

Genetic Association among Some Attributes of Hot Pepper (*Capsicum annuum* L.) Genotypes in West Shoa, Ethiopia

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Abstract: Twenty *Capsicum* genotypes were evaluated to estimate the nature and magnitude of variability among green fruit yield per plant and related characteristics at Bako Agricultural Research Center, Ethiopia, during 2007/2008 cropping season. The aim of the research was to investigate the relationship between yield and other traits of some capsicum genotypes at Ethiopian condition. The estimates of genotypic and phenotypic correlation coefficients between each pair of the traits studied are presented. Significant correlation both at phenotypic and genotypic levels were also observed between some of the traits other than their association with average fruit yield. Fruit yield per plant showed positive and significant phenotypic correlation with fruit length ($r_p = 0.537$), fruit weight ($r_p = 0.616$) and canopy diameter ($r_p = 0.647$). Genotypic correlation coefficient of these traits with average fruit yield per plant, were also positive and high. At genotypic level the path analysis revealed that fruit weight had maximum positive direct effect (0.0586) followed by days to flower (0.0461), canopy diameter (0.0188), plant height (0.0158), days to maturity (0.0143), pericarp thickness (0.0131), fruit per plant (0.0057) and primary branch per plant (0.032). This seems to suggest that these traits are good contributors to average fruit yield per plant.

Key words: Capsicum • Characters • Correlation • Path coefficient analysis • Relationship

INTRODUCTION

Fruits of *Capsicum* plants are among the most heavily consumed spices throughout the world, due to their unique flavor and pungency [1]. It is the most important spice and vegetable crop in the world [2]. It is also the leading spice crop in Ethiopia and the pungent *Capsicum* type (hot pepper) is locally consumed in various food preparations particularly for flavoring and adding color to local stew. In addition to dietary benefits, *Capsicums* are also high value crops and can often provide excellent income-generating opportunities to small farmers. Further, the crop is the main industrial raw material for processing of *Capsaicin* and color oleoresins [3].

Since long ago, several hot pepper (*Capsicum annuum* L. var. *annuum*) genotypes have been widely grown in tropics and typical tropical climate within Ethiopia (between 3° and 18° North latitude; 48° east of

longitude). In Ethiopia, about 64,774 hectare land was covered by hot pepper and 116,739 tones was harvested in 2004 only [4]. However, the productivity of pepper is low even when compared to that of other developing countries [5]. At farmers' level, the yield of pepper is about 0.4 tones per hectare [3] while in Turkey the average yield exceeds 14 tones per hectare [6]. Moreover, the varieties of peppers at the hands of growers are very old; they were released in the early 1980s. This calls for urgent breeding work in order to develop cultivars with better yielding potential. For efficient and effective breeding work; investigation and better understanding of the relationship between yield and other plant trait in the crop is central key for better selection of associated traits towards crop improvement.

Revealing the relationship between yield and other agronomic traits in crops has been considered as a good source of information for the breeder in order to focus on key traits with strong correlation with the target trait.

Thus, several works have been done so far in different crops and reports are available in rice [7], field pea [8], oat seeds [9], soybean [10] and Khorasan wheat [11].

As far as capsicum spp. is concerned, there are research reports on association of fruit color with other traits [12] and determination of genetic variability, heritability and genetic advance in chillies [13]. Moreover, works have been done on morphological and molecular genetic variability aiming at grouping of pepper genotypes in to cluster according to distance [14]. Identification, characterization and estimation of genetic divergence have also been reported in capsicum spp. collections [15].

However information is limited on the relationship between yield and other plant characters. Therefore the objective of this study was to investigate the relationship between yield and other traits of some capsicum genotypes under Bako, Ethiopia condition.

MATERIALS AND METHODS

Study Area: The study was conducted under irrigated condition during 2007/2008 at Bako Agricultural Research Center, which is located at (9° 6' N latitude, 37° 09' E longitudes and an altitude of 1650 m above sea level). The site has an average annual rainfall of 1210 mm. The soil pH ranges from 5 to 6 and clay is the dominant soil texture. The annual mean maximum and minimum temperatures are 28°C and 13°C, respectively [16].

Genetic Materials and Design: Twenty *Capsicum* genotypes including one local check from Bako Agricultural Research Center were used for this experiment (Table 1).

The experiment was laid out in a Randomized Complete Block Design with three replications. In each 5-row plot, an intra-row spacing of 0.3 m and inter-row spacing 0.7 m were maintained to accommodate seven plants per row and 35 plants per plot.

Parameters Recorded and Statistical Analysis

Sixteen Traits: Number of branch per plant, plant height, stem diameter, days to flower, fruit per plant, days to maturity, fruit length, fruit diameter, shape index, fruit weight, canopy diameter, pericarp thickness, pungency index, fruit yield per plant, marketable yield and unmarketable yield were recorded from sample plants in each plot and the results were expressed as mean values. Ten plants were randomly selected from the most inner 20 plants in order to measure the parameters. All the data were represented as averaged per plant observation except for marketable fruit yield and unmarketable fruit yield which were computed as plot observation. Marketable yield represented the total weight of the clean and undamaged fruits which was harvested from net harvestable plots after sorting and expressed in kilogram. Unmarketable fruit yield was computed out of fruits harvested at green fruit maturity or just before 'turning red' stage from net harvestable plots through sorting damaged ones by sun burn, diseases, insects, birds, cracking, etc and was expressed in kilogram.

Table 1: Source, description and origin of the test *Capsicum* genotypes

Serial code	Genotype	Pedigree	Origin/source
1	PBC 223	Jo Saeng Jin	Korea/The World Vegetable Center-AVRDC
2	PBC 600	LC-Serdang	Malaysia/The World Vegetable Center-AVRDC
3	Mareko-Fana	N/A*	BARC/Ethiopia
4	Bako-Local	Bako-Local	BARC/Ethiopia
5	PBC 579	N/A	Sri Lanka/The World Vegetable Center-AVRDC
6	Oda-Haro	N/A	BARC/Ethiopia
7	Oda-Haro	N/A	MARC/Ethiopia
8	Malka-Zala	PBC579	Malaysia /The World Vegetable Center-AVRDC
9	Malka Eshet	N/A	MARC/Ethiopia
10	PBC 830	Bangchang	Thailand/The World Vegetable Center-AVRDC
11	ICPN 9 #1	PBC 76/PBC 517	France/The World Vegetable Center-AVRDC
12	ICPN 9 #2	PBC 1363/PBC 504	Bulgaria/France/The World Vegetable Center-AVRDC
13	ICPN9 #11	PBC 495/PBC 3802	France/Indonesia/The World Vegetable Center-AVRDC
14	ICPN9 #12	PBC 284/PBC 1574	France /Thailand/The World Vegetable Center-AVRDC
15	ICPN9 #15	Pant C-1	India/The World Vegetable Center-AVRDC
16	ICPN9 #18	PBC 506/PBC3851	France/Malaysia /The World Vegetable Center-AVRDC
17	ICPN9 #20	PBC 385/PBC 504	Malaysia/France/The World Vegetable Center-AVRDC
18	ICPN10 #7	N/A	France/Indonesia/The World Vegetable Center-AVRDC
19	ICPN12 #1	N/A	India/The World Vegetable Center-AVRDC
20	Local Check	Local Check	Bako Agr. Research Center/Ethiopia

* N/A=Not available

GenRes Statistical Software [17] was employed for analysis of variance and estimation of correlation among the traits.

The inherent association between two variables; and environmental correlation, the effect of growing environment on a pair of traits was estimated using the formula given by Miller and co-workers [18] as follows:

$$r_p = \frac{P \text{ cov } X Y}{\sqrt{\sigma_p^2 X \cdot \sigma_p^2 Y}}$$

$$r_g = \frac{G \text{ cov } X Y}{\sqrt{\sigma_g^2 X \cdot \sigma_g^2 Y}}$$

Where:

P cov X Y = Phenotypic covariance of character X and character Y

G cov X Y = Genotypic covariance of character X and character Y

r_p = Phenotypic Correlation

σ_p^2 of X = Phenotypic variance for character X,

σ_p^2 of Y = Phenotypic variance for character Y,

r_g = Genotypic Correlation

σ_g^2 of X = Genotypic variance for character X and

σ_g^2 of Y = Genotypic variance for character Y,

The direct and indirect effects of independent traits on fruit yield per plant were examined using the following formula as applied by Dewey and Lu [19]:

$$r_{ij} = p_{ij} + \sum k_k p_{kj}$$

Where:

r_{ij} = Mutual association between the independent character (i) and dependent character (j) as measured by the genotypic correlation coefficients

P_{ij} = Direct effects of the independent character (i) on the dependent variable (j) as measured by the genotypic path coefficients and

$\sum r_{ik} p_{kj}$ = Summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent traits (k).

RESULTS AND DISCUSSION

Fruit yield per plant showed positive and significant phenotypic correlation with fruit length ($r_p = 0.537$), fruit weight ($r_p = 0.616$) and canopy diameter ($r_p = 0.647$). Genotypic correlation coefficient of these traits with

average fruit yield per plant, were also positive and high (Table 2). Similar results were reported by [12] as well as [13] for the crop. Further, positive genotypic correlation of average fruit yield was recorded with number of fruits per plant, in contrast to the results reported by [20] and shape index but the magnitude of their associations were small. However, the association of average fruit yield per plant with days to flower, stem diameter and days to maturity were negative and high which suggested the possibility of achieving higher average fruit yield per plant coupled with early maturity at the expense of reduced stem diameter. In reverse the results of present study pointed out that genotypes taking more days to flowering would produce fewer fruits per plant. Results reported by [21] were also similar to the conclusion of the present study.

Significant correlations both at phenotypic and genotypic levels were also observed between some of the traits other than their association with average fruit yield (Table 2). The association of single fruit weight with fruit length and fruit diameter was positive which are in confirmations with findings by [22, 23]. However a contradicting result was reported by [20] where average fruit weight was negatively correlated with the fruit diameter. The positive significant associations between fruit weight and the other traits considered in this study suggested that an increase in these traits may increase the fruit weight. On the other hand, an increase in levels of other negatively associated traits decreased the fruit weight. Further, positive and significant phenotypic ($r_p = 0.561$) and genotypic ($r_g = 0.644$) associations were found between days to flowering and days to maturity, signifying the possibility of identifying early maturing genotypes in early developmental stage of the crop during flowering without waiting for maturity. At genotypic level number of fruit per plant showed positive and significant correlations with canopy diameter suggesting that any effort of improving canopy diameter would lead to an increased number of fruits per plant. Moreover, significant correlation at genotypic level computed between plant height and canopy diameter ($r_g = 0.605$) as well as stem diameter and days to maturity ($r_g = 0.521$) which indicate that increase in one trait will bring increase in other; for instance increased stem diameter would delay the maturity of the crop. However, for negatively associated traits at genotypic level, such as pungency in percent and fruit length ($r_g = -0.589$), decrease in fruit length could result in highly pungent fruit, i.e. as fruit length reduces pungency level will increase and *vice versa*. The overall results suggested improvement aimed

Table 2: Correlation coefficients at genotypic (above diagonal) and phenotypic (below diagonal) levels among studied traits of *Capsicum* genotypes

Traits ¹	B/P	PH	SD	DFI	F/P	DM	FL	FD	SI	FW	CD	PcT	PI	FY/P
B/P		0.429	0.344	-0.515*	-0.126	-0.386	0.027	-0.158	0.329	-0.005	0.197	0.066	-0.031	-0.037
PH	0.307		0.101	-0.688*	0.244	-0.500*	0.264	-0.007	0.222	0.194	0.605*	0.065	0.111	0.493*
SD	0.189	0.271		0.519*	0.003	0.521*	-0.640*	-0.580*	0.222	-0.675*	-0.764*	0.431	0.585*	-0.642*
DFI	-0.427	-0.567**	0.285		-0.234	0.644*	-0.433	-0.256	-0.142	-0.467*	-0.739*	-0.046	0.133	-0.662*
F/P	-0.107	0.202	-0.044	-0.233		0.175	-0.418	-0.460*	0.349	-0.409	0.451*	-0.232	0.388	0.142
DM	-0.353	-0.411	0.208	0.561*	0.156		-0.320	-0.165	-0.016	-0.300	-0.616*	0.027	0.028	-0.471*
FL	-0.008	0.268	-0.261	-0.377	-0.344	-0.272		0.577*	0.104	0.786*	0.361	0.071	-0.589*	0.592*
FD	-0.105	0.046	-0.294	-0.244	-0.420	-0.156	0.542*		-0.733*	0.913*	0.126	0.198	-0.425	0.451*
SI	0.169	0.101	0.022	-0.106	0.318	-0.041	0.084	-0.660**		-0.438	0.207	-0.201	0.108	0.036
FW	-0.023	0.175	-0.35	-0.455*	-0.38	-0.265	0.739**	0.885**	-0.392		0.290	0.084	-0.611	0.646*
CD	0.077	0.579**	-0.151	-0.630**	0.374	-0.527*	0.341	0.112	0.174	0.270		-0.325	-0.036	0.754*
PcT	0.021	0.069	0.187	-0.068	-0.193	0.005	0.059	0.185	-0.163	0.095	-0.220		0.392	-0.087
PI	-0.028	0.060	0.282	0.128	0.373	0.033	-0.536*	-0.407	0.970**	0.593**	-0.052	0.372		-0.253
FY/P	-0.02	0.442	-0.355	-0.633**	0.187	-0.409	0.537*	0.435	0.036	0.616**	0.647**	-0.044	-0.239	

*, ** Indicate significant at 5% and 1% probability levels respectively.

The phenotypic correlation coefficient must exceed 0.444 and 0.561 to be significant at 5% and 1% probability levels, respectively.

¹ Indicate the values, which are higher than the threshold value of 0.444, which is the 5% probability level for testing simple correlations with 18 degrees of freedom.

¹ B/P=Number of branch per plant, PH= Plant height, SD= Stem diameter, DFI, = Days to flower, F/P= Fruit per plant, DM= Days to maturity, FL= Fruit length, FD= Fruit diameter, SI=Shape index, FW= Fruit weight, CD=Canopy diameter, PcT= Pericarp thickness, PI = Pungency index, FY/P= Fruit yield per plant

Table 3: Genotypic direct effects (bold face) and indirect effects of various traits on fruit yield per plant of *Capsicum* genotypes studied

Traits ¹	B/P	PH	SD	DFI	F/P	DM	FL	FD	SI	FW	CD	PcT	PI	r _g
B/P	0.0032	0.0068	-0.0027	-0.0237	-0.0007	-0.0055	0.0008	0.0202	-0.0213	-0.0003	0.0037	0.0009	0.0001	-0.0370
PH	0.0014	0.0158	-0.0008	-0.0317	0.0014	-0.0071	0.0075	0.0009	-0.0143	0.0114	0.0114	0.0009	-0.0004	0.4930
SD	0.0011	0.0016	-0.0077	0.0239	0.0000	0.0074	-0.0182	0.0741	-0.0143	-0.0395	-0.0144	0.0057	-0.0023	-0.6420
DFI	-0.0017	-0.0109	-0.0040	0.0461	-0.0013	0.0092	-0.0123	0.0327	0.0092	-0.0274	-0.0139	-0.0006	-0.0005	-0.6620
F/P	-0.0004	0.0039	0.0000	-0.0108	0.0057	0.0025	-0.0119	0.0588	-0.0226	-0.0240	0.0085	-0.0030	-0.0015	0.1420
DM	-0.0012	-0.0079	-0.0040	0.0297	0.0010	0.0143	-0.0091	0.0211	0.0010	-0.0176	-0.0116	0.0004	-0.0001	-0.471
FL	0.0001	0.0042	0.0049	-0.0199	-0.0024	-0.0046	0.0285	-0.0737	-0.0067	0.0460	0.0068	0.0009	0.0023	0.592
PD	-0.0005	-0.0001	0.0045	-0.0118	-0.0026	-0.0024	0.0164	-0.1278	0.0474	0.0535	0.0024	0.0026	0.0017	0.451
SI	0.0011	0.0035	-0.0017	-0.0065	0.0020	-0.0002	0.0030	0.0937	-0.0646	-0.0257	0.0039	-0.0026	-0.0004	0.036
PW	0.0000	0.0031	0.0052	-0.0215	-0.0024	-0.0043	0.0224	-0.1167	0.0283	0.0586	0.0055	0.0011	0.0024	0.646
CD	0.0006	0.0096	0.0059	-0.0340	0.0026	-0.0088	0.0103	-0.0161	-0.0134	0.0170	0.0188	-0.0043	0.0001	0.754
PcT	0.0002	0.0010	-0.0033	-0.0021	-0.0013	0.0004	0.0020	-0.0253	0.0130	0.0049	-0.0061	0.0131	-0.0015	-0.087
PI	-0.0001	0.0018	-0.0045	0.0061	0.0022	0.0004	-0.0168	0.0543	-0.0070	-0.0358	-0.0007	0.0051	-0.0039	-0.253

Underlined and bold figures denote direct effects

Residual effect=0.0242

r_g=genotypic correlation

¹B/P=Number of branch per plant, PH= Plant height, SD= Stem diameter, DFI, = Days to flower, F/P= Fruit per plant, DM= Days to maturity, FL= Fruit length, FD= Fruit diameter, SI=Shape index, FW= Fruit weight, CD=Canopy diameter, PcT=Pericarp thickness, PI = Pungency index

Table 4: Phenotypic direct effect (bold face) and indirect effects of various traits on fruit yield per plant of *Capsicum* genotypes studied

Traits ¹	B/P	PH	SD	DFI	F/P	DM	FL	FD	SI	FW	CD	PcT	PI	r _p
B/P	-0.0139	0.0007	0.0011	0.0034	0.0000	0.0009	0.0001	-0.0003	0.0010	0.0002	-0.0013	0.0000	0.0002	-0.0200
PH	-0.0043	0.0022	0.0016	0.0045	0.0000	0.0010	-0.0016	0.0001	0.0006	-0.0012	-0.0097	0.0001	-0.0004	0.4420
SD	-0.0026	0.0006	0.0059	-0.0023	0.0000	-0.0005	0.0016	-0.0007	0.0001	0.0024	0.0025	0.0003	-0.0017	-0.3550
DFI	0.0059	-0.0012	0.0017	-0.0080	0.0000	-0.0014	0.0023	-0.0006	-0.0007	0.0031	0.0106	-0.0001	-0.0008	-0.6330
F/P	0.0015	0.0004	-0.0003	0.0019	-0.0001	-0.0004	0.0021	-0.0010	0.0020	0.0026	-0.0063	-0.0003	-0.0022	0.1870
DM	0.0049	-0.0009	0.0012	-0.0045	0.0000	-0.0025	0.0017	-0.0004	-0.0003	0.0018	0.0089	0.0000	-0.0002	-0.4090
FL	0.0001	0.0006	-0.0015	0.0030	0.0000	0.0007	-0.0061	0.0013	0.0005	-0.0050	-0.0057	0.0001	0.0032	0.5370
FD	0.0015	0.0001	-0.0017	0.0019	0.0001	0.0004	-0.0033	0.0024	-0.0041	-0.0060	-0.0019	0.0003	0.0024	0.4350
SI	-0.0024	0.0002	0.0001	0.0008	0.0000	0.0001	-0.0005	-0.0016	0.0061	0.0026	-0.0029	-0.0003	-0.0006	0.0360
FW	0.0003	0.0004	-0.0021	0.0036	0.0001	0.0007	-0.0045	0.0021	-0.0024	-0.0067	-0.0045	0.0002	0.0035	0.6160
CD	-0.0011	0.0012	-0.0009	0.0050	-0.0001	0.0013	-0.0021	0.0003	0.0011	-0.0018	-0.0168	-0.0004	0.0003	0.6470
PcT	-0.0003	0.0002	0.0011	0.0005	0.0000	0.0000	-0.0004	0.0004	-0.0010	-0.0006	0.0037	0.0017	-0.0022	-0.0440
PI	0.0004	0.0001	0.0017	-0.0010	-0.0001	-0.0001	0.0033	-0.0010	0.0006	0.0040	0.0009	0.0006	-0.0059	-0.2390

Underlined and bold figures denote direct effects

r_p = Phenotypic correlation;

Residual effect=0.0036

¹B/P=Number of branch per plant, PH=Plant height, SD= Stem diameter, DFI= Days to flower, F/P=Fruit per plant, DM= Days to maturity, FL= Fruit length, FD=Fruit diameter, SI= Shape index, FW= Fruit weight, CD= Canopy diameter, PcT=Pericarp thickness, PI = Pungency index

at any one of the traits will automatically affect other associated traits. The results of present study are in agreement with reports of [24]. Even though the work done by [15] revealed that there was a positive correlation between plant height and days to flowering, in present study traits such as branch per plant, days to flowering, plant height, days to maturity, stem diameter, fruit length, fruit diameter, single fruit weight, canopy diameter, number of fruits per plant, pungency index and shape index were negatively correlated. Hence an increase in one of these traits decreased the level of the others.

In order to determine the relative magnitude of various traits contributing to correlation, the observed genotypic and phenotypic correlations were further portioned into their components by path coefficient analysis [25]. Fruit yield, being the complex out come of various traits, was considered to be the resultant variable and the rest of the variables viz, number of branch per plant, plant height, stem diameter, days to flower, fruit per plant, days to maturity, fruit length, fruit diameter, shape index, fruit weight, canopy diameter, pericarp thickness and Pungency index were the causal variables. It was observed that each of these traits did influence fruit yield directly or indirectly (Table 3 and 4).

At genotypic level the path analysis revealed that fruit weight had maximum positive direct effect (0.0586) followed by days to flower (0.0461), canopy diameter (0.0188), plant height (0.0158), days to maturity (0.0143), pericarp thickness (0.0131), fruit per plant (0.0057) and primary branch per plant (0.032) (Table 3). This seems to suggest that these traits are good contributors to average fruit yield per plant. These results are in agreement with the findings of [26].

Path analysis at genotypic level also revealed high and positive direct effect of fruit weight, fruit length, canopy diameter, plant height and fruit per plant on average fruit yield per plant which was not counteracted by their respective indirect negative effects leading to positive genotypic correlation. This implied true relationship between these traits and average fruit yield per plant suggesting the direct selection for such traits to improve average fruit yield per plant would be effective. Similar observations were also recorded by [24].

High and positive indirect effects by shape index through fruit diameter (0.0937), canopy diameter (0.0039), plant height (0.0035), fruit length (0.0030), fruit per plant (0.0020) and primary branch per plant (0.0011) could also have counteracted with its own high direct negative effect (-0.0646) rendering the overall correlation with average fruit yield per plant positive ($r_g=0.036$). Besides

these, the possibilities that positive indirect effects by fruit diameter through fruit weight (0.0535) shape index (0.0474), fruit length (0.0164), stem diameter (0.0045), pericarp thickness (0.0026), canopy diameter (0.0024) and pungency index (0.0017) counteracting with its own high and negative direct effect (-0.1278) leading to positive genotypic correlation ($r_g=0.451$) with average fruit yield per plant (Table 3).

In this study, the indirect effects of shape index and fruit diameter played a more important role in determining average fruit yield per plant and hence need due consideration in improvement program.

Negative direct effects were exerted on average fruit yield per plant by fruit diameter (-0.1278), shape index (-0.0646), stem diameter (-0.0077) and pungency index (-0.0039). Fruit diameter, shape index and fruit per plant revealed direct positive genotypic correlation coefficient $r_g=0.451$, $r_g=0.036$, $r_g=0.142$, respectively with average fruit yield per plant (Table 3). In view of this, it is reasonable to conclude that by keeping other character constant, decreasing the magnitude of either, fruit diameter or shape index or fruit per plant would bring about an increase in average fruit yield per plant in *Capsicum* genotypes.

High indirect negative effects of days to flower on average fruit yield per plant were exerted through fruit weight (-0.0274), canopy diameter (-0.0139), fruit length (-0.0123) plant height (-0.0109), primary branch per plant (-0.0017) and stem diameter (-0.0040), which counteracted with its own high and positive direct effect (0.0461) this rendering the overall correlation coefficient to be negative ($r_g=-0.6620$). In order to utilize the high direct effect exerted on average fruit yield per plant by (0.0461); its negative indirect effects needs to be nullified so as to avoid its undesirable indirect effects through appropriate breeding strategies.

At phenotypic level the path analysis revealed that shape index had maximum positive direct effect (0.0061) followed by fruit diameter (0.0024) and plant height (0.0022) (Table 4). These traits could be considered as main component of selection in breeding program for obtaining higher average fruit yield per plant.

Other traits that showed positive direct effect on average fruit yield per plant were stem diameter (0.0059) and pericarp thickness (0.0017). Stem diameter and pericarp thickness had negative association with average fruit yield per plant, but they showed positive direct effect on average fruit yield per plant (Table 4); indicating that directly influenced average fruit yield per plant via positive correlation; days to flowering (0.0017), pungency index (0.0017), days to maturity (0.0012), pericarp

thickness (0.0011) and shape index (0.0001), while pericarp thickness directly influenced average fruit yield per plant via pungency index (0.0006). These net effects in the system influenced through these characters counterbalanced each other making the correlation of average fruit yield with the two traits negative.

The data on phenotypic path analysis indicated that canopy diameter (-0.0168) had maximum negative direct effect followed by primary branch per plant (-0.0139), days to flowering (-0.0080), fruit weight (-0.0067), fruit length (-0.0061), pungency index (-0.0059), days to maturity (-0.0025) and fruit per plant (-0.0001) (Table 4).

Canopy diameter, fruit weight, fruit length and fruit per plant revealed positive phenotypic correlation $r_p=0.647$, $r_p=0.616$, $r_p=0.537$, $r_p=0.187$, respectively with average fruit yield per plant (Table 4) which implies that improving the above traits through selection would result in an increase in average fruit yield per plant in *Capsicum*.

Favorable positive indirect effect on average fruit yield per plant was observed by canopy diameter through days to flowering (0.0050), days to maturity (0.0013), plant height (0.0012) and pungency index (0.0003) could also have counteracted with its own high direct negative effect (-0.0168) rendering the overall correlation with average fruit yield per plant positive ($r_g=0.6470$). In addition to these, the possibility that positive indirect effect by fruit weight through days to flowering (0.0036), pungency index (0.0035), fruit diameter (0.0021), days to maturity (0.0007), plant height (0.0004), primary branch per plant (0.0003), fruit per plant (0.0001) (Table 4) counteracting with its own high and negative direct effect (-0.0067), leading to positive phenotypic correlations ($r_g=0.616$) with average fruit yield per plant.

According to the results of this study, canopy diameter and fruit weight played a more important role in determining average fruit yield per plant and hence need due consideration in improvement program.

High indirect negative effects of stem diameter on average fruit yield per plant were exerted through primary branch per plant (-0.0026), days to flowering (-0.0023), pungency index (-0.0017), fruit diameter (-0.0007), days to maturity (-0.0005), which counteracted with its own high and positive direct effect (0.0059), thus rendering the overall correlation coefficient to be negative ($r_g=-0.3550$). In order to utilize the high direct effect exerted on average fruit yield per plant (0.0059) by its negative indirect effects, need to be nullified as to avoid its undesirable indirect effects through appropriate breeding strategies. The study showed that there is association between the different attributes of the capsicum genotypes under

investigation. With regards to the yield per plant, canopy diameter, fruit weight and fruit length have a strong association and can be used as a key trait for selection. Breeders will find this result in an attempt to improve the productivity of the crop.

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