Correlation and Path Coefficient analysis for selecting morphological and biochemical traits in Potato (*Solanum tuberosum* L.) in the '*Terai*' region of Uttarakhand

Abstract

Knowledge regarding the direct and indirect effects of traits and understanding of traits' relationship with important morphological and biochemical attributes on yield amplification of breeding materials are vital prerequisites for crop improvement. The main focus of the research was to assess the correlation and path analysis in 32 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. The Central Potato Research Station has a collection of advanced potato breeding lines that have been selected and maintained for a long time. It has characterized its genetic makeup and usefulness for the breeding program. The results revealed that the average weight of tuber per plant, number of tubers per plant, tuber length, tuber girth, number of branches per plant and plant height contributed the highest positive correlation with tuber yield. The path coefficient result revealed that average weight of tuber per plant, number of tubers per plant and number of branches per plant had highest positive direct effect on yield, whereas the effect of others traits were low. Therefore, these specific characters should be given more importance when selecting for yield performance.

Keywords : Potato, Correlation analysis, Path coefficient analysis, Yield

INTRODUCTION

The potato (*Solanum tuberosum* L.) is a widely grown food crop, ranked third in human consumption after rice and wheat (FAOSTAT, 2021), and is grown worldwide as a primary crop, a secondary crop, or an intercrop. 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 (Spooner et al. 2014). The potato has a vast eco-geographical range and among all other major food crops in the world, it shows a unique nature in that it produces stolons or underground stems which in the presence of congenial environmental factors swell to produce tubers (Hijmans, 2001). The majority of potato cultivars are autotetraploid ($2n = 4x = 48$), highly heterozygous, suffer from acute inbreeding depression, and are vulnerable to a wide range of harmful diseases and pests. Autotetraploid cultivars that are propagated from seed tubers constitute the majority in commercial potato production. Potato is a wholesome food that provides proteins, carbohydrates, vitamin B complex, minerals, vitamin C, and high value dietary fibres and phenolic compounds (Woolfe, 1987). 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 produced 50,190,000 tons, which is 13.54% of the world's potato production, while Russia produced 22,436,581 tons, which is 5.95% of the world's potato production. Together, these three countries accounted for over 44% of the world's potato production. Potato production has seen a significant rise in the past 17 years, according to FAOSTAT (2019). The production has increased by approximately 96.54%, from 349,000 tons in 1993 to 863,348 tons in 2010. India has become the second-largest potato producer globally, with production of 51.3 million tons from a cultivated area of 2.16 million hectares with 23.77 tons per hectare productivity (FAOSTAT,2022). In India, potatoes are mainly used for table consumption, accounting for approximately 68% of the total usage. About 7.5% of potatoes are used for processing, 8.5% for seed, and the remaining 16% of produce is wasted due to poor handling during pre- and post-harvest stages. Since the establishment of the Central Potato Research Institute in Shimla in 1949 has developed and released a total of 56 potato varieties that are suitable for various potato-growing regions in the country (Luthra *et al.* 2018). Tuber yield in potatoes is a complex polygenic characteristic (Killick, 1977) that is the result of interaction of diverse factors and has a low heritability. Consequently, more understanding of genetic variation among different potato attributes and how it affects yield should be useful to breeders for further crop improvement (Bhatt, 1973).

The correlation coefficient studies between various quantitative traits provide insight into the relationship between yield and its attributing characteristics. This information utilized to select a superior plant type in the potato breeding program. Several researchers have reported correlations between morphological and biochemical features with potato yield (Mahgoub *et al.* 2015; Rajini, 2015). The estimate of the correlation coefficient only reveals the degree and nature of the association between yield and its constituents. However, it does not provide information about the direct and indirect effects of various yield variables on yield. The most important objective in potato breeding is to achieve high tuber yield while maintaining good quality. The yield of tubers is a complex trait that involves many interrelated components. Therefore, the path coefficient analysis is useful in showing the direct and indirect effects of casual variables on the response variable (Shubha and Singh, 2018). Researchers have widely utilized this method to evaluate the significance of yield components (Sidhu, 1992). The current analysis aims to examine the interrelationship between 32 different agro-morphological and biochemical variables and their effects on crop yield.

Material and methods

The present investigation conducted on the experimental field of the Vegetable Research Centre of the GBPUAT Pantnagar, District Udham Singh Nagar (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, which are part of the '*Terai*' mountain range of the outer Himalayas. The region experiences a humid and subtropical climate, with frost expected from the final week of December to the end of January.

Experimental planting material and field trail :

The 32 diverse potato genotypes were used in the study along with three checks (Table 1), maintained in the Vegetable Research Centre of the University. The experiment was carried out in a randomized block design with three replications. In a plot 20 tubers with comparable size per genotype were planted with two rows spaced 60 cm between rows and 20 cm within rows. The fertilizer dose of (NPK Kg per ha) was applied in a ratio of 160:100:120 Kg per ha in the form of Urea, Single super phosphate, and muriate of potash, respectively. Standard cultural practices were carried out in the experimental plot during the crop season.

Various growth parameters and tuber yield analysis :

The observations related to different growth parameters and yield-related traits were collected from five randomly chosen competitive plants in each plot from each replication. The mean of five plants was used for statistical analysis. Plant emergence per cent at 30 days after planting, plant height at 60 days after planting (cm), tuber girth (cm), tuber length (cm), number of tubers per plant, average weight of tuber yield per plant and tuber yield per plot were measured.

Biochemical analysis :

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

Statistical analysis

The direct and indirect effects and correlation were estimated through path coefficient analysis as described by Dewey and Lu (1959) and Snedecor and Cocharan (1987), respectively, using SAS 9.2 statistical package.

Result and discussion

Character associations

The phenotypic and genotypic correlations among various traits are presented in **Table 2**. All thirteen characters under study showed higher genotypic correlation coefficients than phenotypic correlation coefficients. Tuber yield per plot showed significant and positive correlation with average weight of tuber per plant (0.961 and 0.932), number of tuber per plant (0.517 and 0.510), tuber length (0.352 and 0.343), tuber girth (0.324 and 0.314), plant height (0.318 and 0.308), and specific gravity of tuber (0.2056 and 0.194) at genotypic and phenotypic level respectively. Number of branches per plant was found to be significant and positive correlated with plant height (0.493 and 0.467), tuber length (0.351 and 0.333) and tuber girth (0.349 and 0.332) both at genotypic and phenotypic level respectively. Tuber girth had significantly high and positive correlation for tuber length (0.641 and 0.626) and tuber yield per plot (0.324 and 0.314) both at genotypic and phenotypic level respectively. Dry matter content of tuber showing high significant and positive correlation for specific gravity of tuber (0.335 and 0.326) both at genotypic and phenotypic level respectively. Ascorbic acid content of tuber exhibited significantly high and positive correlation with protein content of tuber (0.506 and 0.487) both at genotypic and phenotypic level respectively. Panigrahi *et al.* (2017) reported total tuber yield at early harvest showed significant positive correlation with germination per cent, marketable tuber yield. Patel *et al.* (2018) they reported that significantly positive correlation were observed between total tuber yield with plant height, number of tubers per plant, average weight of tubers per plant and marketable tuber yield. A previous worker also found similar results, positive correlation of tuber yield with number of tubers per plant also reported by Shubha, and Singh (2018), Lavanya *et al.*(2020), Gebreselassie *et al.* (2022), Nigussie*et al.* (2023) and Sandilya *et al.*(2023). Similar result exhibiting correlation between tuber yield and weight of tuber was reported by Shubha, and Singh (2018), Singh *et al.* (2021), Gebreselassie *et al.* (2022) and Tessema *et al.* (2023).Highly significant positive correlation of tuber yield with plant height also reported byTessema *et al.* (2023) and Tsagaye*et al.* (2023) ;Gusain (2010) and Hunde*et al.* (2022) reported that tuber size and specific gravity of tuber has positive correlation with tuber yield;

Path coefficient analysis

Genotypic correlation coefficient of various yield attributing characters of tuber yield was further partitioned into their direct and indirect effects.

Direct effect on tuber yield

The values of the path coefficient for tuber yield per plot and its components are shown in **Table 3**. The highest positive direct effect which contributed towards tuber yield per plot was observed via 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). Negative direct effects on tuber yield per plant was also exhibited by 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). In several studies, positive direct effect of tuber weight per plant on tuber yield has been reported (Lavanya *et al.* 2020 and Tripura et al. 2016). Similarily, Lavanya *et al.* 2020 and Sahu *et al.*2023 observedpositive direct effect tuber yield per plot. Shubha and Singh (2018);Lavanya *et al.* 2020; Kumar *et al.* 2020; Kumar *et al.* 2022 and Sandilya *et al.* 2023 reported highest direct effect of number of tubers per plant tuber yield. Sahu *et al.* 2023 and Sandilya *et al.* 2023 reported highest direct effect of number of branches per plant on tuber yield. Shubha and Singh (2018) reported tuber size, specific gravity of tuber, total soluble solid content of tuber, protein content of tuber have high positive direct effect on tuber yield.Gusain (2010) reported positive direct effect on tuber yield by protein content of tuber, specific gravity of tuber and total soluble solid content of tuber. Patel *et al.* (2018)reported positive direct effect of total soluble solid content of tuber on total tuber yield. Sandilya *et al.* 2023 and Panigrahi *et al.* 2017 reported plant emergence have direct negative effect on tuber yield**.** Sattar *et al.* 2007 and Panigrahi *et al.* 2017 observed dry matter content have direct negative effect on tuber yield.

Indirect effect of yield components on tuber yield

The indirect effect of various traits on tuber yield per plot are presented in **Table 3**.The plant emergence per cent exhibited positive indirect effect on tuber yield per plot through dry matter content of tuber (0.011). Number of branches per plant had positive indirect effect on tuber yield per plot via height of the plant at 60 days after planting (0.003). The positive indirect effect of number of tuber per plant on tuber yield per plot was exhibited through total soluble solid content of tuber (0.012) and number of branches per plant (0.005). Average weight of tuber per plant had positive indirect effect on tuber yield per plot was exhibited through number of tubers per plant (0.914), tuber length (0.623), tuber girth (0.574), plant height at 60 days after transplanting (0.563), specific gravity of tuber (0.365), weight loss of tuber at 20 days after harvesting (0.301) and plant emergence per cent at 30 days after planting (0.132). The positive indirect effect of plant height at 60 days after planting on tuber yield per plot was exhibited through number of branches per plant (0.006) and it also showed negative indirect effects with number of tubers per plant (-0.001). The positive indirect effect of tuber girth on tuber yield per plot was exhibited through length of tuber (0.004) and it also showed negative indirect effects with number of tubers per plant (-0.001). The positive indirect effect of tuber length on tuber yield per plot was exhibited through protein content of tuber (0.006) and it also showed negative indirect effects with number of branches per plant (-0.006). The dry matter content of tuber have negative direct effect on tuber yield per plot exhibited through specific gravity of tuber (-0.008) and it also showed positive indirect effects with number of tubers per plant (0.006). The positive indirect effect of specific gravity of tuber on tuber yield per plot was exhibited through plant emergence per cent at 30 days after planting (0.003), dry matter content of tuber (0.006) and total soluble solid content of tuber (0.001). Weight loss of tuber at 20 days after harvesting had positive indirect effect on tuber yield per plot was exhibited through tuber length (0.004). Total soluble solid content of tuber had positive indirect effect on tuber yield per plot was exhibited through plant emergence per cent at 30 days after planting (0.004) and specific gravity of tuber (0.001). Ascorbic acid content of tuber had positive indirect effect on tuber yield per plot was exhibited through plant emergence per cent at 30 days after planting (0.001). The positive indirect effect of protein content of tuber on tuber yield per plot was exhibited through number of tubers per plant (0.005) and ascorbic content of tuber (0.009). Path coefficient analysis revealed the average weight of tuber per plant, number of tubers per plant, height of plant at 60 days after planting, girth of tuber and number of branches per plant being the most important variables to increase tuber yield.

The above findings of path studies are in accordance with the findings of Lavanya *et al.* 2020for number of branches per plant, plant height, number of tubers per plant, and tuber yield per plant. Shubha and Singh (2018) reported tuber size have negative indirect effects with number of tubers per plant and similar result were found for specific gravity of tuber, total soluble solid content of tuber, ascorbic acid content of tuber and protein content of tuber. Tripura *et al.* 2016 also found tuber length have indirect negative effect with number of branches per plant. Gebreselassie *et al.* 2022 found that dry matter content of tuber have positive indirect effect with number of tubers per plant.

Conclusion

In the present investigation tuber yield per plot showed highly significant and positive correlation with average weight of tuber per plant, number of tuber per plant, tuber length, tuber girth, number of branches per plant and plant height, which may allow for the direct selection of genotypes for future breeding programme. Direct effect of average weight of tuber per plant, number of tubers per plant, number of branches per plant, plant height, tuber girth, specific gravity of tuber, total soluble solid content and protein content of tuber shows these are the most important direct influencing yield contributing characters. For improving potato tuber yield, the traits with the highest positive effects may be used in genotype selection. Based on character association and path analysis, it has been determined that simultaneous selection of the average weight of tuber per plant, number of tubers per plant, number of branches per plant, plant height, tuber length, tuber girth and specific gravity of tuber will be more fruitful when choosing desirable genotypes because these characteristics exhibit significant and positive correlations as well as a strong direct influence on tuber yield.

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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

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	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

DAP	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

* and ** Significant at P = 5% and 1% levels respectively.

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).