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Combining ability and gene action of hot pepper (*Capsicum annuum* L.) genotypes in Southern Ethiopia

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This work identifies the combining ability of 10 hot pepper (*Capsicum annuum* L.) parents and 45F_1 hybrids obtained from 10 × 10 half diallel. The work aims to identify the parents with the best general combining ability (gca) and crosses with high specific combining ability (sca) for yield, quality and nature of gene action involved. The study was conducted within 2015 and 2016 at six environments in Southern Ethiopia using randomized complete block design (RCBD) with three replications. The combined analysis of variance showed that variance for gca and sca was highly significant for all the traits studied. This indicates that both additive and non-additive gene actions were operating in the inheritance of these traits. Parental level of gca revealed that introduced genotype (AVPP0514) had highest (1843.87) effect followed by Ethiopian variety 'Mareko fana' (930.97) for fresh pod yield and other related traits. The highest sca for hybrids was exhibited by AVPP0514 x AVPP59328, 'Marekofana' x AVPP0514, 'Melkaawaze' x AVPP0206 and AVPP9813 x AVPP0105 for yield and quality traits. This indicates the existence of immense potential for population improvement and heterosis breeding for enhancing productivity and qualities. The ratios of gca mean square to sca mean square were higher than unity for traits, indicating that additive gene action plays a predominant role in the inheritance of most of the traits.

Key words: Additive gene action, hybrid, improvement, parents, quality, yield.

INTRODUCTION

Hot pepper (*Capsicum annuum* L.), of the family, *Solanaceae* (2n = 24), is an important spice and vegetable crop (Gogula, 2015); it covers 67.98% of all the area under vegetables produced in Ethiopia (CSA, 2011/2012). The country produces paprika and *Capsicum* oleoresins for export market. Because of its wide use in Ethiopian diet, the hot pepper is an important traditional crop mainly valued for its pungency and color. The crop serves as source of income particularly for smallholder producers and also contributes significantly to house hold food security in many parts of rural Ethiopia (Shiferaw and Alemayehu, 2014). Combining ability of genotype is the ultimate factor determining future usefulness of the lines for hybrid development (Hallauer and Miranda, 1988). At the same time, it also elucidates the nature of gene actions involved in the inheritance of characters. General combining ability (gca) is attributed to additive gene effects and additive x additive epistasis and is theoretically fixable. On the other hand, specific combining ability (sca) attributable to non-additive gene

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Table 1. Hot pepper (*Capsicum annuum*) parental materials used for study in 2015 to 2016, Southern Ethiopia.

S/N	Parental lines/variety	Origin	Code
1	Melka awaze	Ethiopia	P_1
2	Marako fana	Ethiopia	P_2
3	Melka shote	Ethiopia	P_3
4	Melka zala	Ethiopia	P_4
5	AVPP9813	Asian	P_5
6	AVPP0206	Asian	P_6
7	AVPP0514	Asian	P_7
8	AVPP0512	Asian	P_8
9	AVPP0105	Asian	P_9
10	AVPP59328	Asian	P_{10}

action may be due to dominance or epistasis or both and is non-fixable. The presence of non-additive genetic variance is the primary justification for initiating the hybrid programme (Pradhan et al., 2006; Acquaah, 2007; Skoric et al., 2000).

The mean sum of squares due to gca and sca and their variance ratio are indicator of the nature of gene action (Patil, 2012). In other words, relatively larger gca/sca variance ratio demonstrates importance of additive genetic effects and a lower ratio indicates predominance of dominance and/or epistatic gene effects (Fasahat et al., 2016). High sca effects resulting from crosses where both parents are good general combiners (good gca × good gca) may be ascribed to additive × additive gene action (Dey et al., 2014; Kumar et al., 2015). The high sca effects derived from crosses including good × poor general combiner parents (Kaya and Atakisi, 2004; Dey et al., 2014) may be attributed to favorable additive effects of the good general combiner parent and epistatic effects of poor general combiner, which fulfills the favorable plant attribute. High SCA effects manifested by low × low crosses (May et al., 2010) may be due to dominance × dominance type of non-allelic gene interaction produced over dominance, thus being non-fixable (Skoric et al., 2000; Vasal et al., 1986). The diallel mating design is the most important for gca and sca. In terms of amount of information, it is more informative than North Carollina designs (Acquaah, 2007).

Despite the long history of hot pepper production and its importance in Ethiopia, the research work done so far in variety improvement was almost nil. Although, such genetic studies have been made in various crops, including pepper, in various parts of the world, little or no effort has been made on pepper under Ethiopian condition to exploit the existing potential. In this study, therefore, an attempt was made to generate information on six introduced and four released cultivars of pepper crossed in half-diallel fashion with the following objective:

1. To identify promising parents with better gca effects and single cross hybrids of pepper with promising sca effects.
2. To investigate the type of gene actions involved in traits for hybridization.

MATERIALS AND METHODS

Description of the study areas

The field experiment of F_1 crosses with the parental materials was conducted at six different environments namely Wolaita Soddo, Alaba and Humbo that represent major pepper growing areas in the Southern Ethiopia for two cropping seasons in 2015 to 2016.

Experimental materials

The experimental materials consist of 10 parents (six introduced genotypes from Asian Vegetable Research and Development Center (AVRDC) located in Taiwan and four Ethiopian released varieties). The local parental materials were collected from Melkasa Agricultural Research Center (Table 1).

Treatments, experimental design and field management

The experiment consisted of 45 F_1s and 10 parents with a total of 55 genotypes. The experiment was laid out using RCBD with three replications. Field planting was done using plant spacing of 70 x 30 cm between rows and plants, respectively. Each plot had 2 rows and 10 plants per row. The total plot area was 1.4 x 3.0 m = 4.2 m^2. All other recommended agronomic practices were employed during field management as recommended by Melkasa Agricultural Research Center (MARC).

Data collected

The following data were obtained from ten plants randomly taken from each plot for yield, quality and related traits: Plant height (cm), plant canopy width (cm), stem diameter (cm), branch number per plant, number of fruits per plant, fruit length (cm), fruit width (cm), fruit weight (g), fruit wall thickness (mm), number of seeds per fruit, total fruit yield (kg/ha) and total fruit dry weight (kg/ha).

Statistical analysis

Combining ability analysis of the parents and crosses

The combining ability analysis was carried out by using method 2 and model I (fixed effect model) of Griffing (1956) using SAS software (SAS 9.2 version). The mathematical model underlying this analysis was assumed as follows:

$$X_{ij} = \mu + g_i + g_j + S_{ij} + \frac{1}{bc}\sum_k \sum_l eijk$$

where, X_{ij} = Mean of ijth genotypes over K block; μ = population mean; g_i = general combining ability effect of the ith parent; g_j = General combining ability effect of the jth parent; S_{ij} = Specific combining ability effect of the ijth combination such that $S_{ij} = S_{ji}$; e_{ijk} = The environmental effect pertaining to ijth parent in the kth replication; i, j = 1, 2 ………., p (number of parents); k = 1, 2 ………., b (number of replication).

Table 2. ANOVA for general and specific combining ability of hot pepper (*Capsicum annuum* L.) genotypes studied in six environments, 2015 and 2016, Southern Ethiopia.

SOV	DF	PH	CW	BN	SD	FL	FD	FN	Tic	SN	Yld	DW
Env	5	16278.04**	1665.55**	163.12**	174.76**	70132.89**	5628.85**	307.89**	26.18**	7600.57**	2939604391**	115683560**
Gen	54	424.33**	362.73**	3.88**	3.37**	1623.43**	1625.57**	47.39**	0.43**	2154.30**	132177228**	4351578**
GXE	270	144.83**	87.04**	1.09**	0.75**	643.04**	309.48	7.83**	0.12**	516.75**	27831189**	1307566**
GCA	9	823.075**	529.52**	6.11**	5.55**	4938.53**	195.56**	1854.27**	1.15**	4980.12**	188670890**	2377539**
GCAxE	45	216.99**	109.5**	1.88**	1.17**	507.87**	6.84**	814.88**	709.26**	0.13**	39924049*	1659662**
SCA	45	345.306**	334.02**	3.57**	3.11**	1053.24**	18.42**	1627.41**	0.30**	1707.00**	126369869**	4829197**
SCAxE	225	133.46**	80.62**	0.98**	0.71**	275.92**	8.37**	653.66**	489.51**	0.12**	26846080	1284819
Error	660	67.44	21.13	0.42	0.55	162.35	65.66	2.60	0.05	140.11	14721085	609131
GCA/SCA	-	2.38	1.59	1.71	1.78	4.69	10.62	1.14	3.83	2.92	1.49	0.49
CV		15.13	11.27	11.83	19.43	31.27	9.02	11.81	15.85	15.66	34.06	33.84

*Significant at 5% probability; **=Significant at 1% probability. DF=degrees of freedom; PH=plant height(cm); CW=canopy width (cm); BN=branch number per plant; SD=stem diameter(cm); FL=average fruit length(mm); FD=average fruit diameter(mm); FN=Fruit number per plant; SN=seed number per fruit; TIC=fruit flesh thickness (mm); Yld=fresh fruit yield(kg ha^{-1}); and Dw =fruit/pod dry weight (kg ha^{-1}).

General (g_i) and specific combining ability (S_{ij}) effects

The following effects were obtained:

(i) General combining ability (GCA) effect of the i^{th} parent

$g_i = (X_{i\bullet} + X_{ij} – 2 X_{\bullet\bullet}/P) P+2$

(ii) Specific combining ability (SCA) effect of ij^{th} cross.

$S_{ij} = [X_{ij} – (X_{i\bullet} + X_{ij} + X_{j\bullet} + X_{jj}) P+2 + 2X_{\bullet\bullet}/(P+1) (P+2)]$

RESULTS AND DISCUSSION

ANOVA of general combining ability (gca) and specific combining ability (sca)

Combining ability analysis revealed highly significant (P ≤ 0.01) effects of gca and sca for all traits considered. Gca x e mean squares were significant for all traits but the magnitudes were consistently smaller than the respective gca mean squares. The sca x e effects were significant for all traits except fresh fruit yield and fruit dry weight. Similarly, the magnitudes of sca x e mean squares were smaller than that of sca for all traits except fruit wall thickness (Table 2). The result indicated that the magnitude of mean squares for gca was higher than the mean squares of sca, suggesting that additive gene effects were more important than non-additive gene effects for these traits. This is in agreement with Nsabiyera et al. (2013) and Geleta and Labuschagne (2006) who indicated that gca effects were higher than sca effects on seven pepper parents.

General combining ability study (gca)

The estimates of gca effects of the parents presented in Table 3 indicated significant desirable and undesirable effects depending on the trait under consideration. The analysis revealed that among the introduced genotypes, except parents 6 (AVPP0206) and 10 (AVPP59328), the rest exhibited significant and positive GCA effects in most of the cases including fresh fruit yield and dry weight. Whereas, genotypes AVPP0206 and AVPP59328 showed undesirable gca in almost all growth and yield traits. The Ethiopian genotype 'Marekofana' showed significant positive gca effects in the desired direction for fruit diameter, seed number per fruit, fruit thickness and fresh fruit yield, whereas other Ethiopian genotypes had undesirable gca effects in most of the traits considered (Table 3). Similarly, Fekadu et al. (2009) found that 'Marakofana' was the best general combiner for yield and quality traits among 12 Asian and Ethiopian genotypes studied. Geleta and Labuschagne (2006) also noticed more or less similar result.

The gca effects for fruit length were highly significantly positive (9.24) for AVPP0514 followed by 4.12 for AVPP0512. In contrary, the lowest gca for fruit length (-8.96) was recorded by AVPP59328. Similarly, fruit diameter has both positive and negative gca values with the highest highly significant gca (2.17) recorded for parent Marekofana, whereas the lowest negative value (-1.28) was recorded for parent Melkashote. Fruit number per plant had highly significant positive gca (5.07) and negative gca (-4.33) values for

Table 3. Estimation of general combining ability effects of 10 parents for 11 traits in hot pepper in six environments in 2015 and 2016, Southern Ethiopia.

Parent	PH	CW	BN	SD	FL	FD	FN	SN	Tic	Yld	DW
Melka awaze	2.47**	2.24**	0.17*	-0.01	-1.83*	-0.09	0.62	5.87**	-0.03	-140.58	-0.75
Marekofana	0.33	0.24	-0.01	-0.18*	-2.74**	2.17**	-4.25*	8.78**	0.11**	930.97*	82.24
Melka shote	-1.29	-0.83	0.13	-0.09	-2.50**	-1.28**	5.07**	-5.49**	-0.12**	-1344.28**	-126.86
Melka zala	3.65**	1.13*	0.26**	0.37**	2.60**	0.27	-2.25	-1.34	-0.003	-446.54	-74.41
AVPP9813	0.53	2.04**	0.05	-0.02	1.98*	0.09	-1.51	-3.89**	0.04	213.81	16.94
AVPP0206	-2.11**	-3.09**	-0.16*	-0.05*	-3.21**	-0.74**	2.79	-5.92**	-0.07*	-344.84	-43.80
AVPP0514	-3.12**	0.63	-0.05	0.13	9.24**	0.71**	0.97	-0.90	0.07*	1843.87**	202.41*
AVPP0512	-1.06	-1.49**	0.04	0.10	4.12**	-0.19	1.04	-2.64*	0.06*	525.66	129.16
AVPP0105	0.05	-0.54	-0.36**	-0.20**	1.30	0.18	-4.33**	4.69**	0.03	84.54	-121.09
AVPP59328	0.55	-0.32	-0.06	-0.06	-8.96**	-1.12**	1.85	0.84	-0.09**	-1322.61**	-63.83

*Significant at 5% probability; **=Significant at 1% probability. PH=plant height(cm); CW=canopy width(cm); BN=branch number per plant; SD= stem diameter(cm); FL= average fruit length (mm); FD= average fruit diameter(mm); FN= Fruit number per plant; SN= Seed number per fruit; TIC= fruit flesh thickness (mm); Yld=fresh fruit yield(kg ha^{-1}); and Dw = fruit/pod dry weight (kg ha^{-1}).

parents Melkashote and AVPP0105, respectively. Fresh fruit (pod) yield had positive gca value (1843.87) recorded by parent AVPP0514 followed by (930.97) parent Mareko fana and that of highly significant negative gca (-1344.28) followed (-1322.61) by parents Melka shote and AVPP59328, respectively. In most cases, the gca for fruit dry weight was non-significant except that recorded by parent AVPP0514 (202. 41) (Table 3). Consistent result was reported by Adarsh and Kumari (2015) in that out of 10 parental chilies evaluated, four were found to be good general combiners for fruit yield and other related traits. Nsabiyera et al. (2013) reported the existence of gca and sca effects on hot pepper traits. In support of the current result, additive and non-additive gene actions were reported for most agro-morphological and quality traits on *Capsicums* (Adarsh and Kumari, 2015). Parents with significant negative gca effects are considered desirable and should be selected in a breeding program for traits that need reduced expression in the progeny including days to flowering and fruit maturity, pedicel length and disease incidence. In such cases, parents 6 (AVPP0206) and 10 (AVPP59328) could be selected. In contrast, parents with significant positive gca effects were considered desirable for traits that require increased expression in the progeny. Thus, among released Ethiopian pepper varieties, Melka awaze and Melkazala were selected as parents for plant height, canopy width and primary branch number per plant. Marekofana variety is best combiner for fruit diameter, seed number per fruit, pericarp thickness and fresh fruit yield. Thus, the result indicated that there were introduced and local pepper genotypes which were considered to be the best general combiners for growth, yield and quality.

Estimates of specific combining ability effects of crosses

The current result revealed that highly significant sca values were recorded both positively and negatively by hybrids in traits measured. Out of 45 crosses, only 10 for fresh and 14 for dry weight showed significant sca effects, and among these, only 5 for fresh fruit yield and 7 for dry weight showed desirable (positive) sca effects. The cross combinations of Melka awaze x AVPP0206, Marakofana x AVPP0514, Melkazala x AVPP0105, AVPP9813 x AVPP0105 and AVPP0514 x AVPP59328 were the top desirable crosses for fresh pod yield and dry weight as well (Table 4). The result also indicated that the highest desirable sca value (13410.28) for fruit yield was recorded by crosses between introduced genotypes (AVPP0514 x AVPP59328) followed by sca value (6043.56) obtained by cross made by Ethiopian and introduced genotypes (Marakofana x AVPP0514). This indicates that there are potentials for the production of hybrids from Ethiopian local hot pepper genotypes. Besides the above listed crosses, sca value for dry weight was highly significant for cross Melkashote x AVPP9813. The best three top crosses for dry weight include AVPP0514 x

Table 4. Estimation of specific combining ability effects of crosses for 11 traits in hot pepper in six environments in 2015 and 2016, Southern Ethiopia.

Crosses	PH	CW	BN	SD	FL	FD	FN	SN	Tic	Yld	DW
1x2	7.36**	5.67**	-0.11	0.10	4.19	0.01	-0.79	0.79	0.16	588.43	269.41
1x3	-0.51	-1.21	0.14	-0.23	-3.36	-0.06	-9.26	-0.71	0.02	-580.77	-78.69
1x4	6.38*	9.12**	0.85**	-0.03	-12.97**	0.92	1.00	3.89	0.12	-2293.44	-452.42
1x5	0.25	-0.16	-0.84**	-0.99**	-0.24	0.40	-7.00	-0.03	-0.25**	-1416.88	4.01
1x6	-3.11	-4.28**	0.30	-0.07	10.57**	-0.82	8.35	-3.86	-0.07	3699.42**	587.50**
1x7	0.28	3.84**	-0.07	0.53*	-3.54	0.34	-0.55	1.74	-0.09	767.63	167.66*
1x8	2.29	-1.38	0.12	0.15	2.76	-0.42	0.58	2.60	-0.10	-275.18	98.70
1x9	-1.64	-2.33	-0.10	0.36	9.24**	-0.11	10.33*	-1.18	0.07	576.34	-261.88
1x10	- 2.81	-1.83	0.92*	0.07	-6.03	-1.73*	-10.11	7.27	-0.02	-2869.98	-829.70*
2x3	-8.63**	-3.46**	-0.23	-0.16	-1.85	-2.05**	-8.52	-15.08**	-0.12	-3904.83	-569.64*
2x4	-2.42	-2.50	-0.37	-0.49*	-5.42*	-1.30**	-1.31	5.25	-0.28**	-3450.96**	-390.84
2x5	0.56	-0.43	0.41	0.02	-1.49	-0.31*	5.46	13.27**	0.08	-104.96**	-367.60
2x6	12.22**	8.69**	0.36	0.25	5.89*	1.28**	1.57	13.98**	0.13	1922.17	150.17
2x7	1.47	1.01	0.67**	0.10	12.63**	1.78**	7.28	-3.21	-0.15	6043.56**	866.80**
2x8	-2.59	3.15	0.53*	0.43	-0.09	0.62	7.41	2.19	0.08	1636.27	279.17
2x9	-0.54	-3.43*	-0.59*	0.02	-8.51**	-1.69**	-3.56	-11.11**	0.07	-548.43	-24.63
2x10	0.48	1.25	0.69	-0.11	0.38	1.78*	-8.25	11.67*	-0.16	-431.20	421.67
3x4	1.62	1.49	0.64**	0.35	-0.97	0.01	13.32**	8.76*	-0.12	1828.02	309.09
3x5	0.36	0.04**	0.04	0.51*	-6.52**	-0.46	14.42**	2.72	-0.06	1372.92	840.97**
3x6	-0.58	-1.55*	-0.28	0.40	-0.82	0.06	9.92*	0.32	-0.13	1154.61	201.77
3x7	1.40	-2.61*	-0.20	0.16	13.89**	0.28	1.44	-5.68	0.30**	-1544.68	-22.82
3x8	5.26	-1.51	-0.64**	-1.40**	-3.34	-0.07	-7.66	-15.22**	-0.04	100.34	-467.08
3x9	2.19	-1.38	0.12	0.04	0.75**	0.14	-0.51	7.20*	-0.05	-151.58	-137.65
3x10	12.24**	10.76**	1.23**	9.12	10.72**	-3.22	16.46*	-1.11	-0.07	390.55	257.72
4x5	2.60	-3.50	-0.27	0.29	2.54	0.14	-9.99	11.17**	0.05	-982.13	-397.29
4x6	-4.12	-2.80	0.15	0.03	4.59	0.22	5.53	-0.51	0.20*	1709.96	254.76
4x7	3.18	2.83	-0.08	0.24	1.15	0.72	0.68	-3.09	0.08	1591.78	239.02
4x8	-0.72	2.61*	-0.16	0.30	8.35**	-0.86	-6.80	-4.93	-0.05	436.83	344.31
4x9	-0.07	2.38	0.30	0.34	-1.73	0.61	4.58	-2.21	-0.02	3125.27**	636.91**
4x10	3.18	1.03	0.88*	0.55	-4.80**	0.41	-1.53	-11.67*	0.04	1877.04	369.58
5x6	-2.40	3.53**	0.05	-0.12	-2.81	-0.35	-4.95	-2.46	-0.09	-3014.41**	-621.52**
5x7	-0.31	-0.95	0.15	0.12	4.24	-1.21**	-3.92	-6.57	-0.06	-1338.54	-344.60
5x8	-0.92	-0.79	0.09	0.12	3.52	0.99*	5.47	-6.92*	0.10	1465.31	315.77
5x9	4.39	6.15**	0.51*	0.03	2.67	1.53**	3.92	1.74	0.22*	3457.44**	524.88*
5x10	4.31	2.62	-0.42	0.055	-4.80	-1.31	-15.56	-15.65**	-0.19	-2637.35	-222.65
6x7	-4.06	1.54**	-0.49*	-0.24	-3.41	-0.85	-13.72**	-9.86**	-0.04	-5453.09**	-1157.54**

Table 4. Contd.

6x8	0.51	-0.29	0.29	0.32	-8.99**	0.85	2.48	11.40**	0.18	1294.12	309.10
6x9	0.08	-5.67	0.24	-0.19	-13.84**	-1.93**	-4.76	-25.69**	-0.18	-2076.14	224.82
6x10	-0.34	-9.37**	-0.62	-0.52	-13.21**	-2.44**	-2.28	2.91	-0.32*	-6889.71**	-1022.91**
7x8	0.30	-4.24**	-0.16	-0.10	1.95	-1.33	-8.97	-6.72	-0.04	-1202.24	-7.19
7x9	-5.21*	0.94	0.13	-0.15	4.74	1.41**	-8.00	9.71**	0.04	-648.41	-491.32*
7x10	5.33	4.97*	0.94*	1.41**	20.80**	0.23	52.36**	-5.41	0.05	13410.28**	2679.56**
8x9	0.12	-0.35	-0.23	0.08	-5.27	0.70	3.98	14.82**	-0.08	-1582.77	-336.51
8x10	5.63	6.00**	0.15	0.36	6.40	-0.11	7.29	-24.47**	0.12	-69.11	-50.33
9x10	13.28**	14.36**	-0.39	-0.29	7.07	0.25	-8.38	15.18**	0.02	1935.06	-262.20*

*Significant at 5% probability; **Significant at 1%probability. PH=plant height(cm); CW= canopy width (cm); BN= branch number per plant; SD= stem diameter(cm); FL= average fruit length (mm); FD= average fruit diameter(mm); FN= fruit number per plant; SN= Seed number per fruit; TIC= fruit flesh thickness (mm); Yld=fresh fruit yield(kg ha^{-1}); and Dw = fruit/pod dry weight(kg ha^{-1}).

AVPP59328 (2679.56), Marakofana x AVPP0514 (866.80) and Melkashote x AVPP9813 (840.97) (Table 4).

Furthermore, the result revealed that the parent genotype AVPP0514 has positive significant gca, whereas AVPP59328 has highly significant negative gca effects for yield and other related traits. Sca effect is highly significant in desirable direction. This indicates the strong contribution of additive gene effect of AVPP0514 for the cross and hence should be selected as best combiner for hybrid production in improving yield in pepper production. Statistically significant positive or negative sca effects for fruit yield and other traits showed that the crosses performed better or poorer than what would be expected from the gca effects of their respective parents (Table 4). Parents with various gca effects are combined to produce crosses varying in sca effects. This result is consistent with the findings reported by some researchers (Lohithaswa et al., 2000; Marchesan et al., 2009).

In the case of fruit quality traits such as fruit length and width, some of the hybrids with highly significant and positive SCA effects include Melka awaze x AVPP0206, Marakofana x AVPP0206, Marakofana x AVPP0514, Melkashote x AVPP0105, Melka shote x AVPP59328, Melkazala x AVPP0512, for fruit length; Marako fana x AVPP0206, Marakofana x AVPP0514, AVPP9813 x AVPP0512, AVPP9813 x AVPP0105 and AVPP0514 x AVPP0105 for fruit width. Fruit number per plant had significant positive SCA effects in crosses, such as Melka awaze x AVPP0105, Melkashote x AVPP9813, Melkashote x AVPP59328 and AVPP0514 x AVPP59328. In most cases, the result indicated that, SCA effects of fruit length, width and fruit number had much more related effects with that of fruit yield (Table 4). Navhale et al. (2014) and Lohithaswa et al. (2000) observed and reported almost similar finding.

Moreover, the result showed that the ratios of gca to sca mean squares were greater than that for all traits, except fruit dry weight indicating the influence of additive gene actions in the inheritance of the characters (Table 4). This is again in line with most of the previous findings, suggesting that additive variance (gca) might have played more significant roles in the expression of both plant height and fruit length with contrasting result in other traits (Reif et al., 2007; Fekadu et al., 2009). Similarly, Geleta and Labuschagne (2006) reported that the magnitude of mean squares for gca was higher than that of sca in traits studied in introduced and Ethiopian hot pepper genotypes.

Conclusion

Estimates of gca effects of the parents showed that individually, parents contributed to specific traits. However, parents such as Marekofana (Ethiopian) and AVPP0514 (introduced) showed desirable gca effects for fresh fruit yield and fruit dry weight and could be used in the breeding program for the development of hybrids. Moreover, cross combinations with desirable sca effects included Melka awaze x AVPP0206, Marakofana x AVPP0514, Melkazala x AVPP0105, AVPP9813 x AVPP0105 and AVPP0514 x AVPP59328, while the best three top crosses for dry weight included AVPP0514 x AVPP59328, Marakofana x AVPP0514 and

Melkashote x AVPP9813. These crosses can be used to produce desirable hybrids and hence could be recommended for improvement of yield, and other related traits in pepper production. Moreover, the significant gca and sca mean squares indicated the role of additive and non-additive gene action governing the expression of most traits. Further, the result indicated that the magnitude of mean squares for gca was higher than the mean squares of sca, suggesting that additive gene effects were more important than dominant gene effects for these traits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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