1818 Approaches of improving combining ability for enhancing performance of cotton hybrids.

S.S. Patil, S.A. Patil, V. Ramakrishna, H. B. Deepak and H.B. Mallikarjun

Agricultural Research Station, University of Agricultural Sciences Dharwad-580005, Karnataka, India

Correspondence Author: sspadvance@indiatimes.com

ABSTRACT

Hybrid breeding programs in cross pollinated crops implement population improvement programs aimed at improving combining ability. Improving combining ability in a primarily self pollinated crop such as cotton should work but the procedures need to be modified to suit the mating system of cotton. Two modified approaches of improving combining ability were tested in cotton. One method was practicing reciprocal selection for combining ability based on double cross performance. This method identified two diverse single crosses RAHH178 and RCH25, which were advanced to F_4 generation and subjected to reciprocal selection for combining ability against these two crosses used as reciprocal testers. Nearly one third of the derived F_1's revealed transgressive segregation for combining ability. These lines revealed better combining ability even with other additional testers used in the study. A second method is the triangular approach of improving combining ability against specific tester(s). The triangular approach was assessed by involving two different populations in the F_4 and F_5 generations and this approach also revealed improvement in combining ability. Based on the regression approach the heritability of combining ability (0.24) was determined.

Rapid increase in production and productivity of cotton in India is mainly attributed to overwhelming popularity of cotton hybrids (Anonymous, 2007). The initial success of yield increases in hybrid cotton parallels the progress seen in maize but the long term implementation of genetic concepts and systematic procedures in hybrid cotton breeding is far behind that of maize. Development of hybrid oriented heterotic populations and application of schemes for improving combining ability is an integral part of sustaining the productivity of hybrid maize and other cross pollinated crops (Hallauer and Miranda, 1981). However there are no published reports of releasing cotton hybrids derived from efforts (or schemes) based on improving combining ability.

This basic formula: $H_{F1} = \sum dy^2$ explains how performance (heterosis) of hybrid depends on genetic diversity and extent of dominance existing at different yield influencing loci (Falconer 1981). Success of exploiting heterosis depends on genetic diversity existing between the parents and magnitude of dominance existing at the yield influencing loci. To maximize heterosis, there is a need for utilizing breeding programs aimed at constantly creating variability and increasing genetic diversity between populations that can further be exploited through selection for combining ability between such diverse populations. Also heterosis can be enhanced by increasing dominant gene action. It is difficult to precisely detect and maniplulate the degree of dominant gene action while selecting, based on phenotypic measurements, for high heterosis. However it is possible to create and improve heterotic populations against a tester or reciprocally develop diverse populations which differ for the alleles at a large number of yield influencing loci (showing dominance). To create inbred lines or diverse populations (for the creation of commercially acceptable hybrids) one must practice selection for combining ability between the tester and the population or the two chosen diverse populations. Simply maximizing genetic distances in crosses does not assure the cotton breeder of high heterosis for yield. A repeated measurement of combining ability assures the breeder that heterosis for yield and genetic distance (with desirable alleles at yield influencing loci) is being improved. Once genetic distance is widened between the tester and the population or the two diverse populations it is possible to exploit the same through selection for combining ability.

Methods of Improving Combining Ability. Recurrent selection schemes for improving the combining ability for cross pollinated crops (Allard 1960) involve three basic steps of selfing, evaluation of combining ability, selecting the plants based on combining ability and intermating the selected plants. This marks completion of one cycle of recurrent selection. These procedures of recurrent selection need to be modified to suit the mating system of self pollinated crops.

There are limited efforts made to create variability for combing ability and exploit the same through selection for combining ability in self pollinated crops like cotton (Patil and Patil 2003), and even other cross pollinated crops like sorghum and redgram (Patil 1997). Since the magnitude of heterosis in cotton is high (up to 120%), there is a need of defining systematic approaches to: (a) developing genetically diverse base populations, (b) exploiting them through specific selection schemes of improving combining ability, and (c). maintaining them for future use. The advantage of cotton over maize is that it can be subjected to self pollination, selection and development of lines without any inbreeding depression. It is also easier to continuously compare the improvement of hybrids or testcrosses with the lines since inbreeding does not reduce yield performance in cotton. The first step hence would be selection of plants/lines for combining ability with chosen tester(s). In the second step the lines selected on the basis of testcross performance are crossed to create variability, followed by a third step of selfing and selection for combining ability (with the tester) in segregating generations. This defines one cycle of improving combining ability. If required, additional cycles of such selection for combining ability can be conducted.

Identification of base Population. In maize and other cross pollinated crops, base populations which are naturally subjected to random mating and having inherent variability can be identified or developed by utilizing desired genotypes. These populations can be subjected to different schemes of improving combining ability such recurrent selection for general combining ability or recurrent selection for specific combining ability by utilizing testers appropriate to the situation. Inherent variability of these two chosen populations can be exploited through selection practiced reciprocally by utilizing the opposite base populations as testers. When reciprocal selection for combining ability is practiced in this manner, it helps to increase the genetic distance further more between the populations. (Comstock et al., 1949).

In crops like cotton naturally randomly mating base populations are not available and thus suitable alternative methods have been suggested by Patil and Patil (2003). Their approaches involve identifying diverse genotypes based on their performance in crosses. Assessment of genetic distance can be made based on these crosses which can be single crosses of varietal lines, double crosses or predicted double cross performance. Depending on whether improvement of combining ability is sought on one side (triangular approach) or simultaneously on both sides (through reciprocal selection) different approaches were suggested by Patil and Patil (2003) and in this paper results obtained by following these approaches are presented and the implications for cotton hybrid breeding are discussed.

In the triangular approach, two varieties are chosen (based on test cross performance) to create a base F_1 population. The F_1 is advanced to segregating generations in which variability for combining ability with a tester can be evaluated and exploited. Using this approach a study was initiated at Dharwad and results obtained from this study are presented in this paper.

Reciprocal selection for combining ability. The procedure of reciprocal recurrent selection is a method of population improvement practiced by involving diverse base populations (Comstock et al., 1949). The naturally random mating base populations are utilized in cross pollinated crops. Since it is not possible to have such naturally random mating populations in cotton a modified scheme uses two diverse F_1's as the base populations for reciprocal selection for combining ability. This approach involves an elaborate study of a large set of crosses and one result is that a quadrangular set of crosses can be identified in which A and B parents combine well with C and D. This assessment can be done based on evaluation of single crosses and predicted double cross performance. Alternatively single cross F_1's can be used to make double crosses and based on the actual double cross performance diverse single crosses can be identified. This combination of four parents can thus be utilized for initiating reciprocal selection for combing ability. Since the segregating lines in different generations can be easily obtained in cotton without any inbreeding depression (unlike in maize), the process of assessing variability for combining ability can be initiated in any generation in the opposite populations. In studies carried out by us at Dharwad and Raichur, diverse single cross F_1's have been used as base populations and subjected to reciprocal selection for combining ability. (Patil and Patil, 2003, Somashekhar, 2006) In this presentation results obtained from an earlier study are presented in which actual double cross performance was utilized in identifying diverse single crosses.

MATERIALS AND METHODS

Reciprocal selection for combining ability. In the first phase seven potential hybrids NRHH-6, B-709, RCH-25, RAHH-168, AACH-1065, NRHH-32 and RAHH-178 were crossed in all possible combinations (half diallel method) to develop double crosses. Based on evaluation of double crosses along with commercial check, a pair of single crosses, RCH-25 and RAHH-178 was identified with potential as the most genetically diverse crosses due to the high heterosis observed. These two single crosses were advanced to F_4 generation. Twenty four random F_4 lines from each population were selected and utilized for testing variability for combining ability by crossing with reciprocal F_1 testers. Also these F_4 lines were crossed additionally to four diverse testers (RAH-101, RAH-104, RAH-216 and RAH-308) to assess the broader potential of these lines for use in cotton breeding. The crosses involving F_4 lines and testers are termed as derived F_1's (d F_1's). The schematic representation of creation of variability for combining ability through reciprocal selection is presented in Fig.1.

Triangular approach to improve combining ability. The experimental material of this study consists of three G. hirsutum varietal lines namely RAH-100 (A), RAH-20 (B) and RAH-10 (C), observed to be giving potential crosses with three diverse testers. Two cross, RAHH-92 (A x B) and RAHH-102 (A x C) were selected and advanced to F_4 generation to form two sets of derived populations. F_4 lines of these two populations were crossed to three testers (T1, T2 and T3) to assess the variability for combining ability among these lines in F_4 generation. This evaluation was repeated in the F_5 generation by using the same testers. The performance of derived F_1's involving F_4 and F_5 were compared and utilized to obtain regression value b_{F5-F4} for combining ability. Based on the method of regression approach, the heritability of combining ability was worked out (Smith and Kinman, 1965 and Salimath and Patil, 1990).

RESULTS AND DISCUSSION

Reciprocal selection for combining ability. The analysis of variance revealed significant differences among double crosses. Six crosses were on par with commercial check (Bunny). They also registered high variances and coefficients of variation. The cross RCH-25 x RAHH-178 recorded the highest seed cotton yield with a 10.86 % improvement over the commercial check (Table 1). This indicates that the genetic distance between RCH-25 and RAHH-178 was higher than any other crosses involved in this study. Hence these two hybrids were selected to develop two sets of populations, Population I (RAHH-178 derived lines) and population II (RCH-25 derived lines), in which reciprocal selection for combining ability was initiated.

The F_4 lines of the two populations were crossed to the opposite F_1's as testers to assess variability for combining ability. The performance of F_1's derived through reciprocal selection for combining ability is presented in Table-2. The derived F_1's of population I (RAHH-178 F_4 lines x RCH 25 F_1) showed high variability for combining ability. Six of the derived F_1's revealed significant superiority over the double cross base (RAHH-178 F_1 x RCH-25 F_1) indicating the variability generated in the F_4 lines of RAHH-178. Further, two F_1's were significantly superior over the commercial check (Bunny). The mean of top five derived F_1's (2072 kg ha^{-1}) was highly superior over double cross base and commercial Check. The corresponding lines178-15, 178-8, 178-10, 178-13 and 178-23 revealed transgressive segregation for ability to combine with the reciprocal tester RCH-25 F_1. The mean of top five showed a 24.03 % improvement over double cross base. Similarly in population-II (dF_1's of RCH-25 F_4 lines x 178-F_1), the d F_1's revealed significant improvement in combining ability. Four derived hybrids were significantly superior to the double cross base. Further, eight d F_1's were numerically superior to the commercial check. The mean of top five d F_1's (1929 kg ha^{-1}) was considerably superior to the commercial check as well as over the double cross base. The top five lines identified in population-II are RCH-4, RCH-7, RCH-15, RCH-23 and RCH-11. Top 5 crosses showed 18.41 % improvement over double cross base.

The combining ability of 178-F_4 lines was evaluated by crossing these lines with other four diverse testers viz. RAH-101, RAH-104, RAH-216 and RAH-308. Performance of lines gca values and d F_1's with four testers is given in Table 3. The combining ability analysis of 178-F_4 lines revealed significant differences among crosses as well as among the lines. Also there were significant differences in L x T interaction. The high combiner lines, five each from the two populations are identified as an out come of first cycle of reciprocal selection for combining ability. To assess the improvement in combining ability achieved through first cycle these five lines each from the opposite population can be crossed to obtain 25 (5x5) new crosses and compared with double cross based and commercial check.

In this study single crosses were involved in developing double crosses to identify diverse single cross base population to initiate reciprocal selection for combining ability. The extent of improvement in combining ability revealed by the lines and the superior performance of derived lines confirmed that the approach followed in this study namely selecting diverse single crosses based on actual performance of double crosses as been effective in improving combining ability.

Broader potential (breeding value) of the new lines for use in cotton breeding. One of the objectives of this experiment was to test the lines derived from opposite populations for their combining ability statues against other diverse tester as well this reflects the potential of the new lines for broader application in cotton breeding. The lines of RAHH-178 were crossed to four additional diverse testers and the performance of derived F_1's is presented in Table 3. Many crosses involving these lines were better than commercial check and have potential to develop hybrid cotton. RAHH-178-13 recorded highest gca value followed by RAHH-178-14, RAHH-178-16, RAHH-178-5, RAHH-178-17 and RAHH-178-20 indicating their potential use in cotton breeding. The good lines derived through reciprocal selection from RAHH-178 and RCH-25 or even the base populations should be used with other diverse testers to develop more potential hybrid cottons.

Triangular approach to improve combining ability. In a previous study on assessing potential of cotton varieties, three lines RAH-100 (A), RAH-20 (B) and RAH-10 (C) were identified with high combining ability with three testers. These lines were used in the development of two segregating populations obtain from RAHH-92 (A x B) and RAHH-102 (A x C). The F_4 and F_5 lines were assessed for ability to combine with three diverse testers. The derived F_1's revealed improvement in combining ability as evidenced by their superiority over commercial check Bunny (Table 4).

To assess the consistency of combining ability in two successive generations F_4 and F_5, regression of derived F_1's involving F_5 lines over those in F_4 were calculated. By following the method suggested by Smith and Kinman (1965) and Salimath and Patil (1990), heritability of combining ability was worked out in two populations. Moderate narrow sense heritability value of 24.44 % and 24.66 % were obtained in the two populations. This study reveals the improvement of cotton yield over commercial checks by following two approaches designed to improve combining ability. Either approach can be regularly followed as an integral component of hybrid breeding programs in cotton and other self pollinated crops.

Fig-1: Schematic representation of procedures followed

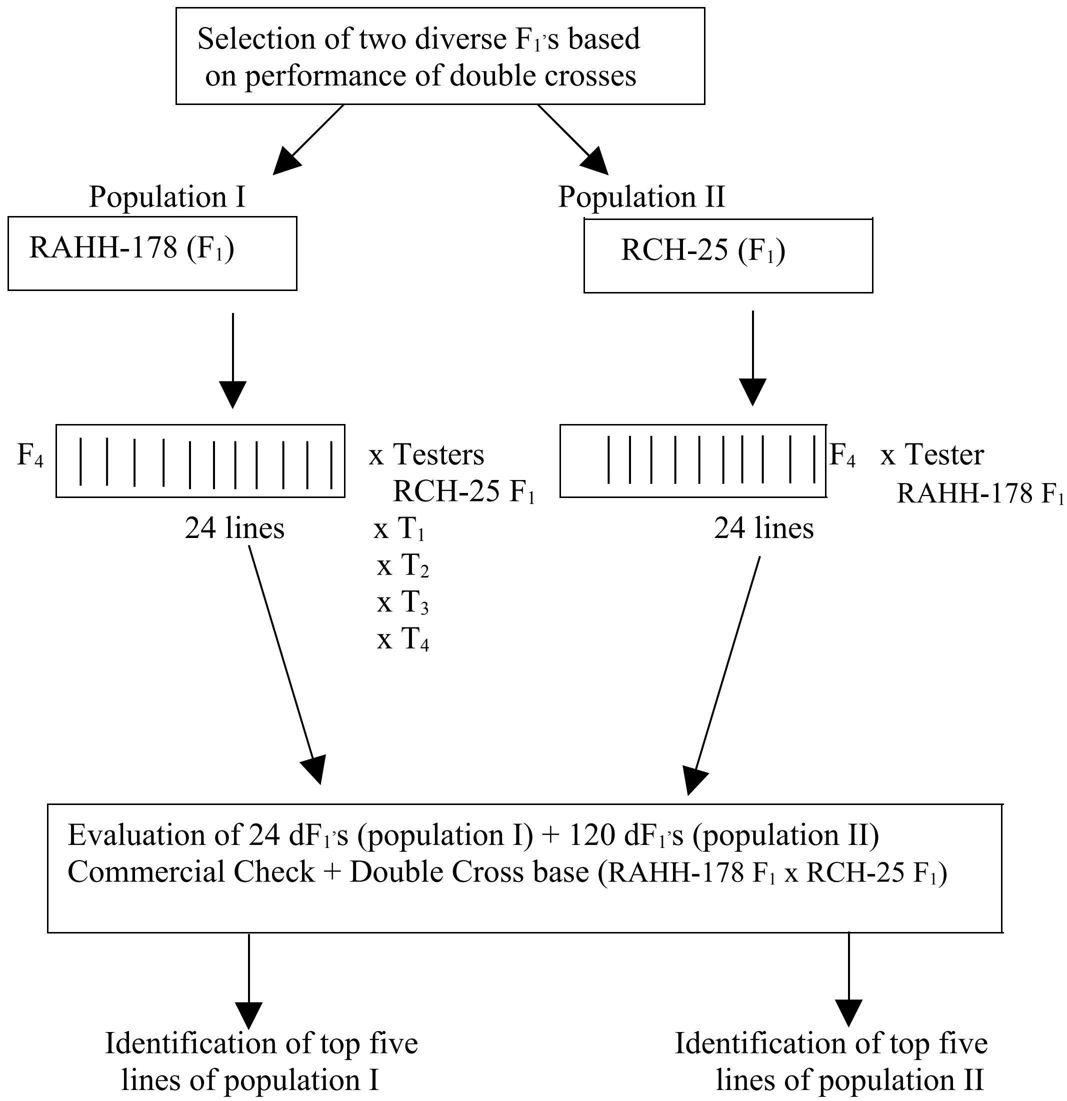

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Table 1: Performance of potential double crosses

Sl.No.	Entry	Seed cotton yield (kgha^{-1})	% improvement over Bunny (CC)	Variance	CV
1	RCH-25 x RAHH-178	2163	10.86	2416.3	32.4
2	B709 x RAHH-178	2016	4.37	1946.9	41.1
3	RCH-25 x RAHH-168	1968	2.01	2133.7	39.8
4	RCH-25 x NRHH-32	1964	1.86	1777.7	29.2
5	NRHH-6 x NRHH-32	1961	1.70	1888.0	37.2
6	RAHH-178 x RAHH-178	1897	-1.66	1655.1	26.1
7	Bunny (Commercial Check)	1928	0.00		
	cd at 5 %	*421.67*			

Table 2: Performance of F_1's derived through reciprocal selection for combining ability

Sl. No	Entry (RAHH-178 F_4 lines x RCH-25 F_1)	Seed cotton yield (kg/ha^{-1})	Per cent improvement over		Sl. No	Entry (RCH-25 F_4 lines x RAHH-178 F_1)	Seed cotton yield (kgha^{-1})	Per cent improvement over	
			C C	Double cross base				C C	Double cross base
1	178-15 x RCH-25 F1	2260	24.99	30.34	1	RCH-25-4 x RAHH178-F_1	1997	15.12	21.18
2	178-8 x RCH-25 F1	2211	23.35	28.82	2	RCH-25-7 x RAHH178-F_1	1948	12.97	19.18
3	178-10 x RCH-25 F1	1992	14.92	20.99	3	RCH-25-15 x RAHH178-F_1	1909	11.21	17.55
4	178-13 x RCH-25 F1	1973	14.09	20.22	4	RCH-25-23 x RAHH178-F_1	1907	11.14	17.48
5	178-23 x RCH-25 F1	1924	11.88	18.17	5	RCH-25-11 x RAHH178-F_1	1885	10.10	16.52
6	178-4 x RCH-25 F1	1907	11.10	17.45	6	RCH-25-22 x RAHH178-F_1	1856	8.66	15.18
7	178-2 x RCH-25 F1	1880	9.86	16.29	7	RCH-25-3 x RAHH178-F_1	1842	7.97	14.54
8	178-17 x RCH-25 F1	1869	9.30	15.78	8	RCH-25-17 x RAHH178-F_1	1809	6.28	12.97
9	178-9 x RCH-25 F1	1864	9.09	15.58	9	RCH-25-24 x RAHH178-F_1	1789	5.23	12.00
10	178-1 x RCH-25 F1	1839	7.82	14.40	10	RCH-25-1 x RAHH178-F_1	1749	3.10	10.02
11	178-16 x RCH-25 F1	1779	4.70	11.50	11	RCH-25-19 x RAHH178-F_1	1742	2.71	9.66
12	178-6 x RCH-25 F1	1751	3.18	10.10	12	RCH-25-20 x RAHH178-F_1	1712	1.00	8.07
13	178-21 x RCH-25 F1	1706	0.67	7.76	13	RCH-25-6 x RAHH178-F_1	1703	0.47	7.57
14	178-18 x RCH-25 F1	1668	-1.61	5.65	14	RCH-25-10 x RAHH178-F_1	1700	0.28	7.40
15	178-19 x RCH-25 F1	1640	-3.33	4.05	15	RCH-25-16 x RAHH178-F_1	1682	-0.77	6.43
16	178-12 x RCH-25 F1	1632	-3.89	3.53	16	RCH-25-8 x RAHH178-F_1	1545	-9.73	-1.89
17	178-14 x RCH-25 F1	1630	-4.01	3.41	17	RCH-25-13 x RAHH178-F_1	1542	-9.95	-2.10
18	178-3 x RCH-25 F1	1600	-5.94	1.62	18	RCH-25-12 x RAHH178-F_1	1506	-12.54	-4.50
19	178-22 x RCH-25 F1	1586	-6.85	0.78	19	RCH-25-14 x RAHH178-F_1	1485	-14.12	-5.97
20	178-20 x RCH-25 F1	1582	-7.16	0.49	20	RCH-25-5 x RAHH178-F_1	1478	-14.71	-6.52
21	178-7 x RCH-25 F1	1575	-7.63	0.05	21	RCH-25-9 x RAHH178-F_1	1477	-14.77	-6.58
22	178-24 x RCH-25 F1	1569	-8.05	-0.34	22	RCH-25-21 x RAHH178-F_1	1453	-16.63	-8.30
23	178-5 x RCH-25 F1	1408	-20.37	-11.78	23	RCH-25-2 x RAHH178-F_1	1438	-17.85	-9.44
24	178-11 x RCH-25 F1	1387	-22.21	-13.49	24	RCH-25-18 x RAHH178-F_1	1187	-42.78	-32.59
Overall Mean		1760	3.67	10.55	**Overall Mean**		1681	-0.84	6.36
Top Five Mean		2072	18.19	24.03	**Top Five Mean**		1929	12.14	18.41
Bunny (CC)		1695	0.00	7.14	**Bunny (CC)**		1695	0.00	7.14
Double cross base		1574	-7.69	0.00	**Double cross base**		1574	-7.69	0.00
cd at 5 %		*322.43*							

Table3: Combining ability status of the F_4 lines of RAHH-178 against additional diverse testers

Sl No.	Line	Seed cotton yield of crosses with RAH-101	RAH-104	RAH-216	RAH-308	Mean with 4 Testers	gca value
1	RAHH-178-13	2016	2236	2118	2050	2105	334.4 **
2	RAHH-178-14	1946	2000	1615	2089	1912	141.7 **
3	RAHH-178-16	1914	1925	1939	1871	1912	141.5 **
4	RAHH-178-5	1697	1887	2029	2026	1910	139.2 **
5	RAHH-178-17	1668	1677	2356	1898	1900	129.3 **
6	RAHH-178-20	2258	1916	1700	1698	1893	122.4 **
7	RAHH-178-11	2234	1917	1441	1877	1867	96.4 *
8	RAHH-178-12	1879	1852	1964	1745	1860	89.1 *
9	RAHH-178-1	1264	1725	2342	1998	1832	61.6
10	RAHH-178-2	1367	1783	2043	2110	1826	55.3
11	RAHH-178-6	1644	1761	1675	2095	1794	23.1
12	RAHH-178-8	1880	1824	1612	1831	1787	15.8
13	RAHH-178-22	1767	1815	1704	1802	1772	1.1
14	RAHH-178-7	2066	1822	1542	1649	1770	-0.9
15	RAHH-178-18	1991	1711	1353	1914	1742	-28.6
16	RAHH-178-4	1403	1931	1662	1877	1718	-52.5
17	RAHH-178-19	2104	1313	1863	1478	1689	-81.3 *
18	RAHH-178-9	1293	1888	1675	1901	1689	-81.3 *
19	RAHH-178-21	1727	1627	1715	1586	1664	-107.1 **
20	RAHH-178-15	1571	1658	1215	2193	1659	-111.4 **
21	RAHH-178-23	1453	1561	1610	1764	1597	-173.6 **
22	RAHH-178-10	1694	1660	1478	1510	1585	-185.3 **
23	RAHH-178-3	1090	1776	1719	1573	1540	-231.2 **
24	RAHH-178-24	1378	1268	1800	1447	1473	-297.6 **
	Bunny (CC)	1695					
	cd at 5 % = 321					cd at 5% = 62	

Table 4: Mean performance (seed cotton yield in Kg ha^{-1}) of derived F_1's and heritability of combining ability

Population-I (RAHH-92)

Sl. No	Entry	Derived F_1 from line in F_4	Derived F_1 from line in F_5
1	R-2(92) x T1	4173	2546
2	R-4(92) x T1	4750	3993
3	R-5(92) x T1	3242	2361
4	R-6(92) x T1	4035	2336
5	R-7(92) x T1	3583	2315
6	R-8(92) x T1	2779	2014
7	R-13(92) x T1	3664	2509
8	R-16(92) x T1	4252	2147
9	R-17(92) x T1	3588	2483
10	R-18(92) x T1	3639	2076
11	R-20(92) x T1	3481	2241
12	R-21(92) x T1	3572	2068
13	R-2(92) x T2	3545	2546
14	R-4(92) x T2	4301	3935
15	R-5(92) x T2	3969	3226
16	R-6(92) x T2	4193	2851
17	R-7(92) x T2	3752	3257
18	R-8(92) x T2	3514	2035
19	R-13(92) x T2	3619	2951
20	R-16(92) x T2	3415	2649
21	R-17(92) x T2	3822	3183
22	R-18(92) x T2	3027	2558
23	R-20(92) x T2	3717	3212
24	R-21(92) x T2	4064	3067
25	R-2(92) x T3	3808	2989
26	R-4(92) x T3	4467	3825
27	R-5(92) x T3	3445	2220
28	R-6(92) x T3	3637	3278
29	R-7(92) x T3	3893	2245
30	R-8(92) x T3	3663	2023
31	R-13(92) x T3	4278	2951
32	R-16(92) x T3	4146	2003
33	R-17(92) x T3	4359	2172
34	R-18(92) x T3	4273	2546
35	R-20(92) x T3	3714	3183
36	R-21(92) x T3	3459	3009
Bunny (CC)		3186	2775
cd at 5 %		269	526
Regression value		**$b_{F5,F4}$= 0.4582**	
Heritability of combining ability (%)		**h^2 = 24.44**	

Population-II (RAHH-102)

Sl. No	Entry	Derived F_1 from line in F_4	Derived F_1 from line in F_5
1	R-1(102) x T1	3971	3500
2	R-2(102) x T1	2483	1830
3	R-3(102) x T1	3573	2400
4	R-5(102) x T1	3224	2030
5	R-7(102) x T1	3594	1700
6	R-11(102) x T1	3611	1950
7	R-12(102) x T1	3346	2150
8	R-13(102) x T1	3381	2880
9	R-14(102) x T1	3247	2350
10	R-18(102) x T1	3141	1725
11	R-19(102) x T1	4180	3500
12	R-23(102) x T1	3620	2450
13	R-1(102) x T2	3444	2475
14	R-2(102) x T2	3478	2000
15	R-3(102) x T2	3265	2550
16	R-5(102) x T2	3313	2500
17	R-7(102) x T2	3686	3175
18	R-11(102) x T2	3055	2350
19	R-12(102) x T2	3042	2755
20	R-13(102) x T2	3810	2650
21	R-14(102) x T2	3916	2434
22	R-18(102) x T2	3475	2154
23	R-19(102) x T2	3907	3600
24	R-23(102) x T2	3323	2560
25	R-1(102) x T3	3799	2700
26	R-2(102) x T3	3486	1700
27	R-3(102) x T3	3877	2250
28	R-5(102) x T3	3599	1835
29	R-7(102) x T3	3634	3048
30	R-11(102) x T3	3758	2500
31	R-12(102) x T3	4282	2205
32	R-13(102) x T3	3903	2375
33	R-14(102) x T3	3025	1967
34	R-18(102) x T3	3367	2018
35	R-19(102) x T3	4233	3230
36	R-23(102) x T3	3943	1850
Bunny (CC)		3186	2775
cd at 5 %		242	352
Regression value		**$b_{F5,F4}$= 0.4436**	
Heritability of combining ability (%)		**h^2 = 24.66**	