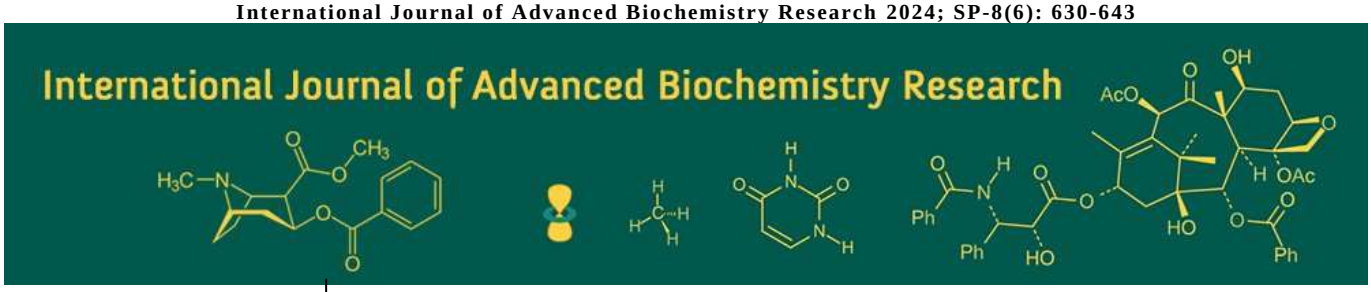


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# Correlation and path coefficient analysis studies in $F_3$, $F_4$ and $F_5$ generations of okra (*Abelmoschus esculentus* L.) cross VRO-3 x 440-10-1

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**Abstract**
The present experiment was conducted on study of correlation and path coefficient analysis in okra (*Abelmoschus esculentus*) cross VRO-3 x 440-10-1 was carried out with $F_3$, $F_4$ and $F_5$ generations during in *Summer*, 2021-22, *Kharif*, 2022-23 and *Rabi*-2022-23 at Horticultural Research Station, Lam, Guntur, Andhra Pradesh. From correlation coefficient studies, it was observed from that fruit yield per plant registered positive significant correlation plant height (0.96), number of fruits per plant (0.97), fruit weight (0.97) and number of seeds per fruit (0.99) in $F_3$ generation, Similarly in $F_4$ generation the traits plant height (0.96), number of fruits per plant (0.76), fruit length (0.88), fruit weight (0.98) and number of seeds per fruit (0.97) respectively in $F_5$ generation, the traits plant height (0.98), number of fruits per plant (0.97), Fruit weight (0.97) and number of seeds per fruit (0.97) were recorded. The results of path coefficient analysis showed that the following characters had positive direct effect on plant height, intermodal length and days to first flowering, fruit girth and number of seeds per fruit in $F_3$ generation. In $F_4$ generation the traits plant height, days to first flowering, days to last picking, fruit weight and shelf-life of fruits respectively in $F_5$ generation the traits plant height, days to last picking, number of seeds per fruit, test weight of seeds and fibre content of fruits were recorded positive direct effect with fruit yield per plant.

**Keywords:** Okra, VRO-3 x 440-10-1, correlation, positive significant, path coefficient, positive direct effect

## Introduction
Okra (*Abelmoschus esculentus* L.) is a Malvaceae vegetable with chromosome number 2n=2x=130. It is an annual vegetable crop, commercially grown for edible vegetable. Because of its highest production potential and availability to consumers, okra is cultivated throughout the tropical and warm temperate regions of the world for its fruits or pods. It is a short duration crop and grown as spring-summer and rainy season crop in Northern India while in South India, it is possible to grow throughout the year and native to Tropical Asia and also considered as native place of India. Tender okra fruits are used as vegetable in countries like India, Brazil, West Africa. Okra fruit contains 90% water, 3% dietary fibre, 7% carbohydrates, 2% protein, with good quantities of minerals, Vitamin-C and A and had moderate contents of thiamin, folate and magnesium (Chopra *et al*., 1956) [3]. In India, the area under okra cultivation is 5.19 lakh ha with an annual production of 63.71 lakh tonnes and productivity of 12.17 MT/ha. West Bengal, Orissa, Bihar, Gujarat, Andhra Pradesh, Telangana, Maharashtra, Assam and Uttar Pradesh are the major okra producing states in the country. Andhra Pradesh with a production of 2.05 lakh tonnes from 13,670 ha ranks fourth in the country with a productivity of 15 t/ha (NHB, 2019-20) [8].
Yield is a complex quantitative trait and polygenically controlled character resulting from multiplicative interaction of yield components. The cumulative effects of such characters determine the dependent variable yield. Hence, selection of genotypes based on yield alone is not effective. Genetic correlation measures the magnitude of relationship between various plant characters that determines the component characters on which selection can be made for yield improvement. These characters play an important role in modifying the system of yield as a whole in magnitude as well as indirection.

If the correlation between yield and a character is due to the direct effect of the character, it reflects a true relationship between them and selection can be practiced for such characters in order to improve yield. Therefore, the study of correlation between yield and yield components is of considerable importance for a breeder in the selection programme. In the present investigation, correlation coefficients between yield and other related component characters and among themselves were estimated and presented here under.

The relation between the yield and other factors is important to bring the simultaneous improvement in correlated traits. The correlation coefficient value between yield and its component characters may sometimes be misleading as it may be an over or under estimate of its association with other characters.

If the number of variables are more, it becomes difficult to measure the contribution of each variable towards the observed correlation. Therefore, partitioning of the observed correlation coefficients into "unidirectional pathways and alternate pathways" help in the characterization of more complex traits like yield. For critical evaluation, the correlation coefficient needs to be split into direct and indirect effects using path coefficient analysis. Since, many characters affect a given trait. Thus, the correlation and path coefficients in combination can give a better insight into cause and effect relationship between different pairs of characters.

If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct selection through this trait will be effective.

If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection.

Correlation coefficient may be negative but the direct effect is positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed *i.e*., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect.

If correlation coefficient is negative and direct effect is also negative, then we have to drop the selection based on that character.

The residual effect determines how best the causal factors account for the variability of the dependent factor. If the residual effect is high, some other factors which have not been considered in the study need to be included in the analysis to account fully for the variation in yield.

Through path analysis, the direct and indirect effects of different yield component traits on yield were worked out in this study.

## Materials and Methods

The present investigation entitled "Correlation and path coefficient analysis studies in okra (*Abelmoschus esculentus*) cross VRO-3 x 440-10-1 was conducted at Dr. YSRHU- Horticultural Research Station, Lam, Guntur of Andhra Pradesh during *Summer* 2021-22, *Kharif* 2022-23 and *Rabi* 2022-23. The experimental site situated on $16.28^0$ North latitude and $80.44^0$ East longitude at an altitude of 31.5 m above mean sea level and falls under humid tropical climate. The experimental site is of rich black cotton soil.

### Experimental material

Six parental lines of okra (VRO-3, VRO-6, 440-10-1, TCR-1674, JPM-20-16-39, HRB-9-2) were crossed in half diallel fashion during *kharif* 2018 and the resulting 15 $F_1$s were evaluated with an objective of estimating the GCA and SCA of the lines for the important traits. Six top-performing $F_1$s from parents with high GCA values were selfed during *Rabi*, 2018-19 with an objective of isolating new high yielding recombinants through selection. The $F_2$ generation was raised from top-six crosses (VRO-3 x HRB 9-2, VRO-6 x 440-10-1, VRO-6 x JPM 20-16-39, VRO-6 x HRB 9-2, 440-10-1 x HRB 9-2, TCR-1674 x JPM-20-16-39) in *Kharif* 2019-20. Among the six crosses, the best performing cross such as VRO-3 x 440-10-1 were selected for further evaluation.

The one hundred and fifty top performing plants were selected in each cross from $F_2$ generation and selfed to get $F_3$ generation for the present study. Selection was exercised in $F_3$, $F_4$ and $F_5$ generations of VRO-3 x 440-10-1 cross during in *Summer* 2021-22, *Kharif* 2022-23 and *Rabi* 2022-23 respectively.

### Technical Programme of Work

**Experiment- I: Evaluation of $F_3$ generation**

Location: Horticultural Research Station, Lam, Guntur, A.P.
Crop: Okra [*Abelmoschus esculentus* (L.) Moench.]
Number of parents: Two (VRO-3 and 440-10-1)
Name of the cross: VRO-3 x 440-10-1
Size of the F3 population: 150 plants per each cross
Spacing: 60 cm x 30 cm
Season: Summer, 2021-22

**Experiment- II: Evaluation of $F_4$ generation**

Location: Horticultural Research Station, Lam, Guntur, A.P.
Crop: Okra [*Abelmoschus esculentus* (L.) Moench.]
Number of parents: Two (VRO-3 and 440-10-1)
Name of the cross: VRO-3 x 440-10-1
Size of the F4 population: 150 plants per each cross
Spacing: 60 cm x 30 cm
Season: Kharif, 2022-23

**Experiment- III: Evaluation of $F_5$ generation**

Location: Horticultural Research Station, Lam, Guntur, A.P.
Crop: Okra [*Abelmoschus esculentus* (L.) Moench.]
Number of parents: Two (VRO-3 and 440-10-1)
Name of the cross: VRO-3 x 440-10-1
Size of the F5 population: 150 plants per each cross
Spacing: 60 cm x 30 cm
Season: Rabi, 2022-23

### Correlation Analysis

Simple correlation coefficients between yield and yield components and inter correlation among the various components were calculated using the formula suggested by Panse and Sukhatme (1967) [9].

Where,
R = Simple correlation coefficient between variable X and Y
Cov. (X.Y) = Simple covariance between X and Y
V (x) = Variance of X
V (y) = Variance of Y

The significance of genotypic correlation coefficient was tested by referring to the standard table given by Snedecor *et al*. (1967) [15].

**Path coefficient Analysis**

Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921) [19] and illustrated by Dewey and Lu (1959) [4] by partitioning the simple correlation coefficients into direct and indirect effects. The direct and indirect effects were ranked based on the scales of Lenka and Misra (1973) [6]. Standard path coefficients which are the standardized partial regression coefficients were obtained using statistical software packages called GENRES. These values were obtained by solving the following set of 'p' simultaneous equation using above package.

P01+ P02 r12+ P0P r1P = r01
P01+ P12 r02 + P0P r2P = r02
P01+ r1P + P02 r2P + P0P = r0P

Where, P01, P02, P0P are the direct effects of variables 1,2, p on the dependent variable 0 and r12, r13, r1P, r P(P-1) are the possible correlation coefficients between various independent variables and r01, r02, r03 r0P are the correlation between dependent and independent variables. The indirect effects of the ith variable via j th variable is attained as (Poj x rij). The contribution of remaining unknown factor is measured as the residual factor, which is calculated and given below.

P 2 ox = 1-[P2 01+2P01P02r12+2P01P03r13+ P2 02+ 2P02P03r13 + P2 0P
Residual factor = √ (P2 ox)
Negligible: 0.00 to 0.09
Low: 0.10 to 0.19
Moderate: 0.20 to 0.29
High: 0.30 to 1.00
Very high: > 1.00

**Results and Discussion**

**1. Correlation Coefficient Analysis**

**1.1 Correlation coefficients of yield and its component characters in $F_3$ generation of the cross VRO-3 × 440-10-1**

The data on association among the yield and yield attributing traits is presented in the table 1.

**1.1.1 Plant height (cm)**

Plant height exhibited significant positive correlation with number of fruits per plant (0.98**), fruit weight (0.98**), number of seeds per fruit (0.96**) and fruit yield per plant (0.96**).

Plant height also exhibited significant negative association with internodal length (-0.97**) and YVMV incidence (-0.92**).

**1.1.2 Days to first flowering**

From the data, it is evident that the trait days to first flowering had significant positive correlation with days to 50% flowering (0.96**), days to first picking (0.83**) and days to last picking (0.79**).

**1.1.3 Internodal length (cm)**

Internodal length was positively associated with YVMV incidence (0.95**), while it had significant negative correlation with number of fruits per plant (-0.98**), fruit weight (-0.98**), number of seeds per fruit (-0.98**) and fruit yield per plant (-0.97**).

**1.1.4 Days to 50% flowering**

Days to 50% flowering exhibited a significant positive correlation with days to first picking (0.79**) and days to last picking (0.75**).

**1.1.5 First flowering node**

It is clear from the data, that the trait first flowering node neither had recorded significant positive nor negative association with any of the traits.

**1.1.6 Days to first picking**

Days to first picking exhibited significant positive correlation with days to last picking (0.95**). It did not show significant negative association with any trait studied.

**1.1.7 Days to last picking**

The trait days to last picking has not recorded any significant positive or negative correlation with any of the traits.

**1.1.8 Number of fruits per plant**

The correlation analysis indicated significant positive association of number of fruits per plant with fruit weight (0.98**), number of seeds per fruit (0.97**) and fruit yield per plant (0.97**).

This trait also recorded significant negative association with YVMV incidence (-0.95**).

**1.1.9 Fruit length (cm)**

Fruit length exhibited significant positive correlation with fruit girth (0.70**).

**1.1.10 Fruit girth (cm)**

Fruit girth had not shown any significant positive or negative association with any traits.

**1.1.11 Fruit weight (g)**

Fruit weight had significant positive association with number of seeds per fruit (0.97**) and fruit yield per plant (0.97**).

This trait has recorded significant negative correlation with YVMV incidence (-0.96**).

**1.1.12 Number of seeds per fruit**

Number of seeds per fruit exhibited significant positive correlation with fruit weight (0.97**) and fruit yield per plant (0.99**).

This trait also exhibited significant negative correlation with YVMV incidence (-0.97**).

**1.1.13 Test weight of seeds (g)**

Test weight of seeds has not recorded any significant positive or negative association with any trait.

**1.1.14 YVMV incidence (%)**

YVMV incidence displayed significant negative association with fruit yield per plant (-0.97**) along with yield contributing traits like number of seeds per fruit (0.97**) fruit weight (0.96**) and number of fruits per plant (0.95**).

**1.1.15 Fibre content (g)**
Fibre content in fruits did not show significant association with any trait.

**1.1.16 Ascorbic acid (mg)**
This trait had not shown significant association either positively or negatively with any trait.

**1.1.17 Shelf-life (Days)**
Shelf-life had not been associated significantly with any of traits.

**1.2 Correlation coefficients of yield and its component characters in $F_4$ generation of the cross VRO-3 × 440-10-1**
The data on association among the yield and yield attributing traits is presented in the table 2.

**1.2.1 Plant height (cm)**
Plant height exhibited significant positive correlation with number of fruits per plant (0.84**), fruit length (0.93**), fruit weight (0.96**) and fruit yield per plant (0.96**).
It also exhibited significant negative association with internodal length (-0.94**), YVMV incidence (-0.95**) and fruit girth (-0.21*).

**1.2.2 Days to first flowering**
From the data it can be interpreted that the trait days to first flowering had significant positive correlation with days to 50% flowering (0.90**), days to first picking (0.75**) and days to last picking (0.69**).
Days to first flowering also exhibited negative association with ascorbic acid content (-0.22*).

**1.2.3 Internodal length (cm)**
Internodal length displayed significant positive association with YVMV incidence (0.97**) and fruit girth (0.21*), while it had significant negative association with number of fruits per plant (-0.73**), fruit length (-0.86**), fruit weight (-0.97**), number of seeds per fruit (-0.95**) and fruit yield per plant (-0.98**).

**1.2.4 Days to 50% flowering**
Days to 50% flowering character recorded a significant positive correlation with days to first picking (0.84**) and days to last picking (0.78**), fruit girth (0.22*) and significant negative association with ascorbic acid content (-0.26*).

**1.2.5 First flowering node**
The parameter first flowering node exhibited negative association with shelf life (-0.21*).

**1.2.6 Days to first picking**
Days to first picking exhibited significant positive correlation with days to last picking (0.93**). It showed negative association with ascorbic acid content (-0.22*).

**1.2.7 Days to last picking**
Days to last picking did not show significant positive correlation with any trait but it recorded significant negative correlation with ascorbic acid content (-0.26**).

**1.2.8 Number of fruits per plant**
The correlation analysis indicated that number of fruits per plant displayed significant positive correlation with fruit length (0.83**), fruit weight (0.76**), number of seeds per fruit (0.79**) and fruit yield per plant (0.76**). This trait also had significant negative association with fruit girth (-0.29**) and YVMV incidence (-0.78**).

**1.2.9 Fruit length (cm)**
Fruit length exhibited significant positive correlation with fruit weight (0.87**), number of seeds per fruit (0.89**) and fruit yield per plant (0.88**) whereas it had significant negative association with YVMV incidence (-0.87**).

**1.2.10 Fruit girth (cm)**
Fruit girth had positive correlation with shelf life (0.20*). This trait also exhibited negative association with fruit weight (-0.21*), number of seeds per fruit (-0.22*) and fruit yield per plant (-0.22*).

**1.2.11 Fruit weight (g)**
Fruit weight parameter had significant positive association with number of seeds per fruit (0.98**) and fruit yield per plant (0.98**) whereas this trait recorded significant negative correlation with YVMV incidence (-0.97**).

**1.2.12 Number of seeds per fruit**
Number of seeds per fruit exhibited significant positive correlation with fruit yield per plant (0.97**). This trait also exhibited significant negative correlation with YVMV incidence (-0.97**).

**1.2.13 Test weight of seeds (g)**
Test weight of seeds had not recorded significant positive or negative association with any trait.

**1.2.14 YVMV incidence (%)**
YVMV incidence displayed significant negative association with fruit yield per plant (-0.98**).

**1.2.15 Fibre content (g)**
Fibre content in fruits showed negative association with ascorbic acid content (-0.24*) and not shown any significant positive association with any trait.

**1.2.16 Ascorbic acid (mg)**
This trait did not show any significant positive or negative association with any trait.

**1.2.17 Shelf-life (Days)**
Shelf-life did not exhibit significant association with any other trait.

**1.3 Correlation coefficients of yield and its component characters in $F_5$ generation of the cross VRO-3 × 440-10-1**
The data on association among the yield and yield attributing traits is presented in the table 3

**1.3.1 Plant height (cm)**
Plant height exhibited significant positive correlation with number of fruits per plant (0.98**), fruit weight (0.98**), number of seeds per fruit (0.98**), fruit yield per plant (0.98**) and first flowering node (0.24*) while it had

significant negative association with internodal length (-0.98**) and YVMV incidence (-0.98**).

**1.3.2 Days to first flowering**
From the data, it can be interpreted that the trait days to first flowering had shown significant positive correlation with days to 50% flowering (0.87**), days to first picking (0.86**) and days to last picking (0.82**). It had not shown any significant negative correlation with any trait.

**1.3.3 Internodal length (cm)**
It is clear from the data that internodal length was positively associated with YVMV incidence (0.97**) while this trait had significant negative correlation with number of fruits per plant (-0.98**), fruit weight (-0.98**), number of seeds per fruit (-0.98**) and fruit yield per plant (-0.97**) and first flowering node (-0.25*).

**1.3.4 Days to 50% flowering**
Days to 50% flowering exhibited significant positive association with days to first picking (0.91**) and days to last picking (0.87**). It did not show significant negative association with any trait.

**1.3.5 First flowering node**
First flowering node had positive association with number of fruits per plant (0.24*), fruit weight (0.24*), number of seeds per fruit (0.23*) and fruit yield per plant (0.25*). This character also had negative association with YVMV incidence (-0.25*).

**1.3.6 Days to first picking**
Days to first picking exhibited significant positive correlation with days to last picking (0.95**).

**1.3.7 Days to last picking**
The trait days to last picking recorded neither significant positive nor negative correlation with any trait.

**1.3.8 Number of fruits per plant**
Number of fruits per plant displayed significant positive correlation with fruit weight (0.98**), number of seeds per fruit (0.98**) and fruit yield per plant (0.97**). This trait also displayed significant negative association with YVMV incidence (-0.97**).

**1.3.9 Fruit length (cm)**
Fruit length exhibited significant positive correlation with fruit girth (0.97**). This character did not show significant negative correlation with any trait.

**1.3.10 Fruit girth (cm)**
Fruit girth showed neither significant positive nor negative correlation with any of traits.

**1.3.11 Fruit weight (g)**
Fruit weight had significant positive association with number of seeds per fruit (0.98**) and fruit yield per plant (0.97**) while negative association with YVMV incidence (-0.97**).

**1.3.12 Number of seeds per fruit**
Number of seeds per fruit exhibited significant positive correlation with fruit yield per plant (0.97**) while negative with YVMV incidence (-0.97**).

**1.3.13 Test weight of seeds (g)**
Test weight of seeds did not show either significant positive or negative association with any trait.

**1.3.14 YVMV incidence (%)**
YVMV incidence displayed significant negative association with fruit yield per plant (-0.97**), number of fruits per plant (-0.97**), fruit weight (-0.97**), number of seeds per fruit (-0.97**) and plant height (-0.98**)

**1.3.15 Fibre content (g)**
Fibre content did not show either significant positive or negative association with any of traits.

**1.3.16 Ascorbic acid (mg)**
This trait recorded neither significant positive nor negative correlation with any trait.

**1.3.17 Shelf-life (Days)**
Shelf-life did not record significant association with any trait.

Correlation coefficients give an idea about the mutual relationship between various plant characters and determine the component characters on which selection can be based for genetic improvement in yield. If the improvement in one character results in a decrease in other character, this will also help the breeder in the selection of characters if necessary. Selection based on yield contributing character to be successful, knowledge of interrelationships among yield attributing characters is necessary as it gives more reliable information for effective selection.

Plant height, number of fruits per plant, fruit weight, number of seeds per fruit in $F_3$, $F_4$ and $F_5$ generations and fruit length in $F_4$; first flowering node in $F_5$ had significant positive association with fruit yield per plant. Thus, the improvement of these traits may result in improvement of fruit yield per plant. Similar results in okra reported by Yadav *et al.* (2017) [20], Prasath *et al.* (2017) [10], Shehal *et al.* (2019) [14], Aditi *et al.* (2020) [1], Rynjah *et al.* (2020) [13], Rajani *et al.* (2022) [12], Bagadiya *et al.* (2022) [2], Vinod are strongly support the findings of the present investigation.

The internodal length in all the generations was observed to be negatively associated with fruit yield per plant indicating that, shorter the internodal length, higher the fruit yield. In a given plant, shorter the internode, more the number of internodes that are accommodated. As okra is expected to produce fruits at every node, the short internodal length thus is expected to contribute for yield. Thus improvement in this trait may lead to decrease in yield. Other characters that showed significant negative association with fruit yield per plant were YVMV incidence in $F_3$, $F_4$ and $F_5$ and fruit girth in $F_4$. True to the findings of this investigation, an increase in disease incidence has lead to corresponding decrease in yield indicating the need for solution of resistance or tolerant types against YVMV. These findings are in agreement with the results reported by Yadav *et al.* (2017) [20], Prasath *et al.* (2017) [10], Aditi *et al.* (2020) [1].

In all the three generations, days to first flowering, days to 50% flowering, days to first picking, days to last picking, test weight of seed, fibre content, ascorbic acid, shelf life; first flowering node in $F_3$ and $F_4$, fruit length and fruit girth in $F_3$ and $F_5$ did not record significant association with fruit yield per plant indicating that improvement of these characters might have not affected the fruit yield per plant of

okra in the present study. Thus, improvement of these traits may not result in improvement of yield. These results are similar to the findings of Yadav *et al.* (2017) [20], Shehal *et al.* (2019) [14], Rynjah *et al.* (2020) [13], Neeraja *et al*. (2022) [7], Bagadiya *et al.* (2022) [2].

## 2. Path Coeffiecent Analysis

### 2.1 Path coefficients of yield and its contributing traits in $F_3$ generation of the cross VRO-3 x 440-10-1

The direct and indirect effects of different independent traits on the dependent variable *i.e*. fruit yield per plant are presented in table 1 and figure 1

#### 2.1.1 Plant height (cm)

Path analysis revealed that the plant height had high positive direct effect (0.3420) and positive correlation coefficient (0.9646) with fruit yield per plant. It was noticed that high negative indirect effects were observed through internodal length (-0.3347) and YVMV incidence (-0.3175) while high positive indirect effect through number of fruits per plant (0.3367), fruit weight (0.3368) and number of seeds per fruit (0.3289)

#### 2.1.2 Days to first flowering

There existed manifestation of negligible positive direct effect on fruit yield per plant by the trait days to first flowering (0.0161) along with positive correlation coefficient (0.0462). There existed negligible indirect effects through all the traits under study.

#### 2.1.3 Internodal length (cm)

The trait internodal length recorded the low positive direct effect (0.1443) and negative correlation coefficient (-0.9723) with fruit yield per plant. It had low positive indirect effect through YVMV incidence (0.1370) whereas low negative indirect effect through plant height (-0.1412) was also recorded.

#### 2.1.4 Days to 50% flowering

Path analysis revealed that the days to 50% flowering trait had negligible negative direct effect (-0.0092) along with positive correlation coefficient (0.0438) with fruit yield per plant. It showed negligible indirect effect through all the traits under study.

#### 2.1.5 First flowering node

Negligible positive direct effect (0.0029) along with negative correlation coefficient (-0.0501) with fruit yield per plant were observed for first flowering node. Negligible indirect effect was noticed through the studied characters.

#### 2.1.6 Days to first picking

The trait days to first picking recorded negligible positive direct effect (0.0102) along with positive correlation coefficient (0.0958) with fruit yield per plant. It had negligible indirect effect through some of the characters under study.

#### 2.1.7 Days to last picking

Path analysis revealed that the days to last picking showed negligible negative direct effect (-0.0373) and positive correlation coefficient (0.1026) with fruit yield per plant. Negligible indirect effect was observed through the traits studied.

#### 2.1.8 Number of fruits per plant

The trait number of fruits per plant had low negative direct effect (-0.1390) along with significant positive correlation coefficient (0.9722) with fruit yield per plant. It had low negative indirect effects through the traits plant height (-0.1368), fruit weight (-0.1373) and number of seeds per fruit (-0.1356). The traits internodal length (0.1365) and YVMV incidence (0.1326) exhibited low positive indirect effects

#### 2.1.9 Fruit length (cm)

Fruit length recorded negligible negative direct effect (-0.0069) and along with positive correlation coefficient (0.0220) with fruit yield per plant. It was observed that fruit length had negligible indirect effects through the traits studied in okra.

#### 2.1.10 Fruit girth (cm)

Fruit girth showed negligible positive direct effect (0.0267) along with positive correlation coefficient (0.0534) with fruit yield per plant. Negligible indirect effects were observed through the characters under study.

#### 2.1.11 Fruit weight (g)

There existed manifestation of negligible negative direct effect (-0.0014) and positive correlation coefficient (0.9767) with fruit yield per plant. All the traits recorded negligible indirect effects

#### 2.1.12 Number of seeds per fruit

Path analysis revealed that the trait number of seeds per fruit recorded high positive direct effect (0.7525) and positive correlation coefficient (0.9917) with fruit yield per plant. This trait recorded high positive indirect effects through plant height (0.7236), number of fruits per plant (0.7344), fruit weight (0.7362). The internodal length (-0.7372) and YVMV incidence (-0.7366) exhibited high negative indirect effect whereas low negative indirect effects were recorded through ascorbic acid (-0.1186)

#### 2.1.13 Test weight of seeds (g)

This trait recorded negligible positive direct effect (0.0170) along with positive correlation coefficient (0.0750) with fruit yield per plant. It showed negligible indirect effects through the traits under study

#### 2.1.14 YVMV incidence (%)

Low negative direct effect (-0.1924) along with negative correlation coefficient (-0.9741) with fruit yield per plant was observed by YVMV incidence Low positive indirect effects were observed through plant height (0.1786), number of fruits per plant (0.1836), fruit weight (0.1853), number of seeds per fruit (0.1875) whereas low negative indirect effects were noticed through internodal length (-0.1827).

#### 2.1.15 Fibre content (g/100 g)

Fibre content had negligible positive direct effect (0.0044) along with significant positive correlation coefficient (0.0684) with fruit yield per plant. Its indirect effect through other characters was negligible.

#### 2.1.16 Ascorbic acid content (mg/100 g)

It recorded negligible negative direct effect (-0.0153) along with negative correlation (-0.1684) with in fruit yield per

plant. Ascorbic acid content in fruits were recorded negligible indirect effects through other traits.

**2.1.17 Shelf-life of fruits**
Shelf-life of fruits had negligible negative direct effect (-0.0056) and was associated positively (0.0433) with fruit yield per plant. It registered negligible indirect effects through some of the traits under study.

**2.2 Path coefficients of yield and its contributing traits in $F_4$ generation of the cross VRO-3 x 440-10-1**
The direct and indirect effects of different independent traits on the dependent variable *i.e.* fruit yield per plant are presented in table 2 and figure 2

**2.2.1 Plant height (cm)**
Path analysis revealed that the plant height had high positive direct effect (0.4778) and significant positive correlation coefficient (0.9679) with fruit yield per plant. It was noticed that high positive indirect effects were observed through number of fruits per plant (0.4034), fruit length (0.4483), fruit weight (0.4586), number of seeds per fruit (0.4652) whereas high negative indirect effects were observed through internodal length (-0.4500), YVMV incidence (-0.4576) and low negative indirect effect through fruit girth (-0.1022).

**2.2.2 Days to first flowering**
Negligible positive direct effect on fruit yield per plant was observed by the trait days to first flowering (0.0102) along with negative correlation coefficient (-0.1032). The characters showed negligible indirect effects for days to first flowering.

**2.2.3 Internodal length (cm)**
The trait internodal length recorded high negative direct effect (-0.3682) and negative correlation coefficient (-0.9827) with fruit yield per plant. It had high positive indirect effect through plant height (0.3468), fruit length (0.3174) fruit weight (0.3586), number of seeds per fruit (0.3533) whereas moderate positive indirect effect through number of fruits per plant (0.2720). The YVMV incidence (-0.3596) had high negative indirect effect.

**2.2.4 Days to 50% flowering**
Path analysis revealed that the days to 50% flowering had negligible negative direct effect (-0.0368) along with negative correlation coefficient (-0.1374) with fruit yield per plant. It showed negligible indirect effect through almost all the traits under study.

**2.2.5 First flowering node**
Negligible positive direct effect (0.0088) along with positive correlation coefficient (0.0109) with fruit yield per plant were observed with the trait of first flowering node. It was noticed that negligible indirect effect existed through the most of the studied traits.

**2.2.6 Days to first picking**
The trait days to first picking recorded negligible negative direct effect (-0.0019) along with negative correlation coefficient (-0.0913) with fruit yield per plant. It had negligible indirect effect through the characters under study.

**2.2.7 Days to last picking**
Path analysis revealed that the days to last picking had negligible positive direct effect (0.0241) and negative correlation coefficient (-0.0856) with fruit yield per plant. Negligible indirect effect was observed through the traits under study.

**2.2.8 Number of fruits per plant**
The number of fruits per plant had negligible negative direct effect (-0.0587) along with significant positive correlation coefficient (0.7662) with fruit yield per plant. It showed negligible indirect effects through the other traits recorded in the present investigation.

**2.2.9 Fruit length (cm)**
Fruit length exerted negligible negative direct effect (-0.0555) and along with positive correlation coefficient (0.8848) with fruit yield per plant. It was observed to have negligible indirect effect through the other studied traits.

**2.2.10 Fruit girth (cm)**
Fruit girth recorded negligible negative direct effect (-0.0210) along with negative correlation coefficient (-0.2257) with fruit yield per plant. It was noticed that negligible indirect effects were observed through the characters involved in the present study.

**2.2.11 Fruit weight (g)**
High positive direct effect (0.3533) and positive correlation coefficient (0.9840) with fruit yield per plant was recorded by the trait fruit weight. It recorded high positive indirect effects through plant height (0.3391), fruit length (0.3107), number of seeds per fruit (0.3474) whereas internodal length (-0.3440), YVMV incidence (-0.3458) noticed high negative indirect effect. Moderate positive indirect effects were noticed through number of fruits per plant (0.2711).

**2.2.12 Number of seeds per fruit**
Path analysis revealed that the number of seeds per fruit had moderate negative direct effect (-0.2100) and positive correlation coefficient (0.9738) with fruit yield per plant. This trait recorded moderate positive indirect effects through YVMV incidence (0.2057) and moderate negative indirect effects through fruit weight (-0.2065) and plant height (-0.2045). Internodal length (0.2015) exhibited low positive indirect effect while, number of fruits per plant (-0.1672) and fruit length (-0.1872) were recorded low negative indirect effect.

**2.2.13 Test weight of seeds (g)**
This trait recorded negligible positive direct effect (0.0042) along with positive correlation coefficient (0.0610) with fruit yield per plant. It showed negligible indirect effects through the other traits under study.

**2.2.14 YVMV incidence (%)**
Low negative direct effect (-0.1108) along with negative correlation coefficient (-0.9797) with fruit yield per plant was observed by YVMV incidence percentage. Low positive indirect effects were observed through plant height (0.1061), fruit weight (0.1085), number of seeds per fruit (0.1085) while low negative indirect effect was observed through internodal length (-0.1082).

**2.2.15 Fibre content (g/100 g)**
Fibre content had negligible positive direct effect (0.0059) along with negative correlation coefficient (-0.1334) with fruit yield per plant. Its indirect effect through other characters were negligible.

**2.2.16 Ascorbic acid content (mg/100 g)**
It showed negligible negative direct effect (-0.0134) along with negative correlation coefficient (-0.0333) with fruit yield per plant. Ascorbic acid content in fruits recorded negligible indirect effects through the other traits studied in the present investigation.

**2.2.17 Shelf-life of fruits (days)**
Path analysis revealed that the shelf-life of fruits had negligible positive direct effect (0.0193) associated with negative correlation coefficient (-0.0397) with fruit yield per plant. It registered negligible indirect effects through the traits under study.

**2.3 Path coefficients of yield and its contributing traits in $F_5$ generation of the cross VRO-3 x 440-10-1**
The direct and indirect effects of different independent traits on the dependent variable *i.e.* fruit yield per plant are presented in table 3 and 4

**2.3.1 Plant height (cm)**
Path analysis revealed that the plant height had high positive direct effect (0.7618) and positive correlation coefficient (0.9880) with fruit yield per plant. High positive indirect effects were observed through number of fruits per plant (0.7510), fruit weight (0.7493) and number of seeds per fruit (0.7491) whereas internodal length (-0.7508), YVMV incidence (-0.7513) exhibited high negative indirect effect. Low positive indirect effect was recorded through first flowering node (0.1864) while low negative indirect effect through ascorbic acid (-0.1216).

**2.3.2 Days to first flowering**
Negligible negative direct effect on fruit yield per plant was observed by the trait days to first flowering (-0.0213) along with positive correlation coefficient (0.1107). It had negligible indirect effects through all other traits studied.

**2.3.3 Internodal length (cm)**
The trait internodal length recorded low negative direct effect (-0.1889) and it had negative correlation coefficient (-0.9793) with fruit yield per plant. It had low positive indirect effect through plant height (0.1862), number of fruits per plant (0.1866), fruit weight (0.1861), number of seeds per fruit (0.1855) while low negative indirect effect through YVMV incidence (-0.1842)

**2.3.4 Days to 50% flowering**
It is clear from the data that, the trait days to 50% flowering showed negligible negative direct effect (-0.0288) along with positive correlation coefficient (0.0448) with fruit yield per plant. It also showed negligible indirect effect through other traits under study.

**2.3.5 First flowering node**
The negligible positive direct effect (0.0072) along with significant positive correlation coefficient (0.2500) with fruit yield per plant was recorded by the trait first flowering node. Negligible indirect effect was observed through the other traits studied in the present investigation.

**2.3.6 Days to first picking**
The trait days to first picking recorded negligible positive direct effect (0.0019) along with positive correlation coefficient (0.0495) with fruit yield per plant. It had negligible indirect effect through some of the traits under present study.

**2.3.7 Days to last picking**
Days to last picking showed negligible positive direct effect (0.0527) and positive correlation coefficient (0.0410) with fruit yield per plant. It was noticed that negligible indirect effect was observed through the characters studied in present investigation.

**2.3.8 Number of fruits per plant**
The trait number of fruits per plant had low negative direct effect (-0.1180) along with positive correlation coefficient (0.9753) with fruit yield per plant. It showed low positive indirect effect through internodal length (0.1165), YVMV incidence (0.1155) whereas low negative indirect effect through fruit weight (-0.1163), plant height (-0.1163) and number of seeds per fruit (-0.1160).

**2.3.9 Fruit length (cm)**
Fruit length recorded negligible positive direct effect (0.0092) along with positive correlation coefficient (0.0566) with fruit yield per plant. Negligible indirect effect was recorded through the other traits

**2.3.10 Fruit girth (cm)**
Fruit girth showed negligible negative direct effect (-0.0100) along with positive correlation coefficient (0.0469) with fruit yield per plant. Negligible indirect effect was observed through the other traits under study.

**2.3.11 Fruit weight (g)**
Fruit weight showed negligible negative direct effect (-0.0496) and positive correlation coefficient (0.9727) with fruit yield per plant. It recorded negligible indirect effect through all other traits under investigation.

**2.3.12 Number of seeds per fruit**
The trait number of seeds per fruit showed low positive direct effect (0.1194) and along with positive correlation coefficient (0.9765) with fruit yield per plant. This trait recorded low positive indirect effect through plant height (0.1174), number of fruits per plant (0.1174) and fruit weight (0.1174) whereas low negative indirect effect through YVMV incidence (-0.1159)

**2.3.13 Test weight of seeds (g)**
This trait recorded negligible positive direct effect (0.0355) and negative correlation coefficient (-0.0180) with fruit yield per plant. It showed negligible indirect effects through the other traits under study.

**2.3.14 YVMV incidence (%)**
It had negligible negative direct effect (-0.0899) along with negative correlation coefficient (-0.9759) with fruit yield per plant. Negligible indirect effect was recorded through the other characters under study.

### 2.3.15 Fibre content (g/100 g)

Fibre content had negligible positive direct effect (0.0263) along with significant positive correlation coefficient (0.0585) with fruit yield per plant. Its indirect effect through other characters were negligible.

### 2.3.16 Ascorbic acid content (mg/100 g)

It showed negligible positive direct effect (0.0006) along with negative correlation (-0.1549) with fruit yield per plant. Ascorbic acid content recorded negligible indirect effects through the other traits under study.

### 2.3.17 Shelf-life of fruits

Shelf-life had negligible negative direct effect (-0.0055) and negative correlation coefficient (-0.0548) with fruit yield per plant. It had negligible indirect effect through the other traits are under present study.

From observations recorded in $F_3$, $F_4$ and $F_5$ generations, high positive direct effect on fruit yield per plant was recorded by the traits *viz.*, plant height in all the three generations, number of seeds per fruit in $F_3$ and fruit weight in $F_4$. Hence, direct selection of these traits would be rewarding. These results are in line with the findings of Solankey *et al*. (2009) [16], Pravin *et al*. (2016) [11], Kavya *et al.* (2019) [5], Yogesh *et al.* (2020) [21], Neeraja *et al*. (2022) [7] and Bagadiya *et al*. (2022) [2] in okra.

In plant breeding, it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield. In other words, residual effect measures the role of the possible independent variables which were not included in the study on the dependent variable. In the present study of cross VR0-3 x 440-10-1, the low residual effect (0.104, 0.109 and 0.14) in $F_3$, $F_4$ and $F_5$ indicate that the characters included in present investigation are the major contributors towards the variability pertaining to the dependent variable *i.e.*, fruit yield per plant.

**Table 1:** Correlation coefficients of yield and its contributing characters in $F_3$ population of the cross VRO-3 x 440-10-1.

| Character | PH | DFF | INL | D50%F | FFN | DFP | DLP | NF/P | FL | FG | FW | NS/F | TWS | YVMV | FC | AA | SL | FY/P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1.00 | 0.07 | -0.97** | 0.08 | -0.02 | 0.12 | 0.13 | 0.98** | 0.02 | 0.02 | 0.98** | 0.96** | 0.03 | -0.92** | 0.04 | -0.13 | 0.08 | 0.96** |
| DFF | | 1.00 | -0.08 | 0.96** | 0.07 | 0.83** | 0.79** | 0.09 | 0.07 | -0.05 | 0.09 | 0.06 | 0.08 | -0.06 | -0.11 | 0.07 | -0.03 | 0.04 |
| INL | | | 1.00 | -0.08 | 0.03 | -0.13 | -0.14 | -0.98** | -0.01 | -0.03 | -0.98** | -0.98** | -0.04 | 0.95** | -0.06 | 0.13 | -0.09 | -0.97** |
| D50%F | | | | 1.00 | 0.10 | 0.79** | 0.75** | 0.10 | 0.08 | -0.05 | 0.09 | 0.06 | 0.07 | -0.06 | -0.12 | 0.04 | -0.04 | 0.04 |
| FFN | | | | | 1.00 | 0.08 | 0.09 | 0.00 | 0.11 | 0.01 | -0.04 | -0.04 | -0.06 | 0.06 | -0.03 | 0.04 | 0.12 | -0.05 |
| DFP | | | | | | 1.00 | 0.95** | 0.14 | 0.03 | -0.03 | 0.15 | 0.12 | 0.03 | -0.12 | -0.15 | -0.05 | -0.05 | 0.09 |
| DLP | | | | | | | 1.00 | 0.15 | 0.06 | -0.00 | 0.16 | 0.12 | 0.03 | -0.13 | -0.12 | -0.11 | -0.06 | 0.10 |
| NF/P | | | | | | | | 1.00 | 0.01 | 0.01 | 0.98** | 0.97** | 0.03 | -0.95** | 0.04 | -0.16 | 0.06 | 0.97** |
| FL | | | | | | | | | 1.00 | 0.70** | 0.01 | 0.00 | -0.11 | -0.04 | -0.04 | 0.00 | -0.03 | 0.02 |
| FG | | | | | | | | | | 1.00 | 0.02 | 0.03 | -0.16 | -0.05 | -0.01 | 0.01 | 0.00 | 0.05 |
| FW | | | | | | | | | | | 1.00 | 0.97** | 0.04 | -0.96** | 0.04 | -0.14 | 0.05 | 0.97** |
| NS/F | | | | | | | | | | | | 1.00 | 0.06 | -0.97** | 0.06 | -0.15 | 0.05 | 0.99** |
| TWS | | | | | | | | | | | | | 1.00 | -0.06 | -0.00 | -0.11 | 0.02 | 0.07 |
| YVMV | | | | | | | | | | | | | | 1.00 | -0.07 | 0.18 | -0.01 | -0.97** |
| FC | | | | | | | | | | | | | | | 1.00 | 0.03 | -0.04 | 0.06 |
| AA | | | | | | | | | | | | | | | | 1.00 | 0.00 | -0.16 |
| SL | | | | | | | | | | | | | | | | | 1.00 | 0.04 |
| FY/P | | | | | | | | | | | | | | | | | | 1.00 |

*Significant at 5% level **significant at 1% level

**Table 2:** Correlation coefficients of yield and its contributing characters in $F_4$ population of the cross VRO-3 x 440-10-1.

| Character | PH | DFF | INL | D50%F | FFN | DFP | DLP | NF/P | FL | FG | FW | NS/F | TWS | YVMV | FC | AA | SL | FY/P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1.00 | -0.12 | -0.94** | -0.14 | -0.02 | -0.11 | -0.11 | 0.84** | 0.93** | -0.21* | 0.96** | 0.97** | 0.05 | -0.95** | -0.18 | 0.01 | -0.02 | 0.96** |
| DFF | | 1.00 | 0.10 | 0.90** | -0.06 | 0.75** | 0.69** | -0.15 | -0.15 | 0.17 | -0.08 | -0.13 | -0.00 | 0.14 | 0.04 | -0.22* | 0.11 | -0.10 |
| INL | | | 1.00 | 0.13 | -0.02 | 0.10 | 0.10 | -0.73** | -0.86** | 0.21* | -0.97** | -0.95** | -0.05 | 0.97** | 0.12 | 0.03 | 0.07 | -0.98** |
| D50%F | | | | 1.00 | -0.04 | 0.84** | 0.78** | -0.15 | -0.17 | 0.22* | -0.11 | -0.14 | -0.02 | 0.17 | 0.07 | -0.26** | 0.10 | -0.13 |
| FFN | | | | | 1.00 | -0.02 | 0.04 | -0.05 | -0.06 | 0.09 | -0.01 | -0.01 | 0.01 | -0.03 | -0.02 | 0.02 | -0.21* | 0.01 |
| DFP | | | | | | 1.00 | 0.93** | -0.14 | -0.18 | 0.11 | -0.07 | -0.10 | -0.01 | 0.12 | 0.08 | -0.22* | 0.13 | -0.09 |
| DLP | | | | | | | 1.00 | -0.17 | -0.18 | 0.09 | -0.07 | -0.10 | -0.05 | 0.12 | 0.06 | -0.26** | 0.09 | -0.08 |
| NF/P | | | | | | | | 1.00 | 0.83** | -0.29** | 0.76** | 0.79** | 0.07 | -0.78** | -0.31 | 0.00 | 0.01 | 0.76** |
| FL | | | | | | | | | 1.00 | -0.19 | 0.87** | 0.89** | 0.05 | -0.87** | -0.19 | -0.00 | -0.01 | 0.88** |
| FG | | | | | | | | | | 1.00 | -0.21* | -0.22* | 0.00 | 0.23* | 0.17 | -0.03 | 0.20* | -0.22* |
| FW | | | | | | | | | | | 1.00 | 0.98** | 0.06 | -0.97** | -0.14 | -0.03 | -0.03 | 0.98** |
| NS/F | | | | | | | | | | | | 1.00 | 0.06 | -0.97** | -0.16 | -0.00 | -0.01 | 0.97** |
| TWS | | | | | | | | | | | | | 1.00 | -0.08 | -0.01 | -0.01 | -0.07 | 0.06 |
| YVMV | | | | | | | | | | | | | | 1.00 | 0.16 | 0.01 | 0.04 | -0.98** |
| FC | | | | | | | | | | | | | | | 1.00 | -0.24* | 0.00 | -0.13 |
| AA | | | | | | | | | | | | | | | | 1.00 | -0.09 | -0.03 |
| SL | | | | | | | | | | | | | | | | | 1.00 | -0.04 |
| FY/P | | | | | | | | | | | | | | | | | | 1.00 |

*Significant at 5% level **significant at 1% level

**Table 3:** Correlation coefficients of yield and its contributing characters in $F_5$ population of the cross VRO-3 x 440-10-1.

| Character | PH | DFF | INL | D50%F | FFN | DFP | DLP | NF/P | FL | FG | FW | NS/F | TWS | YVMV | FC | AA | SL | FY/P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1.00 | 0.12 | -0.98** | 0.05 | 0.24* | 0.05 | 0.04 | 0.98** | 0.06 | 0.05 | 0.98** | 0.98** | -0.05 | -0.98** | 0.03 | -0.16 | -0.04 | 0.98** |
| DFF | | 1.00 | -0.08 | 0.87** | 0.02 | 0.86** | 0.82** | 0.10 | -0.00 | 0.02 | 0.12 | 0.11 | 0.02 | -0.10 | -0.03 | 0.03 | -0.10 | 0.11 |
| INL | | | 1.00 | -0.01 | -0.25* | -0.02 | -0.01 | -0.98** | -0.07 | -0.05 | -0.98** | -0.98** | 0.03 | 0.97** | -0.02 | 0.15 | 0.04 | -0.97** |
| D50%F | | | | 1.00 | -0.01 | 0.91** | 0.87** | 0.05 | -0.02 | 0.00 | 0.07 | 0.05 | -0.03 | -0.05 | -0.10 | -0.04 | -0.04 | 0.04 |
| FFN | | | | | 1.00 | 0.05 | 0.04 | 0.24* | -0.04 | -0.03 | 0.24* | 0.23* | 0.00 | -0.25* | -0.09 | -0.02 | 0.05 | 0.25* |
| DFP | | | | | | 1.00 | 0.95** | 0.05 | -0.09 | -0.06 | 0.07 | 0.05 | -0.03 | -0.04 | -0.09 | 0.04 | -0.05 | 0.05 |
| DLP | | | | | | | 1.00 | 0.04 | -0.08 | -0.05 | 0.06 | 0.04 | -0.01 | -0.03 | -0.15 | 0.03 | -0.04 | 0.04 |
| NF/P | | | | | | | | 1.00 | 0.07 | 0.06 | 0.98** | 0.98** | -0.06 | -0.97** | 0.02 | -0.15 | -0.03 | 0.97** |
| FL | | | | | | | | | 1.00 | 0.97** | 0.06 | 0.04 | -0.15 | -0.07 | 0.09 | 0.01 | -0.06 | 0.05 |
| FG | | | | | | | | | | 1.00 | 0.05 | 0.03 | -0.16 | -0.05 | 0.11 | 0.01 | -0.03 | 0.04 |
| FW | | | | | | | | | | | 1.00 | 0.98** | -0.06 | -0.97** | 0.01 | -0.16 | -0.02 | 0.97** |
| NS/F | | | | | | | | | | | | 1.00 | -0.04 | -0.97** | 0.04 | -0.15 | -0.05 | 0.97** |
| TWS | | | | | | | | | | | | | 1.00 | 0.09 | -0.08 | -0.02 | 0.06 | -0.01 |
| YVMV | | | | | | | | | | | | | | 1.00 | -0.04 | 0.16 | 0.05 | -0.97** |
| FC | | | | | | | | | | | | | | | 1.00 | -0.02 | -0.07 | 0.05 |
| AA | | | | | | | | | | | | | | | | 1.00 | -0.12 | -0.15 |
| SL | | | | | | | | | | | | | | | | | 1.00 | -0.05 |
| FY/P | | | | | | | | | | | | | | | | | | 1.00 |

*Significant at 5% level **significant at 1% level

| | | | |
|---|---|---|---|
| **PH** - Plant height (cm) | **DFP** - Days to first picking | **FW** - Fruit weight (g) | **FC** - Fibre content (g) |
| **DFF** - Days to first flowering | **DLP** - Days to last picking | **NS/F** - Number of seeds per fruit | **AA** - Ascorbic acid (mg) |
| **INL** - Internodal length (cm) | **NF/P** - Number of fruits per plant | **TWS** - Test weight of seeds (g) | **SL** - Shelf-life (days) |
| **D50%F** - Days to 50% flowering | **FL** - Fruit length (cm) | **YVMV** - YVMV incidence (%) | **FY/P** - Fruit yield per plant(g) |
| **FFN** - First flowering node | **FG** - Fruit girth (cm) | | |

**Table 4:** Path coefficients of yield and its contributing characters in $F_3$ population of the cross VRO-3 x 440-10-1.

| Characters | PH | DFF | INL | D50%F | FFN | DFP | DLP | NF/P | FL | FG | FW | NS/F | TWS | YVMV | FC | AA | SL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 0.3420 | 0.0263 | -0.3347 | 0.0273 | -0.0068 | 0.0417 | 0.0453 | 0.3367 | 0.0069 | 0.0100 | 0.3368 | 0.3289 | 0.0134 | -0.3175 | 0.0158 | -0.0443 | 0.0277 |
| DFF | 0.0012 | 0.0161 | -0.0013 | 0.0156 | 0.0013 | 0.0134 | 0.0127 | 0.0016 | 0.0011 | -0.0008 | 0.0015 | 0.0010 | 0.0014 | -0.0011 | -0.0019 | 0.0011 | -0.0005 |
| INL | -0.1412 | -0.0118 | 0.1443 | -0.0117 | 0.0056 | -0.0199 | -0.0213 | -0.1417 | -0.0014 | -0.0053 | -0.1422 | -0.1413 | -0.0071 | 0.1370 | -0.0096 | 0.0195 | -0.0135 |
| D50%F | -0.0007 | -0.0089 | 0.0007 | -0.0092 | -0.0010 | -0.0073 | -0.0069 | -0.0010 | -0.0008 | 0.0005 | -0.0009 | -0.0006 | -0.0007 | 0.0006 | 0.0011 | -0.0004 | 0.0004 |
| FFN | -0.0001 | 0.0002 | 0.0001 | 0.0003 | 0.0029 | 0.0002 | 0.0003 | 0.0000 | 0.0003 | 0.0001 | -0.0001 | -0.0001 | -0.0002 | 0.0002 | -0.0001 | 0.0001 | 0.0004 |
| DFP | 0.0012 | 0.0085 | -0.0014 | 0.0081 | 0.0008 | 0.0102 | 0.0098 | 0.0015 | 0.0004 | -0.0004 | 0.0016 | 0.0012 | 0.0004 | -0.0012 | -0.0015 | -0.0005 | -0.0006 |
| DLP | -0.0049 | -0.0296 | 0.0055 | -0.0282 | -0.0037 | -0.0358 | -0.0373 | -0.0059 | -0.0024 | 0.0003 | -0.0061 | -0.0047 | -0.0013 | 0.0050 | 0.0047 | 0.0042 | 0.0025 |
| NF/P | -0.1368 | -0.0137 | 0.1365 | -0.0147 | -0.0005 | -0.0206 | -0.0218 | -0.1390 | -0.0024 | -0.0025 | -0.1373 | -0.1356 | -0.0055 | 0.1326 | -0.0058 | 0.0225 | -0.0093 |
| FL | -0.0001 | -0.0005 | 0.0001 | -0.0006 | -0.0008 | -0.0003 | -0.0004 | -0.0001 | -0.0069 | -0.0049 | -0.0001 | 0.0000 | 0.0008 | 0.0003 | 0.0003 | 0.0000 | 0.0002 |
| FG | 0.0008 | -0.0014 | -0.0010 | -0.0015 | 0.0005 | -0.0009 | -0.0003 | 0.0005 | 0.0189 | 0.0267 | 0.0006 | 0.0008 | -0.0044 | -0.0014 | -0.0005 | 0.0004 | 0.0001 |
| FW | -0.0014 | -0.0001 | 0.0014 | -0.0001 | 0.0001 | -0.0002 | -0.0002 | -0.0014 | 0.0000 | 0.0000 | -0.0014 | -0.0014 | -0.0001 | 0.0014 | -0.0001 | 0.0002 | -0.0001 |
| NS/F | 0.7236 | 0.0484 | -0.7372 | 0.0454 | -0.0328 | 0.0907 | 0.0947 | 0.7344 | 0.0020 | 0.0226 | 0.7362 | 0.7525 | 0.0473 | -0.7336 | 0.0486 | -0.1186 | 0.0396 |
| TWS | 0.0007 | 0.0015 | -0.0008 | 0.0014 | -0.0011 | 0.0006 | 0.0006 | 0.0007 | -0.0020 | -0.0028 | 0.0007 | 0.0011 | 0.0170 | -0.0011 | -0.0001 | -0.0020 | 0.0003 |
| YVMV | 0.1786 | 0.0127 | -0.1827 | 0.0129 | -0.0130 | 0.0234 | 0.0260 | 0.1836 | 0.0085 | 0.0102 | 0.1853 | 0.1875 | 0.0123 | -0.1924 | 0.0136 | -0.0353 | 0.0019 |
| FC | 0.0002 | -0.0005 | -0.0003 | -0.0005 | -0.0001 | -0.0007 | -0.0005 | 0.0002 | -0.0002 | -0.0001 | 0.0002 | 0.0003 | 0.0000 | -0.0003 | 0.0044 | 0.0001 | -0.0002 |
| AA | 0.0020 | -0.0011 | -0.0021 | -0.0007 | -0.0007 | 0.0008 | 0.0017 | 0.0025 | -0.0001 | -0.0002 | 0.0023 | 0.0024 | 0.0018 | -0.0028 | -0.0005 | -0.0153 | 0.0000 |
| SL | -0.0005 | 0.0002 | 0.0005 | 0.0003 | -0.0007 | 0.0003 | 0.0004 | -0.0004 | 0.0002 | 0.0000 | -0.0003 | -0.0003 | -0.0001 | 0.0001 | 0.0003 | 0.0000 | -0.0056 |
| FY/P | 0.9646 | 0.0462 | -0.9723 | 0.0438 | -0.0501 | 0.0958 | 0.1026 | 0.9722 | 0.0220 | 0.0534 | 0.9767 | 0.9917 | 0.0750 | -0.9741 | 0.0684 | -0.1684 | 0.0433 |

*Significant at 5% level **significant at 1% level

| | |
|---|---|
| PH - Plant height (cm) | FW - Fruit weight (g) |
| DFF - Days to first flowering | NS/F - Number of seeds per fruit |
| INL - Internodal length (cm) | TWS - Test weight of seeds (g) |
| D50%F - Days to 50% flowering | YVMV - YVMV incidence (%) |
| FFN - First flowering node | FC - Fibre content (g) |
| DFP - Days to first picking | AA - Ascorbic acid content (mg) |
| DLP - Days to last picking | SL - Shelf-life of fruits (days) |
| NF/P - Number of fruits per plant | FY/P - Fruit yield per plant (g) |
| FL - Fruit length (cm) | |
| FG - Fruit girth (cm) | |

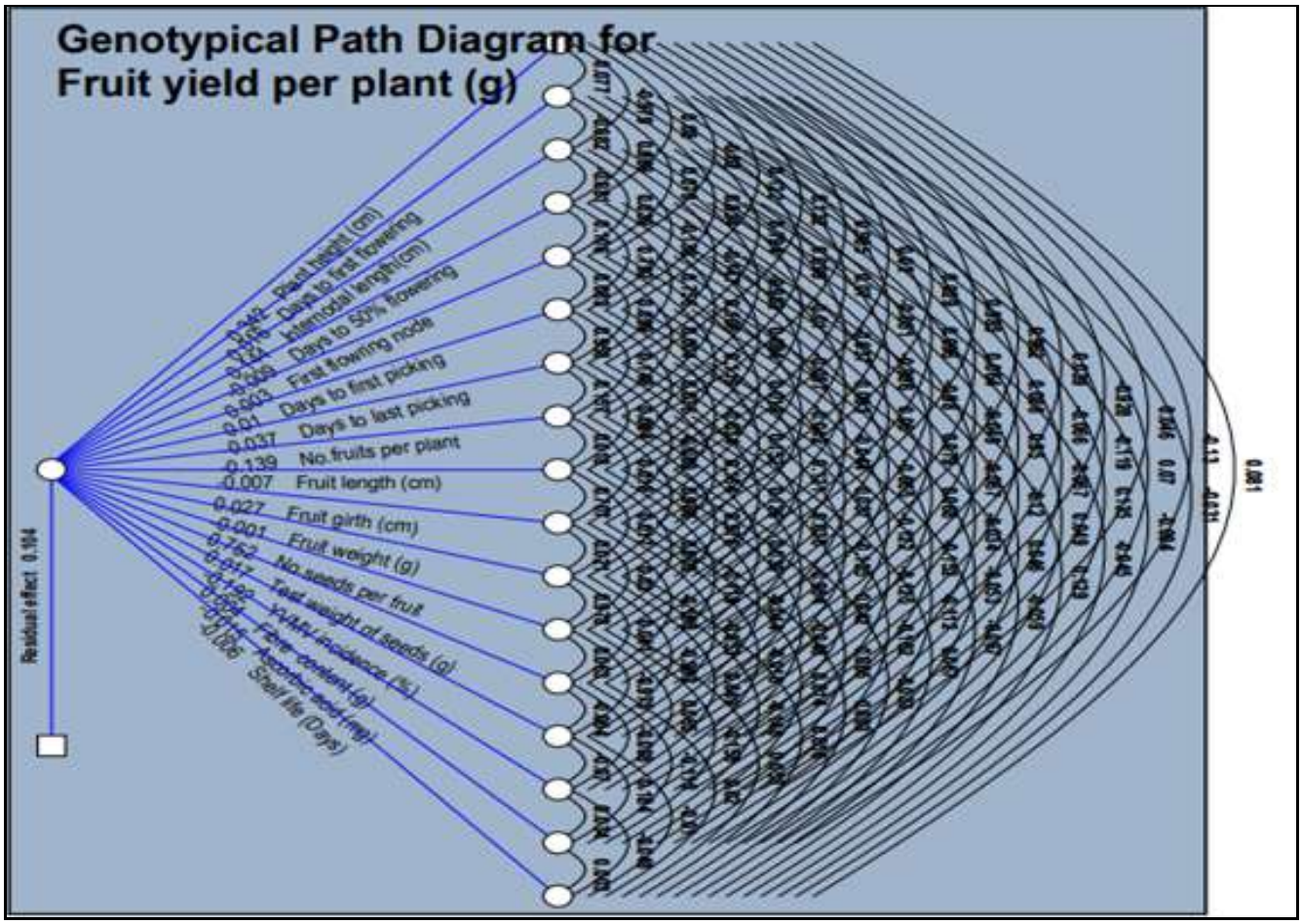


**Fig 1:** Genotypic path diagram representing direct and indirect effects for fruit yield per plant in $F_3$ population of cross VRO-3 x 440-10-1.

**Table 5:** Path coefficients of yield and its contributing characters in $F_4$ population of the cross VRO-3 x 440-10-1.

| Characters | PH | DFF | INL | D50%F | FFN | DFP | DLP | NF/P | FL | FG | FW | NS/F | TWS | YVMV | FC | AA | SL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 0.4778 | -0.0594 | -0.4500 | -0.0672 | -0.0126 | -0.0534 | -0.0528 | 0.4034 | 0.4483 | -0.1022 | 0.4586 | 0.4652 | 0.0282 | -0.4576 | -0.0861 | 0.0055 | -0.0123 |
| DFF | -0.0013 | 0.0102 | 0.0011 | 0.0092 | -0.0007 | 0.0076 | 0.0071 | -0.0016 | -0.0016 | 0.0017 | -0.0008 | -0.0013 | -0.0001 | 0.0014 | 0.0005 | -0.0022 | 0.0012 |
| INL | 0.3468 | -0.0382 | -0.3682 | -0.0510 | 0.0086 | -0.0386 | -0.0383 | 0.2720 | 0.3174 | -0.0779 | 0.3586 | 0.3533 | 0.0188 | -0.3596 | -0.0448 | -0.0127 | -0.0274 |
| D50%F | 0.0052 | -0.0333 | -0.0051 | -0.0368 | 0.0017 | -0.0312 | -0.0290 | 0.0058 | 0.0064 | -0.0083 | 0.0043 | 0.0055 | 0.0008 | -0.0063 | -0.0028 | 0.0097 | -0.0040 |
| FFN | -0.0002 | -0.0006 | -0.0002 | -0.0004 | 0.0088 | -0.0002 | 0.0004 | -0.0005 | -0.0005 | 0.0009 | -0.0001 | -0.0001 | 0.0001 | -0.0003 | -0.0002 | 0.0002 | -0.0019 |
| DFP | 0.0002 | -0.0014 | -0.0002 | -0.0016 | 0.0000 | -0.0019 | -0.0018 | 0.0003 | 0.0003 | -0.0002 | 0.0001 | 0.0002 | 0.0000 | -0.0002 | -0.0002 | 0.0004 | -0.0003 |
| DLP | -0.0027 | 0.0168 | 0.0025 | 0.0190 | 0.0011 | 0.0225 | 0.0241 | -0.0041 | -0.0043 | 0.0022 | -0.0018 | -0.0024 | -0.0013 | 0.0030 | 0.0016 | -0.0064 | 0.0023 |
| NF/P | -0.0496 | 0.0090 | 0.0434 | 0.0093 | 0.0034 | 0.0087 | 0.0101 | -0.0587 | -0.0488 | 0.0175 | -0.0450 | -0.0467 | -0.0044 | 0.0460 | 0.0185 | 0.0000 | -0.0007 |
| FL | -0.0521 | 0.0086 | 0.0479 | 0.0097 | 0.0034 | 0.0101 | 0.0100 | -0.0462 | -0.0555 | 0.0107 | -0.0488 | -0.0495 | -0.0031 | 0.0484 | 0.0108 | 0.0003 | 0.0008 |
| FG | 0.0045 | -0.0036 | -0.0044 | -0.0047 | -0.0021 | -0.0023 | -0.0019 | 0.0062 | 0.0041 | -0.0210 | 0.0046 | 0.0048 | -0.0001 | -0.0048 | -0.0036 | 0.0007 | -0.0043 |
| FW | 0.3391 | -0.0285 | -0.3440 | -0.0408 | -0.0034 | -0.0267 | -0.0260 | 0.2711 | 0.3107 | -0.0769 | 0.3533 | 0.3474 | 0.0230 | -0.3458 | -0.0524 | -0.0113 | -0.0114 |
| NS/F | -0.2045 | 0.0274 | 0.2015 | 0.0312 | 0.0032 | 0.0218 | 0.0211 | -0.1672 | -0.1872 | 0.0479 | -0.2065 | -0.2100 | -0.0137 | 0.2057 | 0.0339 | 0.0008 | 0.0034 |
| TWS | 0.0002 | 0.0000 | -0.0002 | -0.0001 | 0.0000 | -0.0001 | -0.0002 | 0.0003 | 0.0002 | 0.0000 | 0.0003 | 0.0003 | 0.0042 | -0.0004 | -0.0001 | -0.0001 | -0.0003 |
| YVMV | 0.1061 | -0.0157 | -0.1082 | -0.0191 | 0.0041 | -0.0139 | -0.0140 | 0.0868 | 0.0966 | -0.0254 | 0.1085 | 0.1085 | 0.0097 | -0.1108 | -0.0178 | -0.0017 | -0.0054 |
| FC | -0.0011 | 0.0003 | 0.0007 | 0.0004 | -0.0001 | 0.0005 | 0.0004 | -0.0019 | -0.0011 | 0.0010 | -0.0009 | -0.0009 | -0.0001 | 0.0009 | 0.0059 | -0.0014 | 0.0000 |
| AA | -0.0002 | 0.0030 | -0.0005 | 0.0035 | -0.0003 | 0.0031 | 0.0035 | 0.0000 | 0.0001 | 0.0005 | 0.0004 | 0.0001 | 0.0002 | -0.0002 | 0.0032 | -0.0134 | 0.0012 |
| SL | -0.0005 | 0.0022 | 0.0014 | 0.0021 | -0.0042 | 0.0026 | 0.0018 | 0.0002 | -0.0003 | 0.0040 | -0.0006 | -0.0003 | -0.0015 | 0.0009 | 0.0001 | -0.0018 | 0.0193 |
| FY/P | 0.9679 | -0.1032 | -0.9827 | -0.1374 | 0.0109 | -0.0913 | -0.0856 | 0.7662 | 0.8848 | -0.2257 | 0.9840 | 0.9738 | 0.0610 | -0.9797 | -0.1334 | -0.0333 | -0.0397 |

*Significant at 5% level **significant at 1% level

| | |
|---|---|
| PH - Plant height (cm) | FW - Fruit weight (g) |
| DFF - Days to first flowering | NS/F - Number of seeds per fruit |
| INL - Internodal length (cm) | TWS - Test weight of seeds (g) |
| D50%F - Days to 50% flowering | YVMV - YVMV incidence (%) |
| FFN - First flowering node | FC - Fibre content (g) |
| DFP - Days to first picking | AA - Ascorbic acid content (mg) |
| DLP - Days to last picking | SL - Shelf-life of fruits (days) |
| NF/P - Number of fruits per plant | FY/P - Fruit yield per plant (g) |
| FL - Fruit length (cm) | |
| FG - Fruit girth (cm) | |

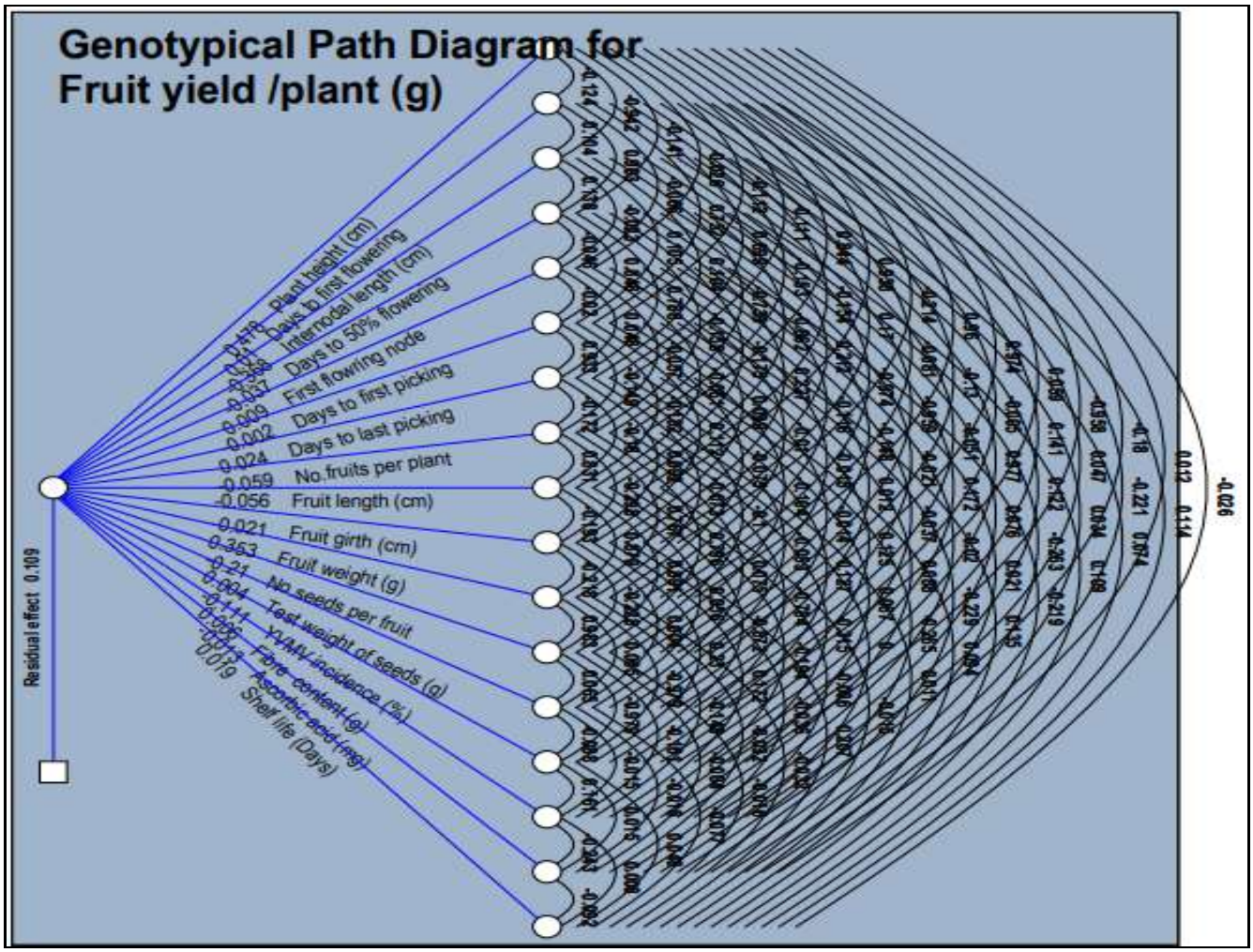


**Fig 2:** Genotypic path diagram representing direct and indirect effects for fruit yield per plant in $F_5$ population of cross VRO-3 x 440-10-1.

**Table 6:** Path coefficients of yield and its contributing characters in $F_5$ population of the cross VRO-3 x 440-10-1.

| Characters | PH | DFF | INL | D50%F | FFN | DFP | DLP | NF/P | FL | FG | FW | NS/F | TWS | YVMV | FC | AA | SL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 0.7618 | 0.0922 | -0.7508 | 0.0441 | 0.1864 | 0.0402 | 0.0310 | 0.7510 | 0.0503 | 0.0439 | 0.7493 | 0.7491 | -0.0420 | -0.7513 | 0.0299 | -0.1216 | -0.0371 |
| DFF | -0.0026 | -0.0213 | 0.0018 | -0.0186 | -0.0005 | -0.0184 | -0.0175 | -0.0023 | 0.0002 | -0.0004 | -0.0027 | -0.0023 | -0.0004 | 0.0023 | 0.0008 | -0.0008 | 0.0023 |
| INL | 0.1862 | 0.0156 | -0.1889 | 0.0034 | 0.0475 | 0.0039 | 0.0024 | 0.1866 | 0.0135 | 0.0105 | 0.1861 | 0.1855 | -0.0060 | -0.1842 | 0.0048 | -0.0283 | -0.0076 |
| D50%F | -0.0017 | -0.0252 | 0.0005 | -0.0288 | 0.0004 | -0.0263 | -0.0251 | -0.0015 | 0.0007 | -0.0001 | -0.0022 | -0.0015 | 0.0010 | 0.0014 | 0.0029 | 0.0012 | 0.0013 |
| FFN | 0.0018 | 0.0002 | -0.0018 | -0.0001 | 0.0072 | 0.0004 | 0.0003 | 0.0018 | -0.0003 | -0.0003 | 0.0017 | 0.0017 | 0.0000 | -0.0018 | -0.0007 | -0.0002 | 0.0004 |
| DFP | 0.0001 | 0.0016 | 0.0000 | 0.0017 | 0.0001 | 0.0019 | 0.0018 | 0.0001 | -0.0002 | -0.0001 | 0.0001 | 0.0001 | -0.0001 | -0.0001 | -0.0002 | 0.0001 | -0.0001 |
| DLP | 0.0021 | 0.0434 | -0.0007 | 0.0459 | 0.0024 | 0.0505 | 0.0527 | 0.0024 | -0.0042 | -0.0028 | 0.0032 | 0.0023 | -0.0008 | -0.0018 | -0.0080 | 0.0017 | -0.0024 |
| NF/P | -0.1163 | -0.0127 | 0.1165 | -0.0061 | -0.0294 | -0.0062 | -0.0054 | -0.1180 | -0.0091 | -0.0073 | -0.1163 | -0.1160 | 0.0075 | 0.1155 | -0.0033 | 0.0183 | 0.0035 |
| FL | 0.0006 | -0.0001 | -0.0007 | -0.0002 | -0.0004 | -0.0009 | -0.0007 | 0.0007 | 0.0092 | 0.0090 | 0.0006 | 0.0004 | -0.0014 | -0.0007 | 0.0009 | 0.0002 | -0.0006 |
| FG | -0.0006 | -0.0002 | 0.0006 | 0.0000 | 0.0003 | 0.0007 | 0.0005 | -0.0006 | -0.0098 | -0.0100 | -0.0005 | -0.0004 | 0.0017 | 0.0006 | -0.0011 | -0.0002 | 0.0003 |
| FW | -0.0488 | -0.0062 | 0.0488 | -0.0038 | -0.0120 | -0.0035 | -0.0030 | -0.0489 | -0.0031 | -0.0026 | -0.0496 | -0.0488 | 0.0034 | 0.0482 | -0.0006 | 0.0083 | 0.0013 |
| NS/F | 0.1174 | 0.0131 | -0.1172 | 0.0064 | 0.0279 | 0.0065 | 0.0051 | 0.1174 | 0.0055 | 0.0045 | 0.1174 | 0.1194 | -0.0057 | -0.1159 | 0.0055 | -0.0190 | -0.0063 |
| TWS | -0.0020 | 0.0007 | 0.0011 | -0.0012 | 0.0002 | -0.0012 | -0.0005 | -0.0023 | -0.0056 | -0.0059 | -0.0024 | -0.0017 | **0.0355** | 0.0032 | -0.0032 | -0.0007 | 0.0021 |
| YVMV | 0.0887 | 0.0098 | -0.0877 | 0.0045 | 0.0227 | 0.0040 | 0.0031 | 0.0880 | 0.0066 | 0.0052 | 0.0875 | 0.0873 | -0.0081 | **-0.0899** | 0.0041 | -0.0144 | -0.0045 |
| FC | 0.0010 | -0.0010 | -0.0007 | -0.0026 | -0.0025 | -0.0024 | -0.0040 | 0.0007 | 0.0026 | 0.0030 | 0.0003 | 0.0012 | -0.0023 | -0.0012 | **0.0263** | -0.0007 | -0.0020 |
| AA | -0.0001 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | -0.0001 | 0.0000 | 0.0000 | -0.0001 | -0.0001 | 0.0000 | 0.0001 | 0.0000 | **0.0006** | -0.0001 |
| SL | 0.0003 | 0.0006 | -0.0002 | 0.0002 | -0.0003 | 0.0003 | 0.0003 | 0.0002 | 0.0003 | 0.0002 | 0.0001 | 0.0003 | -0.0003 | -0.0003 | 0.0004 | 0.0007 | **-0.0055** |
| FY/P | 0.9880 | 0.1107 | -0.9793 | 0.0448 | 0.2500 | 0.0495 | 0.0410 | 0.9753 | 0.0566 | 0.0469 | 0.9727 | 0.9765 | -0.0180 | -0.9759 | 0.0585 | -0.1549 | -0.0548 |

Significant at 5% level **significant at 1% level

| | |
|---|---|
| PH - Plant height (cm) | FW - Fruit weight (g) |
| DFF - Days to first flowering | NS/F - Number of seeds per fruit |
| INL - Internodal length (cm) | TWS - Test weight of seeds (g) |
| D50%F - Days to 50% flowering | YVMV - YVMV incidence (%) |
| FFN - First flowering node | FC - Fibre content (g) |
| DFP - Days to first picking | AA - Ascorbic acid content (mg) |
| DLP - Days to last picking | SL - Shelf-life of fruits (days) |
| NF/P - Number of fruits per plant | FY/P - Fruit yield per plant (g) |
| FL - Fruit length (cm) | |
| FG - Fruit girth (cm) | |

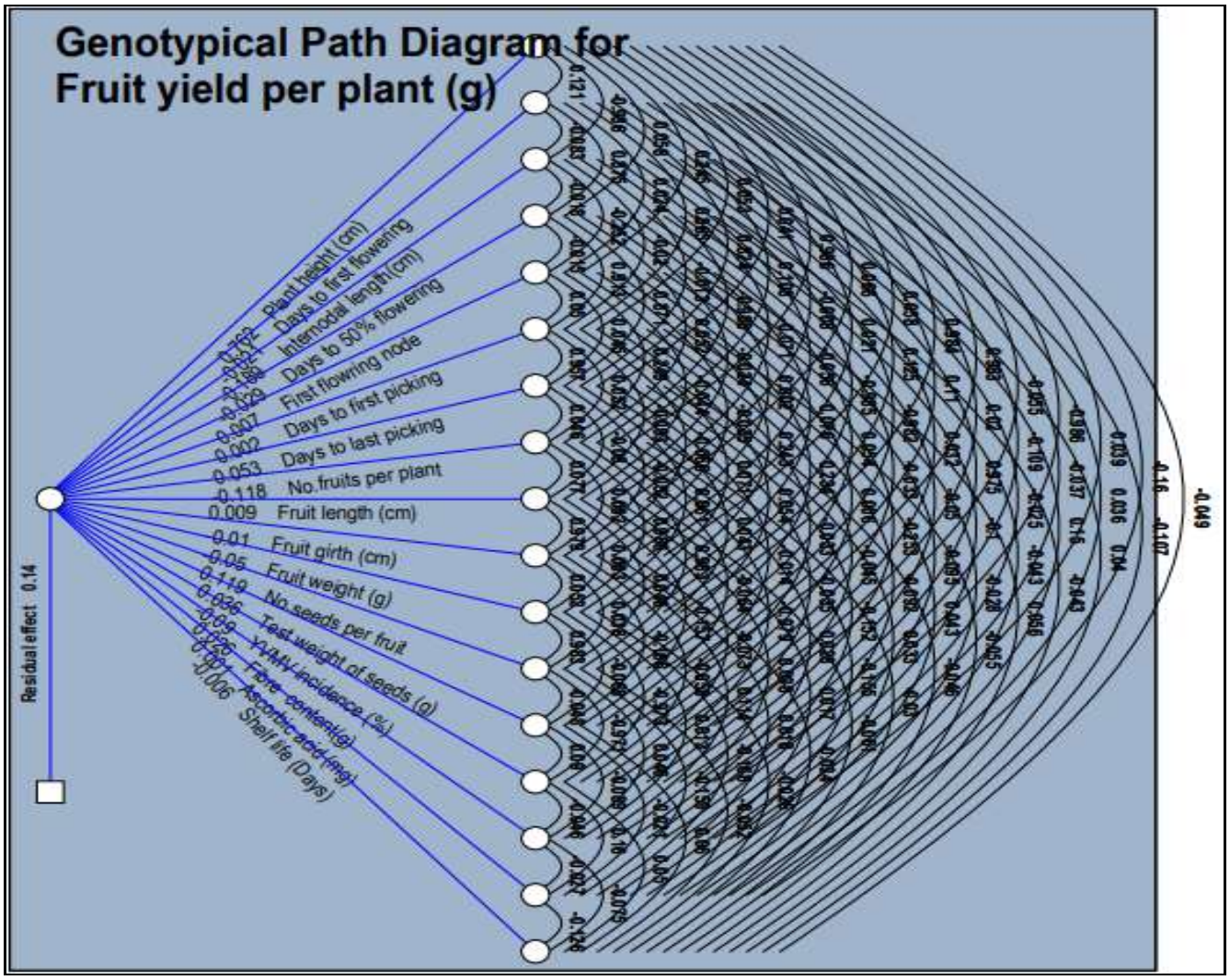


**Fig 3:** Genotypic path diagram representing direct and indirect effects for fruit yield per plant in $F_5$ population of cross VRO-3 x 440-10-1.

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