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Full Length Research Paper

Combining Ability for Yield and Morphological Characters in Southwestern Ethiopian Origin Coffee (C*offea Arabica* L.) Hybrids

Ashenafi Ayano*, Sentayehu Alamirew and Abush Tesfaye

Jima Agricultural Research Center, P. O. Box 192, Jimma, Ethiopia.

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Increasing coffee productivity is one of the highest national priorities of the rural development policy of Ethiopia; and thus, the choice of promising genotypes from diverse genetic base and subsequent utilization of hybrids is one of strategies of improving productivity. A half diallel analysis involving five parents, ten F1 hybrids of Coffea arabica and one check hybrid was studied for several quantitative traits to generate information on combining ability. The genotypes were evaluated in a randomized complete block design (RCBD) with three replications at Melko, Metu and Tepi research centers. Both General Combining Ability (GCA) and Specific Combining Ability (SCA) mean squares were highly significant for yield indicating both additive and non-additive gene actions are important for the inheritance of this economic trait; percentage relative contribution of SCA over GCA was high indicates the predominance of non-additive gene action. Both the additive and non-additive gene actions were involved in the control of the characters studied for fruit length, fruit width, fruit thickness, bean length, bean width, bean thickness and 100-bean weight similar to aforementioned trait. Parental line P4 found to be the best combiner for stem girth, length of first primary branch and internode length showing significant and positive GCA effects for these traits; this parent may contribute favorably for additive genes to its progenies for the synthesis of vigorous hybrids. Parental lines P4 and P5 were found good general combiners for yield showing highly significant GCA effects in across locations GCA effects. These parental lines may have good prospect for the inclusion in the breeding program for yield improvement in synthesis of new high yielding hybrid varieties. Nearly 90% of the crosses showed positive SCA effects for yield out of which five crosses: P3XP5, P1XP5, P2XP5, P2XP4 and P3XP4 showed positive and significant SCA values for yield indicating that these crosses were good combinations.

Key words: Combining ability, gene action, GCA, SCA.

INTRODUCTION

Coffee (*Coffea arabica* L.) is the most important crop, and one of the most enjoyed beverages throughout the world. As a result several hundred millions of people in the world drink coffee. It is one of the leading commodities in the international trade, and currently generates revenue of about US$ 14 billion annually for the producing countries. More than 80 countries, including Ethiopia cultivate coffee, which is exported for more than 165 countries worldwide providing a livelihood for 100 million people around the world (ICO, 2001).

In Ethiopia, coffee is one of the major and leading export items. Ethiopia is currently producing an estimated

*Corresponding author E-mail: ashenafiayanof@yahoo.com.

9.8 million bags that would rank the country as the third largest coffee producer in the world after Brazil and Vietnam (ICO, 2012). Apparently coffee is at the center of Ethiopian culture and economy, contributing to 35% of the country's foreign currency earnings. It accounts for 10% of the gross domestic product, and supports the livelihoods of around 25% of the population of Ethiopia (representing around 20 million people) in one way or another (Gole and Senebeta, 2008).

Ethiopia is both the center of origin and diversification of *C. arabica L.* (Fernie, 1966; Bayetta, 2001). The crop spreads widely from the river bank of Gambella plain (550 m.a.s.l) stretching to the central and Eastern highlands of the country, where it exists in the great range of types within species (Bayetta, 1986). Due to the fact that Ethiopia is the center of origin and diversity, there is enormous genetic variability that offers great potential for improvement of the crop.

Despite its great importance, the average national productivity is very low (500-600 kg ha^{-}) as compared to the average productivity of the world and other major coffee producing countries (Abera, 2007; Workafes and Kassu, 2000). This is attributed to shortage of improved varieties, diseases, insect pests, drought, and poor management (Admasu and Klaus, 2007; Abera, 2007). Among many reasons that limited coffee productivity improvement, shortage of pure line and hybrid varieties is the major one (Bayetta, 2001; Mesfin, 1988; Babur, 2009).

Intensive efforts have been made by Jima Agricultural Research Center (JARC) to boast coffee productivity in the country. Over the last 33 years (1977-2010), thirty seven coffee varieties out of which thirty four pure lines and three hybrids (Ababuna, Gawe and MelkoCH2) were released for the various major coffee growing agro-ecologies of the country (Bayetta et al., 1998; MOA, 2010). On the other hand, there is immense genetic potential of coffee in the country which gives chance for development of improved varieties. In spite of having such large genetic variability in Ethiopia, research work on genetics and breeding of coffee is not adequate.

Currently, the analysis of combining ability has become an important and integral part of all breeding programs. It helps to identify the best combining parent, to know the type of gene action and to choose appropriate breeding methods (Sprague and Tatum, 1942; Mathur and Mathur, 1983). Indeed diallel analysis for combining ability suggested by Griffing (1956) is one of the powerful tools to provide the above information. In arabica coffee, information in this regard is very scarce. Combining ability analysis provides information on the relative importance of additive and non-additive gene effects involved in the expression of the quantitative traits.
Cognizant to this, the present study was conducted to determine the types of gene action involved in the inheritance of various yield and agronomic traits, to estimate general combining ability (GCA) of selected parents, and specific combining ability (SCA) of hybrids.

MATERIALS AND METHODS

The study was conducted at Jima Agricultural Research Center (JARC), Metu Agricultural Research Sub-Center and Tepi National Spice Research Center (TNSRC). Jima is located on latitude 7^{0}40'N longitude 36^{0}47'E , altitude of 1753 masl, minimum and maximum temperature of the area is 11.6 and 26.3 ^{o}C respectively with annual rainfall of 1572 mm/annum. Metu is located on latitude 8^{0}19'N longitude 35^{0}35'E , altitude of 1580 masl, minimum and maximum temperature of the area is 12.7 and 28.9 ^{o}C respectively with annual rainfall of 1829 mm/annum. Tepi is located on latitude 7^{0}11'N longitude 35^{0}25'E , altitude of 1220 masl, minimum and maximum temperature of the area is 15.7 and 29.9 ^{o}C respectively with annual rainfall of 1594 mm/annum. The study locations are among major coffee producing areas in south western Ethiopia.

Five pure lines that were selected from the national collection trials representing the different agro ecologies of southwestern Ethiopia and different canopy classes were used as parents in half diallel crosses. The parental lines included were 75227(P1), 744(P2), 74148(P3), F-34(P4) and 206/71(P5) among which P1, P2 and P4 are open canopy classes P3 and P5are compact in their canopy classes. The released hybrid coffee Ababuna was used as a check.

Growth measurement and assessment

Four years average yield was used for analysis and growth measurement was recorded at the second bearing stages of coffee and based on recommendation by IPGRI (1996) as follows:

- Leaf characteristics: Leaf length (cm), Leaf width (cm), Leaf area (cm^2), Leaf petiole length (cm)
- Stem characteristics: Total plant height (cm), Plant height up to first primary branch (cm), Inter-node length (cm), Stem diameter (girth) (cm)
- Branch characteristics: Length of the 1st single primary branch (cm),
- Fruit characteristics. Fruit length (mm), Fruit width (mm), Fruit thickness (mm)
- Seed/bean characteristics: Bean length (mm), Bean width (mm), Bean thickness (mm), 100-bean weight at 11% moisture (gm)

Table 1. Mean squares due to general combining ability (GCA) and specific combining ability (SCA) for yield, fruit & bean characters in coffee diallel crosses across location.

Source of variation	Df	Yield	Fruit length	Fruit width	Fruit thickness	Bean length	Bean width	Bean thickness	100- bean weight
		Traits							
GCA	4	106.251***	12.384***	4.775***	7.216***	8.098***	0.322***	0.345***	47.105***
SCA	10	99.275***	0.563***	0.142	0.311**	0.553***	0.064**	0.068***	9.623***
GCA X E	8	6.569	0.662***	0.344**	0.263*	0.973***	0.022	0.046**	7.771***
SCA X E	20	9.072	0.277	0.13	0.139	0.176*	0.041*	0.027*	1.724*
Error	84	6.354	0.171	0.106	0.107	0.087	0.022	0.017	0.959
Relative contribution of GCA		30	89.8	93.1	90.3	85.4	66.9	67	66.2
Relative contribution of SCA		70	10.2	6.9	9.7	14.6	33.1	33	33.8

* = significant at P<0.05, **= significant at P<0.01, and ***= significant at 0.001.

Table 2. Mean squares due to general combining ability (GCA) and specific combining ability (SCA) for growth characters in coffee diallel crosses across location.

Source of variation	Df	Plant height	Height up to 1st prim branch	Stem Girth	Length of first primary branch	Inter node length
		Traits				
GCA	4	649.190***	115.175***	3.31***	2165.060***	2.896***
SCA	10	1864.76***	21.732***	0.98***	546.250***	1.056***
GCA X E	8	162.980	8.742	0.140*	137.620**	0.099
SCA X E	20	175.910	6.781	0.061	58.850	0.095
Error	84	111.342	5.782	0.0598	50.242	0.0968
Relative contribution of GCA		12.2	67.9	57.5	61.3	52.3
Relative contribution of SCA		87.8	32.1	42.5	38.7	47.7

* = significant at P<0.05, **= significant at P<0.01, and ***= significant at 0.001

- Yield (kg/ha): fresh cherries were harvested and weighed in grams per tree basis and converted to kg/ha.

RESULTS AND DISCUSSION

Combining ability analysis across locations

GCA and SCA mean squares of yield, fruit and bean characters are presented in (Table 1). Both GCA and SCA mean squares were highly significant for yield indicating both additive and non-additive gene actions are important for this trait. The relative contribution of SCA was as high as 70% for yield. The predominance of SCA sum of squares to GCA sum of squares indicated the relative importance of non-additive gene action for this important trait; similar to the finding of Bayeta (1997). The current result is also in support of work done by Wassu et al. (2008) indicated the importance of additive and non-additive gene actions; non-additive being dominant. This implies that exploiting hybrids by using F1 for such cases is the best approach.

For fruit length, fruit width, fruit thickness, bean length, bean width, bean thickness and 100-bean weight similar to aforementioned traits additive and non-additive gene actions were involved in the control of the characters studied. For the fruit and bean traits relative contribution of GCA was predominant suggesting additive gene action contributed more for these traits. But for majority of fruit and bean characters GCA x E (general combining ability x environment) and SCA x E (specific combining ability x environment) for all bean characters was significant indicating inconsistent results across locations and better to depend on GCA & SCA effects of each locations.

Growth characters

Results from the pooled analysis of combining ability over the three locations are shown in (Table 2). The results

Table 3. Mean squares due to general combining ability (GCA) and specific combining ability (SCA) for leaf characters in coffee diallel crosses across location.

Source of variation	Df	Traits			
		Leaf length	Leaf width	Leaf area	Leaf petiol length
GCA	4	23.027***	12.645***	3781.560***	0.131***
SCA	10	2.455***	0.609***	266.980***	0.013*
GCA X E	8	1.161*	0.218	138.130*	0.004
SCA X E	20	0.537	0.191	81.600	0.007
Error	84	0.527	0.138	53.905	0.006
Relative contribution of GCA		79.0	89.2	85.0	79.8
Relative contribution of SCA		21.0	10.8	15.0	20.2

* = significant at P<0.05 and ***= significant at 0.001.

Table 4. Estimates of general combining ability (GCA) effects of parental lines for yield, fruit and bean characters in coffee diallel crosses across location

Parents	GCA effects of each Traits							
	Yield	Fruit length	Fruit width	Fruit thickness	Bean length	Bean width	Bean thickness	100- bean weight
P1	-0.794**	0.0503	0.154**	0.086	-0.025	-0.0133	-0.0012	0.2124
P2	0.2324	0.7505***	0.404***	0.516***	0.590***	0.125***	0.118***	1.355***
P3	-1.936***	-0.519***	-0.366***	-0.337***	-0.466***	-0.072***	-0.047**	-1.163***
P4	1.235***	-0.0866	-0.0906	0.0797	-0.0994	-0.0438*	0.0191	-0.0698
P5	1.2635***	-0.1954	-0.1012	-0.345	-0.0005	0.0042	-0.0889	-0.3342
SE (gi)	0.28882	0.09171	0.06611	0.05778	0.1111	0.01661	0.024160	0.31413
SE (gi-gj)	0.45667	0.14500	0.10453	0.09136	0.1757	0.02626	0.038200	0.49668

= significant at P<0.01, and *= significant at 0.001, SE (gi)= standard error of general combining ability effects, SE (gi-gj)= standard error of the difference of general combining ability effects.

revealed significant variances of GCA and SCA for all growth characters studied. The result of this study is in line with the study report of Mesfin (1982) who reported importance of additive and non-additive gene actions for five growth characters (stem girth, number of node, number of primary branch, length of first primary branch and number of secondary branch) he studied in F1 crosses of indigenous coffee. Similarly Bayetta (1991) in his nursery evaluation of indigenous coffee crosses reported the importance of both additive and non-additive gene action in seven shoot characters (stem girth, plant height, number of node, internode length, shoot fresh weight, shoot dry weight, shoot volume). The interaction of GCA/Environment was significant for stem girth & length of first primary branch only.

The relative contribution of SCA was higher than GCA for plant height indicating that non additive gene actions are predominantly important for the inheritance of this trait. On the other hand height up to first primary branch, stem girth, length of first primary branch and inter node length exhibited higher variance due to GCA than due to SCA suggesting additive gene actions has role in controlling these traits.

Leaf characters

The mean square values of GCA and SCA for four leaf characters depicted in Table 3. Both GCA and SCA mean squares were significant for leaf length, leaf width, leaf area and leaf petiole length indicating contribution of additive and non-additive gene actions. This result is support by Bayetta (1991) in which he reported the contribution of additive and non-additive gene actions for six leaf characters in his nursery evaluation of indigenous coffee crosses. In the current study the relative contribution of GCA was higher for all leaf characters indicating additive gene action is predominantly important. This implies that selection from segregating generation would be the best approach to improve these characters.

General combining ability effects across location analysis

The estimates of GCA effects of parental lines & crosses for different characters pooled over three environments are given in Tables 4 to 6.

General combining ability effects of parents for yield, fruit and bean characters are given in Table 4. In across location GCA effects for yield (kg ha^{-}) clean coffee parental lines P4 and P5 revealed highly significant GCA effects. This indicates that these two parents were found

Table 5. Estimates of General combining ability (GCA) effects of parental lines for growth characters in coffee diallel crosses across location.

Parents	GCA effects of each Traits				
	Plant height	Height up to 1st prim branch	Stem Girth	Length of first primary branch	Inter node length
P1	0.1067	2.0089***	-0.0014	0.8444	0.1393*
P2	-2.0711	0.5867	-0.0475	2.7778**	0.0707
P3	-4.5156	-1.880***	-0.363***	-10.5556***	-0.3140***
P4	3.7289	-0.4578	0.2971***	5.7111***	0.2489***
P5	2.7511	-0.2578	0.1148	1.2223	-0.1449
SE (gi)	1.43861	0.33317	0.04216	1.32196	0.03552
SE (gi-gj)	2.27465	0.52680	0.06666	2.09021	0.05616

* = significant at P<0.05, **= significant at P<0.01, and ***= significant at 0.001, SE (gi)= standard error of general combining ability effects, SE (gi-gj)= standard error of the difference of general combining ability effects.

to be good general combiners for this important economic trait. These parental lines may have good prospect for the inclusion in the breeding program for yield improvement in development of new high yielding hybrid varieties.

For all fruit and bean characters parental line P2 showed consistently positive and significant GCA effects indicating the good combining ability of this parent. This is probably emanated from the bold fruit and bean nature of this parental line. This result give directions for the improvement of fruit and bean characters parental line P2 found to be good general combiner. In contrary to P2 parent P3 showed significant negative GCA effects for all fruit and bean size characters, indicating the fruit and bean size reducing character of P3. This result may be emanated from its small fruit and bean nature of this parental line.

Growth characters

General combining effects of parents for growth parameters are given in Table 5. Parents P1, P4 & P5 showed positive & non-significant GCA effects for plant height. These effects, however, were negative and non-significant for P2 and P3. In case of height up to first primary branch positive & significant GCA effects were found for parent P1, while negative and significant GCA effect was found in P3. The rest of the parents had non-significant GCA effects. Only parent P4 showed positive and significant GCA effects for stem girth. P3 found negative and significant GCA effects. While P5 showed positive GCA but non-significant result observed. The rest two parents showed negative and non-significant GCA effects for stem girth. Parental lines P2 and P4 exhibited positive and significant GCA effects for length of first primary branch. On the other hand, parental line P3 showed negative and significant GCA effects for length of first primary branch. The rest two parents showed positive and non-significant GCA effects for this trait. Parents P1 and P4 showed positive and significant GCA effects for internode length. While negative and significant GCA effect found for P3. Parent P2 showed positive and non-significant GCA effect. Negative and non-significant GCA effect for parent P5 observed for internode length. GCA effects of parental lines were entirely different for many of growth characters. Parental line P1 showed positive and significant GCA effects only for height up to first primary branch indicating good combiner for this trait. While parental line P2 were only showed significant GCA effect for length of first primary branch indicating its good combining ability of this parent for this trait. On the other hand P3 showed negative GCA effect for all growth characteristics evaluated. This indicates its poor combining ability for growth characters. This probably emanates from very compact nature of this parent. This parent may be useful in the development of hybrid variety having short and compact stature. Parental line P4 showed good combining ability for three growth characters (stem girth, length of first primary branch and internode length) showing significant and positive GCA effects for these traits. In general showing significant and positive GCA effects for growth characters, this parent may contribute favorable alleles for the development of vigorous hybrids.

Leaf characters

General combining ability effects of parents for leaf characters are given in Table 6. Parental lines P2 and P4 consistently showed positive and highly significant GCA effects for all leaf characters studied, indicating the good combining ability of these two parents for improvement of

Table 6. Estimates of General combining ability (GCA) effects of parental lines for leaf characters in coffee diallel cross across location.

Parents	GCA effects of each Traits			
	Leaf length	Leaf width	Leaf area	Leaf petiol length
P1	0.1653	0.0618	1.2756	-0.0049
P2	0.6142***	0.5529***	9.0499***	0.0551***
P3	- 0.6058***	-0.5027***	-8.2750***	-0.0760***
P4	0.5653***	0.3507***	6.5512***	0.0040
P5	-0.739	-0.4627	-8.6017	0.0218
SE (gi)	0.12143	0.05266	1.32439	0.007237
SE (gi-gj)	0.19200	0.08326	2.09404	0.011443

***= significant at 0.001, SE (gi)= standard error of general combining ability effects, SE (gi-gj)= standard error of the difference of general combining ability effects.

Table 7. Estimates of specific combining ability (SCA) effects of F1 Hybrids of coffee for Yield, Fruit & Bean characters across location.

Crosses	SCA effects of each Traits							
	Yield	Fruit length	Fruit width	Fruit thickness	Bean length	Bean width	Bean thickness	100- bean weight
P1XP2	0.1231	0.4317	0.0868	0.1348	0.2047	-0.0422	-0.0528	0.0542
P1XP3	-0.0413	0.1200	-0.0407	0.0116	-0.1393	0.0013	0.0529	0.0609
P1XP4	0.6209	-0.0356	-0.0252	0.0714	0.0756	-0.0469	0.0009	0.3453
P1XP5	6.6644***	-0.0689	-0.1747	0.2100	0.3011	0.0202	0.1611*	2.1689**
P2XP3	0.1653	-0.3136	-0.1874	-0.1786	-0.3391*	-0.0624	-0.0344	-0.6702
P2XP4	3.1942***	-0.1758	0.1193	0.1823*	-0.0797	0.0749	0.0247	0.6031
P2XP5	4.7911***	-0.0653	-0.1880	-0.0653	-0.1447	0.2240**	0.0051	1.4556*
P3XP4	2.2298**	0.2791	0.0273	0.1470	0.2796*	0.0696	0.0616	1.2209**
P3XP5	6.8889***	0.2631	0.2462	0.3456	0.4627*	0.0471	0.1727*	1.2489
P4XP5	1.9711	0.2920	0.1418	0.3413	0.0822	-0.0136	0.1047	0.9089
SE(S_{ij})$\pm$	0.87637	0.1531	0.10491	0.10866	0.12194	0.058725	0.047476	0.38202
SE(S_{ij}-S_{ik})$\pm$	1.31456	0.2296	0.15736	0.16299	0.18292	0.088087	0.071214	0.57303
SE(S_{ij}-S_{kl})$\pm$	1.20002	0.2097	0.14365	0.14879	0.16698	0.080412	0.065010	0.52311

* = significant at P<0.05, **= significant at P<0.01, and ***= significant at 0.001, S.E (Sij)± =standard error of specific combining ability effect; S.E (Sij-Sik)± =standard error of the difference of specific combining ability having one parent in common and S.E (Sij-Skl) ± =standard error of the difference of specific combining ability effects of the crosses having no parents in common

leaf size in synthesis of new hybrid. These two parents do have relatively bigger leaf size than the rest of parental lines included in the study. This nature might give the chance to show significant combining ability of these two parents.

Specific combining ability (SCA) effects across locations

The estimates of SCA effects of crosses for different growth, leaf, yield, fruit, bean and quality characters for across location given in Tables 7-9. The results of different characters are presented below.

Specific combining ability (SCA) effects of crosses for yield, fruit and bean characters are given in Table 7. Out of the total 90% of the crosses showed positive SCA effects for yield of which five crosses namely; (P3xP5, P1xP5, P2xP5, P2xP4 and P3xP4) showed positive and significant SCA effects indicating that these crosses were good combinations for yield. Very good association of percentage heterosis and SCA for yield observed in that nine crosses out of ten showed positive heterosis for yield. Crosses with higher values of SCA effects also showed higher value of mean yield performance, indicating good correspondence between SCA effects and mean yield. Hence such cross combinations could effectively be exploited in hybrid coffee breeding

Table 8. Estimates of specific combining ability (SCA) effects of F1 Hybrids of coffee for growth characters across location.

Crosses	SCA effects of each Traits				
	Plant height	Height up to 1st prim branch	Stem Girth	Length of first primary branch	Inter node length
P1XP2	5.2489	-0.5644	-0.0743	-1.8889	-0.0073
P1XP3	5.2489	0.4578	0.2259*	4.0000	-0.0204
P1XP4	7.8933	2.8133**	0.2263*	2.2889	0.4089**
P1XP5	22.8000*	1.4889	0.5606***	10.4000*	0.6331**
P2XP3	1.6489	0.1022	0.0005	1.5111	-0.0073
P2XP4	11.6267*	0.1244	0.2497**	6.0222*	0.2242
P2XP5	20.4000*	-0.2667	0.5178**	14.2222***	0.1767
P3XP4	9.1822	-2.1867*	0.0511	1.6889	0.2811*
P3XP5	29.7333**	1.3778	0.5965***	12.2222**	0.3209
P4XP5	14.0889	2.0222	0.4657**	14.7111***	0.5693*
$SE(S_{ij})\pm$	3.85905	0.75769	0.07200	2.23201	0.08953
$SE(S_{ij}-S_{ik})\pm$	5.78857	1.13653	0.10799	3.34801	0.13430
$SE(S_{ij}-S_{kl})\pm$	5.28422	1.03751	0.09858	3.05630	0.12260

* = significant at P<0.05, **= significant at P<0.01, and ***= significant at 0.001, S.E (Sij)± =standard error of specific combining ability effect; S.E (Sij-Sik)± =standard error of the difference of specific combining ability having one parent in common and S.E (Sij-Skl) ± =standard error of the difference of specific combining ability effects of the crosses having no parents in common.

program. On the other hand, only cross combinations P1xP3 expressed negative SCA effects for yield which is undesirable as these cross showed a tendency to reduce yield performance.

For hundred bean weight, only three crosses P1xP5, P3xP4 and P2xP5 were best combinations as they showed positive and significant SCA effects for this trait.

Growth characters

Specific combining ability (SCA) effects of crosses for growth parameters are given in Table 8. Four crosses P1xP5, P2xP4, P2xP5 and P3xP5 showed positive and significant SCA effects for plant height. This result indicates possibility of invigoration of height. The rest of the crosses had non-significant SCA effects. On the other hand none of the crosses under study showed negative SCA effects which may give information that the difficulties to obtain combination for shorter hybrid plant stature.

Only cross P1 XP4 showed significant SCA effects for the trait height up to first primary branch. Cross P3XP4 showed negative and significant SCA effect and cross P2XP5 showed negative and non-significant. All the rest showed positive and non-significant SCA effects for this trait.

Out of ten cross combinations in the study seven of them P1XP3, P1XP4, P1XP5, P2XP4, P2XP5, P3XP5 andP4XP5 gave positive and significant SCA effects for stem girth indicating the high possible chance of acquiring good combination for this trait. However, cross P1XP2 showed negative and non-significant SCA effects. The rest of crosses showed positive and non-significant effect for this trait.

For the trait length of first primary branch five crosses P1XP5, P2XP4, P2XP5, P3XP5 & P4XP5 revealed positive and significant SCA effects. While, cross P1XP2 showed negative and non-significant effects. Crosses P1XP4, P1XP5, P3XP4 & P4XP5 revealed positive and significant SCA effects for internode length. However, crosses P1XP2 & P1XP3 showed negative effects. All the rest crosses showed positive and non-significant effects for this trait.

Leaf characters

Specific combining ability (SCA) effects of crosses for leaf characters are given in Table 9. Very few crosses showed positive significant SCA effects for most of leaf characters indicating good association of percentage heterosis and SCA in that most of the crosses didn't

Table 9. Estimates of specific combining ability (SCA) effects of F1 Hybrids of coffee for leaf characters across location.

Crosses	SCA effects of each Traits			
	Leaf length	Leaf width	Leaf area	Leaf petiol length
P1XP2	-0.1653	-0.1107	-1.9763	-0.0084
P1XP3	0.3547	0.0893	2.1764	0.0116
P1XP4	0.4169	0.3360*	6.4001*	0.0538*
P1XP5	0.9600	0.4578	9.4040	0.0178
P2XP3	0.0391	0.1538	1.1188	-0.0373
P2XP4	0.5124	0.1227	4.8592	0.0160
P2XP5	0.4867	0.1489	3.3104	0.0778
P3XP4	0.2213	0.1004	1.6908	0.0249
P3XP5	0.4889	0.1933	3.8600	0.0133
P4XP5	0.9933	0.5244*	11.0718*	0.0156
$SE(S_{ij})\pm$	0.21319	0.12730	2.62835	0.024019
$SE(S_{ij}-S_{ik})\pm$	0.31979	0.19095	3.94253	0.036029
$SE(S_{ij}-S_{kl})\pm$	0.29192	0.17431	3.59902	0.032889

* = significant at P<0.05, S.E (Sij)± =standard error of specific combining ability effect; S.E (Sij-Sik)± =standard error of the difference of specific combining ability having one parent in common and S.E (Sij-Skl) ± =standard error of the difference of specific combining ability effects of the crosses having no parents in common.

showed significant heterosis and SCA. Only P1xP4 and P4xP5 showed positive and significant SCA effects for leaf width and leaf area.

SUMMARY AND CONCLUSIONS

The present experiment was conducted with objectives of: estimate GCA of selected parents, SCA of hybrids and to identify single cross *Coffee arabica* hybrids for yield and yield components.

The experimental material consisting of five indigenous coffee (*Coffea arabica* L.) lines namely P1(75227), P2(744), P3(74148), P4(F34) and P5(206/71) which were selected from south western coffee growing areas of the country based on yield, quality, disease resistance and different morphological characteristics. The lines were crossed in half diallel fashion as per Griffing (1956) model I method 2 to produce 10 F1 hybrids. The F1's, parental lines and check hybrid Ababuna planted at Melko, Metu and Tepi research centers in RCB design in three replications were used for study. The data were recorded for yield, five growth characteristics, four leaf characters, and seven fruit and bean characters.

The analysis of variance due to GCA and SCA was significant for yield, growth parameters, leaf, fruit and bean characters. These results indicate both additive and non-additive gene actions were involved in the inheritance of these traits. The relative contribution of SCA was as high as 70% for yield indicating the predominance of non-additive gene action for inheritance of this important trait. For the fruit and bean traits studied relative contribution of GCA was more suggesting predominance of additive gene action.

Parental lines P4 and P5 showed highly significant GCA effects for yield. This indicates that these two parents were found to be good general combiners for this important economic trait and may have good prospect for the inclusion in the breeding program for yield improvement in synthesis of new high yielding hybrid varieties. Parental line P4 showed good combining ability for three growth characters (stem girth, length of first primary branch and internode length) showing significant and positive GCA effects and this parent may contribute favorable alleles for the synthesis of vigorous hybrids.

Cross combinations P1xP5, P2xP4, P2xP5 and P3xP5 showed positive and significant SCA effects for plant height. Cross combinations P3xP5, P1xP5, P2xP5, P2xP4 and P3xP4 were good combinations for yield. On the other hand, only cross combinations P1xP3 expressed negative SCA effects for yield which is undesirable as these cross showed a tendency to reduce yield performance. For hundred bean weight, P1xP5, P3xP4 and P2xP5 were also good combiners.

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