 43.89 | 29.4 | 32.4 | 69.03 | 62.2 | 54.2 | 11.6 | 11.6 | 13.6 |
| DPW-621-50 | 12.6 | 10.7 | 5.7 | 47.44 | 42.7 | 34.14 | 74 | 72 | 49.9 | 12.6 | 13.1 | 11.7 |
| HD 2967 | 11.9 | 10.9 | 4.6 | 48.07 | 45.07 | 36.97 | 74.1 | 72.1 | 48.7 | 12.7 | 13.2 | 12.3 |
| Mean | 12.4 | 10.4 | 5.03 | 43.22 | 40.06 | 33.4 | 68.9 | 66.9 | 57.9 | 11.8 | 11.8 | 13.3 |

**Table 3:** Stability parameters for Yield and yield contributing traits in wheat

| **Genotype** | **Days to heading** | | | **Days to maturity** | | | **Plant Height** | | | **No. of e.tillers/plant** | | | **Grain filling duration** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Reg. Coef (bi).** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** |
| HD 3043 | 103.778 | 0.73 | 58.08** | 139.000 | 0.80 | 17.33* | 85.264 | 0.10 | -5.44 | 10.333 | 0.81** | -0.41 | 35.222 | 1.93 | -1.63 |
| RAJ 3077 | 106.667 | 0.94 | -9.39 | 141.667 | 0.93 | -3.33 | 90.072 | 0.47 | -6.57 | 9.778 | 0.83 | -0.35 | 35.000 | 0.87 | -2.51 |
| DBW 125 | 102.556 | 0.66 | 3.08 | 138.778 | 0.74 | 0.67 | 88.896 | 0.91 | 2.69 | 9.556 | 0.72 | 1.79* | 36.222 | 0.13 | 1.08 |
| WSM 135 | 104.000 | 0.78 | -9.17 | 139.667 | 0.98 | -3.34 | 82.902 | 0.62** | -6.97 | 10.222 | 1.07 | -0.39 | 35.667 | 2.25 | 2.59 |
| WR 544 | 103.444 | 0.87 | 1.23 | 140.444 | 0.95 | -0.02 | 81.847 | 0.56* | -6.95 | 10.444 | 1.14 | -0.37 | 37.000 | 0.42 | 0.87 |
| NWL 9 | 107.556 | 1.17 | -9.29 | 141.667 | 1.08 | -3.33 | 80.039 | 0.58 | -6.64 | 9.889 | 1.00 | -0.04 | 34.111 | 0.08 | -1.58 |
| RAJ 3765 | 103.444 | 0.78 | -3.71 | 138.889 | 0.82 | -1.29 | 88.618 | 1.66 | 13.83 | 10.000 | 0.91 | -0.38 | 35.444 | 2.14* | -2.53 |
| NIAW 34 | 105.667 | 1.06 | -8.67 | 140.333 | 1.11 | -3.04 | 84.778 | 1.25 | -6.40 | 10.222 | 1.07 | -0.39 | 34.667 | 1.95 | -2.19 |
| RSP 561 | 106.778 | 1.15 | 7.47 | 140.889 | 1.08 | 2.84 | 86.380 | 1.38 | -3.57 | 9.556 | 0.96 | -0.30 | 34.444 | -1.66 | -2.12 |
| NIAW 2477 | 108.778 | 1.12 | -7.37 | 142.222 | 0.98 | -1.86 | 82.542 | 1.43 | -6.28 | 10.222 | 0.96 | -0.30 | 33.444 | -0.13 | 1.08 |
| RAJ 4360 | 108.556 | 1.33 | -8.96 | 141.222 | 1.25 | -3.22 | 83.410 | 1.04 | -6.89 | 10.000 | 0.93 | 0.01 | 32.667 | 0.28 | -1.94 |
| VL 946 | 103.333 | 1.09 | -8.15 | 139.889 | 1.17 | -2.44 | 81.544 | 1.05 | -6.88 | 9.889 | 1.09 | -0.31 | 36.556 | 1.77 | -1.32 |
| J- 07- 47 | 107.778 | 1.13 | -9.34 | 141.111 | 0.96 | -3.34 | 82.043 | 1.17 | -6.94 | 10.222 | 1.07 | -0.39 | 33.333 | -0.91 | 1.43 |
| HW-2012-476 | 102.889 | 1.07 | 2.47 | 138.333 | 1.17 | 2.22 | 85.081 | 1.10 | -6.14 | 10.000 | 0.90 | -0.33 | 35.444 | 3.22 | -1.86 |
| GW-2008-153 | 103.667 | 0.94 | -9.39 | 139.444 | 0.96 | -3.34 | 86.640 | 1.10 | -1.50 | 10.222 | 1.14 | 0.41 | 35.778 | 1.27 | -2.48 |
| AKAW 4702 | 106.778 | 1.12 | -4.87 | 141.333 | 1.12 | -0.80 | 88.013 | 1.40 | -5.48 | 9.222 | 1.09 | -0.31 | 34.556 | 0.69 | -2.41 |
| RWP-2011-17 | 105.111 | 0.84* | -9.39 | 140.222 | 0.92 | -3.33 | 82.121 | 1.16 | 4.08 | 10.333 | 0.90 | -0.33 | 35.111 | 1.86 | -1.82 |
| GW-2013-530 | 112.000 | 1.15 | -9.32 | 144.111 | 1.01 | -3.34 | 84.777 | 0.62 | -4.81 | 9.778 | 1.14 | -0.37 | 32.111 | -0.51 | -0.02 |
| DPW-621-50 | 110.222 | 1.37 | -4.64 | 143.444 | 1.16 | -1.96 | 81.526 | 1.19 | -5.80 | 10.333 | 1.11 | -0.40 | 33.222 | -1.69 | 1.80 |
| HD 2967 | 103.222 | 0.70 | -8.96 | 139.222 | 0.79 | -3.25 | 87.384 | 1.20 | -6.13 | 10.222 | 1.16 | -0.22 | 36.000 | 2.06 | -1.44 |
| General mean | 105.811 | | | 140.595 | | | 84.694 | | | 10.022 | | | 34.800 | | |
| S.E. m ± | 1.9 | | | 1.1 | | | 1.2 | | | 0.34 | | | 0.91 | | |

| **Genotype** | **No of grains/spike** | | | **1000 grain wt.** | | | **Grain yield/plant** | | | **CTD** | | | **Chlorophyll content** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** |
| HD 3043 | 45.556 | -0.23 | 3.86 | 32.902 | 0.77 | -3.93 | 15.582 | 0.68 | -2.44 | 9.021 | 0.98 | -0.12 | 38.288 | 0.81 | -15.32 |
| RAJ 3077 | 44.556 | 0.06 | -9.24 | 29.477 | 1.47 | -1.56 | 13.277 | 0.83 | -0.61 | 9.541 | 0.92 | -0.11 | 41.900 | 1.71 | 208.21** |
| DBW 125 | 39.667 | 1.55 | 12.25 | 29.978 | 1.06 | 0.86 | 12.861 | 1.05 | 13.19* | 9.444 | 1.05 | -0.14 | 39.922 | 1.38 | -2.70 |
| WSM 135 | 42.333 | 1.11 | 10.38 | 28.221 | 1.98 | 0.45 | 13.356 | 1.14 | 2.95 | 9.337 | 1.04 | -0.14 | 41.944 | 1.86 | -11.66 |
| WR 544 | 45.889 | 0.81 | -9.88 | 29.658 | 0.00 | -1.33 | 14.421 | 0.91 | -3.52 | 9.479 | 0.99 | 0.05 | 44.633 | 3.18 | 52.10 |
| NWL 9 | 38.778 | 1.12 | -2.76 | 30.300 | 0.78 | -4.67 | 12.199 | 0.95 | 0.29 | 9.313 | 0.85 | 0.07 | 38.154 | 1.29 | 4.48 |
| RAJ 3765 | 46.556 | 1.78 | -6.25 | 34.320 | 1.10 | -4.06 | 16.904 | 1.30 | -2.79 | 9.129 | 1.02 | 0.00 | 43.422 | 1.68 | -11.41 |
| NIAW 34 | 45.667 | 0.57 | 8.54 | 29.784 | 0.85 | -5.20 | 14.389 | 0.96 | 0.41 | 9.374 | 0.97 | -0.11 | 36.614 | 0.75 | -2.35 |
| RSP 561 | 44.111 | 1.26 | 1.32 | 31.623 | 1.27 | -4.86 | 14.163 | 1.10 | -2.33 | 9.447 | 1.08 | -0.13 | 35.444 | 0.26 | -15.86 |
| NIAW 2477 | 40.333 | 1.69 | -8.23 | 28.308 | 0.79 | -5.16 | 12.563 | 0.98 | -3.19 | 9.367 | 0.97 | -0.13 | 37.044 | 0.84 | 12.92 |
| RAJ 4360 | 41.111 | 1.27 | -9.90 | 26.493 | 0.93** | -5.21 | 11.476 | 0.87 | -2.29 | 9.599 | 1.14 | -0.11 | 32.800 | 1.19 | 22.82 |
| VL 946 | 43.000 | 0.22 | -7.78 | 30.089 | 0.99 | -5.20 | 13.114 | 0.90 | -3.10 | 9.669 | 1.02 | -0.13 | 37.833 | 0.94 | -6.22 |
| J- 07- 47 | 42.889 | 2.10 | -2.59 | 30.756 | 0.68 | -5.05 | 14.346 | 1.19 | -1.70 | 9.359 | 1.00 | -0.09 | 37.544 | 0.77 | 10.73 |
| HW-2012-476 | 42.778 | 0.40 | -9.68 | 33.103 | 0.72* | -5.20 | 14.376 | 0.80 | -3.34 | 8.897 | 0.94 | -0.06 | 39.533 | 0.12 | -18.62 |
| GW-2008-153 | 44.444 | 1.12 | -4.78 | 29.299 | 1.23 | -1.99 | 14.607 | 1.16 | 3.93 | 9.464 | 1.07 | -0.13 | 38.656 | -0.08 | 6.86 |
| AKAW 4702 | 43.889 | 1.20** | -10.04 | 30.221 | 0.90 | -4.87 | 13.072 | 1.08 | -2.43 | 9.668 | 0.98 | -0.13 | 39.367 | -0.19 | -18.76 |
| RWP-2011-17 | 41.000 | 1.16 | -8.75 | 28.882 | 1.68 | -3.80 | 13.144 | 1.02 | -2.47 | 9.261 | 1.07 | -0.13 | 41.944 | 0.73 | -19.19 |
| GW-2013-530 | 42.222 | 1.30 | -9.74 | 28.733 | 0.82 | -5.03 | 12.498 | 1.02 | -3.48 | 9.376 | 0.96 | -0.11 | 34.300 | 0.85 | -19.17 |
| DPW-621-50 | 44.111 | 0.73 | -9.70 | 31.829 | 0.98 | -5.20 | 15.048 | 1.10* | -3.56 | 9.222 | 0.93 | 0.04 | 40.844 | 1.40 | -18.83 |
| HD 2967 | 39.333 | 0.78 | 19.98 | 30.922 | 1.00 | -5.17 | 13.036 | 0.98 | -1.01 | 9.267 | 1.00 | -0.01 | 37.562 | 0.54 | 4.74 |
| General mean | 42.911 | | | 30.245 | | | 13.722 | | | 9.362 | | | 38.888 | | |
| S.E. m ± | 1.9 | | | 0.83 | | | 1.15 | | | 0.16 | | | 3.7 | | |

| **Genotype** | **Starch content** | | | **Protein content** | | |
|---|---|---|---|---|---|---|
| | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** | **Mean** | **Reg. Coef. (bi)** | **Mean Sq. Dev ($S^2$di)** |
| HD 3043 | 65.522 | 0.50 | 7.22 | 11.956 | 1.48 | -0.13 |
| RAJ 3077 | 65.922 | 0.85 | -3.11 | 12.056 | 1.45** | -0.16 |
| DBW 125 | 68.644 | 0.90 | -3.66 | 12.744 | 0.53 | -0.12 |
| WSM 135 | 67.444 | 0.96 | -4.63 | 12.233 | 1.02** | -0.16 |
| WR 544 | 65.267 | 1.08 | -4.22 | 12.133 | 1.21** | -0.16 |
| NWL 9 | 61.167 | 1.22 | 10.46 | 12.344 | 1.11 | -0.15 |
| RAJ 3765 | 63.567 | 1.68 | 3.80 | 12.489 | 0.46 | -0.09 |
| NIAW 34 | 64.100 | 0.70 | -2.82 | 12.422 | 1.13** | -0.16 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RSP 561 | 65.833 | 0.89 | -4.24 | 12.311 | 1.30 | -0.15 |
| NIAW 2477 | 67.378 | 0.73 | -4.38 | 12.444 | 1.01 | -0.16 |
| RAJ 4360 | 65.089 | 0.83 | -4.57 | 12.267 | 0.83** | -0.16 |
| VL 946 | 61.278 | 0.72 | -0.24 | 12.611 | 1.11 | -0.15 |
| J- 07- 47 | 62.433 | 1.55 | 1.37 | 12.444 | 0.63* | -0.16 |
| HW-2012-476 | 64.356 | 0.78 | 3.37 | 12.167 | 1.40 | -0.15 |
| GW-2008-153 | 63.978 | 0.84 | -4.30 | 11.822 | 1.35 | -0.14 |
| AKAW 4702 | 66.500 | 0.98 | -0.42 | 12.133 | 0.99 | -0.15 |
| RWP-2011-17 | 67.467 | 0.86 | -4.31 | 12.544 | 0.76 | -0.06 |
| GW-2013-530 | 62.711 | 0.93 | -4.66 | 12.111 | 0.98* | -0.16 |
| DPW-621-50 | 60.122 | 1.08 | -1.05 | 12.400 | 1.09 | -0.15 |
| HD 2967 | 64.056 | 1.9* | -4.35 | 12.511 | 0.18 | 0.04 |
| General mean | 64.642 | | | 12.307 | | |
| S.E. m ± | 1.30 | | | 0.10 | | |

The mean performance for different characters Early, Normal and Late sowing conditions revealed that wide range of estimates for characters under study. Under Early sowing, conditions the grain yield varied from 12.54 to 25.44 g with a mean value of 18.98 g. Maximum and minimum values for grain filling period were found to be 38 and 31 days, respectively, with an average value of 35 days. Similarly, for 1000 grain weight the minimum and maximum values were found to be 27.37 and 39.91 g, respectively with an average value of 33.3 g. Maximum and minimum values for days to heading were found to be 119 and 105 days, respectively, with an average value of 113 days. Similarly, for days to maturity maximum and minimum values were found to be 152 and 142 days, respectively, with an average value of 148 days. Plant height, with an average value of 89.8 cm, varied from 81.7 to 98.06 cm. No. of effective tillers/plant varied from 10 to 13 tillers with a mean value of 12. Maximum and minimum values for No. of grains/spike were found to be 52 and 41 grains, respectively, with an average value of 47 grains. Among the physiological traits studied, CTD ranged from 11.3 to 12.9 $^0$C with an average value of 12.4 $^0$C while Chlorophyll content ranged from 32.4 to 56.17 SPAD units with an average value of 43.22. In case of biochemical traits, the Starch content ranged from 60.2 to 75.1% with an average value of 68.9% while Protein content ranged from 10.8 to 13.2% with an average value of 11.8%.

Under Normal sowing, conditions the grain yield varied from 9.94 to 21.4 g with a mean value of 15.5 g. Maximum and minimum values for grain filling duration were found to be 39 and 32 days, respectively, with an average value of 36 days. Similarly, for 1000 grain weight the minimum and maximum values were found to be 25.37 and 37.91 g, respectively with an average value of 31 g. Maximum and minimum values for days to heading were found to be 116 and 102 days, respectively, with an average value of 110 days. Similarly, for days to maturity maximum and minimum values were found to be 150 and 140 days, respectively, with an average value of 146 days. Plant height, with an average value of 86.3 cm, varied from 78.7 to 95.06 cm. No. of effective tillers/plant varied from 9 to 13 tillers with a mean value of 11. Maximum and minimum values for No. of grains/spike were found to be 50 and 33 grains, respectively, with an average value of 44 grains. Among the physiological traits studied, CTD ranged from 9.3 to 10.9 $^0$C with an average value of 10.4 $^0$C while Chlorophyll content ranged from 29.4 to 53.17 SPAD units with an average value of 40.06. In case of biochemical traits, the Starch content ranged from 58.2 to 73.1% with an average value of 66.9% while Protein content ranged from 10.8 to 13.2% with an average value of 11.7%.

Under Late sowing, conditions the grain yield varied from 4.13 to 9.8 g with a mean value of 6.68 g. Maximum and minimum values for grain filling duration were found to be 37 and 32 days, respectively, with an average value of 34 days. Similarly, for 1000 grain weight the minimum and maximum values were found to be 20.12 and 33.46 g, respectively, with an average value of 26.26 g. Maximum and minimum values for days to heading were found to be 96 and 91 days, respectively, with an average value of 93 days. Similarly, for days to maturity maximum and minimum values were found to be 130 and 125 days respectively, with an average value of 128 days. Plant height, with an average value of 77.6 cm, varied from 72.11 to 82.22 cm. No. of effective tillers/plant varied from 6 to 8 tillers with a mean value of 7. Maximum and minimum values for No. of grains/spike were found to be 49 and 31 grains, respectively, with an average value of 38 grains. Among the physiological traits studied, CTD ranged from 3.9 to 5.9 $^0$C with an average value of 5.03 $^0$C while Chlorophyll content ranged from 21.4 to 39.94 SPAD units with an average value of 33.4. In case of biochemical traits, the Starch content ranged from 48.7 to 64.6% with an average value of 57.9% while Protein content ranged from 11.7 to 13.9% with an average value of 13.3%. These findings are in agreement with the findings of several researchers like Sharma & Tandon, 1997 [17]; Kaur *et al*., (2007) [8]; Jaiswal *et al*., (2010) [7] and Monu Kumar, (2012) [13] in wheat. Out of 20 genotypes, 9 showed higher mean and $b_i$ value close to unity and non-significant $S^2d_i$ values viz., RAJ 3765, RSP 561, J-07-47, GW-2008-153, DPW-621-50, HD 3043, WR 544, NIAW 34 and HW-2012-476. These genotypes also showed stable performance for different yield attributing, physiological and biochemical traits. Genotype RAJ 3765 showed stable performance for plant height, days to heading, days to maturity, no. of grains/spike, 1000 grain wt. grain filling duration, chlorophyll content and protein content. For plant height, no. of grains/spike, 1000 grain wt., canopy temperature depression, starch and protein content RSP 561 emerged as a stable genotype. Similarly J-07-47 also showed stable performance for no. of effective tillers/plant, 1000 grain wt., and protein content. Genotype GW-2008-153 showed stable performance for plant height, days to heading, no. of effective tillers/plant, no. of grains/spike, grain filling duration and canopy temperature depression. Genotype DPW-621-50 showed stable performance for no. of effective tillers/plant, no. of grains/spike, chlorophyll content and protein content. Genotype HD 3043 showed stable performance for days to heading, days to maturity, no. of effective tillers/plant, no. of grains/spike, 1000 grain wt., grain filling duration and starch content. Genotype WR 544 showed stable performance for plant height, days to heading, days to maturity, no. of effective tillers/plant, no. of grains/spike, grain filling duration, canopy temperature depression, chlorophyll content and starch content. For plant height, days to heading, days to maturity, no. of effective tillers/plant, no. of grains/spike, canopy temperature depression and protein content NIAW 34 emerged as a stable genotype. Genotype HW-2012-476 showed stable performance for plant height, days to heading, days to maturity, 1000 grain wt., grain filling duration and chlorophyll content.

Out of 20 genotypes, 18 genotypes can be predicted on the basis of absence of genotype x environment interaction, non-significant $b_i$ and $S^2d_i$ for Days to heading. Similarly, 19 genotypes can be predicted for Days to maturity, 18 genotypes can be predicted for Plant height, 19 genotypes can be predicted for No. of effective tillers/plant, 19 genotypes can be predicted for Grain filling duration, 19 genotypes can be predicted for No. of grains/spike, 18 genotypes can be predicted for 1000 grain wt., 18 genotypes can be predicted for Grain yield/plant, 20 genotypes can be predicted for Canopy temperature depression, 19 genotypes can be predicted for Chlorophyll content, 19 genotypes can be predicted for Starch content. Similarly, 13 genotypes can be predicted for Protein content. The presence of genotype x environment interaction along with significant $b_i$ was shown by genotype RWP-2011-17 for Days to heading. Similarly, genotypes WSM 135 and WR 544 for Plant height, genotype HD 3043 for No. of eff. tillers/plant, genotype RAJ 3765 for Grain filling duration, genotype AKAW 4702 for No. of grains/spike, genotypes RAJ 4360 and HW-2012-476 for 1000 grain wt., genotype DPW-621-50 for Grain yield/plant, genotype HD 2967 for Starch content and genotypes RAJ 3077, WSM 135, WR 544, NIAW 34, RAJ 4360, J-07-47 and GW-2013-530 for Protein content. The response of above number of genotypes to environmental changes can be approximately measurable. Under the unpredictable category, none of the genotypes were having presence of genotype x environment interaction along with significant $b_i$ and $S^2d_i$. However, genotype HD 3043 showed presence of genotype x environment interaction along with significant $S^2d_i$ for Days to heading. Similarly, genotype HD 3043 for Days to maturity, genotype DBW 125 for Grain yield/plant and genotype RAJ 3077 for Chlorophyll content. The response of such a number of genotypes is unpredictable.

Also, the genotype DPW-621-50 was most responsive for Days to heading as it showed highest regression coefficient. Similarly, genotype RAJ 4360 for Days to maturity, genotype RAJ 3765 for Plant height, genotype HD 2967 for No. of eff. tillers/plant, genotype HD 3043 for Grain filling duration, genotype J- 07- 47 for No. of grains/spike, genotype WSM 135 for 1000 grain wt., genotype J- 07- 47 for Grain yield/plant, genotype RAJ 4360 for Canopy temperature depression, genotype WR 544 for Chlorophyll content, genotype HD 2967 for Starch content and genotype HD 3043 for Protein content was most responsive.

Moreover, the genotype DBW 125 was least responsive for Days to heading as it exhibited lowest regression coefficient. Similarly, genotype DBW 125 for Days to maturity, genotype HD 3043 for Plant height, genotype DBW 125 for No. of eff. tillers/plant, genotype DPW-621-50 for Grain filling duration, genotype HD 3043 for No. of grains/spike, WR 544 for 1000 grain wt., genotype HD 3043 for Grain yield/plant, genotype NWL 9 for Canopy temperature depression, genotype AKAW 4702 for Chlorophyll content, genotype HD 3043 for Starch content and genotype HD 2967 for Protein content was least responsive.

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