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Improving spring wheat by combining winter wheat gene pool

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Abstract

Introgression of winter wheat genes into the spring wheat has been considered as one of the approaches to overcome the stagnation being realized in wheat yields. In this endeavour, information on the combining ability and the manner in which the crosses should be attempted between these two distinct groups of wheat is highly essential. Therefore, twenty eight F_1 progenies developed by crossing 4 winter and 4 spring wheat lines in a half diallel mating design, were evaluated along with their parents. Additive genetic effects were of considerable magnitude for days to heading, spikelets/ear and thousand grain weight. Sappo winter and HS 295 and HD 2380 spring wheat were good general combiners for most of the attributes studied. Crosses Victor/HS 240, NS 879/4/CPAN 1796 and Sappo/CPAN 1796 had significant specific combining ability effects for most of the yield attributes. The study suggested that although general combining ability effects of most winter wheats are average or poor and of spring wheat is good, only appropriate winter × spring crosses in general may give desirable genotypes whereas, the possibilities of deriving suitable genotype from winter × winter and spring × spring wheat crosses is meager.

Key words: Winter wheat, spring wheat, *Triticum aestivum*, combining ability

Introduction

Winter wheats possess various desirable yield attribute(s), in addition to superior nutrient efficiency and a superior level of abiotic tolerance to a number of stresses (drought, heat etc.). Besides, this, many winter wheats have shown stay green tendency even at receding moisture level and high temperature [1]. Winter and spring wheats are supposed to carry different gene pools due to geographical and agro-ecological isolation. One spring × winter combination, named Veery and its progenies *viz.*, Kauz, Attila, Pastor, Bavicora etc. at International Maize and Wheat Improvement Center (CIMMYT), Mexico are the best examples of utilization of winter wheat gene pool. These spring × winter wheat derivatives produced higher yield as spring × winter wheat gene pool recombination has transmitted a higher number of grains through either a higher number of spikes/ m^2 or through bigger spikes [2]. Presently, 80% of the advance spring wheat lines at CIMMYT, Mexico carry one or other winter wheat in their pedigree. It is estimated that 8% increase in yield is due to the use of winter wheat in spring × winter hybridization programme [1].

Winter wheats do not flower in the plains of India under natural condition due to their specific vernalization and photoperiod requirement depending upon their genetic constitution [3-6]. However, under hilly conditions in India, as for example Almora, in Uttaranchal hills (29°36'N, 79°39'E and 1600 masl), the winter wheats usually flower without any artificial vernalization treatment.

Yield, the most important economic character, is product of interaction of various yield attributes. Hence, during selection its components should be given due emphasis [7]. In order to develop high yielding genotypes by exploiting spring and winter wheat gene pools, it is imperative to understand the nature of gene action and the combining ability of spring and winter wheats for yield and yield attributes. Besides this, the most promising direction among winter × winter, spring × winter and spring × spring wheat crosses has also to be found out. The present investigation was, therefore, undertaken to find out nature of gene action governing the expression of yield and yield attributes, to determine general and specific combining abilities among diverse spring and winter wheat genotypes and to find out the most feasible and promising direction of crosses for exploitation of these important diverse gene pools.

Materials and methods

Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora is having quite a large number of exotic winter wheat collections. From the active germplasm set, four winter wheats [Victor, HJA 70581, Sappo and NS 879/4] and four widely cultivated spring wheat [HS 295, HS 240, HD 2380 and CPAN 1796] varieties of north western hills were selected for the combining ability study. These parents were crossed in a set of 8 × 8 diallel cross without reciprocals [8].

Eight parents and 28 F_1s were evaluated under medium fertility ($N:P_2O_5:K_2O$:120:60:40 kg/ha) irrigated conditions at VPKAS (ICAR), Experimental Farm, Hawalbagh, Almora, India (29°36'N 79°40'E and 1250 masl).

The experiment was conducted in a three-replicate randomized complete block design. The plot size was one row 3 m long with inter and intra-raw spacing of 0.30 and 0.10 m, respectively. The crop received 60 kg/ha N, 60 kg/ha P_5O_5 and 40 kg/ha K_2O as basal dose and 30 kg/ha N as a top dressing after first irrigation and at the jointing stage. The crop received three irrigations (50 mm each irrigation). The crop did not have much incidence of leaf rust (*Puccinia recondite*), stripe rust (*Puccinia striiformis*), loose smut (*Ustilago nuda tritici*) and powdery mildew (*Erysphi tritici*).

Five individual competitive plants were selected randomly in each plot of three replications for the purpose of recording of observations. The data on days to heading and days to maturity were recorded on plot basis. Plant height was taken at physiological maturity. The sampled plants were uprooted, dried and data on tillers/plant, number of spikelets/ear, biological yield/plant were recorded. Grain yield/plant and 1000 grain weight were recorded after threshing.

Means of cross-combination (means of 5 plants per replicate) for grain yield and yield attributes were subjected to statistical analysis. Combining ability analysis [8] was conducted using the statistical software package SPAR1 of Indian Agricultural Statistical Research Institute, New Delhi.

Results and discussion

Breeders have considerably augmented the yield potential of spring wheats by introgressing desirable traits from winter wheat. But still a lot of variability in winter wheats germplasm is left unutilized that can be helpful in augmenting the yield attributes in designing high yielding genotypes for getting another quantum jump in yield.

The material used in the present study showed highly significant differences for all the characters studied. The analysis of variance for combining ability (Table 1) revealed the existence of significant variation for all the characters studied. Highly significant variation due to general combining ability (*gca*) as well as specific combining ability (*sca*) indicated that additive as well as non-additive components of heritable variance are involved in the inheritance of these characters. For days to heading, spikelets/ear and thousand grain weight the larger variances in general combining ability (σ^2 *gca*) compared to those of specific combining ability (σ^2 *sca*) indicated that these characters were predominantly controlled by additive gene effects. As this is a fixable component, selection is expected to bring substantial improvement in these characters. Both additive and dominance genetic effects were found important for days to heading in a F_2 of a winter × spring cross by Nanda *et al.*, [9]. Prevalence of additive genetic effects in winter × spring wheat crosses were also suggested by Kant *et al.* [5] and Kant and Gupta [6] for days to heading, grain yield/plant and spikelets/ear. Smaller σ^2 *gca* (σ^2 *gca*/σ^2 *sca* < 1) indicated that days to maturity, effective tillers/plant, plant height, grains/spike, grain weight/spike, biological yield/plant and grain yield/plant were affected by non-additive gene action (Table 2). Salgotra *et al.* [10] and Kant *et al.* [5] also reported non-additive genetic control of tillers/plant, grains per ear, thousand grain weight and biological yield/plant in winter × spring wheat crosses. Therefore, it would be important to evaluate not only the *gca* of parents, but also the *sca* of the cross combinations.

Sappo was the best genotype among winter wheat that exhibited highest desirable *gca* for plant height, spikelets/ear, grains/spike and biological yield/plant. The significant desirable *gca* effects for days to heading, grains/ear and biological yield/plant in the progenies of NS 879/4 winter wheat demonstrated that NS 879/4 was also a good parent for these attributes. HJA 70581 and Victor winter wheats possessed undesirable significant yield attributes for most of the characters except HJA 70581 being desirable for spikelets/ear, indicating they do not have potential for high yield (Table 3). The desirable and large *gca* effects for all the characters except spikelets/ear indicated that HS 295 was a desirable spring wheat parent with high grain yield. Its progeny with high grain yield can be screened from its crossed combinations. The spring wheat HD 2380 possessed desirable *gca* effects for all the characters except spikelets/ear and grains/spike. HS 240 spring wheat had undesirable *gca* effect and CPAN 1796 had desirable significant *gca* effects for days to heading, spikelets/ear and grains/ear (Table 3).

Table 1. Mean squares for yield attributes in winter × spring wheat crosses

Source	df	Days to heading	Plant height	Tillers/ plant	Spikelets/ ear	Grain number/ ear	Grain weight/ ear	Biological yield/plant	Grain yield/ plant	Thousand grain weight
GCA	7	282.5**	147.1**	8.8**	17.7*	236.4**	0.2**	817.1**	102.7**	170.3*
SCA	28	11.8**	60.9**	5.2*	1.5**	40.9**	0.1**	392.6*	61.5**	11.9*
Error	70	1.9	7.1	0.8	0.4	2.3	0.02	4.5	3.6	0.6

*,**Significant at 5% and 1 % level, respectively

combined with this to produce progeny with high effective tillers/plant, grains/ear, grain weight/ear, biological yield/plant, grain yield/plant and thousand grain weight although *gca* effect were average, poor and good for these characters in one or other parent (Table 3 & 4). These results indicate that yield and yield attributes were affected by genes from both female and the male parent and additive gene action was present in the parents having high *gca*, which complemented with the genes of a low *gca* parent. In such situation desirable segregates can be obtained by crossing high × low *gca* combiner and selecting in F_2 generation [11].

Table 2. Predominant gene action for yield attributes in winter × spring wheat crosses

Characters	σ^2 gca	σ^2 sca	σ^2gca/σ^2sca	Gene action
Days to heading	27.08	9.86	2.75	Additive
Plant height	8.62	53.77	0.16	Non-Additive
Effective tillers/Plant	0.36	4.43	0.08	Non-additive
Spikelets/ear	1.62	1.15	1.41	Additive
Grains/spike	19.55	38.61	0.51	Non-additive
Grain wt./spike	0.01	0.09	0.11	Non-additive
Biological yield/plant	42.46	388.05	0.11	Non-additive
Grain yield/plant	4.13	57.88	0.07	Non-additive
1000 grain wt.	15.84	11.30	1.40	Additive

Table 3. *Per se* performance of parents and *gca* for yield and yield attributes in winter and spring wheats

Parents	Days to heading		Plant height (cm)		Effective tillder/ plant		Spikelets/ ear		Grains/ spike		Grain wt./spike (gm)		Biological yield/plant (gm)		Grain yield/plant (gm)		1000 grain wt. (gm)	
	Days	*gca*	cm	*gca*	No.	*gca*	No.	*gca*	No.	*gca*	g	*gca*	g	*gca*	g	*gca*	g	*gca*
Victor	138.33	0.13	98.33	1.29	8.00	-1.49*	20.67	-0.37*	71.00	0.65	3.07	-0.02	60.00	-15.15**	30.00	-3.33**	40.53	-1.13**
HJA 70581	138.67	2.23**	115.00	4.29**	11.67	-0.39	24.67	0.80**	64.67	-4.28**	3.10	-0.08*	68.33	0.92	40.33	-2.10**	41.17	0.10
Sappo	157.67	8.99**	95.00	-7.04**	10.00	-0.46	25.67	1.57**	78.00	5.38**	2.67	-0.07	74.33	6.75**	39.33	-0.07	31.37	-4.36**
NS 879/4	132.00	-1.94**	116.67	4.79**	12.00	0.31	23.67	0.33	78.67	5.35**	2.93	-0.01	75.67	1.28*	44.33	0.50	36.60	-2.99**
HS 295	126.33	-3.84**	106.67	-1.87*	11.00	1.21**	22.00	-0.67*	71.67	1.95**	*3.57	0.29**	70.33	12.68**	47.33	5.33**	50.00	3.27**
HS 240	143.33	4.83**	108.33	-0.54	10.67	-0.69**	22.33	0.33	60.33	-1.55**	2.43	-0.20**	56.33	-9.35**	37.00	-4.13**	39.33	-2.18**
HD 2380	120.00	-8.04**	111.67	-2.21**	12.67	1.21**	17.67	-2.80**	52.00	-8.98**	2.93	0.10**	84.33	6.02**	45.33	3.20**	56.50	8.54**
CPAN 1796	128.33	-2.34**	113.33	1.29	10.33	0.31	23.67	0.80**	71.00	1.48**	2.90	-0.03	64.00	-3.15**	40.00	0.60	38.50	-1.26**
SE ±	4.14	0.41	2.77	0.79	0.51	0.26	0.89	0.18	3.19	0.45	0.12	0.04	3.21	0.63	1.93	0.56	2.80	0.22

*,**Significant at 5% and 1% level respectively

Sca resulting from non-additive genetic effects are important for the breeding potential of cross combinations. When parents such as NS 879/4, Sappo and CPAN 1796 with large potential yield attributes were crossed, NS 879/4/CPAN1796 and Sappo/CPAN 1796 had greater *sca*s for grain yield and yield attributes (Table 4). When parents Victor and HS 240 with average or poor *gca* for all the traits were crossed, their progeny exhibited high *sca* in desirable direction.

When Victor winter wheat was used as female parent and HS 240 spring wheat as male parent, their progeny had high and significant *sca* effects for early heading, more effective tillers/plant, spikelets/ear, grains/ear, grain weight/ear, biological yield/plant and 1000 grain weight (Table 4). These parents were poor general combiners for almost all these characters barring few cases where it is average. It may be inferred that buffers/diverse gene constellation for these traits would have caused this effect [4-6, 11]. Winter wheat NS 879/4 was good general combine; for days to heading, grains/spike and biological yield/plant however; it was average general combiner for other yield components. The winter wheat Sappo was good general combiner for plant height, spikelets/ear, grains/spike, biological yield/plant. The spring wheat variety CPAN 1796

When Sappo winter wheat was used as female parent and HS 295 as male parent, their progeny had high and significant *sca* effects for higher effective tillers/plant, spikelets/ear, grains/ear, biological yield/plant and grain yield/plant (Table 4). These parents were good general combiner for these traits with few exceptions in case of Sappo. These results also indicated that parent included in this study were quite diverse genetically and their diverse genes have combined to put these effects. This cross is valuable because presence of additive gene action and may respond to conventional selection methods. In the present study when winter wheat HJA 70581 and NS 879/4 with average or poor *gca* effects for effective tillers/plant, grain yield/plant and thousand grain weight were crossed, F_1 showed greater and desirable *sca* for these traits. Victor winter wheat combined well with winter wheat Sappo as their F_1 had higher effective tillers/plant, grains/ear, biological yield/plant and grain yield/plant, though the *gca* effects of both parents for these traits were average or poor except for grains/ear and biological yield/plant (Table 4). It may be inferred that buffers for these traits have contained to put this effect [11]. Based on these results it may be inferred that it is also important to evaluate the *sca* of the cross combinations.

Table 4. Crosses having significant *sca* effects

Crosses	DH	PH	TPP	SPE	GPE	GWPE	BYPP	GYPP	TGW
Victor/HS 240	-	+	+	+	+	+	+	+	+
NS 879/4/CPAN 1796	-	0	+	0	+	+	+	+	+
Sappo/CPAN 1796	-	0	+	+	+	+	+	+	0
Sappo/HS 295	0	0	+	+	+	0	+	+	-
NS 879/4/HS 240	+	-	+	0	+	0	+	-	-
HJA 70581/NS 879/4	-	+	+	0	0	0	+	+	+
Victor/sappo	0	+	+	0	+	0	+	+	0
HS 295/HD 2380	+	0	+	0	0	0	+	+	+
HS 295/CPAN 1796, 0	0	+	0	+	0	+	+	-	

-Significant in negative direction, +Significant in positive direction, 0 not significant; DH = Days to heading, PH = Plant height, TPP = Tillers/plant, SPE = Spikelets/ear, GPE = Grain number/ear, GWPE = Grain weight/ear, BYPP = Biological yield/plant, GYPP = Grain yield/plant, TGW = Thousand grain weight

Among the spring wheat parents HS 295 and HD 2380 and CPAN 1796 provided large *gca* for yield and yield attributes for different traits. They produced progenies having high significant *sca* effects for higher effective tillers/plant, biological yield/plant, and grain yield/plant (Table 4). These indicated the genetic diversity available and diverse gene constellation present in these parents. The cross HS 295/HD 2380 is valuable due to the presence of high additive gene action as this is a fixable component and may respond to conventional selected methods.

These results suggest that breeders have been able to manipulate such yield attributes as effective tillers/plant, spikelets/ear, grains/ear, biological yield/plant, grain yield/plant and thousand grain weight in the pursuit of obtaining higher yielding genotypes both in spring as well as winter wheat. Therefore, the probability of getting desirable genotypes with winter × winter or spring × spring wheat crosses is relatively low. However, ample opportunity of deriving high yielding desirable genotypes exists from winter × spring wheat crosses.

Cross combinations of Victor/HS 240 showed significant specific combining ability (*sca*) effects for most of the yield contributing characters followed by NS 879/4/CPAN 1796 and Sappo/CPAN 1796. In addition, combining ability estimates of the parents revealed importance of both additive as well as non-additive gene effects. Although *gca* effects of most of the spring wheat parents were desirable, winter wheat parents have average or poor *gca* for most of the traits. Nevertheless, enough possibilities exist to develop desirable genotypes by involving appropriate winter and spring wheat parents in crossing programme.

References

1. **Nanda G. S. and Sohu V. S.** 1998. Breeding methodologies for wheat improvement. *In*: Nayar *et al.* (eds) Wheat pathology, genetics and breeding for resistance, 1999. Advance course 14-17 Sept. 1998 DWR, Regional Station, Flowerdale, Shimla, India, pp. 51-60.
2. **Villareal R. L., Del Toro E., Mujeeb-Kazi A. and Rajaram S.** 1995. The 1BL/1RS chromosome translocation effect on yield characteristic in a *Triticum aestivum* L. cross. Plant Breed., **14**: 497-500.
3. **Jag Shoran, Hariprasad A. S. and Dube S. D.** 1995. Wheat breeding research at VPKAS. VPKAS. Tech Bull, **7**: (1/95).
4. **Jag Shoran, Kant L. and Singh R. P.** 2003. Winter and Spring wheat: An analysis of combining ability. Cereal Res. Comm., **31**: 347-354.
5. **Kant L., Mani V. P. and Gupta H. S.** 2001. Winter × spring wheat hybridization - a promising avenue for yield enhancement. Plant Breed., **120**: 255-258.
6. **Kant L. and Gupta H. S.** 2002. Potential yield advancement by combining winter and spring wheat gene pools. SABRAO Journal of Breeding and Genetics, **34**: 95-106.
7. **Grafius J. E.** 1964. A geometry for plant breeding. Crop Sci., **4**: 242-248.
8. **Griffing B.** 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust J. Biol Sci., **9**: 463-493.
9. **Nanda G. S., Afzali A. B. and Singh G.** 1990. Genetic analysis of the role of inter-mating in an inter-varietal cross of bread wheat. Indian J. Genet., **50**: 210-215.
10. **Salgotra R. K., Thakur K. S., Sethi G. S. and Sharma J. K.** 1997. Combining ability in winter × spring wheat (*Triticum aestivum* L. Em. Thell.) crosses. Himachal J. Agri. Res., **23**: 9-15.
11. **Langhum D. G.** 1961. The High-Low Method of Crop Improvement. Crop Sci., **1**: 376-378.