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Correlation and Path Coefficient Analysis of Hot Pepper (*Capsicum annuum* L.) Genotypes for Yield and its Components in Ethiopia

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Abstract

Character correlation and path coefficient analysis study was conducted using 55 hot pepper genotypes with the objectives to assess the nature of character correlation at phenotypic and genotypic levels and direct and indirect effects of traits on yield and yield components. The experiment was conducted during 2015-20116 at six environments in Southern Ethiopia using RCBD with three replications. The result revealed that, in most cases, the genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients indicating their inherent association of traits and hence more advantageous for breeding purposes. Phenotypic and genotypic correlation further confirmed that branch number per plant, fruit number per plant, fruit length, fruit diameter and fruit weight were the most important traits for improving the genotypes for higher fruit yield and may be applied for selection in hot pepper productivity. Path analysis revealed that the maximum direct effect on fresh fruit yield was exerted by dry weight (0.6686), average fruit length (0.2185), fruit diameter (0.2085) and average fruit number per plant (0.1444), Thus, on the basis of current result, fruit length, diameter and fruit number per plant could be the most important yield component characters which might be selected for yield improvement while the converse was true with plant height and stem girth (diameter) at phenotypic level.

Keywords: Hot pepper; Correlation; Fruit yield; Path coefficient

Introduction

Hot pepper (*Capsicum annuum* L.), in the family *Solonaceae* (2n=24), is an important spice and vegetable crop [1] which covers 67.98% of all the area under vegetables produced in Ethiopia [2]. The country have been producing 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 the source of income particularly for smallholder producers and also contributes significantly to house hold food security in many parts of rural Ethiopia [3]. When breeders attempt to improve plants, they are generally interested in upgrading several attributes of the phenotype simultaneously. The extent to which these characters are correlated will, therefore, influence the breeder's success [4]. Moreover, development of high yielding cultivars requires knowledge of the existing genetic variation and the extent of association among yield contributing characters (Table 1). Since yield is a complex trait governed by a large number of component traits it is imperative to know the interrelationship between yield and its component traits to arrive at an optimal selection index for improvement of yield [5]. Therefore, selection should be done based on these component characters after assessing their association with the yield.

The correlation between two variables indicates only that the variables are associated; it does not imply a cause and effect relationship [6]. To describe the phenotypic correlation values further, path coefficient analysis was done to identify characters having significant direct and indirect effects on fruit yield [7]. In such situation, the correlation coefficient may be confounded with indirect effect due to common association inherent in trait interrelationships. Path coefficient analysis has proven useful in providing additional information that describes a priori cause-and-effect relationships, such as yield and yield components [8]. Further, path analysis permits the separation of direct effect from indirect effect through other related characters by portioning the correlation coefficients [4,9]. Some researcher argue that Ethiopia is believed to be one of the center of diversity of hot pepper due to diversity of the existing germplasm in diverse growing agroecological zones in the country. Moreover, the crop is becoming high value cash crop since its demand is extremely growing locally and internationally. Despite its potential, existing variability for improvement works and current demand, the research conducted under Ethiopian condition is almost nil regarding traits association and yield component traits (Table 2). Therefore, the objectives of this study was to assess the nature of character correlation at phenotypic and genotypic level and direct and indirect effects of traits on yield and yield components.

S No.	Genotype	Origin	Code
1	Melka awaze	Ethiopia	G_1
2	Marako fana	Ethiopia	G_2
3	Melka shote	Ethiopia	G_3
4	Melka zala	Ethiopia	G_4
5	AVPP9813	Asian	G_5
6	AVPP0206	Asian	G_6
7	AVPP0514	Asian	G_7
8	AVPP0512	Asian	G_8
9	AVPP0105	Asian	G_9
10	AVPP59328	Asian	G_{10}
11-55	F_1-Hybrids	Cross	G_{11}-G_{55}

Table 1: Hot pepper genotypes used in the study.

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Source of variation	Degree of freedom	Mean square of cross product	Expected mean square of product
Location	L-1	$MSCP_{Lxy}$	$б_{exy}$+r $б_{gLxy}$+g $б_{rxy}$+rg $б_{Lxy}$
Replication /Loc	L(r-1)	$MSCP_{rxy}$	$б_{exy}$+g $б_{rxy}$+r $б_{gLxy}$
Genotypes	g-1	$MSCP_{gxy}$	$б_{exy}$+r $б_{gLxy}$+rL $б_{gxy}$
Geno X Loc	(g-1) (L-1)	$MSCP_{gLxy}$	$б_{exy}$+r$б_{gLxy}$
Error	(r-1)(g-1)	$MSCP_{exy}$	$б_{exy}$

Table 2: Analysis of covariance.

Materials and Methods

Description of the study areas

The field experiment was conducted at six different environments (Wolaita Soddo, Alaba, and Humbo locations) that represent major pepper growing areas in the South Ethiopia for two cropping seasons in 2015 and 2016.

Treatments, experimental design and field management

The experiment consisted of 10 parents (six introduced from AVRDC (Asia) and four Ethiopian released varieties obtained from Melkasa Agricultural Research Center). These parents were crossed in half diallel mating design to give 45 F_1 hybrids. Thus, parents and hybrids with a total of 55 genotypes were used in the study. 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. Each plot had 2 rows and 10 plants per row. The total plot area was 1.4 m × 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

Data were collected from randomly taken ten 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], Total fruit dry weight [kg/ha], and Oleoresin content [w/w%].

Statistical analysis

Correlation among traits: Correlation was calculated to investigate the degree of relationship between phenotypic and genotypic variances and also to test the degree of character association between parameters or traits studied.

$$\sigma_{gLxy} = \frac{MSCP_{gLxy} - MSCP_{Lxy}}{r}$$

$$\sigma_{gxy} = \frac{MSCP_{gxy} - MSCP_{gLxy}}{rL}$$

Where, r=Number of replications, g=Number of genotypes,

$MSCP_{rxy}$=replication mean square of cross product for traits x and y,

$MSCP_{gxy}$=genotypic mean square of cross product for traits x and y,

$MSCP_{exy}$=environmental mean square of cross product for traits x and y,

6_{exy}=$MSCP_{exy}$;

According to Hartl and Jones, to test significance of phenotypic correlation coefficient, a quantity t can be calculated: $t = \frac{r}{\sqrt{(1-r^2)/(g-2)}}$

Where 'r' is the absolute value of the correlation coefficient and 'g' is number of genotypes.

If t is greater than the value given on the table using g^{-2} degrees of freedom, r can be considered significantly different from zero. The significance of genotypic correlation coefficient (r_g), can be tested by t-value calculated

as: $t = \frac{r_g}{SEg}$ where, SE_g-Standard error of r_g

$$SE = \sqrt{\frac{1-r_g^2}{2h_x^2 h_y^2}}$$

Where, h^2 × and h^2y-heritability of traits X and Y, respectively.

The calculated t value for each genotypic correlation coefficient was tested against tabulated t-value at (g^{-2}) degrees of freedom.

Path coefficient analysis: The advantage of path analysis is that it provides information on the direct and indirect contribution of causal factors to the effect if the cause and effect relationship is well defined. Path coefficient can be defined as the ratio of standard deviation of the effect due to a given cause to the total standard deviation of the effects. If Y is the effect and X_1 is the cause, the path coefficient for the path from cause X_1 to effect Y is σ_x/σ_y [10].

It is computed by the following general formula:

$r_{ij}=p_{ij}+\Sigma\, r_{ij}\, p_{kj}$

Where, r_{ij} is the mutual association between the independent variable (i) and the dependent variable (j) as measured by correlation coefficient.

p_{ij} is component of direct effect of the independent variable(i) on the dependent variable (j) as measured by correlation coefficient.

$\Sigma\, r_{ij}\, p_{kj}$-is the summation of components of indirect effects of a given independent variable(i) on the dependent variable (j) via all other independent variables (k).

The residual effect (U) implies the unexplained variation of the dependent variable that is not accounted by path coefficient, was calculated using the formula:

$$U = \sqrt{1-R^2}$$

Where, $R^2=\Sigma r_{ik} p_{kj}$

Results and Discussion

Phenotypic and genotypic correlation coefficients

The phenotypic and genotypic correlation coefficients of traits studied for 55 hot pepper genotypes at 6 different environments were presented in Table 3.1. The result revealed that in most cases the genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients indicating their inherent association of traits and hence more advantageous for breeding purposes. Similarly, refs. [5,11,12] reported that magnitude of genotypic correlation

Traits	Ph	CW	BN	SD	FN	FL	FD	Tic	SN	yld	Dw
Ph	**1.00**	0.735**	0.369**	0.216ns	0.045ns	0.027ns	0.195ns	0.089ns	0.321**	0.146ns	0.171ns
CW	0.672ns	**1.00**	0.479**	0.187ns	0.086ns	0.214ns	0.327**	0.330**	0.281**	0.250*	0.147ns
BN	0.353**	0.476**	**1.00**	0.638**	0.468**	0.140ns	0.125ns	0.120ns	0.116ns	0.354**	0.405**
SD	0.229ns	0.200ns	0.599ns	**1.00**	0.434**	0.358**	0.052ns	0.217ns	0.019ns	0.374**	0.451**
FN	0.113ns	0.118ns	0.445**	0.424**	**1.00**	0.040ns	-0.211ns	-0.15ns	-0.011ns	0.482**	0.649**
FL	0.036ns	0.203ns	0.133ns	0.338**	0.045ns	**1.00**	0.322**	0.417**	-0.099ns	0.544ns	0.325**
FD	0.121ns	0.277*	0.095ns	0.048ns	-0.184ns	0.311*	**1.00**	0.706**	0.545ns	0.566**	0.294*
Tic	0.012ns	0.239*	0.087ns	0.195ns	-0.119ns	0.388**	0.654ns	**1.00**	0.287*	0.525ns	0.243ns
SN	0.219ns	0.207ns	0.083ns	0.002ns	-0.005ns	-0.090ns	0.504ns	0.238*	**1.00**	0.239ns	0.081ns
yld	0.139ns	0.249*	0.335**	0.369**	0.497**	0.496**	0.512ns	0.438**	0.180ns	**1.00**	0.860**
DW	0.146ns	0.145ns	0.372**	0.430**	0.641ns	0.288*	0.247*	0.183ns	0.033ns	0.863**	**1.00**

**=statistically highly significant at 1%; *= statistically significant at 5% Probability; Ph=plant height(cm); Cw=Canopy width (cm); Bn=Branch number per plant; SD=stem diameter(cm); FN=Fruit number per plant; FL=average fruit length(mm); FD= average fruit diameter(mm); Tic=fruit flesh thickness (mm); SN=Seed number per fruit; yld=fresh fruit yield(kg/ha); and Dw=Fruit/pod dry weight(kg/ha)

Table 3.1: Genotypic (above) and phenotypic (below diagonal) correlation coefficient of selected traits for 55 hot pepper genotypes tested at 6 environments, 2015 to 2016.

coefficients in general was higher than the phenotypic correlation coefficients for traits studied on Chilli genotypes. Again ref. [13] noted the higher genotypic correlation coefficient than the phenotypic ones, which showed the inherent associations between various characters in Ethiopian Capsicums. The current result illustrated correlation coefficient range of -0.211 to 0.86 and -0.119 to 0.863 at genotypic and phenotypic levels, respectively. The result further illustrated that plant height was non-significantly correlated with most of the traits at phenotypic level except branch number (0.353) while at genotypic level it was positively and significantly correlated with canopy width (0.735), branch number per plant (0.369) and seed number per pod (0.321). However, plant height had non significant correlation with both fresh and dry pod yield at genotypic and phenotypic levels (Table 3.1).

The study confirmed the association of branch number and canopy width was significant at phenotypic (0.476) level. Furthermore, branch number had positively significant association with fruit yield (0.335) and dry weight (0.372) at phenotypic level and 0.354 and 0.405 at genotypic, respectively. Again branch number was significantly correlated with fruit number at both phenotypically (0.445) and genotypically (0.468). Fruit length depicted positive significant correlation at both phenotypic and genotypic levels with fruit width but it had positively significant association only at phenotypic level with fresh fruit yield. Some of earlier reports also show the same findings. Singh [5] reported highest phenotypic correlation between fruit length and fruit girth. Zhani [14] observed positive correlation between fruit weight and length.

Although non significant, fruit number showed negative association with fruit diameter and fruit thickness at both levels that might indicate antagonistic effects of gene actions which could not be bred simultaneously. This agrees with finding reported [7], where Fruit length had significant negative correlation with fruit width. Fruit number and fruit yield were associated significantly and positively at phenotypic (0.497) and at genotypic (0.482) level. Fruit number again genotypically positively associated with dry fruit weight. Generally, the current result exhibited that fresh pod yield had significant positive genotypic and phenotypic correlations with canopy width, branch number, stem diameter and fruit number while only at genotypic level with fruit diameter and phenotypically with fruit length. Dry weight also had almost similar association. Hence, these traits were found to be yield contributing characters towards increased fruit yield and dry weight. This also might indicate complementary gene actions for the traits which could be selected simultaneously. Therefore, branch number per plant, number of fruit per plant, fruit length, fruit diameter and fruit weight were the most important traits for improving the genotypes for higher fruit yield and may be applied for selection in hot pepper productivity. More of the same result was reported in ref. [13] who found high positive genotypic correlation of fruit yield with the number of fruits per plant and pericarp thickness. Usman [11] reported positive and highly significant phenotypic and genotypic associations of fruit length, fruit weight and number of fruits on pepper. Rohini and Lakshmanan [15] found positive and significant correlation of fresh fruit yield per plant with number of branches per plant, fruit length, fruit girth, individual fruit weight and number of fruits per plant. Earlier workers [16-18] also reported more or less same conclusion. Lavinia [19] confirmed the existence of strong correlation between fruit weight to fruit length and diameter and also number and weight of fruits per plant. They further concluded selection made towards increasing length and diameter can be used as indirect selection to obtain higher values of fruit weight.

Path coefficient analysis

The results of phenotypic and genotypic path coefficient analysis was presented in Table 3.2. and 3.3, respectively. Path analysis revealed that the maximum direct effect on fresh fruit yield was exerted by dry weight (0.6686), average fruit length (0.2185), fruit diameter (0.2085) and average fruit number per plant (0.1444) whereas plant height (-0.0173) and stem diameter (-0.0932) depicted negative direct effect and also negative indirect effects though the magnitude is relatively low (Table 3.2). Thus, on the basis of current result, fruit length, diameter and fruit number per plant could be the most important yield component characters which might be selected for yield improvement while the converse was true with plant height and stem girth (diameter) at phenotypic level. This result was consolidated in ref. [15] who reported the direct effect of number of fruits per plant and number of branches per plant on yield and, which could be considered as major yield components and selection indices for improvement. Kumar et al. [18,20,21] indicated that more fruits per plant were highly reliable component on fruit yield. Yatung et al. [22] found number of fruit per plant, fruit weight and number of seed per fruit were the most important traits affecting fruit yield per plant. This investigation also illustrated seed number per fruit and fruit pericarp thickness had positive direct effect but their indirect effect was more magnified through fruit diameter phenotypically indicating fruit diameter was important character both directly and indirectly for improvement and selection of pod yield in hot pepper. Sarkar et al. [7] noticed characters like seeds/fruit, fruit length and fruit width showed direct positive effect on fruit yield with low magnitudes but plant canopy width had negative direct effect on yield. Shimelis et al. [13] also confirmed similar finding.

The results of genotypic path analysis substantiated more of similar effects to that of phenotypic path analysis (Table 3.3). The analysis revealed the existence of positive direct effect of dry weight (0.5685), fruit length (0.2697), fruit number per plant (0.2272) and fruit diameter (0.2141) on fresh fruit yield. Moreover, the magnitude of genotypic direct effects exerted by these yield component characters were relatively higher than their respective phenotypic effects further substantiated the importance and close association of characters to improve yield or to use as selection indices. The result also illustrated that canopy width and stem diameter had exerted negative effects directly and indirectly through other characters that might lead to conclude in such a way that these traits could not be used for yield improvement in hot pepper production. The earlier worker [23] reported the high direct genotypic effect of fruit number per plant on fruit yield whereas plant spread had negative direct effect.

Fruit pericarp thickness showed positive direct effect on fruit yield but its indirect is exerted more by dry weight, fruit length and width. Hence, fruit length and diameter could be considered as characters of indirect selection genotypically to improve yield on hot pepper. In another scenario, both fruit diameter and length exerted their indirect effect via fruit thickness on fruit yield indicating the importance of fruit thickness for indirect selection. Patil [23] found at both phenotypic and genotypic level, the number of fruits per plant recorded positive direct effects. High direct and positive effect of number of fruit per plant [24] again number of fruit per plant and fruit diameter [25,26] on fruit yield had been reported. Kadwey [27] also investigated number of fruits per plant, number of primary branches per plant had positive direct Whereas, negative direct effect was recorded by plant height on fruit yield at genotypic level and fruit width positive indirect effect on green fruit yield via number of fruits per plant.

Conclusion

The phenotypic and genotypic correlation coefficients of traits revealed that, in most, cases the genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients indicating their inherent association of traits and hence more advantageous for breeding purposes. Fruit number and fruit yield were associated significantly and positively at phenotypic (0.497) and genotypic (0.482) level. Fruit number again genotypically positively associated with dry fruit weight. Generally, the current result exhibited

	PH	Cw	BN	SD	FN	FL	FD	TIC	SN	DW	r_P(yld)
PH	**-0.0173**	0.0148	0.0038	-0.0213	0.0164	0.0079	0.0252	0.0014	0.0099	0.0977	0.1385
CW	-0.0116	**0.022**	0.0052	-0.0186	0.017	0.0443	0.0578	0.0271	0.0094	0.0967	0.2493
BN	-0.0061	0.0105	**0.0109**	-0.0558	0.0643	0.0291	0.0199	0.0098	0.0038	0.2486	0.335
SD	-0.004	0.0044	0.0065	**-0.0932**	0.0613	0.0738	0.0101	0.0221	0.0001	0.2875	0.3686
FN	-0.002	0.0026	0.0048	-0.0395	**0.1444**	0.0098	-0.0384	-0.0135	-0.0002	0.4288	0.4968
FL	-0.0006	0.0044	0.0014	-0.0314	0.0064	**0.2185**	0.0648	0.0439	-0.0041	0.1929	0.4962
FD	-0.0021	0.0061	0.001	-0.0045	-0.0266	0.0679	**0.2085**	0.0742	0.0228	0.165	0.5123
TIC	-0.0002	0.0052	0.0009	-0.0182	-0.0172	0.0847	0.1364	**0.1133**	0.0108	0.1223	0.438
SN	-0.0038	0.0045	0.0009	-0.0002	-0.0006	-0.0198	0.1051	0.027	**0.0453**	0.0218	0.1802
DW	-0.0025	0.0032	0.004	-0.0401	0.0926	0.063	0.0515	0.0207	0.0015	**0.6686**	0.8625
Residual=0.325											

Ph=plant height(cm); Cw=Canopy width (cm); Bn=Branch number per plant; SD=stem diameter(cm); FN=Fruit number per plant; FL=average fruit length(mm); FD= average fruit diameter(mm); Tic=fruit flesh thickness (mm); SN=Seed number per fruit; yld=fresh fruit yield(kg/ha); Dw=Fruit/pod dry weight(kg/ha); rP(yld)=yield phenotypic correlation coefficient

Table 3.2: Estimates of phenotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on fresh pod yield of 55 hot pepper genotypes grown at six environments, 2015 to 2016.

	PH	Cw	BN	SD	FN	FL	FD	TIC	SN	DW	r_g(yld)
PH	**0.0186**	-0.0488	0.0157	-0.0323	0.0103	0.0072	0.0418	0.0168	0.0198	0.0974	0.1465
CW	0.0136	**-0.0664**	0.0204	-0.028	0.0194	0.0576	0.0701	0.0622	0.0174	0.0837	0.2500
BN	0.0068	-0.0318	**0.0425**	-0.0954	0.1064	0.0379	0.0269	0.0226	0.0072	0.2305	0.3536
SD	0.004	-0.0124	0.0271	**-0.1494**	0.0986	0.0965	0.0114	0.0408	0.0012	0.2566	0.3744
FN	0.0008	-0.0057	0.0199	-0.0649	**0.2272**	0.0107	-0.0451	-0.0289	-0.0007	0.3687	0.4820
FL	0.0005	-0.0142	0.0059	-0.0535	0.009	**0.2697**	0.0689	0.0786	-0.0061	0.1846	0.5434
FD	0.0036	-0.0217	0.0053	-0.0078	-0.0479	0.0868	**0.2141**	0.1331	0.0336	0.167	0.5661
TIC	0.0017	-0.0219	0.0051	-0.0324	-0.0349	0.1125	0.1513	**0.1884**	0.0177	0.138	0.5255
SN	0.0059	-0.0187	0.0049	-0.0029	-0.0026	-0.0267	0.1167	0.054	**0.0617**	0.0463	0.2386
DW	0.0031	-0.0098	0.0172	-0.0674	0.1474	0.0875	0.0629	0.0457	0.005	**0.5685**	0.8601
Residual = 0.273											

Ph=plant height(cm); Cw=Canopy width (cm); Bn=Branch number per plant; SD=stem diameter(cm); FN=Fruit number per plant; FL=average fruit length(mm); FD= average fruit diameter(mm); Tic=fruit flesh thickness (mm); SN=Seed number per fruit; yld=fresh fruit yield(kg/ha); Dw=Fruit/pod dry weight(kg/ha); r_g(yld)=yield genotypic correlation coefficient

Table 3.3: Estimates of genotypic direct effects (bold and diagonal) and indirect effects (off-diagonal) of traits via other independent traits on fresh pod yield of 55 hot pepper genotypes grown at six environments, 2015 to 2016.

that fresh pod yield had significant positive genotypic and phenotypic correlations with canopy width, branch number, stem diameter and fruit number while only at genotypic level with fruit diameter and phenotypically with fruit length. Dry weight also had almost similar association. Therefore, branch number per plant, number of fruit per plant, fruit length, fruit diameter and fruit weight were the most important traits for improving the genotypes for higher fruit yield and may be applied for selection in hot pepper productivity.

Path analysis revealed that the maximum direct effect on fresh fruit yield was exerted by dry weight (0.6686), average fruit length (0.2185), fruit diameter (0.2085) and average fruit number per plant (0.1444). Thus, on the basis of current result, fruit length, diameter and fruit number per plant could be the most important yield component characters which might be selected for yield improvement while the converse was true with plant height and stem girth (diameter) at phenotypic level. The results of genotypic path analysis substantiated more of similar effects to that of phenotypic path analysis.

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