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# Genetic Divergence in Bread Wheat $F_3$ Populations for Morphological and Yield Traits

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***Abstract:*** *To study genetic divergence for morphological traits in bread wheat $F_3$ populations, an experiment was conducted comprising 13 $F_3$ populations and 6 parental cultivars during 2011-2012 at Khyber Pakhtunkhwa (KP) Agricultural University Peshawar, Pakistan. The experiment was conducted in randomized complete block design (RCBD) with three replications. Results of the data exhibited significant ($P \leq 0.01$) variation among wheat genotypes regarding days to heading, days to maturity, flag leaf area, spikes $m^{-2}$, grains spike$^{-1}$, grain weight spike$^{-1}$, 1000-grain weight and grain yield. Differences among parental (P) cultivars and $F_3$ populations were also highly significant for all the traits. Differences among the P vs $F_3$ were also significant for all the traits except 1000-grain weight. Heritability estimates for all the traits varied between 0.72-0.97. Genetic advance were 2.30 days for days to heading, 2.25 days for days to maturity, 5.54 $cm^2$ for flag leaf area, 175.22 spikes for spikes $m^{-2}$, 12.13 for grains spike$^{-1}$, 0.42 g for grain weight spike$^{-1}$, 8.81 g for 1000-grain weight and 683.16 kg $ha^{-1}$ for grain yield. Based on the results of this study, G-98/PS-2004 and PS-2005/FS in $F_3$ populations can yield potential segregants, hence could be used in upcoming breeding programs for developing new high yielding wheat varieties.*

***Key words:*** *Genetic variability, Parameters, Triticum aestivum L.*

## I. Introduction

Wheat (*Triticum aestivum* L.) is major staple food around the world. For the population of the world, wheat is one of the vital sources of protein and energy between the nutritional cultures (Salem *et al.* 2007). Bread wheat occupies unique position among cultivated crops due to its cultivation on larger acreage as will as its bread making quality and its major share in world trade among food grains (Mangi *et al.* 2010).

The area under cultivation of wheat in Pakistan during 2010-11 is 8900.7 thousand hectares with production of 25213.8 thousand tons and with the average grain yield of 2833 kg $ha^{-1}$. The total area in wheat's cultivation in Khyber Pakhtunkhawa is 724.5 thousand hectares with production of 1155.8 thousand tons and with the average grain yield of 1595 kg $ha^{-1}$ (FBS 2010-11). Therefore, to improve the production of wheat has been superior priority of the government in Pakistan.

The efficiency of the breeding program must be increase for the purpose to cope with the increasing population and lack of cultivated land (Reynolds *et al.* 1999; Slafer *et al*. 2005). To achieve high yielding cultivars is the main aim of a breeding program. Several tolerant varieties of high yield have been developed with the efforts of the breeders and they are extensively cultivated in the country (Ambreen *et al.* 2002; Iqbal and Khan 2006).

Genetic variability and genetic potential for characters in a population helps in the production of high yielding varieties. Selection criteria will be more efficient if the breeder reported high heritability with more genetic advance (Larik *et al.* 2000). Hence to develop high yielding variety, the plant breeder makes an effort to explore genetic potential in the tested material. In order to overcome the growing demand for a swiftly growing population of food in the country and to have more yields per unit area. The plant breeders strive to develop new varieties of high yield potential and wide adaptability that can significantly promote the production of wheat. Keeping these objectives in mind the present study was performed to study performance of some newly developed F3 populations, to determine heritability for yield and its related characters and to identify populations, with potential segregants.

## II. Materials Methods

To study genetic divergence in bread wheat $F_3$ populations for morphological traits, an experiment was conducted during 2011-12 at Khyber Pakhtunkhwa(KP) Agricultural University Peshawar, Pakistan. Breeding material comprised 19 different wheat genotypes including six parental cultivars and 13 $F_3$ segregating

populations (Table I). Wheat genotypes were planted in a randomized complete block design with three replications. Each plot had four rows of five meter length with row to row spacing of 30 cm. Daily cultural practices (i.e. fertilizer application, insect pest control, land preparation and irrigation) were applied to overcome environmental variation. Fifty tillers were taken from each plot to study the variables for days to heading by measuring the days from planting to 50% heading , days to maturity from date of planting until 50 % maturation, flag leaf area by leaf area meter, spikes $m^{-2}$ by counting number of spikes per square meter , grains $spike^{-1}$ by counting number of grains, grain weight $spike^{-1}$ weighing each spike, 1000-grain weight by measuring thousand grains and then weighing them thorough balance and grain yield $ha^{-1}$.
Data were analyzed by using analysis of variance (ANOVA) technique (Steel and Torrie 1980) and MS-Excel computer software to determine differences among different wheat genotypes and for mean separation LSD test was used.

**Heritability estimation:** Genetic ($V_g$), environmental ($V_e$) variances and broad-sense heritability were estimated for different traits according to the procedure of Singh and Chaudhery (1997) as follows.

$h^2_{B.S}$ = Vg/Vp

Where:

$h^2_{B.S}$ = Heritability in broad sense

Vg = Genetic variance

Vp = Phenotypic variance

**Genetic advance:** Genetic advance for various traits was calculated by using the following formula:

G.A. = S.D. x h2 x i

Where

G.A. = Genetic advance

S.D. = Phenotypic standard deviation

$h^2$ = Estimates of heritability in fraction

i = Constant value that reflects the selection intensity.

**Table I. List of Parental cultivars and $F_3$ populations.**

| Parental cultivars | Source | $F_3$ Population | |
|---|---|---|---|
| 1:AUP-4006 | AUP | 1:PS-2004/Janbaz | 8:PS-2005/Janbaz |
| 2:Ghaznavi-98 | AUP | 2:AUP-4006/G-98 | 9:G-98/AUP-4006 |
| 3:Pirsabak-2004 | CCRI | 3:G-98/PS-2004 | 10:FS/PS-2005 |
| 4:Pirsabak-2005 | CCRI | 4:Janbaz/FS | 11:PS-2005/FS |
| 5:Janbaz | AUP | 5:FS/G-98 | 12:G-98/FS |
| 6:Fakhre sarhad | NIFA | 6:FS/PS-2004 | 13:AUP-4006/FS |
| | | 7:PS-2004/FS | |

AUP:Agriculture University Peshawar, CCRI:Cereal Crop Research Institute Nowshera, NIFA:Nuclear Institute for Food and Agriculture.

## III. Results And Discussion

**Days to heading:** Genotypes revealed significant (P≤0.01) variation for days to heading. Differences among parental cultivars, $F_3$ populations and P vs $F_3$ were significant for days to heading (Table II). Days to heading ranged from 133.0 to 138.7 among the parents while from 132.0 to 137.0 days among the $F_3$ wheat populations. Among the parental cultivars PS-2004, PS-2005 and Janbaz were early by taking 133.0, 134.0 and 134.3 days to heading respectively, while Fakhre Sarhad was late by taking 138.7 days to heading. Among the $F_3$ populations PS-2005/FS, PS-2004/AUP-4006 and PS-2005/Janbaz were early by taking 132.0, 132.7 and 133.0 days to heading, respectively. In contrast PS-2005/FS was late by taking 137.0 days to heading among the $F_3$ populations. Days to heading averaged 135.3 and 134.5 days for parents and $F_3$ populations respectively, showing a net difference of 0.8 days in heading (Table IIIA and B). These results are in agreement with finding of Mohammad *et al.* (2001), Asif *et al.* (2004) and Eid (2009). Genetic and environmental variances, heritability and genetic advance for days to heading are given in Table VI. Genetic variance was 2.5 times greater than environmental variance. The resultant heritability and genetic advance for days to heading were 0.72 and 2.30 days, respectively. Same results were reported by Asif *et al.* (2004) and Ayciceky and Yildirim (2006).

**Days to maturity:** Days to maturity showed significant (P≤0.01) differences among wheat genotypes. Differences among parental cultivars, $F_3$ populations and P vs $F_3$ were also significant for days to maturity (Table II). Days to maturity ranged from 165.0 to 171.3 among the parents while from 168.0 to 171.0 days among the $F_3$ wheat populations. Among the parental cultivars, PS-2004 was early by taking 165 days to maturity, while PS-2005 and Janbaz were late by taking 171.3 and 170.7 days to maturity respectively. Among the $F_3$ populations, PS-2004/FS and G-98/PS-2004 were early each taking 168.0 days to maturity. In contrast, G-98/AUP-4006 was late by taking 171.0 days to maturity among the $F_3$ populations. Days to maturity averaged 169.4 and 169.7 for parents and $F_3$ populations respectively showing a net difference of 0.3, days in maturity (Table IIIA and B). Asif *et al.* (2004) and Khan and Naqvi (2011) also found similar results for days to maturity. Genetic and environmental variances, heritability and genetic advance for days to maturity are given in Table VI. Genetic variance was 6.93 times greater than environmental variance. The resultant heritability and genetic advance for days to maturity were 0.87 and 2.25 days, respectively. Similar results were also published by Asif *et al.* (2004) and Khan and Naqvi (2011).

**Flag leaf area ($cm^2$):** Genotypes showed significant (P≤0.01) differences for flag leaf area. Differences among parental cultivars, $F_3$ populations and P vs $F_3$ were also significant for flag leaf area (Table II).Flag leaf area ranged from 22.5 to 32.6 $cm^2$ with a mean value of 26.4 $cm^2$ for parental cultivars while from 21.2 to 33.8 $cm^2$ with a mean value of 28.1 $cm^2$ for $F_3$ populations. Among the parental cultivars, maximum and minimum flag leaf area was recorded for PS-2005 (32.6 $cm^2$) and Fakhre Sarhad, (22.5 $cm^2$). Among the $F_3$ populations, maximum and minimum flag leaf area was recorded for PS-2005/Janbaz (33.8 $cm^2$) and PS-2004/FS (21.2 $cm^2$) (Table IIIA and B). These results are compatible with results of Khan *et al.* (2003) and Khan and Naqvi (2011). Genetic and environmental variances, heritability and genetic advance for flag leaf area are given in Table VI. Genetic variance was 8 times greater than environmental variance. The resultant heritability and genetic advance for flag leaf area were 0.89 and 5.54 $cm^2$, respectively. Similar results were also published by Khan *et al.* (2003).

**Spikes $m^{-2}$:** Genotypes revealed significant (P≤0.01) variation for spikes $m^{-2}$. Differences among parental cultivars, $F_3$ populations and P vs $F_3$ were also significant for spikes $m^{-2}$ (Table II). Spikes $m^{-2}$ ranged from 277.3 to 426.7 with a mean value of 340.7 for parental cultivars while from 243.7 to 462.0 with a mean value of 357.4 for $F_3$ populations. Among the parental cultivars, maximum and minimum values of spikes $m^{-2}$ were recorded for G-98 (426.7) and PS-2005 (277.3). Among the $F_3$ populations, maximum and minimum values recorded for FS/PS-2004 (726.0) and PS-2005/Janbaz (243.7) (Table IIIA and B). These results are compatible with results of Ayciceky and Yildirim (2006) and Mangi *et al.* (2010). Genetic and environmental variances, heritability and genetic advance for spikes $m^{-2}$ are given in Table VI. Genetic variance was 14.36 times greater than environmental variance. The resultant heritability and genetic advance for spikes $m^{-2}$ were 0.93 and 175.22, respectively. Similar results were also published by Ayciceky and Yildirim (2006). Among $F_3$ populations transgressive segregation was observed in FS/PS-2004 for spikes $m^{-2}$.

**Grains spike$^{-1}$:** Genotypes displayed significant (P≤0.01) variations for grains spike$^{-1}$. Variations among parental cultivars, $F_3$ populations and P vs $F_3$ were also highly significant for grain spikes$^{-1}$ (Table III). Grain spikes$^{-1}$ ranged from 32.0 to 45.0 with a mean value of 39.3 for parental lines while from 21.3 to 53.7 with a mean value of 37.9 for $F_3$ populations. Among the parental cultivars, maximum and minimum values of grains spike$^{-1}$ were recorded for AUP-4006 (45.0) and G-98 (32.0). Among the $F_3$ populations, maximum and minimum values recorded for PS-2004/FS (53.7) and FS/PS-2004 (21.3) (Table VA and B). These findings were also encouraged by Memon *et al.* (2007), Ajmal *et al.* (2009) and Eid (2009). Genetic and environmental variances, heritability and genetic advance for grains spike$^{-1}$ are given in Table VI. Genetic variance was 26.21 times greater than environmental variance. The resultant heritability and genetic advance for grains spike$^{-1}$ were 0.96 and 12.13, respectively. Similar results were also published by Waqar-ul-haq *et al.* (2008), Erkul *et al.* (2010) and Rashidi (2011). Among $F_3$ populations transgressive segregation was observed in PS-2004/FS for grains spike$^{-1}$.

**Grain weight spikes$^{-1}$:** Analysis of variance exhibited significant (P≤0.01) variations among wheat genotypes for grain weight spike$^{-1}$. Differences among parental cultivars, $F_3$ populations and P vs $F_3$ were also significant for grain weight spike$^{-1}$ (Table III). Grain weight spike$^{-1}$ ranged from 0.9 to 1.7 g with a mean value of 1.4 g for parental cultivars while from 0.7 to 1.6 g with a mean value 1.3 g for $F_3$ populations. Among the parental cultivars, maximum and minimum values of grain weight spike$^{-1}$ were recorded for PS-2005 (1.7 g) and G-98 were and (0.9 g). Among the $F_3$ populations, maximum and minimum values of grain weight spike$^{-1}$ were recorded for PS-2005/FS (1.6 g) and FS/PS-2004 (0.7 g) (Table VA and B). These results are compatible with result of Erkul *et al.* (2010) and Laghari *et al.* (2010). Genetic and environmental variances, heritability and genetic advance for grain weight spike$^{-1}$ are given in Table VI. Genetic variance was 6 times greater than environmental variance. The resultant heritability and genetic advance for grain weight spike$^{-1}$ were 0.89 and 0.42 g, respectively. These results are in conformity with that of Erkul *et al.* (2010) and Laghari *et al.* (2010).

**1000-grain weight (g):** Genotypes showed significant (P≤0.01) variations for 1000-grain weight. Variations among parental cultivars and $F_3$ populations were also highly significant for 1000-grain weight. However, differences among the P vs $F_3$ were statistically non-significant for 1000-grain weight (Table III). 1000-grain weight ranged from 27.7 to 41.0 g with a mean value of 34.2 g for parental lines while from 22.3 to 41.7 g with a mean value of 33.9 g for $F_3$ populations. Among the parental cultivars, maximum and minimum values of 1000-grain weight were recorded for PS-2005 (41.0 g) and G-98 (27.7 g). Among the $F_3$ populations, maximum and minimum values of 1000-grain weight were recorded for PS-2005/Janbaz (41.7 g) and PS-2004/FS (22.3 g) (Table VA and B). These findings were also encouraged by Eid (2009), Erkul *et al.* (2010) and Rashidi *et al.* (2011). Genetic and environmental variances, heritability and genetic advance for 1000-grain weight are given in Table VI. Genetic variance was 31.12 times greater than environmental variance. The resultant heritability and genetic advance for grain 1000-grain weight were 0.97 and 8.81 g, respectively. Same results were also found by Waqar-ul-haq *et al.* (2008) and Eid (2009).

**Grain yield (kg $ha^{-1}$):** Grain yield was significant ($P \leq 0.01$) affected for different genotypes. Variations among parental cultivars, $F_3$ populations and P vs $F_3$ were also highly significant for grain yield (Table III). Grain yield ranged from 4166.7 to 5167.0 kg $ha^{-1}$ with a mean value of 4546.3 kg $ha^{-1}$ for parental cultivars while from 3722.3 to 5277.7 kg $ha^{-1}$ with a mean value of 4329.0 kg $ha^{-1}$ for $F_3$ populations. Among the parental cultivars maximum and minimum values of grain yield were recorded for PS-2004 (5167.0 kg $ha^{-1}$) and Janbaz (4166.7 kg $ha^{-1}$). Among the $F_3$ populations, maximum and minimum values of grain yield were recorded for G-98/PS-2004 (5277.7 kg $ha^{-1}$) and G-98/AUP-4006 (3722.3 kg $ha^{-1}$) (Table VA and B). These findings were also encouraged by Khan *et al.* (2007) and Khan and Naqvi (2011). Genetic and environmental variances, heritability and genetic advance for grain yield are given in Table VI. Genetic variance was 3 times greater than environmental variance. The resultant heritability and genetic advance for grain yield were 0.78 and 683.16 kg $ha^{-1}$, respectively. Similar results were also reported by Firouzian (2003) and Mangi *et al.* (2010). Among $F_3$ populations transgressive segregation was observed in G-98/PS-2004 for grain yield, for which vigilant selection should be made for the improvement of grain yield in this population in the upcoming generation.

**Table II. Mean squares for days to heading (DH), days to maturity (DM), flag leaf area (FLA) and spikes $m^{-2}$ (SPM) of six parents and 13 $F_3$ wheat populations evaluated at AUP during 2011-2012.**

| SOV | DF | DH | DM | FLA | SPM |
|---|---|---|---|---|---|
| Replication | 2 | $0.02^{NS}$ | $0.07^{NS}$ | 5.42* | $741.95^{NS}$ |
| Genotype | 18 | 8.11** | 5.87** | 34.85** | 32541.78** |
| Parents | 5 | 13.52 ** | 15.39** | 37.97** | 9930.06** |
| $F_3$ Population | 12 | 5.97** | 2.30** | 33.55** | 44391.08** |
| P vs $F_3$ | 1 | 6.73* | 1.13* | 34.85** | 3408.78* |
| Error | 36 | 0.94 | 0.27 | 1.38 | 738.21 |
| CV% | - | 0.72 | 0.31 | 4.27 | 7.72 |

*, ** = Significant at 5% and 1% level of probability respectively, NS= Non significant

**Table III.A. Means for days to heading (DH), days to maturity (DM), flag leaf area (FLA) and spikes $m^{-2}$ (SPM) of six parents evaluated at AUP during 2011-2012**.

| Genotypes | DH | DM | FLA | SPM |
|---|---|---|---|---|
| AUP-4006 | 134.7 | 169.3 | 25.9 | 290.3 |
| Ghaznavi-98 | 134.0 | 171.3 | 32.6 | 277.3 |
| Pirsabak-2004 | 137.0 | 169.7 | 24.1 | 426.7 |
| Pirsabak-2005 | 134.3 | 170.7 | 25.4 | 314.3 |
| Janbaz | 133.0 | 165.0 | 27.9 | 353.0 |
| Fakhre sarhad | 138.7 | 170.3 | 22.5 | 382.7 |
| Mean | 135.3 | 169.4 | 26.4 | 340.7 |
| LSD | 1.61 | 0.87 | 1.95 | 44.99 |

**Table III.B. Means for days to heading (DH), days to maturity (DM), flag leaf area (FLA) and spikes $m^{-2}$ (SPM) of 13 $F_3$ wheat populations evaluated at AUP during 2011-2012.**

| Genotypes | DH | DM | FLA | SPM |
|---|---|---|---|---|
| PS-2004/AUP-4006 | 132.7 | 169.0 | 27.1 | 422.7 |
| PS-2005/Janbaz | 133.0 | 170.0 | 33.8 | 243.7 |
| AUP-4006/G-98 | 135.0 | 170.0 | 24.5 | 380.0 |
| G-98/AUP-4006 | 135.3 | 171.0 | 27.1 | 294.7 |
| G-98/PS-2004 | 135.3 | 168.0 | 27.3 | 372.0 |
| FS/PS-2005 | 137.0 | 170.0 | 27.8 | 297.7 |
| Janbaz/FS | 135.0 | 170.3 | 31.3 | 253.7 |
| PS-2005/FS | 132.0 | 169.7 | 29.7 | 308.3 |
| FS/G-98 | 136.0 | 170.3 | 26.6 | 321.7 |
| G-98/FS | 135.3 | 170.0 | 27.3 | 368.7 |
| FS/PS-2004 | 134.7 | 170.0 | 28.3 | 462.0 |
| AUP-4006/FS | 133.7 | 169.7 | 32.9 | 331.0 |
| PS-2004/FS | 134.0 | 168.0 | 21.2 | 325.7 |

| | | | | |
|---|---|---|---|---|
| Mean | 134.5 | 169.7 | 28.1 | 357.4 |
| LSD | 1.61 | 0.87 | 1.95 | 44.99 |

**Table IV. Mean squares for grains spike$^{-1}$ (GPSP), grain weight spike$^{-1}$ (GWPSP), 1000-grain weight (1000-GW) and grain yield (GY) of six parents and 13 $F_3$ wheat populations evaluated at AUP during 2011-2011.**

| SOV | DF | GPSP | GWPSP | 1000-GW | GY |
|---|---|---|---|---|---|
| Replication | 2 | $4.86^{NS}$ | $0.00^{NS}$ | $1.07^{NS}$ | $9229.07^{NS}$ |
| Genotype | 18 | 149.74** | 0.20** | 78.33** | 637133.61** |
| Parents | 5 | 62.53** | 0.28** | 70.22** | 601634.67** |
| $F_3$ Population | 12 | 196.36** | 0.18** | 88.16** | 656553.97** |
| P vs $F_3$ | 1 | 26.31** | 0.04* | $0.92^{NS}$ | 581584.01** |
| Error | 36 | 1.88 | 0.01 | 0.83 | 55565.55 |
| CV % | - | 3.58 | 6.69 | 2.68 | 5.36 |

*, ** = Significant at 5% and 1% level of probability respectively, NS= Non significant

**Table V.A. Means for grains spike$^{-1}$ (GPSP), grain weight spike$^{-1}$ (GWPSP), 1000-grain weight (1000-GW) and grain yield (GY) of six parents evaluated at AUP during 2011-2012.**

| Genotypes | GPSP | GWPSP | 1000-GW | GY |
|---|---|---|---|---|
| AUP-4006 | 45.0 | 1.5 | 33.3 | 4389.0 |
| Ghaznavi-98 | 42.0 | 1.7 | 41.0 | 5055.3 |
| Pirsabak-2004 | 32.0 | 0.9 | 27.7 | 4166.7 |
| Pirsabak-2005 | 41.3 | 1.4 | 34.0 | 4166.7 |
| Janbaz | 39.0 | 1.5 | 38.3 | 5167.0 |
| Fakhre sarhad | 36.7 | 1.1 | 31.0 | 4333.3 |
| Mean | 39.3 | 1.4 | 34.2 | 4546.3 |
| LSD | 2.27 | 0.15 | 1.51 | 390.34 |

**Table V.B. Means for grains spike$^{-1}$ (GPSP), grain weight spike$^{-1}$ (GWPSP), 1000-grain weight (1000-GW) and grain yield (GY) of 13 $F_3$ wheat population evaluated at AUP during 2011-2012.**

| Genotypes | GPSP | GWPSP | 1000-GW | GY |
|---|---|---|---|---|
| PS-2004/AUP-4006 | 28.3 | 1.2 | 37.0 | 4444.3 |
| PS-2005/Janbaz | 39.3 | 1.6 | 41.7 | 3944.7 |
| AUP-4006/G-98 | 38.0 | 1.2 | 31.0 | 4444.3 |
| G-98/AUP-4006 | 35.0 | 1.2 | 35.3 | 3722.3 |
| G-98/PS-2004 | 43.7 | 1.4 | 30.3 | 5277.7 |
| FS/PS-2005 | 37.3 | 1.3 | 35.0 | 3888.7 |
| Janbaz/FS | 45.0 | 1.5 | 34.0 | 3888.7 |
| PS-2005/FS | 43.7 | 1.6 | 36.0 | 4889.0 |
| FS/G-98 | 33.3 | 1.3 | 39.0 | 4166.7 |
| G-98/FS | 40.0 | 1.2 | 28.3 | 4611.0 |
| FS/PS-2004 | 21.3 | 0.7 | 30.3 | 4555.3 |
| AUP-4006/FS | 33.7 | 1.4 | 41.0 | 4611.3 |
| PS-2004/FS | 53.7 | 1.2 | 22.3 | 3833.3 |
| Mean | 37.9 | 1.3 | 33.9 | 4329.0 |
| LSD | 2.27 | 0.15 | 1.51 | 390.34 |

**Table VI. Genetic variance (Vg), environmental variance (Ve), broad-sense heritability ($h^2$) and genetic advance (GA) for various traits of six parents and 13 $F_3$ wheat populations evaluated at AUP during 2011-2012.**

| Traits | Vg | Ve | $h^2$ | G.A* |
|---|---|---|---|---|
| Days to heading | 2.39 | 0.94 | 0.72 | 2.30 |
| Days to maturity | 1.87 | 0.27 | 0.87 | 2.25 |
| Flag leaf area | 11.13 | 1.39 | 0.89 | 5.54 |
| Spikes m$^{-2}$ | 10601.19 | 738.21 | 0.93 | 175.22 |
| Grains spike$^{-1}$ | 49.29 | 1.88 | 0.96 | 12.13 |
| Grain weight spike$^{-1}$ | 0.06 | 0.01 | 0.89 | 0.42 |
| 1000-grain weight | 25.83 | 0.83 | 0.97 | 8.81 |
| Grain yield | 193856.02 | 55565.55 | 0.78 | 683.16 |

* 10 % selection intensity (k=1.76)

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