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Association and Path Coefficient Analysis Studies in Potato (*Solanum tuberosum* L.) Genotypes at Adet, Northwestern Ethiopia

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ABSTRACT

The experiment was conducted during main rain fall season from June to October, 2018 in Adet, Ethiopia with the objective of estimating the correlation and identifying the direct and indirect effect of yield contributing traits on potato crop. 36 potato genotypes were evaluated in simple lattice design in two replications. The analysis of variance revealed that highly significant ($p \leq 0.001$) difference among potato genotypes for all traits except average stem number. Total tuber yield was positively correlated with days to maturity, plant height, average stem number, marketable, unmarketable, total tuber number and marketable yield while it was negatively correlated with late blight severity percentage at both phenotypic and genotypic level. High correlation was observed between total tuber yield and marketable tuber yield (rp=0.982 and rg=0.986) followed by total tuber number (rp=0.735 and rg=0.789), and marketable tuber number (rp=0.700 and rg=0.737). Days to flowering, days to maturity, average stem number, marketable and unmarketable tuber number, starch content percentage, average tuber weight, and unmarketable tuber yield had positive direct effect on the total tuber yield at both genotypic and phenotypic level. Highly direct effect on total tuber yield was observed by marketable and unmarketable tuber number (3.65 and 1.17 respectively) and average tuber weight (0.56). Therefore, traits with significant positive correlated and direct effect on total tuber yield such as days to maturity stem number, marketable tuber number, marketable tuber yield and average tuber weight should be considered in selection criteria for enhancing tuber yield in potato.

KEYWORDS: Correlation, genotype, late blight, path analysis, potato, yield

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1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important food crops and grown in more than 150 countries, a staple food of about one billion people in the world in which about a half is localized in the developing counties (Anonymous, 2019). Globally, more than one and more billion people eat potatoes as a staple food (Ahmed et al., 2018, Chen et al., 2021). Global potato production has increased by about 20% since 1990, although production is still 50% below that of wheat, maize, and rice (Anonymous, 2019). It is produced for fresh potato tubers is about 359 mt from a total area of 16.5 mha (Anonymous, 2020). Potato is characterized as a cheap and nutritious food security crop (Beals, 2019).

In Ethiopia, during 2019 more than 1 million small holders were engaged in potato production. Since potato is grown from mid-altitudes to very high mountain tops, and from humid to dry areas in the country, improvements in productivity will require widely adaptive varieties (Kolech et al., 2015). The total area allocated to potato has reached 78,478.72 ha with a total production of 1,309,566.804 tons (Anonymous, 2022). Currently, potato is one of the potential food security crop in Ethiopia, due to its wider adaptability, high yielding potential, nutritional quality and needs short growing period (Tewodros et al., 2014). On the other hand, the productivity of this crop in the country is very low (16.67 t $ha^{-1)}$ as compared to the world's average yield of 21.07 t ha^{-1} (Anonymous, 2022 and Anonymous, 2022). The productivity of potato in Ethiopia is attributed to many factors, such as poor agronomic practices, lack of high-quality and improved planting material, high cost of improved seed tubers, disease and pest problems (Woldegiorgis et al., 2008; Abebe and Yigzaw, 2008).

Tuber yield is a polygenic character (Hajam et al., 2019) and the result of interactions among several characters which are greatly influenced by environmental factors. The study of correlation between different quantitative characters provides an idea of association that could be effectively utilized in selecting a better plant type in potato breeding programs (Rahman, 2015). Genotypic and phenotypic correlation coefficients tell us the association between and among two or more characters (Tripura et al., 2016). According to Lavanya et al. (2020) higher genotypic correlation coefficients were noticed than phenotypic correlation coefficients suggesting that little influence of environment and the presence of inherent association between various characters. However, knowledge of correlation alone is often misleading because when more variables are included in a study, the indirect association becomes more complex. In such a situation the path-coefficient analysis provides an effective means of finding direct and indirect causes of association of characters that are helpful to identify the role of each individual character towards yield (Rahman, 2015).

In Ethiopia potato breeding is done through selection of genotypes based on phenotypic characteristics mainly tuber yield and resistance to diseases. For the selection introduction of potato germplasm from International Potato Center (CIP) is done and are characterized and evaluated, for major quantitative traits which are strongly influenced by environmental factors. However, it usually lacks to see the association of characters between the genotypes in the selection process. Therefore, the present study was under taken to estimate the association among desired traits that affect tuber yield and yield component traits and, identify the direct and indirect effect of yield contributing traits on tuber yield in potato.

2. MATERIALS AND METHODS

2.1. Description of the study area

The field experiment was conducted during rainfall season from June to October, 2018 at Adet Agricultural Research Center's experimental station in Northwestern Ethiopia. It is nearly 450 km away from Addis Ababa and 42 km from the Capital City of Amhara Regional State Bahir Dar. Geographically, it is located at 11°16'N latitude and 37°29'E longitude at an altitude of 2240 meter above sea level. The mean annual rain fall is 869 mm and the mean annual temperature is 18.56°C. The soil type of the study area is Nitosol soil. (Anonymous, 2018).

2.2. Treatments, experimental design and cultural practices

A total of 36 potato genotypes of which 33 were advanced genotypes introduced from International Potato Center (CIP) and three nationally released potato varieties as standard checks were used as treatments. All of the 36 genotypes were planted at Adet Agricultural Research Center on station during the main cropping season in 2018. The genotypes were arranged in simple lattice design with two replications and each genotype was planted on a plot of 9 m^2 consisting of four rows, which accommodated 10 plants row^{-1} resulted in 40 plants $plot^{-1}$. The harvested plot size was 1.5×2.4 m=3.6 m^2. The spacing between rows and plants were 0.75 m and 0.30 m, respectively, while the spacing between plots and adjacent blocks were 1 m and 1.5 m, respectively. The experimental field was cultivated to a depth of 25–30 cm by a tractor and furrows (ridges) were made manually after leveling. The planting depth was maintained at 10–15 cm and fertilizer application was made as per the specific recommendation for the location, in which NPS (Nitorgen Phoshorous Sulpher) as a source of phosphorus was applied at a rate of 180 kg ha^{-1} and Urea as a source of nitrogen was applied at rate of 117 kg ha^{-1}. NPS was applied once during planting in the rows, while urea was applied in split application half at emergence and half at 50% flowering as a side dress application. All other agronomic practices such as weeding, cultivation were kept uniform for all treatments in each plot based on recommendation. Spraying fungicides such as Redomil for late blight control was applied once when the disease symptom was visible on the leaf. The two middle rows were used for data collection.

2.3. Data collection

2.3.1. Phonological, growth, tuber yield and yield related traits was collected as follows

Days to 50% emergence: The numbers of days from planting to the emergence of 50% of plants in each plot was recorded.

Days to 50% flowering: Was recorded as actual number of days taken from emergence to the days at which 50% of the plants in each plot produced flowers.

Days to maturity: Was recorded by counting days from emergence to days on which more than 90% of the plant in each plot get yellow.

Plant height in cm: The height of five plants in each plot was measured in centimeter from the ground surface to the tip of the main stem and averaged to get the mean plant height.

Average number of stems plant^{-1}: It was recorded as the average stem count of five hills or plant plot^{-1} at 50% flowering. Only stems that were emerged independently above the soil as single stems were considered as main stems.

Leaf area index (LAI): To determine leaf area index, five plants (hills) were used from each plot. Individual leaf area of the potato plants was estimated from individual leaf length by using the formula developed by Firman and Allen (1989) and leaf area index were determined by dividing the total leaf area of a plant by the ground area covered by a plant.

Log 10 (leaf area in cm^2)=2.06×log10 (leaf length in cm)−0.458 …………….. (1)

Number of marketable tubers plant^{-1}: Number of tubers harvested from five plants (hills) which counted as marketable after sorting tubers which have greater or equal to 20 g weight, free from disease and insect attack. The average number of marketable tubers were counted and registered.

Number of unmarketable tubers plant^{-1}: The tubers that are sorted as diseased, insect attacked and small-sized (<20 g) from five plants as indicated in the above were recorded as unmarketable tuber number. The average number of unmarketable tubers were counted and registered.

Total tuber number plant^{-1}: The total number of tubers produced plant^{-1} was recorded or it was recorded by the sum of both marketable and unmarketable tubers number plant^{-1}.

Average tuber weight (g tuber^{-1}): It was determined by dividing the total fresh tuber weight to the respective total tubers number which was harvested from five plants (hills).

Marketable tuber yield (t ha^{-1}): The total tuber weight which were free from diseases, insect pests, and greater than or equal to 20 g in weight determined from the net plot area and were converted to t ha^{-1}.

Unmarketable tuber yield (t ha^{-1}): It was determined by weighting tubers that were sorted out as diseased, insect attack and small-sized (<20 g) from the net plot area and converted to t ha^{-1}.

Total tuber yield (t ha^{-1}): This was determined as the sum of the weights of marketable and unmarketable tubers from the net plot area and converted to t ha^{-1}.

2.3.2. Tuber quality attributes was calculated as follows

Tuber dry matter content (TDMC) (%): Five fresh tubers were randomly taken from each plot, washed, weighed and sliced at harvest, dried for seven days under sun and finally in oven at 75°C for 72 hours until a constant weight was attained and dry matter percent was calculated (William and Woodbury, 1968).

Dry matter=(weight of sample after drying (g)/Initial fresh weight of sample (g))×100 ………………. (2)

Specific gravity of tubers (SG): was determined by the weight in air and in water method. Five kg tuber of all shapes and sizes were randomly taken from each plot. The tubers were washed with water. Then after the sample were first weighed in air and then re-weighed suspended in water. Specific gravity was calculated according to Kleinkopf et al. (1987) formula.

Specific gravity=(Weight in air/Weight in air-Weight in water) ……………… (3)

Starch (%): The percentage of starch was calculated from the specific gravity as follows:

Starch (%)=17.546+199.07×(SG-1.0988) (Talburt and Smith, 1959).

Total soluble solids (°Brix): The Brix of the raw potato samples was determined using a method as described by Pardo et al. (2000) using hand refractometer. The Brix was measured in the juice obtained after washing, crushing and extracting juice of the tuber samples.

Disease data: Assessment of severity of late blight under field conditions in percent was recorded on a plot basis taking into account the number of plants developing disease symptoms in a leaf and or many leaves and plants free from disease following the procedures of Heinfnings (1987).

2.4. Data analysis

2.4.1. Analysis of variance

Data were subjected to analysis of variance (ANOVA) using SAS statistical software (V. 9.0). Duncan Multiple Range

Test (DMRT) was used to compare means at 5% and 1% level of significance.

2.4.2. Phenotypic and genotypic correlations

Phenotypic and genotypic correlations were computed by calculating variance and then covariance at phenotypic and genotypic level as described by Sharma (1998). Correlation analyses were done to find out traits that were correlated to yield.

Phenotypic correlation coefficient (rpxy)= covpxy/$\sqrt{\sigma^2 px\ \sigma^2 py}$) ....(4)

Where: covpxy=phenotypic covariance between character x and y, σ^2px= phenotypic variance of character x and, σ^2py=phenotypic variance of character y

Genetic correlation coefficient (rgxy)=covgxy/$\sqrt{\sigma^2 gx\ \sigma^2 gy}$ ..(5)

Where: covgxy=genetic covariance for character x and y, σ^2gx=genotypic variance for character x and, σ^2gy=genotypic variance for character y

2.4.3. Path coefficient analysis

The direct and indirect effect of the independent character on total tuber yield ha^{-1} was estimated by the formulae of (Dewey and Lu 1959). rij=Pij+Ʃrik Pkj Where, rijis association between the independent variable (i) and dependent variable (j) as measured by correlation coefficient; Pij is component of direct effect of the independent variable (i) on the dependent variable (j) as measured by path coefficient; and Ʃrik Pkj is summation of components of indirect effects of a given independent variable (i) on a given dependent variable (j) via all other independent character (K). To determine Pij values square matrices of the correlation coefficients between independent characters in all possible pairs were inverted and then multiplied by the correlation coefficient between independent and dependent characters. The residual effect was estimated as described in Dewey and Lu (1995). Residual effect= $\sqrt{(1-R^2)}$

Where, R^2=ƩPij ri .... (6)

3. RESULTS AND DISCUSSION

The result of Analysis of variance showed that there is highly significant (p<0.001) difference among the tested potato genotypes for all traits except average stem number hill^{-1} (Table 1). The findings on variance for tuber yield and its components indicates the existence of substantial amount of variability for most of the traits in experimental material studied. This provides an opportunity for a breeder to select best genotypes for their better tuber yield and other yield related traits. Different authors from related researches reported the existence of significant variation among potato genotypes for different traits (Fekadu et al., 2013; Rahman, 2015; Asefa et al., 2016; Ebrahim et al., 2017 and Fufa et al., 2022).

3.1. Mean performances of genotypes for yield and related traits

The mean performance of all the tested potato genotypes was significant (p<0.001) for marketable tuber yield, total tuber yield and average tuber weight. The potato genotypes gave a wide range of 44.6 to 111.5, 11.9 to 46 and 13 to 52 for average tuber weight (g tuber^{-1}), marketable tuber yield (t ha^{-1}) and total tuber yield (t ha^{-1}), respectively. Genotype CIP-308522.501 gave higher average tuber weight (111.5 g tuber^{-1}) followed by CIP-308985.01 (108.5 g tuber^{-1}), CIP-308482.504 (104 g tuber^{-1}) and CIP-308522.500 (104 g tuber^{-1}). The lower tuber weight (44.6 g tuber^{-1}) was measured in genotype CIP-308530.501 with their population mean of 78.13 g tuber^{-1} (Table 2).

Of the tested potato genotypes, CIP-308517.500, CIP-308526.502, CIP-308522.501 and CIP-30850.01 gave higher marketable tuber yield (t ha^{-1}) (46, 45.9, 44.9 and 44.8) respectively than the other tested genotypes. While the lower marketable tubers yield (t ha^{-1}) (11.9 and 13.1) was obtained in genotype CIP-308522.503 and variety Dagim respectively. Three genotypes CIP-308522.501, CIP-308526.502 and CIP-308517.500 gave higher total tuber yield (52, 47.4, 47.3 t ha^{-1}) respectively while genotype CIP-308522.503 gave lower total tuber yield (13 t ha^{-1}). The results were similar with the work of (Asefa et al., 2016); (Ebrahim et al., 2017) and (Fufa et al., 2022) on potato genotypes for average tuber weight, marketable and total tuber yield and related traits.

Late blight severity percentage ranged from 10 to 92.5% with a mean performance of 59.58%. From the total of 36 tested potato genotype less late blight severity percentage (10%) was recorded in genotype CIP-308522.501 and while genotype CIP-308522.503 was 92.5% damaged than other tested materials in the study area.

3.2. Phenotypic and genotypic correlations

The phenotypic and genotypic association between every two variables were estimated and presented in Table 3. Total tuber yield (t ha^{-1}) showed positive and highly significant phenotypic and genotypic association with days to maturity (rp=0.665 and rg=0.710), marketable tuber number hill^{-1} (rp=0.700 and rg=0.737), total tuber number hill^{-1} (rp=0.735 and rg=0.789), and marketable tuber yield (t ha^{-1}) (rp=0.982 and rg=0.986) at both phenotypic and genotypic level. Thus, direct selection for above traits is helpful in improving total tuber yield of potato affect the growth, development and ultimately tuber yield (Table 3). Lavanya et al. (2020) stated that total tuber yield plot^{-1} was found to be significantly correlated with number of stems (0.8406 and 0.7605), number of tubers plant^{-1} (0.8709 and 0.8697), marketable yield plot^{-1} (0.9112 and 0.9024) at both genotypic and phenotypic level, Similarly, positive and correlation between marketable tuber yield and total tuber

Table 1: ANOVA table showing mean squares of replication; genotype; and error and mean values; CV (%); R^2 and LSD for each trait

Traits	Grand Mean	Rep (Df=1)	Genotype (Df=35)	Error (Df=35)	CV	R^2	LSD
DE	15.74	0.68	13.56**	0.42	4.12	0.98	1.34
DF	48.13	3.13	11.48**	1.43	2.48	0.93	2.46
DM	93.46	23.4	48.74**	1.89	1.47	0.98	2.83
SN	5.12	3.92	2.3^{ns}	1.66	25.15	0.74	2.67
PH	66.84	83.2	131**	2.24	7.3	0.85	10.32
LAI	3.76	2.68	0.97**	0.14	10.12	0.88	0.82
MTNPH	8.70	11.14	16.98**	2.66	18.84	0.87	3.18
UMTNPH	2.90	0.80	2.2*	1.05	35.78	0.68	2.07
TTNPH	11.6	17.91	13.81**	2.24	13	0.91	3.09
ATW	78.13	926.08	618.4**	179.26	17.14	0.78	27.3
MTY	29.28	0.13	195.1**	13.02	12.32	0.94	6.97
UMTY	3.08	0.36	4.36**	1.63	41.2	0.73	2.66
TTY	32.36	0.05	206.7**	12.30	10.81	0.94	6.95
DMC	23.03	2.12	14.89*	6.98	11.47	0.68	5.78
SG	1.14	0.0058	0.0034*	0.00185	3.77	0.66	0.09
STA	28.88	134.4	130.3**	38.68	21.53	0.78	12.51
TSS	3.91	6.69	0.84**	0.30	13.97	0.77	1.26
LB	59.58	50.0	1191.8**	17.86	7.09	0.98	8.49

DE: Days to 50% emergence; Df: Degree of freedom; DF: Days to 50% flowering; DM: Days to maturity; PH: Plant height in cm; SN: Stem number hill^{-1}; LAI: Leaf area index; MTNPH: Marketable tuber number hill plant^{-1}; UMTNPH: Un marketable tuber number hill^{-1} plant^{-1}; TTNPH: Total tuber number hill plant^{-1}; ATW: Average tuber weight (g tuber^{-1}); MTY: Marketable tuber yield (t ha^{-1}); UMTY: Un marketable tuber yield (t ha^{-1}); TTY: Total tuber yield (t ha^{-1}); DMC: Dry matter content (%); SG: Specific gravity; STA: Starch percentage (g 100 g^{-1}); TSS: Total soluble solid (°brix); LB: Late blight severity percentage (%); CV: Coefficient of variation; R^2: coefficient of determination; ns: non-significant;*: Significantly at (p=0.05);**: Significantly at (p=0.01)

Table 2: Mean performance of 36 potato genotypes for yield and yield related traits

Potato genotypes	DF	DM	PH	SN	MTN	TTN	ATW	MTY	TTY	DMC	SG	ST	LB
CIP-308517.501	48^{e-i}	92^{h-k}	69^{b-h}	3.9^{bcd}	13.1^{abc}	14.8^{abc}	56^{jk}	34.2^{c-f}	35.9^{c-g}	25.0^{b-f}	1.15^{a-f}	32.6^{a-h}	52.5^{ij}
CIP-308527.501	46.5^{h-k}	87no	61.3^{e-j}	5^{a-d}	7.2^{f-k}	8.8^{h-l}	60.8^{h-k}	19.3^{k-n}	20.7^{k-n}	24.4^{b-f}	1.19^{a-d}	36.3^{a-e}	87.5^{abc}
CIP-308510.03	48.5^{d-h}	95.5^{efg}	72.7^{b-g}	4.6^{a-d}	7.9^{e-j}	9.8^{g-k}	96.1^{a-g}	34.0^{c-f}	35.9^{c-g}	29.6^{a}	1.23^{a}	43.8^{a}	42.5^{klm}
CIP-308985.01	47.5^{f-j}	97.5^{ed}	72.9^{b-f}	5^{a-d}	8.1^{e-j}	11.1^{d-i}	108^{ab}	38.4^{a-d}	41.7^{bc}	24.2^{b-f}	1.08^{ef}	17.4^{i-l}	32.5^{nop}
CIP-308526.502	50^{b-f}	99.5^{bcd}	71.9^{b-g}	6.2^{a-d}	13.7^{abc}	15.0^{abc}	76^{b-k}	46.0^{a}	47.4^{ab}	21.4^{a-e}	1.18^{a-e}	34.2^{a-f}	27.5^{pq}
CIP-3038522.504	46.5^{h-k}	87.5^{mno}	58^{h-k}	6^{a-d}	10.2^{c-h}	13.5^{a-f}	76^{b-k}	34.5^{c-f}	38^{cde}	19.9^{c-f}	1.18^{a-e}	36.7^{a-e}	45^{jkl}

Table 2: Continue...

Potato genotypes	DF	DM	PH	SN	MTN	TTN	ATW	MTY	TTY	DMC	SG	ST	LB
CIP-308517.500	47^{g-k}	102.5^{b}	90.15^{a}	7.4^{a}	14.1^{ab}	15.8^{a}	74^{c-k}	46.2^{a}	47.3^{ab}	23.0^{a-f}	1.14^{a-f}	26.3^{b-l}	27.5^{pq}
CIP-308526.501	52^{abc}	98.5^{cde}	63.4^{c-j}	3.9^{bcd}	10.6^{b-g}	12.8^{a-g}	98.2^{a-f}	44.4^{ab}	46.4^{ab}	26.3^{b-f}	1.17^{a-f}	31.6^{a-i}	37.5^{l-o}
CIP-308499.502	45.5^{ijk}	102.5^{b}	57.6^{ijk}	5.1^{a-d}	10.7^{b-f}	14.9^{abc}	76.5^{b-k}	35.8^{cde}	40^{bcd}	22.9^{ab}	1.13^{a-f}	27.4^{b-l}	22.5^{q}
CIP-308530.501	51.5^{abc}	86^{o}	56.5^{jk}	5.7^{a-d}	8.3^{e-j}	9.9^{f-k}	44.6^{k}	16.0^{lmn}	17.7^{mn}	22.1^{b-f}	1.15^{a-f}	32.4^{a-h}	87.5^{abc}
CIP-308525.01	47.5^{f-j}	89^{k-o}	58.7^{h-k}	4.7^{a-d}	8.3^{e-j}	10.5^{e-j}	51.9^{k}	19.0^{k-n}	21.2^{j-m}	20.5^{c-f}	1.17^{a-f}	31.6^{a-i}	90ab
CIP-308500.01	50.5^{a-e}	99.5^{bcd}	69.5^{b-i}	7.3^{a}	14.4^{a}	16.2^{a}	65^{g-k}	44.8^{ab}	46.6^{ab}	25.2^{a-d}	1.10^{c-f}	18.9^{g-l}	35^{m-p}
CIP-308522.503	46.5^{h-k}	90^{i-n}	68.4^{b-j}	4.6^{a-d}	3.6^{kl}	5.6^{l}	66.7^{f-k}	11.9^{n}	13^{n}	21.9^{def}	1.18^{a-e}	39.0^{a-d}	92.5^{a}
CIP-308527.502	51.5^{abc}	92.5^{g-j}	60.5^{g-j}	5.6^{a-d}	11.2^{a-d}	14.0^{a-e}	61^{h-k}	30.3^{d-i}	33.5^{d-h}	26.1^{a-d}	1.15^{a-f}	27.7^{b-l}	50^{ijk}
CIP-395077.120	45^{jk}	96.5^{def}	67.4^{c-j}	5.7^{a-d}	12.8^{a-d}	15.7^{a}	66.1^{f-k}	37.5^{cd}	40.4^{bcd}	20.7^{a-f}	1.09^{def}	16.3^{jkl}	42.5^{klm}
CIP-308511.508	51^{a-d}	91^{h-l}	80.5^{ab}	6.7^{abc}	8.6^{e-j}	12.8^{a-g}	86.2^{a-j}	32.8^{d-g}	37.3^{cde}	21.1^{a-d}	1.16^{a-f}	37.0^{a-e}	32.5^{nop}
CIP-308522.501	53^{a}	105.5^{a}	80^{ab}	4.6^{a-d}	9.2^{d-i}	12.7^{a-g}	111^{a}	45.0^{a}	52^{a}	23.7^{a-e}	1.21^{ab}	41.0^{ab}	10^{r}
CIP-308485.002	45.5^{ijk}	92.5^{g-j}	69.6^{b-i}	5.9^{a-d}	8.7^{e-j}	13.1^{a-g}	86.8^{a-j}	33.7^{c-f}	37.6^{cde}	24.9^{b-f}	1.15^{a-f}	27.7^{b-l}	50^{ijk}
CIP-308511.507	52.5^{ab}	101.5^{bc}	67.1^{c-j}	3.6^{cd}	8.6^{e-j}	10.7^{e-j}	75.7^{c-k}	28.6^{e-j}	30.6^{e-i}	23.2^{a-e}	1.10^{c-f}	19.9^{f-l}	72.5^{ef}
CIP-308499.001	51.5^{abc}	96.5^{def}	56.6^{jk}	3.2^{d}	5.7^{i-l}	8.3^{h-l}	92.1^{a-h}	23.3^{i-l}	25.9^{h-l}	25.7^{a-e}	1.08^{ef}	18.0^{h-l}	75^{def}
CIP-308482.506	48.5^{d-h}	88^{l-o}	62.1^{d-j}	4^{bcd}	5.9^{i-l}	10.3^{f-j}	91.2^{a-h}	23.4^{i-l}	31.1^{e-f}	22.4^{a-e}	1.12^{b-f}	27.0^{b-l}	57.5^{hi}
CIP-308522.502	49.5^{c-g}	87^{no}	62.8^{c-i}	4.7^{a-d}	6.8^{h-k}	11.2^{d-i}	89.6^{a-i}	27.7^{e-j}	33.1^{d-h}	23.8^{a-e}	1.13^{a-f}	24.4^{d-l}	77.5^{def}
CIP-308518.001	50^{b-f}	92.5^{g-j}	74.5^{bc}	5.1^{a-d}	6.9^{g-k}	11.9^{b-h}	88.2^{a-j}	27.0^{f-k}	33.6^{d-h}	20.7^{a-f}	1.14^{a-f}	30.9^{a-j}	42.5^{klm}
CIP-308487.500	46.5^{h-k}	87.5^{mno}	74.4^{bcd}	3.9^{bcd}	8.7^{e-j}	10.9^{d-j}	57.6^{ijk}	21.9^{j-m}	23^{i-m}	26.8^{def}	1.10^{b-f}	34.1^{a-f}	77.5^{def}
CIP-308516.500	46.5^{h-k}	96.5^{def}	48.6^{k}	5^{a-d}	6.3^{i-l}	10.9^{d-i}	86^{b-j}	24.0^{h-l}	28.8^{f-j}	22.9^{a-e}	1.21^{abc}	35.8^{a-e}	82.5^{bcd}
CIP-308532.500	46^{h-k}	89.5^{j-n}	57.9^{h-k}	4.7^{a-d}	5.3^{jkl}	8.0^{i-l}	69.6^{f-k}	16.4^{lmn}	19.2^{lmn}	18.7^{c-f}	1.08^{ef}	15.6^{kl}	90^{ab}
CIP-308522.500	46.5^{h-k}	90.5^{i-m}	70.2^{b-h}	3.7^{a-d}	3.1^{l}	6.4^{kl}	104^{a-d}	14.2^{mn}	17.5^{mn}	20.3^{b-f}	1.10^{c-f}	17.2^{i-l}	82.5^{bcd}
CIP-308499.501	46.5^{h-k}	92.5^{g-j}	68.9^{b-i}	4.9^{a-d}	7.9^{e-j}	10.5^{e-j}	71.7^{e-k}	25.1^{g-k}	27.8^{g-k}	20.9^{a-f}	1.15^{a-f}	31.0^{a-j}	82.5^{bcd}

Table 2: Continue...

Potato genotypes	DF	DM	PH	SN	MTN	TTN	ATW	MTY	TTY	DMC	SG	ST	LB
CIP-308530.002	45.5^{ijk}	94^{fgh}	62.3^{c-j}	5.4^{a-d}	5.9^{i-l}	7.3^{jkl}	102^{a-e}	26.6^{f-k}	28^{f-k}	22.0^{ef}	1.14^{a-f}	25.5^{c-l}	77.5^{def}
CIP-308523.500	46^{h-k}	91.5^{h-k}	66.1^{c-j}	5.4^{a-d}	8.4^{e-j}	10.5^{e-j}	76.2^{b-k}	28.5^{e-j}	30.5^{e-h}	27.8^{a-d}	1.14^{a-f}	30.0^{a-k}	70^{fg}
CIP-308482.504	47^{g-k}	98^{de}	73.1^{b-e}	4.4^{a-d}	5.9^{i-l}	8.5^{h-l}	104^{abc}	27.5^{f-j}	31.8^{e-h}	27.3^{b-f}	1.12^{a-f}	22.7^{e-l}	40^{lmn}
CIP-308516.501	45.5^{ijk}	93^{ghi}	74.6^{bc}	6.9^{ab}	11.4^{a-d}	15.5^{ab}	63.8^{g-k}	32.0^{d-h}	36.1^{c-f}	20.1^{a-e}	1.13^{a-f}	24.6^{c-l}	62.5^{gh}
CIP-308482.505	49.5^{c-g}	86^{o}	67.2^{d-j}	5.4^{a-d}	8.2^{e-j}	11.7^{c-i}	51.3^{k}	17.1^{lm}	21.1^{j-m}	16.7^{def}	1.06^{f}	13.6^{l}	90ab
Gudanie	52.5^{ab}	94^{fgh}	60.7^{f-j}	6.3^{a-d}	11.5^{a-d}	14.5^{a-d}	63.9^{g-k}	32.6^{d-g}	35.5^{c-g}	22.7^{a-f}	1.18^{a-e}	33.5^{a-g}	80^{cde}
Belete	44.5^{k}	94^{fgh}	66.2^{c-j}	5.5^{a-d}	10.1^{c-h}	14.0^{a-e}	92.6^{a-h}	41.2^{abc}	45.7^{ab}	23.4^{b-f}	1.21^{abc}	38.7^{a-d}	30^{opq}
Dagim	44.5^{k}	87^{no}	64.8^{c-j}	4.4^{a-d}	4.2^{kl}	6.7^{kl}	70.8^{e-k}	13.1^{n}	15.6^{mn}	21.5^{f}	1.14^{a-f}	39.5^{abc}	90^{ab}
Mean	48.13	93.46	66.84	5.12	8.7	11.52	78.13	29.28	32.43	23.03	1.14	28.88	59.58
Range	45-53	86-10.5	49-90	3-7	3-14	6-16	45-111	12-46	13-52	17-30	1.06-1.23	14-44	10-92.5
CV	2.48	1.47	7.5	25.2	17.8	13	16.96	11.55	10.4	12.19	3.93	21.03	6.92
LSD	2.46	2.83	10.32	2.65	3.18	3.09	27.3	6.97	6.95	5.78	0.093	12.51	8.49

DE: Days to 50% emergence; DF: Days to 50% flowering; DM: Days to maturity; PH: Plant height in cm; SN: Stem number hill^{-1}; MTN: Marketable tuber number plant^{-1}; TTN: Total tuber number hill plant^{-1}; ATW: Average tuber weight (g tuber^{-1}); MTY: Marketable tuber yield (t ha^{-1}); TTY: Total tuber yield (t ha^{-1}); DMC: Dry matter content (%); SG: Specific gravity; LB: Late blight severity percentage (%)

yield was reported by (Fufa et al., 2022; Gebreselassie and Ajema, 2022). According to Amadi et al. (2008) report a significant positive correlation between tuber yield with number of tubers plant^{-1} (r=0.49) and days to maturity (r=0.15) at phenotypic level were recorded. Tripura et al. (2016) also reported that tuber numbers have positive and significant association with total tuber yield and he suggested that the tuber yield can be increased by simple selection of these characters.

Total tuber yield was positive and significantly correlated with plant height (rg=0.408), stem number (rg=0.424), and average tuber weight (g tuber^{-1}) (rg=0.372) at genotypic level. Similar result was reported by Fufa et al., 2022 who found that total tuber yield is positive and significantly correlated (rg=0.608) with plant height at genotypic level. Total tuber yield was also positively and significantly correlated with dry matter content percentage (rp=0.263), plant height (rp=0.535), stem number hill^{-1} (rp=0.322) and average tuber weight (rp=0.340) at phenotypic level (Table 3). A positive and significant correlation between average tuber weight and total tuber yield (Sattar et al., 2007; Amadi et al., 2008; Felenji et al., 2011; Rahman, 2015; Gebreselassie and Ajema, 2022) were reported. Total tuber yield in t ha^{-1} had negative and highly significant phenotypic and genotypic association with late blight severity percentage (rp=-0.878 and rg=-0.903) were observed.

Marketable tuber yield (t ha^{-1}) showed positive and highly significant correlation with days to maturity (rp=0.676 and rg=0.723), marketable tuber number hill^{-1} (rp=0.745 and rg=0.790), total tuber number hill^{-1} (rp=0.720 and rg=0.790) and stem number hill^{-1} (rp=0.338 and rg=0.447) at both phenotypic and genotypic level respectively; it was negatively and highly significant correlated with late blight severity percentage (rp=-0.850 and rg=-0.877) at both phenotypic and genotypic level, respectively. According to Fufa et al. (2022) reports marketable tuber yield was positively and significantly correlated with days to maturity (rg=0.557) and stem number plant^{-1} (rg=0.159) at genotypic level.

Marketable tuber yield (t ha^{-1}) was positively and significant correlated with plant height (rp=0.360), dry matter content percentage (rp=0.289) and average tuber weight (rp=0.292) at phenotypic level and; it was also positively and significant correlated with plant height (rg=0.417) at genotypic level. Similarly, (Fufa et al., 2022) stated that marketable tuber yield was positively and significantly correlated with plant height (rg=0.637) at genotypic level.

Table 3: Phenotypic correlation coefficient (below diagonal) and genotypic correlation coefficient (above diagonal) among the 18 traits of potato genotypes

Traits	DE	DF	DM	PH	SN	LAI	MTN	UTN	TTN
DE	1	0.806**	0.151	0.156	-0.070	-0.147	0.140	-0.264	0.045
DF	0.756**	1	0.255	0.046	-0.057	-0.007	0.208	-0.079	0.181
DM	0.158	0.279*	1	0.329*	0.118	0.058	0.440**	-0.085	0.412*
PH	0.136	0.026	0.284*	1	0.294	-0.039	0.277	-0.066	0.255
SN	-0.063	-0.096	0.063	0.197	1	-0.065	0.600**	0.041	0.618**
LAI	-0.148	-0.052	0.014	0.020	-0.008	1	0.037	-0.217	-0.041
MTN	0.112	0.155	0.360**	0.262*	0.537**	0.067	1	-0.196	0.935**
UTN	-0.219	-0.040	-0.071	-0.056	0.034	-0.138	-0.203	1	0.166
TTN	0.023	0.139	0.331**	0.239*	0.550**	0.011	0.918**	0.203	1
DMC	0.055	0.124	0.262*	0.024	0.014	-0.023	0.132	-0.195	0.053
SG	-0.021	-0.009	0.037	0.021	0.149	-0.195	0.114	0.072	0.144
STA	0.024	-0.048	-0.100	0.066	0.096	-0.24*	0.030	-0.005	0.028
TSS	0.229	0.210	0.264*	0.214	0.021	-0.005	0.248*	-0.123	0.198
LB	-0.035	-0.162	-0.663**	-0.451**	-0.231	-0.045	-0.543**	-0.130	-0.596**
ATW	-0.081	0.037	0.397**	0.114	-0.335**	0.026	-0.378**	0.203	-0.296*
MTY	0.086	0.197	0.676**	0.360**	0.338**	0.014	0.745**	-0.062	0.720**
UTY	-0.187	0.013	-0.124	-0.051	-0.017	-0.112	-0.236	0.90**	0.130
TTY	0.065	0.214	0.665**	0.353**	0.322**	-0.010	0.700**	0.087	0.735**

Table 3: Continue...

Traits	DMC	SG	STA	TSS	LB	ATW	MTY	UTY	TTY
DE	0.061	-0.011	0.036	0.310	-0.035	-0.112	0.087	-0.219	0.069
DF	0.151	0.051	0.002	0.276	-0.166	0.028	0.225	-0.021	0.241
DM	0.301	0.098	-0.081	0.392*	-0.683**	0.44**	0.72**	-0.160	0.71**
PH	0.090	-0.021	0.051	0.188	-0.502**	0.217	0.417*	-0.077	0.408*
SN	-0.229	0.147	0.034	-0.059	-0.323	-0.266	0.45**	-0.068	0.424*
LAI	0.020	-0.295	-0.34*	-0.138	-0.038	0.080	0.021	-0.137	-0.002
MTN	0.115	0.100	0.009	0.282	-0.581**	-0.320	0.79**	-0.261	0.737**
UTN	-0.287	-0.027	-0.055	-0.273	-0.164	0.301	-0.011	0.91**	0.132
TTN	0.012	0.090	-0.011	0.184	-0.644**	-0.213	0.79**	0.068	0.789**
DMC	1	0.248	0.251	0.341*	-0.287	0.280	0.306	-0.222	0.265
SG	0.264*	1	0.89**	0.213	-0.198	0.117	0.239	-0.081	0.238
STA	0.301*	0.89**	1	0.172	-0.123	-0.002	0.086	-0.083	0.083
TSS	0.149	0.135	0.139	1	-0.213	0.056	0.321	-0.315	0.262
LB	-0.24*	-0.136	0.088	-0.180	1	-0.45*	-0.88**	-0.151	-0.903**
ATW	0.210	0.029	-0.042	-0.124	-0.374**	1	0.307	0.327	0.372*
MTY	0.289*	0.159	0.057	0.190	-0.850**	0.292*	1	-0.070	0.986**
UTY	-0.133	0.003	-0.041	-0.146	-0.129	0.201	-0.107	1	0.082
TTY	0.263*	0.173	0.058	0.158	-0.878**	0.34**	0.98**	0.059	1

* significant at (p=0.05), ** significant at (p=0.01)

Days to maturity had positive and highly significant correlation with marketable tuber number hill^{-1} (rp=0.360 and rg=0.440), average tuber weight (rp=0.397 and rg=0.437) at both phenotypic and genotypic level; it also positively and significant correlated with plant height (rp=0.284 and rg=0.329), total soluble solid (rp=0.264 and rg=0.392) at both phenotypic and genotypic level.

Days to maturity was positively and significantly correlated with total tuber number hill^{-1} (rp=0.331), dry matter content percentage (rp=0.262) at phenotypic level and it was also positively correlated with total tuber number hill^{-1} (rg=0.412) at genotypic level. A positive and non-significant correlation between maturity day and dry mater content was described by Fufa et al., 2022. Additionally, a negative and significant correlation was observed between days to maturity and late blight disease severity percentage (rp=-0.663 and rg=-0.683) at both phenotypic and genotypic level (Table 3).

Late blight severity percentage had negative and highly significant correlation with plant height (rp=-0.451 and rg=-0.502), marketable tuber number hill^{-1} (rp=-0.543 and rg=-0.581)), total tuber number hill^{-1} (rp=-0.596 and rg=-0.644), average tuber weight (rp=-0.374 and rg=-0.445) at both phenotypic and genotypic level and it also negatively correlated with dry matter content percentage (rp=-0.241) at phenotypic level (Table 3).

Total tuber dry matter content percentage showed a positive and significant correlation with specific gravity (rp=0.26), starch content percentage (rp=0.301) at phenotypic level and total soluble solid (rg=0.341) at genotypic level. Fufa et al. (2022) reported positive and non-significant correlation between dry matter content and specific gravity at phenotypic level. Tuber starch percentage was positively and highly significantly correlated with specific gravity (rp=0.88 and rg=0.89) at both phenotypic and genotypic level (Table 3).

3.3. Path coefficient analysis

3.3.1. Phenotypic path coefficient analysis

The phenotypic path analysis of the direct effects revealed that days to attain 50% flowering (0.031), days to maturity (0.068), stem number hill^{-1} (0.034), marketable tuber number hill^{-1} (3.652), unmarketable tuber hill^{-1} (1.175), starch percentage (0.108), average tuber weight (0.558) and unmarketable tuber yield (0.094) had a positive direct effect on total tuber yield hectare^{-1}. The direct effect of these characters on total tuber yield t ha^{-1} indicates that, improvement on these traits will increase total tuber yield. Whereas days to 50% emergence (-0.0012), plant height (-0.025), leaf area index (-0.059), total tuber number hill^{-1} (-2.834), tuber dry matter content percentage (-0.0211), specific gravity (-0.069), total soluble solid (-0.012) and late blight severity percentage (-0.0173) had negative direct effect on total tuber yield hectare^{-1}. These indicated that the contribution of these traits for tuber yield is minimum. The highest positive direct effect on total tuber yield was obtained from marketable tuber number hill^{-1} followed by un marketable tuber number hill^{-1} and average tuber weight while lowest recorded from days to attain 50% flowering and average stem number hill^{-1}. The maximum negative direct effect exerted on total tuber yield was total tuber number hill^{-1} while the lower recorded from days to attain 50% emergence (Table 4).

Similarly, positive and direct effect of marketable tuber yield and unmarketable tuber yield, on total tuber yield was reported by Verma and Singh (2016). A positive and direct effect of tuber numbers plant^{-1} on total tuber yield has also been reported by various studies (Sattar et al. (2007); Majid et al. (2011) and Verma and Singh (2016). Tuber number imparted the maximum positive direct effect (2.10) on tuber yield plant^{-1} reported by Tripura et al., 2016. According to Fufa et al. (2022) report stem number plant^{-1} was positively affecting total tuber yield and while specific gravity had negatively direct effect on total tuber yield at phenotypic level. The positive and direct effect of average tuber weight on total tuber yield was reported by Sattar et al. (2007); Majid et al. (2011); Verma and Singh (2016). Sattar et al. (2007) also reported that days to maturity had positive direct effect on tuber yield and plant height and dry matter content percentage had negative direct effect on total tuber yield.

Days to maturity had positive indirect effect on total tuber yield hectare^{-1} through marketable tuber number hill^{-1}, average tuber weight and late blight severity percentage and it also exerted negative indirect effect on total tuber yield viz total tuber number hill^{-1}. Average stem number hill^{-1} exhibit positive indirect effect on total tuber yield through marketable tuber number hill^{-1} and it was also having negative indirect effect viz total tuber number hill^{-1} and average tuber weight (Table 4).

Average tuber weight had negative indirect effect on total tuber yield ha^{-1} through marketable tuber number hill^{-1} it also positive indirect effect on total tuber yield through total and unmarketable tuber number hill^{-1}. Late blight percentage had negative indirect on total tuber yield through marketable and un marketable number hill^{-1} and it also positively indirect effect on total tuber yield viz. total tuber number hill^{-1}. In the present study days to days to maturity, stem number hill^{-1}, marketable tuber number hill^{-1}, and average tuber weight can be used as direct selection criteria for improving total tuber yield (Table 4).

The phenotypic residual effect (0.19) indicated that about 81% of the variability in total tuber yield was contributed by

Table 4: Estimates of direct (bold) and indirect effect (off diagonal) of different traits on total tuber yield at phenotypic level in 36 potato genotypes

Triats	DE	DF	DM	PH	SN	LAI	MTN	UTN
DE	-0.0012	0.0232	0.0107	-0.0034	-0.0022	0.0087	0.4082	-0.2579
DF	-0.0009	0.0307	0.0189	-0.0006	-0.0033	0.0030	0.5655	-0.0466
DM	-0.0002	0.0085	0.0678	-0.0071	0.0022	-0.0008	1.3138	-0.0829
PH	-0.0002	0.0008	0.0192	-0.0250	0.0067	-0.0012	0.9551	-0.0661
SN	0.0001	-0.0030	0.0043	-0.0049	0.0342	0.0005	1.9599	0.0396
LAI	0.0002	-0.0016	0.0009	-0.0005	-0.0003	-0.0589	0.2456	-0.1626
MTN	-0.0001	0.0047	0.0244	-0.0065	0.0183	-0.0040	3.6518	-0.2380
UTN	0.0003	-0.0012	-0.0048	0.0014	0.0012	0.0082	-0.7395	1.1751
TTN	0.0000	0.0043	0.0224	-0.0060	0.0188	-0.0007	3.3521	0.2381
DMC	-0.0001	0.0038	0.0178	-0.0006	0.0005	0.0014	0.4816	-0.2288
SG	0.0000	-0.0003	0.0025	-0.0005	0.0051	0.0115	0.4173	0.0851
STA	0.0000	-0.0015	-0.0068	-0.0017	0.0033	0.0144	0.1098	-0.0063
TSS	-0.0003	0.0064	0.0179	-0.0054	0.0007	0.0003	0.9056	-0.1451
LB	0.0000	-0.0050	-0.0450	0.0113	-0.0079	0.0027	-1.9833	-0.1528
ATW	0.0001	0.0011	0.0269	-0.0029	-0.0115	-0.0015	-1.3810	0.2383
UTY	0.0002	0.0004	-0.0084	0.0013	-0.0006	0.0066	-0.8614	1.0612

Table 4: Continue...

Triats	TTN	DMC	SG	STA	TSS	LB	ATW	UTY	rp
DE	-0.0648	-0.0012	0.0015	0.0026	-0.0028	0.0061	-0.0450	-0.0175	0.0651
DF	-0.3933	-0.0026	0.0006	-0.0052	-0.0025	0.0280	0.0209	0.0012	0.2138
DM	-0.9384	-0.0055	-0.0026	-0.0108	-0.0032	0.1146	0.2216	-0.0116	0.6654**
PH	-0.6764	-0.0005	-0.0014	0.0072	-0.0026	0.0780	0.0638	-0.0048	0.3525**
SN	-1.5594	-0.0003	-0.0103	0.0104	-0.0003	0.0399	-0.1871	-0.0016	0.3220**
LAI	-0.0317	0.0005	0.0134	-0.0263	0.0001	0.0078	0.0144	-0.0105	-0.0096
MTN	-2.6010	-0.0028	-0.0079	0.0032	-0.0030	0.0938	-0.2111	-0.0221	0.7000**
UTN	-0.5742	0.0041	-0.0050	-0.0006	0.0015	0.0225	0.1132	0.0846	0.0867
TTN	-2.8335	-0.0011	-0.0099	0.0030	-0.0024	0.1029	-0.1652	0.0122	0.7351**
DMC	-0.1501	-0.0211	-0.0182	0.0323	-0.0018	0.0417	0.1175	-0.0124	0.2634*
SG	-0.4069	-0.0056	-0.0691	0.0956	-0.0016	0.0235	0.0165	0.0002	0.1733
STA	-0.0791	-0.0063	-0.0613	0.1076	-0.0017	0.0152	-0.0234	-0.0039	0.0584
TSS	-0.5609	-0.0031	-0.0094	0.0150	-0.0121	0.0311	-0.0690	-0.0137	0.1581
LB	1.6881	0.0051	0.0094	-0.0095	0.0022	-0.1728	-0.2088	-0.0121	-0.8783**
ATW	0.8387	-0.0044	-0.0020	-0.0045	0.0015	0.0646	0.5582	0.0189	0.3405**
UTY	-0.3684	0.0028	-0.0002	-0.0044	0.0018	0.0223	0.1124	0.0937	0.0593

DE: Days to 50% emergence; Df: Degree of freedom; DF: Days to 50% flowering; DM: Days to maturity; PH: Plant height in cm; SN: Stem number hill; LAI: Leaf area index; MTN: Marketable tuber number hill plant^{-1}; UTN: Un marketable tuber number hill plant^{-1}; TTN: Total tuber number hill plant^{-1}; ATW: Average tuber weight (g tuber^{-1}); MTY: Marketable tuber yield (t ha^{-1}); UTY: Un marketable tuber yield (t ha^{-1}); TTY: Total tuber yield (t ha^{-1}); DMC: Dry matter content (%); SG: Specific gravity; STA: Starch percentage (g 100 g^{-1}); TSS: Total soluble solid (°brix); LB: Late blight severity percentage (%);*: Significantly at (p=0.05);**: Significantly at (p=0.01) the sixteen-character studied in path analysis. About 19% of the variability towards yield in the present study might be due to environmental factors and sampling errors as stated by Sengupta and Karatia (1971).

3.3.2. Genotypic path coefficient analysis

The genotypic path analysis revealed that days to 50% emergence (0.018), days to 50% flowering (0.021), days to maturity (0.053), stem number hill^{-1} (0.017), marketable tuber number hill^{-1} (3.203), starch percentage (0.078), average tuber weight (0.0570), and unmarketable tuber yield (0.058) showed a positive direct effect on total tuber yield hectare^{-1}. The direct effect of these characters on total tuber yield indicates that, improvement on these traits will increase total tuber yield. Whereas plant height (-0.026), leaf area index (-0.047) total tuber number hill^{-1} (-2.322), tuber dry matter content percentage (-0.012), specific gravity (-0.008), total soluble solid (-0.046) and late blight severity percentage (-0.099) had negative direct effect on total tuber yield ha^{-1}. These indicated that the direct effect on total tuber yield t ha^{-1} is minimum. Marketable tuber number hill^{-1} was exerted maximum positive direct effect on total tuber yield followed un marketable tuber number hill^{-1} and average tuber weight while the lower positive direct effect was exerted by stem number hill^{-1} and days to 50% emergence (Table 5). This indicates that if other factors are held constant, an increase in marketable tuber yield and marketable tuber number hill^{-1} will reflect on increased total tuber yield. Similarly, Fufa et al. (2022) reported that positive direct effect was observed between total tuber yield with days to 50% emergence and days to maturity genotypic level.

Similar result positive and direct effects of tuber number hill^{-1} and average tuber weight on total tuber yield were reported by Haydar et al. (2009) and Rahman (2015). According to Rahman (2015) plant height, dry matter content percentage, specific gravity and total soluble sugar percentage showed direct negative effect on tuber yield. Negative direct effect of plant height on total tuber yield has been reported by Ara et al. (2009).

Days to maturity and stem number hill^{-1}, had a high positive indirect effect on total tuber yield through marketable tuber number hill^{-1} and negative indirect effect on total yield viz total tuber number hill^{-1}. Average tuber weight and late blight severity percentage had high negative indirect effect on total tuber yield through marketable tuber number hill^{-1} and positive indirect effect on total tuber yield viz total tuber number hill^{-1}. In the present study days to maturity, stem number hill^{-1}, marketable tuber number hill^{-1}, average tuber weight, can be used as direct selection criteria for improving total tuber yield t ha^{-1} (Table 5).

The genotypic residual effect (0.12) indicated that about 88% of the variability in tuber yield was contributed by

Table 5: Estimates of direct (bold) and indirect effect (off diagonal) of different traits on total tuber yield at genotypic level in 36 potato genotypes; R=0.12

Traits	DE	DF	DM	PH	SN	LAI	MTN	UTN	TTN
DE	0.0179	0.0170	0.0080	-0.0032	-0.0011	0.0069	0.4468	-0.2349	-0.1036
DF	0.0145	0.0211	0.0135	-0.0009	-0.0009	0.0003	0.6667	-0.0706	-0.4193
DM	0.0027	0.0054	0.0530	-0.0068	0.0020	-0.0027	1.4086	-0.0755	-0.9556
PH	0.0028	0.0010	0.0174	-0.0206	0.0049	0.0018	0.8876	-0.0587	-0.5916
SN	-0.0012	-0.0012	0.0063	-0.0061	0.0165	0.0030	1.9216	0.0363	-1.4354
LAI	-0.0026	-0.0001	0.0031	0.0008	-0.0011	-0.0468	0.1181	-0.1929	0.0963
MTN	0.0025	0.0044	0.0233	-0.0057	0.0099	-0.0017	3.2028	-0.1742	-2.1705
UTN	-0.0047	-0.0017	-0.0045	0.0014	0.0007	0.0101	-0.6269	0.8898	-0.3846
TTN	0.0008	0.0038	0.0218	-0.0053	0.0102	0.0019	2.9937	0.1474	-2.3221
DMC	0.0011	0.0032	0.0159	-0.0019	-0.0038	-0.0009	0.3693	-0.2554	-0.0277
SG	-0.0002	0.0011	0.0052	0.0004	0.0024	0.0138	0.3188	-0.0242	-0.2095
STA	0.0006	0.0000	-0.0043	-0.0010	0.0006	0.0157	0.0277	-0.0493	0.0264
TSS	0.0056	0.0058	0.0208	-0.0039	-0.0010	0.0065	0.9019	-0.2427	-0.4281
LB	-0.0006	-0.0035	-0.0362	0.0104	-0.0053	0.0018	-1.8611	-0.1459	1.4949
ATW	-0.0020	0.0006	0.0231	-0.0045	-0.0044	-0.0037	-1.0255	0.2680	0.4942
UMY	-0.0039	-0.0004	-0.0085	0.0016	-0.0011	0.0064	-0.8363	0.8114	-0.1577

Table 5: Continue...

Traits	DMC	SG	STA	TSS	LB	ATW	UMY	rg
DE	-0.0007	0.0001	0.0028	-0.0142	0.0035	-0.0637	-0.0127	0.0688
DF	-0.0018	-0.0004	0.0001	-0.0126	0.0166	0.0161	-0.0012	0.2410
DM	-0.0037	-0.0008	-0.0063	-0.0179	0.0682	0.2488	-0.0093	0.7101**
PH	-0.0011	0.0002	0.0040	-0.0086	0.0501	0.1238	-0.0045	0.4084*
SN	0.0028	-0.0012	0.0027	0.0027	0.0323	-0.1513	-0.0039	0.4238*
LAI	-0.0002	0.0024	-0.0262	0.0063	0.0038	0.0454	-0.0079	-0.0017
MTN	-0.0014	-0.0008	0.0007	-0.0129	0.0580	-0.1824	-0.0151	0.7369**
UTN	0.0035	0.0002	-0.0043	0.0125	0.0164	0.1716	0.0528	0.1322
TTN	-0.0001	-0.0007	-0.0009	-0.0084	0.0643	-0.1213	0.0039	0.7890**
DMC	-0.0121	-0.0020	0.0195	-0.0156	0.0286	0.1598	-0.0128	0.2652
SG	-0.0030	-0.0081	0.0696	-0.0097	0.0198	0.0668	-0.0047	0.2384
STA	-0.0030	-0.0072	0.0779	-0.0079	0.0123	-0.0011	-0.0048	0.0827
TSS	-0.0041	-0.0017	0.0134	-0.0457	0.0213	0.0319	-0.0182	0.2617
LB	0.0035	0.0016	-0.0096	0.0097	-0.0999	-0.2536	-0.0087	-0.9026**
ATW	-0.0034	-0.0009	-0.0001	-0.0026	0.0445	0.5697	0.0190	0.3720*
UMY	0.0027	0.0007	-0.0065	0.0144	0.0151	0.1866	0.0579	0.0822

DE: Days to 50% emergence; Df: Degree of freedom; DF: Days to 50% flowering; DM: Days to maturity; PH: Plant height in cm; SN: Stem number hill; LAI: Leaf area index; MTN: Marketable tuber number hill plant^{-1}; UTN: Un marketable tuber number hill plant^{-1}; TTN: Total tuber number hill plant^{-1}; ATW: Average tuber weight (g tuber^{-1}); MTY: Marketable tuber yield (t ha^{-1}); UTY: Un marketable tuber yield (t ha^{-1}); TTY: Total tuber yield (t ha^{-1}); DMC: Dry matter content (%); SG: specific gravity; STA: Starch percentage (g 100 g^{-1}); TSS: Total soluble solid (°brix); LB: Late blight severity percentage (%); *: Significantly at (*p*=0.05);**: Significantly at (*p*=0.01)

the sixteen-character studied in path analysis. About 12% of the variability towards yield in the present study might be due to many reasons which were not studied such as, environmental factors and sampling errors as stated by Sengupta and Karatia (1971).

4. CONCLUSION

Total tuber yield was positively and significantly correlated with all traits except late blight severity percentage at both phenotypic and genotypic level. Days to flowering, maturity, stem number, total tuber number hill^{-1}, starch content percentage, and average tuber weight, had a positive and direct effect on the total tuber yield at both genotypic and phenotypic level. Therefore, traits positive significant correlation and direct effect should be considered in selection criteria for enhancing tuber yield.

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6. REFERENCES

Abebe, T., Yigzaw, D., 2008. Review of crop improvement research achievements and future focus in parts of Western Amhara Region: The case of Adet. In: Tesfaye, A. (Ed.), Proceedings of the 1st Amhara Region Regional Workshop on Potato Research and Development Achievements and Transfer Experiences and Future Directions. Bahir Dar, Ethiopia, 85–101.

Ahmed, S., Zhou, X., Pang, Y., 2018. Improving starch related traits in potato crops: Achievements and future challenges. Starch-Stärke 70(9–10), 1700113.

Amadi, C.O., Ene-Obong, E.E., Okocha, P.I., Dung, E.A., 2008. Path analysis of yield of some potato hybrids and their progenitors in Northern Guinea Savanna of Nigeria. Nigerian Journal of Botany 4(2), 28–37.

Anonymous, 2018. Adet Agricultural Research Center, Meteorological unpublished data, 2018. Available at https://en.wikipedia.org/wiki/Adet. Accessed on 2nd January, 2024.

Anonymous, 2019. FAOSTAT, FAO Statistical Databases Available at: http://www.fao.org/potato-2008/en/potato/IYP-6en.pdf. Accessed March 2018.

Anonymous, 2020. FAO (Food and Agriculture Organization) of the United Nations FAOSTAT. Available online: https://www.fao.org/faostat/en/#data/QCL (accessed on 22nd March 2022).

Anonymous, Central Statistical Agency of Ethiopia (CSA), 2022. Agricultural Sample Survey Report on Area and Production (Private Peasant Holdings Meher Season. Central Statistical Agency of Ethiopia, Statistical Bulletin. Addis Ababa, Ethiopia.https://www.statsethiopia.gov.et/wp-content/uploads/2023/05/The-2014-EC-Meher-Season-Report-on-Area-and-Production-of-Major-Crops_Final-1.pdf,accessed. acessed Accessed date: 25th June 2024.

Anonymous, 2022. FAO STAT, 2022. Countries- Select All; Regions - World+(Total); Elements - Production Quantity; Items - Potatoes; https://www.fao.org/faostat/en/#data/QCL/visualize Accessed date: 25th June 2024.

Ara, T., Haydar, A., Islam, M.A., Azad, M.A.S., Khokan, E.H., 2009. Path analysis in potato. Journal of Soil Nature 3(2), 20–23.

Asefa, G., Mohammed, W., Abebe, T., 2016. Genetic variability studies in potato (*Solanum tuberosum* L.) genotypes in Bale highlands, South Eastern Ethiopia. Journal of Biology, Agriculture and Healthcare 6(3), 117–119.

Beals, K.A., 2019. Potatoes, nutrition and health. America Journal Potato Research 102–110.

Chen, X., Jiao, J., Zhuang, P., Wu, F., Mao, L., Zhang, Y., Zhang, Y., 2021. Current intake levels of potatoes and all-cause mortality in China: A population-based nationwide study. Nutrition 81, 110902.

Dewey, D.R., Lu, K.H., 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. Agronomy Journal (51), 515–518. https://dx.doi.org/10.2134/agronj1959.00021962005100090002x.

Ebrahim, S., Wasu, M., Tesfaye, A., 2018. Genetic variability in potato (*Solanum tuberosum* L.) genotypes for tuber quality, yield and yield related traits at Holetta, central highlands of Ethiopia. (MSc.Thesis, Haramaya University).

Fekadu, A., Petros, Y., Zelleke, H., 2013. Genetic variability and association between agronomic characters in some potato (*Solanum tuberosum* L.) genotypes in SNNPRS, Ethiopia. International Journal of Biodiversity and Conservation 5(8), 523–528. http://DOI: 10.5897/IJBC2013.0548.

Felenji, H., Aharizad, S., Afsharmanesh, G.R., Ahmadizadeh, M., 2011. Evaluating correlation and factor analysis of morphological traits in potato cultivars in fall cultivation of Jiroft area. American-Eurasian Journal of Agricultural & Environmental Sciences 11(5), 679–684.

Firman, D.M., Allen, E.J., 1989. Relationship between light interception, ground cover and leaf area index in potatoes. The Journal of Agricultural Science 113(03), 355–359. https://doi.org/10.1017/S0021859600070040.

Fufa, N., Tsagaye, D., Fikre, D., 2022. Correlation and path coefficient analyses of tuber yield and yield components among potato (*Solanum tuberosum* L.) genotypes at Bekoji, Southeastern Ethiopia. International Journal of Agriculture Research, Innovation and Technology (IJARIT) 12(2) 144–154. https://dx.doi.org/10.22004/ag.econ.330303.

Gebreselassie, H., Ajema, L., 2022. Correlation, path coefficient and multivariate analysis for yield and yield associated traits among potato (*Solanum tuberosum* L.) genotypes grown in Eastern Ethiopia. World Journal of Agriculture and Soil Science 8(2), 2022. http://dx.doi.org/10.33552/WJASS.2022.08.000684.

Hajam, M.A., Bhat, T.A., Rather, A.M., Khan, S.H., Ganie, M.A., Shafi, M., 2019. Correlation and path analysis in potato under temperate conditions. Journal of Plant Development Sciences 11(1), 51–55.

Haydar, A., Islam, M.A., Ara, T., Khokan, E.H., Khalequzzaman, K.M., 2009. Studies on genetic variability, correlation and path analysis in potato. International Journal of Sustainable Agricultural Technology 5(1), 40–44.

Heinfnings, J.W., 1987. Late blight of potato *(Phytophthora infestans)* technical information. Lima, Peru, Bulletin, 4, 22.

Kleinkopf, G.E., Westermann, D.T., Wille, M.J., Kleinschmidt, G.D., 1987. Specific gravity of Russet Burbank potatoes. American Potato Journal 64(11), 579–587. https://doi.org/10.1007/BF02853760.

Lavanya, K.S., Srinivasa, V., Ali, S., Lakshmana, D., Kadian, M.S., 2020. Correlation and path analysis for yield and yield-related traits of potato (*Solanum tuberosum* L.) in Karnataka. National Academy Science Letters 43(2), 137–140. https://doi.org/10.1007/s40009-019-00831-z.

Majid, K., Reza, S., Roza, G., Shahzad, J., Roghayyeh, Z., 2011. Correlation and path analysis between yield and yield components in potato (*Solanum tubersum* L.). Middle-East Journal of Scientific Research 7(1), 17–21, ISSN 1990–9233.

Pardo, J.E., Alvarruiz, A., Perez, J.I., Gomez, R., Varon, R., 2000. Physical-chemical and sensory quality evaluation of potato varieties (*Solanum tuberosum* L.). Journal of Food Quality 23(2), 149–160. https://doi.org/10.1111/j.1745-4557.2000.tb00202.x.

Rahman, M.H., 2015. Character association and genetic diversity of potato (*Solanum tuberosum* L.). Department of genetics and plant breeding Sher-E-Bangla Agricultural University Dhaka -1207, (MSc. Thesis), Bangladesh.

Sattar, M.A., Sultana, N., Hossain, M.M., Rashid, M.H., Islam, A.A., 2007. Genetic variability, correlation and path analysis in potato (*Solanum tubersum* L.) Bangladesh. Journal of Plant Breeding and Genetics 20(1), 33–38.

Sengupta, K., Karatia, A.S., 1971. Path co-efficients analysis for some characters in soybean. Indian Journal of Genetics 31, 290–295.

Sharma, J.R., 1998. Statistical and biometrical techniques in plant breeding. New Age International (P) Limited Publishers, New Delhi.

Talburt, W.F., Smith, O., 1959. Potato Processing; Ed. Westport C. T. The Avi Publishing.

Tewodros, A., Paul, C., Struik., Adane, H., 2014. Characterization of seed potato (*Solanum tuberosum* L.) Storage, pre-planting treatment and marketing systems in Ethiopia: Thecase of West-Arsi Zone. African Journal of Agricultural Research 9(15), 1218–1226. URL : http://www.academicjournals.org/artic.

Tripura, A., Das, A., Das, B., Priya, B., Sarkar, K.K., 2016. Genetic studies of variability, character association and path analysis of yield and its component traits in potato (*Solanum tuberosum* L.). Journal of Crop and Weed 12(1), 56–63.

Verma, A., Singh, H., 2016. Assessment of genetic diversity and association among agro-morphological characters in potato (*Solanum tuberosum* L.). Department of Vegetable Science, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar-263145, India 50(4), 345–349. https://DOI:10.18805/ijare.v50i4.11254.

William, M.A., Woodbury, G.W., 1968. Specific gravity dry matter relationship and reducing sugar changes affected by potato variety, production area and storage. American Journal of Potato Research 45(4), 119–131. https://doi.org/10.1007/BF02863065.

Woldegiorgis, G., Gebre, E., Lemaga, B., 2008. Potato variety development. In: Gebremedhin, W., Endale, G., Berga, L. (Eds.), Root and tuber crops: the untapped resources. Ethiopian Institute of Agricultural Research, Ethiopia. Addis Ababa, Ethiopia, 15–32.