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Comparative analysis of genetic variability, correlation and path coefficient based on fruit yield in egg plant (*Solanum melongena* L.)

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Abstract
The study evaluated eggplant genetic yield performance through its various genotypes which were analyzed using correlation and path coefficient methods. The primary objective required researchers to develop trustworthy selection indices which would enable them to evaluate direct and indirect relationships between yield-related characteristics. The Analysis of Variance (ANOVA) results showed that all measured traits displayed highly significant differences between genotypes which demonstrated that selection process requires substantial genetic variability present in the population.
Genotypic correlation coefficients typically exceeded phenotypic correlation coefficients which showed that genetic factors primarily determine trait relationships while environmental factors have only minimal impact. The total fruit yield per plant showed a highly significant positive relationship with both the number of fruits per plant and average fruit weight because these two factors served as primary yield components.
Path coefficient analysis showed us how various attributes created their causal links. The yield showed its strongest positive impact on fruit production with a direct relationship that reached 0.924. The average fruit weight produced a slight decrease in production results through its impact on production outcomes. The study demonstrates that harvesting techniques which boost fruit quantity while maintaining optimal fruit weight will produce greater harvesting results. The study demonstrates that early blooming as a genetic trait leads to better reproductive success while extending the period for crop harvesting. The study demonstrates that through genetic modification eggplant production can be increased through a selection process which evaluates multiple factors including fruit quantity and fruit mass and plant growth rates.
Keywords: *The Analysis of Variance, Genotypic Correlation, Primary Yield Components, Path Coefficient Analysis, Genetic Modification etc.*

I. Introduction

Eggplant (Solanum melongena L.) which people commonly call aubergine or brinjal serves as an essential vegetable crop which farmers worldwide cultivate throughout tropical and subtropical regions of Asia and Africa and the Mediterranean. This Solanaceae family member serves as a crucial dietary component for millions of people who refer to it as "poor man's meat" because it provides various cooking options together with essential nutrients at an affordable price. Eggplant provides multiple health benefits because it contains dietary fiber together with vitamins and minerals while delivering high amounts of anthocyanins and phenolic compounds which give strong antioxidant protection. The continuous income which eggplant cultivation brings throughout its harvesting season allows small-scale farmers to maintain their economic stability. The traditional landraces used for farming produce only limited yields because they have not undergone development to achieve their genetically determined yield potential.

Yield as a Multifaceted Polygenic Characteristic

The principal aim in plant breeding is typically the augmentation of grain or fruit yield. The characteristic of yield functions as a multifaceted agricultural trait because it results from multiple genetic components instead of being determined by a single hereditary factor. The process of yield selection becomes difficult because environmental changes mainly determine yield which exists as the final result of an extended biological system that governs plant growth [1]. The ultimate yield of a plant results from multiple morphological and physiological interactions, including plant height, the quantity of primary and secondary branches, fruit length, and fruit circumference. Each attribute is regulated by a distinct set of genes and is influenced by different levels of environmental pressure. Breeders need to study both yield results and their basic factors because sustainable eggplant productivity improvement requires them to view plants as unified biological systems instead of separate physical components.

The Significance of Correlation Analysis in Breeding

The breeders use correlation analysis to study yield because it helps them understand how different phenotypic and genotypic traits interact with each other. Correlation provides statistical measurements which determine how two variables interact with each other and this helps researchers find secondary traits which boost fruit production [2]. The breeder can use branchiness as a yield indicator when fruit production shows strong correlation with branch quantity. The primary restriction of correlation analysis exists because it can only measure linear connections between two variables while it misses all other types of variable interactions. A strong correlation between two variables may be deceptive if influenced by an unmeasured third variable. The use of correlation in selection criteria discovery provides researchers with basic information but it cannot explain how genetic elements interact with each other within the plant's genetic framework [3].

The Importance of Path Coefficient Analysis

The internal structure of trait relationships remains unclear through correlation analysis thus eggplant breeders need route coefficient analysis as their main research method. Path analysis enables researchers to separate total correlation coefficients into direct and indirect effects which Sewall Wright developed and Dewey and Lu modified for plant breeding applications. The statistical method shows how average fruit weight affects final yield through direct effects and indirect effects which operate through fruit diameter. Breeders can evaluate their best selection indices by discovering which traits yield the highest direct benefits to their harvest results [4]. The method prevents common mistakes which occur when researchers choose features that appear related to yield but actually decrease it when they assess direct effects without considering other factors. Breeders can create breeding programs which improve the genetic quality of eggplant through the combined mathematical system of correlation and route analysis.

Figure 1: Mermaid Diagram on the Polygenic Level, Source: Author Generated

II. Materials & Methods

The research took place at an Agricultural Research Station which had a humid subtropical climate as its primary weather condition. The experimental field contained sandy loam soil with a neutral pH which created perfect conditions for Solanum melongena to access nutrients and develop. The research team conducted their work during the Kharif season because they wanted to study how natural environmental changes affected their results [5]. The average temperature during this period ranged from 24°C to 32°C while relative humidity levels changed between 70% and 85%. The environmental conditions need to be studied because temperature changes together with humidity changes have a strong impact on how plants grow and how they show their yield-related traits. Environmental factors can hide the true genetic potential of the genotypes which researchers are studying.

Botanical Resources and Research Methodology

The research used 45 distinct eggplant varieties which included local landraces and market cultivators and advanced breeding lines as their basis. The researchers could conduct statistical tests and investigate trait relationships because they had access to various genetic material. The researchers conducted the experiment three times using the Randomized Complete Block Design method to minimize experimental errors. The researchers cultivated each genotype in four-row flats which maintained 60 centimeters of space between rows and 50 centimeters of space between plants [6]. The regular spacing between plants reduced their competition for essential resources such as sunlight and water and nutrients, which resulted in limited non-genetic diversity among them.

Data Acquisition and Morphological Analysis

Data were collected from five randomly selected and tagged plants in each replication to assure representativeness [7]. The study measured plant growth through six quantitative attributes which included days to 50% flowering and plant height at maturity and primary branch count and fruit length and fruit girth and average fruit weight and total fruit output per plant. All measurements used calibrated instruments which provided precise results through standardized testing methods. The accuracy of data collection holds critical significance because even the smallest errors will produce incorrect results for correlation and path coefficient estimation.

Statistical Modeling and Path Analysis

The researchers conducted statistical analysis on collected data to determine existing relationships between different features. The researchers used Analysis of Variance (ANOVA) to determine whether different genotypes created significant differences. The researchers calculated genotypic and phenotypic correlation coefficients by using variance-covariance components [8]. The researchers used path coefficient analysis based on the Dewey and Lu (1959) method to separate correlation coefficients into their direct and indirect effects by applying the formula:

$$r_{iy} = P_{iy} + \sum r_{ij} P_{jy}$$

Here, r_{iy}represents here most of the correlation between trait $i$and yield y, $P_{iy}$is the direct effect of trait $i$on yield here, and $\sum r_{ij} P_{jy}$denotes indirect effects via basically other traits. The residual effect was calculated as follows:

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

This value here in normally indicates the proportion of yield variation not explained by the included traits.

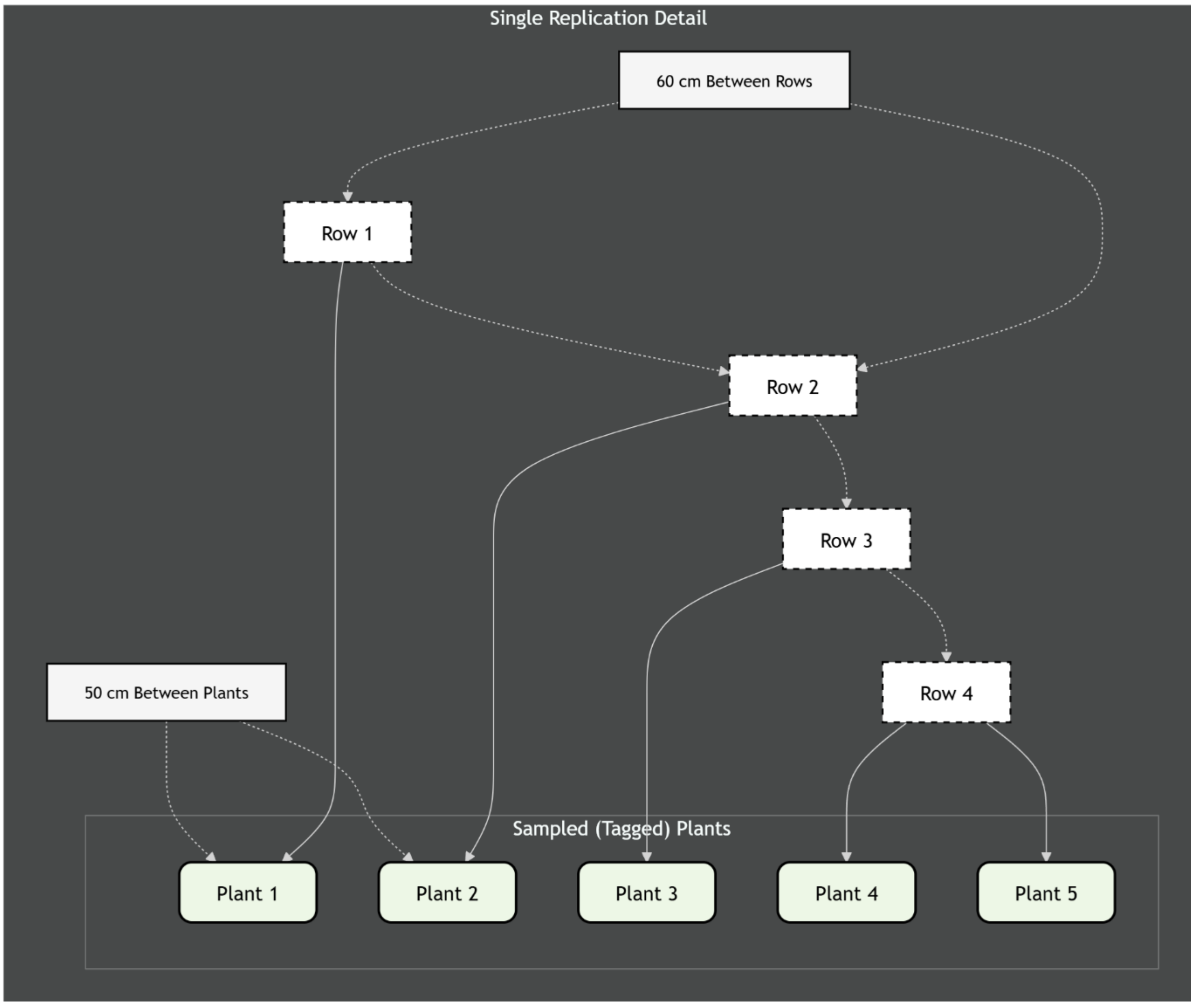

Figure 2; Material based Diagram, Source: Author Generated

III. Results

Analysis of Variance and Genetic Parameters

The first Analysis of Variance (ANOVA) test showed that all forty-five eggplant genotypes displayed statistically significant differences in their observed characteristics. The research demonstrated that the experimental materials displayed substantial genetic variation, which scientists need for their research work to perform effective selection and for conducting statistical experiments that include correlation and path coefficient studies [9]. The phenotypic coefficient of variation (PCV) showed results that were always slightly higher than the genotypic coefficient of variation (GCV) results for every measured characteristic. The pattern shows that environmental conditions affected how traits developed yet the genetic factors still controlled most of the process. The research showed that both GCV and PCV reached high values for the number of fruits per plant and average fruit weight which means these traits can be enhanced through selection and breeding methods.

Genotypic and Phenotypic Correlation Analysis

The correlation analysis showed how different morphological traits interacted with total fruit yield per plant. The genotypic correlation coefficients (r_g) showed stronger results than their phenotypic counterparts (r_p) because environmental factors weakened the genetic link between traits in various genotypes. The total fruit yield per plant showed a strong positive relationship with number of fruits per plant (r_g=0.842, r_p=0.768) and average fruit weight (r_g=0.655, r_p=0.612) [10]. The results indicate that genotypes which produce more fruits or heavier fruits will achieve higher yields for their crops. Fruit girth showed strong positive connection with yield while fruit length showed only weak positive connection to yield. The days to 50% flowering produced a strong negative relationship with yield (r_g=-0.315) which showed that early-flowering genotypes produced higher yields because they had more time to reproduce and more chances to be harvested [11].

Characters	Days to 50% Flowering	Plant Height (cm)	No. of Primary Branches	Fruit Length (cm)	Fruit Girth (cm)	Avg. Fruit Weight (g)	No. of Fruits per Plant	Yield per Plant (kg)
Days to 50% Flowering	1.000	0.142	-0.085	0.112	-0.054	-0.124	-0.284*	-0.315*
Plant Height (cm)	0.115	1.000	0.412**	0.185	0.095	0.104	0.215*	0.288*
No. of Primary Branches	-0.062	0.385**	1.000	0.052	0.114	0.188	0.342**	0.395
Fruit Length (cm)	0.098	0.154	0.041	1.000	-0.324**	0.155	0.118	0.212
Fruit Girth (cm)	-0.041	0.082	0.102	-0.285*	1.000	0.542**	-0.105	0.442
Avg. Fruit Weight (g)	-0.102	0.092	0.154	0.124	0.485**	1.000	-0.215*	0.655
No. of Fruits per Plant	-0.210	0.188	0.285*	0.095	-0.085	-0.195	1.000	0.842
Yield per Plant (kg)	-0.245	0.214	0.312*	0.185	0.395	0.612	0.768	1.000

Table 1: Genotypic (below diagonal) and Phenotypic (above diagonal) Correlation Coefficients, Source: Author Generated

Path Coefficient Analysis: Direct and Indirect Effects

The research used correlation analysis to determine how closely two variables relate to each other while path coefficient analysis divided the observed correlations into direct and indirect effects which helped researchers understand how different traits caused each other [12]. The research discovered that total yield received its strongest direct positive impact from the number of fruits per plant which produced a coefficient of 0.924 while average fruit weight produced a coefficient of 0.485. The results show that these two traits determine yield because any improvements to these traits will lead to higher productivity. The relationship between plant height and primary branch count to yield showed low direct impact because their effects needed other traits to function properly [13].

Characters	Days to 50% Flowering	Plant Height (cm)	No. of Primary Branches	Fruit Length (cm)	Fruit Girth (cm)	Avg. Fruit Weight (g)	No. of Fruits per Plant	Genotypic Correlation with Yield
Days to 50% Flowering	-0.124	0.012	-0.005	0.008	-0.004	-0.060	-0.142	-0.315
Plant Height (cm)	-0.017	0.085	0.024	0.014	0.007	0.050	0.125	0.288
No. of Primary Branches	0.010	0.035	0.058	0.004	0.008	0.091	0.189	0.395
Fruit Length (cm)	-0.014	0.016	0.003	0.074	-0.024	0.075	0.082	0.212
Fruit Girth (cm)	0.007	0.008	0.007	-0.024	0.088	0.263	-0.093	0.442
Avg. Fruit Weight (g)	0.015	0.009	0.011	0.011	0.048	0.485	0.076	0.655
No. of Fruits per Plant	0.035	0.018	0.020	0.009	-0.009	-0.104	**0.924**	0.842

Table 2: Genotypic Path Coefficient Analysis Showing Direct and Indirect Effects on Yield, Source: Author Generated

The analysis of indirect effects further strengthened the understanding of trait interrelationships. The number of primary branches showed a positive correlation with yield, but its direct effect was minimal. The primary effect of this element operated through its positive effect which created more fruits per plant. The research shows that increased branching will create more locations which flowers and fruits can develop. The fruit girth provides indirect yield benefits because it links to average fruit weight, which shows its essential role in determining total yield.

Residual Effect and Model Adequacy

The residual effect measurement showed a result of 0.12 which scientists consider an acceptable value for biological research. The value shows that 88% of eggplant yield variation can be explained through the analyzed traits [14]. The unmeasured factors which include physiological efficiency and photosynthetic capacity and nutrient uptake dynamics account for the remaining 12% of variation. The residual value achieves low measurements which demonstrate that the chosen traits successfully explain how Solanum melongena yield architecture functions [15].

IV. Discussions

The comparative study results deliver complete genetic architecture information which controls eggplant yield while demonstrating that phenotypic selection achieves optimal results through genetic linkages. The study found that genotypic correlation coefficients always exceeded phenotypic correlation coefficients. The base genetic connections between traits remain intact because environmental elements like soil fertility and moisture availability and temperature affect how traits show themselves. Breeders need to depend on genotypic information to create selection indices because phenotypic assessment does not show the complete genetic abilities of a genetic variant.

The number of fruits per plant emerged as the most influential yield component which showed a strong positive link to total yield with a genetic correlation of 0.842. Path coefficient analysis established its significance by showing that it had the strongest direct impact on yield through a 0.924 value. The number of fruits on each plant needs to increase because this change will lead to higher productivity levels. The research showed that more fruits led to smaller average fruit weight through a negative relationship which showed typical eggplant fruiting behavior. The increased number of fruits leads to reduced fruit size because fruits compete for shared resources. The optimal breeding strategy needs to establish equal fruit weight and fruit number so that maximum yields meet market standards.

The research found that yield increased with higher plant height and primary branch count but these traits had minimal direct impact on yield. The research demonstrates that these traits do not act as standalone yield determinants but instead work as indirect yield contributors. The path analysis explained that their main effect on plant productivity stems from their ability to boost fruit production through increased flowering and fruiting locations.

The negative correlation between days to 50% flowering and yield (-0.315) highlights the importance of earliness as a desirable trait. Early flowering genotypes initiate their reproductive growth process earlier which results in an extended period for harvesting and the possibility of multiple picking cycles. The early maturity of crops provides farmers with two benefits because it leads to higher yields and better market opportunities since early produce sells for higher prices. The breeding program needs to focus on developing early flowering genotypes which demonstrate high fruiting capabilities.

The model achieved complete adequacy because the low residual effect (0.12) showed that 88% of yield variation stemmed from the analyzed traits. The selected morphological characters which include fruit number and fruit weight and fruit girth serve as dependable yield performance indicators. The model presents a practical selection method that uses field traits which can be easily measured despite other physiological traits like photosynthetic efficiency and nutrient uptake having an effect on productivity.

V. Conclusion and Recommendations

The analysis of character association and path coefficients in eggplant (Solanum melongena L.) provides a framework for understanding the genetic improvement process. The study demonstrated that yield functions as a complex biological phenomenon which originates from multiple biological factors that depend on the Number of Fruits per Plant and Average Fruit Weight. The two qualities demonstrated strongest positive genotypic relationships which directly affected yield production therefore these two qualities function as the most reliable selection method for main selection

The results demonstrate how earliness functions as an important factor throughout the entire breeding process. The total yield decreases when Days to 50% Flowering increase because genotypes that start their reproductive phase early will extend their harvesting time which results in better production outcomes. The research found that vegetative traits including Plant Height and Number of Primary Branches showed strong links to each other while their effects on results were mostly indirect. The characteristics should function as extra selection parameters which help the plant develop stronger structural support to handle heavier fruit loads.

Breeders need to develop a selection index for eggplant production which identifies genotypes that can produce multiple fruits throughout the growing season without reducing their fruit dimensions. The minimal residual impact (0.12) substantiates that the characteristics discovered in this study are the genuine determinants of eggplant productivity. The upcoming research should focus on joining these physical findings with genetic markers to produce climate-adaptive high-yielding hybrid varieties.

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