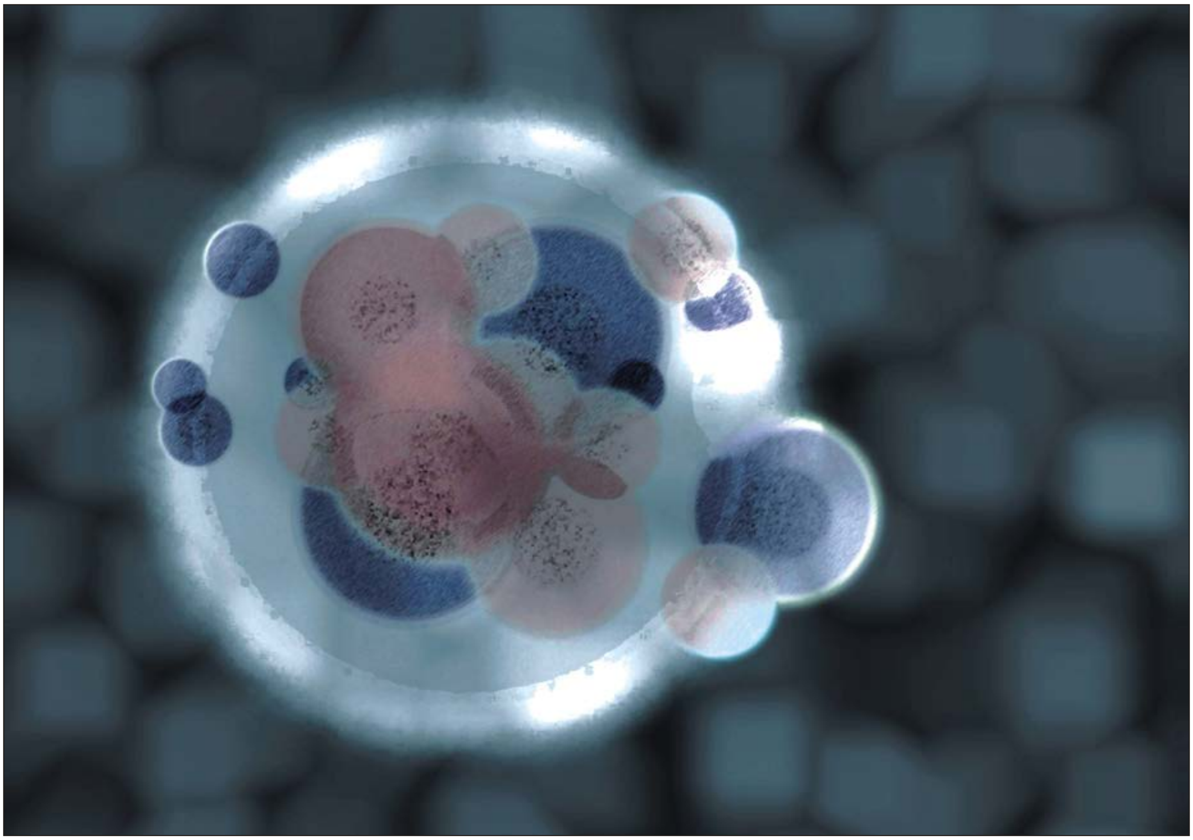

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Relationships Among Yield and Some Yield Characters in Potato (*S. tuberosum* L.)

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Abstract: This research was conducted to determine the relations among tuber yield and some traits of potato using correlations and path coefficient analysis. The experimental design was a Randomized Complete Block Design with three replications in 1999-2000 growing season in Van (Gevaş), Turkey. Simple correlation analysis and path analysis were applied to the means of fourteen potato genotypes in order to determine the relationships between agronomic characters and estimate the direct and indirect effects of some traits on tuber yield. Strong positive and significant correlations were found between tuber yield and plant height (r = 0.745), main stems/plant (r = 0.846), tubers/plant (r = 0.824), average tuber weight (r = 0.936), tuber weight/plant (r = 0.956) and big tuber percentage (r = 0.568). A negative and significant correlation was determined among tuber yield and medium tubers percentage (r = -0.573). According to the path analysis, it can be also that tuber yield was identified by tuber weight/plant, average tuber weight and tubers/plant since these characters had highly positive significant direct effects on tuber yield (56.5, 18.8 and 15.5%, respectively).

Key words: Potatoes, tuber yield, yield traits, correlations, path analysis

INTRODUCTION

Potato is a member of the solanaceae family and it (*Solanum tuberosum*) is closely related to the eggplant, pepper and tomato. The potato (*Solanum tuberosum* L.) originated in the Andes Mountains of South America. Potato varieties were brought to Spain from the mountains of Colombia by Spanish explorers and were marketed there as early as 1576. Potatoes were introduced to Turkey from Russia in the last nineteenth century (Esendal, 1987).

Potatoes are the world's most important vegetable crops. In 2005, total production of potato was 323,102,918 tonnes in the world. The highest amount of production was in Russia with 74,589,388 tonnes; 73,036,500 tonnes in China; 25,000,000 tonnes in India; 19,090,750 tonnes in the USA, 11.624,000 tonnes in Germany and 11,009,392 tonnes in Poland. Also, the production of potato was 4,170,000 tonnes in Turkey (Anonymous, 2005). Therefore, advances in potato breeding may greatly contribute to the world's food supply.

Potato breeders are expected to produce improved cultivars that give high yields of high quality tubers. Genotypic and environmental factors have been affected the yield and quality of potato. For this reason, genetic variation among traits is important for breeding and in selecting desirable types. A wide variety of agronomic traits have been examined in potato germplasm collections for their possible use in the improvement of the productivity of potato cultivars. Expression of various traits is often changed as the changing breeding material and environment. Therefore, the information of character associations between the traits themselves and with the traits themselves and with the yield is important for the breeding material subjected to selection for high yielding genotypes. Considerable emphasis has been given placed upon the inter relationships between yield and yield components in potato. Correlation coefficient analysis measures the magnitude of relationship between various plant characters and determines the component character on which selection can be based for improvement in potato tuber yield. However, path coefficient analysis helps to determine the direct effect of traits and their indirect effects on other traits (Iqbal *et al*., 2006; Yücel *et al*., 2006).

Average tuber weight, tubers/plant, stems/plant, tuber weight/plant and big tuber percentage are the most important components in potato improvement for increasing tuber yield (Islam *et al*., 2002; Aytaç and Esendal, 1996; Maris 1988; Gopal *et al*., 1994; Günel *et al*., 1991; Kara *et al*., 1986; Karadoğan and Günel, 1992) because of direct and indirect correlation with tuber yield (Hossain *et al*., 2000; Yıldırım *et al*., 1997).

The aim of this research to evaluate tuber yield components and their interrelationships by path analysis.

MATERIALS AND METHODS

This study was conducted under irrigation conditions in 1999 and 2000 years and arranged a randomized complete blocks design with three replications in Van (Gevaş), Turkey. The soil of the experimental area was sandy-clay-loam, pH was 7.7, low in organic matter (1.0%), poor in available nitrogen (0.075 mg L^{-1}) and phosphorus content (2.85 kg day^{-1}), rich in potassium and lime contents (55.2 kg day^{-1} and 14%, respectively) and at least in salt content (0.078%). The total rainfall was 409.30 mm and 302.6 mm in the experimental years, compared with the long-term (1965-1995) mean of 452.5 mm. The monthly average temperature (first year 8.9°C and second year 9.1°C) and relative humidity (first year 54.1% and second year 53.4%) means were similar to the long-term average (8.2°C; 65.2%).

Fourteen potato genotypes was used. Each cultivars was sown with 60×30 cm row spacing in 4 rows, 5 m in length in the middle of May in the experiment years. The plot size for each cultivar was 12 m^{-2}. Nitrogenous fertilizer (ammonium sulfate 21% and 150 kg ha^{-1}) and phosphorus fertilizer (triple super phosphate 42% and 100 kg ha^{-1}) were applied before sowing and all standard agronomic practices were applied. Samples were obtained in the second week of October during both the years. Agronomic characters were determined on ten plants randomly selected in the mid-rows all of plots. Tuber yield (kg ha^{-1}), plant height (cm), main stems/plant, tubers/plant, average tuber weight (g), plant tuber weight (kg), dry matter content (%), starch content (%), small tuber (25-35 mm) percentage (%), medium tuber (35-55 mm) percentage (%), big tuber (>55 mm) percentage (%) were determined. The collected data was analyzed through computer TARIST statistical package. In order to determine the relationships between seed yield and the other examined characters simple correlation coefficients were calculated. The path coefficients were separated by using tuber yield as a dependent variable (Wright, 1960).

RESULTS AND DISCUSSION

Means of tuber yield varied between 8500.0 and 22000.0 kg ha^{-1}. Plant height ranged from 35.0 to 68.0 cm. The average tuber weight was between 35.0 to 112.0 g, whereas tuber weight/plant was between 195.0 to 495.0 g. The main stems/plant, tubers/plant, dry matter content, starch content, small tuber percentage, medium tuber percentage and big tuber percentage were between 2.4 and 4.5%, 5.7 and 7.8%, 15.8 and 21.6%, 10.4 and 15.8%, 10.1 and 25.5%, 22.1 and 28.7%, 25.6 and 65.3%, respectively (Table 1). In addition to, the lowest CV was determined for tubers/plant as 7.1%, the highest CV was determined for the medium tuber percentage (27.7%). Similar research results with our study were published by others (Aytaç and Esendal, 1996; Kara *et al*., 1986; Karadoğan and Günel, 1992).

Stronger positive and positive correlations were found between tuber yield and plant height (r = 0.745),

Table 1: Some statistical parameters of potatoes cultivars

Traits	Minimum	Maximum	Mean±SE	CV (%)
Plant height (cm)	35.0	68.0	48.20±1.33	17.9
Main stems/plant	2.4	4.5	3.30±0.08	16.2
Tubers/plant	5.7	7.8	6.60±0.07	7.1
Average tuber weight (g)	35.0	112.0	68.20±2.84	26.9
Tuber weight/plant (g)	195.0	495.0	311.90±12.71	26.4
Tuber yield (kg ha^{-1})	8500.0	22000.0	14620.40±600.28	26.7
Dry matter content (%)	15.8	21.6	18.60±0.22	7.9
Starch content (%)	10.4	15.8	12.90±0.21	10.4
Small tuber percentage	10.1	25.5	15.48±0.65	27.1
Medium tuber percentage	22.1	28.7	35.80±1.53	27.7
Big tuber percentage	25.6	65.3	49.60±1.58	20.7

main stems/plant (r = 0.846), tubers/plant (r = 0.824), average tuber weight (r = 0.936), tuber weight/plant (r = 0.956) and big tuber percentage (r = 0.568). These results showed that any positive increase in such characters will suffice the boast in tuber yield. These findings were in similar with the results of Çalışkan and Yıldırım (1987). On the other hand, negative and significant correlations were determined between tuber yield and medium tubers percentage (r = -0.573); medium tuber percentage and big tuber percentage (r = -0.919); plant height and medium tuber percentage (r = -0.572); main stems/plant and medium tuber percentage (r = -0.578); tubers/plant and medium tuber percentage (r = -0.358); average tuber weight and medium tuber percentage (r = -0.482); tuber weight/plant and medium tuber percentage (r = -0.474) (Table 2). Yıldırım *et al.* (1995) found the similar results for plant height, main stems/plant, average tuber weight, tuber weight/plant and tuber yield. Galarreta *et al.* (2006) determined that a significant correlation between tuber yield with tuber number and tuber weight. Ilisulu (1986) and Er (1984) stated that tubers/plant and tuber yield were increased when used big tubers in sowing. Günel *et al.* (1991) determined that highly positive and significant correlations between tuber yield with big tubers percentage and vegetation period. Yıldırım *et al.* (1997) observed that both yield components (tuber number and tuber weight) were associated with tuber yield, but they indicated that tuber numbers were important than average tuber weight. These results are in agreement with our findings.

Starch content associates with dry matter content. For this reason, the highest positive correlation was determined among dry matter content and starch content (r = 0.999). Plant height exhibited significant and positive correlations with main stems/plant (r = 0.579), tuber numbers (r = 0.642), average tuber weight (r = 0.731), tuber weight/plant (r = 0.715), big tuber tuber weight/plant (r = 0.809). Aytaç and Esendal (1996) reported that tuber yield exhibited positive and significant correlations with average tuber weight, tubers/plant, big tuber percentage,

Table 2: Correlation coefficients among eleven traits of potato

Traits[2]	TY	PH	MS	TN	ATW	PTW	DMC	SC	STP	MTP	BTP
TY	1.000	0.745**	0.846**	0.824**	0.936**	0.956**	0.301ns	0.294ns	0.184ns	-0.573**	0.568**
PH		1.000	0.576**	0.642**	0.731**	0.715**	0.106ns	0.095ns	0.041ns	-0.572**	0.568**
MS			1.000	0.772**	0.854**	0.826**	0.203ns	0.197ns	0.124ns	-0.578**	0.566**
TN				1.000	0.809**	0.809**	0.219ns	0.214ns	-0.027ns	-0.358*	0.382*
ATW					1.000	0.939**	0.366*	0.360*	0.164ns	-0.482**	0.481**
PTW						1.000	0.382*	0.375*	0.107ns	-0.474**	0.493**
DMC							1.000	0.999**	0.154ns	-0.010ns	0.009s
SC								1.000	0.143ns	-0.006ns	0.004ns
STP									1.000	-0.239ns	0.023ns
MTP										1.000	-0.919**
BTP											1.000

ns: Not significant, *: Significant at alpha level, 5%, **: Significant at alpha level, 1%; TY: Tuber yield (kg ha^{-1}), PH: Plant Height (cm); MS: Main Stems/plant; TN: Tuber No./plant; ATW: Average Tuber Weight (g); PTW: Plant Tuber Weight (kg); DMC: Dry Matter Content (%); SC: Starch Content (%); STP: Small Tuber (25-35 mm) Percentage (%); MTP: Medium Tuber (35-55 mm) Percentage (%); BTP: Big Tuber (>55 mm) Percentage (%)

Table 3: The direct and indirect effects of some traits on tuber yield in potato

Traits	Direct effect	PH	MS	TN	ATW	PTW	DMC	SC	STP	MTP	BTP	Corr.
PH	0.0172		-0.0052	0.0895	0.1436	0.4319	-0.0134	0.0078	0.0032	0.0451	0.0251	0.745*
	(2.2)		(0.7)	(11.4)	(18.4)	(55.2)	(1.7)	(1.0)	(0.4)	(5.7)	(3.2)	
MS	-0.0091	0.099		0.1077	0.1677	0.4989	-0.0258	0.0161	0.0098	0.0456	0.0250	0.846**
	(1.0)	(1.08)		(11.8)	(18.3)	(54.5)	(2.8)	(1.8)	(1.0)	(4.9)	(2.7)	
TN	0.1395	0.0110	-0.0070		0.1589	0.4885	-0.0278	0.0175	-0.0021	0.0282	0.0169	0.824**
	(15.5)	(1.2)	(0.8)		(17.8)	(54.4)	(3.1)	(1.9)	(0.2)	(3.1)	(1.9)	
ATW	0.1965	0.0125	-0.0078	0.1128		0.5672	-0.0465	0.0295	0.0129	0.0380	0.0213	0.936**
	(18.8)	(1.2)	(0.7)	(10.8)		(54.3)	(4.4)	(2.89)	(1.24)	(3.6)	(2.0)	
PTW	0.6040	0.0123	-0.0075	0.1128	0.1845		-0.0485	0.0307	0.0085	0.0374	0.0218	0.956**
	(56.5)	(1.1)	(0.7)	(10.6)	(17.3)		(4.5)	(2.9)	(0.8)	(3.5)	(2.0)	
DMC	-0.1270	0.0018	-0.0018	0.0305	0.0719	0.2308		0.0819	0.0121	0.0008	0.0004	0.301ns
SC	0.0819	0.0016	-0.0018	0.0298	0.0706	0.2264	-0.1269		0.0113	0.0005	0.0002	0.294ns
STP	0.0788	0.0007	-0.0011	-0.0038	0.0322	0.0649	-0.0195	0.0117		0.0188	0.0010	0.184ns
MTP	-0.0789	-0.0098	0.0053	-0.0499	-0.0946	-0.2861	0.0013	-0.0005	-0.0188		-0.0406	-0.573**
	(13.5)	(1.7)	(0.9)	(8.5)	(16.2)	(48.8)	(0.2)	(0.1)	(3.2)		(6.9)	
BTP	0.0442	0.0098	-0.0051	0.0534	0.0945	0.2980	-0.0012	0.0004	0.0018	0.0725		0.568*
	(7.6)	(1.7)	(0.9)	(9.2)	(16.3)	(51.3)	(0.2)	(0.1)	(0.3)	(12.5)		

*: Significant at alpha level; Values in parenthesis show percentage

but a significantly negative correlation with small tuber percentage. They also reported positive and significant correlations between average tuber weight and big tuber percentage; main stems/plant and vegetation period, but significant and negative correlations between average tuber weight and main stems/plant, average tuber weight and small tuber percentage, main stems/plant and big tuber percentage. Günel *et al.* (1991) reported that negative and significant correlations between small tuber percentage and tuber yield. Ilisulu (1986) and Er (1984) reported that positive and significant correlation between main stems/plant and small tuber percentage. These findings were in accordance with the results of present study except small tuber percentage.

In order to get a clear picture of the interrelationships between different traits, the direct and indirect effects of different characters were worked out using path coefficient analysis in respect of the yield (Singh *et al.*, 2004). The path coefficient analysis based on tuber yield as a dependent variable revealed that all traits, except main stems/plant, dry matter content and medium tuber percentage showed positive direct effects (Table 3). Compared to the simple correlation analysis, path analysis of tuber yield and its traits demonstrated that tuber weight/plant, average tuber weight and tubers/plants evolved the highest direct influence, 56.5, 18.8 and 15.5%, respectively. Conversely, main stems/plant had a negative and low direct effect (1.0%) with an indirect positive effect via tuber weight/plant (54.5%), average tuber weight (18.3%) and tubers/plant (11.8%) on tuber yield. In addition to, the indirect effects of plant height, tubers/plant, average tuber weight, medium tubers percentage and big tuber percentage through tuber weight/plant were stronger than its direct effects. These analyses showed that tuber weight/plant, average tuber weight, tubers/plant were the main characters for tuber yield. Hossain *et al.* (2000), Islam *et al.* (2002) and Yıldırım *et al.* (1997) stated that average tuber weight, tubers/plant, tuber weight/plant and plant height had positive and high direct effects on tuber weight/plant. Yıldırım *et al.* (1995) also reported that main stems/plant, plant height had positive and high direct effects on tuber yield. Maris (1988) found that tuber number and average tuber weight had equal effects on total yield. These findings were in accordance with the results of present study.

Correlation and path analyses indicated that tuber weight/plant, average tuber weight and tubers/plant were the main components to tuber yield. For this reason, these traits could be used more significantly for potato improvement. Similar research results with our study were published by others (Islam *et al*., 2002; Maity and Chattarzee, 1977; Ilisulu, 1986; Maris, 1988; Günel *et al*., 1991; Yıldırım *et al*., 1995, 1997; Galarreta *et al*., 2006).

In conclusion, correlation coefficient analysis measures the magnitude of relationship between various plant characters and determines the component character on which selection can be based for improvement in potato tuber yield. However, path coefficient analysis helps to determine the direct effect of traits and their indirect effects on yield. Tuber weight/plant, average tuber weight and tubers/plants had major contributions on tuber yield and hence selection for these traits can possibly lead to improvement in tuber yield of potato.

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