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Inheritance Studies for Leaf Rust Resistance and Different Economic Traits in F_2 Generation Developed Through Introgression of Functional Genes in Bread Wheat Genotypes

M. BALOCH[++], A.W. BALOCH, D. R. SHAIKH*, M. A. ASAD**, N. GANDAHI, G. M. BALOCH, G. H. BALOCH, A. M. BALOCH***, M. ALI****

Department of Plant Breeding and Genetics, Sindh Agriculture University, Tandojam, Pakistan

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Abstract: Wheat rusts are potential threat for sustainable wheat production in different parts of the global village. Among these, leaf rust caused by *Puccinia recondita* is one of the most important leaf rust diseases. During the year 2012-13, an experiment was conducted at experimental farm of NIA, Tandojam, which comprised of seven wheat genotypes; four leaf rust resistant (Sunco, Vasco, SD-222 and SD-333) and three susceptible (TD-l, ICARDA and SD-888) were used to develop four F_2 cross combinations (TD-1 x Vasco, ICARDA x SD-222, TD-1 x Sunco and SD-888 x SD-333) in order to study the genetic pattern of resistance genes. The observations were recorded on gain yield plant^{-1} and its associated traits to evaluate genetic potential of the F_2 populations. The analysis of variance revealed significant differences among F_2 populations for majority of the traits studied which suggested that the breeding material is worth for selection of desirable plants from subsequent segregating generations. Based on mean performance, among the parental lines, the parent SD-888 exhibited outstanding performance for spike length and grains spike^{-1}; however, the variety TD-1 ranked second which showed better performance for 1000 grain weight and grain yield plant^{-1}. Considering the F_2 hybrids, the progeny TD-1 x Vasco gave desirable results for 1000 grain weight, grain yield plant^{-1}, whereas cross combination SD-888 x SD-333 also produced interesting results for spike length, spikelets spike^{-1} and grains spike^{-1}. On an average, F_2 progenies gave higher values for most of the traits which could be either due heterotic effects or transgressive segregants developed through recombination of genes. With regards to heritability percentage in broad sense, the F_2 progeny ICARDA x SD-222 expressed high heritability for spike length and grains spike^{-1}. Similarly, the F_2 cross combination SD-888 x SD-333 also showed high heritability for 1000 grain weight and grain yield

1. INTRODUCTION

Wheat *(Triticum aestivum* L.) is one of the world's main cereal crops and is used as staple food for the masses, and is cultivated under both irrigated and rain-fed conditions. Wheat is considered as the first domesticated cereal, and its ability to self-pollinate prominently helped for selection; consequently, a quite high number of commercial varieties have been evolved. Technological advances including preparation of soil, planting time, crop rotation and efficient utilization of irrigation and fertilizer applications and advance harvesting methods, all combined promote wheat as a farmer's friend crop (Baloch *et al.*, 2015).

Wheat has been damaged by various diseases that cause a huge losses to the quantity and quality of produce. Rusts, smuts, powdery mildew, and septoria are important diseases that reduce the yield of wheat. Rusts are the most serious disease of wheat worldwide in spite of great progress made in their control in many countries. There are three types of rusts that attack wheat crop namely, leaf rust *(Puccinia recondita),* stem rust *(Puccinia graminis*) and stripe rust *(Puccinia strifformis)*. Leaf or brown rust of wheat is caused by *Puccinia recondita* which is a major disease of wheat worldwide. Although the average yield and total production have increased in Pakistan but wheat diseases are still important variables in contribution to yield instability (Hussain *et al.*, 2011).

Heritability parameters estimate provides knowledge of the extent to which a particular genetic character can be transmitted from parents to their off-springs (Mangi *et al.*, 2010). Heritability is a useful technique in explaining the genetic consequences of conventional breeding methods. The heritability, genetic advance, phenotypic and genotypic variance provide the useful information to investigate the magnitude of variance in wheat segregating population (Memon *et al.*, 2007).

2. MATERIALS AND METHODS

During the year 2012-13, an experiment was conducted at experimental farm of NIA, Tandojam, which composed of seven wheat genotypes; four leaf rust resistant (Sunco, Vasco, SD-222 and SD-333) and three susceptible (TD-l, ICARDA and SD-888) were used to produce four F_2 cross combinations (TD-1 x Vasco,

[++]Corresponding author's email: munaizabaloch@yahoo.com
*Southern Wheat Research Station, Tandojam, Pakistan
**Nuclear Institute of Agriculture, Tandojam, Pakistan
***College of Horticulture, Northeast Agriculture University, Harbin, China
****Department of Biotechnology, Sindh Agriculture University, Tandojam, Pakistan

ICARDA x SD-222, TD-1 x Sunco and SD-888 x SD-333) in turn to shed the light on genetic pattern of resistance genes. The observations were recorded on gain yield plant^{-1} and its associated traits to evaluate genetic potential of the F_2 populations. The seed of rust spreader (Morocco) and rust inoculum of leaf rust were obtained from head of Plant Breeding and Genetics Division, NIA, Tandojam. The seeds of each parent and their respective F_2 crosses were planted in 4 rows of 2 meter in length with plant to plant distance of 15 centimeter and row to row distance of 30 centimeter in randomized complete block design (RCBD) with four replications. After every 8 experimental lines a spreader row (Morocco) was planted. The recommended dose of fertilizer and irrigations were applied accordingly. The entire data was statistically analyzed using analysis of variance method as suggested by Gomez and Gomez (1984) and the means were compared by Duncan's multiple range test by Statistix v. 8.1 computer package. The heritability of different traits was calculated according to Falconer (1977).

3. RESULTS AND DISCUSSION

Genetic parameters such as genetic variance, phenotypic variance, heritability percentage in broad sense and genetic advance for yield and its associated traits were calculated from each four F_2 cross combinations in wheat. It has been emphasized that without genetic advance, the heritability values do not have practical importance in selection on the basis of phenotypic appearance.

The combined analysis of variance for all the genotypes (including seven parents and their four F_2 progenies) depicted that both the parents and segregating populations differed significantly at $P \geq 0.01$ probability level for all the characters under study, indicating the existence of great genetic variability among the genotypes (**Table-1**). The results of each traits is discussed in following paragraphs.

Spike length (cm): The mean performance of spike length showed that the longest spike was produced by SD-888 (18.33 cm) among all the parental lines, whereas SD-888 x SD-333 produced the longer spike (17.53 cm) than all cross combinations (**Table-2**). Single spike selection with good grains might be a useful criterion for improving wheat yield (Pawar *et al.,* 2002). The heritability estimates (b.s) ranged between 39.64 and 55.37, whereas genetic advance ranged from 4.10 to 6.32 (**Table-3**) for spike length. Among the cross combinations, the cross ICARDA x SD-222 showed high heritability percentage (h^2=55.37%) for spike length coupled with low genetic advance (GA=6.32). Khan *et al.* (2003) found high magnitude of heritability along with low genetic advance for spike length in F_2 population of six cross combinations. Direct selection for spike length could be useful for grain yield improvement in wheat. Similar results have also been reported by Ijaz *et al.* (2015).

Spikelets spike^{-1}: The mean performance of spikelets spike^{-1} is presented in (**Table-2**), which showed that the parental line SD-222 produced maximum number of spikelets spike^{-1} (28.10), whereas the cross SD-888 x SD-333 produced maximum 26.23 spikelets spike^{-1}. Number of spikelets spike^{-1} depends upon spike length and spike density and directly involved in grain yield improvement. The wheat breeding studies have been reported that spikelets spike^{-1} may directly contribute towards grain yield. Heritability estimates varied from 24.33 to 69.31 (**Table-3**), however genetic advance varied between 2.01 and 8.31. The cross TD-1 x Vasco showed high heritability (h^2=69.31%) for spikelets spike^{-1}. Whereas, higher genetic advance (GA=8.31) than rest of the crosses was also observed from the same F_2 cross. This indicated that this trait could be improved by direct selection to enhance the grain yield in wheat cultivars.

Grains spike^{-1}: The mean performance for grains spike^{-1} showed that the parent SD-888 (53.52) and the progeny SD-888 x SD-333 produced the highest number of grains spike^{-1} (63.97) among parental and cross combinations, respectively (**Table-2**). The high heritability percentage (h^2=96.02%) was recorded in ICARDA x SD-222 followed by TD-1 x Vasco (h^2=57.17%), coupled with high and low genetic advance of 36.76 and 0.87, respectively (**Table-3**). Similar results were also found by Sial *et al.* (2007). These results showed that grains spike^{-1} could be used in direct selection criteria for grain yield improvement.

Seed index (g): The data (**Table-2**) indicated that parental lines and cross combinations ranged between 34.31 to 25.95 and 32.83 to 15.40 g, respectively. Among the parental lines, TD-1 gained more 1000 grain weight, whereas among the F_2 progenies, the highest 1000-grain weight was recorded in TD-1 x Vasco 34.31 g. The results of heritability estimates (**Table-3**) represented that higher heritability among all crosses is exhibited by the cross SD-888 x SD-333 (h^2=43.72%) coupled with low genetic advance (GA=3.74). For grain yield improvement, this trait could play an important role in selection of genotypes with high yield. Therefore, 1000-grain weight can be included as selection parameter for varietal development. Sial *et al.* (2013) reported that high heritability associated with high genetic advance for different yield components which could have a better scope for selecting high yielding genotypes.

Grain yield plant^{-1} (g): Grain yield is a total output of all yield components. The mean performance exhibited that grain yield plant^{-1} of cross combinations is considerably higher than the parental lines. The cross TD-1 x Vasco gave maximum grain yield plant^{-1} (16.61g) and TD-1 x Vasco gave the lowest grain yield plant^{-1} of 7.28g (**Table-2**). This result indicated that new cross combinations have potential to be utilized directly or indirectly in wheat breeding programs to improve wheat yield per unit area. The trait grain yield plant^{-1} in present study indicated that the cross SD-888 x SD-333 expressed high heritability (h^2=56.77%) along with moderate genetic advance (GA=18.01%) (**Table-3**). Nanda *et al.* (1982) reported that certain traits of grain yield in wheat are more heritable than other traits. Our results suggested that grain yield of wheat could be improved directly. In general, it is considered that if a character is governed by non-additive gene action, it may give higher heritability with low genetic advance, whereas if the character is governed by additive gene action, both heritability and genetic advance would be in higher values.

Introgression of resistance genes: The scoring results of parental lines and their F_2 population in different cross combinations indicated that all resistant parents showed resistance to the prevailing race of rust, whereas susceptible parents showed susceptibility in the field. In each cross combination of TD-1 x Vasco, ICARDA x SD-222, TD-1 x Sunco, SD-888 x SD-333, out of 20 plants 14, 14, 16 and 13 were resistant whereas, 6, 6, 4, and 7 were observed susceptible, respectively **(Table-4).** The 3: 1 ratio based on reaction pattern in the field is an indicative of the involvement of single dominant gene for resistance to rust. These resistant genes could be proved useful for the development of new resistant cultivars in wheat breeding programs to face the new challenges of rust threat in Southeast Asia, especially in Sindh province.

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Table 1. Mean squares for various morphological traits of four F_2 populations and parental lines of wheat.

Source of variation	D.F	Characters				
		Spike length	Spikelet spike^{-1}	Grains spike^{-1}	1000 grain weight	Grain yield plant^{-1}
Replications	3	0.52	2.43	38.72	6.50	3.16
Genotypes	10	28.29**	28.91**	290.68**	137.35**	56.15**
Errors	30	0.26	0.65	46.39	6.37	1.67

** = Significant at 1% probability level.

Table 2. Means performance of seven parental lines and their four F_2 populations of wheat for various traits.

Parents / F_2 generation	Spike length (cm)	Spikelets spike^{-1}	Grains spike^{-1}	Seed index (1000 grain weight, g)	Grain yield plant^{-1} (g)
TD-1	13.3675d	19.00f	50.00bcd	32.83a	11.45b
Vasco	10.8725f	23.00d	46.33bcde	21.96d	8.57c
Sunco	11.3975f	24.66cd	39.20ef	22.02d	7.00c
ICARDA	11.4925f	24.33d	35.00f	21.78d	7.68c
SD-222	16.83b	28.00a	43.00cdef	15.4e	3.65d
SD-888	18.3325a	25.33c	54.00bc	30.57abc	4.48d
SD-333	13.5425e	21.00e	53.11bc	21.18d	4.10d
TD-1 X Vasco	11.61f	21.33e	54.00ab	34.31a	16.61a
ICARDA X SD-222	14.265c	25.00bc	40.11def	25.95d	7.28c
TD-1 X Sunco	12.3475e	21.00e	44.24bcdef	28.68c	10.46b
SD-888 X SD-333	17.535b	26.66b	64.00a	29.69bc	8.00c

Mean followed by similar alphabetic letters are not significantly different from each other according to DMRT test

Table 3. Heritability analysis (broad sense) in 4 F_2 generations for various traits of bread wheat.

Characters	F_2 progenies	Genetic variance ($\sigma^2 g$)	Phenotypic variance ($\sigma^2 p$)	Heritability (h^2%) broad sense	Genetic advance (GA)
Spike length	TD-1 × Vasco	0.20	0.48	41.11	4.92
	ICARDA × SD-222	0.28	0.50	55.37	6.32
	TD-1 × Sunco	0.22	0.46	47.62	5.48
	SD-888 × SD-333	0.25	0.63	39.64	4.10
Spikelets spike^{-1}	TD-1 × Vasco	0.52	0.74	69.31	8.31
	ICARDA × SD-222	0.52	1.20	43.35	5.98
	TD-1 × Sunco	0.16	0.66	24.33	2.01
	SD-888 × SD-333	0.34	0.91	37.46	3.73
Grains spike^{-1}	TD-1 × Vasco	2.47	4.32	57.17	15.08
	ICARDA × SD-222	3.62	3.76	96.02	36.76

	TD-1 × Sunco	1.26	4.20	30.02	7.68
	SD-888 × SD-333	0.26	7.25	3.60	0.87
Seed index	TD-1 × Vasco	0.53	2.83	18.52	3.74
	ICARDA × SD-222	0.58	1.88	30.80	6.27
	TD-1 × Sunco	0.93	2.77	30.60	8.65
	SD-888 × SD-333	1.17	2.67	43.72	11.67
Grain yield plant^{-1}	TD-1 × Vasco	0.48	2.64	18.30	7.09
	ICARDA × SD-222	0.33	1.97	16.84	9.84
	TD-1 × Sunco	0.57	2.07	27.45	14.18
	SD-888 × SD-333	0.45	0.79	56.77	18.01

Table 4. Reaction pattern of parental lines and four F_2 populations in the field.

F_2 generation/parents	Expected segregation	Adult plant stage		
		Observed segregation		
		Resistant	Susceptible	x^2
TD-1 × Vasco	3.1	14	6	0.266
ICARDA × SD-222	3.1	14	6	0.266
TD1 × Sunco	3.1	16	4	0.266
SD-888 × SD-333	3.1	13	7	1.06
Sunco	Resistant	20	0	0
Vasco	Resistant	20	0	0
SD-222	Resistant	20	0	0
SD-333	Resistant	20	0	0
TD-1	Susceptible	0	20	0
ICARDA	Susceptible	0	20	0
SD-888	Susceptible	0	20	0

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