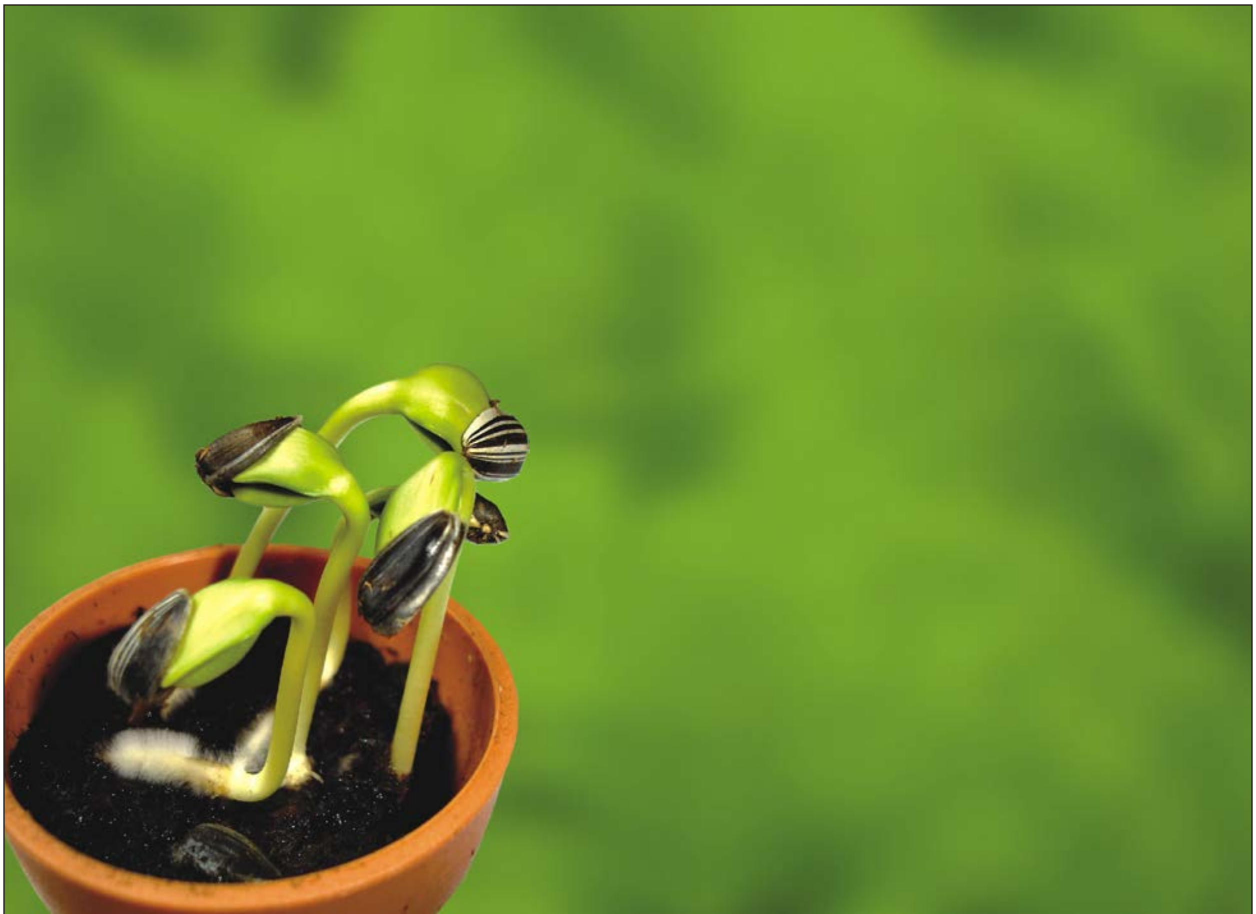

International Journal of Plant Breeding and Genetics

ISSN 1819-3595

Academic Journals Inc.

www.academicjournals.com

OPEN ACCESS International Journal of Plant Breeding and Genetics

ISSN 1819-3595
DOI: 10.3923/ijpbg.2017.63.70

Research Article
Heterosis and Heterobeltiosis Study of Hot Pepper (*Capsicum annuum* L.) Genotypes in Southern Ethiopia

[1]Shumbulo Abrham, [2]Nigussie Mandefro and [3]Alamerew Sentayehu

[1]Department of Horticulture, College of Agriculture, Wolaita Sodo University, Wolaita Sodo, P.O. Box 138, Wolaita Sodo, Ethiopia
[2]Deputy Regional Director, Oxfam America, Horn of Africa Regional Office, Addis Ababa, Ethiopia
[3]Department of Horticulture and Plant Sciences, Jimma University College of Agriculture and Veterinary Medicine, Jimma, Ethiopia

Abstract
Background and Objective: Exploitation of heterosis is one of the practical means of increasing yield and information on the magnitude of heterosis is a basic requisite for identifying crosses that exhibit high amount of exploitable heterosis in hot pepper. The heterosis study was conducted with the objectives of determining the magnitude of heterosis and heterobeltiosis for yield and quality and to identify and select superior F_1 hybrids for yield and quality improvement in hot pepper genotypes. **Materials and Methods:** The field experiment was conducted during 2014 through 2016 at six environments in Southern Ethiopia using 55 hot pepper genotypes that included 10 hot pepper parents and 45 F_1 hybrids obtained from 10×10 half diallel crosses. It was laid out using RCBD with 3 replications and data collected was analyzed using Microsoft excel version 2013. **Results:** Analysis of mid and better parent heterosis confirmed that heterosis ranged from -51.50% in fruit dry weight to 97.66% in fresh fruit yield indicating the existence of sufficient heterosis that can be exploited in hot pepper breeding programs. Fresh fruit yield had mid and better parent heterosis ranging from -38.63 to 97.66% and from -47.24 to 80.44%, respectively. The highest heterosis for oleoresin content were recorded for Melkazala×Avpp59328, Avpp8913×Avpp0512, Marakofana×Avpp0206, Avpp0206×Avpp0105 and Melkazala×Avpp0514. The best selected hybrids in percentage mid and better parent heterosis for fresh fruit and dry weight yield include Melkashote×Avpp59328, Marakofana×Avpp59328, Melkashote×Avpp0105, Avpp0514×Avpp0105 and Avpp9813×Avpp0514. **Conclusion:** The investigation confirmed the existence of variable genetic potential for exploitation of heterosis for yield and quality including oleoresin content in *Capsicum*.

Key words: Fresh fruit yield, heterosis, heterobeltiosis, hot pepper, oleoresin

Citation: Shumbulo Abrham, Nigussie Mandefro and Alamerew Sentayehu, 2017. Heterosis and heterobeltiosis study of hot pepper (*Capsicum annuum* L.) Genotypes in Southern Ethiopia. Int. J. Plant Breed. Genet., 11: 63-70.

Corresponding Author: Shumbulo Abrham, College of Agriculture, Wolaita Sodo University, P.O. Box 138, Wolaita Sodo, Ethiopia Tel: +251 911 39 60 41

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Hot pepper (*Capsicum annuum* L.), (2n = 24), in the family *Solonaceae,* is an important spice and vegetable crop[1,2]. Pepper has diverse uses as spice, condiment, culinary supplement, medicine, vegetable and ornamental plant and is an indispensable spice due to its pungency, taste, appealing color and flavor. It is the second largest commodity after black pepper (*Piper nigrum*) in the international spice trade[3,4].

Hot pepper is one of the major vegetable crops which covers 67.98% of the area in which vegetables are produced in Ethiopia[5]. The country has been producing paprika and *Capsicum* oleoresins for the export market. Hot pepper is an important traditional crop mainly valued for its pungency and color, hence, it has wide use in Ethiopian diet. The crop serves as the source of income particularly for smallholder producers and also contributes significantly to house hold food security in many parts of rural Ethiopia[3-7].

Heterosis is the expression of superiority of F_1 hybrid over the parents in a given trait[8,9], assessed not by absolute value of a trait, but by its usefulness for practical advantages[10]. In another words, heterosis can be explained as increasing of the character value of F_1 hybrids compared to the average value of both parents[11,12]. Heterosis in a desirable direction (hybrid vigor) is the ultimate aim of a plant breeder. In most cases, two major types of estimation of heterosis are reported in literature: (1) Namely mid parent or average heterosis, with superiority of the F_1 over the mean of the two parents and (2) Better parent heterosis (heterobeltiosis), which is the increased vigor of the F_1 over the better parent[13-15].

Heterosis has been widely used in agriculture to increase yield and to broaden adaptability of hybrid varieties in a number of crop species[8]. Exploitation of heterosis was indicated as practical means of increasing yield and other economic traits in *Capsicum* peppers[16]. Information on the magnitude of heterosis in different cross combinations is a basic requisite to for identifying crosses that exhibit high amounts of exploitable heterosis[11].

Extensive work on various aspects of heterosis in vegetable crops has been carried out and tremendous improvement has been made in its exploitation over the past several years[17]. There are many earlier reports indicating the exploitation of heterosis in the development of hybrid varieties in *Capsicum* species.

Some authors agree that Ethiopia is the center of origin for some *Capsicum* species which have immense genetic diversity in the country[17]. Yet production and productivity are challenged by many factors among which improved variety limitation hybrid production for traits of interest are among the core ones. 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 conditions 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 objectives:

- To determine the magnitude of heterosis and heterobeltiosis for fresh pod yield and quality traits
- To identify and select superior F_1 hybrids for yield and quality improvement

MATERIALS AND METHODS

Description of the study areas: The field experiment was performed in six different environments from 2014 through 2016 cropping seasons. The first crossing work was done at 2 locations Wolaita Sodo and Areka (Dubo) to obtain F_1 crosses. Evaluation of F_1 crosses with the parental materials was conducted at 3 different locations (Wolaita Soddo, Alaba and Humbo) that represent major pepper growing areas in Southern Ethiopia for two cropping seasons that gave us six different environments. Details of the study areas are shown in Table 1.

Table 1: Details of the description of the study area

Locations	Wolaita Sodo	Alaba	Humbo
Zone	Wolaita	Special Woreda	Wolaita
Region	SNNPR	SNNPR	SNNPR
Altitude (masl)	1710	1791	1386
Latitude	7°09' N	7°37' N	06°39'808"
Longitude	37°37' E	38°10' E	37°49'571"
Annual average Min. and Max. Temperature (°C)	14-25	17.6-26.5	18.1-27.2
Mean annual Rf (mm)	1520	601-1200	1100
Soil type	Sandy loam	Sandy loam	Sandy

Table 2: Parental materials used in the study

Parental lines/variety	Origin	Code
Melka awaze	Ethiopia	P_1
Marako fana	Ethiopia	P_2
Melka shote	Ethiopia	P_3
Melka zala	Ethiopia	P_4
AVPP9813	Asian	P_5
AVPP0206	Asian	P_6
AVPP0514	Asian	P_7
AVPP0512	Asian	P_8
AVPP0105	Asian	P_9
AVPP59328	Asian	P_{10}

Experimental materials: The experimental materials consist of 10 parents (six introduced pure lines and four Ethiopian released varieties). Six were collected from Asian Vegetable Research and Development Center (AVRDC) located in Taiwan while the rest four local parental materials were collected from Melkasa Agricultural Research Center. Details of the parental materials are presented in Table 2.

Treatments, experimental design and field management: The experiment consisted of 45 F_1 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 70×30 cm between rows and plants, respectively. All other recommended agronomic practices were employed during field management as recommended by Melkasa Agricultural Research Center (MARC).

Data collected: Data were collected from 10 randomly taken plants from each plot for yield, quality and other 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^{-1}), total fruit dry weight (kg ha^{-1}) and oleoresin content (w/w%) were studied.

Statistical analysis

Estimation of mid and better parent heterosis: Heterosis expressed as percent increase or decrease in the performance of F_1 hybrid over the mid parent (average or relative heterosis) and better parent (heterobeltiosis) was computed for each character using the following equation[18-20]:

$$\text{Better parent/heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Mid parent/relative heterosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

The significance of heterosis was tested with a t-test as specified below:

$$\text{For heterobeltiosis } t = \frac{\overline{F_1} - \overline{BP}}{\sqrt{2\,Me/r}}$$

$$\text{For relative heterosis } t = \frac{\overline{F_1} - \overline{MP}}{\sqrt{3\,Me/2r}}$$

Where:

$\overline{BP}$ = Mean performance of better parent
$\overline{MP}$ = Mean mid parental value i.e.,., $(P_1+P_2)/2$
$\overline{P_1}$ = Mean performance of parent one
$\overline{P_2}$ = Mean performance of parent two
$\overline{F_1}$ = mean of F_1 hybrid
Me = Error mean square from ANOVA table
r = Number of replications.

RESULTS

Mid and better parent heterosis: Heterosis and heterobeltiosis analyses for traits of interest were done for means combined over six environments. The over environment combined mean analysis confirmed that the magnitude of heterosis varied from -51.50% in fruit dry weight to 97.66% in fresh fruit weight. The combined mean analysis for heterosis over mid and better parent in percentage is presented in Table 3. The result substantiated that there were significant heterosis effects for the traits considered in the study. The heterosis was more magnified on yield and its components than growth traits in the study. Out of a total of 45 hybrids, 48.89 and 35.56% of crosses had shown mid parent heterosis and better parent heterosis in the desired direction, respectively. The current finding showed percentage mid parent heterosis in fresh fruit yield ranging from -38.63 to 97.66% for hybrids (Melkazala×Avpp0206) and (Melkashote×Avpp59328), respectively and that of better parent ranged from -47.24 to 80.44% for the same crosses. The result depicted that genotypes 24, 17, 23, 4, 32 and 41 were among the top crosses with highest heterosis and heterobeltiosis (Table 3, Fig. 1). In the case of dry fruit (pod) weight, the current finding revealed that mid parent heterosis varied from -48.09 to 61.69% and better parent heterosis ranged from -51.50 to 56.22% for crosses Melkazala×Avpp0206 and Melkashote×Avpp0105, respectively, in both cases. Out of the total, 48.89 and 42.22% of crosses had shown mid parent heterosis and better parent heterosis in the desired direction, respectively (Table 3).

Table 3: Combined mean percentage values of mid and better parent heterosis of yield and selected traits studied in hot pepper genotypes in 6 different environments, 2015 and 2016

	PH		CW		BN		FN		FL		FD		SN		Yld		DW		OL	
Cross	Mid (%)	Bp (%)	Mid (%)	Bp (%)	Mid (%)	BP (%)	Mid (%)	Bp (%)	Mid (%)	Bp (%)	Mid (%)	Bp (%)	Mid (%)	Bp (%)	Mid (%)	Bp (%)	Mid (%)	Bp (%)	Mid (%)	Bp (%)
1	-6.41	-13.25	-11.74	-18.86	-6.28	-3.07	-10.34	-11.36	-1.81	-5.88	5.73	-6.11	6.20	-3.02	-24.32	-34.74	-19.29	-27.82	-74.99	-81.98
2	-15.00	-16.48	-16.50	-19.90	0.34	-12.13	5.81	0.82	4.92	-2.12	2.33	-0.89	7.15	3.01	17.25	-2.71	-8.19	-23.47	-72.99	-78.80
3	6.09	0.45	-0.63	-4.69	-15.98	2.53	18.04	12.42	0.22	0.06	9.78	3.88	9.69	1.55	22.34	9.03	0.12	-6.15	-43.20	-57.49
4	-8.59	-17.67	0.87	-12.74	25.51	5.17	0.74	-14.74	18.19	14.47	31.99	16.28	-1.34	-11.85	48.57	39.07	25.76	21.50	-20.15	-39.13
5	-13.76	-20.75	-11.43	-12.72	4.31	9.21	15.00	7.51	-0.49	-2.78	7.09	3.24	-3.16	-7.82	8.95	4.57	4.93	4.56	-9.73	-32.55
6	-11.50	-15.90	-16.71	-24.14	-18.05	-21.99	-27.77	-33.35	-13.53	-16.04	-0.31	-9.16	-9.61	-14.39	-2.34	-7.29	-13.68	-15.71	1.66	-29.31
7	-13.51	-19.69	-16.87	-24.28	-6.70	-1.99	-27.14	-35.61	-19.81	-23.56	11.76	4.26	-0.02	-3.35	-21.92	-24.59	6.13	-8.64	4.88	-18.36
8	1.58	-9.52	-7.72	-18.76	25.38	10.32	55.30	54.23	9.90	-0.56	-6.97	-19.72	-11.60	-14.87	10.52	-10.72	11.95	-9.21	2.56	-18.63
9	-1.23	-16.25	-10.04	-21.19	-3.55	2.89	69.04	61.44	-3.90	0.06	-15.08	-23.85	-10.97	-24.31	17.72	-9.08	40.02	14.41	22.89	-4.71
10	-17.21	-24.49	-27.58	-35.90	-18.30	-23.37	51.24	45.70	4.36	1.44	-13.41	-20.84	-19.04	-23.27	22.39	16.89	20.72	11.41	14.40	1.49
11	-8.75	-10.78	1.08	-3.30	-0.37	-9.29	37.58	29.62	29.00	23.46	1.72	-4.92	-16.90	-18.13	7.00	3.05	6.64	1.41	34.50	26.98
12	7.34	4.04	7.12	0.19	-14.51	-15.37	-12.55	-25.28	-0.73	-7.72	0.00	-0.90	-28.98	-30.67	-11.04	-27.41	-25.78	-35.60	17.43	8.08
13	1.46	0.51	-5.50	-11.93	-6.11	-9.12	-3.04	-8.37	11.36	4.39	-5.41	-13.16	4.11	-0.35	-14.24	-28.54	-19.72	-28.41	64.83	55.94
14	4.64	1.92	16.40	15.22	8.69	7.77	26.35	17.83	-6.18	-12.57	-4.10	-6.81	1.16	-2.67	-6.21	-15.29	-4.80	-13.00	1.67	-4.13
15	10.81	10.61	11.97	10.83	-0.54	-6.59	-36.03	-42.90	7.43	-1.64	9.41	3.75	1.78	-4.06	-4.27	-14.89	-8.02	-11.94	0.21	-10.19
16	-1.68	-5.85	-0.55	-5.16	-2.96	-3.04	26.39	25.81	21.56	14.45	13.26	9.59	-15.03	-19.61	43.75	32.92	30.25	16.47	-34.47	-42.60
17	16.27	5.50	5.47	0.02	-0.53	-5.07	14.29	7.96	25.15	24.69	24.28	22.94	1.05	-6.66	77.86	55.76	41.41	27.55	-9.34	-18.37
18	-9.57	-15.79	-22.84	-28.88	-3.10	-16.72	-10.25	-18.36	25.80	17.17	-10.71	-12.83	-17.50	-20.68	29.14	19.00	32.09	16.42	-7.62	-13.54
19	-2.10	-13.19	-10.28	-25.05	-9.24	-15.68	-16.30	-26.14	6.48	-3.58	9.92	-0.34	-1.44	-8.69	22.98	-3.14	18.90	-3.59	-22.93	-25.97
20	-5.75	-14.77	-17.41	-21.88	-9.11	-17.31	-11.90	-13.65	6.41	-2.86	-13.03	-13.44	-27.79	-28.53	-14.72	-31.50	-6.62	-22.38	16.71	9.01
21	-19.21	-24.49	-7.36	-18.72	-13.67	-19.67	-10.75	-13.71	-0.54	-9.71	-8.75	-14.32	-23.49	-24.67	-18.06	-28.96	-23.31	-34.82	-23.08	-35.16
22	-15.61	-22.90	-8.98	-20.14	-5.69	-16.57	-17.01	-23.34	19.85	6.95	-6.70	-10.25	-24.03	-23.59	19.09	1.71	18.04	13.58	37.63	36.08
23	-9.62	-20.73	-10.30	-23.80	-10.50	-16.12	18.79	13.93	32.93	28.64	11.09	-1.43	-26.23	-26.09	67.22	61.64	61.69	56.22	26.29	24.44
24	6.25	-11.20	7.57	-9.05	-6.26	-15.83	6.13	-3.20	19.80	16.03	13.38	4.68	5.75	-6.99	97.66	80.44	57.77	53.88	-2.16	-3.77
25	1.32	-3.91	2.16	-8.30	-2.63	-10.52	-25.89	-39.72	-14.31	-16.88	-11.03	-17.53	-21.98	-24.94	-25.54	-37.37	-16.24	-23.97	-32.90	-34.69
26	-19.08	-21.60	-29.14	-31.07	-7.88	-13.54	-17.45	-26.24	0.81	-1.35	-10.90	-12.61	-26.36	-28.49	-38.63	-47.24	-48.09	-51.50	-9.26	-9.46
27	-10.53	-10.88	-15.45	-19.90	6.18	-2.58	23.98	9.42	-11.60	-14.03	0.45	-3.49	-1.33	-3.68	19.90	12.14	11.23	6.66	52.02	35.82
28	-7.10	-9.00	-8.96	-13.75	3.58	0.19	-14.09	-27.22	-21.63	-25.18	-19.46	-20.67	-40.20	-42.82	-17.96	-24.52	11.48	1.72	32.13	25.00
29	-1.12	-7.33	-21.11	-27.87	-13.65	-21.32	20.58	14.09	-7.20	-16.14	-11.08	-19.39	-0.77	-4.76	-26.80	-34.61	-14.20	-26.60	-15.51	-21.99
30	-1.36	-12.28	-12.50	-20.41	3.91	-1.12	2.52	2.23	22.28	17.45	-3.25	-8.62	-7.59	-15.80	48.17	25.66	31.22	13.18	92.16	82.70
31	-12.64	-14.55	0.60	-11.87	-8.11	-10.17	-37.56	-43.92	11.36	10.38	19.91	9.18	15.77	8.28	-11.18	-13.48	-31.57	-33.67	18.72	15.31
32	1.98	-3.64	19.83	13.16	1.20	1.03	72.85	57.22	-11.13	-11.37	2.37	-1.39	10.65	4.01	50.47	34.19	54.94	46.30	-13.45	-24.49
33	0.09	-3.16	1.31	-4.33	-10.18	-14.83	-16.98	-21.03	-7.29	-8.81	11.92	5.22	18.10	8.83	-21.85	-29.19	-17.24	-30.79	65.15	60.38
34	6.94	5.61	20.49	18.06	-4.01	-4.91	9.74	-6.59	5.71	-7.03	2.86	0.42	-19.34	-25.40	-15.06	-34.73	-7.88	-27.24	-37.16	-40.49
35	28.31	19.86	25.31	23.48	-16.28	-19.31	-24.10	-38.13	-1.78	-8.38	2.17	0.16	36.03	28.54	-7.51	-31.79	-15.44	-32.73	-23.94	-25.75
36	-1.72	-5.15	-5.15	-12.43	-8.10	-10.31	7.83	6.33	-9.08	-9.65	3.05	-2.81	0.24	-0.29	-5.39	-13.60	-2.01	-4.63	-4.21	-14.25
37	-6.43	-7.48	-17.10	-23.47	-10.80	-13.54	-26.78	-31.09	-15.43	-17.54	26.95	22.69	0.78	-0.81	-4.03	-10.91	-6.38	-19.65	-13.77	-18.59
38	-13.43	-16.35	-14.87	-24.07	-6.72	-9.64	-4.75	-10.38	-11.36	-21.44	-4.54	-14.94	-11.16	-12.22	-14.47	-33.02	-13.12	-29.73	54.48	42.33
39	14.99	5.24	-0.28	-11.51	-7.88	-9.21	-10.44	-19.78	4.23	-1.96	1.48	-5.89	-4.77	-15.49	-18.52	-38.86	-22.30	-36.69	24.96	18.56
40	-9.91	-12.09	1.83	1.83	3.81	-1.72	-3.03	-7.51	-1.55	-3.41	6.18	3.53	-16.88	-18.62	14.96	12.93	11.14	-2.35	-5.08	-19.23
41	-5.77	-12.01	0.63	-3.09	-11.68	-12.35	13.35	5.26	12.92	-0.47	16.11	9.28	-14.79	-16.25	50.66	26.93	31.72	8.84	31.87	9.85
42	-8.65	-19.04	7.80	3.24	-11.43	-14.78	-22.62	-31.54	-7.71	-13.69	12.99	10.98	21.70	8.51	-0.24	-19.89	-17.50	-31.30	15.52	-1.26
43	-10.31	-14.27	-4.89	-8.41	0.27	-5.75	-2.79	-13.58	11.65	-3.20	4.48	-3.97	-0.83	-1.23	16.59	-3.18	29.93	20.96	-31.65	-33.40
44	-3.64	-12.71	-19.63	-23.03	-9.83	-11.34	-13.82	-26.82	0.03	-8.10	3.83	-0.51	8.57	-4.99	0.27	-20.55	17.93	10.79	6.33	5.77
45	4.78	-0.97	-9.52	-10.04	-12.31	-16.24	-2.21	-7.22	-9.70	-15.27	2.85	-1.52	0.57	-11.69	14.78	8.17	19.79	18.63	-13.04	-15.70

PH: Plant height (cm), CW: Canopy width (cm), BN: Branch number per plant, FN: Fruit number per plant, FD: Average fruit diameter (mm), SN: Seed number per fruit, Yld: Fresh fruit yield (kg ha^{-1}) and DW: Fruit/pod dry weight (kg ha^{-1}), OL: Oleoresin content (w/w%), Mid (%): Percentage mid parent heterosis and Bp (%): Percentage better parent heterosis (heterobeltiosis)

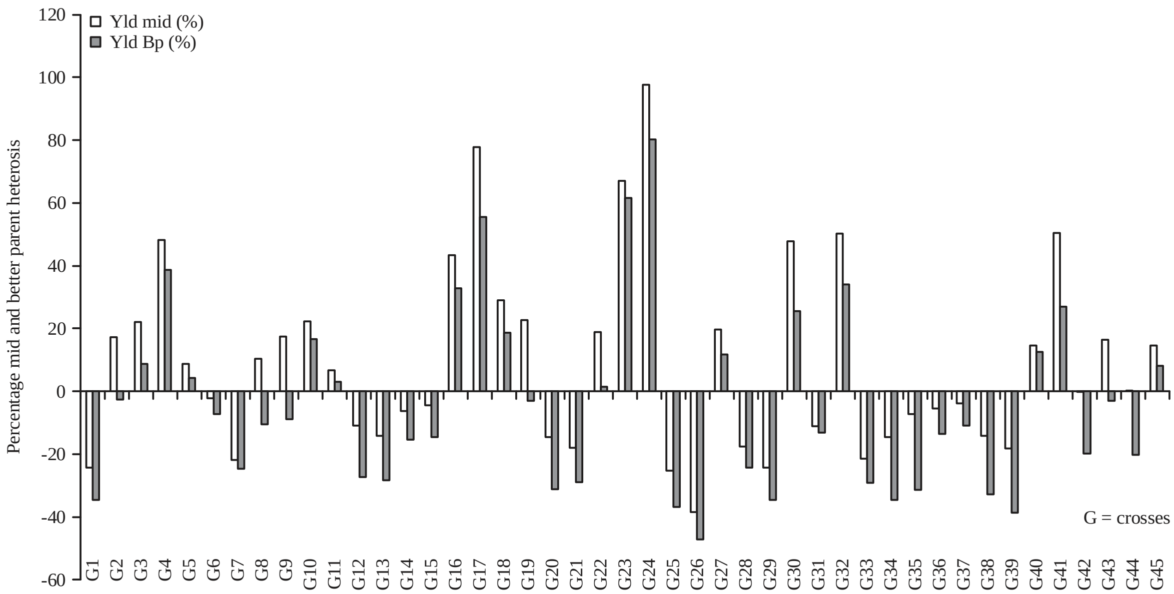

Fig. 1: Percent mid and better parent heterosis performance of fresh fruit yield (kg ha^{-1}) for 55 hot pepper genotypes grown in six different environments, southern Ethiopia, 2015/16

Out of a total of 45 crosses, 53.33 and 31.11% of crosses had shown mid parent and better parent heterosis (Heterobeltiosis) in fruit length in the desired direction, respectively. Average heterosis of fruit length ranged from -21.63 to 32.93% for crosses 28 and 23, respectively, with a heterobeltiosis range of -25.18 to 28.64% for the same crosses. Fruit diameter has shown a heterosis range of -19.46 to 31.99% for crosses Melkazala×Avpp0512 and Melka awaze×Avpp9813. Heterobeltiosis had shown a range of -23.86 to 22.94% for crosses Melka awaze×Avpp59328 and Marakofana×Avpp59328. Of the total, 60 and 33.33% of crosses had shown mid parent heterosis and better parent heterosis superiority in the desired direction, respectively. Fruit number per plant showed significant heterosis for studied genotypes. The percentage heterosis over mid and better parent ranged from -37.56% (Avpp9813×Avpp0206) to 72.85% (Avpp9813×Avpp0514) and -43.92% (Avpp9813×Avpp0206) to 61.44% (Melka Awaze×Avpp59328), respectively (Table 3).

Plant height heterosis ranged from -17.21% (Marakofana×Melkashote) to 28.31% (Avpp9813×Avpp59328) and heterobeltiosis ranged from -24.49 to 19.86% for the same crosses. In general, 31.11 and 17.77% of the crosses showed mid and better parent heterosis in the desired direction. Branch number per plant had heterosis ranging from -18.30% (Marakofana×Melkashote) to 25.51% (Melkaawaze×Avpp9813) while heterobeltiosis ranged from -23.37% (Marakofana×Melkashote) to 10.32% (Melka awaze×Avpp0105). Of all the hybrids, 33.33 and 17.77% of crosses had shown mid and best parent heterosis in the desired direction (Table 3).

The oleoresin content results revealed significant superiority of some hybrids (crosses) in the desired direction for both mid and better parent heterosis. Mid parent heterosis ranged from -74.99% (Melka awaze×Marakofana) to 92.16% (Melkazala×Avpp59328) and that of heterobeltiosis ranged from -81.98 to 82.7% for the same crosses. Of the 45 hybrids, 48.89% showed positive mid parent heterosis while 35.56% had positive better parent haterosis. The genotypes 30, 33, 13 and 38 were among the best crosses or hybrids with highest heterosis and heterobeltiosis in the desired direction for further exploitation (Table 3, Fig.2).

DISCUSSION

The result substantiated that there were significant heterosis effects varying from -51.50% in fruit dry weight to 97.66% in fresh fruit weight indicating crop potential of heterosis breeding for different traits for further improvement in the yield and quality. In fresh fruit yield, mid parent heterosis revealed a range of -38.63 to 97.66% indicating great genetic potential of genotypes for yield boosting by using F_1 hybrids. This result agrees with Devi[21], who indicated the marketable fruit yield average heterosis and heterobeltiosis varied from -20.36 to 113.19% and -22.94 to 102.93%, respectively. Most previous authors reported similar findings were Singh and Chaudhary[22] reported heterosis that ranged from 7.40-33.24% for total fresh yield/plant, Kumar *et al.*[23]

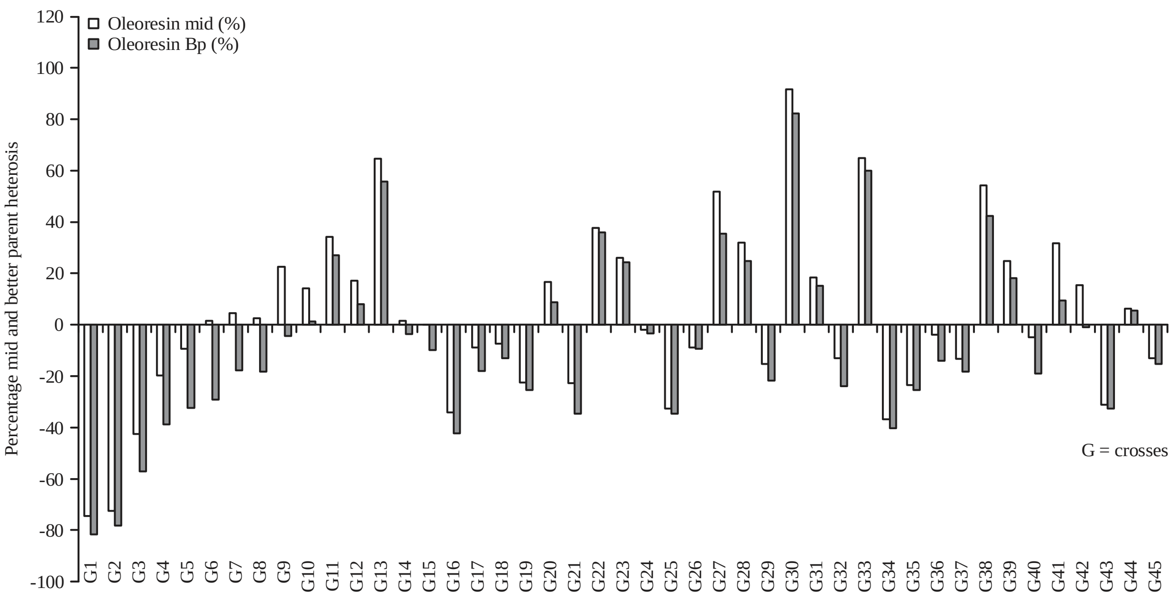

Fig. 2: Percent mid and better parent heterosis performance of oleoresin content for 55 hot pepper genotypes grown in 6 different environments, Southern Ethiopia, 2015/16

reported heterosis ranging from 38.30-119.47 and 7.88-90.78% heterosis and heterobeltiosis, respectively, for yield/plant. Similarly, mid and better parent heterosis in dry weight showed a range from -48.09 to 61.69% and -51.50 to 56.22%, respectively. Out of the total, 48.89 and 42.22% of the crosses had shown superiority in mid and better parent heterosis, respectively, in the desired direction which indicates a great genetic potential for exploitable heterosis. In line with the current finding, Gogula[4] found that the average heterosis and heterobeltiosis for the 30 hybrids studied ranged from -32.47 to 68.93% and -36.35 to 64.77%, respectively. Moreover, other previous studies confirmed the superiority of this trait as observed by Sharma *et al.*[24], Chaudhary *et al.*[18], Hasanuzzaman *et al.*[25], Medeiros *et al.*[26].

Mid and better both parent heterosis in fruit quality such as fruit length and diameter were observed which substantiated the genetic potential of the crop for hybrid production for quality. Average heterosis of fruit length ranged from -21.63 to 32.93% and that of heterobeltiosis ranged from -25.18 to 28.64%. In agreement with the current result, Devi[21] reported the range of heterosis from -8.63 to 148.32% and heterobeltiosis from -34.44 to 113.75%. Some earlier findings also confirmed similar results such as Burli *et al.*[27] reported positive heterobeltiosis, 3.82 and 6.46%, for fruit length and number of fruits, respectively, Shankarnag and Madalageri[28] observed heterobeltiosis of 9.16%, Singh and Hundal[29] noticed heterosis over better parent in 55%, Gogula[4] showed heterosis variation from -3.23 to 14.61% while heterobeltiosis variation from -10.02 to 8.08%. Again fruit diameter has shown a heterosis range of -19.46 to 31.99% and heterobeltiosis has shown a range of -23.86 to 22.94%. Of the total, 60 and 33.33% of crosses had shown mid and better parent heterosis in the desired direction. This result was in concordance with reports made by Shankarnag and Madalageri[28], who observed that the extent of heterobeltiosis was 94.63%; Singh and Hundal[29], who reported 24.48% heterobeltiosis for fruit width, again Davi[21] reported the magnitude of heterosis for fruit width ranged from -30.78 to 13.67% and -39.89 to 7.47% over mid parent and better parent, respectively, Gogula[4] observed the range of -8.06 to 16.27% heterosis and -10.53 to 12.94% of heterobeltiosis. The same were earlier reported by Sharma *et al.* [24].

Fruit number per plant percentage heterosis over mid and better parent ranged from -37.56 to 72.85% and -43.92 to 61.44%, respectively, that again indicated the significant possibility to increase the yield in fruits by exploiting F_1 hybrids. Consistent with the current result, the range of -8.63 to 148.32% and -34.44 to 113.75% over mid and better parent, respectively, were reported by Davi[21]. Other reports substantiated the current finding in such a way that Shankarnag and Madalageri[28] observed 94.63% and Singh and Hundal[29] 66.55% heterobeltiosis for fruit number per plant. Again Gogula[4] reported the range of -38.07 to 70.95% heterosis over mid parent and -46.56 to 41.47% over better parent.

The magnitude of heterosis and heterobeltiosis was relatively smaller in growth traits than yield and quality traits that gives an opportunity for immediate application of hybrid vigor for yield and quality improvement. In plant height, heterosis ranged from -17.21 to 28.31% and heterobeltiosis ranged from -24.49 to 19.86%. This is an indication for variability of genotypes for exploitation of heterosis in growth parameters of *Capsicums*. In line with the current finding, Singh and Hundal[29] observed 37.22% heterobeltiosis for plant height. Similarly, branch number per plant had mid and better parent heterosis ranging from -23.37 to 25.51% and out of a total of 45 hybrids, 33.33 and 17.77% of crosses had shown mid and better parent heterosis in the desired direction, respectively. This also was in line with some previous researcher who reported both positive and negative heterosis and heterobeltiosis in branch number Patel *et al.*[19] and Patil[20].

Oleoresin content result revealed significant superiority of some hybrids (crosses) in the desired direction for both mid and better parent heterosis. Mid parent heterosis ranged from -74.99 to 92.16% and that of heterobeltiosis ranged from -81.98 to 82.7%. Of the 45 hybrids, 48.89 and 35.56% had positive mid and better parent haterosis, respectively, indicating the genetic potential of the crop for heterosis breeding for boosting oleoresin production. Consistent with the current investigation, Gogula[4] observed the range of -5.22 to 47.10% relative heterosis and -11.65 to 35.79% heterobeltiosis in sweet pepper. Again Prasath and Ponnuswami[30] and Ghosh and Pugalendhi[31] reported range of -9.43 to 21.83% and -21.62 to 14.27% heterosis, respectively in chilli oleoresin that implies variation in magnitude of heterosis with genotypes tested.

CONCLUSION

There were superior F_1 hybrids identified with varying magnitude of heterosis in all investigated traits. The top five selected crosses for mid and better parent heterosis include Melkashote×Avpp59328, Melkashote×Avpp0105, Marakofana×Avpp59328, Melka awaze×Avpp9813 and Avpp9813×Avpp0514 for fresh fruit yield and dry pod weight. Oleoresin content revealed significant superiority of some hybrids (crosses) in the desired direction for both mid and better parent. In most cases, the crosses superior in oleoresin were inferior in pod yield except a few. Thus, there is a need for critical evaluation of crosses for simultaneous breeding. Hence, the crop had immense potential for heterosis breeding for further improvement of its different traits.

SIGNIFICANCE STATEMENTS

In Ethiopia, improving hot pepper productivity (yield) is very crucial in order to benefit from pepper production. Hence, hybrid development is one of the best options to utilize the existing genetic variability to improve yield and quality.

ACKNOWLEDGMENTS

The authors would like to thank Wolaita Sodo University and Jimma University College of Agriculture and Veterinary Medicine for their valuable contribution in both facilitation and management support. Our recognition also extends to Melkasa Agricultural Research Center, especially the vegetable program staff, for their cooperation in providing planting materials and AVRDAC for the same. Moreover, our special thanks goes to Prof. Derbew Belew for his unreserved contribution for material transfer from AVRDC.

REFERENCES

1. Mahmoud, A.M.A. and A.A.S.A. El-Eslamboly, 2015. Production and evaluation of high yielding sweet pepper hybrids under greenhouse conditions. Am. Eurasian J. Agric. Environ. Sci., 15: 573-580.
2. Kole, C., 2007. Vegetables: Genome Mapping and Molecular Breeding in Plants. Vol. 5, Springer Science-Business Media, USA.
3. Seleshi, D., 2011. Evaluation of elite hot pepper varieties (*Capsicum species*) for growth, dry pod yield and quality under Jimma Condition, South West Ethiopia. M.Sc. Thesis, Jimma University, Jimma, Ethiopia.
4. Gogula, K.R., 2015. Development of hybrids and their stability in chilli (*Capsicum annuum* L.). Ph.D. Thesis, Dr. Y.S.R. Horticultural University, Venkataramannagudem, India.
5. CSA., 2012. Agricultural sample survey 2011/2012 (2004 E.C.). September 2011-December 2012, Volume IV, Central Statistical Agency, Addis Ababa, Ethiopia, May 2012.
6. EEPA., 2003. Spice potential and market study. Ethiopian Export Promotion Agency (EEPA), Product Development and Market Research Directorate, Addis Ababa, Ethiopia.
7. Mekonen, S. and A. Chala, 2014. Assessment of hot pepper (*Capsicum* species) diseases in Southern Ethiopia. Int. J. Sci. Res., 3: 91-95.
8. Sood, S. and N. Kumar, 2010. Heterosis for fruit yield and related horticultural traits in bell pepper. Int. J. Vegetable Sci., 16: 361-373.

9. Falconer, D.S. and T.F.C. Mackay, 1996. Introduction to Quantitative Genetics. 4th Edn., Benjamin Cummings, London, UK., ISBN-13: 9780582243026, Pages: 464.
10. Sharma, M., 2012. Heterosis and gene action studies for fruit yield and horticultural traits in chilli (*Capsicum annuum* Var. *Annuum* L.). Ph.D. Thesis, Himachal Pradesh Krishi Vishvavidyalaya-Palampur, India.
11. Chandrakant, K., M. Ravindra, M.B. Madalageri and R.C. Jadeesha, 2009. Studies on heterosis in capsicum (*Capsicum annuum* L.) for yield and yield traits. Karnataka J. Agric. Sci., 22: 155-157.
12. Sitaresmi, T., S. Sujiprihati and M. Syukur, 2016. Combining ability of several introduced and local chilli pepper (*Capsicum annuum* L.) genotypes and heterosis of the offsprings. Indonesian J. Agron., 38: 212-217.
13. Shrestha, S.L., B.P. Luitel and W.H. Kang, 2011. Heterosis and heterobeltiosis studies in sweet pepper (*Capsicum annuum* L.). Hortic. Environ. Biotechnol., 52: 278-283.
14. Dagne, W., 2008. Genotypic variability and combining ability of quality protein maize inbred lines under stress and optimal conditions. Ph.D. Thesis, University of the Free State, South Africa.
15. Kalloo, G., 1988. Vegetable Breeding. Vol. 1, CRC Press Inc., Boca Raton, Florida, Pages: 239.
16. Marame, F., H. Singh, L. Desalegne, C. Fininsa and R. Sigvald, 2009. Combining ability and gene action in crosses among Asian and Ethiopian genotypes of hot pepper (*Capsicum annuum* L. Var. *Annuum*). East Afr. J. Sci., 3: 153-160.
17. Aklilu, S., B. Abebie, W. Dagne and T.W. Adeferis, 2016. Genetic variability and association of characters in Ethiopian hot pepper (*Capsicum annum* L.) landraces. J. Agric. Sci., 61: 19-36.
18. Chaudhary, A., R. Kumar and S.S. Solankey, 2013. Estimation of heterosis for yield and quality components in chilli (*Capsicum annuum* L.). Afr. J. Biotechnol., 12: 6605-6610.
19. Patel, J.A., M.J. Patel, A.D. Patel, R.R. Acharya and M.K. Bhalala, 2001. Heterosis studies over environments in chilli (*Capsicum annuum* L.). Vegetable Sci., 28: 130-132.
20. Patil, M.Y., 2012. Heterosis and combining ability studies in chilli (*Capsicum annuum* L.). M.Sc. Thesis, Botany College of Agriculture, Dapoli, India.
21. Devi, M.B., 2014. Heterosis and combining ability studies for yield and horticultural traits in bell pepper (*Capsicum annuum* L. var. *grossum* Sendt.) under protected environment. Ph.D. Thesis, College of Agriculture, India.
22. Singh, A.K. and B.R. Chaudhary, 2005. Genetic architecture: Heterosis and inbreeding depression in chillies. Res. Crops, 6: 318-332.
23. Kumar, S., K.S. Heera and T. Prabhu, 2005. Diallel analysis in chilli (*Capsicum annuum* L.) for yield and capsaicin content. Res. Crops, 6: 116-118.
24. Sharma, V.K., S. Punetha and B.B. Sharma, 2013. Heterosis studies for earliness, fruit yield and yield attributing traits in bell pepper. Afr. J. Agric. Res., 8: 4088-4098.
25. Hasanuzzaman, M., M.A. Hakim, M.M. Hanafi, S. Abdul, M.M. Islam and A.K.M. Shamsuddin, 2013. Study of heterosis in Bangladeshi chilli (*Capsicum annuum* L.) landraces. Agrociencia, 47: 683-690.
26. Medeiros, A.M., R. Rodrigues, L.S.A. Goncalves, C.P. Sudre, H.S. de Oliveira and M.H. dos Santos, 2014. Gene effect and heterosis in *Capsicum baccatum* var. *pendulum*. Cienc. Rural, 44: 1031-1036.
27. Burli, A.V., M.G. Jadhav, S.M. More and B.N. Gare, 2001. Heterosis studies in chilli. J. Maharashtra Agric. Univ., 26: 208-209.
28. Shankarnag, B. and M.B. Madalageri, 2006. Studies on heterosis in male sterile based hybrids in chilli (*Capsicum annum* L.). Int. J. Agric. Sci., 2: 327-329.
29. Singh, R. and J.S. Hundal, 2001. Manifestation of heterosis in chilli (*Capsicum annuum* L.). Vegetable Sci., 28: 124-126.
30. Prasath, D. and V. Ponnuswami, 2008. Heterosis and combining ability for morphological, yield and quality characters in paprika type chilli hybrids. Indian J. Hortic., 65: 441-445.
31. Ghosh, A. and L. Pugalendhi, 2012. Studies on the improvement of chilli (*Capsicum annuum* L.) cv Co 4 for quality characters through hybridization. Electron. J. Plant Breed., 3: 811-817.