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YIELD AND NUTRIENTS CONTENT OF TWO CONTRASTING (SPRING AND WINTER) CROSSED ECOTYPES OF WHEAT

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Abstract

Two divergent ecotypes of five winter wheat were crossed with ten spring wheat lines in line × tester fashion. EC609406 and EC609396 were identified as good general combiners for grain yield per plant, 1000-grain weight, reduced days to heading and yellow rust resistance. Among the spring wheats, HD3096 was found to be a good general combiner for yield, yellow rust resistance, 1000-grain weight, Fe content and early heading. Cross EC609412/PBW590 had significant and desirable SCA effect for gain yield per plant, early heading and yellow rust resistance whereas cross EC609406/HD2967 had significant SCA effect for Fe content and 1000-grain weight with negative SCA for yellow rust resistance. Cross MvEmese/HI1562 and EC629405/HD2967 showed significant positive SCA effect for Zn content and early heading.

Introduction

Spring and winter wheats are divergent ecotypes and one of the breeding approaches is to utilize the winter wheat gene pool for genetic improvement of spring wheat, since the two groups remained almost independent of each other due to different ecological requirements (Akerman and Mackey 1949). Hybridizing these two divergent groups is likely to bring complementary factors together for improvement of yield and agronomic traits (Pinthus 1967, Grant and Mckenzie 1970, Mani and Rao, 1978, Mishra *et al.* 2015) and stripe rust resistance (Upadhyay and Kumar 1975). The information regarding the combining ability of these two distinct groups under Indian conditions is restricted to mostly yield and yield attributing traits (Kant *et al*. 2001, Shoran *et al.* 2003) and very little or no information available for nutritional traits Fe and Zn content. The line × tester mating design introduced by Kempthorne (1957) is a biometrical technique available to estimate the combining ability effects and aids in selecting desirable parents and cross-combinations for exploitation (Jain and Sastry 2012). In self-pollinated crops like wheat, the estimates of general combining ability (GCA) are very useful because the variance due to general combining ability can be fixed in further generations (Falconer 1989, Biljana and Marija 2005).

The objective of the present experiment is to identify good general combiners and specific cross-combinations for yield, flowering time, 1000-grain weight, yellow rust resistance and Fe and Zn content in winter and spring wheats.

Material and Methods

The present experiment was carried at the ICAR-Indian Institute of Wheat and Barley Research, Karnal during 2013-14 crop season. The experimental material comprised 15 genotypes, wherein five winter wheat lines (L1-EC609396 (Dragana), L2-EC609406 (Evropa 90), L3 EC609412 (Helena), L4-EC629405 and L5-Mv Emese were used as female parent hence hereafter designated as lines and ten spring wheat varieties (T1-WH1125, T2- PBW 590, T3-RAJ4083, T4-NW4035, T5- HI1562, T6-HD2967, T7-DPW621-50, T8-K307, T9-WH1021 and T10-HD3096)

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used as male parent, designated as testers, to generate 50 crossed F_1 seeds during 2012 - 2013 according to line × tester mating design as per Kempthorne (1957).

The crossed F_1 seeds along with 15 parents were sown in a randomized block design with two replications during 2013 - 2014. Each plot comprised two rows of 2 m length spaced 30 cm apart. Recommended cultural practices were adopted to raise a good crop. Severe hybrid necrosis was observed in one cross EC609406/WH1125 at seedling stage; hence the data was recorded only on 49 F_1s.

Ten competitive plants were tagged in each plot and data were recorded for days to heading, grain yield per plant, thousand grains weight (TGW) and yellow rust incidence on modified Cobb's scale (Peterson 1948) for per cent severity and response type based on Roelfs *et al.* (1992). Coefficient of infection (CI) was calculated following Stubbs *et al.* (1986). Fe (ppm) and Zn (ppm) in wheat were estimated through energy-dispersive X-ray fluorescence spectrometry (EDXRF) as standardized by Paltridge *et al.* (2012). Data recorded were subjected to statistical analysis as per Singh and Chaudhary (1985).

Results and Discussion

The analysis of variance revealed that significant variation among treatments for all the characters studied which allowed further analysis for general combining ability. The trait wise description for combining ability is presented below:

Based on mean *per se* performances, the winter and spring wheats were contrasting with each other for days to heading (Table 1). The winter wheats were late in heading (about 153 days), while spring wheat were quite early in heading (about 98 days).

Genetic variability in the parents in the form of *per se* performance may not be transmitted to the progenies so the ability of parents to transfer its traits to the progenies is estimated in terms of general combining ability (GCA) and specific combining ability (SCA) effects. Winter wheat EC 609406 (–0.32), EC 609396 (–1.33) and EC609412 (–0.73) and spring wheat HD3096 (–5.18), WH1021 (–3.78), NW4035 (–2.68), HI1562 (–1.68) and PBW590 (–1.28) had significant negative GCA effects that was desirable. These lines and testers were found as good general combiners for reducing the flowering time in the crop.

The data displayed in Table 2 indicated that EC629405/HD2967 had highest significant SCA effect in negative direction (–5.12) for early flowering followed by (EC609406/DPW621-50) (–5.0), (EC609396/WH1125) (–3.54); (EC609412/PBW590)(–3.47), (EC609396/PBW590) (–3.37): Mv Emese/HD2967 (–3.32); (Mv Emese/HI1562) (–3.12) (EC609412/NW4035) (–2.07) and (EC609412/WH1021) (–1.97). Except EC629405/HD2967 and Mv Emese/HD2967, all crosses showing significant SCA effect had one or both parents with high GCA effect and they are likely to enhance the concentration of favourable alleles (Kenga *et al.* 2004). Verma and Srivastava (2004) mentioned that positive SCA effects were associated with crosses having at least one parent as a good general combiner. In self pollinated crops best hybrids having high SCA are expected to generate transgressive segregants which could be further selected as homozygous lines (Fellahi *et al.* 2013).

The winter wheats produced low grain yield per plant (8.11 g) as compared to spring wheat (14.51 g) cultivars. Among winter wheat parents the yield varied from 5.57 g (Mv Emese) to 11.19 g (EC609412) and from 5.60 g (PBW590) to 21.29 g (HD2967) in spring lines. The good general combiners identified were EC 609412 (4.91) and EC 609396 (3.98) in the winter wheats and HD3096 (4.37) in spring wheat (Table 1). Positive and highly significant SCA effect for grain yield per plant was observed (Table 2) in the cross-combinations EC609412/HI1562 (13.90), EC609396/HD3096 (11.48) and EC609412/PBW590 (8.36) which had one or both the parents

Table 1. General combining ability effects and *per se* performance of five winter wheat lines and ten spring wheat testers for different traits.

S.N	Parents	Days to heading		Yield/plant		TGW		Fe concentration		Zn concentration		Yellow rust	
		GCA	Days	GCA	g	GCA	g	GCA	ppm	GCA	ppm	GCA	CI
L1	EC609396	–1.33**	147	3.98**	6.45	8.72**	21.79	1.12*	37.20	–0.40	46.45	–20.12**	0.00
L2	EC609406	–3.20**	151	–3.78**	10.41	–10.11**	25.50	–1.42**	37.90	–0.65	41.75	26.11**	7.50
L3	EC609412	–0.73**	151	4.91**	11.19	2.39**	21.63	–0.30	36.45	0.78	40.35	–16.32**	5.00
L4	EC629405	2.12**	156	–3.68**	6.92	0.19	18.60	0.82	40.50	–1.72**	38.80	6.534**	0.20
L5	Mv Emese	2.82**	159	–1.81*	5.57	–2.21**	20.23	–0.36	36.60	1.91**	40.85	6.40**	0.10
Mean Value (SE)			152.8 (0.22)		8.11 (0.93)		21.55 (0.43)		37.73 (0.54)		41.64 (0.51)		2.56 (1.45)
T1	WH1125	8.89**	110	1.77	17.61	3.01**	37.11	0.37	38.45	1.77**	24.05	–20.02**	0.40
T2	PBW590	–1.28**	92	–2.48	5.60	1.09	19.06	–0.42	36.85	0.52	22.45	15.384**	70.00
T3	Raj 4083	5.08**	90	2.36	15.08	1.04	24.45	–0.28	39.30	–2.24**	31.35	7.68**	40.00
T4	NW4035	–2.68**	98	1.36	18.83	–2.69**	33.41	–0.51	37.85	–2.27**	23.95	9.88**	6.00
T5	HI1562	–1.68**	101	–1.31	9.62	–7.32**	19.35	0.47	40.95	1.72**	22.60	19.38**	80.00
T6	HD2967	7.52**	105	–0.74	21.29	2.59 **	30.85	–0.80	41.95	2.10**	26.85	–17.04**	50.00
T7	DPW621-50	3.72**	101	0.90	17.96	0.22	33.59	–1.88	36.85	–0.15	23.20	–8.12**	20.00
T8	K307	1.32**	100	–4.45**	20.54	–2.92**	33.76	0.12	38.75	0.37	25.45	0.984	30.00
T9	WH1021	–3.78**	92	–2.58	6.81	1.19	20.65	1.18	39.05	–0.34	23.50	5.88**	70.00
T10	HD3096	–5.18**	93	5.54**	11.77	4.37**	25.40	1.78*	38.20	–1.12	22.60	–18.04**	0.00
Mean Value (SE)			98.2 (0.30)		14.51 (1.32)		27.76 (0.61)		38.82 (0.76)		24.6 (0.72)		36.64 (2.04)

*, **Significant at $p = 0.05$ and 0.01, respectively.

Table 2. Specific combining ability effect of crosses developed from hybridizing five lines and ten testers in wheat.

Sl.No.	Cross-combination	DTH	Yield/ plant	TGW	Fe	Zn	Yellow rust
1	(L1T1)EC609396/WH1125	–3.54**	–7.41*	–6.73**	–1.53	0.70	20.02**
2	(L1T2)EC609396/PBW590	–3.37**	–5.59	0.65	1.50	5.15**	–15.38**
3	(L1T3)EC609396/Raj 4083	1.93**	1.04	–1.96	–1.36	–2.14	–7.68
4	(L1T4)EC609396/NW4035	1.03	6.50*	1.34	2.54	–0.51	–9.88*
5	(L1T5)EC609396/HI1562	0.53	–0.29	0.96	0.46	1.50	–19.38**
6	(L1T6)EC609396/HD2967	0.33	–1.76	–1.96	–2.87	–5.03**	17.04**
7	(L1T7)EC609396/DPW621-50	2.13**	–6.71*	–1.417	–1.33	0.87	8.11
8	(L1T8)EC609396/K307	0.53	6.10*	2.25	0.912	–1.95	–0.98
9	(L1T9) EC609396/WH1021	–1.37*	–3.72	8.08**	2.30	0.61	–5.88
10	(L1T10) EC609396/HD3096	0.03	11.48**	–1.83	–0.70	0.44	18.03**
11	(L2T1) EC609406/WH1125	NA	NA	NA	NA	NA	NA
12	(L2T2) EC609406/PBW590	–1.0	0.38	–5.40**	–1.76	–0.60	18.39**
13	(L2T3) EC609406/Raj 4083	–1.19	3.86	–1.36	–1.62	3.26	6.09
14	(L2T4) EC609406/NW4035	1.40*	0.06	0.01	–1.22	–0.81	–6.11
15	(L2T5) EC609406/HI1562	0.90	–4.65	–3.32*	–2.60	0.80	14.39**
16	(L2T6) EC609406/HD2967	6.70**	5.41	6.83**	5.47**	2.92	–29.19**
17	(L2T7) EC609406/DPW621-50	–5.00**	0.34	1.67	1.94	–1.08	1.89
18	(L2T8) EC609406/K307	0.40	–2.29	–1.51	–0.90	0.50	2.79
19	(L2T9) EC609406/WH1021	2.00**	–4.57	–2.44	0.19	0.46	–2.11
20	(L2T10) EC609406/HD3096	2.90**	2.86	7.93**	0.79	–4.01	–22.19**
21	(L3T1) EC609412/WH1125	–0.64	–4.67	–2.01	–1.81	1.67	16.22**
22	(L3T2) EC609412/PBW590	–3.47**	8.36**	0.38	–0.73	–0.88	–11.68*
23	(L3T3) EC609412/Raj 4083	–0.67	5.71	3.08	–0.09	–0.92	–6.48
24	(L3T4) EC609412/NW4035	–2.07**	–1.11	1.66	0.81	1.26	–13.68**
25	(L3T5) EC609412/HI1562	2.93**	13.90**	7.12**	0.23	–2.13	–15.68**
26	(L3T6) EC609412/HD2967	1.73*	–3.03	–5.04**	–0.048	0.086	13.24**
27	(L3T7) EC609412/DPW621-50	2.53**	–3.61	–3.39	–1.47	0.94	4.32
28	(L3T8) EC609412/K307	0.93	–10.19**	–5.11**	0.98	0.57	3.22
29	(L3T9) EC609412/WH1021	–1.97**	5.15	2.80*	1.27	–2.32	0.32
30	(L3T10) EC609412/HD3096	–1.07	–10.85**	–0.16	0.77	1.41	14.24**
31	(L4T1) EC629405/WH1125	2.50**	4.08	–0.48	3.47*	1.61	–6.63
32	(L4T2) EC629405/PBW590	1.68*	–2.28	5.11**	–1.75	–3.88*	–2.03
33	(L4T3) EC629405/Raj 4083	–1.52*	–5.53	0.58	–0.96	0.53	15.67**
34	(L4T4) EC629405/NW4035	0.08	–7.71**	–5.59**	1.44	1.31	13.47**
35	(L4T5) EC629405/HI1562	–0.92	–6.01*	–4.71**	0.812	–5.73**	13.97**
36	(L4T6) EC629405/HD2967	–5.12**	–1.62	0.87	1.03	5.34**	5.39
37	(L4T7) EC629405/DPW621-50	1.68*	4.30	1.98	0.56	1.04	–8.53
38	(L4T8) EC629405/K307	–0.92	7.05*	4.54**	–0.04	–0.33	–20.13**
39	(L4T9) EC629405/WH1021	2.18**	6.96*	0.14	–3.00	1.03	–2.53
40	(L4T10) EC629405/HD3096	–1.42*	0.41	–3.052*	–1.648	–1.244	–4.61
41	(L5T1) Mv Emese/WH1125	–1.19	4.59	0.12	–1.41	–4.6**	–6.10
42	(L5T2) Mv Emese/PBW590	6.48**	–0.48	0.28	2.88	0.29	8.10
43	(L5T3) Mv Emese/Raj 4083	1.78**	–4.71	0.65	4.17*	–0.65	–10.20*
44	(L5T4) Mv Emese/NW4035	–0.12	2.64	3.59**	–3.43*	–1.17	13.60**
45	(L5T5) Mv Emese/HI1562	–3.12**	–2.57	0.90	1.24	5.64**	4.10
46	(L5T6) Mv Emese/HD2967	–3.32**	1.37	0.31	–3.44*	–3.24	–9.08*
47	(L5T7) Mv Emese/DPW621-50	–1.02	6.06*	2.16	0.44	–1.69	–8.40
48	(L5T8) Mv Emese/K307	–0.62	–0.296	0.84	–0.81	1.29	12.50**
49	(L5T9) Mv Emese/WH1021	–0.52	–3.44	–7.58**	–0.62	0.30	7.60
50	(L5T10) Mv Emese/HD3096	–0.12	–3.51	–1.88	0.93	3.48*	–8.08
SE (SCA effect)		0.68	2.95	1.37	1.70	1.61	4.57
SE (Gi-Gj) for lines		0.30	1.32	0.61	0.76	0.72	2.04
SE (Gi-Gj) for testers		0.43	1.86	0.87	1.07	1.02	2.89
SE (Sij-Skl)		0.96	4.17	1.94	2.41	2.27	6.46

*,**Significant at p = 0.05 and 0.01%, respectively.

with high GCA effect. Sharma and Chaudhary, (2009) observed that the winter × spring wheat hybrids were observed to be the best with respect to yield contributing traits and spring and winter wheat parents could be effectively utilized in future hybridization programmes for wheat improvement. They also reported that superior hybrid combinations for one or more traits were identified, all of which involved at least one good general combiner for one or more traits in their parentage.

The 1000-grain weight in spring wheat testers (27.76 g) was more as compared to winter wheat lines (21.55 g). In lines it ranged from 18.60 g (Mv Emese) to 25.50 g (EC609406), whereas in testers it varied from 19.06 g (PBW590) to 37.11 g (WH1125). The good general combiners identified for thousand grains weight were EC609396 (8.72), EC609412 (2.39) among the winter wheats and HD3096 (4.37) and WH 1125 (3.01) in spring wheat (Table 1). Cross-combinations EC609396/WH1021 (8.08), EC609406/HD3096 (7.93), EC609412/HI1562 (7.12), EC629405/ PBW590 (5.11), EC629405/K307 (4.54) and Mv Emese/NW4035 (3.59) had positive and highly significant SCA effect for higher grain weight (Table 2). All the crosses showing significant SCA effect for thousand grains weight had one or both the parents in their combinations with high GCA effect except EC629405/PBW590, EC629405/K307 and Mv Emese/NW4035.

The mean value of iron content presented in Table 1 indicated that spring wheat (38.82 ppm) had slightly higher iron content than the winter wheats (37.73 ppm). Morgounov *et al.* (2007) reported that spring wheat cultivars possessed higher Fe-grain concentrations than winter wheats. In winter wheats it varied from 36.45 ppm (EC609412) to 40.50 ppm (EC629405), while in spring wheat it ranged from 36.85 (PBW590 and DPW621-50) to 41.95 (HI1562). Winter wheat line EC609396 (1.12) and spring wheat HD3096 (1.78) were identified as good general combiner for iron content. Only one cross-combination EC609406/HD2967 was which had highly significant and positive SCA effect (5.47) for iron content (Table 2) and it could be exploited further for improvement of iron content.

The mean zinc content in winter wheats (41.64 ppm) was quite high as compared to spring wheat (24.6 ppm) (Table 1). Morgounov *et al.* (2007) reported that by contrast, winter wheats showed higher Zn-grain concentrations than spring genotypes. Among winter wheats Mv Emese (1.91) and in spring lines HD2967 (2.10), WH 1125 (1.77) and HI1562 (1.72) were identified as good general combiners for zinc.

Cross-combinations Mv Emese/HI1562 (5.64), EC629405/HD2967 (5.34) and EC609396/ PBW590 (5.15) had highly significant and desirable SCA effect for zinc content (Table 2).

The coefficient of infection for yellow rust incidence was quite low in winter wheats (2.56) as compared to spring wheat (36.64) (Table 1). No disease development was observed in EC609396 and HD3096. Among winter wheat lines EC609396 (–20.116) was best general combiner for resistance to yellow rust followed by EC 609412 (–16.316) and among testers WH 1125 (–20.016), HD 3096 (–18.036) had significant negative desirable GCA effects and desirable per se performance for resistance to yellow rust. Among 49 cross-combinations, crosses EC609406/ HD2967 (–29.19); EC609406/HD3096 (–22.19); EC609405/K307 (–20.13); EC609396/HI1562 (–19.38); EC609412/HI1562 (–15.68); EC609396/PBW590 (–15.38) and EC609412/NW4035 (–13.68) had desirable and highly significant SCA effect (Table 2) for yellow rust resistance. All crosses, except EC609405/K307, showing high SCA effect for yellow rust resistance had one or both the parent with high GCA for yellow rust in the crosses.

Winter wheat lines EC609406 and EC609396 were good general combiners for yield per plant, TGW, reduced flowering and yellow rust resistance. Among the spring wheats, HD3096 was a good general combiner for yield, yellow rust resistance, TGW, Fe content and early heading. These genotypes may be further exploited in specific breeding programme to obtain superior segregants for various traits. High GCA effects are mostly due to additive gene effects or additive × additive interaction effects (Griffing 1956).

Among the crosses EC609412/PBW590 had significant and desirable SCA effect for gain yield per plant, early heading and yellow rust resistance. Cross EC609412/HI1562 had significant and desirable effect for yield per plant, yellow rust resistance and thousand grains weight. Similarly, cross EC609405/K307 also represents significant and desirable SCA effects for yield, yellow rust resistance and TGW. EC609406/HD2967 had significant and positive SCA effect for Fe content and thousand grains weight and desirable negative SCA for yellow rust resistance. This cross was best specific combiner to increase Fe content and thousand grains weight along with yellow rust resistance Cross-combinations MvEmese/HI1562 and EC629405/HD2967 presented significant positive effect for Zn content and early heading. Cross EC609396/PBW590 had significant SCA effect for high Zn content, yellow rust resistance and early heading.

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