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Studies on Inter-traits Relationship and Path Co-efficient for Fruit Yield and its Related Traits in Pumpkin (*Cucurbita moschata* Duch ex. Poir)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the summer of 2019, a field experiment was carried out at the Acharya Narendra Deva University of Agriculture and Technology of Main Experiment Station in Kumarganj, Ayodhya (U.P), India. The research material consisted of twenty-eight genotypes, including three standard checks viz., Azad Kaddu, Arka Chandan, and Pusa Vikash, conducted in a Completely Randomized Block Design (RBD) with three independent replications. The germplasm of pumpkin was collected from different sources to study path co-efficient analysis of different characters on fruit yield per plant at the phenotypic and genotypic levels for different quantitative traits. The path co-efficient analysis revealed that the highly positive direct contribution towards fruit yield came from average fruit weight (0.781) followed by the number of fruit per plant (0.750) but also as well as fruit equatorial circumference (0.021) and flesh thickness (0.048) was exerted a positive direct effect on fruit yield per plant and these traits might be considered as a high yield symbols of pumpkin and might be used as selection criteria in the breeding program to improve the yield in pumpkin.

Keywords: Pumpkin; germplasm; path co-efficient; and fruit yield.

1. INTRODUCTION

Pumpkin is a member of the Cucurbita genus, which is one of the numerous diversified genera in the plant kingdom [1]. A large plant family is known as Cucurbitaceae, which includes more than 800 species and 130 genera [2], and all of these species have a basic chromosomal number of 2n= 2x= 40. Some of the cultivated species' fruits are commonly referred to as "pumpkins" [3]. They include various species of pumpkins (Cucurbita); the most common types are *Cucurbita moschata, Cucurbita maxima*, and *Cucurbita pepo*. For food preparation and cooking frequently use pumpkins. Its leaves, flowers, fruits, peels, and seeds are edible. Pumpkin is consumed both uncooked and preserved in dishes like soups, smoothies, and juices. Additionally, pumpkin flesh is used to baked goods such as cakes, cookies, chocolates, and candies [4]. It is believed in central-South America where the genus Cucurbita originated. It is a wonderful vegetable with the potential to be used as both a healthy diet and a kind of medicine, because the fruits and seeds are a high supply of important nutrients and phytochemicals like -carotene, total flavonoids, total phenolic, etc. [5]. In India, it covers an area of 99000 hectares and produces 2117 metric tons annually, or 21.3 tonnes per hectare on an average in 2020-21 [6]. Compared to other cucurbitaceous vegetables, pumpkin has received less focus in crop improvement, while second-richest source of beta carotene after carrots. Carotene, a precursor to vitamin A, is very abundant in the yellow and orange-fleshed fruits (3,332 IU), and vitamins B and C are also present in adequate quantities. It could help people with their nutritional condition, especially those in disadvantaged populations that need more vitamin A [7]. Additionally, pumpkin contains antioxidants (such polyphenols and carotenoids), which are essential for human health [8]. “Pumpkins have been recognized as a superior source of provitamin A carotenoids, which are essential in preventing vitamin A insufficiency” [4]. “Several minerals, including potassium, iron, zinc, copper, magnesium, selenium, and phosphorus, as well as phytochemicals, including α tocopherol, β tocopherol, tocopherol, β sitosterol, stigmasterol, squalene, and β carotene, were observed in various pumpkin varieties” [9]. “Fruit yield per plant was significantly and positively correlated with, fruit length, fruit diameter, flesh thickness, vine length, and average weight of the fruit. According to the path coefficient analysis, the fruit diameter had the most positive and direct effect on fruit yield followed by primary branches and fruits per plant, which shows an actual association between these traits and yield per plant” [10]. The purpose of the current study was to determine the most appropriate selection criteria for increased fruit yield through an analysis of the direct and indirect effect of various attributes on pumpkin fruit yield. Path coefficient analysis research reveals the degree to which various plant characteristics contribute to yield, increasing confidence in the choice of significant yield-contributing traits.

2. MATERIALS AND METHODS

This study, included 28 accessions with three standard checks varieties viz., Arka Chandan, Azad Kaddu, and Pusa Vikash from *Cucurbita moschata* were considered for analysis. The Main Experiment Station of the Department of

Vegetable Science at Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P), conducted the experiment from the first week of March to the first week of July based on a Randomized Block Design with three replications. The seeds were sown in the summer, with a plot size of 3 x 3 m, 6 plants per plot, a row-to-row spacing of 3 m, and a plant-to-plant spacing of 0.50 m. All the suggested agronomic packages of practices and plant protection measures were followed to producing a high-quality crop. “Node number to first staminate flower anthesis, node number to first pistillate flower anthesis, days to first staminate flower anthesis, days to first pistillate flower anthesis, days to first fruit harvest, number of primary branches, fruit polar circumference (cm), fruit equatorial circumference (cm), vine length (m), flesh thickness (cm), number of fruits per plant, average fruit weight (kg), and fruit yield per plant (kg) were observed” [11].

Five competitive and randomly selected plants from each genotype and replication are used to collect the data for each of the thirteen quantitative traits. OPSTAT statistical software was used for each and every statistical analysis. Statistical analysis was used to evaluate the path coefficient among genotypes [12].

3. RESULTS AND DISCUSSION

3.1 Path Coefficient Analysis

Different characteristics of direct and indirect influences on fruit yield were estimated to be resolved using path coefficient analysis. In Tables 1 and 2, respectively, the Path coefficient analysis was presented.

The direct and indirect effects of different characters on fruit yield per plant at the phenotypic level are presented in Table 1. The highly positive direct effect on yield per plant was exerted by average fruit weight (0.781) followed by the number of fruit per plant (0.750) but also as well as days to first staminate flower anthesis (0.120), and the number of primary branches (0.105), exerted a positive direct effect on fruit yield per plant. The direct effects on fruit yield per plant showed by the rest of the traits were substantially too low such as namely flesh thickness (0.048) and days to first harvest (0.032), fruit equatorial circumference (0.021), and vine length (0.009). Although, average fruit weight showed the highest positive direct effects on fruit yield per plant. Most of the characters namely node number to first staminate flower appearance (-.092), fruit polar circumference (-0.029), node number to pistillate flower appearance (-0.021), and days to first pistillate flower anthesis (-0.012) exerted negative direct effects on fruit yield per plant *via.* This trait.

Fruit equatorial circumference (0.147) and flesh thickness (0.033) showed indirect positive effects *via*. Average fruit weight on fruit yield per plant. However, fruit polar circumference (-0.278) exhibited a high negative and considerable indirect effect *via.* average fruit weight on the fruit yield per plant. Indirect effects the number of fruit per plant (-0.269), vine length (-0.188), days to first pistillate flower anthesis (-0.142), days to first staminate flower anthesis (-0.135), number of primary branches (-0.129) and node number at first flower anthesis (-0.128) were showed indirect negative effects *via.* average fruit weight on fruit yield per plant.

Flesh thickness (0.112) and vine length (0.120) showed indirect positive effects *via*. number of fruit yield per plant on the fruit yield per plant while average fruit weight (-0.258) indirect negative effect *via*. number of fruit per plant on fruit yield per plant. The rest of the traits on fruit yield were very low.

The direct and indirect effects of different traits on fruit yield at the genotypic level are presented in Table 2. Substantial positive and direct effects on fruit yield per plant were exerted by days to first fruit harvest (2.245) followed by days to first pistillate flower anthesis (2.203), vine length (1.369), flesh thickness (0.908), number of fruit per plant (0.459), number of primary branches (0.135) and fruit equatorial circumference (0.046) While high order negative direct effect on fruit yield per plant was exerted by days to first staminate flower anthesis (-3.497) followed by fruit polar circumference (-2.026), node number at first staminate flower anthesis (-0.858), average fruit weight (-0.518) and node number at first pistillate flower anthesis (-0.157). Days to first pistillate flower anthesis (-0.646), days to first staminate flower anthesis (-0.568), days to first fruit harvest (-0.521), number of primary branches (-0.131), and node number at first pistillate flower appearance (-0.117) exhibited considerable negative indirect effects on fruit yield *via.,* days to first staminate flower anthesis through which average fruit weight (0.156), flesh thickness (0.138) and fruit equatorial circumference (0.105) showed considerable positive indirect effect respectively. Days to first

Table 1. Direct and indirect effect of different characters on fruit yield at a phenotypic level in pumpkin germplasm

Characters	Node number at first staminate flower anthesis	Node number at first pistillate flower anthesis	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Days to first fruit harvest	Number of primary branches	Fruit polar circumference (cm)	Fruit equatorial circumference (cm)	Vine length (m)	Flesh thickness (cm)	Number of fruit per plant	Average fruit weight (kg)	Fruit yield per plant (kg)
Node number at first staminate flower anthesis	**-0.092**	-0.003	0.062	-0.006	0.011	0.016	0.000	-0.003	0.000	-0.006	0.061	-0.128	-0.088
Node number at first pistillate flower anthesis	-0.012	**-0.021**	0.032	-0.002	0.006	0.031	-0.006	-0.001	0.004	0.005	0.089	-0.037	0.089
Days to first staminate flower anthesis	-0.047	-0.006	**0.120**	-0.005	0.013	0.030	0.001	-0.001	0.002	-0.005	0.003	-0.135	-0.028
Days to first pistillate flower anthesis	-0.046	-0.004	0.054	**-0.012**	0.017	0.017	-0.005	0.001	0.000	-0.010	0.082	-0.142	-0.046
Days to first fruit harvest	-0.031	-0.004	0.048	-0.006	**0.032**	0.014	-0.004	0.001	0.001	-0.006	-0.027	-0.033	-0.018
Number of primary branches	-0.014	-0.006	0.035	-0.002	0.004	**0.105**	-0.003	0.003	0.001	0.012	-0.073	-0.129	-0.068
Fruit polar circumference (cm)	0.001	-0.004	-0.003	-0.002	0.005	0.009	**-0.029**	0.002	0.002	0.003	0.031	-0.276	-0.262*
Fruit equatorial circumference (cm)	0.015	0.001	-0.007	-0.001	0.002	0.013	-0.003	**0.021**	-0.002	0.015	0.066	0.147	0.267*
Vine length (m)	0.002	-0.009	0.031	0.000	0.002	0.007	-0.006	-0.004	**0.009**	-0.005	0.120	-0.188	-0.041
Flesh thickness (cm)	0.011	-0.002	-0.012	0.002	-0.004	0.027	-0.002	0.006	-0.001	**0.048**	0.112	0.033	0.219*
Number of fruit per plant	-0.007	-0.003	0.001	-0.001	-0.001	-0.010	-0.001	0.002	0.001	0.007	**0.750**	-0.269	0.469**
Average fruit weight (kg)	0.015	0.001	-0.021	0.002	-0.001	-0.017	0.010	0.004	-0.002	0.002	-0.258	**0.781**	0.515**

R SQUARE = 0.7729 RESIDUAL EFFECT = 0.4766

Bold values show direct and normal values show indirect effects

Table 2. Direct and indirect effect of different characters on fruit yield on the genotypic level in pumpkin germplasm

Characters	Node number at first staminate flower anthesis	Node number at first pistillate flower anthesis	Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Days to first fruit harvest	Number of primary branches	Fruit polar circumference (cm)	Fruit equatorial circumference (cm)	Vine length(m)	Flesh thickness (cm)	Number of fruit per plant	Average fruit weight(kg)	Fruit yield per plant(kg)
Node number at first staminate flower anthesis	**-0.858**	-0.021	-2.315	1.660	1.362	0.021	0.098	-0.006	-0.016	-0.146	0.042	0.094	-0.086
Node number at first pistillate flower anthesis	-0.117	**-0.157**	-1.214	0.512	0.760	0.044	-0.568	-0.006	0.645	0.125	0.039	0.038	0.101
Days to first staminate flower anthesis	-0.568	-0.054	**-3.497**	1.846	1.946	0.049	-0.152	-0.003	0.483	-0.169	0.009	0.118	0.007
Days to first pistillate flower anthesis	-0.646	-0.037	-2.929	**2.203**	1.949	0.031	-0.520	0.003	0.013	-0.285	0.039	0.111	-0.068
Days to first fruit harvest	-0.521	-0.053	-3.031	1.912	**2.245**	0.033	-0.555	0.004	0.159	-0.165	-0.066	0.010	-0.027
Number of primary branches	-0.131	-0.051	-1.267	0.508	0.547	**0.135**	-0.272	0.012	0.097	0.273	-0.032	0.106	-0.075
Fruit polar circumference (cm)	0.041	-0.044	-0.263	0.566	0.615	0.018	**-2.026**	-0.002	0.339	0.095	0.031	0.268	-0.362**
Fruit equatorial circumference (cm)	0.105	0.021	0.191	0.130	0.183	0.036	0.088	**0.046**	-0.448	0.355	-0.050	-0.219	0.440**
Vine length (m)	0.010	-0.074	-1.234	0.021	0.262	0.010	-0.501	-0.015	**1.369**	-0.114	0.084	0.138	-0.046
Flesh thickness (cm)	0.138	-0.022	0.650	-0.691	-0.407	0.041	-0.212	0.018	-0.172	**0.908**	0.055	-0.060	0.247*
Number of fruit per plant	-0.078	-0.013	-0.069	0.186	-0.324	-0.010	-0.139	-0.005	0.250	0.109	**0.459**	0.172	0.540**
Average fruit weight (kg)	0.156	0.012	0.795	-0.474	-0.042	-0.028	1.046	0.020	-0.364	0.105	-0.153	**-0.518**	0.556**

R SQUARE = 0.6888 RESIDUAL EFFECT = 0.5578
Bold values show direct and normal values show indirect effects

fruit harvest (-3.031), days to first pistillate flower anthesis (-2.315), number of primary branches (-1.267), vine length (-1.234), and node number at first pistillate flower anthesis (-1.214) exhibited considerable negative indirect effects on fruit yield while average fruit weight (0.195), flesh thickness (0.650) and fruit equatorial circumference (0.191) showed the highest positive indirect effect on fruit yield *via.* days to first staminate flower anthesis, respectively.

An indirect positive effect of days to first fruit harvest (1.912), days to first staminate flower anthesis (1.846), node number at first staminate flower anthesis (1.660), fruit polar circumference (0.566), node number at fist pistillate flower anthesis, (0.512) number of primary branches (0.508), number of fruit per plant (0.186) and fruit equatorial circumference (0.130) showed a positive indirect effect on fruit yield *via.* days to first pistillate flower anthesis, through which flesh thickness (-0.691) and average fruit weight (-0.474) showed a negative indirect effect on fruit yield via. these traits.

The indirect positive effect of days to first pistillate flower anthesis (1.949), days to first staminate flower anthesis (1.946), node number at first staminate flower anthesis (1.362), node number at fist pistillate flower anthesis, (0.760), fruit polar circumference (0.615), number of primary branches (0.547), vine length (0.262) and fruit equatorial circumference (0.183) showed the positive indirect effect on fruit yield *via.* days to first fruit harvest, through which flesh thickness (-0.407) and number of fruit per plant (-0.324) showed the negative indirect effect on fruit yield *via*. these traits (days to first fruit harvest).

Node number at first pistillate flower appearance (-0.568), days to first fruit harvest (-0.555), Days to first pistillate flower anthesis (-0.520), vine length (0.501), flesh thickness (-0.212) days to first staminate flower anthesis (-0.152), and number of fruit per plant (-0.139) exhibited considerable negative indirect effects on fruit yield *via.* fruit equatorial circumference, through which average fruit weight (1.046) showed a considerable positive indirect effect on fruit yield respectively. Node number at first pistillate flower appearance (0.645), days to first staminate flower anthesis (0.483), fruit equatorial circumference (0.339), number of fruit per plant (0.250), and days to first fruit harvest (0.159) exhibited considerable positive indirect effects on fruit yield *via.* vine length, through which average fruit weight (-0.364) and flesh thickness (-0.172) showed a considerable negative indirect effect on fruit yield.

An indirect positive effect of fruit equatorial circumference (0.355), number of primary branches (0.273), node number at fist pistillate flower anthesis, (0.125), number of fruit per plant (0.109), and average fruit weight (0.105) showed the positive indirect effect on fruit yield *via.* flesh thickness, through which days to first pistillate flower anthesis (-0.285), days to first staminate flower anthesis (-0.169), days to first fruit harvest (-0.165), node number at first staminate flower anthesis (-0.146) and vine length (-0.114) showed a negative indirect effect on fruit yield via. this trait (flesh thickness).

Average fruit weight showed an indirect negative effect on fruit yield *via.* number of fruit per plant. Fruit polar circumference (0.268), number of fruit per plant (0.172), vine length (0.138), days to first staminate flower anthesis (0.118), days to first pistillate flower anthesis (0.111), number of primary branches (0.106) showed a positive indirect effect on fruit yield *via*. Average fruit weight while fruit equatorial circumference showed a negative indirect effect on fruit yield *via*. These traits (average fruit weight).

Previous researchers have also noted the positive direct effects of numerous traits on fruit yield viz. for average fruit weight. Mohsin et al. [13], Shivananda et al. [14], Yadegari et al. [15], Murlidharan et al. [16], Naik et al. [17] for number of fruits per plant Mohsin et al. [13], Shivananda et al. [14], Murlidharan et al. [16], Naik et al. [17], Sulatana et al. [18] for several branches [16] for days to first pistillate flower anthesis [18] for vine length [16] for flesh thickness (Khirud Panging, 2023) for the equatorial and polar circumference of fruit [1] for number of primary branches [16].

4. CONCLUSION

This experiment assessed the positively inter-traits relations and path co-efficient with the fruit yield. The direct effects of different characters on fruit yield per plant at the phenotypic level revealed that the highly positive direct effect on yield per plant was exerted by average fruit weight (0.781) followed by the number of fruit per plant (0.750) and node number to first staminate flower appearance (-.092), fruit polar circumference (-0.029), node number to pistillate flower appearance (-0.021), and days to first pistillate flower anthesis (-0.012) exerted negative direct effects on fruit yield per plant *via.*

these traits. The direct effects of different characters on fruit yield per plant at the genotypic level revealed that positive and direct effects on fruit yield per plant were exerted by days to first fruit harvest (2.245) followed by days to first pistillate flower anthesis (2.203), vine length (1.369), flesh thickness, while high order negative direct effect on fruit yield per plant was exerted by days to first staminate flower anthesis (-3.497) followed by fruit polar circumference (-2.026), node number at first staminate flower anthesis (-0.858), average fruit weight (-0.518) and node number at first pistillate flower anthesis (-0.157). In conclusion, the path coefficient analysis revealed that focusing to the node number to first staminate flower appearance, node number to pistillate flower appearance, days to first pistillate flower anthesis, vine length, flesh thickness on several fruits per plant, and fruit equatorial circumference on average fruit weight could improve total yield per plant in pumpkin. As a result, these traits should be prioritized during selection in order to develop high-yielding genotypes in pumpkins.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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