Plant Archives Vol. 26, Supplement 1, 2026 pp. 94-98 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.013

GENETIC ASSOCIATION AND DIRECT–INDIRECT EFFECTS OF YIELD COMPONENTS IN POTATO (*SOLANUM TUBEROSUM* L.) UNDER NORTHERN DRY ZONE OF KARNATAKA INDIA

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(Date of Receiving : 14-08-2025; Date of Acceptance : 18-10-2025)

ABSTRACT

An experiment was conducted during the *Rabi* season of 2024–25 at Sector No. 1, University of Horticultural Sciences, Bagalkot, to study the relationship between tuber yield and its component traits in seventeen potato (*Solanum tuberosum* L.) genotypes. The trial was laid out in a randomized complete block design (RCBD) with two replications. Correlation and path coefficient analyses were employed to determine the nature and extent of associations among yield and related traits. A strong positive and significant correlation was observed for marketable tuber weight per plant (r = 0.935), plant spread (r = 0.841) and germination percentage (r = 0.841). Strong but non-significant positive correlations were noted for total biomass and dry matter content. Path coefficient analysis revealed that plant spread, germination percentage and number of tubers per plant exerted the highest direct effects on tuber yield, with path coefficients of 0.664, 0.491 and 0.323, respectively. These findings suggest that improving traits such as plant spread, germination percentage, and number of tubers per plant could effectively enhance tuber yield in potato breeding programs under the northern dry zone conditions of Karnataka.
***Keywords* :** Correlation, Path analysis, Potato Yield component.

Introduction

Potato (*Solanum tuberosum* Linn), a member of the Solanaceae family, is a major food crop globally and often recognized as the "King of Vegetables." The genus Solanum typically has a base chromosome number of 12 and among its various ploidy types, tetraploid forms (2n=4x=48) are the most widely cultivated and productive, as reported by Dodds (1962). Potatoes offer a well-balanced nutritional profile, comprising 75–80 per cent water, 16–20 per cent carbohydrates, 2.5–3.2 per cent crude protein, 1.2–2.2 per cent true protein, 0.8–1.2 per cent, mineral content, 0.1–0.2 per cent fats and about 0.6 per cent fibre per 100 grams (Ezeikal *et al*., 1999).

Association studies help in understanding the degree and nature of relationships among different traits, which cannot be fully explained by genetic variability parameters alone. A positive association indicates that an increase in one desirable trait is accompanied by an increase in other related traits, whereas a negative association reflects an opposite trend between the traits. However, correlation analysis alone does not provide a complete picture, as environmental effects also play a role. Phenotypic and genotypic correlations allow breeders to assess the environmental influence on trait expression, though genotypic correlation is considered more dependable (Guler, Adak and Ulukan, 2001; Onder and Babaoglu, 2001).

Path analysis proposed by Dewey and Lu (1959) helps in breaking down correlation coefficients into direct and indirect effects of different traits on yield. This approach measures the direct impact of one variable on another. Such insights are highly valuable for breeders as they help in identifying the key yield-contributing traits and effectively utilizing genetic resources for systematic crop improvement.

Correlation studies highlight the relationships between traits but do not explain the nature of dependency of one trait on another. At times, correlation results may be misleading due to the influence of a third factor. In contrast, path coefficient analysis separates and quantifies the direct and indirect effects of several independent traits on a dependent trait, usually yield. This method helps in identifying the true cause of relationships along with residual effects, making it a useful tool for indirect selection. However, the complexity of the analysis increases with the number of independent traits involved. Since biochemical traits generally have little impact on yield, yield-attributing traits are more appropriate for assessing direct and indirect effects. In this study, genotypic path coefficient analysis was conducted to evaluate yield-related traits.

Materials and Methods

The study was conducted at Sector No. 1, University of Horticultural Sciences, Bagalkot, during the *Rabi* season of 2024–25 using seventeen potato genotypes collected from the S.D. Agricultural University, Potato Research Station, Deesa (Gujarat) and AICRP on Potato, Horticultural Research and Extension Centre, Somanahalli Kaval, Hassan (Table 1). The experiment followed a Randomized Complete Block Design (RCBD) with two replications. Each treatment was planted in plots measuring 2.4 m × 1.0 m with spacing of 60 cm between rows and 30 cm between plants. Every plot contained five rows with five plants per row, totalling twenty-five plants per plot and a spacing of one metre was maintained between adjacent plots. All standard agronomic practices were implemented, including timely irrigation and fertilizer application as per crop requirements. Observations were recorded on the mean of five randomly chosen plants from the central rows of each plot for traits such as germination percentage, plant height (75 DAS), number of leaves (75 DAS), plant spread (cm^2), number of haulms emerged, number of tubers per plant, tuber size (cm^2), total fresh biomass (kg), dry matter content, marketable tuber weight (g/plant) and total tuber yield per plant. Genotypic (r_g) and phenotypic (r_p) correlation coefficients were estimated according to the procedure described by Kwon and Torrie (1964). Path coefficient analysis was performed using genotypic correlation values to determine the direct and indirect effects of various morphological and yield-related traits on tuber yield, following the method proposed by Dewey and Lu (1959).

Table 1 : Potato genotypes/varieties used in the study and their sources

Sl. No.	Genotypes	Source
1	Kufri Pukhraj	S.D. Agricultural University Potato research station Deesa, (Gujarat)
2	Kufri Badshah	S.D. Agricultural University Potato research station Deesa, (Gujarat)
3	Kufri Khyati	S.D. Agricultural University Potato research station Deesa, (Gujarat)
4	Kufri Sukhyati	S.D. Agricultural University Potato research station Deesa, (Gujarat)
5	Kufri Ganga	S.D. Agricultural University Potato research station Deesa, (Gujarat)
6	Kufri Mohan	S.D. Agricultural University Potato research station Deesa, (Gujarat)
7	Kufri Laukar	S.D. Agricultural University Potato research station Deesa, (Gujarat)
8	Kufri Sangam	S.D. Agricultural University Potato research station Deesa, (Gujarat)
9	Kufri Kiran	S.D. Agricultural University Potato research station Deesa, (Gujarat)
10	Kufri Lima	S.D. Agricultural University Potato research station Deesa, (Gujarat)
11	Kufri Jyoti	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan
12	AICRP-42	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan
13	AICRP -85	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan
14	AICRP-15	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan
15	AICRP-48	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan
16	AICRP-24	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan
17	AICRP-16	AICRP on Potato, Horticultural Research and Extension Centre Somanahalli (Kaval), Hassan

Results and Discussion

Genotypic and Phenotypic correlations

The analysis of correlation coefficients (Tables 2 and 3) demonstrated both phenotypic and genotypic relationships among yield and its associated traits in potato. In most instances, genotypic correlation values were found to be greater than their corresponding phenotypic ones, suggesting that environmental influences might have masked or altered the true expression of these traits (Nandipuri, Singh and Lal, 1973). Similar findings were reported by Johnson, Robinson and Comstock (1955), who stated that higher genotypic correlations over phenotypic ones indicate a strong inherent relationship among characters. In the present investigation, tuber weight per plant (g) emerged as the most influential yield parameter, showing a highly significant (P=0.01) and positive association at the genotypic level (Table 2) with marketable tuber weight per plant (r_g=0.935), plant spread (cm) (r_g=0.841), germination percentage (r_g=0.841), number of haulms (r_g=0.812), number of tubers per plant (r_g=0.673), plant height at 75 DAS (r_g=0.614), and number of leaves at 75 DAS (r_g=0.582). The trait also exhibited a positive but non-significant relationship with total biomass (r_g=0.212), tuber size (r_g=0.210), and dry matter content (r_g=0.127). Similarly, at the phenotypic level (Table 3), tuber weight per plant (g) recorded a significant (P=0.01) and positive correlation with marketable tuber weight (r_p=0.880), plant spread (r_p=0.799), germination percentage (r_p=0.757), number of haulms (r_p=0.627), number of leaves at 75 DAS (r_p=0.536), plant height at 75 DAS (r_p=0.523), and number of tubers per plant (r_p=0.560). However, positive but non-significant associations were observed with tuber size (r_p=0.197), total biomass (r_p=0.186), and dry matter content (rp=0.128).

The findings of the present investigation indicated that various traits influenced tuber yield per plant indirectly through their association with other characters. Germination percentage exerted favourable indirect impacts via plant spread (0.563), marketable tuber weight per plant (0.220) and number of tubers per plant (0.217), whereas it showed unfavourable effects through number of leaves at 75 DAS (-0.348) and number of haulms emerged (-0.419). Likewise, plant height at 75 DAS displayed positive indirect contributions through plant spread (0.501) and germination percentage (0.283), while a negative association was noted through number of leaves at 75 DAS (-0.441). The number of haulms emerged also had beneficial indirect effects through plant spread (0.612) and germination percentage (0.433). Conversely, total biomass (-0.058) and dry matter content (-0.008) contributed marginally negative indirect influences. Taken together, these results emphasize that parameters such as plant spread, germination percentage and the number of tubers per plant are key intermediary factors that enhance tuber yield potential in potato genotypes.

Association study

Tuber yield per plant showed a positive and significant relationship with traits such as germination percentage and plant height at 75 DAS (Table 2 & 3). A comparable trend was observed for the number of leaves at 75 DAS, in agreement with Patel *et al.* (2013). Likewise, plant spread, number of haulms emerged, number of tubers per plant and marketable tuber weight per plant also displayed a significant positive association with yield, as reported by Rangare and Rangare (2013). However, tuber size, total biomass and dry matter content had a positive but non-significant correlation with yield per plant (Rangare *et al.*, 2014), to suggest that yield mainly depends on growth and yield-related attributes, while tuber size, biomass and dry matter exert relatively lesser influence.

Genotypic path coefficients for morphological parameters

Path coefficient analysis divides the overall correlation into direct and indirect components, allowing assessment of how much each trait contributes toward yield formation. This statistical technique helps identify characters that exert a direct influence on the dependent variable, as well as those that act indirectly through other associated attributes. Hence, it is a valuable method for vegetable breeders, as it aids in selecting genotypes based on traits that significantly affect the desired outcome.

Additionally, it provides insight into residual effects, which represent the contribution of other factors not accounted for in the current investigation. In the present research, genotypic path coefficients were estimated, as genotypic-level analysis alone can reveal the true magnitude of trait relationships, reflecting the actual genetic potential of the varieties under study (Table 4). The results indicated that plant spread showed the highest positive direct effect (0.664) on tuber weight per plant, followed by germination percentage (0.491), number of tubers per plant (0.323), marketable tuber weight per plant (0.289), tuber size (0.149), dry matter content (0.114) and plant height at 75 DAS (0.140). Conversely, the number of leaves at 75 DAS (-0.441), number of haulms (-0.475) and total biomass (-0.118) exhibited negative direct effects on tuber yield per plant.

The present study indicated that the majority of traits had a significant relationship with tuber weight per plant (Table 4). The highest positive direct effect on tuber weight was recorded for plant spread, followed by germination percentage, number of tubers per plant, marketable tuber weight per plant, tuber size, dry matter content and plant height at 75 DAS, whereas number of leaves at 75 DAS, number of haulms emerged and total biomass exhibited negative direct effects.

In breeding programs, traits that are positively associated with yield and exert direct influence are given priority. Enhancing features such as the number of tubers per plant, plant spread and tuber size increases the likelihood of favourable yield outcomes. Consequently, selecting genotypes with a higher number of tubers per plant, larger tubers, wider plant spread and greater marketable tuber weight can directly improve yield potential. Rajkumar *et al*. (2000) highlighted the value of indirect selection through these traits, while Rangare *et al*. (2014) and Patel *et al*. (2013) emphasized the importance of considering both direct and indirect positive contributions when identifying superior potato genotypes.

Conclusion

The correlation study showed that traits such as germination percentage, plant height at 75 DAS, number of leaves, plant spread, number of haulms and marketable tuber weight per plant had a significant positive relationship with tuber weight per plant at both genotypic and phenotypic levels. Hence, selecting genotypes exhibiting higher values for these traits could indirectly boost tuber yield potential.

Path coefficient analysis further revealed that germination percentage, plant height at 75 DAS, number of leaves, plant spread, number of haulms, number of tubers per plant, tuber size and marketable tuber weight per plant exerted a strong positive direct effect on tuber yield per plant. These findings highlight the importance of these traits in determining yield and suggest they should be prioritized as key selection parameters in potato improvement programs.

Table 2 : Genotypic correlation coefficients of potato genotypes

Traits	1	2	3	4	5	6	7	8	9	10	11
1	**1.000**	0.576**	0.788**	0.847**	0.882**	0.673**	0.604**	0.491**	0.043	0.760**	0.841**
2		**1.000**	0.909**	0.754**	0.485**	0.712**	0.275*	0.275*	-0.147	0.350*	0.614**
3			**1.000**	0.775**	0.813**	0.703**	0.317*	0.280*	-0.097	0.521**	0.582**
4				**1.000**	0.921**	0.839**	0.059	0.125	-0.068	0.936**	0.934**
5					**1.000**	0.864**	0.483**	0.243	-0.026	0.741**	0.812**
6						**1.000**	0.094	0.212	-0.300*	0.446*	0.673**
7							**1.000**	0.548**	0.175	0.242	0.210
8								**1.000**	-0.019	0.203	0.212
9									**1.000**	0.244	0.127
10										**1.000**	0.935**
11											**1.000**

1. GP: Germination percentage **2. PH-75:** Plant height at 75 days **3. NV-75:** Number of leaves at 75 days
4. PS: Plant spread (cm^2) **5. NHE:** Number of haulms emerged **6. NTP:** Number of tubers per plant
7. TS: Tuber size (cm^2) **8. TFB:** Total fresh biomass (kg) **9.DMC:** Dry matter content
10. MTWP: Marketable tuber weight (g) per plant **11.TWP:** Tuber weight per plant

Table 3 : Phenotypic correlation coefficients of potato genotypes

Traits	1	2	3	4	5	6	7	8	9	10	11
1	**1.000**	0.546**	0.676**	0.578**	0.777**	0.506**	0.528**	0.429*	0.017	0.693**	0.757**
2		**1.000**	0.707**	0.554**	0.489**	0.504**	0.216	0.212	-0.139	0.351*	0.523**
3			**1.000**	0.627**	0.681**	0.578**	0.318*	0.277*	-0.073	0.469**	0.536**
4				**1.000**	0.595**	0.581**	0.060	0.088	0.019	0.732**	0.799**
5					**1.000**	0.583**	0.412*	0.212	-0.061	0.614**	0.627**
6						**1.000**	0.079	0.167	-0.232	0.397*	0.560**
7							**1.000**	0.547**	0.175	0.220	0.197
8								**1.000**	-0.020	0.174	0.186
9									**1.000**	0.219	0.128
10										**1.000**	0.880**
11											**1.000**

1. GP: Germination percentage **2. PH-75:** Plant height at 75 days **3. NV-75:** Number of leaves at 75 days
4. PS: Plant spread (cm^2) **5. NHE:** Number of haulms emerged **6. NTP:** Number of tubers per plant
7. TS: Tuber size (cm^2) **8. TFB:** Total fresh biomass (kg) **9.DMC:** Dry matter content
10. MTWP: Marketable tuber weight (g) per plant **11.TWP:** Tuber weight per plant

Table 4 : Genotypic path coefficients for morphological parameters of potato genotypes

Traits	GP	PH 75	NV 75	PS	NHE	NTP	TS	TFB	DMC	MTWP	rG
GP	**0.491**	0.081	-0.348	0.563	-0.419	0.217	0.090	-0.058	0.005	0.220	0.841
PH75	0.283	**0.140**	-0.401	0.501	-0.230	0.230	0.041	-0.032	-0.017	0.101	0.614
NV75	0.387	0.127	**-0.441**	0.515	-0.386	0.227	0.047	-0.033	-0.011	0.15	0.582
PS	0.416	0.106	-0.342	**0.664**	-0.437	0.271	0.009	-0.015	-0.008	0.270	0.934
NHE	0.433	0.068	-0.359	0.612	**-0.475**	0.279	0.072	-0.029	-0.003	0.214	0.812
NTP	0.330	0.100	-0.310	0.557	-0.410	**0.323**	0.014	-0.025	-0.034	0.129	0.673
TS	0.297	0.039	-0.140	0.040	-0.229	0.030	**0.149**	-0.065	0.020	0.070	0.210
TFB	0.241	0.039	-0.123	0.083	-0.115	0.068	0.082	**-0.118**	-0.002	0.059	0.212
DMC	0.021	-0.021	0.043	-0.045	0.012	-0.097	0.026	0.002	**0.114**	0.071	0.127
MTWP	0.373	0.049	-0.230	0.622	-0.352	0.144	0.036	-0.024	0.028	**0.289**	0.935

Note: Residual = 0.0149

GP: Germination percentage
PH-75: Plant height at 75 days
NV-75: Number of leaves at 75 days
PS: Plant spread (cm)
NHE: Number of haulms emerged
NTP: Number of tubers per plant
TS: Tuber size (cm^2)
TFB: Total fresh biomass (kg)
DMC: Dry matter content
MTWP: Marketable tuber weight (g) per plant

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