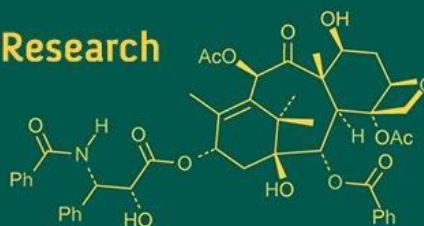


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## Character association and path coefficient analysis in ash gourd (*Benincasa hispida* (Thunb.) Cogn.)

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### Abstract

Ash gourd (*Benincasa hispida* (Thunb.) Cogn.) is a nutritionally rich and medicinally important cucurbit cultivated across diverse agro-climatic regions in India. Despite its economic and industrial value, particularly in the food and pharmaceutical sectors, systematic breeding efforts remain limited. The present study aimed to identify key yield-contributing traits and quantify their direct and indirect effects on fruit yield to support effective selection in ash gourd improvement programmes. Eighteen genotypes were evaluated during *rabi* 2023 at the College of Horticulture, Bagalkot using an augmented block design. Observations were recorded for growth, earliness and yield traits. Correlation and path coefficient analyses were performed following standard statistical procedures. Fruit yield per vine showed significant positive correlation with vine length, number of branches, fruit diameter, average fruit weight, flesh thickness and seed cavity size, indicating their strong influence on productivity. Earliness traits exhibited significant negative associations with yield. Path analysis revealed high positive direct effects of number of branches, average fruit weight and flesh thickness, supported by additional positive contributions from vine length, fruit diameter and seed cavity size. Negative direct effects were observed for earliness traits. The low residual effect (0.031) confirmed the adequacy of the evaluated traits. Overall, the results indicate that selection for average fruit weight, flesh thickness, number of branches and vine length would be most effective for developing high-yielding ash gourd genotypes.

**Keywords:** Ash gourd, yield traits, path analysis, correlation, genotypes, productivity

### Introduction

Ash gourd [*Benincasa hispida* (Thunb.) Cogn.] is an important cucurbitaceous vegetable cultivated across diverse agro-climatic regions for both tender and mature fruits. It is highly valued by growers and consumers alike due to its remarkable shelf life under ambient conditions, ease of transport and appreciable nutritional content. Various parts of the ash gourd plant, including the pulp, leaves, seeds and flowers, possess a wide range of therapeutic properties such as anti-inflammatory, antibacterial, anticancer, anti-obesity, neuroprotective, antipyretic and diuretic effects. Owing to these pharmacological attributes, ash gourd is recognized as a crop of significant medicinal importance (Islam *et al.*, 2021) <sup>[9]</sup>. The fruit is not only rich in vital nutrients such as vitamins and flavonoids but also contains several bioactive metabolites with potential applications in the treatment of numerous ailments (Grover *et al.*, 2001; Gu *et al.*, 2013) <sup>[6, 7]</sup>. In India, ash gourd is widely used in preparing petha, a traditional sweet with global recognition. The fruit also holds cultural significance, being offered to the goddess during Ayudha Puja in southern states and Durga Puja in eastern and northern regions (Rodrigues, 2018) <sup>[20]</sup>. Despite its growing industrial significance, limited attention has been given to the varietal improvement of existing ash gourd varieties cultivated across different regions of India. To meet the rising demand, it is essential to identify and develop superior plant types that combine multiple desirable traits. Analysing yield-contributing traits and their interrelationships is vital for effective crop improvement, particularly in identifying high-yielding genotypes. Hallauer and Miranda Filho (1988) <sup>[1]</sup> noted that correlation coefficients play a key role in plant breeding by measuring the genetic and non-genetic relationships between traits, thereby supporting indirect selection strategies. Cruz and Regazzi (1997) <sup>[4]</sup> further emphasized their value in estimating potential selection gains for associated traits.

According to Kurek *et al.* (2002) <sup>[12]</sup>, studying trait relationships through correlation enables early or combined selection, as indirect selection based on simple, heritable and easily measurable traits can often lead to greater genetic improvement than direct selection alone. As the number of traits in a correlation study increases, indirect associations become more complex. Since yield is a polygenic trait influenced by the environment, path coefficient analysis serves as a useful tool to separate direct and indirect effects of contributing traits. Direct and indirect effects analysis is a statistical tool in plant breeding used to clarify cause-effect relationships between genetic or environmental factors and key crop traits such as yield (Crevelari *et al.*, 2018) <sup>[3]</sup>. Path analysis quantifies both the direct and indirect contributions of each component to the target trait, enabling the identification of the most influential factors for effective selection. In view of these considerations, the present study was undertaken to identify the key pathways influencing the enhancement of important plant traits and to evaluate the direct and indirect effects of these traits on yield.

## Materials and Methods

The present study was conducted in *rabi* season of 2023 at the experimental block of the Department of Vegetable Science, College of Horticulture, Bagalkot and included a total of 18 ash gourd genotypes collected from various sources across India as well as World Vegetable Centre, Taiwan laid out in augmented block design. The crop was grown as per the package of practice recommended by UHS, Bagalkot under irrigated condition. Five plants were selected randomly from each genotype to record observation on growth, earliness and yield parameters. Correlation and path coefficient analyses were performed following the procedures outlined by Johnson *et al.* (1955) <sup>[10]</sup> and Dewey and Lu (1959) <sup>[5]</sup>, respectively.

## Results and Discussion

The inheritance pattern of a trait is often complex and influenced by multiple related characters; therefore, understanding trait associations is essential for establishing effective selection criteria in a breeding programme. Investigating the components of yield and the nature of their interrelationships is essential and forms a prerequisite for effective yield improvement. Correlation coefficients provide a clear understanding of the extent of association between pairs of traits and help determine whether simultaneous improvement of correlated traits is feasible. Knowledge of the genetic association between yield and its component characters enhances the efficiency of selection by enabling breeders to make informed choices and appropriately balance one trait with another.

The phenotypic relationships between fruit yield per vine and its associated traits are presented in Table 1. In the present investigation, fruit yield per vine exhibited a significant and positive correlation with vine length (0.804), number of branches per vine (0.955), fruit diameter (0.727), average fruit weight (0.932), flesh thickness (0.923) and seed cavity size (0.881). Therefore, selection pressure for any one of the traits will also improve the other trait, ultimately resulting in higher yield. Similar positive associations with fruit yield have also been reported by several earlier studies, including those of Nagaraju *et al.*

(2016) <sup>[11]</sup> in ash gourd and Prasanth *et al.* (2020) <sup>[18]</sup> and Nithinkumar *et al.* (2022) <sup>[15]</sup> in bitter gourd. The trait, fruit length displayed non-significant positive correlation with yield per vine (0.249). Whereas the trait number of fruits per vine showed non-significant negative correlation with yield per vine. Earliness traits such as node to first female flower (-0.922), days first female flower (-0.507) showed significant negative correlation with fruit yield per vine. Similar results were noticed by Ziaul *et al.* (2019) <sup>[23]</sup>; Nithinkumar *et al.* (2022) <sup>[15]</sup> in bitter gourd.

Path coefficient analysis is a useful statistical approach that partitions the observed correlation into their direct and indirect components. Unlike simple correlation, it accounts not only for the relationship between each independent trait and the dependent trait, but also for the interrelationships among the independent traits themselves. This allows for a more precise understanding of the causal structure governing yield and its components. The present study was undertaken to elucidate the direct and indirect contributions of various yield components to overall yield. The objective was to examine the specific factors responsible for the observed correlation and to determine the relative importance of each causal variable. Such information is valuable for formulating effective selection strategies aimed at developing high-yielding genotypes (Table 2). At phenotypic level, the highest positive direct effects on fruit yield per plant were contributed by number of branches (0.702), average fruit weight (0.664), flesh thickness (0.609). Others traits like node to first male flowering, days to first male flowering, number of male flowers, number of vine length (0.347), fruit diameter (0.304), seed cavity size (0.124), number of fruits per vine (0.090) and fruit length (0.040) displayed positive direct effects on yield per vine. Hence, direct selection for these traits would be effective and beneficial for improving fruit yield. Similar results have been documented by Nithinkumar *et al.* (2022) <sup>[15]</sup> in bitter gourd, Latif *et al.* (2008) <sup>[13]</sup>; Ananda *et al.* (2023) <sup>[2]</sup>; Thakur *et al.*, (2024) <sup>[22]</sup> in ash gourd. These studies also concluded that selecting these key parameters can effectively enhance yield, as they contribute positive direct and indirect effects via multiple associated traits. Earliness traits like node to first female flower (-0.272), days to first female flower (-0.083), days to first harvest (-0.403) showed negative direct effect on yield. Similar findings were observed by Sowmya *et al.*, 2019 <sup>[21]</sup>; Nithinkumar *et al.* (2022) <sup>[15]</sup> in bitter gourd, Panda *et al.* (2015) <sup>[16]</sup>; Manikandan *et al.* (2017) <sup>[14]</sup> in ash gourd. The residual effect was 0.031, indicating a negligible influence and suggesting that no important yield-contributing trait was omitted from the analysis. Ananda *et al.* (2023) <sup>[2]</sup> emphasized that greater priority should be placed on selecting genotypes with higher average fruit weight, a greater number of fruits per plant and longer vine length. The combined results of path analysis and correlation coefficients in the present study indicated that greater emphasis should be placed on selecting genotypes with traits such as average fruit weight, flesh thickness that exhibit strong positive direct and indirect effects on yield. Earlier researchers such as Resmi and Sreelathakumary (2012) <sup>[19]</sup>, Nagaraju *et al.* (2016) <sup>[11]</sup>, Manikandan *et al.* (2017) <sup>[14]</sup>, Pradhan *et al.* (2020) <sup>[17]</sup> and Ananda *et al.* (2023) <sup>[2]</sup> also reported similar findings in their studies.

**Table 1:** Estimates of the phenotypic correlation coefficient between 18 different traits in ash gourd genotypes

|      | VL      | NB      | NFF      | NMF      | DMF      | DFE     | D50%    | FL       | FD       | NFPV     | DFH     | FT       | SC       | AFW      | FY       |
|------|---------|---------|----------|----------|----------|---------|---------|----------|----------|----------|---------|----------|----------|----------|----------|
| VL   | 1.000** | 0.828** | -0.807** | -0.882** | -0.467   | -0.374  | -0.374  | 0.056    | 0.582*   | -0.161   | -0.101  | 0.696**  | 0.743**  | 0.718**  | 0.804**  |
| NB   |         | 1.000** | -0.932** | -0.964** | -0.610** | -0.437  | -0.437  | 0.141    | 0.770**  | -0.507*  | -0.190  | 0.928**  | 0.900**  | 0.942**  | 0.955**  |
| NFF  |         |         | 1.000**  | 0.927**  | 0.691**  | 0.538*  | 0.538*  | -0.156   | -0.695** | 0.508*   | 0.339   | -0.927** | -0.830** | -0.911** | -0.922** |
| NMF  |         |         |          | 1.000**  | 0.528*   | 0.385   | 0.385   | -0.123   | -0.705** | 0.413    | 0.136   | -0.879** | -0.870** | -0.913** | -0.953** |
| DMF  |         |         |          |          | 1.000**  | 0.852** | 0.852** | -0.487*  | -0.585*  | 0.540*   | 0.676** | -0.742** | -0.658** | -0.692** | -0.648** |
| DFE  |         |         |          |          |          | 1.000** | 1.000** | -0.622** | -0.545*  | 0.571*   | 0.818** | -0.657** | -0.552*  | -0.573*  | -0.507*  |
| D50% |         |         |          |          |          |         | 1.000** | -0.622** | -0.545*  | 0.571*   | 0.818** | -0.657** | -0.552*  | -0.573*  | -0.507*  |
| FL   |         |         |          |          |          |         |         | 1.000**  | 0.053    | -0.323   | -0.575* | 0.293    | 0.178    | 0.224    | 0.249    |
| FD   |         |         |          |          |          |         |         |          | 1.000**  | -0.632** | -0.242  | 0.795**  | 0.917**  | 0.833**  | 0.727**  |
| NFPV |         |         |          |          |          |         |         |          |          | 1.000**  | 0.482*  | -0.694** | -0.588*  | -0.707** | -0.524*  |
| DFH  |         |         |          |          |          |         |         |          |          |          | 1.000** | -0.445   | -0.268   | -0.353   | -0.172   |
| FT   |         |         |          |          |          |         |         |          |          |          |         | 1.000**  | 0.914**  | 0.976**  | 0.923**  |
| SC   |         |         |          |          |          |         |         |          |          |          |         |          | 1.000**  | 0.946**  | 0.881**  |
| AFW  |         |         |          |          |          |         |         |          |          |          |         |          |          | 1.000**  | 0.932**  |
| FY   |         |         |          |          |          |         |         |          |          |          |         |          |          |          | 1.000**  |

\* indicates significance at 5%, \*\* indicates significance at 1%

|                                                        |                                   |                          |
|--------------------------------------------------------|-----------------------------------|--------------------------|
| VL-Vine length at final harvest (m)                    | D50%-Days to 50 percent flowering | FY-Fruit yield (kg/vine) |
| NB-Number of branches per vine at final harvest        | FL-Fruit length (cm)              |                          |
| NFF-Node to first female flower                        | FD-Fruit diameter (cm)            |                          |
| NMF-Node to first male flower                          | NFPV-Number of fruits per vine    |                          |
| NF-Number of female flowers per vine at peak flowering | FT-Flesh thickness (mm)           |                          |
| NM-Number of male flowers per vine at peak flowering   | SC-Seed cavity size (cm)          |                          |
| DFE-Days to first female flower                        | FW-Average fruit weight (kg)      |                          |
| DMF-Days to first male flower                          | DFH-Days to first harvest         |                          |

**Table 2.** Estimates of direct and indirect effects of component characters on yield of ash gourd using phenotypic correlation

|      | VL     | NB     | NFF    | NMF    | DMF    | DFE    | D50.   | FL     | FD     | NFPV   | DFH    | FT     | SC     | AFW    | 'r' with FY |
|------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------------|
| VL   | 0.347  | 0.583  | 0.221  | 0.218  | -0.031 | 0.030  | 0.212  | 0.003  | -0.177 | -0.014 | -0.040 | -0.427 | 0.092  | 0.478  | 0.804**     |
| NB   | -0.288 | 0.702  | 0.254  | 0.238  | -0.040 | 0.039  | 0.238  | 0.006  | -0.235 | -0.046 | -0.077 | -0.567 | 0.112  | 0.624  | 0.955**     |
| NFF  | 0.281  | -0.653 | -0.273 | -0.231 | 0.045  | -0.045 | -0.291 | -0.007 | 0.210  | 0.046  | 0.137  | 0.567  | -0.103 | -0.604 | -0.922**    |
| NMF  | 0.305  | -0.674 | -0.254 | -0.248 | 0.035  | -0.032 | -0.212 | -0.005 | 0.216  | 0.037  | 0.056  | 0.537  | -0.108 | -0.604 | -0.953**    |
| DMF  | 0.163  | -0.428 | -0.188 | -0.131 | -0.066 | -0.070 | -0.450 | -0.021 | 0.177  | 0.049  | 0.274  | 0.451  | -0.082 | -0.458 | -0.648**    |
| DFE  | 0.125  | -0.323 | -0.147 | -0.094 | 0.055  | -0.084 | -0.519 | -0.027 | 0.168  | 0.058  | 0.327  | 0.403  | -0.066 | -0.385 | -0.507*     |
| D50. | 0.139  | -0.316 | -0.150 | -0.099 | 0.056  | -0.082 | -0.529 | -0.027 | 0.168  | 0.051  | 0.323  | 0.403  | -0.069 | -0.385 | -0.507*     |
| FL   | -0.021 | 0.098  | 0.044  | 0.030  | -0.032 | 0.051  | 0.323  | 0.044  | -0.015 | -0.029 | -0.234 | -0.177 | 0.022  | 0.146  | 0.249       |
| FD   | -0.201 | 0.541  | 0.188  | 0.176  | -0.038 | 0.046  | 0.291  | 0.002  | 0.305  | -0.057 | -0.097 | -0.482 | 0.114  | 0.551  | 0.727**     |
| NFPV | 0.056  | -0.358 | -0.139 | -0.102 | 0.035  | -0.054 | -0.296 | -0.014 | 0.192  | 0.090  | 0.194  | 0.421  | -0.073 | -0.471 | -0.524*     |
| DFH  | 0.035  | -0.133 | -0.093 | -0.035 | 0.045  | -0.068 | -0.423 | -0.025 | 0.073  | 0.043  | -0.403 | 0.274  | -0.033 | -0.232 | -0.172      |
| FT   | -0.243 | 0.653  | 0.254  | 0.218  | -0.049 | 0.055  | 0.349  | 0.013  | -0.241 | -0.062 | -0.181 | 0.610  | 0.113  | 0.651  | 0.923**     |
| SC   | -0.257 | 0.632  | 0.226  | 0.216  | -0.043 | 0.044  | 0.296  | 0.008  | -0.281 | -0.053 | -0.109 | -0.555 | 0.124  | 0.631  | 0.881**     |
| AFW  | -0.250 | 0.660  | 0.248  | 0.226  | -0.045 | 0.049  | 0.307  | 0.010  | -0.253 | -0.064 | -0.141 | -0.598 | 0.118  | 0.664  | 0.932**     |

Critical rg value 0.031 at 5 percent

\* indicates significance at 5%, \*\* indicates significance at 1%

|                                                        |                                   |                          |
|--------------------------------------------------------|-----------------------------------|--------------------------|
| VL-Vine length at final harvest (m)                    | D50%-Days to 50 percent flowering | FY-Fruit yield (kg/vine) |
| NB-Number of branches per vine at final harvest        | FL-Fruit length (cm)              |                          |
| NFF-Node to first female flower                        | FD-Fruit diameter (cm)            |                          |
| NMF-Node to first male flower                          | NFPV-Number of fruits per vine    |                          |
| NF-Number of female flowers per vine at peak flowering | FT-Flesh thickness (mm)           |                          |
| NM-Number of male flowers per vine at peak flowering   | SC-Seed cavity size (cm)          |                          |
| DFE-Days to first female flower                        | FW-Average fruit weight (kg)      |                          |
| DMF-Days to first male flower                          | DFH-Days to first harvest         |                          |

## Conclusion

The present study revealed that fruit yield in ash gourd is strongly influenced by key traits such as number of branches, average fruit weight, flesh thickness, vine length and fruit diameter. Correlation and path analyses confirmed these traits as major positive contributors through both direct and indirect effects, while earliness traits showed negative direct effects on yield. The low residual effect indicated that all important yield components were included in the analysis. Overall, the findings suggest that selection

for average fruit weight, flesh thickness, number of branches and vine length would be highly effective in developing high-yielding ash gourd genotypes.

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