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# CORRELATION AND PATH ANALYSIS OF DIVERSE FENNEL (*FOENICULUM VULGARE* MILL.) GENOTYPES FOR SEED YIELD AND ASSOCIATED TRAITS

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**ABSTRACT**

In the present investigation, thirty-eight diverse genotypes were utilized to understand the correlation and path analysis among seed yield and related yield attributing characteristics in fennel. The experiment was conducted following a randomized complete block design at the College of Horticulture, Bagalkot, during the year 2020-21. Data pertaining to 17 agronomic and quality traits were recorded in three replicates and subjected to statistical analysis. A majority of the traits exhibited high correlation coefficients at both genotypic and phenotypic levels, indicating inherent associations among them. Parameters such as plant height, days to initial flowering, days to maturity, number of umbels per plant, number of seeds per umbellet, and harvest index displayed significant positive correlations with seed yield per plant at both phenotypic and genotypic levels. Conversely, traits like dry umbel weight, test weight and aphid incidence showed negative associations with most of the studied traits. Based on path analysis, the number of branches per plant, days to 50 per cent flowering, number of seeds per umbellet, and oil content exerted a higher positive direct effect on seed yield per plant, revealing the need to emphasize on these characters for the genetic enhancement of fennel to augment seed yield.

***Key words :*** Fennel, Seed yield, Correlation, Path analysis.

## Introduction

Fennel (*Foeniculum vulgare* Mill), an essential seed spice, belongs to the Apiaceae family and is predominantly cultivated in temperate and subtropical regions for its seeds. With a rich history as one of the oldest seed spices, fennel offers a distinctive flavor utilized in various applications within the food, cosmetic and pharmaceutical industries due to its beneficial medicinal effects (Rather *et al.*, 2016). Research has highlighted the potential uses of the essential oil derived from fennel as a valuable antioxidant, antispasmodic, with antibacterial, anticancer and antifungal properties (El-Awadi and Hassan, 2010; Badgujar *et al.*, 2014; Lucinewton *et al.*, 2005; Olle and Bender, 2010). The increasing commercial demand for fennel underscores the necessity to develop superior genotypes with enhanced yield and quality standards (Spice Board & Ministry of Agriculture and Farmers Welfare, Govt. of India, 2022-23).

Fennel originated from the Mediterranean region, where it exhibits a high level of genetic variability (Miranldi, 1999). Fennel breeding program plays a crucial role in its enhancement for cultivation and utilization. Commencing a breeding program, for any crop with genetic diversity necessitates acquiring information about agronomically important traits to facilitate the selection and breeding of improved varieties effectively (Singh *et al*., 2020).

The relationships between various traits and their effects on yield, both direct and indirect effects, lay the foundation for a successful breeding initiative (Kushwah *et al*., 2021). As a quantitative trait, yield involves complex inheritance influenced by environmental fluctuations, thus demanding the indirect selection of highly heritable traits for yield enhancement (Terfa *et al*., 2020). Additionally, understanding the associations and interactions of different traits with yield aids breeders in selection processes with enhanced precision and accuracy (Hassani *et al*., 2023). The magnitude and direction of these trait associations with yield were assessed through genotypic and phenotypic correlation coefficients (Baye *et al*., 2020). The determination of the relative importance of direct and indirect influences of the component characters towards seed yield is established through path analysis (Bhuva *et al*., 2020). Breeding studies in various seed spices have utilized correlation and path analysis techniques (Kumar *et al*., 2022). Therefore, detailed insights into significant characters for improvement programs can be obtained through correlation studies and path analysis. The primary objective of this study was to examine the direct and indirect influences of the component traits on seed yield and to identify key traits for consideration in fennel enhancement initiatives.

## Materials and Methods

The research was conducted at Udyanagiri Campus, College of Horticulture, Bagalkot, Karnataka, India. Bagalkot situated in the northern dry zone of Karnataka, has co-ordinates of 16°12′ N, 75°45′ E, with an average elevation of around 610 m. The region experiences a warm and arid climate with minimal rainfall, averaging 318 mm annually, and is characterized by laterite soil.

From October 2020 to March 2021, the experiment took place to coincide with the cold and dry weather required by the fennel crop for flowering. A total of thirty-eight fennel genotypes were sourced from various institutions across India, showcasing a wide range of variability in 17 traits related to yield, including days to germination, plant height, number of branches per plant, days to first flowering, days to 50% flowering, days to maturity, number of umbels per plant, number of umbellets per umbel, number of seeds per umbellet, fresh umbel weight (g), dry umbel weight (g), test weight (g), biomass yield per plant (g), harvest index, oil content (%), aphid incidence and seed yield per plant (g). The experiment followed a Randomized Complete Block Design (RCBD) with two replications, with genotypes randomly assigned within each replication.

The soil underwent two rounds of ploughing, harrowing, and was brought to a fine tilth prior to being divided into sections measuring 2.5 m × 2.2 m. In the process of land preparation, farmyard manure was administered as a basal dose at a rate of 15 tonnes per hectare, in conjunction with a complete dose of phosphorus and potassium, as well as a half dose of nitrogen (100:120:60 kg NPK/ ha). At 30 days after sowing (DAS), the remaining half dose of nitrogen was applied as a top dressing. The crop was sown in lines in November 2020, with row spacing set at 50 cm. Thinning was carried out post emergence of seedlings by maintaining 20 cm between plants. Observations were recorded from five randomly selected plants in each treatment. Aphid incidence was documented during the flowering stage, as it was at its peak during this period. Upon reaching full maturity, the crop was harvested. Following the threshing process, the seeds underwent manual sorting and cleaning. Post field sampling from the seeds and subsequent drying of samples at 40°C, the essential oil was extracted through hydro-distillation in a Clevenger apparatus for approximately 3 hours. Each treatment involved the use of 100 g of dried seed powder and 1000 cc of water. The essential oils extracted from fennel seeds were obtained from dried green seeds (pasty stage) due to data indicating that fennel seeds at this stage possess the highest concentration of essential oil (Stefanini *et al*., 2006).

Pearson’s phenotypic and genotypic correlation coefficients were calculated for the 16 quantitative traits pairwise among the various cultivars as per the methodologies of Johanson *et al*. (1955), Miller *et al*. (1958), Singh and Chaudhury (1985). The statistical significance of the correlation coefficients was evaluated utilizing the table of “t” values by Fisher and Yates (1963) at (n-2) degrees of freedom. Among the seventeen phenotypic traits, seed yield was considered the dependent variable, while the remaining variables were viewed as independent. The standard genotypic path coefficients, equivalent to standard partial regression coefficients, were computed by solving a set of ‘p’ simultaneous equations using the “DOLITTLE TECHNIQUE” with the spar 1 computer software proposed by Goulden (1959).

The correlation coefficient may not always be sufficient to explain causal relationships between variables, as the association between two variables could be influenced by a third variable. Path analysis offers a rational interpretation of observed correlations by modelling the cause-and-effect relationships among variables. Consequently, it becomes feasible to scrutinize the correlation coefficient of variables in terms of variance and covariance using path analysis (Gu *et al.*, 2019).

Path analysis has been developed as a statistical tool for analysing cause-and-effect relationships within a system of interconnected variables. A path coefficient, serving as a standardized partial regression coefficient, gauges the direct impact of a predictor variable on the dependent variable (Mohammadi *et al.*, 2003; Steel and Torrie, 1980). This facilitates the breakdown of the correlation coefficient into direct and indirect effects (Gu *et al.*, 2019), with unexplained effects being treated as residual effects. Plant breeders have utilized path analysis to comprehend the association between productivity and its constituents in different crops. In this study, the direct and indirect effects of path analysis were categorized using the Lenka and Misra (1973) scale.

## Results and Discussion

### Correlation study

A study of correlation was conducted to investigate the relationship between traits using Pearson's correlation coefficient. The correlation results are presented in Tables 1 and 2. Upon analysing genotypic and phenotypic correlations, it was found that there were positive and significant correlations of seed yield per plant with plant height (r = 0.378** and r = 0.362*), days to first flowering (r = 0.362* and r= 0.312*), number of umbels per plant (r = 0.316* and r = 0.312*), number of seeds per umbellet (r=0.302* and r = 0.283*), dry umbel weight (r= 0.325* and r = 0.319*), and harvest index (r = 0.679** and r = 0.667**).

**Table 1 :** Pearson's genotypic correlation coefficient analysis among seed yield attributing quantitative traits of fennel genotypes.

| Genotypical Correlation Matrix | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | **PH (cm)** | **NOB/P** | **DTG** | **DTFF** | **DT 50%F** | **DTM** | **NOU/P** | **NOUt/U** | **NOF /Ut** | **FUW (g)** | **DUW (g)** | **TW (g)** | **BY/P (g)** | **HI** | **OC %** | **AI %** | **SY/P (g)** |
| **PH (cm)** | 1.0000 | 0.282* | 0.341* | 0.542** | 0.0094 | -0.360* | 0.254* | 0.434** | 0.458** | 0.407** | 0.645** | -0.388** | 0.0864 | 0.1134 | 0.1959 | -0.0882 | 0.378** |
| **NOB/P** | | 1.0000 | 0.333* | 0.384** | 0.1132 | -0.0880 | 0.248* | 0.0186 | -0.1605 | 0.671** | 0.498** | -0.1894 | 0.0228 | -0.0298 | -0.308* | 0.0008 | -0.0782 |
| **DTG** | | | 1.0000 | 0.0625 | 0.331* | 0.1987 | 0.1623 | 0.1720 | 0.1645 | 0.367* | 0.378** | -0.256* | -0.0348 | -0.0595 | -0.1615 | 0.0488 | -0.0697 |
| **DTFF** | | | | 1.0000 | 0.412** | -0.368* | -0.0388 | -0.0898 | -0.0259 | 0.284* | 0.454** | -0.288* | -0.1280 | 0.277* | -0.0914 | -0.310* | 0.362* |
| **DT50%F** | | | | | 1.0000 | 0.410** | -0.280* | -0.1447 | -0.1299 | 0.1754 | 0.0738 | -0.1733 | -0.1333 | 0.1584 | -0.0211 | 0.0046 | -0.0660 |
| **DTM** | | | | | | 1.0000 | -0.1357 | -0.1755 | -0.0355 | -0.328* | -0.480** | 0.1555 | -0.0546 | -0.1364 | 0.294* | 0.1566 | -0.367* |
| **NOU/P** | | | | | | | 1.0000 | 0.278* | 0.284* | 0.347* | 0.1979 | -0.234* | 0.2247 | 0.1415 | -0.0839 | -0.0580 | 0.316* |
| **NOUt/U** | | | | | | | | 1.0000 | 0.713** | 0.305* | 0.390** | -0.2193 | 0.321* | -0.1239 | 0.323* | 0.1553 | 0.2031 |
| **NOS/Ut** | | | | | | | | | 1.0000 | 0.1224 | 0.234* | -0.0509 | 0.1766 | 0.0715 | 0.1628 | -0.0648 | 0.302* |
| **FUW (g)** | | | | | | | | | | 1.0000 | 0.766** | -0.386** | 0.289* | -0.0972 | -0.0594 | 0.0167 | 0.1466 |
| **DUW (g)** | | | | | | | | | | | 1.0000 | -0.400** | 0.1236 | 0.1238 | -0.0394 | 0.0079 | 0.325* |
| **TW (g)** | | | | | | | | | | | | 1.0000 | -0.321* | 0.1445 | 0.0062 | -0.2117 | -0.290* |
| **BY/P (g)** | | | | | | | | | | | | | 1.0000 | -0.720** | 0.395** | 0.228* | -0.0935 |
| **HI** | | | | | | | | | | | | | | 1.0000 | -0.327* | -0.302* | 0.679** |
| **OC %** | | | | | | | | | | | | | | | 1.0000 | 0.0934 | -0.1976 |
| **AI %** | | | | | | | | | | | | | | | | 1.0000 | -0.278* |
| **SY/P (g)** | | | | | | | | | | | | | | | | | 1.0000 |

*Significant @ 5% probability ** Significant @ 1% probability

**PH:** Plant height, **NOB/ P**: Number of branches/ plant, **DTG:** Days to germination, **DTFF:** Days to first flowering, **DT50%F:** Days to 50 % flowering, **DTM:** Days to maturity, **NOU/ P:** Number of umbels/ plant, **NOUt/ U:** number of umbellets/ umbel, **NOS/ Ut:** Number of seeds/ umbellet, **FUW:** Fresh umbel weight, **DUW**: Dry umbel weight, **TW:** Test weight, **BY/ P**: Biomass yield/ plant, **HI:** Harvest index, **OC:** Oil content, **AI:** Aphid incidence, **SY/ P:** Seed yield/ plant.

**Table 2 :** Pearson's phenotypic correlation coefficient analysis among seed yield attributing quantitative traits of fennel genotypes.

| Parameters | Phenotypical Correlation Matrix | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PH (cm) | NOB/P | DTG | DTFF | DT 50% F | DTM | NOU/P | NOUt/U | NOF /Ut | FUW (g) | DUW (g) | TW (g) | BY/P (g) | HI | OC % | AI % | SY/P (g) |
| PH (cm) | 1.0000 | 0.238* | 0.315* | 0.428** | -0.0175 | -0.270* | 0.249* | 0.423** | 0.412** | 0.388** | 0.616** | -0.366* | 0.1125 | 0.1179 | 0.1880 | -0.0726 | 0.362* |
| NOB/P | | 1.0000 | 0.273* | 0.338* | 0.0959 | -0.1385 | 0.2140 | 0.0043 | -0.1416 | 0.602** | 0.458** | -0.1706 | 0.0243 | -0.0399 | -0.249* | -0.0136 | -0.0584 |
| DTG | | | 1.0000 | 0.0561 | 0.282* | 0.0925 | 0.1498 | 0.1556 | 0.1703 | 0.358* | 0.363* | -0.239* | -0.0442 | -0.0558 | -0.1532 | 0.0495 | -0.0633 |
| DTFF | | | | 1.0000 | 0.291* | -0.297* | -0.0647 | -0.1083 | -0.0268 | 0.253* | 0.389** | -0.272* | -0.1239 | 0.230* | -0.0745 | -0.230* | 0.312* |
| DT50%F | | | | | 1.0000 | 0.1618 | -0.228* | -0.1541 | -0.1021 | 0.1275 | 0.0578 | -0.0969 | -0.1119 | 0.0897 | -0.0220 | -0.0180 | -0.0393 |
| DTM | | | | | | 1.0000 | -0.0813 | -0.0771 | 0.0096 | -0.229* | -0.343* | 0.1209 | -0.0748 | -0.0720 | 0.1720 | 0.1433 | -0.296* |
| NOU/P | | | | | | | 1.0000 | 0.272* | 0.262* | 0.340* | 0.1880 | -0.2247 | 0.2060 | 0.1416 | -0.0809 | -0.0582 | 0.312* |
| NOUt/U | | | | | | | | 1.0000 | 0.672** | 0.302* | 0.380** | -0.2076 | 0.308* | -0.1117 | 0.299* | 0.1520 | 0.1964 |
| NOS/Ut | | | | | | | | | 1.0000 | 0.1309 | 0.2207 | -0.0118 | 0.1567 | 0.0641 | 0.1191 | -0.0650 | 0.283* |
| FUW (g) | | | | | | | | | | 1.0000 | 0.755** | -0.365* | 0.276* | -0.0940 | -0.0702 | 0.0198 | 0.1426 |
| DUW (g) | | | | | | | | | | | 1.0000 | -0.373** | 0.1298 | 0.1179 | -0.0376 | 0.0147 | 0.319* |
| TW (g) | | | | | | | | | | | | 1.0000 | -0.281* | 0.1215 | -0.0206 | -0.1978 | -0.281* |
| BY/P (g) | | | | | | | | | | | | | 1.0000 | -0.676** | 0.367* | 0.2206 | -0.0829 |
| HI | | | | | | | | | | | | | | 1.0000 | -0.303* | -0.278* | 0.667** |
| OC % | | | | | | | | | | | | | | | 1.0000 | 0.0762 | -0.1729 |
| AI % | | | | | | | | | | | | | | | | 1.0000 | -0.267* |
| SY/P (g) | | | | | | | | | | | | | | | | | 1.0000 |

*Significant @ 5% probability ** Significant @ 1% probability

**PH:** Plant height, **NOB/ P**: Number of branches/ plant, **DTG:** Days to germination, **DTFF:** Days to first flowering, **DT50%F:** Days to 50 % flowering, **DTM:** Days to maturity, **NOU/ P:** Number of umbels/ plant, **NOUt/ U:** number of umbellets/ umbel, **NOS/ Ut:** Number of seeds/ umbellet, **FUW:** Fresh umbel weight, **DUW**: Dry umbel weight, **TW:** Test weight, **BY/ P**: Biomass yield/ plant, **HI:** Harvest index, **OC:** Oil content, **AI:** Aphid incidence, **SY/ P:** Seed yield/ plant.

Improvement in these traits could lead to an enhancement in seed yield, suggesting that positive selection should be applied to these traits for seed yield improvement. These findings align with previous studies by various researchers *viz.*, Jindla *et al.* (1985), Bhandari and Gupta (1991), Agnihotri *et al.* (1997), Garg *et al.* (2003), Jain *et al.* (2003), Singh and Sastry (2005), Lal (2007), Cosge *et al.* (2009), Idhol *et al.* (2009), Dashora and Sastry (2011), Mangesha *et al.* (2013), Yadav *et al.* (2013), Sefidan *et al.* (2014), Singh *et al.* (2015b), Mohan *et al.* (2016) and Ram *et al.* (2017).

On the other hand, traits such as days to maturity (r = -0.367* and r = -0.296*), test weight (r = -0.386** and r= -0.365*) and aphid incidence (r = -0.278* and r = -0.267*) exhibited significant negative correlations with seed yield per plant. Days to maturity can serve as a selection criterion for increasing seed yield if negative selection is practiced, indicating that a shorter period to 50 % flowering results in higher seed yield per hectare. Similar observations were reported by previous researchers Jindla *et al.* (1985), Bhandari and Gupta (1991) and Yadav *et al.* (2013).

## Path coefficient analyses

Path coefficient analysis was conducted in the current study to explore the relationships among fennel components. The analysis focused on genotypic associations and is presented in Table 3.

The path coefficient analysis at the genotypic level unveiled that the number of branches per plant (r = 2.7229) had the highest and significant positive direct effect on seed yield per plant, followed by days to 50% flowering (r = 2.3168),

**Table 3 :** Genotypic path coefficient analysis among seed yield attributing quantitative traits of fennel genotypes.

| Genotypic path matrix of Seed yield /plant | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | **PH (cm)** | **NOB/P** | **DTG** | **DTFF** | **DT 50% F** | **DTM** | **NOU/P** | **NOUt/U** | **NOF /Ut** | **FUW (g)** | **DUW (g)** | **TW (g)** | **BY/P (g)** | **HI** | **OC %** | **AI %** | **SY/P (g)** |
| **PH (cm)** | **-0.8931** | -0.2520 | -0.3044 | -0.4843 | -0.0084 | 0.3211 | -0.2271 | -0.3871 | -0.4089 | -0.3632 | -0.5759 | 0.3460 | -0.0771 | -0.1013 | -0.1750 | 0.0788 | 0.378** |
| **NOB/P** | 0.7685 | **2.7229** | 0.9057 | 1.0460 | 0.3082 | -0.2398 | 0.6752 | 0.0505 | -0.4369 | 1.8265 | 1.3565 | -0.5158 | 0.0622 | -0.0811 | -0.8397 | 0.0022 | -0.0782 |
| **DTG** | 0.0630 | 0.0614 | **0.1847** | 0.0115 | 0.0611 | 0.0367 | 0.0300 | 0.0318 | 0.0304 | 0.0678 | 0.0699 | -0.0472 | -0.0064 | -0.0110 | -0.0298 | 0.0090 | -0.0697 |
| **DTFF** | -1.2555 | -0.8894 | -0.1446 | **-2.3153** | -0.9528 | 0.8509 | 0.0899 | 0.2080 | 0.0600 | -0.6572 | -1.0502 | 0.6662 | 0.2963 | -0.6417 | 0.2115 | 0.7187 | 0.362* |
| **DT50%F** | 0.0217 | 0.2622 | 0.7670 | 0.9535 | **2.3168** | 0.9502 | -0.6476 | -0.3353 | -0.3009 | 0.4063 | 0.1709 | -0.4015 | -0.3089 | 0.3669 | -0.0489 | 0.0108 | -0.0660 |
| **DTM** | 1.2350 | 0.3025 | -0.6827 | 1.2625 | -1.4090 | **-3.4354** | 0.4663 | 0.6028 | 0.1219 | 1.1258 | 1.6482 | -0.5343 | 0.1877 | 0.4687 | -1.0092 | -0.5380 | -0.367* |
| **NOU/P** | 0.1357 | 0.1323 | 0.0866 | -0.0207 | -0.1491 | -0.0724 | **0.5336** | 0.1481 | 0.1515 | 0.1852 | 0.1056 | -0.1249 | 0.1199 | 0.0755 | -0.0448 | -0.0309 | 0.316* |
| **NOUt/U** | -0.7374 | -0.0316 | -0.2926 | 0.1528 | 0.2462 | 0.2985 | -0.4722 | **-1.7012** | -1.2136 | -0.5195 | -0.6627 | 0.3730 | -0.5454 | 0.2108 | -0.5499 | -0.2642 | 0.2031 |
| **NOS/Ut** | 0.9596 | -0.3363 | 0.3448 | -0.0543 | -0.2722 | -0.0744 | 0.5950 | 1.4953 | **2.0960** | 0.2565 | 0.4896 | -0.1067 | 0.3703 | 0.1499 | 0.3412 | -0.1359 | 0.302* |
| **FUW (g)** | -1.1068 | -1.8256 | -0.9995 | -0.7726 | -0.4773 | 0.8919 | -0.9448 | -0.8311 | -0.3331 | **-2.7215** | -2.0849 | 1.0506 | -0.7864 | 0.2645 | 0.1616 | -0.0455 | 0.1466 |
| **DUW (g)** | 0.3180 | 0.2457 | 0.1865 | 0.2237 | 0.0364 | -0.2366 | 0.0976 | 0.1921 | 0.1152 | 0.3778 | **0.4931** | -0.1974 | 0.0610 | 0.0611 | -0.0194 | 0.0039 | 0.325* |
| **TW (g)** | 0.3875 | 0.1895 | 0.2557 | 0.2878 | 0.1733 | -0.1556 | 0.2340 | 0.2193 | 0.0509 | 0.3861 | 0.4004 | **-1.0002** | 0.3214 | -0.1445 | -0.0062 | 0.2117 | -0.290* |
| **BY/P (g)** | -0.0129 | -0.0034 | 0.0052 | 0.0191 | 0.0199 | 0.0082 | -0.0336 | -0.0479 | -0.0264 | -0.0431 | -0.0185 | 0.0480 | **-0.1493** | 0.1075 | -0.0590 | -0.0340 | -0.0935 |
| **HI** | 0.0617 | -0.0162 | -0.0323 | 0.1507 | 0.0861 | -0.0742 | 0.0769 | -0.0674 | 0.0389 | -0.0528 | 0.0673 | 0.0786 | -0.3914 | **0.5436** | -0.1779 | -0.1642 | 0.679** |
| **OC %** | 0.4066 | -0.6400 | -0.3352 | -0.1896 | -0.0438 | 0.6097 | -0.1741 | 0.6709 | 0.3379 | -0.1233 | -0.0818 | 0.0129 | 0.8197 | -0.6793 | **2.0754** | 0.1938 | -0.1976 |
| **AI %** | 0.0260 | -0.0002 | -0.0144 | 0.0914 | -0.0014 | -0.0461 | 0.0171 | -0.0457 | 0.0191 | -0.0049 | -0.0023 | 0.0623 | -0.0671 | 0.0889 | -0.0275 | **-0.2945** | -0.278* |
| **SY/P (g)** | 0.378** | -0.0782 | -0.0697 | 0.362* | -0.0660 | -0.367* | 0.316* | 0.2031 | 0.302* | 0.1466 | 0.325* | -0.290* | -0.0935 | 0.679** | -0.1976 | -0.278* | **1.0000** |
| **Partial $R^2$** | -0.3373 | -0.2130 | -0.0129 | -0.8386 | -0.1530 | 1.2617 | 0.1688 | -0.3456 | 0.6330 | -0.3990 | 0.1604 | 0.2903 | 0.0140 | 0.3688 | -0.4102 | 0.0820 | |

*Significant @ 5% probability ** Significant @ 1% probability Residual effect: 0.855

**PH:** Plant height, **NOB/ P**: Number of branches/ plant, **DTG:** Days to germination, **DTFF:** Days to first flowering, **DT50%F:** Days to 50 % flowering, **DTM:** Days to maturity, **NOU/ P:** Number of umbels/ plant, **NOUt/ U:** number of umbellets/ umbel, **NOS/ Ut:** Number of seeds/ umbellet, **FUW:** Fresh umbel weight, **DUW**: Dry umbel weight, **TW:** Test weight, **BY/ P**: Biomass yield/ plant, **HI:** Harvest index, **OC:** Oil content, **AI:** Aphid incidence, **SY/ P:** Seed yield/ plant

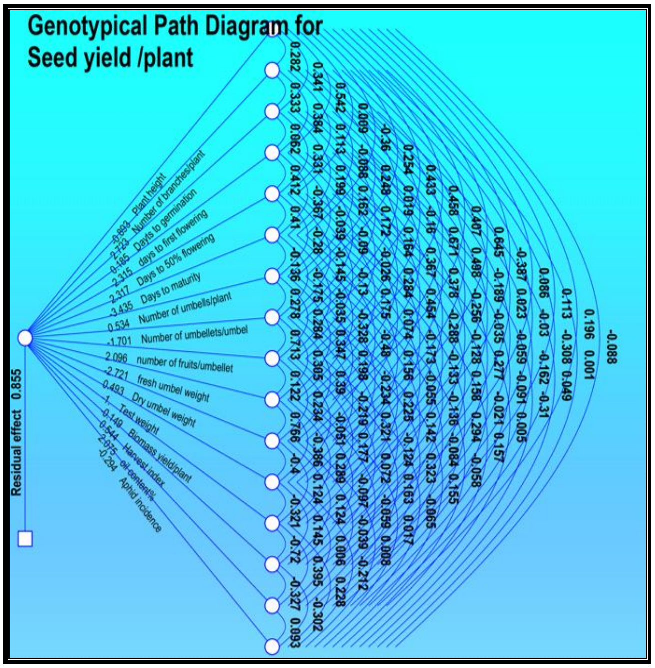


**Fig. 1 :** Genotypical path diagram for seed yield per plant from their associated traits among 38 fennel genotypes.

number of seeds per umbellet (r = 2.0960), and oil content (r = 2.0754). Conversely, harvest index (r = 0.5436) and number of umbels per plant (r = 0.5336) showed non-significant positive direct effects on seed yield per plant. Although these traits had significant correlations with seed yield per plant, indicating indirect cumulative effects on seed yield through other characters. High indirect effects of these characteristics were predominantly observed via days required for maturity, seed weight, and biomass yield per individual plant, underscoring the significance of these traits as pivotal selection criteria for enhancing seed yield in fennel. These findings align with prior studies by Bhandari and Gupta (1991), Agnihotri *et al.* (1997), Jain *et al.* (2003), Dashora and Sastry (2011), Yadav *et al.* (2013), and Sefidan *et al.* (2014).

Meanwhile, days to maturity (r= -3.4354), weight of fresh umbels (r = -2.7215), days to initial flowering (r= -2.3153), number of umbellets per umbel (r = -1.7012), test weight (r = -1.0002), plant height (r= -0.8931) and aphid infestation (r = -0.2945), exhibited sequentially declining negative direct impacts on seed yield per plant. Similar outcomes were documented by Agnihotri *et al.* (1997), Jain *et al.* (2003), Mangesha *et al.* (2013) and Yadav *et al.* (2013).

The residual effects depicted the extent to which the causal factors elucidated the variability in the dependent factor. Minimal residual effects signified that the causal factors adequately explicated the dependent variable. In this investigation, the residual effect for seed yield was computed to be 0.855. As the residual effects for seed yield were relatively substantial, it is plausible that there exist essential additional factors influencing seed yield that were not accounted for in this study. The path diagram illustrating seed yield ispresented in Fig. 1.

It is deduced that a substantial level of association exists among 17 traits of fennel (*Foeniculum vulgare* Mill.), as evidenced by the findings of the correlation and path coefficient analysis. The genotypic and phenotypic assessment demonstrated a significant and positive correlation between seed yield and various traits such as plant height, days to initial flowering, days to maturity, number of umbels per plant, number of seeds per umbellet and harvest index. The results of the path analysis highlighted those key variables including the count of seeds per umbellet, number of branches per plant, days to reach 50 per cent flowering and oil content were the major contributors to seed yield. Additionally, there was an indication that the number of umbels per plant and harvest index also played a role in influencing seed yield.

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