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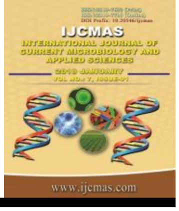

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Combining Ability of Six Wheat Genotypes and their F_1 Diallel Crosses for Nitrogen Use Efficiency (NUE) and Related Traits Under 50 Per Cent Nitrogen Condition

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ABSTRACT

Breeding of wheat (*Triticum aestivum* L.) cultivars with improved adaptation to low-N fertilization has gained importance worldwide nowadays. The present investigation aimed to identify the best general combiners and parental combinations for recombination breeding under low nitrogen condition to improve the nitrogen use efficiency. Six parents and fifteen F1s were evaluated under 50 per cent nitrogen condition using randomized complete block design with three replications. In general, means of NUE of the three parents GW 322, 2 WYCYT 34 and K 9107 were higher in magnitude than those of the three other parents, UAS 323, RAJ 4248 and C306. Both GCA and SCA mean squares were significant, but the magnitude of GCA was lesser than SCA, for all studied traits suggesting the existence of a greater portion of non-additive than that of additive genetic variance in controlling the inheritance of these traits. In general, the best general combiners among the six parents were GW 322 followed by 2 WYCYT 34 and UAS 323 parents. The best SCA effects were exhibited by F1's namely, GW 322 × C 306, 2 WYCYT 34 × C 306, 2 WYCYT 34 × RAJ 4248 and K 9107 × C 306 for important NUE traits, grain yield and harvest index. Results suggest that parents having good GCA can be employed in recombination breeding while, the F1s with good SCA effects may be further advanced to select high NUE segregants with care taken for selection in later segregating generations under low-N conditions. Results indicate that the best-performing parents and hybrid crosses for grain yield and nitrogen use efficiency and their components could be employed in future breeding programs and it also suggests that selection should be postponed to later segregating generations under low-N conditions to develop N-efficient genotypes of wheat.

Keywords

Triticum aestivum, NUE, N-uptake, N-utilization, N-harvest index, GCA, SCA

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Introduction

Wheat (*Triticum aestivum* L.) is one of the leading cereals of many countries of the world including India. It is the most important food crop in our country and is the main source of protein and energy. Among the cereals, bread wheat (*Triticum aestivum* L.) is commonly identified as a species with a higher requirement of nutrients, especially nitrogen. Thus, breeding wheat cultivars with improved adaptation to less favourable, but more optimized N fertilization regimes has gained importance (Al-Naggar *et al.,* 2015). It has been estimated that by 2025 the consumption of nitrogen (N) fertilizer will increase from 60 to 90 per cent (Ortiz-Monasterio, 2002). Therefore, it is necessary to improve cultivars that have high N use efficiency. Recovery of applied N in cereal grain is usually less than 50% worldwide (Johnson and Raun, 2003). According to Moll *et al.,* (1982), N use efficiency (NUE) in cultivar development can be divided in two-component: (i) uptake efficiency (UPE) (total plant N/N supplied), which is the ability of the crop to extract N from the soil; and (ii) utilization efficiency (UTE) (Grain yield/total plant N), which measures the capacity of the plant to convert the already absorbed N in the plant into grain yield. The efficiency of nitrogen use and plant adaptation to less favourable nutrient regimes is complex with various factors involved (Hirel *et al.,* 2007). Although numerous reports on genotypic variation in components of N efficiency already suggest potential applications of this genetic knowledge for wheat improvement (Baresel *et al.,* 2008 and Barraclough *et al.,* 2010) relatively fewer attempts have been made to breed wheat for these traits (Wolfe *et al.,* 2008). In this direction, knowledge of prepotency of parental lines for combining ability is very useful in selection of desirable lines. In view of above facts, the present experiment was undertaken to identify the best general combiners and to estimate combining ability effects of different genotypes.

Materials and Methods

Three categories of wheat genotypes namely, high (GW 322 and 2 WYCYT 34), medium (K 9107 and UAS 323) and low (RAJ 4248 and C 306) NUE genotypes (Satisha, 2016) were selected as parents on the basis of their yield potential and NUE component traits like harvest index, NUE *etc.* These six parents were crossed in all possible combinations excluding reciprocals in a diallel fashion to produce 15 F_1S constituted in experimental materials for this experiment and the experiment was laid out in randomized block design with three replications. All the F_1 hybrids along with their parents were grown in 6 rows of 1.5 meter length bed with a spacing of 20 cm between rows under 50 per cent of recommended N during *rabi* 2016-17 at All India Coordinated Wheat Improvement Project, University of Agricultural Sciences, Dharwad. The observations were recorded on traits namely, chlorophyll content at booting, anthesis and grain filling stage, days 50 per cent flowering, days to maturity, plant height, number of productive tillers, spike length, number of spikelets per spike, leaf length, leaf width, number of grains per spike, thousand grain weight, grain yield, biomass, harvest index, grain protein content and nitrogen use efficiency on randomly selected competitive plants of parents and from each replication in parents and F_1s. The data were analyzed for combining ability as per the method 2, model I of Griffing (1956).

Results and Discussion

Analysis of variance for combining ability

The analysis of variances for combining ability for different yield, yield attributes, NUE and related traits is presented in (Table 1). Both GCA and SCA variances were significant for all the characters. Variance due to general combining ability (GCA) and specific combining ability (SCA) was found to be significant for all the characters studied indicating the importance of both additive and non-additive genetic variance in controlling the expression of yield and its attributes, NUE and NUE related traits. The magnitude of SCA variance was much larger than GCA variance for most of the characters except number of spikelets per spike. Further, the variance ratio was less than unity for most of the characters except for the trait number of spikelets per spike, hence depicting the preponderance of dominant gene action in control of these traits. On the other hand, Gorny *et al.,* (2011) observed non-additive effects for grain yield and NUE component traits under low N conditions in wheat. However, Hammad *et al.*, (2013) recorded the involvement of both additive and non-additive gene action in the expression of yield and its components. These observations are in partial conflict with data reported by Le Gouis *et al.*, (2002) at low N condition, where in diallel F1 hybrids exhibited markedly higher GCA/SCA ratios for grain yield, grain N yield and total above ground N than in those grown under high-N nutrition condition.

General combining ability effects of the parents

Estimate of gca effects of the parents for different yield, yield attributes, NUE and related traits are shown in Table 2. Interestingly, both high NUE parents GW 322 and 2WYCYT 34 exhibited high significant positive gca effects for chlorophyll content at grain filling stage, number of productive tillers, grain yield and NUE. The parents GW 322 and 2WYCYT 34 were not only good general combiners but their per se performance was also superior for most of the characters studied.

Table.1 Analysis of variance for combining ability for yield, yield attributes, NUE and related traits in bread wheat

Character	GCA	SCA	Error	GCA variance	SCA variance	GCA/SCA Ratio
SPAD-I	2.70**	1.63**	0.18	0.31	1.44	0.21
SPAD-II	1.76**	1.52**	0.17	0.19	1.34	0.14
SPAD-III	10.29**	8.27**	0.39	1.23	7.87	0.15
DFF	1.78**	1.15 **	0.14	0.2	1	0.2
DM	35.90**	25.73**	0.17	4.46	25.55	0.17
PH	93.81**	25.15**	0.4	11.67	24.74	0.47
NPT	10.54 **	6.16**	0.55	1.24	5.61	0.22
SL	0.56**	0.74**	0.15	0.05	0.59	0.086
LL	8.74**	8.36**	0.3	1.05	8.06	0.13
LW	0.01**	0.05**	0.003	0.013	0.047	0.27
NSS	0.49**	0.34**	0.34	0.018	0.002	7.12
NGS	0.85*	2.08**	0.27	0.073	1.8	0.04
GY	1.87**	1.68**	0.12	0.21	1.55	0.14
TGW	2.95**	6.35**	0.51	0.3	5.84	0.052
BM	3.58**	16.69**	0.48	0.38	16.21	0.023
HI	6.52**	55.30**	7.4	11.86	115.1	0.1
GPC	0.40**	0.66**	0.07	0.041	0.59	0.07
NUE	2.76**	2.48**	0.18	0.32	2.29	0.14

* and ** indicates significant at 5 (%) and 1 (%) level of significance, respectively.

SPAD-1 = Chlorophyll content at booting stage, SPAD-2 = Chlorophyll content at anthesis, SPAD-3 = Chlorophyll content at grain filling stage, DFF = Days to fifty per cent flowering, DM= Days to maturity, PH = Plant height (cm), NPT = Number of productive tillers, SL = Spike length (cm), LL= Leaf length (cm), LW= Leaf width (cm), NGS = Number of grains per spike, NSS= Number of spikelets per spike, TGW = Thousand grain weight (g), GY = Grain yield, BM = Biomass, HI= Harvest index (%), GPC= Grain protein content (%), NUE = Nitrogen use efficiency.

Table.2 Estimates of general combining ability effects of six parents used in diallel study

Parents	SPAD-I	SPAD-II	SPAD-III	DFF	DM	PH	NPT	SL	LL	LW	NSS	NGS	GY	TGW	BM	HI	GPC	NUE
GW 322	0.78**	0.71**	0.56**	0.77**	-3.65**	-0.106**	1.23**	-0.07	0.33	-0.03*	0.22	-0.40*	1.05**	0.50*	1.09**	-0.97*	0.28**	1.10**
2 WYCYT 34	-0.08	-0.01	1.53**	-0.18	1.68**	-1.44**	1.06**	-0.15	-0.86**	0.05*	0.34**	0.13	0.42**	0.44	0.06	-0.66	0.27**	0.51**
K9107	-0.94**	-0.41**	-0.68**	-0.18	0.38*	2.18**	-0.09	-0.03	1.11**	-0.01	-0.06	-0.06	0.22	0.59*	-0.94**	0.72	0.04	0.27
UAS323	-0.08	0.41**	0.80**	-0.30*	0.47*	-0.52*	-1.01**	0.52**	0.74**	0.02	-0.27	0.51**	0.26*	-0.83**	0.02	1.33**	-0.18*	0.31
RAJ4248	-0.08	-0.32*	-1.39**	-0.47**	-1.06**	-4.56**	-1.63**	-0.20	0.31	0.02	-0.23	-0.27	-0.10	-0.23	-0.35	0.16	-0.07	0.13
C306	0.41**	-0.36*	-0.82**	0.36**	2.18**	5.43**	0.44	-0.06	-1.64**	-0.05*	0.01	0.09	-0.92**	-0.53*	0.10	-0.58	-0.23**	-0.53**
C.D. at 5 % (Gi-Gj)	0.55	0.54	0.80	0.48	0.54	0.82	0.95	0.50	0.70	0.07	0.75	0.67	045	0.91	0.89	3.49	0.33	0.55
C.D. at 1 % (Gi-Gj)	0.86	0.85	1.26	0.75	0.85	1.28	1.50	0.78	1.10	0.11	1.17	1.05	0.71	1.43	1.39	5.48	0.53	0.87

* and ** indicates significant at 5 (%) and 1 (%) level of significance, respectively.

SPAD-1 = Chlorophyll content at booting stage, SPAD-2 = Chlorophyll content at anthesis, SPAD-3 = Chlorophyll content at grain filling stage, DFF = Days to fifty per cent flowering, DM= Days to maturity, PH = Plant height (cm), NPT = Number of productive tillers, SL = Spike length (cm), LL= Leaf length (cm), LW= Leaf width (cm), NGS = Number of grains per spike, NSS= Number of spikelets per spike, TGW = Thousand grain weight (g), GY = Grain yield, BM = Biomass, HI= Harvest index (%), GPC= Grain protein content (%), NUE = Nitrogen use efficiency

Table.3 Estimates of specific combining ability effects for fifteen single cross hybrids used in the diallel study

Cross	SPAD-I	SPAD-II	SPAD-III	DFF	DM	PH	NPT	SL	LL	LW	NSS	NGS	GY	TGW	BM	HI	GPC	NUE
GW 322 x K9107	1.16**	-0.75	-2.44**	-0.18	0.85*	0.57	0.46	1.30**	-0.43	0.05	-0.70	-0.22	-0.23	0.48	0.62	-5.76*	0.88**	-0.28
GW 322 x 2WYCYT 34	-0.99*	-1.58**	-1.35**	-0.51	7.22**	-7.13**	0.29	-0.51	-0.22	-0.01	0.54	1.56**	-2.70**	0.41	1.29	-9.75**	-1.15**	-3.28**
GW 322 x RAJ4248	-0.32	-2.00**	-4.90**	-0.56	-0.69	-0.67	-0.66	0.23	-3.07**	-0.05	0.12	-3.68**	-0.64	-2.91**	-6.83**	4.97*	-0.05	-0.77
GW 322 x C306	0.88*	-0.56	-0.43	1.27**	-1.27**	9.98**	-1.07	1.10**	2.75**	0.03	0.87*	-0.39	1.28**	-2.81**	-0.88	8.20**	-0.004	1.55**
GW 322 x UAS323	-0.75	0.21	2.49**	1.60**	6.76**	2.28**	-1.28	-0.66	0.49	-0.11	-0.16	0.52	0.12	-2.07**	-1.18	2.70	-1.43**	0.14
K9107 x 2WYCYT 34	-1.03*	-1.35**	-0.25	0.10	2.85**	1.61*	-2.70**	0.74*	-2.76**	-0.20	0.83*	0.23	-0.12	-2.08**	-4.96**	1.81*	-0.48	-0.15
K9107 x RAJ4248	0.23	0.69	4.08**	-1.60**	-5.06**	4.73**	4.33**	-0.53	-3.01**	-0.04	0.08	1.64**	0.27	0.90	5.84**	-4.34**	-0.70**	0.33
K9107 x C306	-1.46**	0.39	-0.32	-0.43	2.68**	-2.92**	-4.07**	-0.13	-0.21	0.21	-0.16	-0.72	1.03**	2.45**	-3.73**	7.86**	-0.36	1.26**
K9107 x UAS323	-1.22**	1.25**	-0.95	1.89**	5.72**	-1.97**	-0.28	0.96*	6.38**	0.43	-0.54	-0.47	-0.58	-0.80	-0.97	0.13	0.68*	-0.72
2 WYCYT 34 x RAJ4248	-1.39**	0.76	-1.57*	1.06**	4.31**	-3.63**	-0.11	0.31	3.29**	0.32*	-0.33	0.44	0.92*	-0.75	-1.21	4.49**	1.10**	1.12*
2 WYCYT 34 x C306	0.24	0.56	0.22	0.23	-4.94**	-2.97**	-0.91	1.18**	2.82**	0.34*	0.41	1.06*	1.51**	4.24**	-2.69**	6.44*	1.04**	1.83**
2 WYCYT 34 x UAS323	-0.58	0.18	0.95	-1.10**	0.10	-1.67**	-0.45	-0.58	-0.29**	0.06	-0.29	0.64	0.14	0.24	-2.61**	-0.48	0.09	0.16
RAJ4248 x C306	-0.72	0.34	2.55**	0.85*	2.47**	-5.51**	-1.86*	-0.77*	2.07**	-0.06	0.66	1.14*	0.33	-0.71	-2.90**	2.70	0.53*	0.40
RAJ4248 x UAS323	0.78	0.26	3.05**	0.19	4.18**	-3.22**	2.92**	-0.03	0.41	-0.07	0.29	0.73	0.37	-2.44**	-0.70	2.27	-0.03	0.45
C306 x UAS 323	-1.58**	-1.96**	-3.31**	-1.31*	-3.39**	-4.22**	-0.82	-0.16	-0.18	0.01	0.04	0.69	1.24**	-1.78*	-1.75*	8.90**	0.41	1.50**
C.D. (Sij-Sik) at 5 %	1.22	1.19	1.78	1.06	1.20	1.81	2.11	1.10	1.56	0.16	1.65	1.48	1.00	2.02	1.96	7.72	0.74	1.22
C.D. (Sij-Sik) at 1 %	1.69	1.66	2.47	1.48	1.66	2.51	2.93	1.53	2.16	0.23	2.30	2.06	1.40	2.81	2.73	10.71	1.03	1.70
C.D. (Sij-Skl) at 5 %	1.13	1.10	1.65	0.98	1.11	1.67	1.95	1.02	1.44	0.15	1.53	1.37	0.93	1.87	1.82	7.15	0.69	1.13
C.D. (Sij-Skl) at 1 %	1.57	1.53	2.29	1.37	1.54	2.32	2.71	1.42	2.00	0.21	2.13	1.90	1.29	2.60	2.52	9.92	0.96	1.57

* and ** indicates significant at 5 (%) and 1 (%) level of significance, respectively.

SPAD-1 = Chlorophyll content at booting stage, SPAD-2 = Chlorophyll content at anthesis, SPAD-3 = Chlorophyll content at grain filling stage, DFF = Days to fifty per cent flowering, DM= Days to maturity, PH = Plant height (cm), NPT = Number of productive tillers, SL = Spike length (cm), LL= Leaf length (cm), LW= Leaf width (cm), NGS = Number of grains per spike, NSS= Number of spikelets per spike, TGW = Thousand grain weight (g), GY = Grain yield, BM = Biomass, HI= Harvest index (%), GPC= Grain protein content (%), NUE = Nitrogen use efficiency.

Among the medium NUE parents, high gca effects were noted for days to maturity, plant height, leaf length, thousand grain weight, number of grains per spike and grain yield (K9107). While, UAS 323 recorded superior performance for chlorophyll content during anthesis stage, spike length, leaf length and harvest index. Low NUE parent C 306 showed significant and positive sca effects for the traits like chlorophyll content at booting stage, days to fifty percent flowering, days to maturity and plant height which are of least importance.

Over all the study of GCA effects of the parents suggests that the parents GW 322 and 2WYCYT 34 are best general combiners for most important traits like NUE and related traits, yield and yield attributes. These parents are expected to have more additive genes for the respective characters. Hence, they could be used as potential donors for yield and NUE. Thus, identified parents can be further used to study the genetic mechanism controlling NUE.

Specific combining ability effects of the 15 diallel crosses

Estimation of sca effects of the crosses for yield and its attributes, NUE and related traits are presented in Table 3. The F_1 hybrid, GW 322 × C 306 exhibited significant, positive sca effects for the traits *viz*., chlorophyll content at booting stage, days to fifty per cent flowering, spike length, leaf length, number of spikelets per spike, grain yield, harvest index and NUE. While, the significant, positive sca effects for the traits like spike length, leaf length and width, number of grains per spike, thousand grain weight, grain yield, biomass, harvest index, grain protein content and NUE have been observed in the cross 2WYCYT 34 × C 306. The cross 2WYCYT 34 × RAJ 4248 showed the positive significant sca effects for the traits namely, days to fifty per cent flowering, days to maturity, leaf length and width, grain yield, harvest index, grain protein content and NUE. The hybrid cross, K 9107 × C 306 exhibited significant, positive sca effects for the traits *viz*., days to maturity, grain yield, harvest index, thousand grain weight and nitrogen use efficiency. C 306 × UAS 323 showed significant, positive sca effects for the traits like grain yield, harvest index and NUE.

With respect to sca effects however it has been observed that, the F_1 hybrids namely GW 322 × C 306, 2 WYCYT 34 × C 306, 2 WYCYT 34 × RAJ 4248, K 9107 × C 306 and C 306 × UAS 323 exhibited high sca effects with respect to NUE, grain yield and harvest index and hence, found be the best specific combiner for NUE and yield attributes, These crosses could be extensively used in breeding programme to recover the superior segregants. The crosses, especially those showing high SCA effects and including one parent with high GCA effects are expected to release more transgressive segregants (Al-Naggar *et al.*, 2015).

The present investigation was carried out to identify the combining ability of different parents and the best cross combination for yield, yield attributes, NUE and related traits under 50 per cent nitrogen condition. It was also meant to determine the nature of gene action, combining ability and genetic variance. Analysis of variance revealed that both GCA and SCA variances were important for all characters.

The ratio of GCA to SCA revealed the presence of more non-additive gene action. Further, the ratio of GCA variance to SCA variance was less than unity for all the characters indicating the predominance of non-additive gene action in controlling these characters. Therefore, selection should be postponed to later segregating generations under low-N conditions to develop N-efficient genotypes of wheat. The parents GW 322 and 2 WYCYT 34 were identified as good general combiners for NUE and related traits. Under low-N conditions, the hybrids like, GW- 322 × C 306, 2 WYCYT 34 × C 306, 2 WYCYT 34 × RAJ 4248, K 9107 × C 306 and C 306 × UAS 323 exhibited high sca effects with respect to NUE, grain yield and harvest index, hence were identified as good crosses and can be used in the future breeding programme to improve nitrogen use efficiency traits in bread wheat under low-N conditions to obtain higher values of selection gain.

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