ESTIMATION OF SOME GENETIC PARAMETERS AFFECTING POTATO BREEDING PROGRAMS

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ABSTRACT

Nine potato cultivars (genotypes) were grown under three different locations, Alexandria governorate, Egypt during the summer seasons of 2011and 2012 to determine some genetically parameters affecting potato breeding programs. Phenotypic (p) and genotypic (g) variability and their respective coefficient of variations, genetic advance, and broad-sense heritability, correlation coefficients among all pairs of some important potato characters along with direct and indirect effects of some traits on potato yield trait were studied .The obtained results showed that all the morphological, yield and yield component characters showed highly affecting with the genotype by environment interaction (G X E). The genotypic and phenotypic coefficients of variations had nearly equal values for the characters tuber dry matter, tuber specific gravity and tuber shape index. This result appeared that these traits were not seriously affected by the changes in the environmental factors, indicating a highly significant effect of genotype on phenotypic expression and thus would reflect positive effects for selection during the cycles of the breeding program. The characters plant length (cm), total yield (ton/fed.), No. of tubers/plant, marketable yield (%) and reducing sugars (%) possessed moderate heritability values. Accordingly, it might be stated that phenotypic selection for these characters would be reasonably effective. High heritability value along with high genetic advance as per cent of the mean was obtained for average tuber weight (gm) and tuber shape index traits. Hence, selection for the previous characters would prove quite effective since the characters seemed to be governed by additive genes action. Tuber yield (ton/fed.) showed highly positive correlation with each of the characters plant length (cm), foliage fresh weight (gm), No. of tubers/plant, average tuber weight (gm) and marketable yield (%). No. of tubers/plant and average tuber weight traits showed positive direct effects on the total tubers yield per feddan. Plant length (cm) and marketable yield (%) characters have indirect positive effects on total tuber yield per feddan through its positive relations with both No. of tubers per plant and average tuber weight (gm).

Keywords: Potato, *Solanum tuberosum*, *L*., phenotypic selection, broad-sense heritability, genetic advance, genotypic coefficient of variation, phenotypic coefficient of variation, correlation coefficient and path analysis.

INTRODUCTION

Potatoes are one of the most important crops around the world. Potato is a plant belonging to family *Solanaceae*. There are about five thousand potato varieties worldwide. Apart from the five thousand cultivated varieties, there are about 200 wild species and subspecies, many of which can be cross-bred with cultivated varieties, which have been done repeatedly to transfer the resistances to certain pests and diseases from the gene pool of wild species to the gene pool of cultivated potato species. The major species grown worldwide is *Solanum tuberosum* (a tetraploid with 48 chromosomes), and modern varieties of this species are the most widely cultivated (http://en.wikipedia.org/wiki/Potato#Genetics).The total area planted with potatoes, according to estimates of the Egyptian Ministry of Agriculture for the year 2012 about 200 thousands feddan spread over three seasons (summer, nili and winter) with a total production reached more than 2 million tons, with an average productivity about 10 tons per feddan. It was recorded more than one hundred potato cultivars are handling in Egyptian markets.

The amount of variability that exists in the germplasm collections of any crop is of utmost importance towards breeding for better varieties. Particularly, genetic variability for a given character is a basic prerequisite for its improvement by systematic breeding (Tsegaye, *et al*., 2007). Estimates of various parameters for assessment of genetic variability *viz*., mean range of variation, heritability, genetic advance and coefficients of variation help the plant breeders in devising suitable plant type by bringing improvement in quantitatively inherited traits (Naik et al., 2012).

Potato is highly heterozygous and although self pollination is the main pollination, cross pollination is happening with insects especially with bees so it is considered that many of the traits show continuous variation. Since it is highly heterozygous, there is extensive variability within the species, which is available for exploitation by plant breeders (Jones *et al*., 1986). Therefore, this research aimed to understanding the nature and extent of variability among numbers of potato cultivars and studying the inheritance of potato attributes throughout estimating number of genetic parameters such as genotypic and phenotypic variability magnitudes, heritability, genotypic and phenotypic coefficient of variations and genetic advance. Phenotypic correlation coefficients among each pairs of the studied characters and the direct and indirect effects of some important characters on potato yield were considered as aims of this study.

MATERIALS AND METHODS

Nine potato cultivars (genotypes) were imported from Netherlands. These cultivars were Agria, Arinda, Diamant, Lady Rosetta, Marfona, Monalisa, Picasso, Spunta, and Vivaldi. These cultivars were grown during the two successive summer seasons of 2011 and 2012 at three different locations, i.e., El-Nahda region, Sabaheya experimental farm and Abees region, Alexandria governorate, Egypt. The characteristics of these cultivars were tabulated in Table (1), these characteristics were obtained from the Netherlands catalogue of potato varieties (2000). Planting take place on the first of January in both years, using cut potato seeds. Tuber seeds were planted in rows, 70 cm in wide, 6.0 m long and at spacing of 30 cm within rows. All the agricultural practices used for commercial potato production, as common in each area, were carried out in both years.

Table (1): The characteristics of the nine tested potato cultivars.

Characteristics / cultivars	Tubers	Dry matter content	Consumer quality	Maturity	Foliage
Agria	Very large, long oval, uniform in shape, yellow, smooth to medium smooth skin, yellow flesh shallow eyes	Good to medium	Fairly firm to floury; none after cooking blackening; suitable for chips	Moderately early to moderately late	Good
Arinda	Large, long-oval, very uniform in shape, yellow skin, shallow eyes, pale yellow flesh	Low	Firm to fairly; little after cooking blackening; suitable for fresh consumption	Moderately early	Good to fairly good
Diamant	Large, oval, uniform to moderately uniform in shape, yellow skin, rather shallow eyes, pale yellow flesh	Good	Fairly firm to floury; little to slight discoloration after cooking blackening; suitable for chips and crisps	Moderately early to moderately late	Very good to good
Lady Rosetta	Large, round, very uniform to uniform in shape, red skin, rather yellow eyes, pale yellow flesh	Very high	Floury; traces after cooking blackening; suitable for crisps	Moderately early to moderately late	Good to fairly good
Marfona	Very large, round to oval, uniform to moderately uniform in shape, yellow skin, rather shallow eyes, pale yellow flesh	Very low	Fairly firm; little after cooking blackening; suitable for fresh consumption	Moderately early to moderately late	Good
Monalisa	Large, oval, uniform in shape, yellow skin, shallow eyes, pale yellow flesh	Low	Fairly firm; traces after cooking blackening; suitable for fresh consumption	Moderately early	Fairly good
Picasso	Very large, oval, uniform to moderately uniform in shape, yellow skin, rather shallow eyes, pale yellow flesh	Medium	Fairly firm, slight discoloration after cooking blackening; suitable for fresh consumption	Moderately early to moderately late	Very good to good
Spunta	Very large, long, uniform in shape, yellow skin, very shallow eyes, pale yellow flesh	Medium	Fairly firm; traces after cooking blackening; suitable for fresh consumption	Moderately early	Good
Vivaldi	Large, long-oval, very uniform to uniform in shape, yellow skin, very shallow eyes, fairly yellow flesh	Medium	Firm to fairly; traces after cooking blackening,; suitable for fresh consumption	Early to moderately early	Good

Measurements

1-Vegetative growth and yield parameters: Ten whole plant samples per plot were randomly chosen, 90 days after planting, for the determination of the vegetative growth parameters (plant length (cm) and number of branches). Tuber yield parameter was calculated for a plot (16.8 m^2) and then attributed to yield per feddan (3800 m^2). Tubers yield was also determined for randomly choose ten plants then the average tuber weight and the numbers of tubers per plant were calculated.

2-Physical characteristics: Random samples 0f 20 tubers per cultivar from each replicate were used to measure the physical characteristics of the tubers; tuber length and diameter were measured to calculate the tuber shape index **(L/D).** Tuber specific gravity was determined by weighting a certain weight of tubers for each cultivar, then the specific gravity was computed according to the following equation:-

$$\text{Tuber specific gravity} = \frac{\text{Tuber's weight in air}}{\text{Tuber's weight in air - Tuber's weight in water}}$$

3-Tuber quality: Random samples of 10 tubers per cultivar from each replicate were used to determine the following characters:

a- Tuber dry matter (%) was carried out by weighing a certain weight of fresh tubers and then dried **at constant weight.**

$$\text{Dry matter \%} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

b- Reducing and non-reducing sugars percentages (%) were colourimetrically determined, according to the method of Dubios *et. al*. (1956).

c- Determination of starch: Tuber starch percentage (%) was determined according to the method described in A.O.A.C. (1970).

Experimental design and statistical analysis

Each experiment consisted of nine cultivars; each one was grown in four rows in each of the three replications. The experiments were arranged in a randomized complete blocks design (R. C. B. D), with three replicates. Collected data of the two years of 2011 and 2012 were subjected to a combined analysis of the variance as outlined by McIntosh (1983), in which, replications and years were considered as random effects in the mathematical model; while, the cultivars and locations were fixed. Analysis of data was carried out using the MSTAT (1991). The ANOVA and the expected mean squares are presented in Table (2). Phenotypic and genotypic variances were calculated using the method suggested by Burton and Devane (1953).

Table (2): The general form of the combined analysis of variance.

S. O. V.	D.F.	M.S.	E. M. S.
Locations (L)	(l-1)	M_9	$\delta^2_e + ly\,\delta^2_r + ry\,\delta^2_l$
Years (Y)	(y-1)	M_8	$\delta^2_e + ly\,\delta^2_r + rl\,\delta^2_y$
L × Y	(l-1)(y-1)	M_7	$\delta^2_e + ly\,\delta^2_r + r\,\delta^2_{ly}$
Repl./L/Y	(r-1)ly	M_6	$\delta^2_e + ly\,\delta^2_r$
Cultivars (g)	(v-1)	M_5	$\delta^2_e + rly\,\delta^2_g$
g × L	(g-1)(l-1)	M_4	$\delta^2_e + rs\,\delta^2_{gl}$
g × Y	(g-l)(y-1)	M_3	$\delta^2_e + rl\,\delta^2_{gy}$
g × L ×Y	(g–1)(l–1)(y–1)	M_2	$\delta^2_e + r\,\delta^2_{gly}$
Error	(g–1)(r– 1)ly	M_1	δ^2_e

Where, l, y, r and g are numbers of locations, years, replicates and cultivars, respectively. In this respect:- $\delta^2_p = \delta^2_g + \delta^2_{gy} + \delta^2_{gl} + \delta^2_{gly} + \delta^2_e$
Where: δ^2_p = Phenotypic variance, δ^2_g = Genotypic variance, δ^2_{gy} = Variance of genotypic x year interaction, δ^2_{gl} = Variance of genotypic x location interaction, δ^2_{gly} = Variance of genotypic x location x year interaction, δ^2_e = Environmental variance (error mean square).

Variance components values were used to calculate the genotypic variance and its combinations with the various environmental variables as follows :

$$\delta^2_g = \frac{M_5 - M_1}{rly} \quad ; \quad \delta^2_{gl} = \frac{M_4 - M_1}{rs} \quad ; \quad \delta^2_{gy} = \frac{M_3 - M_1}{rl}$$

$$\delta^2_{gly} = \frac{M_2 - M_1}{r} \quad ; \quad \delta^2_e = M_1$$

Estimation of genetic parameters:

Genetic parameters were estimated for different traits of potato cultivars.

1. Genotypic and phenotypic coefficient of variation (G.C.V and P.C.V)

The genotypic and phenotypic coefficient of variation was computed according to Burton and Devane (1953) and expressed as percentage.

$$G.C.V = \frac{\sqrt{\delta^2_g}}{\bar{X}} \times 100 \quad , \quad P.C.V = \frac{\sqrt{\delta^2_p}}{\bar{X}} \times 100$$

Where: δ^2_g = Genotypic coefficient of variation; δ^2_p = Phenotypic coefficient of variation;

X = General mean of the each studied character

PCV and GCV values were categorized as low, moderate and high values as indicated by Sivasubramanian and Menon (1973) as follows: 0-10% low; >10-20 % moderate; >20% high.

2. Heritability (H%)

Heritability in the broad–sense was calculated for the different traits, as elicit by Collins *et al*. (1987), from the following formula: H% = δ^2_g / (δ^2_g + δ^2_m) X 100

Where; $\delta^2_m = \delta^2_{gl} / l + \delta^2_{gy} / y + \delta^2_{gly} / ly + \delta^2_e / rly$

where; δ^2_g is the genetic variance; δ^2_m is the expected variance of a genotypic mean; δ^2_{gl} / l is the variance due to interaction of genotypes x locations; δ^2_{gy} / y is the variance due to interaction of genotypes x years; δ^2_{gly} / ly is the variance due to interaction of genotypes x locations x years; and δ^2_e / rly is the error variance.

3. Genetic advance (GA)

The extent of genetic advance to be expected by selecting five percent of the superior progeny was calculated by using the following formula given by Robinson *et al.* (1949). GA= i δ_p h²

Where:

i = Efficiency of selection which is 2.06 at 5% selection intensity.

δ_p = Phenotypic standard deviation.

h² = Heritability in broad sense.

4. Genetic advance as per cent of mean (GAM)

GAM as per cent of mean where calculated as illustrated by Johnson *et al.,* (1955). $GA\overline{M}$ = (GA/X) x 100; Where: GA= Genetic adv$\overline{a}$nce; X = General mean of a character. The GAM as per cent of mean was categorized as low, moderate or high as follows: 0 – 10% Low; 10-20% Moderate and more than 20% High (Johnson *et al.,* 1955).

5. Correlation coefficient and path-coefficient analyses

Simple correlation coefficients (r) were calculated for each pairs of the studied traits as shown by Dospekhove (1984). Path-coefficient was calculated as initially proposed by Wright (1921 and 1934) and later described Williams *et al*. (1990).

RESULTS AND DISCUSSION

Mean performances of the tested potato cultivars for the studied characters:

The data of Tables (3 and 4) showed that the tested potato cultivars were significantly differed genetically for all the studied characters. These results are in accordance with the results obtained from the data of the Tables of mean squares for cultivars (genotypes) mean squares of all the studied characters (Table, 5). In this respect, the cultivar Picasso possessed the highest yield, where this cultivar gave the tallest plants, highest number of tubers per plant, high foliage fresh weight and highest average tuber weight values. The cultivar Diamant gave the lowest yield, where this cultivar appeared low values for plant length and number of tubers per plant. With respect to the tuber quality characteristics, the cultivar Vivaldi gave the highest percentage for dry matter, specific gravity and starch content traits. The values of the total sugars percentages ranged from 7.07% for the cultivar Arinda to 6.21% for the cultivar Monalisa; while the values for reducing sugars percentages ranged from 3.17 for the cultivar Diamant to 2.57% for the cultivar Agria. These significant differences among the tested cultivars are in agreement with the results obtained by Moussa (1995) and Pérez *et al*.,(2009) for plant length, number of branches per plant and number of tubers per plant; Ali *et al*., (2008); Pérez *et al*.,(2009) and Al-jarmuozi (2012) for average tuber weight and tuber yield per feddan; Ali *et al*., (2008) and Al-jarmuozi (2012) for tuber shape index trait and Al-jarmuozi (2012) for potato tuber quality characters; i.e., dry matter, specific gravity, reducing sugars, total sugars and starch content.

Table (3): Mean performances of the tested potato cultivars for the vegetative and yield component characters combined over three locations and two years.

Cultivars \ characters	Plant length (cm)	No. of branches / plant	Foliage fresh weight (g)	Total tuber yield (ton/fed.)	No. of tubers / plant	Average tuber weight (gm)	Marketable yield (%)
Agria	30.14	2.54	302.50	8.72	6.48	73.83	68.51
Arinda	26.94	2.86	325.33	8.59	6.74	74.56	72.52
Diamant	26.65	2.85	319.94	7.83	5.69	77.39	65.04
Lady Rosetta	29.23	2.66	310.28	9.86	6.14	79.00	75.29
Marfona	32.15	2.62	315.28	8.62	7.01	73.61	69.44
Monalisa	29.59	2.64	320.89	9.66	6.09	71.89	81.51
Picasso	32.59	3.10	324.33	10.36	6.68	82.50	69.22
Spunta	29.98	2.54	308.89	9.07	6.71	75.22	63.58
Vivaldi	31.61	3.08	318.50	9.60	6.60	73.28	73.09
L.S.D. 0.05	1.00	0.38	14.37	0.64	0.80	7.57	5.18

Table (4): Mean performances of the tested potato cultivars for the studied quality tuber characters combined over three locations and two years.

Cultivars \ characters	Dry matter (%)	Tuber specific gravity	Tuber starch (%)	Total sugars (%)	Reducing sugars (%)	Tuber shape index
Agria	20.21	1.08	12.01	6.92	2.57	1.13
Arinda	18.88	1.08	11.70	7.07	2.93	1.44
Diamant	22.91	1.09	11.59	6.82	3.17	1.33
Lady Rosetta	22.14	1.11	11.37	6.65	2.91	1.23
Marfona	21.01	1.11	11.68	6.27	2.63	1.59
Monalisa	21.28	1.10	11.24	6.21	2.92	1.17
Picasso	20.45	1.10	11.95	6.57	2.89	1.35
Spunta	23.21	1.09	11.57	6.29	2.71	1.21
Vivaldi	23.66	1.11	12.05	6.22	2.93	1.27
L.S.D. 0.05	1.28	0.03	0.44	0.70	0.54	0.03

Genotype by environment interaction:

Genotype X environment interaction may be defined as the failure of genotypes to have the same relative performance from one environment to another, as reported by Baker (1988) and Yang and Baker (1991). The data presented in Table (5) of the combined analyses of variance, clear that most of the studied morphological, yield components and tubers quality characteristics showed strong dependence on the environmental factors. The significant and highly significant environmental main effects (year and location) indicated that there were fluctuations in the environmental conditions throughout the different experiments of the present investigation. The results reflected significant and highly significant effects for the environmental combinations (year X location interaction) on the performances of most of the studied characters. The presence of the effects of such interaction suggested that climate was a significant factor in location differences affecting these characters from year to year. All the studied characters showed highly significant genotypic differences indicating that the evaluated cultivars differed in their genetic potential with respect to these characters. A similar conclusion was reached by Harris (1974) and Estévez (1984). The first-order interactions (cultivar X year and cultivar X location) appeared to be significant for most studied characters indicating that the evaluated cultivars did not respond similarly, when grown under individual environments. In other words, the significant cultivar X year interaction, indicated that the cultivars tended to rank differently when grown at different years or different locations, as mentioned also by Abd El-Moneim and Cocks (1993). A similar conclusion was reached by Yildirim and Caliskan (1985); Lynch and Kozub (1988); El-Hity (1994) and Moussa (1995). The effects of the second-order interactions (cultivar X year X location), which would be considered as the genotype X environment interaction, showed highly significant differences on all the performances of the studied morphological, yield and yield components characters, as appears from Table (5). For tuber quality characteristics; Tuber starch content, total and reducing sugars contents, showed highly significant differences for cultivar X year X location interaction. Such result, generally, suggested that the evaluated cultivars showed different responses, with regard to most of the studied characters, when grown under different environments. Similar results were also reported by the investigators Miller *et a*l. (1959) and Fernandez and Chen (1989). Accordingly, it seemed that these characters should be measured over multiple locations, and years to separate cultivar X environment interaction components from total genotypic variance, as stated by Yildirim and Caliskan (1985).

Genetic parameters:

Partitioning the variance into its components is of prime importance for the breeder, where it gives indicators to the magnitudes of these components and their effects on the response of the studied characters to improve the outcome of the breeding programs. The data presented in Table (6) revealed that the genotypic variance represented large portion from the total variance (more than 25 %) for the characters; average tuber weight, marketable yield, tuber dry matter, tuber specific gravity and tuber shape index. The other studied characters; except for reducing sugars, showed that the variances due to the interactions between genotypes and the environmental factors (δ^2_{gy}, δ^2_{gl} and δ^2_{gyl}) playing an important role in affecting on the performance these characters. These results meant that these types of interactions should be concerned with the genotypic performance under different environmental conditions. The error variance for reducing sugars trait seemed to be had relatively large portion in magnitude in comparison with the calculated values of the total variance. In such case, a relatively larger number of replications should be used to give a better estimation for the error variance.

The estimated values of genotypic and phenotypic coefficients of variation are presented in Table (6). The data showed that these two parameters were found to have nearly equal values for the characters tuber dry matter, tuber specific gravity and tuber shape index. The previous result indicated that these traits were not seriously affected by the changes in the environmental factors, indicating a highly significant effect of genotype on phenotypic expression, thus would reflect positive effects for selection during the cycles of the breeding program. The other studied traits showed large differences between the two parameters (G.C.V. and P.C.V.), indicating that these characters was significantly affected by the environmental conditions.

Table (5): Mean squares of the studied potato characters combined over three locations and two years.

S.O.V.	D.F.	Plant length (cm)	No. of branches / plant	Foliage fresh weight (g)	Total tuber yield (ton/fed.)	No. of tubers / plant	Average tuber weight (gm)	Marketable yield (%)
Years	1	14.94**	32.76**	28242.72**	4.54**	45.45**	636.06**	7846.84**
Locations	2	1379.22**	3.03**	29963.41**	606.56**	94.80**	10026.97**	17255.74**
Years x Locations	2	384.29**	0.85*	10939.35**	8.96**	3.04**	201.96	2051.16**
Rep (Years x Locations)	12	0.72	0.15	243.19	0.37	0.25	74.16	14.40
Cultivars	8	78.62**	0.61**	1052.84**	11.15**	14.32**	2559.80**	534.94**
Cultivars x Years	8	7.47**	1.26**	1762.89**	0.74*	4.86**	426.17**	152.85**
Cultivars x Locations	16	37.12**	0.97**	1363.73**	8.83**	4.74**	180.94**	162.30**
Cultivars x Years x Locations	16	33.65**	0.72**	980.27**	3.12**	4.77**	263.66**	75.59**
Pooled error	96	0.76	0.11	156.39	0.31	0.48	43.44	20.31

Cont. (5):

S.O.V.	D.F.	Dry matter (%)	Tuber specific gravity	Tuber starch (%)	Total sugars (%)	Reducing sugars (%)	Tuber shape index
Years	1	80.90**	0.16151**	220.64**	0.28	3.35**	0.0186**
Locations	2	67.63**	0.02952**	22.24**	36.42**	6.68**	0.0589**
Years x Locations	2	2.84	0.01653**	20.47**	2.72*	0.61	0.0299**
Rep (Years x Locations)	12	0.99	0.00031	0.14	0.50	0.20	0.0003
Cultivars	8	44.64**	0.00302**	1.24**	1.93**	0.61**	0.3792**
Cultivars x Years	8	6.92**	0.00177*	2.63**	2.68**	0.16	0.0145**
Cultivars x Locations	16	3.00**	0.00095	1.07**	1.79**	0.43*	0.0165**
Cultivars x Years x Locations	16	1.08	0.00068	1.21**	1.42**	0.13	0.0064**
Pooled error	96	1.24	0.00070	0.15	0.37	0.22	0.0005

***,** denote significant and highly significant at 5% and 1% of probability, respectively**

Table (6): Variance components, coefficient of variations, genetic advance and broad-sense heritability values of the studied potato characters.

Characters	δ^2_g*	δ^2_{gy}	δ^2_{gl}	δ^2_{gyl}	δ^2_e	G.C.V %	P.C.V %
Plant length (cm)	4.33	0.75	6.06	10.96	0.76	6.96	16.00
No. of branches / plant	0.0278	0.1278	0.1433	0.2033	0.11	6.02	28.25
Foliage fresh weight (g)	49.8028	178.50	201.2233	274.6267	156.39	2.23	9.28
Total yield (ton/fed.)	0.6022	0.0478	1.42	0.9367	0.31	8.49	19.92
No. of tubers / plant	0.7689	0.4867	0.71	1.43	0.48	13.57	30.47
Average tuber weight (gm)	139.7978	42.5255	22.9167	73.4067	43.44	15.62	23.71
Marketable yield (%)	28.5905	14.7267	23.665	18.4233	20.33	7.54	14.50
Dry matter (%)	2.4111	0.6311	0.2933	0.05	1.24	7.21	9.99
Tuber specific gravity	0.00013	0.00005	0.0000	0.0000	0.0000	1.04	1.22
Tuber starch (%)	0.0606	0.2756	0.1533	0.3533	0.15	2.10	8.52
Total sugars (%)	0.0867	0.2567	0.2367	0.35	0.37	4.49	17.38
Reducing sugars (%)	0.0217	0.0067	0.035	0.03	0.22	5.17	19.64
Tuber shape index	0.021	0.0015	0.0027	0.002	0.0005	11.15	12.80

δ^2_g = Genotypic variance, δ^2_{gy} = Variance of genotypic x year interaction, δ^2_{gl} = Variance of genotypic x location interaction, δ^2_{gly} = Variance of genotypic x location x year interaction, δ^2_e = Error variance.
G.C.V and P.C.V represent the genotypic and phenotypic coefficient of variations, respectively.

Table (6) Continue:

Characters	Genetic advance (GA)	Genetic advance as percent of mean (GAM)%	Genetic variance	Phenotypic variance	% of the genotypic variance from the total variance	Broad-sense heritability (H%)
Plant length (cm)	4.96	16.60	4.33	22.86	18.94	50.38
No. of branches / plant	0.25	9.01	0.0278	0.6122	4.54	15.49
Foliage fresh weight (g)	11.55	3.65	49.8028	860.5428	5.78	19.11
Total yield (ton/fed.)	1.77	19.42	0.6022	3.3167	18.16	47.32
No. of tubers / plant	2.06	31.88	0.7689	3.8756	19.84	50.79
Average tuber weight (gm)	28.19	37.24	139.7978	322.0867	43.40	76.25
Marketable yield (%)	12.61	17.78	28.5905	105.7355	27.04	59.51
Dry matter (%)	3.68	17.10	2.4111	4.6255	52.13	83.10
Tuber specific gravity	0.02	1.81	0.00013	0.00018	72.22	72.22
Tuber starch (%)	0.39	3.36	0.0606	0.9928	6.10	19.13
Total sugars (%)	0.55	8.33	0.0867	1.3001	6.67	23.26
Reducing sugars (%)	0.46	16.29	0.0217	0.3134	6.92	40.26
Tuber shape index	0.32	24.95	0.021	0.0277	75.81	94.59

Data representing genetic advance are presented in Table (6). Even though heritability values provide the basis for selection on the phenotypic performance, the estimates of heritability and genetic advance should always be considered simultaneously as high heritability will not always be associated with high genetic advance (Johnson *et al*., 1955). The values of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. High values of genetic advance are indicative of additive gene action whereas, low values are indicative of non-additive gene action (Singh and Narayanan, 1993). Thus the heritability estimates will be reliable if accompanied by a high genetic advance. The expected genetic advance was expressed here as percentage of genotypes mean for each studied characters so that, comparison could be made among various characters, which had different units of measurement. Progress that could be expected from selecting the top 5% of the genotypes (GA), (Table, 6), ranged from 0.02 for the tuber specific gravity up to 28.19 for the average tuber weight; while the genetic advance, as a percentage of mean, ranged from 1.81% for tuber specific gravity to 37.24% for average tuber weight (Table, 6). Some of the studied characters showed moderate to high genetic advance values (more than 10%); i.e., plant length, total yield (ton/fed.), No. of tubers/plant, average tuber weight, marketable yield, tuber dry matter, reducing sugars and tuber shape index. The other studied characters; i.e., No. of branches/plant, foliage fresh weight, tuber specific gravity, tuber starch content and total sugars, showed low genetic advance values.

The data of broad-sense heritability values for the studied characters are recorded in Table (6). Heritability percentage, which specifies the proportion of the total variability that is due to genetic variance, was low (h^2_{bs}<33.33%) for No. of branches/plant, foliage fresh weight, tuber starch content and total sugars. These results indicated that phenotypic selection for the mentioned characters did not seem to be effective. The characters plant length, total yield, No. of tubers/plant, marketable yield and reducing sugars possessed moderate heritability values (33.33% < h2bs < 66.66%), as appears in Table (6). Accordingly, it might be stated that phenotypic selection for these characters would be reasonably effective. The characters; which possessed high heritability values (h^2_{bs} > 66.66%); i.e. average tuber weight, tuber dry matter, tuber specific gravity and tuber shape index indicated that phenotypic selection for such characters would be highly efficient. Swarup and Chaugale (1962) reported that high heritability along with high genetic advance is an important factor for predicting the resultant effect for selecting the best individual genotypes than heritability values alone. In the present study, high heritability value along with high genetic advance as per cent of the mean was obtained for the two traits average tuber weight and tuber shape index (Table, 6). As stated by Panse and Sukhatme (1964), high heritability values associated with equally high genetic advance is chiefly due to dominance and epistasis, the genetic gain would be low. Hence, selection for the mentioned characters (average tuber weight and tuber shape index) would prove quite effective since the characters seemed to be governed by additive genes action.

Correlation coefficients and path analysis:

Information on the interrelationships of tuber yield with its component characters and also among the component characters themselves would be useful to the breeder in developing an appropriate selection strategy. Since, yield is a complex character and influenced by number of traits and selection based on yield is usually not much effective, indirect selection on the basis of desirable component characters could be of great use. Data presented in Table (7) showed that correlation coefficient values were positive and significant or highly significant for the following pairs of characters:

- Plant length with each of; total yield, No. of tubers/plant, average tuber weight and marketable yield.
- No. of branches/plant with foliage fresh weight.
- Foliage fresh weight with each of; total yield, No. of tubers/plant, average tuber weight and marketable yield.
- Total yield with each of; No. of tubers/plant, average tuber weight, marketable yield and total sugars.
- No. of tubers/plant with each of; average tuber weight and marketable yield.
- Average tuber weight with each of; marketable yield and total sugars.
- Total sugars with reducing sugars.

Data presented in Table (7) showed that each pairs of the following characters were either significant or highly significant, but negatively correlated:

- Total yield with tuber specific gravity.
- Average tuber weight with tuber specific gravity.
- Tuber dry matter with total sugars.
- Tuber specific gravity with total sugars.

It could be concluded from the previous results that plant length, average tuber weight, No. of tubers/plant, average tuber weight and marketable yield are good indicators for the prediction of high crop production per feddan. Similar results were also obtained by Moussa (1995), Arsalan (2007), Khayatnezhad *et al*., (2011) and Al-jarmuozi (2012).

Data of Table (8) demonstrated that there is a large and mainly positive direct effect of both No. of tubers/plant and average tuber weight on the total tubers yield per feddan. These direct effects of the No. of tubers and average tuber weight on the total yield per feddan reached 0.4583 and 0.4635, respectively from the total direct effects of the studied characters. The data of Table (7) appeared that tuber yield per feddan seemed to be closely and highly positive correlated with both No. of tubers per plant (0.8527) and average tuber weight (0.8498), respectively. It could be seen from the previous results that direct selection for the largest number of tubers per plant and or the highest average tuber weight value may be effective to induce highly potato tuber production per feddan. Data shown in Table (8) demonstrated that, plant length and marketable yield characters have indirect positive effects on the total tuber yield per feddan through its positive relations with both No. of tubers per plant (0.3020 and 0.3212) and Average tuber weight (0.2870 and 0.3693). The residual effect value reached 0.2702 and this means that the unexpected variation in phenotypic level was 27%.

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It also indicated that 73% of variations for the total production per feddan are indicated in this study. The results by Ara *et al*. (2009) indicated that main shoot number showed highest positive direct effect on tuber yield followed by fresh weight / plant at 80 days after planting and number of leaves per plant. The authors illustrated that selection based on the previous mentioned characters would give better response to the improvement of fresh tuber yield in potato. Similar results were also reported by Hayder *et al*., (2009). Al-jarmuozi (2012) stated that the character tuber yield per plant had direct positive effect on the total yield per feddan. The author demonstrated that average tuber weight and plant height had indirect positive effects on the total tuber yield per feddan through its relation with the tuber yield per plant. It could be concluded from the previous results of the path analysis that the main factors affecting the high tuber yield per feddan are the number of tubers per plant and the average tuber weight characters.

Table (8): Direct and indirect effects of five different characters on the total tuber yield component for nine potato cultivars.

characters	Plant length (cm)	Foliage fresh weight (gm)	No. of tubers/plant	Average tuber weight (gm)	Marketable yield (%)	Total
Plant length (cm)	0.1121	0.0114	0.3020	0.2870	0.0026	0.7151
Foliage fresh weight (gm)	0.0107	0.1194	0.1789	0.1768	0.0024	0.4882
No. of tubers/plant	0.0739	0.0466	0.4583	0.2706	0.0033	0.8527
Average tuber weight (gm)	0.0694	0.0455	0.2675	0.4635	0.0038	0.8498
Marketable yield (%)	0.0622	0.0603	0.3212	0.3693	0.0047	0.8177

Residual effect= 0.2702

Conclusion

The environmental factors have important effects on the phenotypic selection for most of the potato traits studied especially the morphological and yield component characters, which lead to impede progress during the selection program. Selection for high tuber yield (ton per feddan) trait showed large dependency on the characters number of tubers per plant and average tuber weight characters, therefore, interesting with these two characters during the selection program is highly conducive to improving the potato crop yield. Estimation of the parameter genetic advance along with the heritability estimate values provide the breeder with important information about the gene action affecting the character studied and thus leads to faster access for the breeding program objectives through the least possible breeding cycles.

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تقدير بعض المقاييس الوراثية المؤثرة على برامج تربية البطاطس

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تمت زراعة تسعة أصناف من البطاطس المستوردة من هولندا وهى أجريا ، ارندا ، ديامانت ، ليدى روزيتا ، مارفونا ، موناليزا ، بيكاسو ، سبونتا ، ڤيڤالدى ، فى ثلاثة مواقع مختلفة وهى مزرعة محطة بحوث البساتين بالصبحية ، ومنطقة النهضة ، ومنطقة ابيس خلال العروة الصيفية لعامين متتاليين ٢٠١١ ، ٢٠١٢ . أجريت الدراسة بغرض تقدير عدد من المقاييس الوراثية المؤثرة على قدرة المربى على فهم طبيعة التوارث وتأثير العوامل البيئية وطبيعة الفعل الجينى المؤثرعلى الصفات المدروسة ، وتأثير ذلك على نجاح الإنتخاب المظهرى لعدد من الصفات الهامة فى البطاطس. كذلك درست علاقات التلازم بين أزواج الصفات المدروسة ، وأيضا علاقات التأثير المباشر والغير مباشر لعدد من الصفات المدروسة على صفة المحصول الكلى للبطاطس (طن/فدان).

أهم النتائج المتحصل عليها:-

١- كان للعوامل البيئية ، وكذلك **تأثير** التداخل بين العوامل البيئية والتراكيب الوراثية تاثيرا كبيرا على معظم الصفات المدروسة وخاصة الصفات المورفولوجية وصفات المحصول الكلى من الدرنات (طن/فدان) ومكوناته .

٢- سجلت درجة التوريث فى النطاق العريض قيما عالية لكل من صفتى متوسط وزن الدرنة (جم) ، و دليل شكل الدرنة متزامنة مع قيما عالية لنسبة التحسن الوراثى المتوقعة جيل بعد جيل أثناء البرنامج الإنتخابى مما يشير الى إمكانية حدوث تحسين سريع لهاتين الصفتين عن طريق الإنتخاب مقارنة بباقى الصفات المدروسة .

٣- وجود تلازم جوهرى وإيجابى بين صفة المحصول الكلى للفدان من الدرنات (طن/فدان) وكل من صفات طول النبات (سم) ، وزن العرش الطازج (جم) ، عدد الدرنات / نبات ، متوسط وزن الدرنة (جم) ، النسبة المئوية للمحصول الصالح للتسويق .

٤- بينت النتائج وجود تأثير مباشر قوى وإيجابى لصفتى عدد الدرنات / نبات ، متوسط وزن الدرنة (جم) على صفة المحصول الكلى من الرنات (طن/ فدان) ، أيضا وجود تأثير إيجابى غير مباشر لصفتى طول النبات (سم) ، المحصول الكلى من الدرنات الصالح للتسويق (%) على صفة المحصول الكلى من الدرنات (طن/فدان) من خلال تاثير تلك الصفتين الإيجابى على صفتى عدد الدرنات للنبات ، متوسط وزن الدرنة (جم) .

هذا ، ويوصى البحث بالإهتمام بالتركيز على تحسين صفتى عدد الدرنات للنبات ، و متوسط وزن الدرنة لما لهما من تاثير إيجابى ومباشر على زيادة المحصول الكلى للفدان مع عدم إغفال الدورالسلبى الذى تلعبه العوامل البيئية والتداخل بين العوامل البيئية والتراكيب الوراثية فى التاثير على فعالية الإنتخاب المظهرى أثناء دورات البرنامج الإنتخابى.

قام بتحكيم البحث

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