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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 study was conducted at 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 ($p < 0.001$) 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 ($r_p = 0.982$ and $r_g = 0.986$) followed by total tuber number ($r_p = 0.735$ and $r_g = 0.789$), and marketable tuber number ($r_p = 0.700$ and $r_g = 0.737$). 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 coefficient Analysis; Potato; Tuber yield

## Introduction

Potato (Solanum tuberosum L.) is one of the most important food crops worldwide. It ranks third after rice and wheat in terms of human consumption [1]. The total world potato production was 370,436,581 metric tons. In Ethiopia, during 2019/20 growing season more than 1 million small holders were engaged in potato production. The total area allocated to potato has reached 70,362.22 ha with a total production of 924,728.361 tons [2]. Now a day 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. On the other hand, the productivity of this crop in the country is very low (13.14 t $ha^{-1}$) as compared to the world's average yield of 20.36 tons $ha^{-1}$. 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.

Tuber yield is the cumulative effect of many component characters individually contributing towards yield. Yield is the result of interactions among several characters which are greatly influenced by environmental factors. As yield is the main object of a breeder, so it is important to know the relationship between various characters that have direct and indirect effect on yield [3]. 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. Genotypic and phenotypic correlation coefficients tell us the association between and among two or more 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 [4]. According to, Rahman MH path co-efficient is a standard tool which measures the direct influence of one character upon another and permits the separation of correlation co-efficient into components of direct and indirect effects and it also provides valuable additional information for improving tuber yield via selection for its yield components.

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.

## Materials and Methods

### Description of the Study Area

The field experiment was conducted at Adet Agricultural Research

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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 11016'N latitude and 37029'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 18.560$^{C}$ [5]. The soil type of the study area is Nitosol soil.

## 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 2018/19. The genotypes were arranged in simple lattice design with two replications and each genotype was planted on a plot of 9m$^2$ consisting of four rows, which accommodated 10 plants per row resulted in 40 plants per plot. The harvested plot size was 1.5 m x 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 25-30cm by a tractor and furrows (ridges) were made manually after leveling. The planting depth was maintained at 10-15cm 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 117kg 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.

## Data Collection

## 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 per plant**: It was recorded as the average stem count of five hills or plant per plot 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 DM and Allen EJ and leaf area index were determined by dividing the total leaf area of a plant by the ground area covered by a plant.

$$\text{Log 10 (leaf area in cm}^2\text{)} = 2.06 \times \text{log10 (leaf length in cm)} - 0.458 \quad (1)$$

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

**Number of unmarketable tubers per plant**: The tubers that are sorted as diseased, insect attacked and small-sized (<20g) 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 per plant**: The total number of tubers produced per plant was recorded or it was recorded by the sum of both marketable and unmarketable tubers number per plant.

**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 20g in weight determined from the net plot area and were converted to tons per hectare.

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

**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 tons per hectare.

## 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 75oc for 72 hours until a constant weight was attained and dry matter percent was calculated [6].

$$\text{Dry matter} = \frac{\text{weight of sample after drying (g)}}{\text{initial fresh weight of sample (g)}} \times 100 \quad (2)$$

**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 GE formula.

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}} \quad (3)$$

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

Starch (%) =17.546 + 199.07 × (SG-1.0988) [7].

**Total soluble solids (0Brix)**: The Brix of the raw potato samples was determined using a method as described by Pardo JE 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 Henfling.

## Data analysis

### Analysis of variance

Data were subjected to analysis of variance (ANOVA) using SAS statistical software (V. 9.0, SAS Institute, 2002). Duncan Multiple Range Test (DMRT) was used to compare means at 5% and 1% level of significance.

### 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 JR. Correlation analyses were done to find out traits that were correlated to yield.

**Phenotypic correlation coefficient (rpxy)** $= \frac{covpxy}{\sqrt{\sigma 2px\, \sigma 2\, py}}$ (4)

Where: covpxy= phenotypic covariance between character x and y, σ2px= phenotypic variance of character x and, σ2py = phenotypic variance of character y

**Genetic correlation coefficient (rgxy)** $= \frac{covgxy}{\sqrt{\sigma 2gx\, \sigma 2\, gy}}$ (5)

Where: covgxy = genetic covariance for character x and y, σ2gx = genotypic variance for character x and, σ2gy = genotypic variance for character y

### Path coefficient analysis

The direct and indirect effect of the independent character on total tuber yield per hectare was estimated by the formulae of (Dewey and Lu 1959). rij = Pij + Σrik 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 Σrik 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 DR and Lu KH. Residual effect = $\sqrt{1-R^2}$ Where, $R^2$= ΣPij ri………………… (6)

## Results and Discussions

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 per hill (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 [8-10].

### 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), marketable tuber yield (t $ha^{-1}$) and total tuber yield (t $ha^{-1}$), respectively. Genotype CIP-308522.501 gave higher average tuber weight (111.5g/tuber) followed by CIP-308985.01 (108.5g/tuber), CIP-308482.504 (104g/tuber) and CIP-308522.500 (104g/tuber). The lower tuber weight (44.6g/tuber) was measured in genotype CIP-308530.501 with their population mean of 78.13g/tuber (Table 2).

Of the tested potato genotypes, CIP-308517.500, CIP-308526.502,

**Table 1**: ANOVA table showing mean squares of replication, genotype, and error and mean values, CV (%), R2 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 | 2.3ns | 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 | 8.7 | 11.14 | 16.98** | 2.66 | 18.84 | 0.87 | 3.18 |
| UMTNPH | 2.9 | 0.8 | 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** | 12.3 | 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** | 0.3 | 13.97 | 0.77 | 1.26 |
| LB | 59.58 | 50 | 1191.8** | 17.86 | 7.09 | 0.98 | 8.49 |

**Note: 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 per hill, **LAI:** leaf area index, **MTNPH:** marketable tuber number per hill/ plant, **UMTNPH:** un marketable tuber number per hill/plant, **TTNPH:** total tuber number per hill/plant, **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/100g), TSS- total soluble solid (0 brix), **LB:** late blight severity percentage (%), **CV:** coefficient of variation, **R2:** coefficient of determination ,ns, non-significant,*significantly at 5%,** significantly at 1%

**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.$^{9c-g}$ | 25.0$^{b-f}$ | 1.15$^{a-f}$ | 32.6$^{a-h}$ | 52.5$^{ij}$ |
| **CIP-308527.501** | 46.5$^{h-k}$ | 87$^{no}$ | 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$^{jkl}$ |
| **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$^{a-i}$ | 90$^{ab}$ |
| **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$^{bcd}$ |
| **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.$^{06f}$ | 13.6$^{l}$ | 90$^{ab}$ |
| **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 | 03-Jul | Mar-14 | Jun-16 | 45-111 | Dec-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 |

**Note: DE:** Days to 50% emergence, **DF:** days to 50% flowering, **DM:** days to maturity, **PH:** plant height in cm, **SN:** stem number per hill, **MTN:** marketable tuber number per hill/ plant, **TTN:** total tuber number per hill/plant, **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 (%)

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 [11-14] 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. According to Wassu Mohammed [15] late blight disease severity percentage was ranged from 10 to 86% in 21 potato genotypes including farmers' cultivar at Haramaya University during main cropping seasons.

## 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 per hill (rp = 0.700 and rg = 0.737), total tuber number per hill (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). In accordance with this result, positive and significant correlation of numbers of tubers per plants with total tuber yield at both phenotypic and genotypic level was reported by Mishra [16]. Lavanya et al. [17] stated that total tuber yield per plot was found to be significantly correlated with number of stems (0.8406 and 0.7605), number of tubers per plant (0.8709 and 0.8697), marketable yield per plot (0.9112 and 0.9024) at both genotypic and phenotypic level, Similarly, positive and correlation between marketable tuber yield and total tuber yield was reported by [18-22]. According to Amadi CO report a significant positive correlation between tuber yield with number of tubers per plant (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) (rg =0.372) at genotypic level. Similar result was reported by Nimona et al., 2021 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 per hill (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 [23-26] 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 per hill (rp =0.745 and rg =0.790), total tuber number per hill (rp =0.720 and rg =0.790) and stem number per hill (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 Nimona et al. (2022) reports marketable tuber yield was positively and significantly correlated with days to maturity (rg =0.557) and stem number per plant (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, (Nimona et al., 2022) stated that marketable tuber yield was positively and significantly correlated with plant height (rg =0.637) at genotypic level.

Days to maturity had positive and highly significant correlation with marketable tuber number per hill (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.

**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 | DMC | SG | STA | TSS | LB | ATW | MTY | UTY | TTY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DE** | 1 | 0.806** | 0.151 | 0.156 | -0.07 | -0.147 | 0.14 | -0.264 | 0.045 | 0.061 | -0.011 | 0.036 | 0.31 | -0.035 | -0.112 | 0.087 | -0.219 | 0.069 |
| **DF** | 0.756** | 1 | 0.255 | 0.046 | -0.057 | -0.007 | 0.208 | -0.079 | 0.181 | 0.151 | 0.051 | 0.002 | 0.276 | -0.166 | 0.028 | 0.225 | -0.021 | 0.241 |
| **DM** | 0.158 | 0.279* | 1 | 0.329* | 0.118 | 0.058 | 0.440** | -0.085 | 0.412* | 0.301 | 0.098 | -0.081 | 0.392* | -0.683** | 0.44** | 0.72** | -0.16 | 0.71** |
| **PH** | 0.136 | 0.026 | 0.284* | 1 | 0.294 | -0.039 | 0.277 | -0.066 | 0.255 | 0.09 | -0.021 | 0.051 | 0.188 | -0.502** | 0.217 | 0.417* | -0.077 | 0.408* |
| **SN** | -0.063 | -0.096 | 0.063 | 0.197 | 1 | -0.065 | 0.600** | 0.041 | 0.618** | -0.229 | 0.147 | 0.034 | -0.059 | -0.323 | -0.266 | 0.45** | -0.068 | 0.424* |
| **LAI** | -0.148 | -0.052 | 0.014 | 0.02 | -0.008 | 1 | 0.037 | -0.217 | -0.041 | 0.02 | -0.295 | -0.34* | -0.138 | -0.038 | 0.08 | 0.021 | -0.137 | -0.002 |
| **MTN** | 0.112 | 0.155 | 0.360** | 0.262* | 0.537** | 0.067 | 1 | -0.196 | 0.935** | 0.115 | 0.1 | 0.009 | 0.282 | -0.581** | -0.32 | 0.79** | -0.261 | 0.737** |
| **UTN** | -0.219 | -0.04 | -0.071 | -0.056 | 0.034 | -0.138 | -0.203 | 1 | 0.166 | -0.287 | -0.027 | -0.055 | -0.273 | -0.164 | 0.301 | -0.011 | 0.91** | 0.132 |
| **TTN** | 0.023 | 0.139 | 0.331** | 0.239* | 0.550** | 0.011 | 0.918** | 0.203 | 1 | 0.012 | 0.09 | -0.011 | 0.184 | -0.644** | -0.213 | 0.79** | 0.068 | 0.789** |
| **DMC** | 0.055 | 0.124 | 0.262* | 0.024 | 0.014 | -0.023 | 0.132 | -0.195 | 0.053 | 1 | 0.248 | 0.251 | 0.341* | -0.287 | 0.28 | 0.306 | -0.222 | 0.265 |
| **SG** | -0.021 | -0.009 | 0.037 | 0.021 | 0.149 | -0.195 | 0.114 | 0.072 | 0.144 | 0.264* | 1 | 0.89** | 0.213 | -0.198 | 0.117 | 0.239 | -0.081 | 0.238 |
| **STA** | 0.024 | -0.048 | -0.1 | 0.066 | 0.096 | -0.24* | 0.03 | -0.005 | 0.028 | 0.301* | 0.89** | 1 | 0.172 | -0.123 | -0.002 | 0.086 | -0.083 | 0.083 |
| **TSS** | 0.229 | 0.21 | 0.264* | 0.214 | 0.021 | -0.005 | 0.248* | -0.123 | 0.198 | 0.149 | 0.135 | 0.139 | 1 | -0.213 | 0.056 | 0.321 | -0.315 | 0.262 |
| **LB** | -0.035 | -0.162 | -0.663** | -0.451** | -0.231 | -0.045 | -0.543** | -0.13 | -0.596** | -0.24* | -0.136 | 0.088 | -0.18 | 1 | -0.45* | -0.88** | -0.151 | -0.903** |
| **ATW** | -0.081 | 0.037 | 0.397** | 0.114 | -0.335** | 0.026 | -0.378** | 0.203 | -0.296* | 0.21 | 0.029 | -0.042 | -0.124 | -0.374** | 1 | 0.307 | 0.327 | 0.372* |
| **MTY** | 0.086 | 0.197 | 0.676** | 0.360** | 0.338** | 0.014 | 0.745** | -0.062 | 0.720** | 0.289* | 0.159 | 0.057 | 0.19 | -0.850** | 0.292* | 1 | -0.07 | 0.986** |
| **UTY** | -0.187 | 0.013 | -0.124 | -0.051 | -0.017 | -0.112 | -0.236 | 0.90** | 0.13 | -0.133 | 0.003 | -0.041 | -0.146 | -0.129 | 0.201 | -0.107 | 1 | 0.082 |
| **TTY** | 0.065 | 0.214 | 0.665** | 0.353** | 0.322** | -0.01 | 0.700** | 0.087 | 0.735** | 0.263* | 0.173 | 0.058 | 0.158 | -0.878** | 0.34** | 0.98** | 0.059 | 1 |

**Note: DE:** Days to 50% emergence, **DF:** days to 50% flowering, **DM:** days to maturity, **PH:** plant height in cm, **SN:** stem number per hill, **LAI:** leaf area index, **MTN:** marketable tuber number per hill/ plant, **UTN:** un marketable tuber number per hill/plant, **TTN:** total tuber number per hill/plant, **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/100g), **TSS:** total soluble solid (0 brix), **LB:** late blight severity percentage (%), * significant at 5%, ** significant at 1%

Days to maturity was positively and significantly correlated with total tuber number per hill (rp =0.331), dry matter content percentage (rp =0.262) at phenotypic level and it was also positively correlated with total tuber number per hill (rg =0.412) at genotypic level. A positive and non-significant correlation between maturity day and dry mater content was described by Nimona 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 per hill (rp =-0.543 and rg =-0.581)), total tuber number per hill (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. Nimona 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).

## Path coefficient analysis

### 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 per hill (0.034), marketable tuber number per hill (3.652), unmarketable tuber per hill (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 per hectare. 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 per hill (-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 per hectare. 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 per hill followed by un marketable tuber number per hill and average tuber weight while lowest recorded from days to attain 50% flowering and average stem number per hill. The maximum negative direct effect exerted on total tuber yield was total tuber number per hill 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 A and Singh D [27] Rangare SB and Rangare NR, Panigrahi KK [28]. A positive and direct effect of tuber numbers per plant on total tuber yield has also been reported by various studies [29]. Tuber number imparted the maximum positive direct effect (2.10) on tuber yield plant-1 reported by Tripura et al., 2016. According to Nimona et al. (2022) report stem number per plant was positively affect 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

**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 | TTN | DMC | SG | STA | TSS | LB | ATW | UTY | rp |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DE | **-0.0012** | 0.0232 | 0.0107 | -0.0034 | -0.0022 | 0.0087 | 0.4082 | -0.2579 | -0.0648 | -0.0012 | 0.0015 | 0.0026 | -0.0028 | 0.0061 | -0.045 | -0.0175 | 0.0651 |
| DF | -0.0009 | **0.0307** | 0.0189 | -0.0006 | -0.0033 | 0.003 | 0.5655 | -0.0466 | -0.3933 | -0.0026 | 0.0006 | -0.0052 | -0.0025 | 0.028 | 0.0209 | 0.0012 | 0.2138 |
| DM | -0.0002 | 0.0085 | **0.0678** | -0.0071 | 0.0022 | -0.0008 | 1.3138 | -0.0829 | -0.9384 | -0.0055 | -0.0026 | -0.0108 | -0.0032 | 0.1146 | 0.2216 | -0.0116 | 0.6654** |
| PH | -0.0002 | 0.0008 | 0.0192 | **-0.025** | 0.0067 | -0.0012 | 0.9551 | -0.0661 | -0.6764 | -0.0005 | -0.0014 | 0.0072 | -0.0026 | 0.078 | 0.0638 | -0.0048 | 0.3525** |
| SN | 0.0001 | -0.003 | 0.0043 | -0.0049 | **0.0342** | 0.0005 | 1.9599 | 0.0396 | -1.5594 | -0.0003 | -0.0103 | 0.0104 | -0.0003 | 0.0399 | -0.1871 | -0.0016 | 0.3220** |
| LAI | 0.0002 | -0.0016 | 0.0009 | -0.0005 | -0.0003 | **-0.0589** | 0.2456 | -0.1626 | -0.0317 | 0.0005 | 0.0134 | -0.0263 | 0.0001 | 0.0078 | 0.0144 | -0.0105 | -0.0096 |
| MTN | -0.0001 | 0.0047 | 0.0244 | -0.0065 | 0.0183 | -0.004 | **3.6518** | -0.238 | -2.601 | -0.0028 | -0.0079 | 0.0032 | -0.003 | 0.0938 | -0.2111 | -0.0221 | 0.7000** |
| UTN | 0.0003 | -0.0012 | -0.0048 | 0.0014 | 0.0012 | 0.0082 | -0.7395 | **1.1751** | -0.5742 | 0.0041 | -0.005 | -0.0006 | 0.0015 | 0.0225 | 0.1132 | 0.0846 | 0.0867 |
| TTN | 0 | 0.0043 | 0.0224 | -0.006 | 0.0188 | -0.0007 | 3.3521 | 0.2381 | **-2.8335** | -0.0011 | -0.0099 | 0.003 | -0.0024 | 0.1029 | -0.1652 | 0.0122 | 0.7351** |
| DMC | -0.0001 | 0.0038 | 0.0178 | -0.0006 | 0.0005 | 0.0014 | 0.4816 | -0.2288 | -0.1501 | **-0.0211** | -0.0182 | 0.0323 | -0.0018 | 0.0417 | 0.1175 | -0.0124 | 0.2634* |
| SG | 0 | -0.0003 | 0.0025 | -0.0005 | 0.0051 | 0.0115 | 0.4173 | 0.0851 | -0.4069 | -0.0056 | **-0.0691** | 0.0956 | -0.0016 | 0.0235 | 0.0165 | 0.0002 | 0.1733 |
| STA | 0 | -0.0015 | -0.0068 | -0.0017 | 0.0033 | 0.0144 | 0.1098 | -0.0063 | -0.0791 | -0.0063 | -0.0613 | **0.1076** | -0.0017 | 0.0152 | -0.0234 | -0.0039 | 0.0584 |
| TSS | -0.0003 | 0.0064 | 0.0179 | -0.0054 | 0.0007 | 0.0003 | 0.9056 | -0.1451 | -0.5609 | -0.0031 | -0.0094 | 0.015 | -0.0121 | 0.0311 | -0.069 | -0.0137 | 0.1581 |
| LB | 0 | -0.005 | -0.045 | 0.0113 | -0.0079 | 0.0027 | -1.9833 | -0.1528 | 1.6881 | 0.0051 | 0.0094 | -0.0095 | 0.0022 | **-0.1728** | -0.2088 | -0.0121 | -0.8783** |
| ATW | 0.0001 | 0.0011 | 0.0269 | -0.0029 | -0.0115 | -0.0015 | -1.381 | 0.2383 | 0.8387 | -0.0044 | -0.002 | -0.0045 | 0.0015 | 0.0646 | **0.5582** | 0.0189 | 0.3405** |
| UTY | 0.0002 | 0.0004 | -0.0084 | 0.0013 | -0.0006 | 0.0066 | -0.8614 | 1.0612 | -0.3684 | 0.0028 | -0.0002 | -0.0044 | 0.0018 | 0.0223 | 0.1124 | **0.0937** | 0.0593 |

**R= 0.19**

**Note: 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 per hill, **LAI**: leaf area index, **MTN:** marketable tuber number per hill/ plant, **UTN:** un marketable tuber number per hill/plant, **TTN:** total tuber number per hill/plant, **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/100g), **TSS:** total soluble solid (0 brix), **LB:** late blight severity percentage (%),* significant at 5%, ** significant at 1%

**Citation:** Zeleke AA, Abebe TD Getahun BB (2024) Association and Path Coefficient Analysis Studies in Potato (*Solanum tuberosum* L.) Genotypes at Adet, Northwestern Ethiopia. J Plant Genet Breed 8: 216.



on total tuber yield was reported by Sattar MA, Majid K, Verma A and Singh, D. Sattar MA 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 per hectare through marketable tuber number per hill, average tuber weight and late blight severity percentage and it also exerted negative indirect effect on total tuber yield viz total tuber number per hill. Average stem number per hill exhibit positive indirect effect on total tuber yield through marketable tuber number per hill and it was also having negative indirect effect viz total tuber number per hill and average tuber weight (Table 4).

Average tuber weight had negative indirect effect on total tuber yield per hectare through marketable tuber number per hill it also positive indirect effect on total tuber yield through total and unmarketable tuber number per hill. Late blight percentage had negative indirect on total tuber yield through marketable and un marketable number per hill and it also positively indirect effect on total tuber yield viz total tuber number per hill. In the present study days to days to maturity, stem number per hill, marketable tuber number per hill, 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 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 [30].

## 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 per hill (0.017), marketable tuber number per hill (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 per hectare. 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 per hill (-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 per hectare. These indicated that the direct effect on total tuber yield t ha$^{-1}$ is minimum. Marketable tuber number per hill was exerted maximum positive direct effect on total tuber yield followed un marketable tuber number per hill and average tuber weight while the lower positive direct effect was exerted by stem number per hill 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 per hill will reflect on increased total tuber yield. Similarly, Nimona 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 per hill and average tuber weight on total tuber yield were reported by Haydar A [31] and Rahman MH [32]. According to Rahman MH plant height, dry matter content percentage, specific gravity and total soluble sugar percentage showed direct negative effect on tuber yield. Negative direct

**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.

| Traits | DE | DF | DM | PH | SN | LAI | MTN | UTN | TTN | DMC | SG | STA | TSS | LB | ATW | UMY | rg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DE | **0.0179** | 0.017 | 0.008 | -0.0032 | -0.0011 | 0.0069 | 0.4468 | -0.2349 | -0.1036 | -0.0007 | 0.0001 | 0.0028 | -0.0142 | 0.0035 | -0.0637 | -0.0127 | 0.0688 |
| DF | 0.0145 | **0.0211** | 0.0135 | -0.0009 | -0.0009 | 0.0003 | 0.6667 | -0.0706 | -0.4193 | -0.0018 | -0.0004 | 0.0001 | -0.0126 | 0.0166 | 0.0161 | -0.0012 | 0.241 |
| DM | 0.0027 | 0.0054 | **0.053** | -0.0068 | 0.002 | -0.0027 | 1.4086 | -0.0755 | -0.9556 | -0.0037 | -0.0008 | -0.0063 | -0.0179 | 0.0682 | 0.2488 | -0.0093 | 0.7101** |
| PH | 0.0028 | 0.001 | 0.0174 | **-0.0206** | 0.0049 | 0.0018 | 0.8876 | -0.0587 | -0.5916 | -0.0011 | 0.0002 | 0.004 | -0.0086 | 0.0501 | 0.1238 | -0.0045 | 0.4084* |
| SN | -0.0012 | -0.0012 | 0.0063 | -0.0061 | **0.0165** | 0.003 | 1.9216 | 0.0363 | -1.4354 | 0.0028 | -0.0012 | 0.0027 | 0.0027 | 0.0323 | -0.1513 | -0.0039 | 0.4238* |
| LAI | -0.0026 | -0.0001 | 0.0031 | 0.0008 | -0.0011 | **-0.0468** | 0.1181 | -0.1929 | 0.0963 | -0.0002 | 0.0024 | -0.0262 | 0.0063 | 0.0038 | 0.0454 | -0.0079 | -0.0017 |
| MTN | 0.0025 | 0.0044 | 0.0233 | -0.0057 | 0.0099 | -0.0017 | **3.2028** | -0.1742 | -2.1705 | -0.0014 | -0.0008 | 0.0007 | -0.0129 | 0.058 | -0.1824 | -0.0151 | 0.7369** |
| UTN | -0.0047 | -0.0017 | -0.0045 | 0.0014 | 0.0007 | 0.0101 | -0.6269 | **0.8898** | -0.3846 | 0.0035 | 0.0002 | -0.0043 | 0.0125 | 0.0164 | 0.1716 | 0.0528 | 0.1322 |
| TTN | 0.0008 | 0.0038 | 0.0218 | -0.0053 | 0.0102 | 0.0019 | 2.9937 | 0.1474 | **-2.3221** | -0.0001 | -0.0007 | -0.0009 | -0.0084 | 0.0643 | -0.1213 | 0.0039 | 0.7890** |
| DMC | 0.0011 | 0.0032 | 0.0159 | -0.0019 | -0.0038 | -0.0009 | 0.3693 | -0.2554 | -0.0277 | **-0.0121** | -0.002 | 0.0195 | -0.0156 | 0.0286 | 0.1598 | -0.0128 | 0.2652 |
| SG | -0.0002 | 0.0011 | 0.0052 | 0.0004 | 0.0024 | 0.0138 | 0.3188 | -0.0242 | -0.2095 | -0.003 | **-0.0081** | 0.0696 | -0.0097 | 0.0198 | 0.0668 | -0.0047 | 0.2384 |
| STA | 0.0006 | 0 | -0.0043 | -0.001 | 0.0006 | 0.0157 | 0.0277 | -0.0493 | 0.0264 | -0.003 | -0.0072 | **0.0779** | -0.0079 | 0.0123 | -0.0011 | -0.0048 | 0.0827 |
| TSS | 0.0056 | 0.0058 | 0.0208 | -0.0039 | -0.001 | 0.0065 | 0.9019 | -0.2427 | -0.4281 | -0.0041 | -0.0017 | 0.0134 | **-0.0457** | 0.0213 | 0.0319 | -0.0182 | 0.2617 |
| LB | -0.0006 | -0.0035 | -0.0362 | 0.0104 | -0.0053 | 0.0018 | -1.8611 | -0.1459 | 1.4949 | 0.0035 | 0.0016 | -0.0096 | 0.0097 | **-0.0999** | -0.2536 | -0.0087 | -0.9026** |
| ATW | -0.002 | 0.0006 | 0.0231 | -0.0045 | -0.0044 | -0.0037 | -1.0255 | 0.268 | 0.4942 | -0.0034 | -0.0009 | -0.0001 | -0.0026 | 0.0445 | **0.5697** | 0.019 | 0.3720* |
| UMY | -0.0039 | -0.0004 | -0.0085 | 0.0016 | -0.0011 | 0.0064 | -0.8363 | 0.8114 | -0.1577 | 0.0027 | 0.0007 | -0.0065 | 0.0144 | 0.0151 | 0.1866 | **0.0579** | 0.0822 |

**R=0.12**

**Note: 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 per hill, **LAI:** leaf area index, **MTN:** marketable tuber number per hill/ plant, **UTN:** un marketable tuber number per hill/plant, **TTN:** total tuber number per hill/plant, **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/100g), **TSS:** total soluble solid (0 brix), **LB:** late blight severity percentage (%),* significant at 5%, ** significant at 1%

effect of plant height on total tuber yield has been reported by Ara T.

Days to maturity and stem number per hill, had a high positive indirect effect on total tuber yield through marketable tuber number per hill and negative indirect effect on total yield viz total tuber number per hill. Average tuber weight and late blight severity percentage had high negative indirect effect on total tuber yield through marketable tuber number per hill and positive indirect effect on total tuber yield viz total tuber number per hill. In the present study days to maturity, stem number per hill, marketable tuber number per hill, 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 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 [34].

## Conclusions

The research result indicated the presence of wide variations among potato genotypes for tuber yield and yield related traits. Genotype CIP-308522.501, CIP-308526.502, CIP-308517.500, CIP-308500.01 and CIP-308626.501 gave higher total tuber yield t $ha^{-1}$ and less late blight severity percentage than the released potato varieties. Total tuber yield (t $ha^{-1}$) was positively and significantly correlated with days to maturity, plant height, stem number per hill, marketable and total tuber number per hill, average tuber weight and marketable tuber yield while it was negatively correlated with late blight severity percentage at both phenotypic and genotypic level. Days to 50% flowering, days to maturity, stem number per hill, total tuber number per hill, starch content percentage, and average tuber weight, had a positive and direct effect on the total tuber yield (t $ha^{-1}$) at both genotypic and phenotypic level. Therefore, traits positive significant correlation and direct effect should be considered in selection criteria for enhancing tuber yield.

## Declaration

### Author contribution statement

**Awoke Ali**, MSc. Horticultural crop researcher in Ethiopian Institute of Agricultural Research, proposed and designed the experiment, recorded the data, analyzed the row data, interpreted the results and wrote the paper.

**Tiegist Dejene**, PhD an Associate Professor, lecture and senior researcher of plant breeding and genetics in College of Agriculture and Environmental Science, Bahir Dar University, Ethiopia. She advised me from proposal preparation to the final research result and interpretation, give comments and reviewing the manuscript.

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The final manuscript was read and approved by each authors for publication.

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The data used and analyzed for this study can be made available from the corresponding author on reasonable request

### Declaration of interest's statement

The authors declare that they have no conflict of interest

### Additional information

No additional information is available for this paper

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