GENETIC STUDIES OF SOME YIELD AND YIELD ASSOCIATED TRAITS IN F3 SEGREGATING GENERATIONS OF WHEAT

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ABSTRACT:- *The studies on the heritability estimates were conducted during 2013-14 to examine the performance of four F_3 segregating generations originated from five parental lines of bread wheat Triticum aestivum. The experiment was conducted in a 3 replicated Randomized Complete Block Design. Five parental genotypes (Marvi, CM-24/87, Bhittai, NIA-Amber and NIA-Sunahri) and their four F_3 hybrids (Marvi × CM-2487, CM-2487 × Bhittai, NIA-Amber × Marvi, NIA-Sunahri × Marvi) were evaluated. Environmental variance ($\delta^2 e$), genetic variance ($\delta^2 g$), heritability [b.s] (h^2%), genetic advance (GA) and phenotypic variance ($\delta^2 p$) were analyzed for days to heading, days to maturity, plant height, spike length, spikelet's spike^{-1}, grains spike^{-1} and grain yield per plant. The results revealed that the parents and the segregating progenies were significantly ($P<0.05$) different with each other for all the traits investigated. The ANOVA of F_3 segregating populations and their parental lines for the traits days to heading, days to maturity, plant height, spike length, spikelet's spike^{-1}, grains spike^{-1}and grain yield per plant were highly significant ($P<0.01$). However, differences for days to heading, days to maturity, plant height, spike length, grains spike^{-1}and grain yield per plant were non-significant ($P>0.05$) among F_3 segregating populations and significant ($P<0.01$) for spikelet's spike^{-1}. F_3 progenies showed varied response for different traits and progeny NIA-Sunhari × Marvi took maximum days to heading (94.1), NIA-Amber × Marvi took maximum days to maturity (137.3); progeny CM × Bhittai produced plants of maximum height (99.00 cm); NIA-Sunhari × Marvi resulted in maximum spike length (by F_3 progeny Marvi × CM. Maximum plant height (99.00 cm) was observed in F_3 progenyCM × Bhittai and minimum plant height (72.6 cm); while the maximum spike length (11.4 cm) and progeny Marvi × CM produced highest number of spikelet's spike^{-1} (22.3) and subsequently maximum grains (40.2) spike^{-1}. The maximum grains yield (16.89 g) was noted in Marvi × CM, followed by F_3 progeny NIA-Sunahri × Marvi (15.58 g) and minimum grains yield (15.01 g) was observed in F_3 progeny NIA-Amber × Marvi However, in most cases the F_3 progenies could surpass their parental lines. The genetic studies revealed that F_3 progeny Marvi × CM manifested highest heritability estimates for days to heading (h^2=84.57) and days to maturity (h^2=69.56%); while NIA-Sunhari × Marvi manifested highest heritability estimates for plant height (h^2=80.53%), and spikelet's spike^{-1} (h^2=82.26%). However, CM × Bhittai resulted in maximum heritability estimates for spike length (75.35%) and grains spike^{-1} (81.48%). Maximum genetic advance was noted for F_3 progenies NIA-Sunhari × Marvi for days to heading (9.55), plant height (20.39) and spikelet's spike^{-1} (4.83) and NIA-Amber × Marvi for spike length (4.58); while CM × Bhittai for days to maturity (5.24) and grains spike^{-1} (6.36). For grain yield per plant, the high heritability estimates were exhibited by NIA-Amber × Marvi(77.88%) followed by NIA-Sunahri × Marvi and CM x Bhittai (67.83%).*

Keywords: Performance, Yield, Segregation population, heritability, genetics.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and belongs to Poaceae or Gramineae family and originated in the Ethiopian highlands [1]. *Triticum durum*, *Triticum monococcum*, *Triticum dicoccum* and *Triticum spelta* are the other cultivated species, but *Triticum aestivum* is a hexaploid species that is the most widely cultivated in the world [2;3;4]. It is grown across a wide range of environments and has the highest adaptation among all the crop species. Worldwide more land is devoted to the production of wheat than any other crop. Wheat is a source of staple food of masses and feed for animals [5]. Pakistan is among top ten wheat producing countries of the world [6]. Its adaptation and diverse consumption in the human nutrition lead to present as the most important cereal in Pakistan and averagely used for about 60 percent of daily human diet with per capita consumption of 125 kg [7]. The area under wheat cultivation was 9039 thousand hectares during 2013-14, showing 4.4 percent increase over 2012-13. The wheat grain production during 2013-14 was 25.286 million tons showing 4.4 percent increase over last year showing; while the yield per hectare in 2013-14 remained 2797 kg, showing no change almost over the last year yield of 2796 kg per hectare [8]. Efforts on various aspects of wheat crop have been under way to increase its production. The most important factor in the process of crop production has always been a good variety in any crop. Cotton breeders managed to produce high yielding varieties through various genetic manipulations and breeding approaches and consequently a significant progress was achieved in this connection. The environmental change affects grain yield of wheat because the varieties of diversified origin are under cultivation at commercial level with the farmers. The yields fluctuate widely as a result of its interaction with various environmental factors because yield is a complicated quantitative parameter and is the product of several contributing factors affecting grain yield directly or indirectly. Wheat production can be increased through the development of productive cultivars which better adapt various agro-climatic conditions and also resist all types of biotic and a-biotic stresses. Selection for grain yield improvement can only be effective if sufficient genetic variability is present in the breeding material [9]. The heritability of a trait within a population is the proportion of observable differences in a trait between individuals within a population that is due to genetic differences. Factors including genetics, environment and random chance can all contribute to the variation between individuals in their observable characteristics. Heritability measures the fraction of phenotype variability that can be attributed to genetic variation [10]. High heritability values indicate the genetic relationship between parents and progeny. The heritability of a character describes the extent to which it is transmitted from one generation to the other generation. Information on heritability parameters and the evaluation of the relationship between important quantitative traits is very useful in any effective wheat breeding program [11]. It is well known fact that quantitative characters depending on the nature of gene action are differently influenced by environmental variation. Moreover, the extents of heritability of quantitative traits are negatively correlated with environment. Low heritability of trait indicates greater influence of environmental factors over genetic makeup of traits [12]. The evaluation of elite wheat varieties and advanced lines is essential for the further improvement of wheat. Most of the previous studies were carried out by using a single method and usually described the validity of methods and performance of trials, whereas the performances of genotypes in given environments were reported seldom. However, the performance of a genotype under the influence of yield components on yield is more important for wheat cultivation and improvement [13]. Increase in one component usually causes the decreasing of other components. Although a number of morpho-physiological traits have proved associated with yield of wheat under semi-arid conditions; their contribution to selection can be adversely affected by the fact that this association may be environment-specific [14].

MATERIALS AND METHODS

The experiment was conducted during rabi season 2013-14 to carryout genetic studies of some yield and yield associated traits in F_3segregating generations of wheat, at the experimental fields of Nuclear Institute of Agriculture (NIA), Tandojam. The wheat breeding material for research work consisted of four F_3 populations of bread wheat (*Triticum aestivum* L.) along with their five parental lines which were evaluated under field conditions. The details of the experiment are given as follows:

Experimental design

The experiment was laid out in a three replicated Randomized Complete Block Design (RCBD) in a plot size of 13.5m^2 and plot size for the single progeny was 0.45 m^2 (1.35$m^2/_3$ single spike progeny row) each 1.5 meter long.

Cultural operations

All the necessary cultural operations were performed in all the plots uniformly and the plots were kept free of weeds throughout the growing period of the crop.

Time and method of sowing

Every three single spikes selected from F_2 progeny was grown as F_3 in 1.5m long. The row to row and plant to plant space of 30 cm and 15 cm was kept, respectively. Drilling method was used for sowing and after four weeks of sowing, thinning was done to maintain 15 cm plant to plant space. The plot size was 13.5m^2, and plot size for the single progeny was 0.45 m^2 (1.35$m^2/_3$ single spike progeny row). The sowing was done on 21 November 2013.

Irrigations

Canal water as well as tube well water was used to irrigate the experimental crop. The experimental crop was irrigated four times throughout the growing season.

Breeding material

Parental lines: Five (05)

Marvi
CM-24/87
Bhittai
NIA-Amber
NIA-Sunahri

F_3 cross combinations

Marvi × CM-2487
CM-2487 × Bhittai
NIA-Amber × Marvi
NIA-Sunahri × Marvi

Observations recorded

Days to heading
Days to maturity
Plant height (cm)
Spike length (cm)
Spikelet's spike^{-1}
Grains spike^{-1}
Grain yield plant^{-1} (g)

The experimental crop was harvested at maturity and the above observations were recorded by the following procedures:

Days to heading: The date of sowing was recorded and the time period taken by the crop from the sowing date till the heading was recorded in days and average was calculated.

Days to maturity: From the sowing date till the crop reached to its physiological maturity, the period was recorded in days in all the plots and average was worked out.

Plant height: Plant height (cm) was measured at physiological maturity. Five representative plants were selected in each experimental unit and the height measured from ground level to the tip of the spike.

Spike length (cm): Length of the spike of main tiller was measured in centimeters from the base of spike to the upper most spikelet's excluding awns.

Number of spikelet's per spike: The number of spikelets in the primary tiller of each selected plants were counted and the data were recorded as spikelets per spike.

Number of grains per spike: The main spike or primary tiller of each selected plant was threshed separately and number of grains was counted replication wise.

Grain yield per plant (g): After harvesting, each selected plant was threshed separately with single plant wheat thresher and cleaned in the laboratory. The grains were weighed on electric balance and yield per plant was recorded in grams.

Statistical analysis

The data recorded were subjected to analysis of variance technique for a Randomized Complete Block Design as outlined by Steel and Torrie (1980) through Statix 8.1 computer program for all the traits. The genotype means for each parameter were further separated and compared by using the least significant difference (LSD) test at 5% level of probability. For each trait the genetic, environmental and phenotypic variations, broad sense heritability (h^2) and expected response to selection was further estimated from the ANOVA mean squares according to Burton (1952).

Genotypic variance (Vg)

$$Vg = \quad S^2 = \frac{SS}{n-1}$$

$$SS = \sum x^2 - \frac{(\sum x)^2}{n}$$

Environmental variance (Ve) $$Ve = \frac{VP_1 + VP_2}{2}$$

Phenotypic variance (Vp) = Vg + Ve

Genetic advance (GA) = k × h^2× sd

Heritability

The heritability (b.s) was calculated for variance components followed by Gardener (1961) as under:

$$H^2 = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 e_{/r}} \quad \text{Or} \quad \frac{\sigma^2 g}{\sigma^2 p}$$

$$\text{Coefficient of } H^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

RESULTS

In order to determine the heritability of various traits in F_3 segregating generations of bread wheat *Triticum aestivum* L., the experiment was conducted at the experimental farm of Nuclear Institute of Agriculture (NIA), Tandojam during 2013-14. Five parental wheat genotypes (Marvi, CM-24/87, Bhittai, NIA-Amber and NIA-Sunahri) and four F_3 hybrids (Marvi × CM-2487, CM-2487 × Bhittai, NIA-Amber × Marvi, NIA-Sunahri × Marvi) were included in the experiment. Environmental variance (δ^2e), genetic variance (δ^2g), Heritability [b.s] (h^2%), genetic advance (GA) and phenotypic variance (δ^2p) were analyzed for days to heading, days to maturity, plant height, spike length, spikelet’s spike^{-1}, grains spike^{-1} and grain yield per plant.

Analysis of variance

The collected data were subjected to analysis of variance (ANOVA) using Statics (ver. 8.1) computer software. The ANOVA was conducted for seven traits of economic importance recorded from four cross combinations and their five parental lines of bread wheat. The ANOVA for all the traits studied for four F_3 segregating populations are summarized in Table 1. The results revealed that the parents and the segregating progenies were significantly (P<0.05) different with each other for all the traits investigated in this experiment. The mean squares from ANOVA of four F_3 segregating populations and their parental lines for the days to heading, days to maturity, plant height, spike length, spikelet’s spike^{-1}, grains spike^{-1} and grain yield per plant were highly significant (P<0.01). However, differences for days to heading, days to maturity, plant height, spike length, grains spike^{-1}and grain yield per plant were non-significant (P>0.05) among F_3 segregating populations and significant (P<0.01) for spikelet’s spike^{-1} between F_3 segregating populations.

Table 1. Analysis of variance showing mean squares for various morphological traits of four F_3 population and five parental varieties of bread wheat

Source	DF	Days to heading	Days to maturity	Plant height	Spike length	Grains spike^{-1}	Spikelet’s spike^{-1}	Grain yield per plant (g)
Replications	2	0.0744	59.378	111.634	0.2681	24.573	0.6781	2.1015
Entries	8	94.6542**	202.529**	229.250**	20.2523**	121.959**	20.0979**	12.3094*
Parents	4	133.808**	35.6417**	325.433**	36.8917**	183.817**	28.1993**	18.9729**
Hybrids	3	18.9986^{NS}	111.683**	164.083**	4.4000^{NS}	47.6201*	15.9853**	2.08873^{NS}
Error	16	5.3015	14.681	35.562	1.6202	13.303	1.3552	1.88972
Total	33	---	---	---	---	---	---	---

** = Highly significant
* = Significant
NS = Non-Significant

Mean performance

Number of days to heading

The data in Table 2 showed the mean performance of F_3populations and their parental lines. There was a significant difference in the number of days taken to heading between F_3 progenies and their parental varieties (P<0.05). The data showed that parental line NIA-Sunahri took maximum number of days to heading (94.1), followed by NIA-Amber (83.0), CM (79.8), Bhittai (78.6) and Marvi (78.0). Among F_3 progenies, NIA-Sunahri × Marvi took maximum days (81.1) to heading as compared to CM × Bhittai (77.3), NIA-Amber × Marvi (76.7) and lowest number of days taken to heading (75.7) was recorded in F_3 progeny Marvi × CM. It was observed that mostly the F_3 progenies took lesser days to heading as compared to their parental lines.

Number of days to maturity

There was significant (P<0.05) difference in the number of days taken to maturity amongF_3 progenies and their parental lines. The data indicated that delayed maturity was observed in parental lines, while the F_3 progenies showed earliness in maturity. The maximum days to maturity were recorded in parental lines Bhittai (145.6), NIA-Sunahri (144.5), NIA-Amber (143.5) and CM (140.00); while the reduced number of days to maturity was observed by the F_3 progenies Marvi ×

CM (83.4), CM × Bhittai (122.6), NIA.Sunhari × Marvi (128.5) and NIA. Amber × Marvi (76.7). It was observed that F_3 progeny Marvi × CM showed remarkable earliness in maturity when compared with their parental varieties.

Plant height

The plant height of F_3 progenies and their parental lines differed significantly (P<0.05). The data in Table 2, showed that among the parental lines, the maximum plant height was noted in CM (98.6 cm), followed by Bhittai (96.5 cm) and lowest by parental line NIA-Sunahri (72.6 cm). Among F_3 progenies, the maximum plant height (99 cm) was observed in CM × Bhittai, followed by NIA-Amber × Marvi (94.00 cm) and minimum plant height (93.00 cm). The experimental results showed a marked change in plant height in F_3 progenies when compared with their parental lines.

Spike length

The data in Table 2 indicated that the highest spike length (15.6 cm) was observed in parental line Bhittai, followed by Marvi (11.0 cm) and minimum spike length (6.5 cm) was observed by parental line CM. Among F_3 progenies, the maximum spike length (11.4 cm) was noted in NIA-Sunahri × Marvi, followed by F_3 progeny Marvi × CM (11.2 cm) and minimum spike length (8.8 cm) was observed in F_3 progeny NIA-Amber × Marvi. There was a mixed trend of effectiveness in F_3 progenies over their parental lines.

Spikelet's spike^{-1}

The data regarding the spikelet's spike^{-1} in wheat (Table 2) indicated that among the parental lines the more spikelet's spike^{-1} (23.3 and 22.0) were noted in parental lines CM and Bhittai, respectively; followed by Marviand NIA-Sunahri with 17.8 and 17.00 spikelet's spike^{-1}, respectively while minimum spikelet's spike^{-1} (16.6) was noted in parental line NIA-Amber. Among F_3 progenies, the maximum spikelet's spike^{-1}(22.3) was noted in Marvi × CM, followed by F_3 progeny NIA-Sunahri × Marvi (20.1) and minimum spikelet's spike^{-1}(17.0) was observed in F_3 progeny CM × Bhittai. Apparently the spikelet's spike^{-1} in the F_3 progenies was decreased slightly when compared with their parental lines.

Grains spike^{-1}

The grains spike^{-1} varied significantly (P<0.05) between F_3 progenies and their parental lines. The data in Table 2 showed that among the parental lines the more grains spike^{-1} (49.3 and 44.3) were achieved in parental lines Bhittai and CM, respectively; followed by NIA-Sunahri (39.3); while minimum grains spike^{-1} (31.6 and 31.5) was noted in parental lines NIA-Amber and CM, respectively. Among F_3 progenies, the maximum grains spike^{-1} (40.2) was noted in Marvi × CM, followed by F_3 progeny NIA-Sunahri × Marvi (37.1) and minimum grains spike^{-1} (31.8) was observed in F_3 progeny NIA-Amber× Marvi. Apparently the grains spike^{-1} in the parental lines was higher than their F_3 progenies.

Grains yield per plant

The grain yield per plant varied significantly (P<0.05) between F_3 progenies and their parental lines. The data in Table 2 showed that among the parental lines the more grain yield (20.72 and 18.62 g) were achieved in parental lines Bhittai and Marvi, respectively; followed by NIA-Sunahri (16.52 g); while minimum grains yield (16.35 and 14.08 g) was noted in parental lines NIA-Amber and CM, respectively. Among F_3 progenies, the maximum grains yield (16.89 g) was noted in Marvi × CM, followed by F_3 progeny NIA-Sunahri × Marvi (15.58 g) and minimum grains yield (15.01 g) was observed in F_3 progeny NIA-Amber × Marvi. Apparently the grains yield in the parental lines was higher than their F_3 progenies.

Table 2.Comparative mean performance of various traits of four F_3 populations and their five parental lines of bread wheat

Genotypes	Days to heading	Days to maturity	Plant height (cm)	Spike length (cm)	Spikelet's spike^{-1}	Grains spike^{-1}	Grain yield per plant
Marvi	78.0 C	137.3 B	86.1 B	11.0 B	17.8 C	44.3 A	18.62 AB
CM	79.8 C	140.0 A	98.6 A	6.5 D	23.3 A	31.5 C	14.08 D
Bhittai	78.6 C	145.6 A	96.5 A	15.6 A	22.0 A	49.3 A	20.72 A
NIA.Amber	83.0 B	143.5 A	90.5 A	9.8 C	16.6 C	31.6 C	16.35 BCD
NIA.Sunhari	94.1 A	144.5 A	72.6 C	8.0 C	17.0 C	39.3 B	16.52 BCD
Marvi × CM	75.7 D	83.4 E	93.0 A	11.2 B	22.3 A	40.2 B	16.89 BC
CM × Bhittai	77.3 D	122.6 D	99.0 A	11.0 B	17.0 C	32.5 C	15.28 CD
NIA-Amber × Marvi	76.7 D	137.3 B	94.0 A	8.8 C	18.3 C	31.8 C	15.01 CD
NIA-Sunhari × Marvi	81.1 B	128.5 C	81.3 B	11.4 B	20.1 B	37.1 B	15.58 CD
S.E.±	1.88	3.12	4.86	1.04	0.95	2.97	1.17
LSD 0.05	3.98	6.63	10.32	2.20	2.02	6.31	2.49

Days to heading

The environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for days to heading are presented in Table-3. The data showed that low moderate amount of genetic variability was present in F_3 populations. Low, moderate and high heritability (h^2) estimates that ranged from 68.11 to 84.57%, coupled with fair amount of genetic advance from 0.65 to 23.45. Among the F_3 progenies, Marvi × CM, NIA-Amber × Marvi and NIA. Sunhari x Marvi manifested high heritability percentages, i.e. h^2=84.57, 79.22 and 75.84% that were associated with low to moderate genetic advance (GA=2.29, 2.44 and 9.55), respectively; while F_3 progenyCM × Marvi and Bhittai expressed heritability estimates of h^2=68.11% with genetic advance of 1.43. All the F_3 progenies manifested high heritability estimates with lower genetic advance for this trait. However, the progeny NIA-Sunhari × Marvi showed most promising results with higher heritability estimates (75.84% b.s) with moderate genetic advance (9.55). The days to heading was mainly controlled by additive genetic factors and the progenies which expressed high heritability estimates with fair genetic advance may be valuable segregating populations in order to select the desirable plants for days to heading in consequent segregating generations.

Table 3. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%), genetic advance (GA), for number of days taken to heading by F_3 segregating populations of bread wheat

F_3 progenies	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	0.17	0.91	1.08	84.57	2.29
CM × Bhittai	0.21	0.44	0.65	68.11	1.43
NIA-Amber × Marvi	0.29	1.11	1.40	79.22	2.44
NIA-Sunhari × Marvi	5.67	17.79	23.45	75.84	9.55

Days to maturity

The data in regards to environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for days to maturity are presented in Table-4. The data showed that lower genetic variability was present in F_3 populations. Moderately higher heritability (h^2) estimates were recorded that ranged from 55.17 to 69.56% with genetic advance from 1.98 to 5.24. Among the F_3 progenies, Marvi × CM manifested higher heritability percentages (h^2=69.56%) associated with low genetic advance (GA=3.90); while F_3 progenies CM × Bhittai, NIA. Sunhari × Marvi and NIA-Amber × Marvi expressed heritability estimates of h^2=58.52, 58.41 and 55.17% with genetic advance of 5.24. 1.98 and 2.55, respectively. The F_3 progenies manifested moderately higher heritability estimates with lower genetic advance for the days to maturity. However, the F_3progeny Marvi ×CM showed most encouraging results with moderately higher heritability estimates (69.90% b.s) with genetic advance of 3.90.

Table 4. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%), genetic advance (GA), for number of days taken to maturity by F_3 segregating populations of bread wheat

F_3population	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	1.42	3.24	4.65	69.56	3.90
CM × Bhittai	4.92	6.94	11.85	58.52	5.24
NIA-Amber × Marvi	1.42	1.74	3.16	55.17	2.55
NIA-Sunhari × Marvi	0.71	1.00	1.70	58.41	1.98

Plant height

Plant height trait in wheat has linear influence on the production of number tillers, effective tillers and spikelet's spike^{-1} and hence grain number spike^{-1} is influenced accordingly that leads to influence the grain yields plant^{-1}. From breeding point of view, in wheat, dwarf varieties may produce longer spikes with more spikelet's spike^{-1} as compared to tall growing varieties. The data analyzed for environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for plant height are presented in Table-5. The results indicated that substantial amount of genetic variability was present in F_3 populations. Low, moderate and high heritability (h^2) estimates that ranged from 47.75 to 80.53%, coupled with fair amount of genetic advance from 4.36 to 20.39. Among the F_3 progenies, NIA-Sunhari × Marvi manifested highest heritability percentage (h^2=80.53%) that was associated with fair genetic advance (GA=20.39); while F_3 progeny NIA. Amber × Marvi expressed lowest heritability estimates (h^2=47.75%) and genetic advance of 4.36. Most of the progenies however, manifested high heritability estimates coupled with moderately higher genetic advance for this trait. The results of study in regards to plant height indicated that the plant height is mainly controlled by additive genetic factors and the progenies which expressed high heritability estimates and consequently more genetic advance may be valuable segregating populations in order to select the desirable plants for plant height in consequent segregating generations

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Table 5. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%) and genetic advance (GA), for plant height of F_3 segregating populations of bread wheat

F_3 population	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	11.08	19.92	31.00	64.25	9.30
CM × Bhittai	18.33	24.67	43.00	57.36	9.78
NIA-Amber × Marvi	6.46	5.90	12.36	47.75	4.36
NIA-Sunhari × Marvi	18.46	76.36	94.81	80.53	20.39

Spike length

The spike length in wheat is a trait of great economic significance affecting the grain yield directly. Longer spikes result in more spikelet's and in result more grains spike^{-1} result in higher grain yield plant^{-1}. The larger spikes may be more important for higher yields; however, in wheat, varieties bearing longer spikes produce higher grain yields. Table-6 exhibited the genetic parameters such as environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for the spike length for all the four F_3 progenies. The results showed that all the four F_3 progenies showed considerably higher genetic variability than environmental variability and resulting in higher heritability estimates ranging from 56.14 to 75.35%. The F_3 progenies indicated low genetic advance which varied from 1.10 to 4.58. Among the progenies, the high heritability estimates were exhibited by CM × Bhittai (75.35%), NIA-Amber × Marvi (74.63%) and NIA-Sunahri × Marvi (62.27%) with genetic advance of 2.55, 4.58 and 1.82, respectively; while the lowest heritability estimates (56.14%) were manifested by the F_3 progeny Marvi × CM with genetic advance of 1.10. F_3 progenies CM × Bhittai and NIA-Amber × Marvi exhibited higher heritability estimates, but did not give appreciable genetic advances need to select subsequent segregating progenies.

Table 6. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%) and genetic advance (GA), for spike length of F_3 segregating populations of bread wheat

F_3 population	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	0.25	0.32	0.57	56.14	1.10
CM × Bhittai	0.42	1.27	1.69	75.35	2.55
NIA-Amber × Marvi	1.42	4.17	5.58	74.63	4.58
NIA-Sunhari × Marvi	0.48	0.79	1.26	62.27	1.82

Spikelet's spike^{-1}

Spikelet's spike^{-1} trait in wheat has great influence on the number of grains spike^{-1} that leads to influence the grain yields plant^{-1}. From breeding point of view, in wheat, the varieties with longer spikes produce more spikelet's spike^{-1} as compared to those with shorter spikes. The data analyzed for environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for spikelet's spike^{-1} are shown in Table-7. The results indicated that substantial amount of genetic variability was present in F_3 populations which resulted in moderate to high heritability (h^2) estimates ranged from 50.66 to 82.26%. However, the lower amount of genetic advance was noted ranged from 1.33 to 4.83. Among the F_3 progenies, NIA-Sunhari × Marvi manifested highest heritability percentage (h^2=82.26%) that was associated with relatively fair genetic advance (GA=4.83); while F_3 progeny CM × Bhittai expressed lowest heritability estimates (h^2=50.66%) with similar genetic advance of 1.33. The F_3progenies however, manifested high heritability estimates but the genetic advance for this trait was lower. The results for spikelet's spike^{-1}showed that the spikelet's spike^{-1} is mainly controlled by additive genetic factors and the progenies which expressed high heritability estimates and more genetic advance may be valuable segregating populations in order to select the desirable plants for this trait in consequent segregating generations.

Table 7. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%) and genetic advance (GA), for number of spikelet's spike^{-1} of F_3 segregating populations of bread wheat

F_3population	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	0.88	1.94	2.81	68.90	3.00
CM × Bhittai	0.50	0.51	1.01	50.66	1.33
NIA-Amber × Marvi	0.79	0.87	1.66	52.40	1.76
NIA-Sunhari × Marvi	0.91	4.20	5.11	82.26	4.83

Number of grains spike^{-1}

The number of grains plant^{-1} has direct influence on the grain yield; as this is a major yield component having deep relationship with grain yield. Increasing the grain yield which is the main goal of wheat breeders may be achieved by improving this trait. The results in relation to various genetic traits such as environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for the number of grains plant^{-1} are displayed in Table-8 for all the four F_3 progenies. Results revealed that all the F_3 progenies showed considerably higher genetic variability than the environmental variability, resulting in high heritability estimates ranging from 65.48 to 81.48%. The F_2 progenies indicated lower genetic advance which varied from 3.45 to 6.36. Among the progenies, the high heritability estimates were exhibited by CM × Bhittai (81.48%), NIA-Sunahri × Marvi (78.69%) and NIA-Amber × Marvi (75.17%) with genetic advance of 6.36, 4.61 and 5.13, respectively. The genetic advance was highest (6.36) in CM × Bhittai; while the lowest genetic advance (3.45) was observed in F_3progeny Marvi × CM.F_3 progeny CM × Bhittai manifested higher values for all the genetic parameters, thus could be potential breeding population for selection from subsequent segregating generations to improve number of grains plant^{-1}.

Table 8. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%) and genetic advance (GA), for number of grains spike^{-1} of F_3 segregating populations of bread wheat

F3 population	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	1.42	2.69	4.10	65.48	3.45
CM × Bhittai	1.67	7.33	9.00	81.48	6.36
NIA-Amber × Marvi	1.71	5.17	6.88	75.17	5.13
NIA-Sunhari × Marvi	1.08	4.00	5.08	78.69	4.61

Grain yield per plant

The number of grains yield per plant has direct influence on the grain yield; as this is a major yield component having deep relationship with grain yield. Increasing the grain yield which is the main goal of wheat breeders may be achieved by improving this trait. The results in relation to various genetic traits such as environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (Vp), broad sense heritability (h^2) and genetic advance (GA) for the grain yield per plant are displayed in Table-9 for all the four F_3 progenies. Results revealed that all the F_3 progenies showed considerably higher genetic variability than the environmental variability, resulting in high heritability estimates ranging from 59.44 to 77.88%. The F_2 progenies indicated lower genetic advance which varied from 0.01 to 0.22. Among the progenies, the high heritability estimates were exhibited by NIA-Amber × Marvi (77.88%), NIA-Sunahri × Marvi (69.14%) and CM x Bhittai (67.83%) with genetic advance of 0.03, 0.01 and 0.03, respectively. The genetic advance was highest (0.22) in Marvi x CM; while the lowest genetic advance (0.01) was observed in F_3 progeny NIA-Sunhari × Marvi. F_3 progeny NIA-Amber × Marvi manifested higher values for all the genetic parameters, thus could be potential breeding population for selection from subsequent segregating generations to improve grain yield per plant.

Table 9. Genetic parameters viz. environmental variance (δ^2e), genetic variance (δ^2g), phenotypic variance (δ^2p) heritability [b.s] (h^2%) and genetic advance (GA), for grain yield per plant of F_3 segregating populations of bread wheat

F3 population	Environmental Variance (δ^2e)	Genetic Variance (δ^2g)	Phenotypic Variance (δ^2p)	Heritability [b.s] h^2%	Genetic advance (GA)
Marvi × CM	0.86	3.33	8.83	59.44	0.22
CM × Bhittai	0.77	1.67	6.50	67.83	0.08
NIA-Amber × Marvi	0.91	2.33	5.33	77.88	0.03
NIA-Sunhari × Marvi	0.64	2.67	5.33	69.14	0.01

DISCUSSION

Heritability in wheat of a trait within a population is the proportion of observable differences between individuals caused by genetic differences and measures the fraction of phenotype variability that can be attributed to genetic variation [10]. High heritability values indicate the genetic relationship between parents and progeny [11]. The present study was conducted on the heritability estimates to examine the performance of four F_3 segregating generations originated from five parental lines of bread wheat. The study showed that F_3 progenies showed varied response for different traits and progeny NIA-Sunhari × Marvi took maximum days to heading (94.1), NIA-Amber × Marvi took maximum days to maturity (137.3); progeny CM × Bhittai produced plants of maximum height (99.00 cm); NIA-Sunhari × Marvi resulted in maximum spike length (by F_3 progeny Marvi × CM. Maximum plant height (99.00 cm) was observed in F_3 progeny CM × Bhittai and minimum plant height (72.6 cm); while the maximum spike length (11.4 cm) and progeny Marvi × CM produced highest number of spikelet's spike^{-1} (22.3) and subsequently maximum grains (40.2) spike^{-1}. The maximum grains yield (16.89 g) was noted in Marvi × CM, followed by F_3 progeny NIA-Sunahri × Marvi (15.58 g) and minimum grains yield (15.01 g) was observed in F_3 progeny NIA-Amber × Marvi. Apparently the grains yield in the parental lines was higher than their F_3 progenies. These results are further supported by those of [15] who reported that outcomes of analysis of variance depicted highly significant variation among wheat genotypes for all studied attributes in both. The genetic studies revealed that F_3 progeny Marvi × CM manifested highest heritability estimates for days to heading (h^2=84.57) and days to maturity (h^2=69.56%); while NIA-Sunhari × Marvi manifested highest heritability estimates for plant height (h^2=80.53%), and spikelet's spike^{-1} (h^2=82.26%). However, CM × Bhittai resulted in maximum heritability estimates for spike length (75.35%) and grains spike^{-1} (81.48%). Maximum genetic advance was noted for F_3 progenies NIA-Sunhari × Marvi for days to heading (9.55), plant height (20.39) and spikelet's spike^{-1} (4.83); and NIA-Amber × Marvi for spike length (4.58); while CM × Bhittai for days to maturity (5.24) and grains spike^{-1} (6.36). Highest heritability estimates (h^2=77.88%) were observed for NIA-Amber × Marvi followed by (69.14, 67.83 and 59.44%) for NIA-Sunhari × Marvi, CM × Bhittai and Marvi × CM. [16] concluded that the broad-sense heritability value for plant height and number of tillers per plant ranged from 49.83 to 88.83 and 52.25 to 88.82%, respectively. The broad sense heritability for grain yield per plant ranged from 65.58 to 90.01%. The genetic advance values for plant height 6.30 to 19.88, number of tillers per plant 1.87 to 4.42, grain yield per plant 4.78 to 10.10 respectively. [17] Showed very high heritability and moderate to high genetic advance were observed for number of spikes per plant in different crosses. [18] (2004) Heritability estimates for 1000-kernel weight, spikes per m^2 and grains per spike 1 were 62, 74 and 77%, respectively. The genotypic and phenotypic correlations of 1000 grains weight with grains per spike plant, spikes plant and grain yield were non-significant. Similarly, [19] reported moderate to very high broad sense heritability for all the morphological characters except number of fertile tillers per plant. Plant height exhibited the greatest heritability (92.08%) while number of fertile tillers per plant showed minimum value of heritability (40.71%). [20] Found maximum heritability for days to heading and days to maturity and value of genetic advance ranged from a minimum of 0.06 for grain weight per spike to a maximum of 9.79 for yield. [21] Reported that heritability estimates were low for 100-grain weight, number of tillers per plant. Grain yield per plant was moderately correlated with ear length, number of tillers per plant and number of grains per year. One-hundred seed weight was negatively correlated with and number of grains per year. [22] Found that heritability values were 9.07, 15.01, 2.97, 3.0, 9.22 and 5.61 % for plant height, spikelet's spike^{-1}, seeds spike^{-1}, seed weight spike^{-1}, 1000-kernel weight and seed yield respectively. [23] Reported positive correlation of number of spikelet's per spike, number of grains per spike and 1000 grain weight with grain yield at both genotypic and phenotypic levels. However, number of tillers per m^2 and spike length contributed negatively towards grain yield at both levels. Plant height was positively correlated with grain yield at genotypic level, whereas negatively correlated at phenotypic levels. [24] Reported that the magnitude of broad sense heritability of plant height, tillers per plant and grains per spike and grain yield was high with values 0.94, 0.98, 0.92 and 0.91 respectively and was low in case of number of spikelets per spike (0.24). The values of genetic advance ranged from 0.044 for 1000 grain weight to 25.289 for plant height. Fairly high estimates of heritability and genetic advance for plant height, number of tillers and grains per spike suggested that selection for these traits could be practiced more effectively. Some recent researches have also supported the findings of the present study. [25] Found that genotypic coefficient of variability (GCV) and Phenotypic Coefficient of Variability (PCV) was relatively higher for grain yield per plot (20.13, 23.27%), number of kernels per spike (18.30, 20.70%) and spike weight (11.80, 15.20%) across the locations. This implies the presence of more additive gene effects for potential crop improvement. Beside this, high genetic advance was also observed for spike length, number of kernels per spike and thousand-kernel weight. These indicate that there is good scope for crop improvement through selection. [26] Reported that total variability calculated through multiple correlation in the population for yield improvement accounted by fertile tiller number and kernel weight of main spike was 78.6% compared to 82.4% accounted by the all characters. It is concluded that more fertile tiller number and kernel weight of main spike are major yield contributing factors in selecting high yielding wheat cultivars. [27] Found that high heritability estimates were observed for seed index, total biomass, grains per spike and plant height, indicating that these traits were predominantly controlled by additive gene effects and direct selection may be effective for these traits. [28] Found that maximum genotypic differences were observed for all the studied parameters. Highest heritability estimates and expected genetic advance were found for all the traits except chlorophyll concentration index, spike length and number of spikelet spike^{-1} which exhibited moderate heritability. [15] Reported that outcomes of analysis of variance depicted highly significant variation among wheat genotypes for all studied attributes in both. Heritability assessed the relative significance of gene action in genetic variation and plays vital role in selection process for yield improvement in collaboration with genetic advance.

CONCLUSIONS

The parents and the segregating progenies were significantly ($P<0.05$) different with each other for all the traits investigated. Differences for days to heading, days to maturity, plant height, spike length, grains spike^{-1}, and grain yield were non-significant ($P>0.05$) among F_3 segregating populations and significant ($P<0.01$) for spikelet's spike^{-1}. Among F_3progenies, NIA-Sunhari × Marvi took maximum days to heading, NIA-Amber × Marvi took maximum days to maturity; CM × Bhittai produced plants of maximum height; NIA-Sunhari × Marvi resulted in maximum spike length, Marvi × CM produced highest number of spikelet's spike^{-1} and maximum grains spike^{-1}. F_3 progeny Marvi × CM manifested highest heritability estimates for days to heading and days to maturity. F_3 progeny NIA-Sunhari × Marvi manifested highest heritability estimates for plant height and spikelet's spike^{-1}. F_3 progeny CM × Bhittai resulted in maximum heritability estimates for spike length and grains spike^{-1}. Maximum genetic advance was noted for F_3 progenies NIA-Sunhari × Marvi for days to heading, plant height and spikelet's spike^{-1}; NIA-Amber × Marvi for spike length; CM × Bhittai for days to maturity and grains spike^{-1}. NIA-Amber × Marvi exhibited highest heritability for grain yield followed by NIA-Sunahri × Marvi and CM x Bhittai.

REFRENCES

[1] Belderok, B, J. Mesdag and Donner, D.A.,"Bread making quality of wheat: A Century of Breeding in Europe". *Kluwer Academic Publisher: Dordrecht, the Netherlands*. 30–31 pp (2000).

[2] Moon, D.,"In the Russian Steppes: the Introduction of Russian Wheat on the Great Plains of the United States". *Journal of Global History* **3**: 203–225 (2008).

[3] Tsenov, N., D. Atanasova, I. Todorov and Dochev, V.,"Environmental effect on common winter wheat productivity", *Proc. of 18th EUCARPIA General Congress, 9-12 Sept. 2008, Valencia, Spain*. 480-484 pp (2008).

[4] Farzi, A. and Bigloo, B.S.M.,"Evaluation of genetic diversity of wheat lines by for related traits to drought tolerance". *The 11th Iranian Congress of Agronomy Science and Plant Breeding*.155-157 p (2010).

[5] Reynolds, M.P., S. Rajaram and Sayre, K.D.,"Physiological and genetic changes of irrigated wheat in the post green revolution period and approaches for meeting projected global demand". *Crop Science* **39**:1611-1621 (1999).

[6] Khan, M.H. and Dar, A.N., "Correlation and path coefficient analysis of some quantitative traits in wheat". *African Crop Science Journal*. **18**(1): 9-14. (2009).

[7] Habib, I. and Khan, A.S.,"Genetic model of some economic traits in bread wheat (*Triticum aestivum* L.)". *Asian Journal of Plant Sciences*. **2**(17-24): 1153-1155(2003).

[8] GOP.,"Economic Survey of Pakistan, 20013-2014". *Minister of Food and Agriculture, Government of Pakistan, Islamabad*. (2014).

[9] Ali, M.A, N.N. Nawab, G. Rasool and Saleem, M.,"Estimates of variability and correlations for quantitative traits in *Cicer arietinum* L". *J. Agric. Social Sci*. **4**(4): 177-179 (2008).

[10] Raj, A., V. Oudenaarden and Alexander, A.,"Nature, nurture or chance: Stochastic gene expression and its consequences". *Cell*, **135**(2): 216–226 (2008).

[11] Rajper, M.M, B.A. Ansari and Malik, A.J.,"Heritability of grain yield and yields related characters of F_4 population of wheat (*Triticum aestivum* L.)". *Pak. J. Agric. Engg. Vet. Sci.* **12**(1-2): 9-14 (1996).

[12] Deswal, R.K, S.S. Grakh and Berwal, K.K.,"Genetic variability and characters association between grain yield and its components in wheat". *Annals of Biology (Ludhiana)*. **12**(2): 221-224 (1996).

[13] Vaughan, J.G. and Judd, P.A.,"The Oxford Book of Health Foods". *Oxford University Press*. 35. Pp (2003).

[14] Yu, Y.,"Sichuan wheat". *Sichuan Science and Technology Press, Chengdu, China*. (1993).

[15] Rehman, S.U, M.A. Abid, M. Bilal, J. Ashraf, S. Liaqat, R.I. Ahmed and Qanmber, G.,"Genotype by trait analysis and estimates of heritability of wheat (*Triticum aestivum* L.) under drought and control conditions". *Basic Research Journal of Agricultural Science and Review*. **4**(4): 127-134 (2015).

[16] Khan, A.S, I. Salim and Ali, Z.,"Heritability of various morphological traits in Wheat". *Inter. J. Agri. and Biol*. **5**(2): 131-140 (2003).

[17] Chandra, D, M.A. Islam and Barma, N.C.D.,"Variability and interrelationship of nine quantitative characters in F5 bulks of five wheat crosses". *Pak. J. Biol. Sci*. **7**(6): 1040-1045 (2004).

[18] Humaira, Gul, M. Fida, M. Maqbool and Naz, A.,"Studies on yield and yield components in wheat vs triticale". *Sarhad J. Agri*. **20**(4): 533-536 (2004).

[19] Kashif, M. and Khaliq, I.,"Heritability, correlation and path coefficient analysis for some metric traits in wheat". *Inter. J. Agri. and Biol.* **6**(1): 138-142 (2004).

[20] Safeer-ul-Hassan, M, M. Munir, M.Y. Mujahid, N.S. Kisana, Z. Akram and Nazeer, A.W.,"Genetic analysis of some biometric characters in bread wheat (*Triticum aestivum* L.)". *J. Biol.* Sci. **4**(4): 480-485 (2004).

[21] Biju, S. and Malik, S.K.,"Association analysis in wheat". *Int. J. Agri. Sci*. **2**(2): 427-428 (2006).

[22] Koksal, Y, E. Sozen, A. Esra and Cifci, A.,"Heritability and correlation of yield and qualitytraits in durnm wheat (*Triticum Durum*)". *Indian Journal of Agricultural Science*. **77**(9): 245-246 (2007).

[23] Zahid, A, S.U. Ajmal and Munir, M.,"Estimation of correlation coefficient among some yield parameters of wheat under rained conditions". *Pak. J. Bot.* **40**(4): 1777-1781 (2008).

[24] Ajmal, S.U, N. and Zakir, M.Y.M.,"Estimation of genetic parameters and character association in wheat". *J. Agric. Biol. Sci.* **1**(1): 15-18 (2009).

[25] Jalata, Z, A. Ayana and Zeleke, H.,"Variability, heritability and genetic advance for some yield and yield related traits in Ethiopian barley (*Hordeum vulgare* L.) Landraces and Crosses". *International Journal of Plant Breeding and Genetics***.** **5**(1): 44-52 (2011).

[26] Al-Tabbal, J.A. and Al-Fraihat, A.H.,"Heritability studies of yield and yield associated traits in wheat genotypes". *Journal of Agricultural Science*. **4**(4): 23-29 (2012).

[27] Baloch, A.W, S.K. Baloch, S.A. Channa, A.M. Baloch, M. Ali, M.A. Junejo and Baloch, G.M.,"Character association and heritability analysis in Pakistani elite bread wheat cultivars". *International Journal of Applied Biology and Pharmaceutical Technology*. **5**(4): 20-21 (2014).

[28] Salman, S, S.J. Khan, J. Khan, R.U. Khan and Khan, I.,"Genetic variability studies in bread wheat (*Triticum aestivum* L.) accessions". *Pakistan J. Agric. Res.* **27**(1): 1-7 (2014).