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Estimation Of Some Genetic Parameters In Potatoes (*Solanum Tuberosum* L.) Under Effect Of Planting Date

Amer Abdulla hussein Al-ubouri [1], Shamil Younis Hassan AL-Hamadany [2], Wiam Yahya Rasheed Al-Shakarchy [3], Waleed badrideen Mahmood Allela [4]
[1]Hort. & Landscape Design Department, College of Agriculture and Forestry, Mosul University. Iraq, weaam.yehya@uomosul. edu.iq
[2]Hort. & Landscape Design Department, College of Agriculture and Forestry, Mosul University. Iraq , shamil@uomosul.edu.iq
[3]Field Crop Department, College of Agriculture and Forestry, Mosul University. Iraq, amer_ah_juboori@uomosul.edu.iq
[4]Therapeutic Nutrition Techniques Department, AL-Noor University – College of Health and Medical Techniques, waleed.badrideen@alnoor. edu.iq

Abstract .
The study was conducted under the conditions of Nineveh Governorate - Iraq on the nature of inheritance of some growth and yield traits of two imported potato varieties of the E rank (Bada and Sefra) under the influence of three planting dates (1/2/2024, 10/2/2024 and 20/2/2024, during the spring growing season of 2024/2025 at the College of Agriculture and Forestry / University of Mosul as a factorial experiment with sixtreatments according to a complete randomized block design and three replicatThe results of the analysis of variance indicate that there are significant differences between the two cultivars for all the studied traits except for the traits of total number of tubers per plant and number of marketable tubers per plant. The moral superiority of the Sefra cultivar over the Bada cultivar was for the yield traits represented by the total yield per plant and the total yield of tubers, while the moral superiority of the Bada cultivar over the Sefra cultivar was for the traits of the marketable yield per plant and the marketable yield of tubers. The first planting date 1/2/2024 showed a significant superiority over the other two dates for the yield traits represented by the total yield per plant, the total yield of tubers, the marketable yield per plant and the marketable yield of tubers. The Bada cultivar plants planted on the first date gave the best values for the yield traits represented by the total yield per plant, the total yield of tubers, the marketable yield per plant and the marketable yield of tubers. Genetic and environmental variances were significantly greater than zero for all traits. Broad-sense heritability was high for plant height, number of aerial stems, average total and marketable tuber weight, marketable plant yield, and marketable tuber yield. High heritability indicates that the appearance of an individual is strongly related to its genetic makeup, which suggests that direct improvements can be made to these traits in the following seasons. Expected genetic improvement values as a percentage of mean were high for number of aerial stems, medium for plant height, average total and marketable tuber weight, and low for the other traits.
Keywords: *Planting dates, inheritance and genetic improvement, potato.*

INTRODUCTION .

Potatoes (*Solanum tuberosum* L.) are the world's fourth most important food crop (after rice, wheat and maize) in terms of production (Razdan and Mattoo, 2005).Worldwide, more than 320 million tons of potatoes are grown annually on 20 million hectares of land (FOA, 2010) . Potato is a good food security crop as it produces large amounts of food energy (30-35 tons/ha starch in 3-4 months) and its production is relatively stable under current conditions where production of other crops may decline (Gebremedhin et al., 2008; FOA, 2010).High crop yields require knowledge of the nature and amount of variation in genetic stocks because genetic variations are desirable for plant breeders, and the success of any breeding program must depend on the desirable genetic variants present in the plant community. Without the occurrence of these variants, plant species that surpass their parents in productive and qualitative traits would not exist.Researchers have divided phenotypic variation into environmental variation, which is the difference between plants with identical genetic compositions and grown in different environmental conditions. The appearance of the trait is the final result of the interaction of genetic composition and environment. Phenotypic variation occurs as a result of genetic and environmental influences, and genetic variation, which is the difference between plants with dissimilar genetic compositions and grown in the same or controlled environmental conditions (Al-Sahouki, 1990).Environmental differences may mask genetic differences, so the more phenotypic differences there are between individuals within a single genetic makeup and the reasons for them are due to environmental variation, the more difficult it becomes to select for genetic differences. On the other hand, the less the effect of the environment on changing the trait compared to genetic differences, the more effective selection will be because most of the traits of the selected plants will be inherited by the offspring (Al-Mufarji, 2006). Hence the need to find a quantitative measure to describe the extent of the environment's influence on traits. This measure is known as the degree of heritability. The heritability ratio represents the ratio between the components of the genetic variance of the trait to the phenotypic variance. This is what is expressed as heritability in the broad sense. Heritability plays an important role in choosing the appropriate method for breeding and improving desired traits. Selection is based on it, especially if its value is high. Selection is affected by the variations in the community in which selection is required, the intensity of selection and heritability, and these factors enter together into the equation for estimating the expected genetic improvement of the quantitative trait. Estimating genetic improvement (Genetic Advance) is the largest application of the quantitative genetics theory in plant breeding and improvement programs (Al-Kamer, 1999).Planting timing for potatoes is as important as for other vegetable crops, and depends largely on the location and each production area has an “optimum” planting period during which conditions are favourable for the highest potential yield in a given season (Thornton and Nolte, 2005). However, there are no specific standards for planting potatoes.Accordingly, the current study aims to estimate the heritability rate, genetic and phenotypic variations, their coefficients, and the expected genetic improvement of the yield traits and their components for two potato varieties under study, under the influence of different planting dates under the conditions of Nineveh Governorate, for the purpose of selecting the best of these traits in subsequent early generations, and more effectively to continue the good ones in future breeding programs for this crop.

Materials and Methods .

This study was carried out in the vegetable field of the Department of Horticulture and Landscape Engineering / College of Agriculture and Forestry / University of Mosul / Mosul city, which is located at latitude 36.35 degrees north and longitude 43.15 degrees east, and is 223 meters above sea level (Guest, 1966), with the aim of estimating some genetic parameters under the conditions of Nineveh Governorate for two imported potato varieties of the E rank, namely (Bada and Sefra) under the influence of three planting dates (1/2/2024, 10/2/2024, and 20/2/2024).he seeds of the two varieties were planted at the above dates on 3 m long rows with a distance of 25 cm between one tuber and another and 75 cm between one row and another. It was carried out as a factorial experiment with three replicates within a Randomized Complete Block Design, so that the number of treatments became eight (2×3=6). Each treatment was represented by two rows, so that the number of experimental units became (2×3×3×2=36) experimental units. Agricultural service operations were carried out equally for all treatments (Matloub et al., 1989).Data were recorded for ten randomly selected plants for each experimental unit. Data were statistically analyzed using SAS (2010) software, and Duncan's multiple range test was used to compare mean values at 0.05 probability level.Estimate the phenotypic, genetic and environmental variance and the coefficient of phenotypic and genetic variation according to (Steel and Torrie, 1980).

$\delta^2 P = \delta^2 G + \delta^2 E$

Whereas:

($\delta^2 P$) Phenotypic variance

($\delta^2 G$) Genotypic variance

($\delta^2 E$) Environmental variance

$\delta^2 G = (\delta^2 \text{ Cultivars} - \delta^2 E) / RB$

Whereas:
Mean square of Cultivars= δ^2 Cultivars
δ2 E= Mean squared experimental error
δ^2 E = Mse
R= Number of iterations
Mulching types (3) = B
100. × = ($\sqrt{\ }$ δ^2 P / Ỹ) PCV %
100. × GCV % = ($\sqrt{\ }$ δ^2 G / Ỹ)
Whereas:
(PCV) Phenotypic Coefficients of Variation
(GCV) Genotypic Coefficients of Variation
(Ỹ) is the arithmetic mean of the trait.
Heritability broad sense H2(b.s) was estimated according to (Hanson et al., 1955) and the following equation:
100 . × δ^2 P)/ H^2(b.s)= (δ^2 G
The expected genetic improvement E.G.A. was estimated based on the equation given by Kempthorne (1969) as follows.
δ^2 P)]. $\sqrt{\ }$ E.G.A. = [(K H^2(b.s)
Whereas:
(E.G.A) Expected Genetic Advance
K = 2.06 which is the selection intensity for 5% of the plants.
The expected genetic improvement was estimated as a percentage of the arithmetic mean (E.G.A.%) as follows:
100. × δ^2 P) / Ỹ] $\sqrt{\ }$ = [(K H^2(b.s) %E.G.A.

Result and Discussion .

Table (1) shows the results of the analysis of variance for the studied traits in potatoes, which shows that the two varieties showed significant differences among themselves for all the studied traits except for the traits of total number of tubers per plant and number of marketable tubers per plant, which were significant at a probability level of 0.01 for the traits of plant height, number of aerial stems, average total tuber weight, and average marketable tuber weight, and at a probability level of 0.05 for the traits of total plant yield, total tuber yield, marketable plant yield, and marketable tuber yield. The existence of such significant differences between varieties is necessary to study their genetic behavior with the aim of selecting the best and improving them. The existence of these differences and variations between varieties is the basic material for plant breeders with the aim of exploiting them by deriving new hybrids that are superior in one or more traits.The three planting dates showed significant differences at 0.01 probability level for all the studied traits. The differences between the interaction (variety × planting dates) reached the level of significance at 0.05 probability level for the trait of average tuber weight and at 0.01 probability level for the rest of the traits. The presence of significant effects of genetic interaction (variety × environment (planting dates) indicates that the contribution of the interaction (variety × environment) for these traits measured on the total variance was high, which indicates that this interaction will have a significant impact on future breeding programs. This is in line with what was reported by Mishra et al. (2017), Al-Zebari et al. (2021) , Rohit et al. (2022), Naiem et al. (2022), Seid et al. (2023), Singh et al. (2024) and Agha et al. (2024 a , b) about the presence of significant differences between varieties for growth and yield traits in potato.

Table (1): Analysis of variance for the studied traits in potatoes, which represent the mean square values.

		Mean Squares									
S D	D f	h p (cm)	N a s (s. p-1)	T n t(t. p-1)	N m t(t. p-1)	A t w (g. p-1)	A m w t (g. p-1	T y p (g. p-1)	T y t (t. ha-1)	M y p (g. p-1)	M y t (t. ha-1)
R	2	0.430	0.0451	0.050	0.007	0.586	4.587	411.896	1.171	402.055	1.104
V	1	357.781 **	2.000 **	1.100	1.165	655.823 **	710.896 **	4507.604 *	12.820 *	9321.122 *	26.503 *
S C	2	165.263 **	1.013 **	5.722 **	5.423 **	582.415 **	65.702 **	207295.019 **	589.571 **	191017.388 **	542.36 ** 9
S C ×V	2	345.875 **	0.500 **	10.753 **	8.577 **	167.515 **	17.926 *	322047.154 **	915.932 **	275103.388 **	783.38 ** 0
E E	10	0.551	0.074	0.227	0.295	2.618	4.520	469.510	1.334	213.555	0.612

* and ** are significant at the 0.05 and 0.01 probability levels, respectively.Sources of difference / S D Replicate / R Varieties / v Soil Cover/ S C Varieties ×Soil Cover/ S C ×V Experimental Error/ E E degrees of freedom/ D f Height of the plant (cm)/ h p Number of aerial stems (stem. plant-1)/ N a s (s. p-1) Total number of tubers of the plant (tuber. plant-1) / T n t(t. p-1) Number of marketable tubers of the plant (tuber. plant-1) / N m t(t. p-1) Average total tuber weight (g. plant-1) / A t w (g. p-1) Average marketable weight of tuber (g. plant-1 / A m w t (g. p-1 Total yield of plant (g. plant-1) / T y p (g. p-1) Total yield of tubers (tons. ha-1) / T y t (t. ha-1) Marketable yield of plant (g. plant-1) / M y p (g. p-1) Marketable yield of tubers (tons. ha-1) / M y t (t. ha-1) .The results of Table 2 show that the Bada variety is superior in plant height, number of aerial stems per plant, marketable yield per plant, and total yield per unit area, while the Sefra variety is superior in tuber weight rate, plant yield, and total yield per unit area. This difference in the results is due to the difference in genetic traits of both varieties under study (Haile et al., 2015).

Table (2): Effect of varieties on the growth and yield of potatoes.

Varieties	Studied attributes									
	h p (cm)	N a s (s. p-1)	T n t(t. p-1)	N m t(t. p-1)	A t w (g. p-1)	A m w t (g. p-1	T y p (g. p-1)	T y t (t. ha-1)	M y p (g. p-1)	M y t (t. ha-1)
Al Bada	67.69 a 4	2.86 1 a	8.19 6 a	6.63 0 a	134.15 7 b	164.30 3 b	1115.4 0 b	59.48 4 b	1092.8 9 a	58.28 6 a
Sefra	58.77 7 b	2.19 4 b	7.70 2 a	6.12 1 a	146.23 0 a	176.87 2 a	1125.6 1 a	60.02 9 a	1086.0 0 b	57.91 7 b

• The means that carry the same alphabetical letters do not differ significantly from each other according to Duncan's multiple range test at a probability level of 0

Table 3 shows the superiority of the first planting date on 1/2/2024 in most of the vegetative growth characteristics and yield characteristics, represented by the number of aerial stems per plant, the total number of tubers per plant, the number of marketable tubers per plant, the average total tuber weight, the average marketable tuber weight, the total yield per plant, the total yield of tubers, the marketable yield per plant, and the marketable yield of tubers compared to the planting date on 10/2/2024, which gave the lowest values for these characteristics, while the date 20/2/2024 gave the highest increase in the pat compared to the planting date 10/2/2024. The reason for this is that there is enough time to form a good vegetative group for the plant, which in turn led to an increase in the number of branches, the number of leaves, and an increase in the leaf area of the plant, which is reflected in an increase in metabolism and thus an increase in the yield of the pat. This study is consistent with what was found by Keleta et al. (2018).

Table (3): Effect of Planting Date on the growth and yield of potatoes.

Planting Date	h p (cm)	N a s (s. p-1)	T n t(t. p-1)	N m t(t. p-1)	A t w (g. p-1)	A m w t (g. p-1	T y p (g. p-1)	T y t (t. ha-1)	M y p (g. p-1)	M y t (t. ha-1)
1/2/2024	65.708 b	3.000 a	8.721 a	7.416 a	150.903 a	173.107 a	1314.30 a	70.092 a	1278.17 a	68.160 a
10/2/2024	57.208 c	2.333 b	6.851 b	5.553 b	138.163 b	166.840 b	943.72 c	50.328 c	923.50 c	49.262 c
20/2/2024	66.791 a	2.250 b	8.275 a	6.156 b	131.515 c	171.817 a	1103.51 b	58.850 b	1066.67 b	56.883 b

• The means that carry the same alphabetical letters do not differ significantly from each other according to Duncan's multiple range test at a probability level of 0.05.Table 4 shows the effect of interaction between varieties and planting dates. It appears from the table that the Bada variety is superior for the first planting date in the number of aerial stems, the total number of tubers per plant, the number of marketable tubers per plant, the total yield per plant, the total yield of tubers, the marketable yield per plant, and the marketable yield of tubers compared with the lowest values for the Sefra variety under the second planting date in the characteristics of the number of aerial stems, the total number of tubers per plant, and the number of marketable tubers per plant, or with the Bada variety under the third planting date in the characteristics of the total yield per plant, the total yield of tubers, the marketable yield per plant, and the marketable yield of tubers. The same variety under the second planting date gave the lowest values in the characteristics of the average weight of the total and marketable tuber per plant compared with the highest values for those characteristics and for the Sefra variety under the first planting date, while the Bada variety was superior under the third planting date in the characteristic of plant height, while the Sefra variety under the second planting date gave the lowest values in height. Plant

Table (4): The effect of interaction between varieties and planting dates on the studied traits in potatoes.

Varieties	planting dates	h p (cm)	N a s (s. p-1)	T n t(t. p-1)	N m t(t. p-1)	A t w (g. p-1)	A m w t (g. p-1	T y p (g. p-1)	T y t (t. ha-1)	M y p (g. p-1)	M y t (t. ha-1)
Al Bada	1/2/2024	61.750 d	3.500 a	10.073 a	8.686 a	149.580 a	168.297 c	1506.61 a	80.347 a	1461.67 a	77.954 a
	10/2/2024	68.000 c	2.833 b	7.483 b	6.110 c	133.127 c	160.983 d	996.25 d	53.130 d	983.67 bc	52.472 bc
	20/2/2024	73.333 a	2.250 cd	7.033 bc	5.093 d	119.767 d	163.630 d	843.34 e	44.976 e	833.33 c	44.432 c
Sefra	1/2/2024	69.666 b	2.500 bc	7.370 b	6.146 c	152.227 a	177.917 a	1121.99 c	59.836 c	1094.67 b	58.366 b
	10/2/2024	46.416 f	1.833 d	6.220 c	4.996 d	143.200 b	172.697 b	891.19 de	47.527 de	863.33 c	46.052 c
	20/2/2024	60.250 e	2.250 cd	9.516 a	7.220 b	143.263 b	180.003 a	1363.67 b	72.725 b	1300.00 a	69.333 a

• The averages that carry the same alphabetical letters for each factor and the overlap between them do not differ significantly from each other according to Duncan's multiple range test at a probability level of 0.05. The results of Table (5) show the values of phenotypic variances and their total genetic and environmental components and genetic parameters for the traits under study in potatoes. It is clear that the genetic and environmental variance was significant above zero for all traits. These results are consistent with what Luthra et al. (2018), Hu et al. (2022), Shetty et al. (2023), and Singh et al. (2024) reached regarding significant values of genetic and environmental variance for some traits.The results indicate that the environmental variance values were higher than the genetic variance values for the traits of total number of tubers per plant, number of marketable tubers per plant, total yield per plant, and total yield of tubers, and lower than that for the other traits.The results also showed that the highest values of the coefficient of genetic and phenotypic variation were for the number of aerial stems trait and the lowest for the total yield of tubers trait, which is consistent with what was obtained by Prajapati et al. (2020), Zeleke et al. (2021), Tessema et al. (2022), and Likeng-Li-Ngue et al. (2023). This can be explained by the fact that most of these traits are quantitative traits that are greatly affected by the environmental conditions surrounding the plant, and therefore selection is effective on the basis of external appearance values (Al-Mukhtar, 1988). It is clear that the values of the phenotypic coefficient of variation were much higher than the values of the genetic coefficient of variation for all traits, which indicates the significant role of the environmental effect (soil coverage) in the phenotypic change of traits to varying degrees.This genetic, phenotypic and environmental diversity of the studied traits leads to a high heritability of these traits under the influence of the studied planting dates. This may also be attributed to the presence of large variations between the two cultivars. The heritability values in the broad sense ranged between 0.246 for the trait number of marketable tubers per plant and 0.986 for the trait plant height. It is noted that they were high for plant height, number of aerial stems, average total and marketable tuber weight, marketable plant yield and marketable tuber yield, and medium for the traits total plant yield and total tuber yield, and low for the traits total and marketable tubers per plant.This high heritability indicates the importance of additive and non-additive effects of genes controlling the inheritance of these traits (Mather and Jinks, 1982). High heritability is evidence that the individual's appearance is closely related to its genetic makeup, which indicates the possibility of making direct improvements to these traits in the following seasons. It is also useful in choosing the appropriate breeding method (Allard, 1960). This is consistent with the findings of Asefa et al. (2016), Hunde et al. (2022), Rohit et al. (2022), and Singh et al. (2024) regarding high heritability.It is noted that the expected genetic improvement as a percentage of the average trait ranged between 2.719 for the total plant yield trait and 32.489 for the number of aerial stems trait, as it was high for this trait, while it was medium for the traits of plant height and the average total and marketable tuber weight, and low for the rest of the other traits. This is consistent with what was indicated by Singh et al. (2020), Al-Ajili (2021), Zeleke et al. (2021), Seid et al. (2023), Likeng-Li-Ngue et al. (2023) and Saleh et al. (2025) . The high heritability rate, which is consistent with the high values of genetic improvement, gives an indication of the prediction that we will obtain by selection, and thus it can be said that the method of total selection achieves the desired success (Welsh, 1981).

Table (5): The overall mean and components of phenotypic variation (genetic and environmental) and genetic parameters for the studied traits in potatoes.

G f	h p (cm)	N a s (s. p-1)	T n t(t. p-1)	N m t(t. p-1)	A t w (g. p-1)	A m w t (g. p-1	T y p (g. p-1)	T y t (t. ha-1)	M y p (g. p-1)	M y t (t. ha-1)
G V	39.692 17.213±	0.214 0.096±	0.097 0.053±	0.096 0.056±	72.578 31.553±	78.486 34.203±	448.677 217.375±	1.276 0.618±	1011.952 448.513±	2.876 1.275±
E V	0.551 0.208±	0.074 0.027±	0.227 0.085±	0.295 0.111±	2.618 0.989±	4.520 1.708±	469.510 177.458±	1.334 0.504±	213.555 80.716±	0.612 0.231±
P V	40.243	0.288	0.324	0.391	75.196	83.006	918.187	2.610	1225.507	3.488
G C V	9.962	18.306	3.918	4.860	6.076	5.193	1.890	1.890	2.919	2.919
P C V	10.031	21.236	7.160	9.808	6.185	5.340	2.704	2.703	3.213	3.214
H B S	0.986	0.743	0.299	0.246	0.965	0.945	0.488	0.489	0.825	0.824
E G A	12.885	0.821	0.351	0.317	17.238	17.736	30.462	1.627	59.495	3.170

E % G A	20.376	32.489	4.416	4.972	12.296	10.397	2.719	2.723	5.461	5.456
G A	63.236	2.527	7.949	6.375	140.193	170.587	1120.506	59.756	1089.444	58.101

Genetic features / G f / Genotypic Variance / G V / Environmental Variance / E V / Phenotypic Variance / P V / Genotypic Coefficients of Variance / G C V / Phenotypic Coefficients of Variance / P C V / Heritability Broad Sense / H B S / Expected Genetic Expected Genetic Advance E G A / General Average G A %Advance / E G A /

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