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Correlation and Path Coefficient Analysis among Yield and Yield Associated Traits in Potato (*Solanum tuberosum* L.) Accessions in the '*Terai*' Region of Uttarakhand

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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 a breeding program, knowledge regarding the direct and indirect effects of traits and understanding the traits' relationships in potato genotypes are vital prerequisites for crop improvement. The main focus of the research was to assess the correlation and path analysis in 32

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CPRI advanced potato breeding lines using a randomized block design with three replications to direct proper selection criteria for tuber yield in the *Terai* region of Uttarakhand. Each genotype was assessed for twelve yield-related traits, and the mean data was used for further analysis. Correlation coefficient analysis showed that the average weight of tubers per plant, number of tubers per plant, tuber length, tuber girth, number of branches per plant, and plant height contributed to the highest positive correlation with tuber yield. The path coefficient result revealed that the average weight of tubers per plant, number of tubers per plant, and number of branches per plant had the highest positive direct effect on yield, whereas the effects of other traits were low. Therefore, these specific characters could be used as selection criteria to improve the yield performance of potatoes.

Keywords: Selection criteria; crop improvement; correlation; direct effect; yield.

1. INTRODUCTION

The potato (*Solanum tuberosum* L.) is a widely grown food crop, ranked third in human consumption after rice and wheat [1], and is grown worldwide as a primary crop, a secondary crop, or an intercrop. It is a wholesome food that provides proteins, carbohydrates, vitamin B complex, minerals, vitamin C, high-value dietary fibers, and phenolic compounds [2]. The potato is an Andean native, and with a vegetative propagation strategy, it developed a short-day dependence on tuber development. Potato is a member of the Solanaceae family and is specifically a member of the *Petota* section of the *Solanum* genus [3]. The cultivated potato (*Solanum tuberosum* L.) is a tetraploid crop with a chromosome number of 2n = 4x = 48. Its inheritance follows a tetrasomic pattern, which results in complex genetic segregation. Potato, with its extensive eco-geographical range, has unique characteristics compared to other major food crops. It develops stolons (underground stems) under favorable environmental conditions, which then enlarge to form tubers [4]. Autotetraploid cultivars are propagated from seed tubers and constitute the majority of commercial potato production. In 2019, China, India, and Russia were the three leading countries in potato production. China produced 91,818,950 tons of potatoes, accounting for 24.78% of the world's total potato production. Similarly, India contributed 50,190,000 tons, accounting for 13.54% of the global potato production, while Russia produced 22,436,581 tons, representing 5.95% of global potato production. Collectively, these three countries accounted for over 44% of global potato production [5]. India has emerged as the world's second-largest producer of potatoes, with a total production of 51.3 million tons from a cultivated area of 2.16 million hectares, achieving a productivity of 23.77 tons per hectare FAOSTAT, 2022 [6]. In India, potatoes primarily serve as a staple for table consumption, constituting approximately 68% of their total usage. Additionally, around 7.5% of potatoes are utilized for processing, 8.5% for seed purposes, while the remaining 16% of the produce goes to waste due to inadequate handling during pre- and post-harvest stages [7].

Since the establishment of the Central Potato Research Institute in Shimla in 1949, have developed and released a total of 56 potato varieties that are suitable for various potato-growing regions in the country [8]. The primary goal in potato breeding is to achieve high tuber yield while ensuring good quality. Tuber yield in potatoes is a complex polygenic characteristic [9] resulting from interactions among various factors and has a low heritability. Consequently, a better understanding of genetic variation among different potato attributes and its effect on yield would be valuable for breeders in further improving the crop [10].

Correlation coefficient studies among various quantitative traits offer valuable insights into the relationship between yield and its contributing characteristics. This information guides the selection of superior plant types in potato breeding programs. However, the correlation coefficient **estimate only indicates** the degree and nature of the association between yield and its constituents and does not offer insights into the direct and indirect effects of various yield variables on overall yield. Therefore, path coefficient analysis proves valuable in revealing both the direct and indirect effects of the causal variables on the response variable **[**11]. Researchers have widely used this method to assess the significance of yield components [12-15]. The current analysis aims to explore the interrelationship between thirteen different morphological and biochemical variables and their impact on tuber yield.

2. MATERIALS AND METHODS

The field experiment was conducted at the Vegetable Research Centre of GBPUAT Pantnagar, Uttarakhand, during the rabi season of 2017-2018. Geographically, Pantnagar is situated in the Shivalik hills at 29.5° N and 79.3° E, with an elevation of 244 m above mean sea level. The region falls within the 'Terai' mountain range of the outer Himalayas and experiences a humid subtropical climate, with frost expected from the final week of December to the end of January.

2.1 Experimental Planting Material and Field Trail

The study utilized 32 diverse potato genotypes, along with three checks (Table 1), maintained at the Vegetable Research Centre of the University. The experiment followed a randomized block design with three replications. In each plot, twenty tubers of comparable size per genotype were planted, with a spacing of 60 cm between rows and 20 cm within rows**.** The fertilizer dose of NPK (160:100:120 Kg per ha) was applied in the form of Urea, Single super phosphate, and muriate of potash, respectively. During the study, we followed recommended cultural practices, agronomic operations, and plant protection measures.

2.2 Various Growth Parameters and Tuber Yield Analysis

Observations were recorded on various growth parameters and yield-related traits from five randomly selected competitive plants within each plot across all replications. The mean values from these five plants were used for subsequent statistical analysis. The data were recorded for plant emergence percentage at 30 days after planting, plant height at 60 days after planting, tuber girth, tuber length, number of tubers per plant, average weight of tuber yield per plant, and total tuber yield per plot.

2.3 Biochemical Analysis

For tuber dry matter, total soluble solids (TSS), specific gravity, ascorbic acid, and protein, biochemical analysis was carried out at the Department of Vegetable Science at G. B. Pant University of Agriculture and Technology.

2.4 Statistical Analysis

The path and correlation analysis were estimated as described by Dewey and Lu [16] and Snedecor and Cocharan [17], respectively, using SAS 9.2 statistical package.

Table 1. List of potato (*Solanum tuberosum* L.) genotypes under study and source of seed

Sl. No.	Genotype	Source	Sl. No.	Genotype	Source
1	K. Surya	CPRI, Shimla	17	K.Khyati	CPRI, Shimla
2	P-29	CPRI, Shimla	18	P-25	CPRI, Shimla
3	PH-3	CPRI, Shimla	19	P-23	CPRI, Shimla
4	C-8	CPRI, Shimla	20	P-30	CPRI, Shimla
5	P-33	CPRI, Shimla	21	P-31	CPRI, Shimla
6	P-11	CPRI, Shimla	22	P-40	CPRI, Shimla
7	P-7	CPRI, Shimla	23	P-27	CPRI, Shimla
8	P-12	CPRI, Shimla	24	C-14	CPRI, Shimla
9	P-14	CPRI, Shimla	25	MM-11	CPRI, Shimla
10	K.Sindhuri	CPRI, Shimla	26	P-34	CPRI, Shimla
11	C-17	CPRI, Shimla	27	C-6	CPRI, Shimla
12	C-20	CPRI, Shimla	28	K.Lalit	CPRI, Shimla
13	P-9	CPRI, Shimla	29	P-4	CPRI, Shimla
14	P-22	CPRI, Shimla	30	K.Puskar	CPRI, Shimla
15	C-15	CPRI, Shimla	31	K.Frysona	CPRI, Shimla
16	C-28	CPRI, Shimla	32	P-15	CPRI, Shimla

3. RESULTS AND DISCUSSION

3.1 Character Associations

The genotypic and phenotypic correlations among various traits are summarized in Table 2**.** In the present study, most of the characters showed higher genotypic correlation coefficients than their corresponding phenotypic correlation coefficients, suggesting a stronger inherent association among the studied traits. In the present study, tuber yield per plot showed significant and positive correlations with the average weight of tuber per plant (0.961 and 0.932), number of tubers per plant (0.517 and 0.510), tuber length (0.352 and 0.343), number of branches per plant (0.342 and 0.336), tuber girth (0.324 and 0.314), plant height (0.318 and 0.308), and specific gravity of tuber (0.206 and 0.194) at both the genotypic and phenotypic levels, respectively.

The data suggests that an increase in positively associated traits contributes to an increase in yield per plant**.** In line with this, Panigrahi et al. [18], Patel et al. [19], Shubha, and Singh [11], Lavanya et al. [20], Singh et al. [21], Gebreselassie and Ajema [22], Hunde et al. [23], Nigussie et al. [24], Sandilya et al. [25], Tessema et al. [26] and Tsagaye et al. [27] also reported a significant correlation between tuber yield and several other traits, including tuber number**,** tuber weight**,** plant height**,** main stem per plant**,** average tuber weight**,** and tuber weight per plant**.** Consequently, improving tuber yield in potatoes is possible by employing an appropriate breeding strategy that selectively targets these positively correlated traits.

On the other hand, tuber yield per plot negatively and significantly correlated with the total soluble sugar content of the tuber (-0.317 and -0.315) at both the genotypic and phenotypic levels, respectively. Haq et al. [28] and Patel *et al.* [19] also reported that there is a significant negative correlation between tuber yield and total soluble sugar content of the tuber. Also, in the present study, tuber yield per plot had a non-significant negative correlation with the ascorbic acid content of the tuber, protein content of the tuber, and tuber dry matter. These findings are in agreement with previous work reported by Levy et al. [29], Luthra et al. [30], Patel *et al.* [19], and Gebreselassie and Ajema [22].

3.2 Path Coefficient Analysis

Path coefficient analysis was conducted to partition the correlation coefficients between tuber yield and yield-related traits into direct and indirect effects via pathways **(Table 3)**. The highest positive direct effect which contributed towards tuber yield per plot was observed via the average weight of tuber yield per plant (1.769), followed by number of branches per plant (0.251), number of tubers per plant (0.120), protein content of tuber (0.018) and specific gravity of tuber (0.017), whereas the effect of other traits were low (≤0.013). This implies that direct selection based on the average weight of tuber yield per plant, the number of branches per plant and the number of tubers per plant could significantly enhance the yield per plant. Similar to our findings, Gusain [31], Tripura et al. [32], Patel et al. [16], Shubha and Singh [11] Lavanya et al. [20], Kumar et al. [33], Kumar et al. [34], Sandilya et al. [22] and Sahu et al. [35] also reported that average weight of tuber yield per plant, number of branches per plant, number of tubers per plant, protein content of tuber and specific gravity of tuber had high positive direct effect on tuber yield.

Plant emergence per cent 30 days after planting (-0.033), dry matter content of tuber (-0.025), tuber length (-0.017) and ascorbic acid content of tuber (-0.003) had a direct negative effect on tuber yield per plant. These results are in agreement with the report of Panigrahi et al. [18], Lavanya et al. [20], Gebreselassie and Ajema [22] and Sandilya et al. [25].

The average weight of tuber per plant positively influenced tuber yield per plot through several indirect pathways. Notably, it exerted a significant positive effect through the number of tubers per plant (0.914), tuber length (0.623), tuber girth (0.574), plant height at 60 days after transplanting (0.563), and specific gravity of tuber (0.365). Similarly, the number of tubers per plant had a positive indirect effect on tuber yield per plot via the total soluble solid content of the tuber (0.012) and the number of branches per plant (0.005). Furthermore, the number of branches per plant indirectly influenced tuber yield per plot positively, primarily through the height of the plant at 60 days after planting (0.003). Plant emergence per cent 30 days after planting (0.008), dry matter content of tuber (0.006), tuber length (0.003), and ascorbic acid content of tuber (0.001) exerted an indirect positive effect on tuber yield per plot through a number of tubers per plant. The above findings align with the research conducted by Tripura et al. [32], Shubha and Singh [11], Lavanya et al. [20], and Gebreselassie and Ajema [22].

Table 2. Phenotypic and genotypic coefficient of correlation for tuber yield and its attributing traits in potato

Characters		No. of branches per plant	Plant height at 60DAP (cm)	Tuber girth (cm)	Tuber length (cm)	No. of tubers per plant	Average weight of tuber per plant(g)	Tuber dry matter (%)	Specific gravity of tuber (g/cm^3)	Total soluble solid content of tuber (%)	Ascorbic acid content of tuber (mg/100g)	Protein per cent	Weight loss of tuber 20 DAH (%)	Tuber yield per plot (Kg)
Plant emergence per cent at 30 DAP	rp	0.140	0.218*	0.198	0.030	-0.154	0.049	-0.236*	0.111	0.275**	0.271**	0.158	0.173	0.049
	rg	0.241*	0.320**	0.338**	-0.003	-0.234*	0.075	-0.308**	0.156	0.366**	0.373**	0.231*	0.075	0.075
No. of branches per plant	rp		0.467**	0.332**	0.333**	-0.249*	0.342	0.086**	-0.065	0.054	0.010	-0.016	0.249*	0.342**
	rg		0.493**	0.349**	0.351**	-0.263**	0.336	0.091**	-0.084	0.063	-0.021	-0.016	0.272**	0.336**
Plant height at 60 DAP (cm)	rp			0.178	0.353**	-0.086	0.308**	0.212*	0.111	-0.107	0.095	-0.010	0.265**	0.308**
	rg			0.182	0.385**	-0.084	0.318**	0.214*	0.108	-0.118	0.092	-0.004	0.270**	0.318**
Tuber girth (cm)	rp				0.626**	-0.162	0.314**	-0.078	0.088	0.164	0.051	-0.049	0.149	0.314**
	rg				0.641**	-0.164	0.324**	-0.088	0.095	0.169	0.048	-0.052	0.147	0.324**
Tuber length (cm)	rp					-0.140	0.343**	0.072	0.267**	-0.002	-0.311**	-0.333**	0.309**	0.343**
	rg					-0.151	0.352**	0.077	0.278**	0.001	-0.319**	-0.352**	0.320**	0.352**
Number of tubers per plant	rp						0.510**	-0.231*	0.183	-0.524**	-0.066	0.247*	-0.161	0.511**
	rg						0.517**	-0.233*	0.195	-0.535**	-0.060	0.258*	-0.163	0.517**
Average weight of tuber per plant (g)	rp							-0.012	0.194	-0.315**	-0.170	-0.049	0.167	0.932**
	rg							-0.011	0.206*	-0.317**	-0.165	-0.050	0.170	0.961**
Tuber dry matter (%)	rp								0.326**	0.145	-0.237*	0.090	-0.039	-0.012
	rg								0.335**	0.147	-0.246*	0.092	-0.044	-0.011
Specific gravity of tuber (g/cm^3)	rp									0.073	-0.159	0.015	-0.069	0.194
	rg									0.069	-0.171	0.014	-0.074	0.206*
Total soluble solid content of tuber (%)	rp										-0.028	-0.121	-0.067	-0.315**
	rg										-0.031	-0.123	-0.077	-0.317**
Ascorbic acid content of tuber (mg/100g)	rp											0.487**	-0.223*	-0.171
	rg											0.506**	-0.235*	-0.165
Protein per cent of tuber	rp												-0.440**	-0.049
	rg												-0.459**	-0.050
Tuber yield per plot (Kg)	rp													1.000
	rg													1.000

, Significant at P = 5% and 1% levels, respective*

Table 3 Genotypic path coefficient showing direct and indirect effects of different characters on tuber yield in potato

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**-0.033**	-0.008	-0.011	-0.011	0.001	0.008	-0.003	0.011	-0.005	-0.012	-0.012	-0.008	-0.008
2	0.001	**0.251**	0.003	0.001	0.001	-0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.001
3	0.004	0.006	**0.013**	0.002	0.005	-0.001	0.004	0.003	0.001	-0.002	0.001	-0.001	0.003
4	0.003	0.003	0.001	**0.007**	0.004	-0.001	0.002	-0.001	0.001	0.001	0.001	-0.004	0.001
5	0.000	-0.006	-0.007	-0.011	**-0.017**	0.003	-0.006	-0.003	-0.005	0.000	0.006	0.006	-0.006
6	0.005	0.005	0.002	0.003	0.003	**0.120**	-0.011	0.005	-0.004	0.012	0.001	-0.005	0.003
7	0.132	-0.063	0.563	0.574	0.623	0.914	**1.769**	-0.019	0.365	-0.561	-0.293	-0.088	0.301
8	0.008	-0.002	-0.005	0.002	-0.002	0.006	0.001	**-0.025**	-0.008	-0.004	0.006	-0.003	0.001
9	0.003	-0.002	0.002	0.002	0.005	0.003	0.004	0.006	**0.017**	0.001	-0.003	0.002	-0.001
10	0.004	0.001	-0.001	0.002	0.000	-0.005	-0.003	0.002	0.001	**0.011**	-0.001	-0.002	-0.001
11	0.001	0.001	-0.001	-0.001	0.001	0.001	0.001	0.001	0.001	0.001	-**0.003**	**-**0.001	0.001
12	0.004	-0.003	-0.001	-0.009	-0.006	0.005	-0.001	0.007	0.002	-0.002	0.009	**0.018**	-0.008
13	0.003	0.003	0.003	0.002	0.004	-0.002	0.002	-0.001	-0.001	-0.001	-0.003	-0.006	**0.012**

Note: Bold diagonal value indicate direct effect, Residual effect = 0.0028

1: Plant emergence per cent at 30 days after planting, 2: Number of branches per plant, 3: Plant height at 60 days after planting (cm), 4 : Tuber girth (cm), 5: Tuber length (cm), 6: Number of tubers per plant, 7: Average weight of tuber per plant (g), 8: Dry matter content of tuber (per cent), 9: Specific gravity of tuber (g per cm^3), 10: Total soluble solid content of tuber (per cent), 11 : Ascorbic acid content of tuber (mg per 100g) 12: Protein content of tuber (per cent) and 13: Weight loss of tuber at 20 days after harvesting (per cent)

4. CONCLUSION

The results of this study suggest that it is feasible to identify high-yielding types with desirable quality characteristics among the studied genotypes. Traits such as the average weight of the tuber, number of fruits per plant, number of branches per plant, plant height, tuber girth, and protein content of tuber are considered pivotal factors influencing potato tuber yield, owing to their direct positive effects and positive correlation with yield. As a recommendation, the practical significance lies in selecting traits with a positive correlation and a significant direct impact on tuber yield. These traits are crucial in the selection of potato genotypes intended for achieving high total tuber yield per plot.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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