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Estimation of correlation and path analysis for growth, yield and yield traits for chilli germplasm

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Abstract

A comprehensive investigation was conducted on forty chilli genotypes to estimate correlation coefficients and path analysis for growth, yield and quality parameters. The study revealed significant associations among various morphological, yield and biochemical traits. Phenotypic correlation coefficients were generally higher than genotypic correlation coefficients, indicating environmental influence on trait expression. Fruit yield per plot demonstrated strong positive correlations with plant height (0.4264P, 0.4428G), number of primary branches (0.3181P, 0.3286G), average fruit weight (0.7201P, 0.7420G), fruit length (0.3762P, 0.3785G), and oleoresin content (0.3209P, 0.3246G). Path coefficient analysis at both phenotypic and genotypic levels revealed that fruit yield per plot exhibited the highest positive direct effect (0.9859P, 1.0075G) on fruit yield per plant, followed by fruit length, duration of crop, and days to first fruiting. The residual effects were 0.0832 at phenotypic level and 0.039 at genotypic level, indicating that the selected traits adequately explained the variability in fruit yield. The positive associations of biochemical parameters with yield indicate the feasibility of simultaneous improvement for both yield and quality attributes. These findings provide valuable insights for selection strategies in chilli breeding programs aimed at yield improvement.

Keywords: Chilli, correlation coefficient, path analysis, yield traits, direct effects, indirect effects

Introduction

Chilli (*Capsicum annum* L.) stands as one of the most economically significant vegetable crops cultivated globally, valued for its culinary applications and medicinal properties. The genetic improvement of chilli for enhanced yield and quality attributes necessitates a thorough understanding of the interrelationships among various plant characters and their direct and indirect contributions to yield. Correlation studies provide insights into the nature and magnitude of association between yield and its component traits, while path coefficient analysis partitions these correlations into direct and indirect effects, facilitating the identification of key selection criteria.

The success of any breeding program depends on understanding the relationships between yield and its contributing factors. While correlation coefficients indicate the direction and magnitude of association between traits, they do not reveal the actual contribution of each character towards yield. Path coefficient analysis, introduced by Wright ^[10] and subsequently adapted for plant breeding by Dewey and Lu ^[4], overcomes this limitation by splitting correlation coefficients into measures of direct and indirect effects through a system of simultaneous equations. This analytical approach enables breeders to identify traits that can be effectively utilized as selection criteria for yield improvement.

In chilli breeding programs, simultaneous consideration of multiple traits is essential as yield is a complex character influenced by numerous morphological, physiological and biochemical components. Understanding the correlation patterns among these traits and their path coefficients helps in formulating effective breeding strategies. The present investigation was undertaken to estimate correlation coefficients at phenotypic and genotypic levels for various yield-contributing traits, determine direct and indirect effects of component characters on fruit yield through path analysis, and identify key traits that can serve as effective selection criteria

for yield enhancement in chilli.

Materials and Methods

Experimental Material

The experimental material comprised forty diverse chilli genotypes collected from different geographical regions. The details of genotypes used in the study are presented in Table 1.

Experimental Design and Observations

The genotypes were evaluated in a randomized block design with three replications during the growing season. Standard agronomic practices were followed to raise a healthy crop. Observations were recorded on randomly selected competitive plants from each replication for nineteen quantitative traits including plant height (cm), number of primary branches per plant, days to 50% flowering, number of flowers per axil, days to fruit set, days to first fruiting, days to first harvest, days to last harvest, duration of crop (days), average fruit weight (g), fruit length (cm), fruit diameter (cm), fruit yield per plant (g), fruit yield per plot (kg), recovery percentage (%), ascorbic acid content (mg/100g), oleoresin content (%), capsanthin content (ASTA units), capsaicin content (%), and chlorophyll content (%).

Correlation Coefficient Analysis

Phenotypic and genotypic correlation coefficients were estimated according to the method suggested by Al-Jibouri *et al.* [1]. The phenotypic correlation coefficient measures the observable association between traits, while the genotypic correlation coefficient reflects the inherent genetic association free from environmental effects.

Path Coefficient Analysis

Path coefficient analysis was conducted following the method outlined by Dewey and Lu [4] to partition the correlation coefficients into direct and indirect effects, with fruit yield per plant as the dependent variable. The direct effects were represented by path coefficients, which measure the direct influence of an independent variable on the dependent variable. Indirect effects were calculated by multiplying the path coefficient of a trait with the corresponding correlation coefficient between that trait and other independent variables. The residual effect was computed to determine how well the causal factors explained the variability in fruit yield per plant.

Results and Discussion

Correlation Studies

Correlation coefficient analysis revealed important associations among yield contributing characters. Phenotypic correlation coefficients were generally higher than the corresponding genotypic correlation coefficients for most trait combinations, indicating environmental influence on trait expression. However, the trends of association remained consistent at both levels, suggesting that selection based on phenotypic correlations would be effective. The phenotypic and genotypic correlation coefficients of various traits with fruit yield per plot are presented in Table 2.

Fruit yield per plot, the principal economic trait, showed significant positive correlations with several morphological and biochemical traits. Plant height exhibited positive and significant correlation with fruit yield per plot at both phenotypic (0.4264) and genotypic (0.4428) levels, indicating that taller plants tend to produce higher yields. This positive association can be

attributed to the fact that taller plants have more nodes available for fruit bearing, resulting in increased yield potential. Similarly, number of primary branches per plant demonstrated positive and significant correlation with fruit yield (0.3181P, 0.3286G), suggesting that plants with more branches provide additional sites for fruit production, thereby contributing to higher overall yield.

Among fruit characters, average fruit weight showed strong positive correlation with fruit yield per plot (0.7201P, 0.7420G), indicating that genotypes with heavier fruits contribute significantly to overall yield. This strong association suggests that selection for increased fruit weight would be an effective strategy for yield improvement. Fruit length (0.3762P, 0.3785G) and fruit diameter (0.5614P, 0.5774G) also exhibited positive and significant associations with yield, reinforcing the importance of fruit size parameters in determining yield potential.

Number of flowers per axil showed positive and significant correlation with fruit yield (0.2926P, 0.3134G), indicating that genotypes producing more flowers per axil have the potential for higher fruit set and consequently higher yields. Recovery percentage demonstrated significant positive correlation (0.3333P, 0.4387G) with fruit yield. Regarding biochemical parameters, oleoresin content displayed positive and significant correlation (0.3209P, 0.3246G), capsanthin content (0.4523P, 0.4573G), capsaicin content (0.3404P, 0.3440G), chlorophyll content (0.4172P, 0.4239G), and ascorbic acid content (0.2258P, 0.2266G) showed positive associations with yield, indicating that simultaneous improvement of both yield and quality is feasible.

Table 1: Phenotypic (P) and Genotypic (G) correlation coefficients of important traits with fruit yield per plot

Trait	Phenotypic (P)	Genotypic (G)
Plant height (cm)	0.4264*	0.4428*
Number of primary branches per plant	0.3181*	0.3286*
Number of flowers per axil	0.2926*	0.3134*
Average fruit weight (g)	0.7201*	0.7420*
Fruit length (cm)	0.3762*	0.3785*
Fruit diameter (cm)	0.5614*	0.5774*
Recovery percentage (%)	0.3333*	0.4387*
Ascorbic acid content (mg/100g)	0.2258*	0.2266*
Oleoresin content (%)	0.3209*	0.3246*
Capsanthin content (ASTA units)	0.4523*	0.4573*
Capsaicin content (%)	0.3404*	0.3440*
Chlorophyll content (%)	0.4172*	0.4239*

* Significant at 5% level

Path Coefficient Analysis

While correlation coefficients indicate the nature and strength of association among characters, they do not provide information about the cause-and-effect relationships. Path coefficient analysis provides a more comprehensive understanding by partitioning the correlation coefficients into components of direct and indirect effects. This analysis helps in identifying the relative importance of each causal factor and reveals the actual pathways through which independent variables influence the dependent variable. In the present study, path coefficient analysis was performed at both phenotypic and genotypic levels with fruit yield per plant as the dependent variable and other yield-contributing traits as independent variables. The direct effects of various component characters on fruit yield per plant are presented in Table 3.

Table 2: Direct effects of component characters on fruit yield per plant

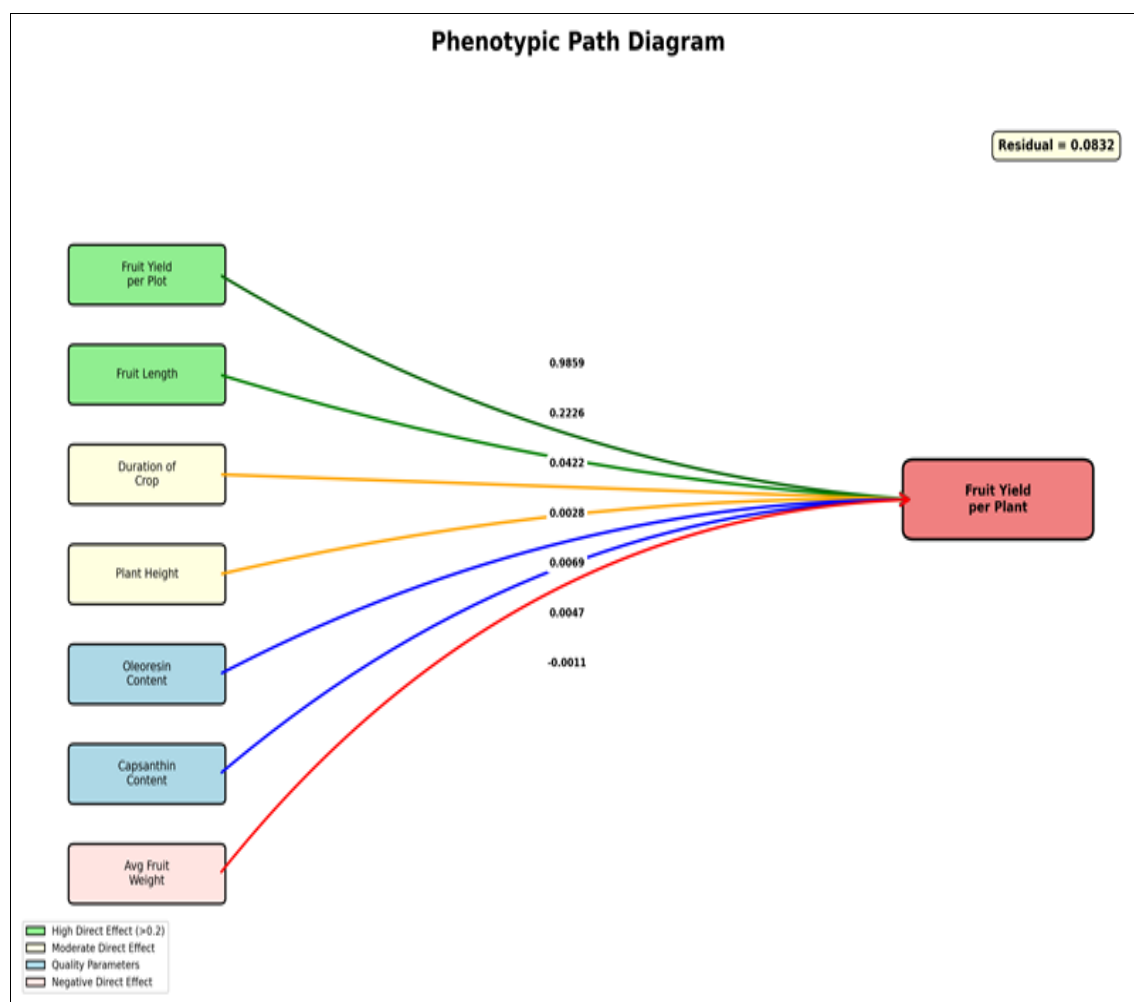
Character	Phenotypic Direct Effect	Genotypic Direct Effect
Plant height (cm)	0.0028	0.0003
Number of primary branches per plant	0.0026	0.0012
Days to 50% flowering	-0.0012	-0.0001
Number of flowers per axil	0.0035	0.0003
Days to fruit set	-0.0013	0.0316
Days to first fruiting	0.0147	0.0051
Duration of crop	0.0422	0.0147
Average fruit weight (g)	-0.0011	-0.0001
Fruit length (cm)	0.2226	0.3164
Fruit diameter (cm)	-0.0011	-0.0520
Fruit yield per plot (kg)	0.9859	1.0075
Recovery percentage (%)	-0.0208	-0.0590
Ascorbic acid content (mg/100g)	0.0017	0.0105
Oleoresin content (%)	0.0069	0.0449
Capsanthin content (ASTA units)	0.0047	0.0139
Capsaicin content (%)	-0.0027	-0.0065
Chlorophyll content (%)	-0.0079	-0.0161
Residual effect	0.0832	0.0390

The path coefficient analysis results revealed that fruit yield per plot exhibited the highest positive direct effect on fruit yield per plant at both phenotypic (0.9859) and genotypic (1.0075) levels. This exceptionally high direct effect indicates that fruit yield per plot is the most important determinant of fruit yield per plant,

suggesting that direct selection for this trait would be highly effective. Among other traits, fruit length showed substantial positive direct effects (0.2226P, 0.3164G) on fruit yield per plant. Duration of crop exhibited positive direct effects (0.0422P, 0.0147G), indicating that genotypes with longer bearing period contribute positively to overall fruit yield.

Plant height (0.0028P, 0.0003G) and number of primary branches per plant (0.0026P, 0.0012G) demonstrated positive direct effects, although the magnitude was relatively small. However, these traits exhibited substantial positive correlations with yield, indicating that their contribution to yield is primarily through indirect effects via other yield components. Among biochemical parameters, oleoresin content exhibited positive direct effects (0.0069P, 0.0449G), with substantially higher effect at genotypic level. Capsanthin content (0.0047P, 0.0139G) and ascorbic acid content (0.0017P, 0.0105G) also showed positive direct effects.

Conversely, fruit diameter, recovery percentage, capsaicin content, and chlorophyll content showed negative direct effects on fruit yield per plant. However, these traits exhibited positive correlations with yield due to their strong positive indirect effects through other components, particularly fruit yield per plot. The residual factor was 0.0832 at phenotypic level and 0.039 at genotypic level, both of low magnitude, indicating that the nineteen characters adequately explained the variability in fruit yield per plant.

**Fig 1:** Phenotypic path diagram showing direct effects of various traits on fruit yield per plant

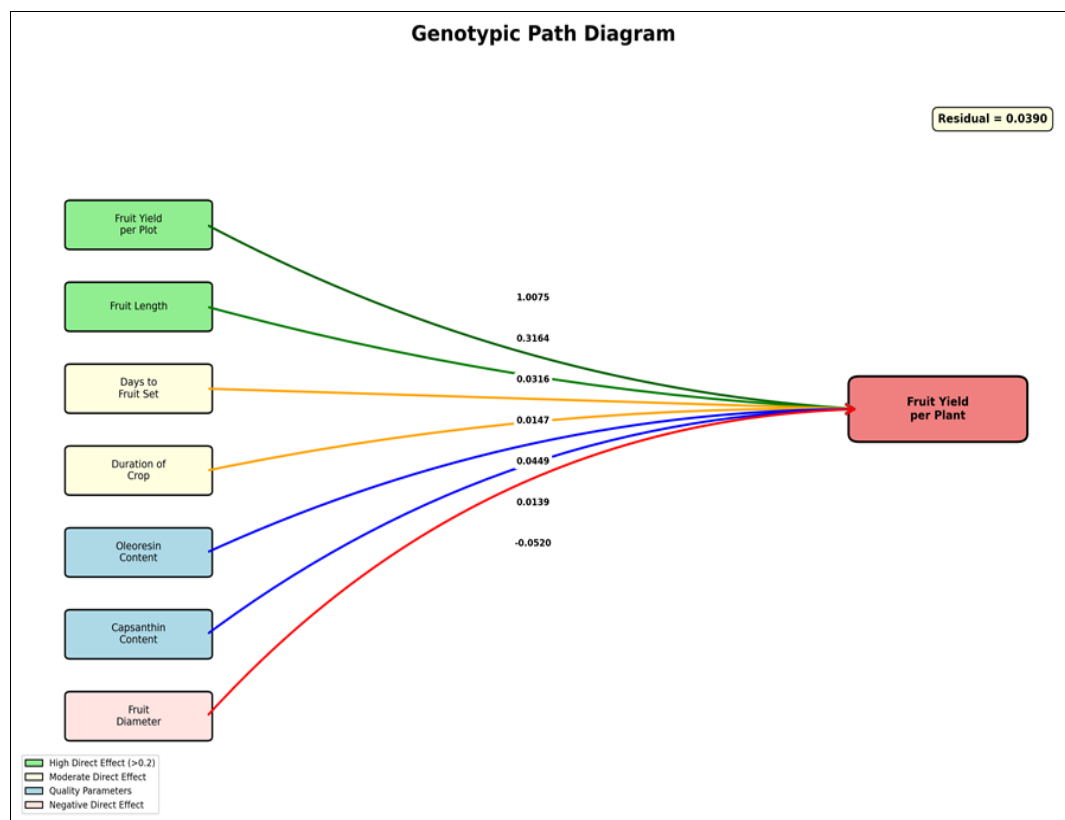


Fig 2: Genotypic path diagram showing direct effects of various traits on fruit yield per plant

Implications for Breeding Strategy

The findings from correlation and path coefficient analysis have important implications for formulating effective breeding strategies in chilli. The results clearly indicate that direct selection based on fruit yield per plot would be most effective for improving fruit yield per plant, given its exceptionally high direct effect. Fruit length, with substantial positive direct effects at both levels, emerges as another important selection criterion.

Although plant height, number of primary branches, average fruit weight, and fruit diameter showed small or negative direct effects, their strong positive correlations with yield indicate significant contribution through indirect effects. The positive direct effects of oleoresin, capsanthin, and ascorbic acid content indicate that improvement of these quality traits would not compromise yield, enabling development of cultivars combining high yield with superior biochemical attributes.

Table 3: List of chilli genotypes used in the study

Tr.No.	Genotype	Source	Tr.No.	Genotype	Source
T ₁	SR-6514	NBPGR, Hyderabad	T ₂₁	LCA-620	RARS, Lam, Guntur, AP
T ₂	IC-528454	NBPGR, Hyderabad	T ₂₂	LCA-625	RARS, Lam, Guntur, AP
T ₃	IC-255896	NBPGR, Hyderabad	T ₂₃	LCA-334	RARS, Lam, Guntur, AP
T ₄	AAT-2	NBPGR, Hyderabad	T ₂₄	IC-572480	NBPGR, Hyderabad
T ₅	SINDHUR	RARS, Lam, Guntur, AP	T ₂₅	EC-399565	NBPGR, Hyderabad
T ₆	NIC-23923	NBPGR, Hyderabad	T ₂₆	EC-399574	NBPGR, Hyderabad
T ₇	WARANGAL CHAPATA	Landrace, Warangal, Telangana	T ₂₇	EC-378688	NBPGR, Hyderabad
T ₈	PSR-7075	NBPGR, Hyderabad	T ₂₈	EC-391083	NBPGR, Hyderabad
T ₉	HIRKANI	PDKV, Akola	T ₂₉	EC-402109	NBPGR, Hyderabad
T ₁₀	IC-572469	NBPGR, Hyderabad	T ₃₀	EC-399567	NBPGR, Hyderabad
T ₁₁	SD-5335	NBPGR, Hyderabad	T ₃₁	PSR-13976	NBPGR, Hyderabad
T ₁₂	ST-13874	NBPGR, Hyderabad	T ₃₂	NIC-19969	NBPGR, Hyderabad
T ₁₃	IC-214966	NBPGR, Hyderabad	T ₃₃	ST-13837	NBPGR, Hyderabad
T ₁₄	PSR-13944	NBPGR, Hyderabad	T ₃₄	NIC-19967	NBPGR, Hyderabad
T ₁₅	PSR-7074	NBPGR, Hyderabad	T ₃₅	PBC-80	NBPGR, Hyderabad
T ₁₆	EC-402101	NBPGR, Hyderabad	T ₃₆	EC-399572	NBPGR, Hyderabad
T ₁₇	PSR-13968	NBPGR, Hyderabad	T ₃₇	SR-3429	NBPGR, Hyderabad
T ₁₈	SRS-13578	NBPGR, Hyderabad	T ₃₈	EC-399575	NBPGR, Hyderabad
T ₁₉	EC-391087	NBPGR, Hyderabad	T ₃₉	EC-401105	NBPGR, Hyderabad
T ₂₀	AVPP-9813	AVRDC, Taiwan	T ₄₀	ST-13875	NBPGR, Hyderabad

Discussion

The present investigation highlights the importance of understanding the interrelationships among yield and its component traits in chilli improvement programmes. Correlation analysis revealed that fruit yield is a complex trait governed by several interdependent morphological and biochemical characters. Similar findings have been reported in earlier studies, where fruit weight, fruit length, plant height, and number of branches were identified as key contributors to yield enhancement.

Genotypic correlations were consistently higher than phenotypic correlations, indicating a strong inherent genetic association among traits and relatively lower environmental influence. This pattern suggests that selection based on phenotypic performance would be reasonably effective for genetic improvement, a conclusion supported by several quantitative genetic studies in *Capsicum* and related crops.

Path coefficient analysis further clarified the nature of these associations by partitioning correlation coefficients into direct and indirect effects. Traits such as fruit length and plant architecture traits exerted appreciable direct effects on yield, while certain quality traits contributed indirectly through their association with fruit size attributes. Comparable results were documented by Dewey and Lu ^[4] and later validated in chilli by multiple authors.

The low residual effect obtained in the present study indicates that the majority of yield variation was adequately explained by the traits included in the model. This reinforces the reliability of the selected characters for inclusion in selection indices aimed at simultaneous improvement of yield and quality. Similar interpretations have been drawn in path analytical studies conducted in solanaceous vegetables.

Conclusion

The present investigation on forty chilli genotypes revealed significant correlations among growth, yield, and quality parameters. Phenotypic correlation coefficients were generally higher than genotypic coefficients, indicating environmental influence, though trends remained consistent at both levels. Fruit yield per plot showed strong positive correlations with plant height, number of primary branches, average fruit weight, fruit dimensions, and multiple biochemical parameters.

Path coefficient analysis revealed that fruit yield per plot exhibited the highest positive direct effect (0.9859P, 1.0075G) on fruit yield per plant, identifying it as the most critical selection criterion. Fruit length showed substantial positive direct effects (0.2226P, 0.3164G), followed by duration of crop and days to first fruiting. Several traits, despite showing negative or negligible direct effects, contributed significantly through positive indirect effects. The low residual effects (0.0832P, 0.039G) confirmed that the analyzed traits adequately explained yield variability.

The positive correlations and direct effects of biochemical parameters indicate the feasibility of simultaneous improvement of yield and quality traits. A breeding strategy integrating direct selection for fruit yield per plot and fruit length, while considering the indirect contributions of plant height, branching, and fruit weight parameters, is recommended. The identified relationships between morphological and biochemical traits with yield can be effectively utilized to develop high-yielding chilli cultivars with enhanced quality attributes.

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