COMBINING ABILITY ASSESSMENTS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN WHEAT (*Triticumaestivum* L.) HYBRIDS UNDER LATE PLANTING

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Abstract

The study was conducted to assist the combining ability of 20 F_1 hybrids developed by crossing wheat synthetic lines (Syn L1, Syn L2, Syn L3, Syn L4 and Syn L5) as female with four local cultivars (Fakhr-e-Sarhad, Atta Habib, Khyber-87 and Saleem-2000) as male. The experiment was planted atthe University of Agriculture, Peshawar, Pakistan during wheat season 2013-14using atriplicate Randomized Complete Block (RCB) design. The main aim of the study was to determine General Combining Ability (GCA) and Specific Combining Ability (SCA) for days to maturity, spikes per plant, grains spike^{-1},1000-Kernel weight, and grain yield plant^{-1}under late (mid-December) planting. Parental genotypes Syn L3, Saleem-2000 and Atta Habib were desirable best general combiners for days to maturity, grains spike^{-1}, 1000-kernel weight, and grain yield plant^{-1}under late planting. F_1 hybrids Syn L4×Khyber-87 and Syn L1×Saleem-2000 were the best desirable specific combinations for 1000-Kernel weight, and grain yield under late planting. Estimates of variances due to σ^2gca, σ^2sca and their ratio σ^2gca/σ^2sca indicated that σ^2sca were greater than σ^2gca (σ^2sca>σ^2gca) for all traits indicating a predominantly strong role of non-additive genes in inheritance of these traits under late planting.

Keywords: F_1 wheat hybrids, General combing ability (GCA), Specific combining ability (SCA), non-additive gene effect, Late planting

Introduction

Wheat (*Triticumaestivum* L.) is the indispensable food source for world population. During 2014-15, in Pakistan wheat was planted on 8.90 million hectares with a total production of 25.48 million tons and average national yield of 2775 kg ha^{-1} (MNFS&R, 2015). It is important to increase per unit yield by developing wheat genotypes with high yield potential to feed the increasing population and overcome food shortage. This could be achieved by combining together good attributes from available resources of wheat Germplasm into a single genotype (Khan et al., 2014). Knowledge of factors responsible for high yields has been rendered difficult because yield is considered to be a complex quantitative trait (Singh et al. 2010). Breeders should try to cross good general combiners and their transgressive segregants should be selected from subsequent hybrids for yield to develop high yielding varieties.

Agricultural productivity is affected by different climatic factors like rainfall pattern, temperature hike, changes in sowing and harvesting dates, water availability and land suitability etc. All these factors remarkably influence yield and agricultural productivity. Delayed wheat planting is one of the major yield limiting factors in rice-wheat, cotton-wheat, sugar cane-wheat cropping system as well as in rainfed areas of the country. In these cropping systems, 70-75% wheat is sown after harvest of rice, cotton and sugar cane crops. Late October to Mid-November is the best time for wheat sowing in Pakistan to harvest maximum wheat yield. Any delay in wheat planting beyond November 15 cause yield decrease up to 50 kg ha^{-1} per day (Khan, 2004). Improvement in yield and its related traits, require an effective hybridization program to overcome this issue. The assessment of GCA effects for yield components has a potential in selecting parental genotypes, to develop high yielding hybrids (Ali et al. 2014; Ali et al. 2014a,b; Jahangir et al. 2014; Qamar et al. 2014; Azam et al. 2013). Line × tester analysis is an evaluation technique, which is a modified form of top cross scheme developed by Kempthrone (1957).

Combining ability analysis among various genetic techniques is used to test the performance of parental genotypes in different cross combinations that characterize the nature and magnitude of gene effects in the expression of various yield and quality traits. Highly significant differences for GCA and SCA in wheat genotypes for all the traits under stressed condition were observed by Sheikh and Singh (2000). They stated that, additive genetic component was of prime importance in inheritance traits excluding grain yield per plant and tillers per plant, in which non-additive components were superior. Therefore, desirable transgressive segregant is one having both or at least one parent with good general combining ability (GCA). Saeed et al. (2005) also found highly significant mean squares of SCA for 1000-kernel weight, spike density, grain yield per plant and grains per spike. Mousavi et al. (2006) obtained non-additive gene action for flag leaf area, 50% heading, spikelets per spike, seed yield, grains per spike and seed weight using ten genotypes and their 41 F_1 hybrids, which were significantly different.

Materials and Methods

The research work was carried out at Research Farm of theUniversity of Agriculture, Peshawar. Five synthetic lines (here referred as lines) and four adaptable wheat cultivars (here referred as tester) were crossed in Line × tester fashion to develop F_1 hybrid population during 2012-13 cropping season. The selected synthetic wheat lines performed best under abiotic stress condition were received from the Wide Wheat Program, National Agricultural Research Centre (NARC), Islamabad, Pakistan. Among the testers, Fakhr-e-Sarhad and Atta Habib are full season cultivars, while Khyber-87 and Saleem-2000 are short season cultivars in Khyber Pakhtunkhwa Province of Pakistan (Subhan et al., 2004).

***Development of F_1 population*:** The breeding materials (lines and testers) were sown during Oct-Nov 2012 in three crossing blocks, each at 10 days interval to ensure timely pollen availability and to be able to make as many crosses as possible for making crosses in line × tester fashion. Two rows per genotype were planted in each crossing block. The row length was 2 meters, and plant to plant distance was kept 10 cm. Twenty to thirty good looking spikes were emasculated in each line and later pollinated by a specific tester in each cross combination to get enough F_1 seed (Table 1).

Table 1. List of synthetic wheat lines and testers with their pedigree crossed in line×tester fashion to develop 20 F_1populations.

Genotypes	Pedigree
***I.* Synthetic Lines**	
Syn L1	SNIPE/YAV79//DACK/TEAL/3/Ae.tauschii
Syn L2	ALTAR84/ Ae. Tauchii
Syn L3	ROK/KML// Ae. Tauchii
Syn L4	ACO89/ Ae. Tauchii
Syn L5	DOY1/ Ae. Tauchii
***II.* Testers**	
Fakhr-e-Sarhad	PFAU"S"/SERI/BIW"S"
Khyber-87	KVZ/TRM//PTM/ANA(LIRA "S")
Saleem-2000	CHAM-6//KITE/PGO
Atta Habib	Inqalab91*2/Tukuru
F1 Hybrids	
Syn L1×Fakhre Sarhad	Syn L1×Saleem 2000
Syn L2×Fakhre Sarhad	Syn L2×Saleem 2000
Syn L3×Fakhre Sarhad	Syn L3×Saleem 2000
Syn L4×Fakhre Sarhad	Syn L4×Saleem 2000
Syn L5×Fakhre Sarhad	Syn L5×Saleem 2000
Syn L1×Khyber 87	Syn L1×Atta Habib
Syn L2×Khyber 87	Syn L2×Atta Habib
Syn L3×Khyber 87	Syn L3×Atta Habib
Syn L4×Khyber 87	Syn L4×Atta Habib
Syn L5×Khyber 87	Syn L5× Atta Habib

***Field evaluation of parents and F1 hybrids*:** The experimental materials consisting of 29 genotypes (9 parents and 20 F1 hybrids) were planted under late (December 15, 2013) planting condition. The experiment was designed in triplicate Randomized Complete Block (RCB) having two rows of 3 meter length. Spacing between plants and rows was kept as 10cm and 30 cm, respectively. Standard cultural practices were adopted throughout growing season.

***Data recording and statistical analysis*:** Observations were recorded on ten mature selected plants per genotype per replication for days to maturity, spikes per plant, grains spike^{-1}, 1000-kernel weight, and grains yield plant^{-1}. 1000-kernel weight and grains yield plant^{-1} was measured by JM-B series electronic balance. Data were analyzed using mixed effect model proposed by Annicchiarico (2002).Traits showing significant differences were further analyzed using line × tester procedure of Kempthorne (1957).

Traits measurement
Data were recorded on the following traits at appropriate time:

Days to maturity
Days to maturity were recorded as the number of days from the date of planting till physiological maturity (loss of green pigment from peduncle bearing the spike) in about 50% plants in a plot.

Spikes per plant
Number of spikes plant^{-1} was computed by counting spikes bearing tillers in each of the selected plant.

Grains spike^{-1}
Each of the ten randomly selected spikes, used for recording spike length and spikelets spike^{-1} data, was threshed separately. The total number of grains from each spike were counted and recorded as number of grains spike^{-1}.

1000-kernel weight
Three samples of 100-grains (g) were taken at random from the grains of ten selected plants of each genotype in each replication and were weighed using an electronic balance. The 1000-grain weight was deduced from the average of the 3-samples.

Grain yield plant $^{-1}$
Grain yield plant^{-1} was determined from the weight of grains obtained after threshing each of the ten selected plants separately.

Results and Discussion

***Genetic variation*:** Analysis of variance showed highly significant differences ($p \leq 0.01$) among genotypes, parents and the crosses (F_1 hybrids) for the given traits under late planting condition. Similarly, Parents vs. Crosses contrast were also significant for days to maturity, grains spike^{-1}, 1000-kernel weight, and grain yield plant^{-1} except spikes per plant (Table 2). However, differences among lines were non-significant ($p \geq 0.05$) for all traits under study. In contrast, differences among testers for spikes per plant, grains spike^{-1} and 1000-kernel weight and grain yield were significant ($p \leq 0.05$).Similarly, Line×tester interaction were highly significant ($p \leq 0.01$) for given traits under late planting (Table 2).

***Estimation of variances due to general combining ability and specific combining ability*:** Estimates of variances due to general combining ability, specific combining ability and their ratio revealed that magnitude of σ^2 sca was greater than σ^2 gca for spikes per plant, grains spike^{-1}, 1000-kernel weight and grain yield under late planting. The resultant ratios of σ^2 gca to σ^2 sca was less than unity indicating predominantly strong role of non-additive gene action in the inheritance of traits (Table 2).

General combining ability: General combining ability (GCA) of the lines or testers is useful tools for selecting the hybrid parents in cross pollinated plants (Longin et al., 2013). Maturity is an important physiological trait in wheat. Early maturing cultivars are desirable to avoid terminal stress due to sudden rise in temperature during late grain filling stage. Parental lines Syn L1, SynL5 and tester Saleem-2000 expressed significantly negative GCA which is desirable for physiological maturity. Number of spikes per plant is the major yield contributing trait in wheat which depend on genotypes and environments. Syn L3 among lines showed significantly positive GCA effect for 1000-kernel weight and grain yield under late planting (Table 3). Spike length,1000-grain weight is an important character contributing towards grain yield. Similarly, Syn L5 showed significantly positive GCA was for 1000-kernel weight only. However, Atta Habib among testers showed significantly positive GCA for grains spike^{-1}, 1000-kernel weight and grain yield under late planting condition. Rest of the testers and synthetic lines had either non-significant or significantly negative GCA. More spike length generally results in more spikelets and grains spike^{-1} which ultimately increase grain yield. Parental genotype Syn L3 (wheat line)and Atta Habib was the best general combiner for most of yield contributing traits under late planting conditions (Table 3).Syn L2 among lines and Khyber-87 among testers were poor general combiners for most of the traits under study. Variation for grain yield plant^{-1}among parents was partitioned among lines and testers to find out the potential male (testers) and female (lines) parents. Jatav et al. (2014) suggested that lines with high GCA values for important yield trait like grain yield should be used in future breeding programs to improve wheat yield. Parental line Syn L3 and testers Atta Habib andSaleem-2000 were the best general combiners for grain yield under late planting condition.

Table 2. Mean squares from line × tester analysis for days to maturity, spikes plant^{-1}, grains spike^{-1}, 1000-kernel weight and grain yield of wheat parents and F_1 hybrids under late planting.

Source	df	DM	SP^{-1}	GS^{-1}	1000-kernel wt	GYP^{-1}
Replications	2	2.52	0.19	0.26	0.57	1.72
Genotypes	28	10.30**	2.68**	17.28**	22.75**	24.76**
Parents	8	8.06**	1.40**	12.62**	22.63**	5.12**
F1s	19	10.75**	2.81**	19.63**	14.77**	7.47**
Parents vs F1s	1	22.15**	10.6**	9.94*	175.17**	510.45**
Lines	4	34.93**	0.46^{NS}	18.50 ^{NS}	8.25 ^{NS}	2.91 ^{NS}
Testers	3	5.92 ^{NS}	11.82**	55.73**	39.47*	15.60**
Lines × Testers	12	3.90**	1.34**	10.98**	10.78**	6.96**
Error	56	0.78	0.18	0.98	0.52	0.68
σ^2_{GCA}		1.22	0.36	1.94	0.97	0.17
σ^2_{SCA}		1.04	0.38	3.33	3.42	2.09
$\sigma^2_{GCA}/\sigma^2_{SCA}$		1.18	0.93	0.58	0.28	0.08
CV (%)		0.6	5.9	1.92	1.78	4.23

*, ** = Significant at 5 and 1% probability level, respectively. NS = Non-Significant

Table 3. General combining ability for days to maturity, spikes plant, grains spike, 1000-kernel weight and grain yield plant^{-1} of wheat parents tested under late planting.

Genotypes	DM	SP^{-1}	GS^{-1}	1000-KWt	GYP^{-1}
LINES					
Syn L1	-1.82**	0.17	1.90**	-1.02**	-0.05
Syn L2	0.18	-0.13	-0.56	-0.14	-0.44**
Syn L3	-0.48	-0.02	0.15	0.68**	0.83**
Syn L4	2.77**	0.22	-0.01	-0.41*	-0.29
Syn L5	-0.65*	-0.24	-1.49**	0.98**	-0.04
TESTERS					
FakhreSarhad	0.88**	1.21**	-0.70**	-1.45**	-1.00**
Khyber 87	-0.25	-0.29*	-2.24**	-1.28**	-0.75**
Saleem 2000	-0.58*	-0.02	0.64*	0.93**	0.93**
Atta Habib	-0.05	-0.90**	2.29**	1.81**	0.83**
SE $_{\text{for GCA of lines}}$	0.25	0.13	0.29	0.208	0.24
SE $_{\text{for GCA of testers}}$	0.23	0.11	0.26	0.186	0.21

*, ** = Significant at 5 and 1% probability level, respectively.

Specific combining ability: Three F_1 hybrids exhibited desirable significantly negative SCA effects for maturity under late planting. The cross combination Syn L5×Atta Habib was the best specific combiners for spikes per plant under late planting. Generally, the parents of the cross combinations with significant SCA were mostly poor general combiners. The only F_1 hybrid with significantly positive SCA effect under late planting was Syn L3×Khyber-87 and was good specific combiner for spikes per plant and grains spike^{-1}. Whereas, Syn L4×Khyber-87 was good specific combiner for 1000-kernel weight and grain yield plant^{-1}under late planting environment. The F_1 hybrids with significant SCA were mostly derived from good × good and good × poor general combiners for 1000-kernel weight. Majeed et al. 2011 reported significantly positive as well as negative GCA and SCA effects of different magnitude for 1000-kernel weight in bread wheat.Five cross combinations out of the total 20 F_1 hybrids were proved to be best specific combiners for grain yield plant^{-1}due to their significantly positive SCA effects under late planting condition. Among five F_1 hybrids Syn L1×Saleem-2000 were best specific combiner for grains plant^{-1}under late planting condition (Table 4).

Table 4. Specific combining ability for days to maturity, spikes plant^{-1}, grains spike^{-1}, 1000-kernel weight, and grain yield plant^{-1}of F_1 hybrids tested under late planting.

F_1 hybrids	DM	SP^{-1}	GS^{-1}	1000-KWt	GYP^{-1}
Syn L1×Fakhre Sarhad	-1.38**	-0.06	1.57**	1.85**	-1.11**
Syn L2×Fakhre Sarhad	0.28	-0.80**	-1.14	-0.94*	-0.19
Syn L3×Fakhre Sarhad	0.62	0.01	-1.15*	1.24**	0.28
Syn L4×Fakhre Sarhad	1.37**	1.00**	2.05**	-0.86*	0.93**
Syn L5×Fakhre Sarhad	-0.88	-0.15	-1.34*	-1.29**	0.08
Syn L1×Khyber-87	0.42	0.35	1.48*	-4.44**	-1.25**
Syn L2×Khyber-87	-1.25*	-0.04	-2.43**	0.96*	-0.77
Syn L3×Khyber-87	-0.58	0.66**	1.76**	0.23	0.86*
Syn L4×Khyber-87	1.17	-0.19	-1.65**	2.08**	2.02**
Syn L5×Khyber-87	0.25	-0.77**	0.84	1.17**	-0.86
Syn L1×Saleem-2000	0.42	-0.1	-0.7	1.96**	2.80**
Syn L2×Saleem-2000	1.42*	0.41	0.86	0.28	0.05
Syn L3×Saleem-2000	0.08	-0.31	-1.39*	-1.75**	-0.85
Syn L4×Saleem-2000	-1.83**	0.1	0.24	-0.34	-2.76**
Syn L5×Saleem-2000	-0.08	-0.1	0.99	-0.15	0.76
Syn L1×Atta Habib	0.55	-0.19	-2.35**	0.63	-0.44
Syn L2×Atta Habib	-0.45	0.43	2.71**	-0.3	0.91**
Syn L3×Atta Habib	-0.12	-0.35	0.77	0.28	-0.29
Syn L4×Atta Habib	-0.7	-0.91**	-0.64	-0.88*	-0.2
Syn L5×Atta Habib	0.72	1.01**	-0.49	0.27	0.02

*, ** = Significant at 5 and 1% probability level, respectively.

DM= Days to maturity, SP^{-1}= Spikes per plant, GS^{-1}= Grains spike^{-1}, 1000-KWt= 1000-kernel weight, GYP^{-1}= Grain yield Plant^{-1}

Conclusion:

It was concluded that parental genotypes i.e. Syn L3, Saleem-2000 and Atta Habib were tolerant to abiotic stress (terminal heat stress) under late planting condition and also was found the best general combiners for most traits like grains spike^{-1}, 1000-kernel weight and grain yield. The F_1 hybrid Syn L4×Saleem 2000 was desirable for early maturity under late planting. Cross combination Syn L3×Khyber-87 exhibited tolerance to terminal heat stress under late planting and was the best specific combiner for spikes per plant and grains spike^{-1}, while Syn L1×Saleem-2000 for 1000-kernel weight and grain yield plant^{-1} under late planting condition. The preponderance of non-additive type of gene actions usually indicated that selection of superior plants should be postponed to later generations.

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