Research Article

Inbreeding depression analysis in F₂ segregating population of bread wheat

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Abstract

The present experiment was conducted to analysis mean performance and inbreeding depression in six F₂ hybrids. The F₂ populations of wheat along with their parents differed significantly ($P \leq 0.01$) for all yield and its components, suggesting that abundant genetic diversity is available in these genotypes. For mean performance, among the parents, the variety TD-1 demonstrated better performance for early maturity, plant height, tillers plant⁻¹, spikelets spike⁻¹, grains spike⁻¹, seed index and grain yield plant⁻¹; however, among the F₂ progenies, the F₂ progeny TD-1 x Imdad exhibited better performance for various traits such as days to 50% heading, plant height, grains spike⁻¹, seed index and grain yield plant⁻¹, indicating that these genetic resources can further be utilized in various breeding programs to improve bread wheat. With regards to inbreeding depression, the F₂ progeny TJ-83 x Moomal expressed low amount of inbreeding depression for various traits including spike length (-9.88%), spikelets spike⁻¹ (-0.82%), seed index (-5.98%), grain yield plant⁻¹ (-3.62%) while same F₂ progeny also showed maximum (-3.72%) inbreeding depression for the trait days to 50% heading, and indeed is desirable for that trait. Consequently, the F₂ progeny TJ-83 x Moomal would be useful F₂ hybrid to be utilized for commercial cultivation since this progeny showed minimum inbreeding depression for variety of traits.

Key words: Bread wheat; F₂ segregating population; Inbreeding depression; Grain Yield.

Introduction

Wheat is a principal crop and considered as a great source of carbohydrates in human diet. It is extensively cultivated in Pakistan and used as major staple food [1]. Human population of the world is rising at a great

pace; hence there is demand for stunning improvement in food production to feed increasing population. Due to considerable achievements made in crop research, quite a large number of new crop cultivars have been evolved and the production has been

outstandingly improved all over the world. Wheat breeders have been done a great deal of research on wheat crop in Pakistan and as a consequences country is self-sufficient in wheat production [2].

For any successful breeding program, the proper parental selection and the breeder's intense judgment in selecting promising genotypes within the segregating populations is pre-requisite. The research on heterosis and inbreeding depression in economically important crops including wheat is an essential approach for genetic parameter's interpretation. The nature and extent of heterosis and inbreeding depression may possibly play a crucial role for plant breeder in making the suitable breeding methods [3]. Therefore, the current study was done to mark out the extent of inbreeding depression in bread wheat and identify superior crosses which would profitably be utilized in future wheat improvement programs.

Materials and Methods

In order to study the inbreeding depression for grain yield and its component in F_2 hybrids of wheat (*Triticum aestivum* L.), the experiment was conducted during the year 2012-13 at the experimental field of Sindh Agriculture University, Tandojam. The seed of four parents (TD-1, TJ-83, Imdad and Moomal) along with their six F_2 hybrids (TD-1 $\times$ TJ-83, TD-1 $\times$ Imdad, TD-1 $\times$

Moomal, TJ-83 $\times$ Imdad, TJ-83 $\times$ Moomal and Imdad $\times$ Moomal) of wheat were sown in Randomized Complete Block Design (RCBD) with three replications during Rabi, 2012-13. The six rows of three meter long of each genotype were grown by keeping 15 cm plant to plant and 30 cm row to row distance through hand drill method. After 25 days of germination, thinning was done to maintain plant to plant and row to row distance and all recommended agronomic practices were applied. Ten plants per replication per genotype were randomly selected and tagged for recording the various phenotypic traits (Table-2). The analysis of variance was carried out according to statistical method developed by [4], whereas inbreeding depression was calculated as suggested by [5].

$$\text{Inbreeding depression} = \frac{F_2 - F_1}{F_1} \times 100$$

Results and discussion

Analysis of variance

The analysis of variance calculations (Table 1) from F_2 populations of wheat along with their parents were significantly different at $P < 0.01$ level for all the investigated traits which indicated that significance in the difference was found among the F_2 hybrids as well as among the parents. This demonstrates that used plant sources may be evaluated for further research. The results of each character are discussed below.

Table 1. Mean squares from analysis of variance of F_2 hybrids along with their parents for various quantitative traits in bread wheat genotypes.

Source of variances	D.F.	Days to 50% heading	Plant height	Tillers plant ⁻¹	Spike length	Spikelets spike ⁻¹	Grains spike ⁻¹	Seed index	Grain yield plant ⁻¹
Replication	2	0.89	1.08	0.14	0.17	0.02	0.40	1.27	0.49
Genotypes	9	19.10**	208.59**	1.96**	4.33**	8.39**	28.99**	19.95**	4.09**
Error	18	0.93	0.29	0.05	0.08	0.17	0.09	1.36	0.08

** = Significant at 0.01 probability level

Days to 50% heading

Early maturity is a key character in crop plants, since early maturing genotypes need a lesser amount of resources and empties the field in advance for other crops to be sown timely. The data with regards to number of days taken to 50% heading of F₂ hybrids and their parents in wheat (Table-2) showed that variety TD-1 took minimum days to 50% heading; while among the F₂ hybrids, TD-1 x TJ-83 took minimum number of days to

50% heading, indicating that parent TD-1 has the worth to breed for early maturing cultivars. Inbreeding depression percentage was maximum in TJ-83 x Moomal (-3.72%) and TD-1 x Imdad with -2.97% (Table-3) among the F₂ hybrids which is indeed a desirable for this trait. These results are further supported by Hammad [6], who worked on six wheat crosses and reported a higher amount of inbreeding depression for days to heading.

Table 2. Mean performance of F₂ hybrids along with their parents for various quantitative traits in bread wheat genotypes.

Genotypes	Days to 50% heading	Plant height (cm)	Tillers plant ⁻¹	Spike length (cm)	Spikelets spike ⁻¹	Grains spike ⁻¹	Seed index (1000 grain wt. gm)	Grain yield plant ⁻¹ (gm)
TD-1	65.00	62.33	7.66	12.67	19.67	62.33	50.10	16.45
TJ-83	70.33	84.05	5.88	12.87	17.98	55.67	43.36	13.98
Imdad	69.66	79.55	5.87	9.88	16.25	56.32	46.33	14.65
Moomal	72.66	85.65	5.33	10.88	15.66	51.65	44.67	13.25
TD-1 x TJ-83	69.00	82.55	6.33	11.12	18.33	60.53	49.90	15.55
TD-1 x Imdad	67.33	72.68	5.33	11.92	17.80	57.27	45.67	16.33
TD-1 x Moomal	68.00	75.67	5.87	11.13	15.87	55.00	45.38	15.69
TJ-83 x Imdad	69.67	80.50	5.90	10.21	16.87	56.00	43.83	13.90
TJ-83 x Moomal	68.67	81.18	6.33	12.75	20.40	56.40	43.67	14.89
Imdad x Moomal	73.00	94.09	7.67	13.48	19.80	53.73	40.76	13.23
LSD (p≤0.05)	1.65	0.91	0.35	0.46	0.70	0.49	1.99	0.46

Table 3. Inbreeding depression in F₂ hybrids for days to 50% heading and plant height.

F ₂ hybrids	Days to 50% heading			Plant height		
	F ₁ hybrids	F ₂ hybrids	Inbreeding depression	F ₁ hybrids	F ₂ hybrids	Inbreeding depression%
TD-1 x TJ-83	66.00	65.00	-1.51	85.33	82.55	-3.25
TD-1 x Imdad	67.33	65.33	-2.97	75.65	72.68	-3.92
TD-1 x Moomal	66.33	66.00	-0.49	80.25	75.67	-5.70
TJ-83 x Imdad	68.66	69.67	1.47	89.66	80.50	-10.21
TJ-83 x Moomal	71.33	68.67	-3.72	88.65	81.18	-8.42
Imdad x Moomal	72.66	73.00	0.46	97.5	94.07	-3.51

Plant height

Plant height has been considered as one of the most important traits in wheat breeding and it is well known that dwarf wheat cultivars not only boost grain yield but also show great resistance against lodging and are nitrogenous fertilizer responsive. Among the parents, the cultivar TD-1 (62.33 cm), while among the F₂ hybrids, TD-1 x Imdad (75.65 cm) produced short stature plants (Table-2); yet, these breeding materials would be proved better genetic resources for future breeding programs, especially while target is to produce dwarf wheat varieties. The highest inbreeding depression was observed in the crosses TJ-83 x Imdad (-10.21%) and TJ-83 x Moomal (-8.42%) (Table-3) indicating that these two F₂ progenies could rather be exploited in further breeding programs as these F₂ population showing desirable results. These results are further supported by Larik [7] and Singh [8] and they penned inbreeding depression for all the studied traits, suggested that inbreeding depression was primarily associated with epistasis, linkage disequilibrium and abnormal segregation at meiosis due to higher ploidy level.

Tillers plant⁻¹

Among yield components, tillers plant⁻¹ is a vital plant attributes that enhances grain yield in wheat. To develop promising cultivars, not only grain yield but yield associated components such as tillers plant⁻¹ also entail a special consideration. Among the parents, the maximum number of tillers plant⁻¹ (Table-2) was produced by the genotype TD-1 (7.66), followed by TJ-83 (5.88), while among the F₂ hybrids, Imdad x Moomal (7.67) resulted in maximum number of tillers plant⁻¹, signifying that these plant materials including parents and F₂ progenies could be proved backup materials in upcoming breeding programs because these plant resources possess better yield related trait in shape of maximum tillers plant⁻¹ as compared to other parents and crosses. The minimum inbreeding depression (Table-4) was calculated from the cross Imdad x Moomal (-0.39%), it reveals that this cross combination can further be used as hybrid since it possesses better gene recombination as compared to other F₂ progenies. Similar results have also been reported by Singh [9] and Singh [10] who also found inbreeding depression for yield components in wheat including the number of tillers plant⁻¹.

Table 4. Inbreeding depression in F₂ hybrids for tillers plant⁻¹ and spike length.

F ₂ hybrids	Tillers plant ⁻¹			Spike length		
	F ₁ hybrids	F ₂ hybrids	Inbreeding depression	F ₁ hybrids	F ₂ hybrids	Inbreeding depression%
TD-1 x TJ-83	9.33	6.33	-32.15	14.36	11.12	-22.56
TD-1 x Imdad	6.66	5.33	-19.97	14.30	11.92	-16.64
TD-1 x Moomal	8.33	5.87	-29.53	15.55	11.13	-28.42
TJ-83 x Imdad	6.33	5.90	-6.79	11.50	10.21	-11.21
TJ-83 x Moomal	6.75	6.33	-6.22	12.75	11.49	-9.88
Imdad x Moomal	7.70	7.67	-0.39	13.48	11.93	-11.49

Spike length

Spike length is a trait of more significance, because bigger spike is supposed to generate extra grains consequential in higher yield plant⁻¹. The mean performance of F₂ hybrids along with parents is illustrated in Table-2 which exhibited that parent TJ-83 and TD-1 gave maximum spike length of 12.87 and 12.67 cm, respectively, while among the F₂ hybrids, the maximum spike length was observed in cross Imdad x Moomal (11.93 cm). These parents and F₂ hybrid have worth as being utilized potential wheat crop materials in target research programs where spike length is considered as main trait for bread wheat improvement. Table-4 shows that cross TJ-83 x Moomal expressed minimum inbreeding depression (-0.82%), providing opportunities to be exploited its potentiality of being less destructed in favorable gene recombination. The present findings are further in line with those of Lal [3].

Spikelets spike⁻¹

Spikelets spike⁻¹ is also an important trait in wheat, as more number of the spikelets spike⁻¹, more number of the grains spike⁻¹,

consequently higher the grain yield plant⁻¹. The mean performance (Table-2) referred that among the parents, the maximum number of spikelets spike⁻¹ was counted from parent TD-1 (19.67). However in F₂ hybrids, TJ-83 x Moomal gave the highest number of spikelets spike⁻¹ (20.40), demonstrating that above mentioned parent and F₂ hybrid possess greater potential to show better performance, thus could be proved useful plant materials for plant breeders. The information of inbreeding depression regarding number of spikelets spike⁻¹ is given in Table-5. The maximum inbreeding depression was recorded in TD-1 x Moomal (-32.52%), followed by TD-1 x Imdad (-18.79%), TD-1 x TJ-83 (-17.80%) and TJ-83 x Imdad (-17.01%). However, the minimum inbreeding depression was shown by the cross of TJ-83 x Moomal (-0.82%). Considering the low amount of inbreeding depression, various researchers [10, 11, 12] have suggested that in some cases low inbreeding depression designates additive x additive and additive x dominance type of gene action which may be a cause of low inbreeding depression.

Table 5. Inbreeding depression in F₂ hybrids for spikelets spike⁻¹ and grains spike⁻¹.

F ₂ hybrids	Spikelets spike ⁻¹			Grains spike ⁻¹		
	F ₁ hybrids	F ₂ hybrids	Inbreeding depression	F ₁ hybrids	F ₂ hybrids	Inbreeding depression%
TD-1 x TJ-83	22.30	18.33	-17.80	64.72	60.53	-6.47
TD-1 x Imdad	21.92	17.80	-18.79	57.45	57.27	-0.31
TD-1 x Moomal	23.52	15.87	-32.52	58.33	55.00	-5.70
TJ-83 x Imdad	20.33	16.87	-17.01	58.55	56.00	-4.35
TJ-83 x Moomal	20.57	20.40	-0.82	57.82	56.40	-2.45
Imdad x Moomal	20.35	19.80	-2.70	55.78	53.73	-3.67

Grains spike⁻¹

Grains spike⁻¹ is also a key trait in wheat breeding; it directly involves in enhancing the grain yield plant⁻¹. The mean performance of number of grains spike⁻¹ (Table-2) revealed that parent TD-1 set more number of grains spike⁻¹ (62.33) followed by Imdad (56.32). In case of F₂ hybrids, TD-1 x TJ-83 set maximum number of grains spike⁻¹ (60.53) followed by hybrid TD-1 x Imdad (57.27). In brief, these parents and F₂ retain potentiality to show superior performance for future breeding programs, especially for grains spike⁻¹. The calculated inbreeding depression for the trait number of grains spike⁻¹ is presented in Table-5. All F₂ progenies expressed inbreeding depression, however, the observed inbreeding depression for this trait was not as greater as other traits showed in the present study, it ranged from -0.31 to -6.47%. The obtained results support the initiative that F₂ populations may possibly work as a hybrid crop if suitably managed and if parents are recognized through their performance in segregating population, since F₁ hybrids cannot illuminate the constancy of F₂ populations. Therefore, such F₂ populations

would be desirable to use as hybrid wheat to enhance the grains spike⁻¹ and eventually grain yield plant⁻¹.

Seed index

Seed index is one of the most important yield contributing traits. The mean performance of parents and F₂ hybrids (Table-2) showed that among the parents, the cultivar TD-1 (50.10 g) resulted in maximum seed index value followed by Imdad (46.33 g). On the other hand, among the F₂ hybrids, TD-1 x TJ-83 (49.90 g) recorded the highest seed index value, followed by TD-1 x Imdad (45.67 g). Indeed, the performance of these parents as well as F₂ hybrids indicates their valuable use in upcoming breeding projects. Inbreeding depression for the trait seed index (1000 grain weight g) is presented in Table-6. It was found that inbreeding depression existed in all F₂ progenies for seed index, ranging from -5.98 to -16.21%. However, inbreeding depression was low to moderate, indicating that little inbreeding depression exists for F₂ generations and it is possible to select high yielding F₂ populations for further use.

Table 6. Inbreeding depression in F₂ hybrids for seed index and grain yield plant⁻¹.

F ₂ hybrids	Seed index			Grains yield plant ⁻¹		
	F ₁ hybrids	F ₂ hybrids	Inbreeding depression	F ₁ hybrids	F ₂ hybrids	Inbreeding depression%
TD-1 x TJ-83	53.15	49.90	-6.11	18.50	15.55	-15.94
TD-1 x Imdad	50.75	45.67	-10.01	17.68	16.33	-7.63
TD-1 x Moomal	52.95	45.38	-14.29	16.60	15.69	-5.48
TJ-83 x Imdad	47.25	43.83	-7.23	15.55	13.90	-10.61
TJ-83 x Moomal	46.45	43.67	-5.98	15.45	14.89	-3.62
Imdad x Moomal	48.65	40.76	-16.21	15.48	13.23	-14.53

Grain yield plant⁻¹

High grain yield is very critical for improvement of crop cultivars for farmer's perspective. Yield is a trait controlled by many genes and is end product of interaction between various genetic and environmental components. The chief objective of wheat breeding is to enhance wheat production by exploiting the potential of existing genetic materials available to them. The mean performance of F₂ hybrids and their parents for grain yield plant⁻¹ (Table-2) exhibited that among the parents, the parent TD-1 gave maximum grain yield plant⁻¹ (16.45 g); however, among the crosses TD-1 x Imdad gave the highest grain yield plant⁻¹ (16.33 g). Since, greater yield is always a prime objective of an agriculturist, so these breeding materials could be a valuable addition in any breeding programs. The information of inbreeding depression for grain yield plant⁻¹ is given in Table-6. The cross combination TD-1 x TJ-83 showed higher inbreeding depression of -15.94%, while TJ x Moomal displayed minimum inbreeding depression of -3.62%. Similar results have also been reported by [13, 14, 15, 16] who also observed a high amount of inbreeding depression for grain yield in different F₂ populations and stated that inbreeding depression in polyploids has been found to exceed what is envisaged by the coefficient of inbreeding. Such response is ascribed in reduction of favorable interactions among several alleles caused by inbreeding and abnormal segregation during meiosis.

Authors' contributions

Conceived and designed the experiments: AW Baloch, GM Baloch, FJ Depar & MJ Baloch. Performed the experiments: FJ Depar, N Gandahi & IA Baloch. Analyzed the data: MS Depar & AM Baloch. Contributed reagents/materials/analyses

tools: TA Baloch. Wrote the paper: AW Bloch & M Baloch.

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