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Correlation Coefficient and Path Analysis of Yield and It's Components Analysis 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

The current experiment was designed to evaluate the correlation coefficient and path analysis of yield and its components in pumpkin (*Cucurbita moschata* Duch ex. Poir) among various genotypes. The study involved 35 distinct genotypes, including a control, to measure both quantitative and qualitative traits. It was conducted in a randomized block design with three replications at Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, during the summer of 2021. Observations included the node number at first staminate and pistillate flower anthesis, days to anthesis of both flower types, days to first fruit harvest, fruit polar length, fruit equatorial circumference, flesh thickness, number of fruits per plant, average fruit weight, and total fruit yield per plant. The genotypes were assessed for yield through correlation coefficients and path analysis, indicating promising breeding values as supported by the analysis of variance. Among the 35 genotypes, four yielded significantly more than the highest-performing control, Narendra Agrim.

Keywords: Correlation coefficient; path analysis; genotypes; direct; indirect effect.

1. INTRODUCTION

“Pumpkin (*Cucurbita moschata* Duch. ex. The pumpkin (*Cucurbita moschata* Duch. ex. Poir.) is a climbing vegetable that reproduces sexually and is monoecious. It belongs to the genus Cucurbita, within the order Cucurbitales and the family Cucurbitaceae [1]. Its chromosome count is 2n=40” [2]. The pumpkin, regionally referred to as Kashiphal, Sitaphal, or Kaddu [3], was initially domesticated across various regions of Central and South America [4]. “It is nutritionally superior to many fruits and vegetables, with higher levels of energy, carbohydrates, vitamins, and minerals, and is especially abundant in carotenoid pigments” [5]. “Additionally, it is a day-neutral plant.) is a climbing vegetable that is sexually propagated and monoecious, belonging to the genus Cucurbita, within the order Cucurbitales and the family Cucurbitaceae” [1]. It has a chromosome number of 2n= 40 [2]. In different regions, pumpkin is known by various names such as Kashiphal, Sitaphal, and Kaddu [3]. The primary sites where cultivated Cucurbita species were originally domesticated are located in various parts of Central and South America [4]. Pumpkin has more energy, carbs, vitamins, and minerals than other fruits and vegetables, and is particularly rich in carotenoid colours [5]. It is a day-neutral plant.

“The term pumpkin derives from the Greek word "Pepon," meaning "large melon" or "round and enormous fruit." The species that constitute pumpkins include Cucurbita moschata, Cucurbita pepo, Cucurbita maxima, Cucurbita mixta, Cucurbita ficifolia, and Telfairia occidentalis” (Caili et al., 2006). Mature fruits that have been preserved have higher quantities of carotene. Fresh entire pumpkins' beta-carotene concentration increased by 12.63 per cent after three months of storage in the shade [6]. Pumpkin has a lot of energy and carbohydrates and is a wonderful source of vitamins, particularly those with strong carotenoid colours and minerals. It may help people's nutritional health, especially those who are more susceptible to vitamin A deficiency. A serious issue in many South Asian nations is night blindness. The problem can simply be rectified by encouraging the general public to consume more pumpkins.

In India, pumpkin cultivation covers 99 thousand hectares, yielding an annual production of 2,117 thousand metric tons (MT), with an average yield of 22.5 MT/ha, according to the National Horticulture Board (NHB, 2018–19). Uttar Pradesh is the leading producer, contributing 360.16 thousand metric tons of pumpkin, characterized by single, unisexual, or fasciculate flowers, varying in color from yellow to deep orange. Path coefficient analysis assists in dividing correlation coefficients into direct and indirect effects, thus establishing the relative significance of each causal factor.

2. MATERIALS AND METHODS

During the summer of 2021, the current study took place at the primary research facility of The Vegetable Science Department is part of the Acharya Narendra Deva University of Agriculture & Technology, situated in Narendra Nagar, Kumarganj, Ayodhya, Uttar Pradesh. Geographically, Kumarganj lies at an altitude of 113 meters above sea level and is located between 24.470- and 26.560-degrees north latitude and 82.120- and 83.980-degrees east longitude. The region experiences a humid subtropical climate, and the experimental site features clay-loam soil. The semi-arid region of Kumarganj receives an average of 1200 mm of rainfall annually. In this region, the months of July through September get heavy rainfall. A prolonged period of cloud cover and heavy rain can occasionally have a significant negative impact on the regional agricultural sector. Wintertime rains are also common, but they usually occur during a Cool, dry season. The summer's hot period typically begins around mid-April and persists until mid-June, coinciding with the onset of the monsoon's visible presence. The experiment was conducted using a randomized block design (RBD) with three replications to assess the performance of thirty-five genotypes, including one control. Each genotype was planted in rows that were 3 meters long and spaced 3 meters apart, with a 0.5-meter spacing between plants within each row. The sowing date for the experiment was March 4, 2021.

3. RESULTS AND DISCUSSION

In the field of vegetable breeding, understanding the nature of the relationship between fruit production and its constituent parts is highly valuable. Correlation coefficients are statistics that quantify the relationship and the degree of it between two or more variables. According to a correlation study, choosing one character will advance all other positively connected characters. Due to natural associations, either positive or negative, many of the characters have correlations with other characters. The primary characteristic, total fruit yield (kg), exhibited a significantly positive phenotypic correlation with several factors: number of fruits per plant (rp=0.522), average fruit weight (rp=0.394), and days to first pistillate flower anthesis (rp=0.334). Conversely, average fruit weight (rp=-0.461) demonstrated a highly significant negative phenotypic correlation with the number of fruits per plant. Fruit equatorial circumference (cm) and average fruit weight were strongly and positively correlated (rp=0.352). There was a nearly significant positive correlation among all maturity traits, including node to first staminate and pistillate flower anthesis, days to first staminate and pistillate flower anthesis, and days to first fruit harvest. Average fruit weight and flesh thickness had a negative and significant correlation with the number of fruits per plant, fruit polar circumference, fruit equatorial circumference, and days to first staminate and pistillate flower anthesis.

Many studies have investigated the genotypic and phenotypic correlation coefficients associated with fruit yield and its contributing characteristics, including plant growth characteristics, maturity characteristics, and the shape, size, and quality of pumpkins documented by researchers in India and around the world [7,8], (Mohanty, 2001), [9].

The primary characteristic, total fruit yield (kg), showed strong and positive genetic associations with both the number of fruits per plant (rp=0.528) and the time to first pistillate flower anthesis (rp=0.507). Additionally, total fruit yield was significantly and positively correlated with average fruit weight (rp=0.395). In contrast, the number of fruits per plant had a significant and negative genetic correlation with average fruit weight (rp=-0.464). Furthermore, the number of fruits per plant was significantly and positively correlated with the time to first pistillate flower anthesis (rp=0.364), while average fruit weight was significantly and positively correlated with fruit equatorial circumference (cm) (rp=0.401).

The time until the initial fruit harvest demonstrated strong positive genetic correlations with both the node count at the first staminate flower's anthesis (rp=0.467) and the time to the first staminate flower's anthesis (rp=0.638). It also showed a highly significant negative genetic correlation with flesh thickness (cm) (rp=-0.578). In addition, flesh thickness had a significant positive genetic correlation with the node count at the first staminate flower's anthesis (rp=0.342). Moreover, the fruit's equatorial circumference (cm) exhibited highly significant negative genetic correlations with the node count at the first staminate flower's anthesis (rp=-0.466), the node count at the first pistillate flower's anthesis (rp=-0.395), and the time until the first pistillate flower's anthesis (rp=-0.466).

All maturity traits exhibited nearly substantial and positive connections with each other, including the node to the first emergence of staminate and pistillate flowers, the duration to the first fruit harvest, and the time till the first staminate and pistillate flower anthesis. The average fruit weight and the thickness of the flesh were significantly correlated negatively with the correlation coefficients for the number of fruits per plant, fruit polar circumference, fruit equatorial circumference, and the timing of the first staminate and pistillate flower anthesis. Furthermore, the genotypic correlation estimates published by Mohanty et al. (2001) and Amaral et al. [7] were greater than the actual values. In contrast to the comparable phenotypic connections between fruit yield and its constituent parts, the genotypic associations were, nevertheless, more extensive [10].

Path coefficient analysis is a tool to divide the observed correlation coefficient into direct and indirect effects of yield components on fruit yield to provide a clearer picture of character associations for formulating effective selection strategy.

Table 2 displays At the phenotypic level, several characteristics have direct and indirect effects on fruit yield per plant. Average fruit weight (0.755), number of fruits per plant (0.866), and days until first pistillate flower anthesis (0.180) significantly and positively impact total fruit output per plant. Conversely, days to first staminate flower anthesis (0.088) has a minimal direct effect on total fruit production. Nonetheless, average fruit weight exerts the strongest direct positive influence on overall fruit yield. Traits such as days to first fruit harvest (-0.016), node number at first staminate flower anthesis (-0.039), node number at first pistillate flower anthesis (-0.117), and fruit equatorial circumference (-0.002) negatively affect total fruit yield. Indirectly, fruit equatorial circumference (0.001), flesh thickness (0.000), days to first fruit harvest (0.001), and days to first pistillate flower anthesis (0.042) positively influence total fruit yield via average fruit weight. However, fruit polar length (-0.008) shows a significant negative indirect effect via average fruit weight. Other indirect effects include average fruit weight (-0.348), fruit polar length (-0.008), days to first pistillate flower anthesis (-0.026), days to first staminate flower anthesis (-0.004), and node number at first staminate flower anthesis (-0.001), which negatively impact total fruit yield via the number of fruits per plant. Flesh thickness (0.015) and fruit polar length (0.008) have positive indirect effects via average fruit yield on total fruit yield. The influence of the remaining traits on fruit yield is very low.

Table 3 shows Several traits impact fruit yield at the genotypic level, both directly and indirectly. The number of fruits per plant (0.914) had a significant positive direct effect on total fruit production. This was followed by fruit equatorial circumference (0.687), days to first fruit harvest (0.478), average fruit weight (0.380), node number at first pistillate flower emergence (0.211), flesh thickness (0.155), and fruit polar length (0.141). However, days to first pistillate flower anthesis (-0.226) and days to first staminate flower anthesis (-1.026) exerted a substantial negative direct effect on overall fruit yield. Node number at first staminate flower anthesis (0.020), node number at first pistillate flower emergence (0.054), and days to first staminate flower anthesis (0.057) displayed a highly positive indirect effect on the number of fruits per plant.Remaining characters showed a negative indirect effect, namely the number of fruits per plant. The node number at first staminate flower anthesis (0.136), days to first staminate flower anthesis (0.015), fruit polar length (0.028), fruit equatorial circumference (0.276), flesh thickness (0.023), and days to first fruit harvest (0.006) all exhibited a highly positive indirect effect in relation to average fruit weight. Conversely, the remaining node number at first pistillate flower anthesis (-0.042), days to first pistillate flower anthesis (-0.003), and the number of fruits per plant (-0.024) showed a negative indirect effect in relation to average fruit weight. The node number at first staminate flower anthesis (0.365), days to first pistillate flower anthesis (0.054), fruit polar length (0.036), and average fruit weight (0.005) demonstrated a highly positive indirect effect in relation to days to first fruit harvest. On the other hand, the node number at first pistillate flower appearance (-0.050), days to first staminate flower anthesis (-0.655), and fruit equatorial circumference (-0.131) showed a highly negative indirect effect in relation to days to first fruit harvest. Days to first staminate flower anthesis (-0.097) and days to first fruit harvest (-0.276) had a negative indirect effect on fruit equatorial circumference. Kumaran et al. (1998) also reported a high positive direct effect of the number of fruits per plant and fruit weight on fruit yield.

Table 1. Estimates of phenotypic correlation coefficient between 10 characters in pumpkin

Characters	First staminate flower anthesis node number	First pistillate flower anthesis node number	Days the initial staminate flower anthesis	Days the first pistillate flower anthesis	polar length of fruit (cm))	equatorial circumference of Fruit (cm)	Flesh thickness (cm)	Days to first fruit harvest	Average fruit weight (kg)	Number of fruit per plant	Total fruit yield Per Plant(kg)
Node number at first staminate Flower anthesis	1	0.361*	0.362*	0.284	0.102	-0.214	0.184	0.194	0.115	0.023	0.131
Node number at first pistillate flower anthesis		1	0.308	0.218	0.053	-0.321	0.059	-0.171	-0.172	0.224	0.011
Days to first staminate flower anthesis			1	-0.16	0.12	0.026	0.092	0.304	-0.011	-0.05	-0.032
Days to first pistillate flower anthesis				1	0.044	-0.237	-0.031	-0.012	0.007	0.231	0.334*
Fruit polar length (cm)					1	-0.01	0.052	0.104	0.187	-0.173	0.048
Fruit equatorial circumference (cm)						1	0.143	-0.136	0.352*	-0.243	0.076
Flesh thickness (cm)							1	-0.316	0.13	-0.004	0.206
Days to first fruit harvest								1	0.012	-0.057	-0.051
Average fruit weight (kg)									1	-0.461**	0.394*
Number of fruit per plant										1	0.522**

Table 2. Estimates of genotypic correlation coefficient between 10 characters in pumpkin

Characters	First staminate flower anthesis node number	First pistillate flower anthesis node number	Days the initial staminate flower anthesis	Days the first pistillate flower anthesis	polar length of fruit (cm))	equatorial circumference of Fruit (cm)	Flesh thickness (cm)	Days to first fruit harvest	Average fruit weight (kg)	Number of fruit per plant	Total fruit yield Per Plant(kg)
Node number at first staminate Flower anthesis	1	0.702**	0.639**	0.591**	0.08	-0.466**	0.342*	0.467**	0.175	0.026	0.196
Node number at first pistillate flower anthesis		1	0.443**	0.393*	0.087	-0.395*	0.057	-0.238	-0.2	0.258	0.01
Days to first staminate flower anthesis			1	-0.279	0.15	0.072	0.094	0.638**	-0.014	-0.055	-0.036
Days to first pistillate flower anthesis				1	0.032	-0.466**	-0.025	-0.239	0.012	0.364*	0.507**
Fruit polar length (cm)					1	-0.067	0.07	0.252	0.201	-0.188	0.051
Fruit equatorial circumference (cm)						1	0.154	-0.191	0.401*	-0.279	0.093
Flesh thickness (cm)							1	-0.578**	0.149	-0.006	0.235
Days to first fruit harvest								1	0.012	-0.082	-0.064
Average fruit weight (kg)									1	-0.464**	0.395*
Number of fruit per plant										1	0.528**

** &** Significant at 5% & 1% respectively*

Table 3. Direct and indirect effect of 10 characters on fruit yield on phenotypic level in pumpkin germplasm

Characters	First staminate flower anthesis node number	First pistillate flower anthesis node number	Days the initial staminate flower anthesis	Days the first pistillate flower anthesis	polar length of fruit (cm))	equatorial circumference of Fruit (cm)	Flesh thickness (cm)	Days to first fruit harvest	Average fruit weight (kg)	Number of fruit per plant	Total fruit yield Per Plant(kg)
Node number at first staminate Flower anthesis	**-0.039**	-0.014	-0.014	-0.011	-0.004	0.008	-0.007	-0.008	-0.005	-0.001	0.131
Node number at first pistillate flower anthesis	-0.042	**-0.117**	-0.036	-0.026	-0.006	0.038	-0.007	0.020	0.020	-0.026	0.011
Days to first staminate flower anthesis	0.032	0.027	**0.088**	-0.014	0.011	0.002	0.008	0.027	-0.001	-0.004	-0.032
Days to first pistillate flower anthesis	0.051	0.039	-0.029	**0.180**	0.008	-0.043	-0.006	-0.002	0.001	0.042	0.334*
Fruit polar length (cm)	0.005	0.002	0.005	0.002	**0.044**	-0.001	0.002	0.005	0.008	-0.008	0.048
Fruit equatorial circumference (cm)	0.001	0.001	0.000	0.001	0.000	**-0.002**	0.000	0.000	-0.001	0.001	0.076
Flesh thickness (cm)	0.021	0.007	0.011	-0.004	0.006	0.016	**0.115**	-0.036	0.015	0.000	0.206
Days to first fruit harvest	-0.003	0.003	-0.005	0.000	-0.002	0.002	0.005	**-0.016**	0.000	0.001	-0.051
Average fruit weight (kg)	0.087	-0.130	-0.008	0.005	0.141	0.266	0.099	0.009	**0.755**	-0.348	0.394*
Number of fruit per plant	0.020	0.194	-0.043	0.200	-0.150	-0.211	-0.003	-0.049	-0.399	**0.866**	0.522**

Bold values shows direct and normal values shows indirect effects, R SQUARE = 0.8267 Residual Effect = 0.4163

Table 4. Direct and indirect effect of 10 characters on fruit yield on genotypic level in pumpkin germplasm

Characters	First staminate flower anthesis node number	First pistillate flower anthesis node number	Days the initial staminate flower anthesis	Days the first pistillate flower anthesis	polar length of fruit (cm))	equatorial circumference of Fruit (cm)	Flesh thickness (cm)	First days to fruit harvest	Average fruit weight (kg)	Number of fruit per plant	Total fruit yield Per Plant(kg)
Node number at first staminate Flower anthesis	**0.780**	0.547	0.499	0.461	0.062	-0.364	0.267	0.365	0.136	0.020	0.196
Node number at first pistillate flower anthesis	0.148	**0.211**	0.093	0.083	0.018	-0.083	0.012	-0.050	-0.042	0.054	0.01
Days to first staminate flower anthesis	-0.656	-0.455	**-1.026**	0.286	-0.154	-0.074	-0.097	-0.655	0.015	0.057	-0.036
Days to first pistillate flower anthesis	-0.133	-0.089	0.063	**-0.226**	-0.007	0.105	0.006	0.054	-0.003	-0.082	0.507**
Fruit polar length (cm)	0.011	0.012	0.021	0.005	**0.141**	-0.010	0.010	0.036	0.028	-0.027	0.051
Fruit equatorial circumference (cm)	-0.320	-0.272	0.050	-0.320	-0.046	**0.687**	0.106	-0.131	0.276	-0.192	0.093
Flesh thickness (cm)	0.053	0.009	0.015	-0.004	0.011	0.024	**0.155**	-0.090	0.023	-0.001	0.235
Days to first fruit harvest	0.223	-0.114	0.305	-0.114	0.120	-0.091	-0.276	**0.478**	0.006	-0.039	-0.064
Average fruit weight (kg)	0.066	-0.076	-0.005	0.005	0.076	0.153	0.057	0.005	**0.380**	-0.176	0.395*
Number of fruit per plant	0.023	0.235	-0.050	0.332	-0.172	-0.255	-0.005	-0.075	-0.424	**0.914**	0.528**

4. CONCLUSION

The number of fruits per plant and the number of days before the first pistillate flower anthesis, respectively, showed a highly substantial and positive association with the most important feature, total fruit output (kg). There is a considerable positive link between the average fruit weight and the total fruit output per plant. The average fruit weight showed a negative association with the number of fruit per plant, which was extremely significant. Days to first pistillate flower showed a substantial and positive link with the number of fruit per plant.

All the maturity characters *viz.*, node to first staminate and pistillate flower appearance, days to first staminate and pistillate flower anthesis and days to first fruit harvest were almost significantly and positively correlated among themselves. The correlation coefficients between the number of fruit per plant, fruit polar circumference, fruit equatorial circumference, and days to first staminate and pistillate flower anthesis with average fruit weight and flesh thickness were negative and statistically significant.

The highly positive direct effect on total fruit yield per plant was exerted by number of fruit per plant followed by average fruit weight and days to first pistillate flower anthesis exerted positive direct effect on total fruit yield per plant. The other characters' direct effects on the total fruit yield per plant were noticeably too little, as evidenced by the days until the first staminate flower anthesis. Fruit polar length, however, showed a strong negative and significant indirect effect via. On the total fruit output per plant, the average fruit weight. This implies that earliness and lesser fruit weight will result from selection for a bigger number of fruits per plant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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