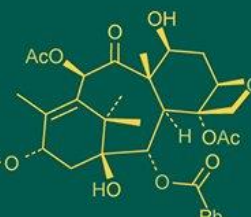
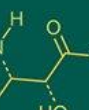
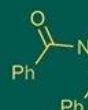


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## Assessment of genetic variability, character association and path coefficient analysis for yield and quality traits in black pepper (*Piper nigrum* L.) genotypes

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### Abstract

**Background:** Black pepper (*Piper nigrum* L.), the “King of Spices,” is a strategically important perennial crop whose productivity in Karnataka, India, is constrained by a narrow genetic base and devastating diseases. Systematic evaluation of available germplasm is essential to identify superior genotypes and establish effective selection criteria for crop improvement.

**Methods:** Twenty-five diverse black pepper genotypes were evaluated in a Randomized Complete Block Design with three replications during the 2024-2025 cropping season. Data were recorded on 20 quantitative traits encompassing growth, yield components and quality parameters. Genetic variability parameters (GCV, PCV, broad-sense heritability and GAM) were estimated and genotypic and phenotypic correlation coefficients were computed. Path coefficient analysis was performed with dry berry yield per vine as the dependent variable.

**Results:** Analysis of variance revealed highly significant differences ( $P < 0.01$ ) among genotypes for all traits. High heritability ( $>98\%$ ) coupled with high genetic advance as a percentage of mean ( $>160\%$ ) was recorded for dry and fresh berry yield per vine, indicating predominance of additive gene action. Panniyur-1 (11.46 kg/vine), Vellamban (9.08 kg/vine) and Arakulamundi (8.80 kg/vine) were identified as superior yielders. Path coefficient analysis established fresh berry yield per vine as the trait with the maximum positive direct effect (0.7222) on dry berry yield.

**Conclusion:** The study confirmed substantial genetic variability in the evaluated germplasm, providing considerable scope for selection. Fresh berry yield per vine was identified as the most critical and reliable primary selection criterion. The non-significant correlation between yield and quality traits allows for simultaneous improvement of both attributes.

**Keywords:** Genetic variability, heritability, path analysis, phytophthora resistance, *Piper nigrum*, selection criteria

### 1. Introduction

Black pepper (*Piper nigrum* L.), venerated as the “King of Spices,” is a perennial climbing vine indigenous to the humid tropical forests of the Western Ghats in Southern India. It holds an unparalleled position in the global spice trade, valued for its characteristic pungency derived from piperine and its aromatic essential oils (Arya, 2021) [3]. India is a leading global player, functioning as the largest producer, consumer and exporter of a wide array of high-quality spices, with black pepper being a cornerstone of its agricultural export economy (Spices Board India, 2023) [18].

In recent decades, the epicenter of black pepper cultivation in India has shifted from Kerala to Karnataka, which now accounts for over 50% of the national production. The crop is extensively cultivated across the Malenadu region, including districts like Shivamogga, Kodagu and Chikkamagaluru, primarily as a high-value intercrop in coffee and arecanut plantations (Hegde, 2021) [7]. However, despite this geographical expansion, the average productivity remains significantly below its potential. This “yield gap” is a critical challenge attributed to a confluence of factors: a narrow genetic base due to over-reliance on a few traditional cultivars, escalating susceptibility to devastating diseases like Phytophthora foot rot (quick wilt) and slow decline complex and mounting pressure from insect pests (Krishnamurthy *et al.*, 2021; Aravind *et al.*, 2022) [9, 2].

Compounding these issues, the intensifying effects of climate change, manifesting as erratic rainfall and prolonged droughts, pose a significant threat to the sustainability of black pepper cultivation (Yusuf *et al.*, 2021) <sup>[20]</sup>.

A sustained and targeted crop improvement program is imperative to address these challenges. The bedrock of any such program is the existence of ample genetic variability, which provides the raw material for selection and breeding (Allard, 1960) <sup>[1]</sup>. Therefore, the systematic characterization of available germplasm to quantify the extent of genetic variation is the first and most crucial step (Govindaraj *et al.*, 2015) <sup>[6]</sup>. The estimation of key genetic parameters like the Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), heritability ( $h^2b$ ) and Genetic Advance as a percentage of the Mean (GAM) helps breeders understand the genetic control of various traits and predict the potential gains from selection. High heritability coupled with high genetic advance for a trait indicates the predominance of additive gene action, making simple phenotypic selection highly effective (Johnson *et al.*, 1955; Patel *et al.*, 2023) <sup>[8, 11]</sup>.

While identifying variability is essential, understanding the interrelationships between yield and its component traits is equally critical for devising an efficient selection strategy. Yield is a complex quantitative trait governed by multiple genes and influenced by the environment. Therefore, direct selection for yield alone can be misleading. A more effective approach is to practice indirect selection based on its component traits. Correlation analysis quantifies the degree of association between traits, but path coefficient analysis provides a deeper understanding by partitioning these correlations into direct and indirect effects, thereby revealing the causal relationships (Wright, 1921; Dewey & Lu, 1959) <sup>[19, 5]</sup>. Recent studies in black pepper have consistently used this approach to identify key direct contributors to yield, such as the number of spikes and berry weight (Shivakumar & Saji, 2019; Singh *et al.*, 2021) <sup>[15, 17]</sup>. Given the urgent need to enhance black pepper productivity in Karnataka, this investigation was designed to systematically evaluate a diverse set of genotypes. The primary objectives were: (1) to assess the extent of genetic variability, heritability and genetic advance for key growth, yield and quality traits; and (2) to study the character association and path coefficients to identify key selection criteria for yield improvement.

## 2. Materials and Methods

### 2.1 Experimental Site and Conditions

The field investigation was conducted during the 2024-2025 cropping season at a farmer's field in Haalugudde village, Anandapura, Shivamogga district, Karnataka, India (approximate latitude of 14.15° N, longitude of 75.32° E and elevation of 640 m above MSL). The site represents the typical agro-ecological conditions of the Malenadu region. The region has a humid tropical monsoon climate with an average annual rainfall of around 2000 mm. The soil is predominantly lateritic, with a clay-loam texture and a naturally acidic pH (5.5-6.5), which is optimal for black pepper cultivation.

### 2.2 Plant Material and Experimental Design

A total of twenty-five diverse black pepper genotypes, comprising released varieties (Panniyur-1, Panniyur-2, Panniyur-3, Panniyur-5, IISR Thevam, Arka Coorg Excel), farmer selections (Karimunda, Sigandini), local landraces

(Arakulamundi, Cholamundi, etc.) and advanced breeding lines (V-1 to V-8) were chosen for the study. The experiment utilized 6-year-old, established and stable-bearing vines trained on Subabul (*Leucaena leucocephala*) as support standards. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

### 2.3 Cultural Practices

All experimental vines were maintained under uniform and recommended cultural practices. Nutrient management included the annual application of well-decomposed farmyard manure at 10 kg per vine and the recommended dose of NPK fertilizers (100:40:140 g/vine/year) in two equal splits. Regular manual weeding and mulching were performed. Supplementary drip irrigation was provided during dry months and an integrated approach to plant protection, including prophylactic sprays of Bordeaux mixture (1%), was followed.

### 2.4 Observations Recorded

Data were recorded on five randomly selected vines for each genotype in every replication for 20 quantitative parameters.

**2.4.1 Growth Parameters:** Number of leaves per meter, leaf length (cm) and leaf width (cm) of fully expanded leaves, vine length (m) from ground level to the growing tip, number of fruit-bearing lateral branches (plagiotropes) per meter of the main stem, length of plagiotropic shoots (cm) and number of orthotropic runner shoots per vine.

**2.4.2 Yield Component Traits:** Number of spikes per plagiotropic shoot, number of spikes per square meter of canopy, spike length (cm) from pedicel to tip, fresh weight of mature spikes (g), total number of berries on a representative spike, weight of 100 fresh mature berries (g) and weight of 100 dried berries (g).

**2.4.3 Yield and Quality Traits:** Fresh berry yield per vine (kg) was the cumulative weight from all pickings. Dry berry yield per vine (kg) was recorded after drying to a constant moisture level (10-12%). Dry recovery (%) was calculated. Essential oil (%) was estimated by hydro-distillation, Oleoresin (%) by Soxhlet extraction and Bulk density (g/l) was measured using a one-litre cylinder.

**2.4.4 Biotic Stress:** Field screening for quick wilt (Phytophthora foot rot) and slow wilt was conducted visually using a 0-5 rating scale (0=no symptoms, 5=complete vine death).

### 2.5 Statistical Analysis

The collected data were subjected to Analysis of Variance (ANOVA) to test the significance of differences among genotypes. Genetic parameters including Genotypic Coefficient of Variation (GCV), Phenotypic Coefficient of Variation (PCV), broad-sense heritability ( $h^2b$ ) and Genetic Advance as a percentage of Mean (GAM) were estimated according to Burton (1952) <sup>[4]</sup> and Johnson *et al.* (1955) <sup>[8]</sup>. Genotypic and phenotypic correlation coefficients were calculated and path coefficient analysis was performed to partition the correlation coefficients into direct and indirect effects, with dry berry yield per vine as the dependent variable, following the method of Dewey and Lu (1959) <sup>[5]</sup>.

### 3. Results

#### 3.1 Analysis of Variance and Genetic Variability Parameters

The analysis of variance (ANOVA) revealed highly significant differences ( $P < 0.01$ ) among the 25 genotypes for all 20 quantitative characters studied, confirming the existence of a broad spectrum of genetic variability within the experimental material (Table 1). The estimates of genetic parameters for all traits are presented in Table 2.

A wide range of variation was observed for all traits. For the

primary economic trait, dry berry yield per vine, the performance ranged from a low of 1.23 kg (Sigandini) to a remarkable high of 11.46 kg (Panniyur-1). High genotypic (GCV) and phenotypic (PCV) coefficients of variation were observed for dry berry yield per vine (82.94%, 83.44%), fresh berry yield per vine (78.41%, 79.09%), number of laterals/m<sup>2</sup> (46.76%, 47.26%) and number of spikes/plagiotropic shoot (46.53%, 47.25%). The narrow gap between PCV and GCV for these traits indicates minimal environmental influence and high genetic control.

**Table 1:** Analysis of Variance (ANOVA) for various growth, yield and quality traits in black pepper genotypes

| Trait                               | Replication MS | Treatment MS | Error MS |
|-------------------------------------|----------------|--------------|----------|
| Number of leaves/m <sup>2</sup>     | 16.649         | 819.289**    | 28.000   |
| Leaf length (cm)                    | 1.127          | 17.229**     | 1.224    |
| Leaf width (cm)                     | 0.067          | 12.349**     | 0.540    |
| Vine length (m)                     | 0.181          | 2.256**      | 0.064    |
| Number of laterals/m <sup>2</sup>   | 0.840          | 66.310**     | 0.471    |
| Length of plagiotropic shoot (cm)   | 8.382          | 493.555**    | 9.214    |
| Number of runner shoots/vine        | 0.115          | 11.427**     | 0.149    |
| Number of spikes/plagiotropic shoot | 0.233          | 51.608**     | 0.529    |
| Number of spikes/m <sup>2</sup>     | 3.080          | 360.844**    | 9.593    |
| Spike length (cm)                   | 0.525          | 31.650**     | 1.213    |
| Fresh spike weight (g)              | 0.636          | 52.290**     | 0.731    |
| Number of berries per spike         | 11.567         | 834.250**    | 13.650   |
| 100-fresh berry weight (g)          | 0.057          | 16.801**     | 0.642    |
| 100-dry berry weight (g)            | 0.111          | 1.404**      | 0.150    |
| Fresh berry yield per vine (kg)     | 0.126          | 163.945**    | 0.940    |
| Dry berry yield per vine (kg)       | 0.137          | 22.339**     | 0.089    |
| Dry recovery (%)                    | 3.139          | 18.238**     | 5.309    |
| Essential oil (%)                   | 0.078          | 2.363**      | 0.057    |
| Oleoresin (%)                       | 1.102          | 43.138**     | 0.770    |
| Bulk density (g/l)                  | 1519.906       | 3995.184**   | 1673.700 |

\*Significance at 5%; \*\*Significance at 1%

High heritability ( $h^2b$ ) coupled with high genetic advance as a percentage of mean (GAM) was recorded for these critical traits. For instance, dry berry yield per vine showed  $h^2b$  of 98.82% and GAM of 169.85%. This combination is a strong indicator of the predominance of additive gene action, suggesting that direct phenotypic selection would be highly effective in achieving rapid genetic gains for these traits.

Quality traits also exhibited high variability. Essential oil

content ranged from 0.75% (Panchami) to 3.90% (Vijay), with high GCV (33.21%) and  $h^2b$  (93.07%). Oleoresin content varied from 2.60% (Neelamundi) to 13.67% (Nateshan Kudi), also showing high GCV (36.65%) and  $h^2b$  (94.83%). In contrast, traits like bulk density showed low GCV (4.93%) and low  $h^2b$  (31.62%), indicating a strong environmental influence and limited scope for improvement through direct selection.

**Table 2:** Estimates of genetic variability, heritability and genetic advance for various traits in black pepper genotypes

| Trait                               | Mean   | Range         | GCV (%) | PCV (%) | $h^2b$ (%) | GA    | GAM (%) |
|-------------------------------------|--------|---------------|---------|---------|------------|-------|---------|
| Number of leaves/m <sup>2</sup>     | 59.53  | 31.33-102.00  | 27.28   | 28.69   | 90.40      | 31.81 | 53.43   |
| Leaf length (cm)                    | 14.38  | 8.63-18.33    | 16.07   | 17.81   | 81.33      | 4.29  | 29.85   |
| Leaf width (cm)                     | 9.19   | 5.67-14.33    | 21.60   | 23.03   | 87.93      | 3.83  | 41.72   |
| Vine length (m)                     | 4.51   | 3.28-7.01     | 18.94   | 19.76   | 91.93      | 1.69  | 37.41   |
| Number of laterals/m <sup>2</sup>   | 10.02  | 4.67-27.33    | 46.76   | 47.26   | 97.90      | 9.55  | 95.32   |
| Length of plagiotropic shoot (cm)   | 60.99  | 35.00-88.33   | 20.83   | 21.42   | 94.60      | 25.46 | 41.74   |
| Number of runner shoots/vine        | 4.96   | 2.00-8.67     | 39.09   | 39.86   | 96.19      | 3.92  | 78.98   |
| Number of spikes/plagiotropic shoot | 8.87   | 2.67-17.33    | 46.53   | 47.25   | 96.99      | 8.37  | 94.40   |
| Number of spikes/m <sup>2</sup>     | 41.16  | 6.33-65.00    | 26.29   | 27.34   | 92.43      | 21.43 | 52.06   |
| Spike length (cm)                   | 13.03  | 7.83-21.50    | 24.44   | 25.86   | 89.32      | 6.20  | 47.58   |
| Fresh spike weight (g)              | 10.94  | 5.50-21.33    | 37.89   | 38.69   | 95.92      | 8.36  | 76.44   |
| Number of berries per spike         | 72.59  | 46.50-118.33  | 22.79   | 23.35   | 95.25      | 33.25 | 45.81   |
| 100-fresh berry weight (g)          | 13.48  | 8.67-18.47    | 17.22   | 18.21   | 89.35      | 4.52  | 33.53   |
| 100-dry berry weight (g)            | 4.70   | 3.55-6.34     | 13.76   | 16.05   | 73.54      | 1.14  | 24.31   |
| Fresh berry yield per vine (kg)     | 9.40   | 3.52-32.77    | 78.41   | 79.09   | 98.30      | 15.06 | 160.15  |
| Dry berry yield per vine (kg)       | 3.28   | 1.23-11.46    | 82.94   | 83.44   | 98.82      | 5.58  | 169.85  |
| Dry recovery (%)                    | 34.30  | 29.44-39.89   | 6.05    | 9.04    | 44.81      | 2.86  | 8.35    |
| Essential oil (%)                   | 2.64   | 0.75-3.90     | 33.21   | 34.43   | 93.07      | 1.74  | 66.00   |
| Oleoresin (%)                       | 10.25  | 2.60-13.67    | 36.65   | 37.64   | 94.83      | 7.54  | 73.53   |
| Bulk density (g/l)                  | 564.65 | 494.36-657.60 | 4.93    | 8.76    | 31.62      | 32.22 | 5.71    |

### 3.2 Character Association and Path Analysis

Genotypic correlation coefficients were generally higher in magnitude than their phenotypic counterparts, indicating a strong inherent association between traits. A selection of key correlations is presented in Table 3. Dry berry yield per vine (DBYV) exhibited a highly significant and strong positive genotypic correlation with fresh berry yield per vine (FBYV) ( $r = 0.9160$ ), vine length (VL) ( $r = 0.537$ ), dry recovery (DRP) ( $r = 0.491$ ) and bulk density (BD) ( $r = 0.412$ ). Yield components like number of spikes/m<sup>2</sup> (NSPM) ( $r = 0.587$ ) and number of laterals/m<sup>2</sup> (NLPM) ( $r = 0.498$ ) also showed a strong positive association. A particularly advantageous finding was the non-significant correlation between DBYV and the main quality traits, oleoresin (OC%) ( $r = 0.000$ ) and essential oil (EOCP) ( $r = 0.181$ ).

To delineate the causal relationships, path coefficient analysis was performed with DBYV as the dependent variable (Table 4). The analysis revealed that fresh berry yield per vine (FBYV) exerted the maximum positive direct effect (0.7222) on DBYV. This substantial direct contribution confirms it as the most critical component influencing the final economic yield. The second most important positive direct contributor was dry recovery (DRP) (0.1788), followed by bulk density (BD) (0.1244) and vine length (VL) (0.0952). Other traits, despite having strong correlations, exerted their influence primarily through large positive indirect effects channeled through FBYV. For instance, the strong correlation of vine length with dry yield was largely due to its high indirect effect via fresh berry yield (0.3607). This finding unequivocally establishes that

selection focused on improving fresh berry yield and dry matter accumulation efficiency is the most direct and efficient path to developing high-yielding black pepper varieties.

**Table 3:** Genotypic correlation coefficients of key traits with dry berry yield per vine (DBYV) in black pepper genotypes

| Trait (Abbreviation)                     | r with DBYV | Significance |
|------------------------------------------|-------------|--------------|
| Fresh berry yield per vine (FBYV)        | 0.9160      | **           |
| Number of spikes/m <sup>2</sup> (NSPM)   | 0.5870      | **           |
| Vine length (VL)                         | 0.5374      | **           |
| Number of laterals/m <sup>2</sup> (NLPM) | 0.4980      | **           |
| Dry recovery (DRP)                       | 0.4910      | **           |
| Bulk density (BD)                        | 0.4124      | *            |
| Leaf width (LW)                          | 0.3468      | **           |
| Number of leaves/m <sup>2</sup> (NLPM)   | 0.3456      | **           |
| Leaf length (LL)                         | 0.2963      | **           |
| Essential oil % (EOCP)                   | 0.1811      | NS           |
| Oleoresin % (OC%)                        | 0.0480      | NS           |

\*Significant at 5%; \*\*Significant at 1%; NS = Non-significant

Legend: NLPM – Number of Leaves/m<sup>2</sup>; LL – Leaf Length; LW – Leaf Width; VL – Vine Length; NLPM – Number of Laterals/m<sup>2</sup>; LPSL – Length of Plagiotropic Shoot; NRSV – Number of Runner Shoots/vine; NSPS – Number of Spikes/Plagiotropic Shoot; NSPM – Number of Spikes/m<sup>2</sup>; SL – Spike Length; SW – Fresh Spike Weight; NBS – Number of Berries per Spike; FBW100 – 100-Fresh Berry Weight; DBW100 – 100-Dry Berry Weight; FBYV – Fresh Berry Yield per vine; DRP – Dry Recovery (%); EOCP – Essential Oil (%); OC% – Oleoresin (%); BD – Bulk Density; DBYV – Dry Berry Yield per vine.

**Table 4:** Genotypic path coefficient analysis showing direct effects of key traits on dry berry yield per vine (DBYV)

| Trait                                      | Direct Effect | r with DBYV |
|--------------------------------------------|---------------|-------------|
| Fresh berry yield per vine (FBYV)          | 0.7222        | 0.9997**    |
| Dry recovery (DRP)                         | 0.1788        | 0.4910**    |
| Bulk density (BD)                          | 0.1244        | 0.4124*     |
| Vine length (VL)                           | 0.0952        | 0.5374**    |
| Spike length (SL)                          | 0.2391        | 0.2503*     |
| Number of berries per spike (NBS)          | 0.3427        | 0.2703*     |
| Number of spikes/plagiotropic shoot (NSPS) | 0.0875        | 0.2140 NS   |
| Number of leaves/m <sup>2</sup> (NLPM)     | 0.0453        | 0.3456**    |
| Number of laterals/m <sup>2</sup> (NLPM)   | 0.0369        | 0.2595 NS   |
| Number of spikes/m <sup>2</sup> (NSPM)     | 0.0439        | 0.2423 NS   |
| Essential oil % (EOCP)                     | 0.0369        | 0.1811 NS   |
| Oleoresin % (OC%)                          | 0.0409        | 0.0480 NS   |

\*Significant at 5%; \*\*Significant at 1%; NS = Non-significant

### 3.3 Identification of Superior Genotypes

**3.3.1 High Yield:** Panniyur-1 (11.46 kg/vine), Vellanamban (9.08 kg/vine) and Arakulamundi (8.80 kg/vine) were the top three genotypes for dry berry yield.

**3.3.2 Disease Resistance:** Vijay and Karimunda showed high field resistance to both quick wilt and slow wilt diseases, each recording the lowest possible disease score of 1.

**3.3.3 Quality Traits:** Vijay recorded the highest essential oil content (3.90%), while Nateshan Kudi had the highest oleoresin content (13.67%).

**3.3.4 Yield Components:** Panniyur-1 also had the longest spikes (21.50 cm), while Panchami had the highest number of berries per spike (118.33). V-2 was superior for the number of laterals and spikes per unit area, making it a

valuable donor for improving the vine framework.

## 4. Discussion

The success of any plant breeding program is contingent upon the magnitude of existing genetic variability in the base population. The highly significant differences observed among the 25 black pepper genotypes for all traits in this study confirm that the evaluated germplasm is a rich reservoir of genetic diversity, providing immense potential for breeding.

### 4.1 Genetic Variability and Scope for Selection

The study revealed high GCV and PCV values for key economic traits, particularly dry berry yield per vine, fresh berry yield per vine and number of laterals. The combination of high heritability (>98%) with high GAM (>160%) for these traits is a significant finding. It strongly indicates that the variation is predominantly due to additive

gene effects, which are heritable and can be effectively accumulated through selection (Ningwal *et al.*, 2023) <sup>[10]</sup>. This implies that simple phenotypic selection for genotypes with high fresh berry yield would be a highly reliable and effective strategy for achieving rapid genetic improvement in black pepper. These findings are in strong agreement with previous reports by Polesa *et al.* (2022) <sup>[12]</sup> and Shivakumar *et al.* (2020) <sup>[16]</sup>, who also documented high heritability and genetic advance for yield-contributing traits, reinforcing the efficacy of direct selection.

The identification of genotypes like Panniyur-1 and Vellanamban with nearly ten-fold higher yield than the lowest performer underscores the vast potential for enhancing productivity through the deployment of superior genetic material. The identification of Vijay and Karimunda as highly resistant to both Phytophthora foot rot and slow wilt is of paramount importance. These diseases are the primary biotic constraints in black pepper cultivation and these genotypes serve as invaluable donor parents for resistance breeding programs (Santhosh *et al.*, 2023) <sup>[13]</sup>.

#### 4.2 Character Association and Selection Criteria

Understanding the complex web of inter-trait relationships is crucial for devising an efficient selection strategy. The strong positive correlation between dry berry yield and fresh berry yield ( $r=0.916$ ) is logical and economically important. However, path analysis provided a more profound insight by confirming that fresh berry yield per vine had the highest positive direct effect on dry yield. This result establishes fresh berry yield not just as a correlated trait but as the most critical causal factor influencing the final economic yield. Therefore, breeders should prioritize fresh berry yield as the primary selection criterion. This strategy simplifies the selection process, as fresh weight is easier and quicker to measure than dry weight. This finding corroborates the conclusions of Patel *et al.* (2023) <sup>[11]</sup> and Shivakumar and Saji (2019) <sup>[15]</sup>, who also identified fresh yield as the most significant direct contributor to dry yield in black pepper.

A particularly advantageous finding was the non-significant correlation between yield and the primary quality parameters (oleoresin and essential oil). This suggests an absence of pleiotropic effects or tight genetic linkages that would cause a negative trade-off. This allows breeders the flexibility to pursue a concurrent selection strategy, improving yield and quality simultaneously. This is critical for developing modern cultivars that meet the dual demands of high productivity for farmers and specific quality profiles for the processing industry (Sasikumar *et al.*, 2023) <sup>[14]</sup>.

#### 5. Conclusion

This investigation successfully established the existence of significant genetic variability among the studied black pepper genotypes, offering considerable scope for crop improvement through selection. Key economic traits, particularly fresh and dry berry yield per vine, exhibited high heritability coupled with high genetic advance, indicating that direct phenotypic selection can be an effective strategy for achieving rapid genetic gains. The genotypes Panniyur-1, Vellanamban and Arakulamundi were identified as superior for high yield, while Vijay and Karimunda were recognized as valuable sources of resistance to devastating wilt diseases. Path coefficient analysis unequivocally established fresh berry yield per vine as the most critical trait, exhibiting the highest positive

direct effect on dry berry yield, thereby making it the primary and most reliable selection criterion for breeders aiming to improve economic yield. The non-significant correlation between yield and quality traits suggests that these traits can be improved simultaneously and independently, which is crucial for developing commercially successful varieties. Overall, the findings provide a clear and robust roadmap for future black pepper breeding programmes, emphasizing direct selection for superior fresh berry yield and the strategic utilization of identified genotypes for introgression of disease resistance.

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