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**Research Article**

# Correlation coefficients, path analysis and disease reaction between yield and yield components in Potato (*Solanum tuberosum* L.) genotypes in Bale, South Eastern Ethiopia

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**Abstract**

Study on the relationships between yield and its components will improve the efficiency of breeding programmes by determining appropriate selection criteria. An investigation was carried out on 24 potato genotypes to find out the association among yield, yield components and their direct and indirect effects on tuber yield of potato. The experiment was laid out in randomized complete block design with three replications at Sinana Agricultural Research Center. The association was analyzed by correlation coefficient, and further subjected to path analysis to estimate direct and indirect effects of each character on tuber yield. Positive and significant genotypic and phenotypic correlation were found between total tuber yield and marketable tuber yield (rg=0.99), leaf area index ($r_g$=0.82), plant height($r_g$=0.56), stem number per plant($r_g$=0.56), average tuber weight ($r_g$=0.74) and biomass yield ($r_g$=0.69). Path analysis of tuber yield and its components shows that marketable tuber yield and average tuber weight had maximum positive direct genotypic and phenotypic effect on total tuber yield indicating their importance in selection for tuber yield improvement.

*Keywords*

Correlation; Path coefficient analysis; Disease progress curve; Percent severity; potato

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## Introduction

Potato is a very important food and cash crop especially on the highland and mid altitude areas of Ethiopia (Gebremedhin *et al.*, 2008). Potato cropping systems help to improve resilience especially among smallholder farmers by providing direct access to nutritious food, increasing household incomes and reducing their vulnerability to food price volatility (Andre *et al.*, 2014 and FAO, 2014). Character association studies provide reliable information on the nature, extent and directions of selection (Kumar and Chauchan, 1979). Studies on genotypic and phenotypic correlations among characters of crop plants are useful in planning, evaluating and setting selection criteria for the desired characters in breeding program (Johnson *et al.*, 1955). Correlations between different characters of crop plants may arise either from genotypic or environmental factors. Characters that are not easily measured or which are largely influenced by the environment has low heritability ratio hence, there is a need to examine the relationships among various characters (Burhan, 2007). Accordingly, this experiment was carried out on 24 potato genotypes to investigate the association among yield, yield components and their direct and indirect effects on tuber yield of potato.

## Materials and Methods

### *Description of the Study Areas*

This experiment was conducted in Southeastern Ethiopia, Bale Zone, at Sinana Agricultural Research Center. Sinana is located at $07^0$ N and $40^0$ $10'$ E at an altitude of 2400 (m.a.s.l.) Average annual maximum and minimum temperatures are 21 and 9°C, respectively.

### *Experimental Procedures*

A total of 24 potato genotypes which consisted of 20 advanced clones, three released varieties as standard checks and one farmer's cultivar kellecho (Table 1) were planted on 12 August, 2014 during the "Bona" cropping season. The experiment was arranged in randomized complete block design (RCBD) with three replications. The spacing between rows and plants was 0.75 m and 0.30 m, respectively while the spacing between plots and adjacent replications was 1m and 1.5m.

### *Data Collection*

The middle rows were used for data collection. Data were collected on growth parameters, tuber yields and yield components. Percent severity index and area under disease progress curve was calculated from disease severity collected weekly.

## Results and Discussion

### *Correlation Coefficient*

Genotypic correlation coefficient values ranged as low as $r_g$= -0.09 between total tuber yield and unmarketable tuber number per hill and as high as $r_g$=0.99 between total tuber yield and marketable tuber yield. Positive and significant genotypic correlations in the range between $r_g$ =0.43 and $r_g$ = 0.99 was observed between total tuber yield per hectare and marketable tuber yield, leaf area index, plant height, stem number per plant, average tuber weight, biomass yield and marketable tuber number per hill (Table 2). Hence, improvement of total tuber yield in Potato is possible through selection of genotypes that performing best than others for those strongly correlated traits. This showed that total tuber yield per hectare is the end product of components of several yield contributing characters. Jaime *et al.* (2014) reported significant association between tuber yield and stem number per plant, tuber dry matter content, average tuber weight and biomass yield. This is in agreement with the results obtained in earlier studies (Berga and Caesar, 1990).

Negative and significant genotypic correlations was recorded between total tuber yield and percent severity index ($r_g$= -0.8) and area under disease progress curve ($r_g$= -0.6). This indicated that selection of genotypes with low disease severity increased the total tuber yield and selection should be against the high disease infection as a breeding strategy. Hamed *et al.* (2011) reported the presence of negative genotypic correlations between total tuber yield and small size tuber per plant. Similar results were reported by Fekede (2011) who indicated negative association of tuber yield with percent severity index and area under disease progress curve.

The association of most of the traits with total tuber yield at phenotypic level exhibited similar trend with genotypic association except the correlation coefficient value differences which ranged from $r_p$= -0.07 (between total tuber yield and unmarketable tuber number per hill) to $r_p$=0.98 (between total tuber yield and marketable tuber yield) as well as negative and significant phenotypic association was recorded between total tuber yield and percent severity index and area under disease progress curve.

### *Path Coefficient Analysis*

Marketable tuber yield, average tuber weight, stem number per plant, harvest index, leaf area index, marketable tuber number per hill and biomass yield had positive direct effect at genotypic and phenotypic level on total tuber yield (Table 3 and 4). This suggested that these characters are good contributors to increase tuber yield and selection of genotypes with highest values for these traits leads to the increment of tuber yield. Hossain *et al.* (2000) reported positive direct genotypic effects of tuber yield per plant, average tuber weight and harvest index on total tuber yield. This is in line with Abraham *et al.* (2014) who too indicated stem number per plant, plant height and average tuber weight had positive direct effect on tuber yield. Hence, these traits will be given due consideration during selection.

On the other hand, unmarketable tuber yield, unmarketable tuber number per hill, percent severity index and area under disease progress curve exerted negative direct genotypic and phenotypic effect on tuber yield. This suggested that selection is better to be directed genotypes with low mean values for these traits since selection in favor of genotypes with high mean values will lead to the reduction of tuber yield. Majid *et al.* (2011) reported the direct genotypic but negative effect of small tuber per plant and plant height on tuber yield.

The path coefficient analysis indicated that the various characters influenced the tuber yield favorably or unfavorably *via* other characters.



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**Table 1. List of potato genotypes used in the study**

| No. | Acc. code | No. | Acc. code | No. | Acc. code | No. | Acc. code |
|---|---|---|---|---|---|---|---|
| 1 | CIP-395096.2 | 7 | CIP-396244.12 | 13 | CIP-391930.1 | 19 | CIP-395077.12 |
| 2 | CIP-392640.524 | 8 | CIP-395114.5 | 14 | CIP-391381.9 | 20 | CIP-399053.15 |
| 3 | CIP-396031.201 | 9 | CIP-396029.205 | 15 | CIP-395112.19 | 21 | Ararsa(CIP-90138.12) |
| 4 | CIP-397079.26 | 10 | CIP-399062.102 | 16 | CIP-393382.44 | 22 | Belete(CIP-393371.58) |
| 5 | CIP-395017.242 | 11 | CIP-395017.229 | 17 | CIP-391058.175 | 23 | Guddane(CIP386423.13) |
| 6 | CIP-399078.11 | 12 | CIP-396240.23 | 18 | CIP-396039.103 | 24 | Kellacho(local) |

**Note:** The source of all genotypes except the local cultivar "Kellacho" was CIP

**Table 2. Genotypic (above diagonal) and phenotypic (below diagonal) correlations of 13 characters in 24 potato genotypes studied at Sinana, in 2014 cropping season**

| | PH | SN | LAI | BMY | MTN | unMTN | ATW | HI | MTY | unMTY | PSI | AUDP | TTY |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | **1** | 0.31 | 0.5* | 0.51* | 0.51* | 0.04 | 0.5* | -0.07 | 0.54* | 0.02 | -0.35 | -0.18 | 0.56* |
| SN | 0.18 | **1** | 0.4* | 0.26 | 0.59* | -0.4* | 0.22 | -0.06 | 0.54* | 0.31 | -0.29 | -0.06 | 0.56* |
| LAI | 0.49** | 0.31 | **1** | 0.68* | 0.73** | -0.29 | 0.63* | 0.11 | 0.85** | -0.41* | -0.8** | -0.73** | 0.82** |
| BMY | 0.36* | 0.15 | 0.41* | **1** | 0.69* | -0.12 | 0.48* | -0.16 | 0.72** | -0.31 | -0.61* | -0.59* | 0.69* |
| MTN | 0.44** | 0.55** | 0.67** | 0.44** | **1** | -0.06 | 0.58* | 0.19 | 0.90** | -0.3 | -0.68** | -0.48** | 0.88** |
| unMTN | 0.03 | 0.38* | -0.24 | -0.10 | 0.00 | **1** | -0.47** | -0.29 | -0.15 | 0.83** | 0.25 | 0.48* | -0.1 |
| ATW | 0.44** | 0.16 | 0.58** | 0.25 | 0.54** | -0.42* | **1** | 0.11 | 0.72** | -0.41* | -0.64* | -0.51* | 0.74** |
| HI | -0.02 | 0.00 | 0.17 | -0.16 | 0.23 | -0.19 | 0.18 | **1** | 0.11 | -0.51* | -0.18 | -0.15 | 0.11 |
| MTY | 0.48** | 0.41* | 0.68** | 0.52** | 0.80** | -0.13 | 0.65** | 0.07 | **1** | -0.31 | -0.84** | -0.61* | 0.99** |
| unMTY | 0.01 | 0.26 | -0.37* | -0.24 | -0.24 | 0.76** | -0.39 | -0.31 | -0.23 | **1** | 0.35 | 0.56* | -0.21 |
| PSI | -0.28 | -0.26 | -0.7** | -0.37* | -0.6** | 0.18 | -0.6** | -0.15 | -0.73** | 0.33* | **1** | 0.81** | -0.8** |
| AUDPC | -0.16 | -0.02 | -0.65** | -0.44** | -0.43** | 0.43** | -0.46** | -0.13 | -0.57** | 0.55** | 0.76** | **1** | -0.6* |
| TTY | 0.49** | 0.42* | 0.63** | 0.49** | 0.77** | -0.07 | 0.63** | 0.05 | 0.98** | -0.16 | -0.67** | -0.52** | **1** |

*, and **, significant at $P \leq 0.05$ and $P \leq 0.01$ respectively. PH=plant height, SN = stem number per hill, LAI = leaf area index, BMY=biomass yield, MTN = marketable tuber number per hill, ATW = average tuber weight, HI = harvest index, MTY = marketable tuber yield, unMTY = unmarketable tuber yield, PSI=percent severity index, AUDPC=area under disease progress curve, TTY=total tuber yield.

Growth parameters *viz*. plant height, stem number per plant, leaf area index and biomass yield exerted positive indirect genotypic and phenotypic effect *via* average tuber weight and marketable tuber yield.

Similarly, yield components namely marketable tuber number, average tuber weight and harvest index besides exerting positive direct effect on total tuber yield also showed favorable indirect influence on total tuber yield through leaf area index and marketable tuber yield. Sattar *et al*. (2007) suggested that plant height, biomass yield and stem number per plant had high positive indirect effect on tuber yield. Hence, these characters are more important than other traits for the genetic improvement of potato.

In other case, most of the growth parameters and yield components exerted negative genotypic and phenotypic indirect effect *via*, unmarketable tuber number per hill, unmarketable tuber yield and both disease parameters *viz*. percent severity index and area under diseases progress curves

In conclusion, this result suggested the importance of considering marketable tuber yield, average tuber weight, marketable tuber number, biomass yield and leaf area index in selection of genotypes for high tuber yield because of their strong correlation to yield and had positive direct or indirect effect on tuber yield. However, selection of genotypes for the lower mean values for unmarketable tuber yield and tuber number per hill, percent severity index and area under disease progress curve is necessary since these traits had highly negative and significant correlation to yield as well as they exerted strong negative direct or indirect effect on tuber yield.

**Table 3. Genotypic direct (underlined) and indirect effect of 12 characters on potato tuber yield at Sinana, 2014 cropping season**

| Variable | PH | SN | LAI | BMY | MTN | unMTN | ATW | HI | MTY | unMTY | PSI | AUDPC | rg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | **-0.01** | -0.01 | 0.01 | -0.02 | 0 | 0 | 0.09 | 0 | 0.53 | 0 | -0.02 | 0.02 | 0.56* |
| SN | 0 | **0.4** | 0 | 0.01 | 0 | -0.06 | 0.04 | 0 | 0.53 | -0.07 | -0.09 | -0.19 | 0.56* |
| LAI | -0.01 | -0.02 | **0.09** | -0.02 | 0.03 | -0.03 | 0.11 | 0 | 0.82 | -0.04 | -0.05 | -0.07 | 0.83** |
| BMY | -0.01 | 0.01 | 0.01 | **0.3** | 0 | -0.07 | 0.08 | -0.01 | 0.7 | -0.04 | -0.05 | -0.16 | 0.70** |
| MTN | -0.01 | -0.03 | 0.01 | -0.02 | **0.05** | -0.04 | 0.1 | 0.01 | 0.88 | -0.02 | -0.03 | -0.05 | 0.89** |
| unMTN | 0 | -0.02 | 0 | 0 | 0 | **-0.06** | -0.08 | -0.01 | -0.15 | 0.08 | 0.02 | 0.05 | -0.1 |
| ATW | -0.01 | -0.01 | 0.01 | -0.01 | 0 | -0.05 | **0.17** | 0 | 0.71 | -0.04 | -0.04 | 0.05 | 0.75** |
| HI | 0 | 0 | 0 | 0.01 | 0 | -0.03 | 0.02 | **0.04** | 0.11 | -0.05 | -0.01 | 0.02 | 0.1 |
| MTY | -0.01 | 0.02 | 0.01 | 0.02 | 0.01 | -0.01 | 0.13 | 0 | **0.91** | -0.03 | -0.05 | -0.02 | 0.99** |
| unMTY | 0 | -0.01 | 0 | 0.01 | 0 | 0.08 | -0.06 | -0.02 | -0.26 | **-0.07** | 0.02 | 0.06 | -0.2 |
| PSI | 0.03 | 0.01 | -0.01 | -0.02 | 0 | 0.02 | -0.11 | -0.01 | -0.72 | 0.03 | **-0.17** | 0.08 | -0.83** |
| AUDPC | -0.1 | -0.01 | -0.03 | 0.02 | 0 | 0.05 | -0.09 | -0.01 | -0.6 | 0.04 | 0.08 | **-0.19** | -0.84** |

PH=plant height, SNP= stem number per hill, LAI = leaf area index, BMY=biomass yield, MTNPH = marketable tuber number per hill, unMTN = unmarketable tuber number per hill, ATW = average tuber weight, HI = harvest index, MTY = marketable tuber yield, unMTY = unmarketable tuber yield, PSI=percent severity index, AUDPC=area under disease progress curve.

**Table 4. Phenotypic direct (underlined) and indirect effect of 12 characters on potato tuber yield at Sinana, 2014 cropping season**

| Variable | PH | SN | LAI | BMY | MTN | unMTN | ATW | HI | MTY | unMTY | PSI | AUDPC | $r_p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | **0.02** | 0.01 | -0.02 | 0.01 | -0.03 | -0.02 | 0.02 | 0 | 0.53 | 0 | -0.03 | -0.01 | 0.49** |
| SN | 0.01 | **0.02** | -0.01 | 0 | -0.04 | 0.02 | 0.01 | 0 | 0.45 | 0.01 | -0.03 | -0.02 | 0.42* |
| LAI | 0.01 | 0.01 | **0.05** | 0 | -0.04 | -0.01 | -0.02 | 0 | 0.75 | -0.01 | -0.09 | -0.02 | 0.63** |
| BMY | -0.01 | 0 | -0.01 | **0.08** | -0.03 | -0.01 | 0.01 | 0 | 0.57 | -0.01 | -0.04 | -0.06 | 0.49** |
| MTN | 0.01 | 0.01 | -0.02 | 0 | **0.03** | 0 | 0.02 | 0.01 | 0.89 | -0.01 | -0.08 | -0.07 | 0.77** |
| unMTN | 0 | -0.01 | -0.01 | 0 | -0.02 | **-0.03** | -0.02 | 0 | 0.14 | 0.03 | 0.02 | 0.03 | -0.07 |
| ATW | 0.01 | 0 | -0.02 | 0 | -0.04 | -0.02 | **0.04** | 0 | 0.72 | -0.01 | -0.07 | 0.03 | 0.63** |
| HI | 0 | 0 | -0.01 | 0 | -0.02 | -0.01 | 0.01 | **0.02** | 0.08 | -0.01 | -0.02 | 0.01 | 0.05 |
| MTY | 0.01 | 0.01 | -0.02 | 0 | -0.05 | -0.01 | 0.03 | 0 | **1.1** | -0.01 | -0.09 | -0.07 | 0.98** |
| unMTY | 0 | 0 | 0.01 | 0 | 0.02 | 0.04 | -0.02 | 0.01 | -0.26 | **-0.03** | 0.04 | -0.04 | -0.16 |
| PSI | -0.01 | 0 | 0.03 | 0 | 0.04 | 0.01 | -0.02 | 0 | -0.8 | 0.01 | **-0.05** | -0.05 | -0.67* |
| AUDPC | 0 | 0 | 0.02 | 0 | 0.03 | 0.02 | -0.02 | 0 | -0.63 | 0.02 | 0.09 | **-0.07** | -0.52* |

PH=plant height, SNP= stem number per hill, LAI = leaf area index, BMY=biomass yield, MTNPH = marketable tuber number per hill, unMTN = unmarketable tuber number per hill, ATW = average tuber weight, HI = harvest index, MTY = marketable tuber yield, unMTY = unmarketable tuber yield, PSI=percent severity index, AUDPC=area under disease progress curve for both genotypic and phenotypic.

## Competing Interest

The authors declare that they have no competing interests.

## Authors' contributions

GA draft manuscript and carried out the experiment. WM coordinated the work and inter prated the results; both authors read and approved the final content of the manuscript. GA submitted the final manuscript through his user account.

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