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COMBINING ABILITY ANALYSIS OF PHYSIO-MORPHIC PARAMETERS OF SPRING WHEAT (*TRITICUM AESTIVUM* L.) UNDER WATER DEFICIT CONDITIONS

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ABSTRACT
To identify the best parents for using in breeding program to develop drought tolerant genotypes, combining ability analysis was performed for root shoot ratio and relative water contents by using seven genotypes as female and five as male in a line × tester fashion. Thirty five crosses along with twelve parents were grown at the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the year 2017 in randomized complete design in three replications. Data were subjected to analysis of variance and combing ability factor analysis. General combining ability (GCA) and Specific combining ability (SCA) effects were significant for both traits. The parent genotypes 9860, Manthar 2003 and 9610 transmitted high relative water contents and root shoot ratio to its off spring based on positive and significant value of GCA in both moisture environments.. Cross combinations Aas 2011×9610 and Manthar 2003×9495 indicated highest positive significant SCA effects for root shoot ratio and relative water contetns in normal and water deficit conditions. Therefore, these hybrids can be recommended for water deficit tolerant heterosis breeding.

KEYWORDS: *Triticum aestivum;* wheat; combining ability; physio-morphic; wheat; Pakistan.

INTRODUCTION
Wheat is not only staple food in Pakistan, but also in many other countries of subcontinent (FAO, 2018). Due to its nutritional value and choice of people wheat is being utilized in daily food in the form of bread, chipati, crackers, etc. In Pakistan wheat is playing its major role in economy and have strong share in GDP. Wheat contributes 10.3% in agriculture and 2.2% in GDP (Anon. 2017-2018).Water deficit is one of the most widespread ecological stresses that influence normal physiological and morphological processes of plants. Water deficit keeps on persistent confront to agricultural scientists. It is predicted that by the year 2025, approximately 1.8 billion people will face extreme water sacracity and 65% of the world's inhabitants will breathe under water-stressed situation (Nezhadahmadi *et al.,* 2013). Since yield is an intricate attribute and is burly influenced by the milieu (Hall, 2001), massive losses can be caused by water deficit, a constant worry in most arid and semi-arid areas. Water shortage condition effects 32% wheat yield out of 99 million hectares cultivated in developing countries and 60 million hectares cultivated in developed countries (Hall, 2001). To cope with the present scenario it is very important to develop water deficit tolerant new lines. Root shoot ratio and relative water contents have been considered as very good slection criteria for water deficit tolerance at seedling stage (Rashid *et al*., 2019). Line x tester (Istipliler *et al*., 2015) mating design provides the opportunity to find out gene action through gernal combining ability and specific combing ability of the selected lines. This information is useful for understanding and categorizing of parent lines in terms of hybrids performance. It is helpful in selection of parents on the basis of their inheritance pattern for hybridization programs. Gene action, general combing ability and specific combining ability provide the knowledge about the best crosses and combiners (Rajput and Kandhalkar, 2018). This knowledge would be very useful for breeding program to develop water deficit tolerance and high economic productive wheat cultivars. The main objective of the study is to determine combining ability analysis of physio-morphic parameters of spring wheat under water deficit conditions

MATERIALS AND METHODS
Seven lines of wheat were selected from University of Agriculture Faisalabad and Wheat Research Insitute Faisalabad on the basis of previous performance in field alongwith five broad genetic based high yielding testers and crosses were made in Line x Tester mating design (Istipliler *et al*., 2015). All the hybrids seed alongwith parents were planted in triplicate fashion in double factor factorial under RCBD. The first factor was normal irrigation and second factor was deficit irrigation. The polyhtene bags were packed with sand

and seed was implanted in these bags. Pressure membrane apparatus (Gugino *et al.*, 2009) was used to estimate the field capacity of the sand. Plants in normal moisture milieu were watered at 100% field capacity after interval of one days. Plants in inadequate moisture were watered at 50% field capacity. Hoagland solution's composition was made according to Li and Cheng (2015). This solution provides nutrients to plants and provided alongwith irrigation Water. Water was withheld after 40 days and after three days plant were uprooted and data were recorded for root-shoot ratio and relative water contents. The statistical procedures were used according to Stee *et al*. (1997).

Root shoot ratio was calculated using following formula:
RS ratio = Root length/Shoot length
Relative water contents were calculated using following formula:
RWC% = [(Fresh shoot weight–Dry shoot weight) / (Turgid weight–Dry shoot weight)] × 100

Assessment of General Combing Abilit effects:

Lines: *(gi)* = *xi../ rt – x../ rlt*
Testers: (gj) = x.j./ r1- x../ rlt
l = Number of lines
t = Number of testers
r = Number of replications
x..=Total of all hybrids over replications
xi = Total number of F_1 resulting from crossing ith lines with all testers

Assessment of Specific Combing Ability Effects:
Sij= xij / r - xi... / rt – x. j./ rl + x../ rlt

Where

xij = Total of hybrids between ith line and jth tester over replications.
x.j = Total of jith tester over lines and r replications

RESULTS AND DISCUSSION

Genetic variability was confirmed by analysis of variance among all parents and crosses presented (Table 1). The root shoot ratio of top ten best performer parents and hybrids presented in (Fig1). The commercial variety Manthar 2003 performed better in water deficit condition. The genotype maintained root shoot ratio and retained highest percentage of relative of water contents (Fig. 2) in both normal and water deficit condition. The GCA value for seedling traits under normal and water deficit conditions presented in Table 2. Different types of effects were observed including positive, negative significant and non significant under both environmental conditions. Line (9860) and Manthar (2003) indicated positive highly significant GCA for root shoot ratio and reletive water contents under normal and water deficit conditions. Among the testers, 9610 indicated positive highly significant GCA for root shoot ratio and relative water contents under both environments. Specific combining abilities effects values presented in Table 3 for normal and water deficit conditions.

The hybrids Aas 2011×9610, 9860×9495, 9864×9495, Manthar 2003×9495, Chakwal 86×9526, 9846×9526, 9860×9505, 9846×9505, 9864×9505, 9787×9505 and 9846×9521 indicated positive significant SCA for both moisture environments. The significant variation was observed among parents and F_1 population for root shoot ratio and RWC%. The results were in accordance with (Siddig *et al.,* 2013). In this studies two parameters were used for screening of F_1 population for water deficit tolerance and combining ability analysis. The morphological trait was root shoot ratio and physiological trait was relative water contents. The root shoot ratio is based on two other morphological traits i.e. root length and shoot length. While RWC% is based on physio morphic traits included fresh weight, dry weight and turgid weight. The root shoot ratio and RWC% both traits are interconnected. The efficacy of traits becomes more vibrant when selection is performed during seedling stage. The reason is fast growing of vegetative organs of plants i.e shoot and root. The race of growth is affected with availability of water. Root is the first organ which is effected by water shortage condition. Root arrangement establishes the possible capacity of soil that can be dug for moisture and victuals (Rashid *et al*., 2019). Root study can be the source of improvement in cereal productivity (Lynch, 2007; Foulkes *et al*., 2009). Genetic factors and environment combinely develop the root (Passioura, 1983). The study about root length supports deeper roots because deep roots can make easy access to subsoil water for plant which can augment grain yield (Kirkegaard *et al*., 2007). However, deep roots can effect the shoot length. In normal moisture conditions root and shoot continuously grow from germination to anthesis stage (Barley, 1970; Evans *et al*., 1975). In water deficit condition only root develop. Although extensive root length supports plant in respiration and extraction of moisture especialy when plants are in dry soil (Blum, 2005). However, the slip of balance between root and shoot length considerably effects grain yield (Lynch, 2007). In arid environment usually plant survived through deeper root length with low yield (Shimazaki *et al*., 2005). The plant used all its reserves to enlarge root length for search of water which slow down shoot growth. In this regard yield is reduced but water use efficiency increased (Xue *et al*., 2006). In this case if plants survived from water shortage it will produce very low yield. Therefore the study was aimed to select those genotypes which minutely effected due to water shortage. The phenomena was observed in Matnhar 2003 which indicated very small change in root shoot length under water shortage conditions. The results were in accordance with Baloch *et al*. (2012). Percentage of relative water contents is the indication of amount of water present in plant. The comparison of genotype for RWC% in two treatments reflects the water status of plant. Tavakol *et al.* (2007) observed that increase in stress caused reduction in relative water contents. Almeselmani *et al*. (2011) found relative water contents as good criteria for selection drought tolerant varieties of wheat. To maintain RWC% Matnhar 2003 maintained maximum percentage of relative water contents. The results were in accordance with Soleimani *et al.* (2014). It was concluded root shoot ratio and relative water contents should be considered in wheat for water deficit tolerance (Rashid *et al*., 2019). Line x tester analysis is very useful in studying the combing ability including GCA and SCA and gene action. Line × tester analysis is one of breeding tactic to assess GCA effects of cultivars and also provide information concerning genetics of certain characters. Sprague and Tatum (1942) categorized combining ability into SCA and GCA. The GCA is a mainly function of additive gene effects and helps in selection of good general combiner for breeding programs. The SCA is a primarily function of dominance gene effects and facilitate in selection of superior hybrids (Rajput and Kandhalkar (2018). In self–pollinated crops like wheat, SCA effects are not much important as they are mostly related to non-additive gene effects excluding those of arising from complementary gene action or linkage effects they cannot be fixed in pure lines. Further superiority of the hybrids might not specify their ability to yield transgressive segregates; rather SCA would provide satisfactory criteria. However, if a cross combination exhibiting high SCA as well as high *per se* performance having at least one parent as good general combiner for a specific trait, it is expected to throw desirable transgressive segregants in later generations. Genetic variability between all parents and crosses under both water regimes was confirmed by analysis of variance (Khan *et al*., 2002; Awan *et al.* 2007; Noorka *et al*., 2007). The positive and significant value of GCA indicated the capacity of genotypes for producing usefull segregates. These lines can be considered for variety development program. The positive and significant value of SCA indicated the capacity for hybrid development.

Table 1. Mean square values from analysis of variance for F_1 seedling related traits under normal and water deficit conditions

S.O.V	D.F	Root/Shoot		RWC%	
		N	D	N	D
Replications	2	0.0001	0.006	0.001	0.001
Treatments	46	403**	530**	760.9**	554.4**
Parents	11	434.1**	554.2**	2427.4**	509.7**
Parents vs crosses	1	686.2**	202.2**	1958.2**	8666.5**
Crosses	34	222.1**	280.2**	186.5**	330.3**
Lines	6	447.2**	331.2**	380.1**	499.8**
Testers	4	223.1*	232.1**	51.3**	500.4**
Lines x Testers	24	315.1**	328.1**	160.6**	259.6**
Error	92	0.005	0.003	0.001	0.002

=Values showing * and ** stand for significance at 0.05 and 0.01 probability level, respectively. R/S: Root shoot ratio,RWC%: Relative water contents.

Table 2. General combining ability (GCA) effects under normal and water deficit conditions

Genotypes	Normal irrigation		Water defificit	
Lines/Testers	**R/S**	**RWC%**	**R/S**	**RWC%**
Lines				
Aas 2011	-0.049	0.017	-0.013*	0.034
Chakwal 86	-0.079	-2.306	-0.0032	-2.20
9860	5.76**	5.51**	5.68**	5.48**
9846	0.0089	0.44	0.024	0.063
9864	0.041	0.003	-0.072	0.04
9787	-0.036	-0.55	0.024	-8.44
Manthar 2003	3.03*	4.23**	3.01*	4.16**
Testers				
9610	4.31**	4.89**	4.28**	4.56**
9495	0.030	0.44	0.032	0.23
9526	0.038	-6.83	-0.033	-1.44
9505	-0.023	1.84	-0.0	-2.05
9521	-0.014	-1.95	0.02	-6.21

=Values showing * and ** stand for significance at 0.05 and 0.01 probability level, respectively. R/S: Root shoot ratio,RWC%: Relative water contents.

Table 3. Specific combining ability (SCA) effects under normal and water deficit conditions

Crosses	Normal irrigation		Water deficit	
	R/S	RWC%	R/S	RWC%
Aas 2011×9610	4.44*	13.82**	4.37*	13.55**
Chakwal 86×9610	-0.05	0.39	-0.30*	-1.42
9860×9610	0.05	-1.64	-0.02	-1.02
9846×9610	0.05	-1.89	0.18	-0.02
9864×9610	0.002	1.31	0.18	1.26
9787×9610	-0.009	0.42	0.05	0.05
Manthar 2003×9610	-0.10	0.022	0.28	0.08
Aas 2011×9495	0.03	-1.01	-0.12	0.59
Chakwal 86×9495	0.03	0.02	-0.18	-1.01
9860×9495	4.45**	3.27*	4.22*	3.22*
9846×9495	0.02	-1.51	0.04	-1.5
9864×9495	6.69**	5.91**	6.27**	5.89**
9787×9495	-0.057	-1.9	0.13	-0.96
Manthar 2003×9495	4.87*	5.81**	4.83*	5.45**
Aas 2011×9526	-0.05	-1.1	-0.11	-0.78
Chakwal 86×9526	3.10*	3.51*	3.91*	3.98*
9860×9526	0.04	-1.61	-0.34	-0.79
9846×9526	2.14*	8.92**	2.12*	8.86**
9864×9526	0.037	-2.25	0.05	-1.82
9787×9526	0.067	-1.07	0.25	0.89
Manthar 2003×9526	-0.04	-1.24	-0.03	0.25
Aas 2011×9505	-0.014	-1.95	0.07	-1.61
Chakwal 86×9505	0.047	-1.58	0.08	-1.26
9860×9505	3.18*	3.53*	3.15*	3.61*
9846×9505	2.15*	2.33*	2.17*	2.30*
9864×9505	2.36*	2.70*	2.31*	2.68*
9787×9505	2.57*	4.91**	2.11*	4.88**
Manthar 2003×9505	-0.067	1.52	-0.08	-0.52
Aas 2011×9521	0.042	-1.56	0.03	-1.07
Chakwal 86×9521	0.042	-0.58	-0.08	-2.74
9860×9521	0.04	0.28	-0.14	-1.14
9846×9521	4.74**	2.58*	4.63**	2.42*
9864×9521	-0.021	-0.17	-0.03	-0.66
9787×9521	-0.075	-0.42	-0.01	-0.07
Manthar 2003×9521	-0.018	-0.89	-0.04	-0.63

=Values showing * and ** stand for significance at 0.05 and 0.01 probability level, respectively. R/S: Root shoot ratio. RWC%: Relative water contents.

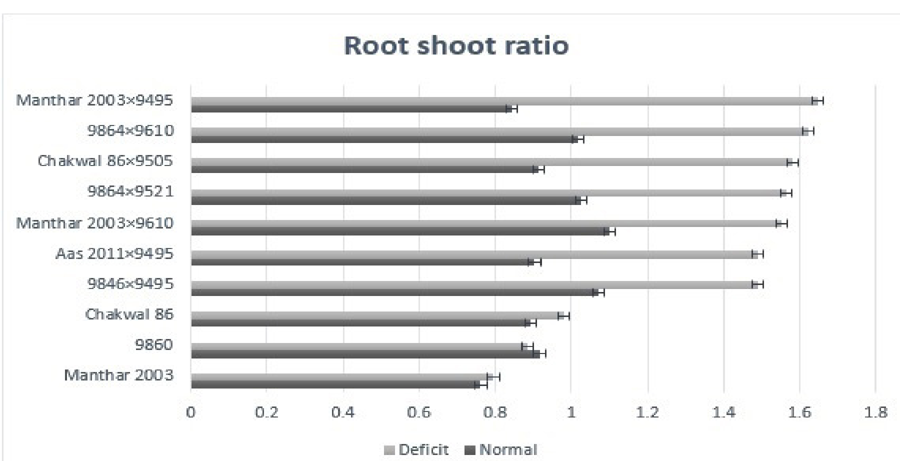

Fig 1. Comparison of parents and hybrid wheat genotypes for root shoot ratio under normal and water deficit conditions

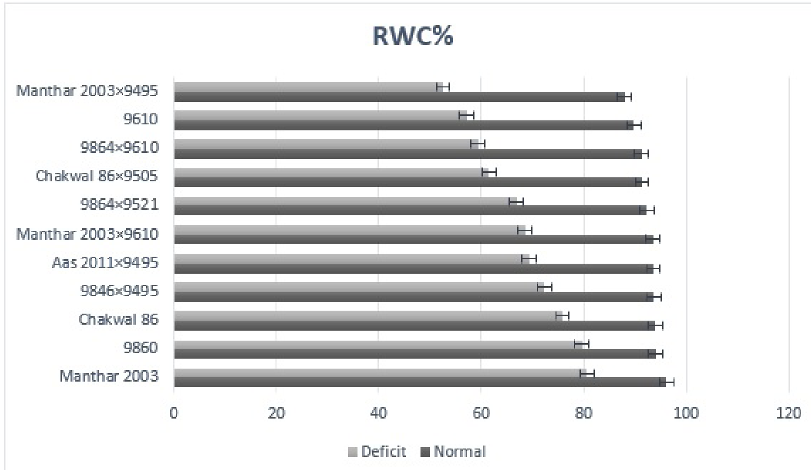

Fig 2. **Comparison of parents and hybrid wheat genotypes for relative water contents under normal and water deficit conditions**

CONCLUSION

This study manifested that parent line Manthar 2003 can be considered as water deficit tolerant genotypes. The GCA value of 9860, Manthar 2003 and tester parent 9610 can be used to produce successful water deficit tolerant segregates. Hybrids Aas 2011×9610, 9860×9495, 9864×9495, Manthar 2003×9495, Chakwal 86×9526, 9846×9526, 9860×9505, 9846×9505, 9864×9505, 9787×9505 and 9846×9521 indicated maximum positive significant SCA effects. Therefore these hybrids can be recommended for heterosis breeding under water deficit conditions.

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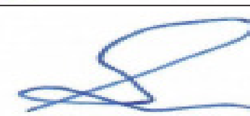
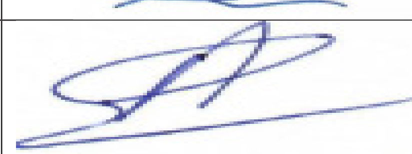
CONTRIBUTION OF AUTHORS

S. No.	Author name	Contribution	Signature
1.	Kashif Rashid	Planned and conducted research experiment, prepared writeup	
2.	Hafeez Ahmad Sadaqat	Contributed in planning and execution of research experiment	
3.	Abdus Salam Khan	Interpreted results and prepared writup	
4.	Nisar Ahmed	Critically reviewd the manuscript and interpreted the results