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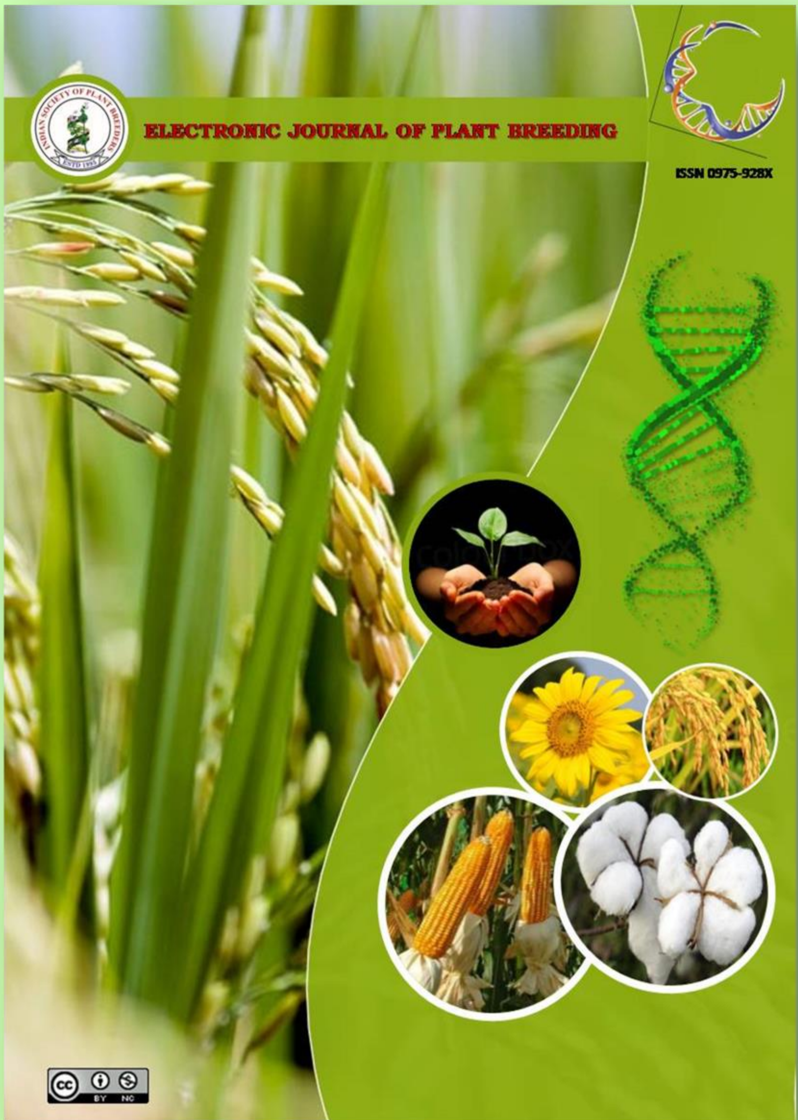

ISSN: 0975-928X

Volume: 10

Number:1

EJPB (2019) 10(1):277-284

DOI: 10.5958/0975-928X.2019.00033.4

https://ejplantbreeding.org

Electronic Journal of Plant Breeding, 10 (1): 277 – 284 (Mar 2019) DOI: 10.5958/0975-928X.2019.00033.4
ISSN 0975-928X

Research Article

Combining ability analysis for quantitative traits in China aster [*Callistephus chinensis* (L.) Nees]

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(Received: 20 Oct 2018; Revised: 05 Feb 2019; Accepted: 06 Feb 2019)

Abstract
A line x tester analysis was carried out involving 11 divergent genotypes (6 lines and 5 testers) and 30 F_1 hybrids of China aster for assessing the combining ability for 13 economic traits, during 2017. The genotypes Matsumoto White and Phule Ganesh Violet among lines and testers, showed good general combining ability for most of the economical traits. The cross combinations Matsumoto Scarlet x Phule Ganesh Violet, Matsumoto White x Phule Ganesh Violet and Matsumoto Red x IIHRJ3-2 showed best specific combining ability for various traits. The variance of *sca* was the highest for all the traits except for plant spread and days to first flowering which indicated the dominance of additive gene effects. Hence, it was inferred that specific combining ability can be exploited for the creation of novel flower colours and phenotypes.

Key words
Line, tester, China aster, combining ability.

Introduction

China aster belongs to the family Asteraceae and is a native of China (Navalinskien *et al*., 2005). It is commercially grown as flowering annual for cut and loose flower which are used in flower decoration, preparation of bouquets and garlands. It can also be used in land*sca*pe gardening as a bedding plant to provide mass aesthetic effect. In India, it is commercially grown by small and marginal farmers in Karnataka, Tamil Nadu, Andhra Pradesh, Maharastra and West Bengal (Raghava, 1984). There is need to develop novel flower colours and forms in China aster as the consumers preferences changes frequently. Estimation of combining ability is an important tool which can be utilized in the design of successful breeding programs in various ornamental crops (Bayat *et al*., 2012; Ai *et al*., 2015). To understand the probable use of any genotype as a good line or tester parent in hybridization, there is a need to evaluate its own performance along with its *gca* effect and the performance of F_1 hybrid derived from it. General combining ability (*gca*) of genotypes is normally associated with additive gene action, while specific combining ability (*sca*) governed by dominance and epistasis gene action (Malik *et al*., 2004). Parents differing in their combining ability and the use of good general combiners are expected to give useful segregants. In similar way, superior cross combinations can be categorized in respect to their specific combining ability effects (Singh and Misra, 2008). It also provides necessary information on nature and magnitude of gene effects for growth traits (Kumar *et al*., 2008). In the present study, 11 genotypes (6 lines and 5 testers) and their 30 F_1 hybrids were studied by line x tester analysis for effects of *gca* and *sca* of lines, testers and F_1 hybrids in China aster.

Material and Methods

An experiment was carried out during 2017 in the field of Division of Floriculture and Medicinal Crops, ICAR-Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru, India. The experimental site was geographically located at 13^o 58’ N Latitude, 78^{o}E Longitude and at an elevation of 890 m above mean sea level. The experimental material consisted of six lines *viz.*, Matsumoto Pink, Matsumoto Red, Matsumoto Rose, Matsumoto Yellow, Matsumoto Scarlet and Matsumoto White and 5 testers *viz.*, Phule Ganesh Violet, Phule Ganesh Purple, IIHRJ3-2, IIHRG13 and Local White crossed in line x tester mating design to produce 30 F_1 hybrids. The design Robinson’s North Carolina Design II (Comstock and Robinson, 1952) was used to estimate combining ability for 13 economic traits.

Twenty plants each of 6 lines, 5 testers and 30 F_1 hybrids were planted in randomized complete

Electronic Journal of Plant Breeding, 10 (1): 277 – 284 (Mar 2019) DOI: 10.5958/0975-928X.2019.00033.4
ISSN 0975-928X

block design with two replication at spacing of 25 cm x 25 cm under open field condition and five plants were selected randomly for recording observations. Observations were recorded on plant height (cm), number of leaves per plant, plant spread (cm), number of branches per plant, days to first flowering, flower stalk length (cm), flower head diameter (cm), 100 flowers weight (g), number of flowers per plant, weight of flowers per plant (g), duration of flowering (days) and vase life (days). The recommended agronomical practices were adopted to raise the crop. The data generated was used to estimate general combining ability of parents and specific combining ability of cross combinations using appropriate formulae and statistical package WINDOSTAT version 8.6.

Results and Discussion

The variances due to *gca* and *sca* effects are presented in Table 1. The results of analysis of variance for combining ability relating to 13 economic traits showed significant differences for the 30 crosses. The variance due to *sca* was higher than *gca* variance for all the traits except for plant spread and days to first flowering. The mean square values due to *gca* effects of female parents were significant only for days to first flowering and flower head diameter, and number of leaves per plant, plant spread and days to first flowering for male parent. The mean squares due to *sca* effect for all the traits were significant. The results showed that *sca* effects were more important for the performance of the cross combinations which indicated that non additive gene action played a major role in expression of traits (Kumar *et al*. 2004).

Estimates of *GCA* effects for the 13 economic traits in 11 parents of China aster are presented in Table 2. Among the 6 lines (female parents), Matsumoto White (Line 6) was the best general combiner exhibiting significant general combining ability for maximum number of traits *viz*., number of leaves per plant, plant spread, flower stalk length, number of flowers per plant, weight of flowers per plant, duration of flowering, flower yield per hectare and Matsumoto Scarlet (Line 5) for plant height, number of branches per plant, flower head diameter, 100 flower weight and vase life. Among the 5 testers (male parents), Phule Ganesh Violet (Tester 1) was the most superior general combiner exhibiting significant general combining ability for maximum number of traits *viz*., plant spread, flower stalk length, flower diameter, 100 flower weight, number of flowers per plant, weight of flowers per plant, duration of flowering and flower yield per hectare (Table 3).

While comparing the *gca* effects with *sca* effects, the cross Matsumoto Scarlet x Phule Ganesh Violet (L5 x T1) has high *sca* effects for plant height, number of leaves per plant, number of branches per plant (Table 4) with high *gca* effect of the female parent and low *gca* effect of the male parent for these traits. The cross Matsumoto White x Phule Ganesh Violet (L6 x T1) exhibited maximum *sca* for plant spread and vase life (Table 4 and Table 6, respectively). The same combination also has high *gca* effect for both the parents for plant spread, while high female parent *gca* and low male parent *gca* for vase life. The cross combinations Matsumoto Scarlet x IIHRJ3-2 (L5 x T4) and Matsumoto Yellow x IIHRJ3-2 (L4 x T4) showed maximum *sca* effect for flower head diameter with a high *gca* effect of female parent and low *gca* effect of male parent and 100 flower weight with low *gca* effects of both the parents, respectively (Table 5). The cross Matsumoto Red x IIHRJ3-2 (L2 x T3) established a high *sca* effect for weight of flowers per plant and flower yield per hectare (Table 6), with a low *gca* effect for both the parents. It is identified as best specific cross combinations for exploitation of higher yield. It is a fact that cross combinations which exhibited positive *sca* effects or negative *sca* effects for various traits could result from parents having *gca* effects of either high x high, low x high, high x low or low x low of Line x Tester combinations. Hence, it may not be possible to ascertain the relationship between *gca* and *sca* in hybrids of China aster. The findings are in conformity with the studies of Lou *et al*. (2011) in zinnia and Ai *et al*. (2015) in marigold. The unpredictability of the *sca* for the given cross combinations with known *gca* may relate to the precise degree of divergence among the parents (Hallauer and Miranda, 1988).

Genetic component analysis of 13 economic traits of China aster was done. The relative importance of *gca* and *sca* were differed among the traits. Thus, the ratio of variance of *gca* to variance of *sca* was more than one for plant spread and days to first flowering which indicated the dominance of additive gene effects for these traits, while, it was less than one for all the remaining traits suggesting the dominant role of non-additive genetic effects. Kumar *et al*. (2004) and Pavani (2014) in China aster and Namita *et al*. (2011) in marigold also reported the role of non- additive gene effects for the expression of the traits such as plant height, plant spread, stalk length, flower diameter, flower weight, duration of flowering and vase life. Most of the traits except plant spread and days to first flowering were controlled by non-additive gene action. Hence, these traits can be improved through standard selection procedure like reciprocal recurrent selection as it exploits both additive as well as non-additive genetic variance (Kumar *et al*., 2004).

A line x tester analysis was carried out involving 11 divergent genotypes (6 lines and 5 testers) and 30 F_1 hybrids of China aster for assessing the combining ability for 13 economic traits. The mean squares due to *gca* was significant for number of leaves per plant, plant spread and days to first flowering, and *sca* was significant for all the traits. Three genotypes *i.e*. Matsumoto Scarlet and Matsumoto White (as lines) and Phule Ganesh Violet (as tester) with good *gca* are recommended for future use in breeding to exploit heterosis. The crosses L5 x T1 (Matsumoto Scarlet x Phule Ganesh Violet), L6 x T1 (Matsumoto White x Phule Ganesh Violet) and L2 x T3 (Matsumoto Red x IIHRJ3-2) with high *per se* exhibited overall best performance for most of the economic traits such as plant height, plant spread, flower stalk length, flower head diameter, 100 flower weight and vase life in terms of *sca* were also the best cross combinations for exploitation of heterosis.

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Electronic Journal of Plant Breeding, 10 (1): 277 – 284 (Mar 2019) DOI: 10.5958/0975-928X.2019.00033.4
ISSN 0975-928X

Table 1. Analysis of variance for combining ability of lines, testers and their crosses

Source of variation	df	Plant height (cm)	No. of leaves/ plant	Plant spread (cm)	No. of branches/ plant	Days to first flowering	Flower stalk length (cm)	Flower head diameter (cm)	100 flowers weight (g)	No. of flowers/ plant	Weight of flowers/ plant (g)	Duration of flowering (days)	Flower yield/ hectare (q)	Vase life (days)
Line effect	5	175.96	10.79	16.30	9.54	549.99**	65.88	0.63*	1417.47	208.42	208.42	85.09	704.49	4.44
Tester effect	4	116.71	34.20**	360.52**	21.63	324.18**	90.18	0.18	306.63	46.79	46.79	44.46	216.85	4.00
L x T effect	20	85.87**	17.55**	34.69**	8.53**	55.17**	36.48**	0.21**	670.40**	88.27**	88.27**	47.95**	323.14**	2.32**
Error	29	2.89	2.32	1.82	1.48	0.71	3.78	0.03	4.91	2.76	2.76	2.93	9.43	0.04

Note: * and ** indicates significance of value at p= 0.05 and p=0.01, respectively

Table 2. Variance due to *gca* and *sca* effects

Source of variation	Plant height (cm)	No. of leaves/plant	Plant spread (cm)	No. of branches/plant	Days to first flowering	Flower stalk length (cm)	Flower head diameter (cm)	100 flowers weight (g)	No. of flowers/plant	Weight of flowers/ plant (g)	Duration of flowering (days)	Flower yield/ hectare (q)	Vase life (days)
Variance of *GCA*	13.04	1.85	17.00	1.30	39.68	6.80	0.03	77.95	11.37	40.93	5.67	28.88	0.38
Variance of *SCA*	41.49	7.70	16.61	3.62	27.27	16.65	0.09	332.88	42.86	156.34	22.75	110.33	1.14
Variance of *GCA*/*SCA*	0.31	0.24	1.02	0.36	1.46	0.41	0.33	0.23	0.27	0.26	0.25	0.26	0.33

Electronic Journal of Plant Breeding, 10 (1): 277 – 284 (Mar 2019) DOI: 10.5958/0975-928X.2019.00033.4
ISSN 0975-928X

Table 3. Estimates of general combining ability (*gca*) effects of lines and testers for vegetative, flowering, yield and postharvest traits

Line/Tester	Plant height (cm)	No. of leaves/ plant	Plant spread (cm)	No. of branches/ plant	Days to first flowering	Flower stalk length (cm)	Flower head diameter (cm)	100 flower weight (g)	Number of flowers/ plant	Weight of flowers/ plant (g)	Duration of flowering (days)	Flower yield/ hectare (q)	Vase life (days)
Line 1	-0.57**	-0.26**	0.06	-0.04**	-9.13**	-3.10**	-0.12**	1.14	-3.35**	-5.81**	-3.67**	-4.88**	-0.72**
Line 2	-0.90**	-0.74**	-1.76**	0.88*	1.99**	-1.79**	-0.17**	7.46**	-0.10**	-0.11**	-0.49**	-0.09**	-0.59**
Line 3	-2.26**	-0.59**	-0.5**	-0.94**	-1.48**	-0.39**	-0.13**	-6.05**	-4.08**	-8.40**	0.56	-7.06**	0.39**
Line 4	-5.91**	-0.51**	0.09	-1.37**	-3.84**	-0.40**	-0.13**	-14.48**	-0.98**	-5.39**	-0.90**	-4.53**	-0.45**
Line 5	5.25**	0.06	-0.07**	1.01**	-0.60**	1.48*	0.48**	18.90**	0.82	6.35*	-0.72**	5.33*	0.88**
Line 6	4.39**	2.04**	2.19**	0.46	13.06**	4.20**	0.07**	-6.95**	8.59**	13.37**	5.21**	11.23**	0.48**
Tester 1	0.56	-0.92**	9.13**	0.16	2.57**	3.28**	0.11**	5.97**	2.33**	6.32*	2.26**	5.31**	-0.06**
Tester 2	-2.26**	-1.40**	-0.19**	-1.65**	2.28**	1.66*	0.03**	3.19**	-0.43**	-0.41**	1.39*	-0.34**	-0.69**
Tester 3	4.78**	1.91**	-2.24**	2.05**	-6.67**	-0.50**	-0.20**	-3.16**	0.73	0.98	-0.98**	0.83	0.53**
Tester 4	-3.27**	-1.35**	-5.52**	-0.54**	5.92**	-4.01**	0.08**	0.78	-3.05**	-5.38**	-2.61**	-4.52**	0.64**
Tester 5	0.19	1.76**	-1.18**	-0.02**	-4.10**	-0.43**	-0.02**	-6.77**	0.42	-1.52**	-0.06**	-1.28**	-0.42**
SE ± (Line)	0.54	0.46	0.38	0.36	0.25	0.56	0.05	0.68	0.50	1.02	0.49	0.86	0.07
SE ± (Tester)	0.49	0.42	0.35	0.33	0.23	0.52	0.05	0.62	0.46	0.93	0.45	0.78	0.06

Note: * and ** indicates significance of value at p= 0.05 and p=0.01, respectively

Table 4. Estimates of specific combining ability (*sca*) of crosses effects for vegetative traits

Sl. No.	Cross	Plant height (cm)	Number of leaves/plant	Plant spread (cm)	Number of branches per plant
1	L1 × T1	-0.20	-0.72	-6.02**	-0.64
2	L1 × T2	-2.22	1.94	0.44	0.50
3	L1 ×T3	-1.67	-2.05	-0.78	-2.62**
4	L1 ×T4	6.54**	4.72**	2.29*	2.64**
5	L1 ×T5	-2.46*	-3.89**	4.08**	0.12
6	L2 × T1	-9.13**	0.44	-3.95**	-0.97
7	L2 × T2	4.11**	-0.33	2.99**	0.75
8	L2 ×T3	9.66**	0.94	2.87**	3.05**
9	L2 ×T4	-3.05*	0.78	-0.10	-1.12
10	L2 ×T5	-1.59	-1.83	-1.81*	-1.71*
11	L3 × T1	-5.59**	-2.21*	-4.22**	-2.24**
12	L3 × T2	1.97	0.19	3.52**	1.65*
13	L3 ×T3	1.44	1.62	1.77*	-0.88
14	L3 ×T4	1.48	-0.62	-0.32	1.04
15	L3 ×T5	0.69	1.02	-0.75	0.45
16	L4 × T1	4.73**	1.45	1.86*	0.94
17	L4 × T2	9.12**	-0.31	2.76**	1.33
18	L4 ×T3	-4.41**	-0.13	-1.78*	-1.53
19	L4 ×T4	-3.45**	-0.29	0.55	-1.03
20	L4 ×T5	-5.99**	-0.73	-3.38**	0.29
21	L5 × T1	10.77**	4.97**	1.73	3.39**
22	L5 × T2	-11.37**	-1.38	-4.66**	-3.30**
23	L5 ×T3	-4.06**	1.47	0.30	2.34**
24	L5 ×T4	3.89**	-6.60**	1.88*	-2.91**
25	L5 ×T5	0.77	1.54	0.75	0.49
26	L6 × T1	-0.58	-3.93**	10.60**	-0.48
27	L6 × T2	-1.62	-0.11	-5.04**	-0.92
28	L6 ×T3	-0.96	-1.85	-2.38**	-0.36
29	L6 ×T4	-5.42**	2.00	-4.30**	1.39
30	L6 ×T5	8.57**	3.89**	1.11	0.38
	SEm ±	1.20	1.04	0.86	0.80
	C.D. (P=0.05)	2.45	2.12	1.75	1.64
	C.D. (P=0.01)	3.31	2.86	2.36	2.21

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ISSN 0975-928X

Table 5. Estimates of specific combining ability (*sca*) effects of crosses for flowering traits

Sl. No.	Cross	Days to first flowering	Flower stalk length (cm)	Flower head diameter (cm)	100 flowers weight (g)	Number of flowers/ plant
1	L1 × T1	-0.31	-2.93*	-0.23*	-5.33**	3.71**
2	L1 × T2	-1.10	-0.56	0.51**	21.11**	1.71
3	L1 ×T3	2.93**	-1.98	-0.06	-3.90*	-2.20
4	L1 ×T4	-4.72**	7.19**	-0.19	-19.04**	3.50**
5	L1 ×T5	3.19**	-1.72	-0.04	7.16**	-6.72**
6	L2 × T1	-1.67**	-3.54**	-0.07	-9.35**	-7.23**
7	L2 × T2	-2.55**	3.54**	-0.10	-20.37**	5.12**
8	L2 ×T3	-2.35**	4.20**	0.24*	18.03**	8.46**
9	L2 ×T4	4.84**	-1.52	-0.29*	-7.31**	-0.60
10	L2 ×T5	2.08**	-2.62*	0.21	18.99**	-5.74**
11	L3 × T1	3.71**	3.60**	-0.16	1.16	-5.39**
12	L3 × T2	-3.08**	1.22	0.10	10.35**	3.44**
13	L3 ×T3	0.45	1.72	0.08	0.59	3.29**
14	L3 ×T4	-1.72**	-5.52**	-0.14	-14.60**	-1.60
15	L3 ×T5	0.62	-1.02	0.12	2.50	0.26
16	L4 × T1	0.16	3.45*	-0.06	-6.36**	1.93
17	L4 × T2	0.21	1.40	0.12	-13.73**	5.84**
18	L4 ×T3	3.90**	-1.68	-0.16	1.97	0.02
19	L4 ×T4	-3.10**	0.91	0.30*	33.48**	-4.95**
20	L4 ×T5	-1.17*	-4.08**	-0.19	-15.37**	-2.84*
21	L5 × T1	-5.92**	-2.68*	-0.11	-4.84**	9.04**
22	L5 × T2	-1.79**	-5.98**	-0.52**	-14.61**	-13.12**
23	L5 ×T3	-4.18**	-1.48	-0.11	-8.86**	-2.78*
24	L5 ×T4	13.73**	5.28**	0.66**	27.50**	4.08**
25	L5 ×T5	-1.84**	4.87**	0.08	0.80	2.78*
26	L6 × T1	4.01**	2.10	0.62**	24.71**	-2.06
27	L6 × T2	8.31**	0.39	-0.10	17.25**	-2.98*
28	L6 ×T3	-0.75	-0.78	0.00	-7.81**	-6.79**
29	L6 ×T4	-8.67**	-6.28**	-0.35**	-20.05**	-0.44
30	L6 ×T5	-2.90**	4.57**	-0.18	-14.10**	12.26**
	SEm ±	0.56	1.26	0.11	1.52	1.13
	C.D. (P=0.05)	1.15	2.58	0.23	3.12	2.30
	C.D. (P=0.01)	1.55	3.48	0.31	4.20	3.11

Electronic Journal of Plant Breeding, 10 (1): 277 – 284 (Mar 2019) DOI: 10.5958/0975-928X.2019.00033.4
ISSN 0975-928X

Table 6. Estimates of specific combining ability (*sca*) effects of crosses for flower yield and vase life

Sl. No.	Cross	Weight of flowers/plant (g)	Duration of flowering (days)	Flower yield/r hectare (q)	Vase life (days)
1	L1 × T1	4.98*	3.91**	4.18*	-0.14
2	L1 × T2	7.61**	-0.72	6.39**	0.49**
3	L1 ×T3	-5.01*	-1.44	-4.21*	-0.73**
4	L1 ×T4	2.60	1.62	2.18	0.83**
5	L1 ×T5	-10.18**	-3.36**	-8.55**	-0.45**
6	L2 × T1	-16.31**	-5.61**	-13.70**	-0.61**
7	L2 × T2	4.83*	0.01	4.06*	0.69**
8	L2 ×T3	21.08**	5.88**	17.71**	0.81**
9	L2 ×T4	-2.84	-0.74	-2.38	-0.64**
10	L2 ×T5	-6.77**	0.46	-5.69**	-0.25
11	L3 × T1	-10.84**	2.17	-9.11**	-1.08**
12	L3 × T2	8.51**	-4.87**	7.15**	-0.25
13	L3 ×T3	5.45*	0.57	4.58*	-0.17
14	L3 ×T4	-4.92*	-0.70	-4.13*	0.72**
15	L3 ×T5	1.80	2.83*	1.51	0.78**
16	L4 × T1	1.32	-1.95	1.11	0.59**
17	L4 × T2	7.33**	12.60**	6.16**	-0.45**
18	L4 ×T3	0.60	-2.21	0.51	1.01**
19	L4 ×T4	-3.05	-4.49**	-2.56	-1.44**
20	L4 ×T5	-6.04*	-3.96**	-5.21*	0.30
21	L5 × T1	16.74**	4.37**	14.03**	-1.08**
22	L5 × T2	-28.61**	-8.34**	-24.04**	-1.11**
23	L5 ×T3	-8.07**	0.19	-6.78**	0.34*
24	L5 ×T4	13.90**	3.92**	11.68**	0.90**
25	L5 ×T5	6.04*	-0.14	5.07*	0.95**
26	L6 × T1	4.11	-2.89*	3.46	2.32**
27	L6 × T2	0.34	1.31	0.28	0.63**
28	L6 ×T3	-14.06**	-2.99*	-11.81**	-1.26**
29	L6 ×T4	-5.70*	0.40	-4.79*	-0.37*
30	L6 ×T5	15.31**	4.18**	12.86**	-1.32**
	SEm ±	2.29	1.11	1.92	0.15
	C.D. (P=0.05)	4.68	2.26	3.93	0.31
	C.D. (P=0.01)	6.30	3.04	5.29	0.42

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