Genetic parameters, heritability and correlation coefficient values among some characters of jerusalem artichoke (*Helianthus tuberosus L.)*

Nashwa I. Abo El Fadel and Sameh A. M. Moussa
Sabaheya Horticultural Research Station, Horticultural Research Institute, Agricultural Research center, Egypt.

ABSTRACT

Two jerusalem artichoke (*Helianthus tuberosus* L.)cultivars; genotypes, were grown under two different locations; i.e., Alexandria governorate and south El-tahrir region. Planting conducted on May for the two years 2010 and 2011 of the study. The investigation was done to determine some genetic parameters affecting jerusalem artichoke 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 jerusalem artichoke characters were studied .The obtained results showed that most of the studied characters were highly affected by the environmental factors especially from one location to the other. The genotypic and phenotypic coefficients of variations had mostly equal values for most studied traits. This result confirmed that these traits were seriously affected by the changes in the environmental factors. This means that these environmental factors would show negative effects for selection during the cycles of the breeding program. The characters number of tubers / plant, average tuber weight, total tuber yield (ton/fed.), potassium and nitrogen percentages possessed moderate high heritability values (in broad-sense). Accordingly, it might be stated that phenotypic selection for these characters would be reasonably effective. The recorded data showed that dominance and epistasis gene actions had the major role to influence the inheritance of the studied characters .Hence, selection for these characters would not be quite effective since it seemed to be governed by dominance and epistasis gene actions. Tuber yield (ton/fed.) showed highly positive correlation with each of the characters: plant height (cm) and average tuber weight.

Keywords jerusalem artichoke, *Helianthus tuberosus, L.*, phenotypic selection, broad-sense heritability, genetic advance, genotypic coefficient of variation, phenotypic coefficient of variation and correlation coefficient.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus L.)*is a member of the Aster (Asteraceae) family, it is an uncommon vegetable crop in Egypt and it does not grown in a commercial scale. It is native to North America, where it was cultivated by the Indians before the arrival of the Europeans. It was introduced into Europe in the early 17th century. It grows successfully, under a wide range of temperature, soils and rainfall producing edible underground tubers. It is anherbaceousperennial plant. The flowers are yellow and produced in capitated flowerheads. The flowers are hermaphrodite and are pollinated by Bees and flies. The tubers are elongated and uneven, typically 7.5–10 centimeters long and 3–5 centimeters thick, and vaguely resembling ginger root, with a crisp texture when raw. They are varying in color from pale brown to white; red or purple. The tuber contains about 10% protein, no oil, and a surprising lack of starch. However, it is rich in the carbohydrate inulin (76%), which is a polymer of the monosaccharide fructose. Jerusalem artichokes have also been promoted as a healthy choice for diabetics, because fructose is better tolerated by diabeticpeople. Tubers also contain about nitrogenous2–3 percent substances, vitamin C, and B-complex vitamins (Baker *et al.*, 1990). Only a small number of crops accumulate inulin in amounts sufficient for cost-effective extraction. Chicory and jerusalem artichoke are the most important inulin-storing species and tubers are low in calories because it contains little protein or fat, but is high in fiber (Meijer *et al., 1993;* Kays and Nottingham, 2008). Plant-derived inulin can be processed and modified to serve as a feedstock for numerous industrial applications (Parameswaran, 1995). The demand for inulin is growing, particularly within the food industry.

A great deal of morphological variation has been noted in jerusalem artichoke, despite being a crop that has undergone relatively little systematic selection, suggesting that genetic improvement is possible. Tubers, for instance, vary in color, shape, size, and surface topography (Kays and Nottingham, 2008).

Nowadays, in Egypt, more attention is directed to promote jerusalem artichoke production to meet the increased demands for our progressive national medical and technology industries purposes, furthermore, the crop produces large haulm that can be used as green fodder or silage (Magda *et al.* 2007).

The aim of this investigation was to study the genetic behavior of some economical and morphological characters of jerusalem artichoke. Also, expecting the genetic improvement of the studied characters during the cycles of the breeding programs and studying the effect of both genetic and environmental factors on these characters, Broad-sense heritability and correlation coefficients among the pairs of the studied traits are considered in this study

MATERIALS AND METHODS

Two field experiments were carried out during two successive summer seasons of 2010 and 2011 at two different locations i.e., Sabaheya Horticultural research station, Alexandria, clay loam soil and south El-tahrirr egion, sandy calcareous soil. Two cultivars of jerusalem artichoke were tested in this study; the first one was Fuseau cultivar having white- yellow skin, yellow flesh and the tuber is spindle. The second cultivar was the local cultivar (balady), characterized by yellow skin, white fleshed and the tuber is irregular.

Tubers were planted on May, 12th and 20thof 2010 and 2011 summer seasons, respectively. The experimental unit was 20m^2, consisted

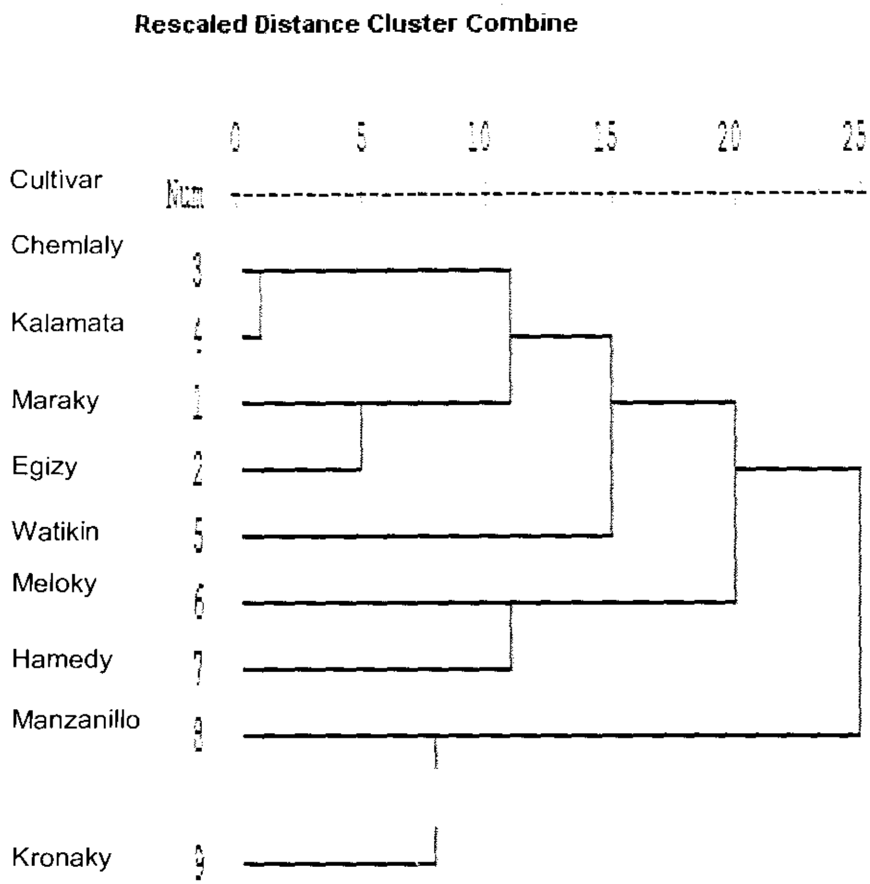

Fig. (6): Dendrogram based on three systems (isozymes, RAPD and ISSR-PCR) of the nine studied olive cultivars.

Finally, the results revealed that the dendrograms obtained from the analysis showed the genetic relationship among the nine studied olive cultivars. The results demonstrated the reliability of isozymes, RAPDs and ISSRs to identify all studied olive cultivars and to reveal the degree of their relatedness to each other. The analysis also reveals the presence of an interesting amount of genetic diversity among the studied individuals.

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

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

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

Calculation of genetic parameters

Genetic parameters were calculated for different jerusalem artichoke cultivars.

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

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

$$G.C.V.=\frac{\sqrt{\delta^2 g}}{\bar{x}}X100 \qquad P.C.V.=\frac{\sqrt{\delta^2 p}}{\bar{x}}X100$$

Where: δ^2_g=Genotypic variation; δ^2_p=phenotypic variation; $\bar{x}$= General mean of the 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%)

Heritabilities in the broad – sense were calculated for the different traits, as elicitated by Collins *et al.* (1987), from the following formula: $H\%=\delta^2_g/(\delta^2_g+\delta^2_m)\times 100$

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).

$GA = i\ \delta_p h^2$

Where:

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

δ_p= Phenotypic standard deviation.

h^2= Heritability in broad sense.

4. Genetic advance as percent of mean (GAM)

GAM as percent of mean where calculated as illustrated by Johnson *et al.* (1955). GAM=(GA/$\overline{X}$)x 100; where : GA= Genetic advance ; $\overline{X}$= General mean of a character. The GAM as percent 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 analysis

Simple correlation coefficients (r) were calculated for each pairs of the studied traits as shown by Dospekhove (1984).

RESULTSAND DISCUSSION

Mean performances of the studied cultivars all over the four different environments

The data presented in Table (2) showed that the tested jerusalem artichoke cultivars were significantly differed for average tuber weight, total tuber yield per feddan, potassium, nitrogen and phosphorus percentages. The local cultivar (Balady) possessed higher tuber yield per fed. On the contrary, the Fuseau cultivar tubers gave higher potassium, nitrogen and phosphorus percentages. Meanwhile, the tested cultivars did not show any significant differences for plant height, number of branches per plant, number of tubers per plant and inulin content. Numerous researches for tuber crops especially potato detected significant genotypic differences among the tested cultivars, Moussa (1995) and Pérez *et al.* (2009) for plant height, number of branches per plant and number of tubers per plant; Ali *et al.* (2008); Pérez *et al.* (2009) and Al-jarmuozi *et al.* (2012) for average tuber weight and tuber yield per feddan and Al-jarmuozi *et al.* (2012) for potato tuber quality characters; i.e., dry matter, specific gravity, reducing sugars, total sugars and starch content.

Table (2): Mean performances of the two jerusalem artichoke cultivars for the studied traits over all the tested environments.

Characters / Cultivars	Plant height (cm)	No. of branches / plant	No. of tubers / plant	Average tuber weigh (gm)	Total tuber yield (ton/fed.)	Tuber potassium (%)	Tuber nitrogen (%)	Tuber phosphorus (%)	Tuber inulin (%)
Fuseau cultivar	161.0	9.73	65.4	56.27	17.5	3.26	0.69	0.39	15.10
Local cultivar (balady)	162.8	9.65	56.0	67.92	16.8	3.51	0.72	0.41	15.08
L.S.D. 0.05	3.749	0.434	1.96	5.90	0.05	0.059	0.009	0.007	0.253

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 the other, as reported by Baker (1988) and Yang and Baker (1991). The data presented in Table (3) of the combined analyses of variance, cleared that most of the studied characters showed strong dependence on the environmental factors especially for the location effects. 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 effects of the environmental combinations (location X year interaction) on the performance of the nitrogen percentage. 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. Number of tubers per plant, average tuber weight, potassium and nitrogen percentages 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 location and cultivar X year) appeared to be significant for most of the 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 also 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 significant and highly significant differences on the performances of number of branches per plant, average tuber weight and nitrogen percentage, as appears from Table (4).Such result, generally suggested that the evaluated cultivars showed different responses, with regard to the mentioned characters, when grown under different environments. Similar conclusion was also reported by Miller *et al.* (1959) and Fernandez and Chen (1989). Accordingly, it seemed that these characters should be measured over multiple locations, and years to detect cultivar X environment interaction components from total genotypic variance, as stated by Yildirim and Caliskan (1985).

Table(3): Mean squares for the studied traits over the four different environments

S.O.V.	D.F.	Plant height (cm)	No. of branches / plant	No. of tubers / plant	Average tuber weight (gm)	Total tuber yield (ton/fed)	Tuber potassium (%)	Tuber nitrogen (%)	Tuber phosphorus (%)	Tuber inulin (%)
Locations	1	15528.6**	86.22**	615.8**	38.61	194.8**	0.001	0.51**	0.388*	8.42**
Years	1	97.9	0.06	5.97	2.32	2.55	0.27**	0.001	0.0001	0.57
LocationsxYears	1	89.5	0.25	17.29	35.37	0.06	0.03	0.006**	0.0001	0.11
Repl. / L. /Y.	8	64.1	0.47	5.902	10.12	0.468	0.007	0.001	0.048	0.195
Cultivars	1	20.4	0.04	528.5**	806.3	3.09**	0.38**	0.007**	0.0001	0.005
Cultivars x Locations	1	236.4**	11.53**	408.1**	218.3**	3.34**	0.001	0.006**	0.39**	0.53**
Cultivars x Years	1	1.3	0.32	58.38**	39.01	3.46	0.27**	0.002**	0.004**	0.11
Cultivars xLocationsxYears	1	0.3	1.29*	0.00	130.7**	0.001	0.001	0.001**	0.0001	0.87**
Pooled error	8	15.8	0.21	4.356	9.80	0.13	0.004	0.0001	0.00005	0.072

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

Genetic parameters

Partitioning of the variance into its components is of prime importance for the breeder, where it indicates 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 (4) revealed that the genotypic variance represented large portion from the total variance (more than 25 %) for number of tubers per plant, average tuber weight, potassium and nitrogen percentages. The other studied characters; number of branches per plant, total tuber yield per feddan, phosphorus and inulin percentages showed that the variances due to the interactions between genotypes and the environmental factors (δ^2_{gy}, δ^2_{gl} and δ^2_{gyl}) played an important role to affect the performance of 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 plant height seemed to have 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 calculation of the error variance.

The estimated values of genotypic and phenotypic coefficients of variation are presented in Table (4). The data showed that these two parameters were found to have somehownearly equal values for potassium percentage. This result indicated that this trait was 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 were significantly affected by the environmental conditions.

Table (4): Variance components, coefficient of variations, genetic advance and broad-sense heritability values of the studied jerusalem artichoke characters.

Characters	δ^2_g *	δ^2_{gl}	δ^2_{gy}	δ^2_{gly}	δ^2_e	G.C.V %	P.C.V %
Plant height (cm)	0.382	36.762	2.419	5.155	15.807	0.38	4.80
No. of branches / plant	0.014	1.886	0.018	0.359	0.212	1.22	16.28
No. of tubers / plant	43.683	67.295	9.004	1.451	4.356	10.87	18.45
Average tuber weight (gm)	806.28	218.28	39.01	130.73	9.80	13.12	20.12
Total tuber yield (ton/fed.)	0.247	0.535	0.555	0.043	0.13	2.89	7.15
Tuber potassium (%)	0.031	0.0005	0.044	0.001	0.004	5.21	8.42
Tuber nitrogen (%)	0.0006	0.001	0.0003	0.0003	0.0001	3.50	6.85
Tuber phosphorus (%)	0.000004	0.065	0.0006	0.00002	0.00005	0.50	64.23
Tuber inulin (%)	0.0056	0.0763	0.0063	0.266	0.072	0.50	4.33

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 (4) 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 height (cm)	1.65	1.021	0.382	60.525	0.63	1.69
No. of branches / plant	2.43	25.11	0.014	2.489	0.56	1.30
No. of tubers / plant	9.73	16.01	43.683	125.789	34.73	52.91
Average tuber weight (gm)	13.87	22.34	66.73	156.10	42.75	68.37
Total tuber yield (ton/fed.)	0.565	3.29	0.247	1.51	16.36	30.46
Tuber potassium (%)	0.275	8.14	0.031	0.081	38.27	57.62
Tuber nitrogen (%)	0.033	4.72	0.0006	0.0023	26.09	42.86
Tuber phosphorus (%)	0.00004	0.009	0.000004	0.066	0.006	0.01
Tuber inulin (%)	0.033	0.222	0.0056	0.426	1.31	4.71

Data represented genetic advance are presented in Table (4). Even though heritability values provide the basis for selection on the phenotypic performance, the values 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 to understand the type of gene action involved in the expression of various polygenic characters. High values of genetic advance are indicator of additive gene action whereas; low values are indicated non-additive gene action (Singh and Narayanan, 1993). Thus the heritability values 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, 4), ranged from 0.00004 for the phosphorus percentage up to 13.87 for the average tuber weight; while the genetic advance, as a percentage of the mean, ranged from 0.009% for phosphorus percentage to 25.11% for the number of branches per plant. Some of the studied characters showed moderate to high genetic advance values (more than 10%); i.e., number of branches per plant and number of tubers/plant and average tuber weight. The other studied characters; i.e., plant height, total tuber yield per feddan, potassium, nitrogen, phosphorus and inulin percentages of tuber, showed low genetic advance values.

Broad-sense heritability values for the studied characters are recorded in Table (4). Heritability percentage, which specifies the proportion of the total variability due to genetic variance, was low (h^2_{bs}<33.33%) for plant length, number of branches per plant, phosphorus percentage and inulin percentage. These results indicated that phenotypic selection for the mentioned characters did not seem to be effective. The number of tubers/plant, total tuber yield per feddan, potassium and nitrogen percentages possessed moderate heritability values (33.33% < $h2_{bs}$< 66.66%), as appeared in Table (4). Accordingly, it might be stated that phenotypic selection for these characters would be reasonably effective. High heritability value was recorded only for the average tuber weight (more than 66.66 %). This result indicated that selection for such character could be more efficiency during the breeding program. Swarup and Chaugale (1962) reported that high heritability along with high genetic advance is an important factor to predict the resultant effect for selecting the best individual genotypes than heritability values alone. In the present study, none of the studied characters possessed high heritability value along with high genetic advance as per cent of the mean except for the character average tuber weight (Table, 4). This result meant that dominance and epistasis gene actions had the major role in influencing the inheritance of such characters. The recorded data clearly showed that phenotypic selection for these studied characters would not be very effective and the progress to improve such characters would be low and need a lot of numerous breeding cycles to achieve the goals of the breeding program.

Correlation coefficients

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 (5) showed that correlation coefficient values were positive and significant or highly significant for the following pairs of characters:

- Plant height with each of; number of tubers per plant, total tuber yield (ton per feddan) and tuber inulin percentage.
- Number. of branches/plant with each of nitrogen and phosphorus percentages.
- Total tuber yield (ton per feddan) with inulin percentage.
- Nitrogen percentage with phosphorus percentage.

Data presented in Table (5) showed that each pairs of the following characters were either significant or highly significant, but negatively correlated:

- Plant height with each of number of branches per plant, tuber nitrogen and phosphorus percentages.
- Number of branches per plant with each of number of tubers per plant, total tuber yield (ton per feddan) and inulin percentage.
- Number of tubers per plant with total tuber yield per (ton per feddan).
- Total tuber yield (ton per feddan) with each of nitrogen and phosphorus percentages.
- Nitrogen with inulin percentages.
- Phosphorus with inulin percentages.

It could be concluded from these results that plant height and number of tubers per plant 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) in there researches on potato crop.

CONCLUSION

The environmental factors, especially location effects, have important effects on the phenotypic selection for most of the studied jerusalem artichoke traits, which lead to impede progress during the selection program. Selection for high tuber yield showed large dependence on the plant height and number of tubers per plant, therefore, concerning our attention on these two characters during the selection program is highly conducive to improve the total tuber crop yield .Estimation of the parameter genetic advance along with the heritability estimate values provide the breeder an 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.

Table (5): Correlation coefficients calculated values for each pairs of the studied jerusalem artichoke characters.

characters	Plant height (cm)	No. of branche s / plant	No. of tubers / plant	Average tuber weight	Total tuber yield	Tuber potassiu m (%)	Tuber nitrogen (%)	Tuber phosphorus (%)
No. of branches / plant	-0.9608**							
No. of tubers / plant	0.6517*	-0.7291*						
Average tuber weight (g)	0.0197	0.1415	-0.6824					
Total tuber yield (ton/fed.)	0.9457**	-0.9146**	0.6587*	-0.1035				
Tuber potassium (%)	0.0611	-0.0755	-0.2716	0.3510	0.0456			
Tuber nitrogen (%)	-0.9726**	0.9164**	-0.6612	0.0428	-0.9811**	0.0613		
Tuber phosphorus (%)	-0.9653**	0.8857**	-0.6414	-0.0389	-0.9526**	0.0592	0.9855**	
Tuber inulin (%)	0.9310**	-0.8645**	0.6823	0.0414	0.7969*	-0.0547	-0.8766**	-0.9097**

*, ** Significant at 5% and 1% levels of probability, respectively.

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الملخص العربى

تقدير عدد من المقاييس الوراثية ودرجات التوريث ومعاملات التلازم بين عدد من صفات نبات الطرطوفة

نشوة إبراهيم أبو الفضل ، سامح عبد المنعم محمد موسى

محطة بحوث البساتين بالصبحية - معهد بحوث البساتين- مركز البحوث الزراعيةج .م .ع

زرع صنفين من الطرطوفة وهما صنف الفيوزا والصنف المحلى (البلدى) خلال الموسمان الصيفيان لعامى 2010 ، 2011. أجريت الدراسة فى موقعين هما مزرعة محطة بحوث البساتين بالصبحية بالاسكندرية وإحدى المزارع الخاصة بمنطقة جنوب التحرير. أجريت الدراسة بغرض تقدير عدد من المقاييس الوراثية المؤثرة على قدرة المربى على فهم طبيعة التوارث وتأثير العوامل البيئية وطبيعة الفعل الجينى المؤثرعلىعدد من الصفات المدروسة لنبات الطرطوفة ، وتأثير ذلك على نجاح الإنتخاب المظهرى لعدد من الصفات الهامة فى االطرطوفة. كذلك درست علاقات التلازم بين أزواج الصفات المدروسة .

درس عددتسعةصفات وهى :- إرتفاع النبات (سم) ، عدد الفروع للنبات، عدد الدرنات للنبات ، متوسط وزن الدرنة (جم)، المحصول الكلى بالطن للفدان ، نسبة كل من البوتاسيوم ، النيتروجين ، الفوسفور ، الانيولين فى الدرنات .

وكانت أهم النتائج المتحصل عليها:-

1- كان للعوامل البيئية ،خاصة عامل المكان وكذلك تأثير التداخل بين العوامل البيئية والتراكيب الوراثية تاثيرا كبيرا على عدد من الصفات المدروسة.
2- سجلت درجة التوريث فى النطاق العريض قيما منخفضة لمعظم الصفات المدروسة ، وأوضحت نتائج قيم التحسن الوراثى المتوقعة جيل بعد جيل أثناء البرنامج الإنتخابىأن تلك الصفات تتأثر بالفعل الجينى الراجع للسيادة وكذلك للتداخل بين الجينات الغير أليلية مما ينبىء عن أن تحسين تلك الصفات يتطلب عدد كبير من الأجيال لحدوث التحسين المطلوب .
3- وجود تلازم جوهرى وا يجابى بين صفة المحصول الكلى للفدان من الدرنات (طن/فدان) وكل من صفات طول النبات (سم) ، وعدد الدرنات للنبات .

هذا ، ويوصى البحث بالإهتمام بالتركيز على تحسين صفتى إرتفاع النبات وعدد الدرنات 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.