The effect of the variety and some agricultural treatments on the quality and quantity of Industrial potatoes

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Abstract
The experiment was conducted in Abu Ghraib District, Baghdad, during the spring season of 2022 to study the response of two potato varieties, Agria (v1) and Arsinal (v2), to eight different fertilizer levels [T1: Control, T2: Full recommended dose, T3: ½ recommended dose + phosphoric acid + humic acid, T4: ½ recommended dose + potassium, T5: ½ recommended dose + calcium, T6: ½ recommended dose + phosphoric acid + humic acid + potassium, T7: ½ recommended dose + humic acid + calcium, T8: ½ recommended dose + phosphoric acid + humic acid + potassium + calcium]. The experimental trial was conducted according to a factorial experiment in randomized complete block design with sixteen treatments and three replications. The results showed that the Arsinal variety had a higher average number of stems with 3.10 stems plant-1, while the Agria variety excelled in dry weight of vegetative system 36.637 grams plant-1. Regarding the treatments, T8 treatment showed the highest average plant height of 92.58 cm and 3.100 stems plant-1. For the tuber yield, T6 treatment outperformed in most traits, with 5.192 tubers plant-1, and 0.714 grams plant-1 for average tuber weight. The same treatment also resulted in the highest plant yield of 0.789 kg plant-1. In terms of qualitative traits, the Arsinal variety outperformed in most traits, with the highest average tuber hardness of 8.334 grams dm2, , 21.367% dry matter, and the lowest sugar content of 1.458%. T6 treatment also excelled in the qualitative traits under study; achieving 22.443% dry matter and 1.382% sugar content.

Keywords: Potato, Manufacturing potatoes, Industrial potatoes

Introduction

Potato (Solanum tuberosum L.) is one of the most important vegetable crops, rich in nutrients and energy, it is widely used and tops the list of tuber crops, it plays a crucial role in the human diet by providing suitable food to meet the increasing nutritional requirements due to the global population explosion, it ranks fourth globally as a strategic and economic crop, following wheat, maize, and rice [6.[

Potato is a versatile crop with multiple uses. Most of the production is used for food consumption, accounting for 54% of household consumption. Processed potato products constitute 8% of the total potato production. In recent years, there has been a shift in consumption patterns from fresh potatoes to processed potatoes. The demand for pre-prepared potato products, such as potato fingers, in factories is estimated to be around 11 million tons annually, this sector has witnessed significant development in many countries worldwide, with several factories established for this purpose [5].The demand for raw materials in the manufacturing of these varieties is focused on

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elongated or oval-shaped tubers with a medium to large size with superficial eyes, free from deformities, and having a good dry matter and starch content, with low sugar content [7.[

The varieties differ from each other in terms of growth nature, maturity, quantity and quality of the yield, resistance to prevalent diseases in the region, as well as various other characteristics such as skin color, flesh color, number and depth of eyes, and other traits. The superiority of any potato variety cannot be determined unless it is planted under the same conditions and in a comparable environment. [10.[

Potatoes are stressful crops to the soil that have a high affinity for absorbing nutrients from the soil. Therefore, it is necessary to provide them with appropriate quantities of nutrients in order to increase the yield and improve its quality per unit area [6]. Mineral fertilizers are considered one of the solutions to increase production and overcome the problem of global food security. The most important mineral fertilizers are nitrogen, phosphorus, and potassium. Nitrogen contributes to the construction and formation of protoplasm by entering into protein synthesis. It also participates in the formation of enzymes, nucleic acids, and some hormones. Phosphorus is involved in the formation of nucleic acids and energy-rich compounds (ATP), and it plays a role in activating the carbon metabolism process and the formation of enzyme co-factors. It also encourages root growth and improves nutrient uptake [9.[

Research Objective

Due to the increasing demand for high-quality processed potatoes and the growth and spread of factories that require specific varieties, coupled with farmers' adherence to cultivating specific varieties and the availability of seeds (tubers) for specific varieties, as it relies on external imports, the current research aims to determine the manufacturing specifications of some locally cultivated potato varieties and their susceptibility to preparation and processing factors, in order to identify the most suitable treatments to obtain a superior product within the same variety, whether for household or commercial use.

Materials and methods

The experiment was conducted in a private field in the Al-Ridwaniyah Al-Gharbiyah area, southwest of Baghdad, during the spring season of 2022. Two potato varieties, Agria (V1) and Arsinal (V2), were studied at the Elite level, along with various agricultural treatments, to assess quantitative and qualitative traits. The potato tubers were planted on January 15, 2022, with a furrow length of 8 meters and a spacing of 75 cm between furrows and 25 cm between tubers. The experimental unit consisted of 32 plants in a single row, with three furrows per experimental unit and three replications. Soil samples were taken at depth of 0-30 cm before planting and the chemical and physical properties of field soil was determined (Table 1). The treatments applied were as follows:

T1: Control (no additives.(

T2: Full fertilizer recommendation

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T3: ½ fertilizer recommendation + phosphoric acid + humic acid.
T4: ½ fertilizer recommendation + foliar potassium ion
T5: ½ fertilizer recommendation + foliar calcium.
T6: ½ fertilizer recommendation + phosphoric acid + humic acid + potassium.
T7: ½ fertilizer recommendation + humic acid + calcium.
T8: ½ fertilizer recommendation + humic acid + phosphoric acid + potassium + calcium.

Table 1. Chemical and physical properties of field soil

Parameter	Value	Unit
pH 1:1	7.52	-
Ec 1:1	2.19	dS m^{-1}
N	48	mg kg^{-1}
P	8	mg kg^{-1}
K^+	135	mg kg^{-1}
Ca^{2+}	14.2	meq L^{-1}
Mg^{2+}	7.8	meq L^{-1}
Na^+	4.4	meq L^{-1}
Cl^-	4.1	meq L^{-1}
SO_4^{2-}	5.9	meq L^{-1}
HCO^{3-}	16.3	meq L^{-1}
Organic matter	25	g kg^{-1}
Sand	281	g kg^{-1}
Silt	558	g kg^{-1}
Clay	180	g kg^{-1}
Bulk density	1.3	Mg m^{-3}
Soil Texture	**Silty caly loam**	

The following traits were studied:

-1 Plant height (cm): The measurement was taken from the soil surface to the top of the tallest stem at the end of the season for selected plants, and the average was calculated.

-2 Number of main stems per plant.

-3 Dry weight of total vegetative biomass (g plant-1): Five plants were randomly cut four days before the end of the season from each experimental unit from the area where the stem touched the soil and were first placed in a regular room containing electric heaters to dry, then transferred to an electric oven at a temperature of 65-70 °C until the weight stabilized ,

-4 Number of tubers plant-1: It was calculated as follows: the number of marketable tubers per plant = the number of marketable experimental unit tubers/ the number of experimental unit plants.

-5 Average tuber weight (g plant-1): Calculated as the total weight of tubers in the experimental unit divided by the total count of tubers in the experimental unit.

-6 Yield per plant (kg plant-1): Calculated as the total yield of the experimental unit divided by the total count of plants in the unit.

-7 Tuber hardness (kg 0.50 cm^{-2}): Measured using a penetrometer with a metal probe area of 0.5 cm^2, with multiple readings

taken for each tuber, and the average was calculated.

-8 Percentage of dry matter in tubers (%): Five randomly selected tubers from each experimental unit were cut into small pieces, dried in an electric oven at 65-70°C until a constant weight was achieved, and the percentage of dry matter was calculated. As mentioned by [4]. after which it was weighed and the percentage of dry matter was calculated according to the following equation:

The percentage of dry matter = (dry weight of tubers / tuber fresh weight) x 100.

-9 Total sugar concentration in tubers: Determined according to the [12.[

Result and discussion

Vegetative growth traits

Plant height (cm(

The results showed that there were no significant differences between the two varieties under study. However, the fertilizer treatments revealed significant differences. Treatment T8 exhibited the highest mean plant height of 92.58 cm, while the control treatment (T1) had a mean plant height of 65.48 cm. The results indicates significant interaction between fertilizer treatments and the variety. The interaction treatment V2 T8 had the highest mean plant height of 93.20 cm, while treatment V2T2 had the lowest mean height of 61.23 cm.

Table 2: Effect of variety and fertilizer treatments and interaction on plant height (cm)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	**69.07**	**61.90**	**65.48**
T2	**73.77**	**61.23**	**67.50**
T3	**76.17**	**84.90**	**80.53**
T4	**76.10**	**74.53**	**75.32**
T5	**69.67**	**74.40**	**72.03**
T6	**90.70**	**91.57**	**91.13**
T7	**81.70**	**88.57**	**85.13**
T8	**91.97**	**93.20**	**92.58**
Mean variety (V)	**78.64**	**78.79**	
LSD 0.05	**V**	**T**	**T x V**
	Ns	**2.91****	**4.11****

Number of stem per plant

The results showed significant differences between the varieties (Table 3), with the V2 variety outperforming with 3.1 stems per plant compared to the V1 variety with a lower average number of stems of 2.69 stems plant-1. The results of the fertilizer treatments showed clear significant differences, with the T3 treatment outperforming with 3.1 stems plant-1 compared to the control treatment of 2.7 stems plant-1. The results also indicate significant interaction between the fertilizer treatments and the variety, with the V2T7 interaction treatment outperforming with the highest average of 3.5 stems per plant, while the V1T4 treatment gave the lowest average of 2.47 stems per plant.

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Table 3: Effect of variety and fertilizer treatments and interaction on number of stem per plant-1

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	2.50	2.90	2.70
T2	2.97	2.87	2.92
T3	2.73	3.47	3.10
T4	2.47	2.73	2.60
T5	2.70	3.10	2.90
T6	2.93	3.07	3.00
T7	2.60	3.50	3.05
T8	2.63	3.20	2.92
Mean variety (V)	2.69	3.10	
LSD 0.05	V	T	T x V
	0.14**	0.28*	0.40*

Vegetative dry weight (gm plant-1(

The results revealed no significant differences between the two varieties (Table 4). The results of the fertilizer treatments showed clear significant differences, with the T6 treatment outperforming with the highest average vegetative dry weight of 58.443g while the control treatment T1 recorded the lowest average of 36.360 g. The results also showed significant interaction between the fertilizer treatments and the variety, with the V1T6 interaction treatment outperforming with the highest average of 60.137g, while the V2T1 treatment gave the lowest average of 36.083 g-1.

Table 4: Effect of variety and fertilizer treatments and interaction on vegetative dry weight (gm plant-1)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	36.637	36.083	36.360
T2	42.507	40.970	41.738
T3	48.433	48.673	48.553
T4	44.280	42.600	43.440
T5	46.347	46.273	46.310
T6	60.137	56.750	58.443
T7	53.800	49.583	51.692
T8	57.383	56.150	56.767
Mean variety (V)	36.637	36.083	
LSD 0.05	V	T	T x V
	0.4416	0.8838	1.25

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Yield characters

Number of tubers plant-1

The results indicate significant differences between the varieties (Table 5), with the V2 variety outperforming with an average of 5.05 tubers plant-1, compared to the V1 variety which had a lower average number of tubers of 4.65 tubers plant-1. The results of the fertilizer treatments showed significant differences, with the T8 treatment outperforming with the highest average of 5.08 tubers plant-1, while the T4 treatment recorded the lowest average of 4.53 tubers plant-1. The results also showed significant interaction between the fertilizer treatments and the variety, with the V1T6 interaction treatment outperforming with the highest average of 5.21 tubers plant-1, while the V1T4 treatment had the lowest average of 4.17 tubers plant-1.

Table 5: Effect of variety and fertilizer treatments and interaction on number of tubers (tuber plant-1)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	**4.90**	**4.73**	**4.83**
T2	**4.27**	**5.22**	**4.75**
T3	**4.75**	**5.08**	**4.91**
T4	**4.17**	**4.90**	**4.53**
T5	**4.67**	**5.17**	**4.92**
T6	**5.21**	**5.17**	**5.19**
T7	**4.16**	**5.03**	**4.59**
T8	**5.09**	**5.07**	**5.08**
Mean variety (V)	**4.65**	**5.05**	
LSD 0.05	**V**	**T**	**T x V**
	0.193	**0.387**	**0.547**

Average tuber weight (g plant-1(

The results indicated significant differences between the varieties (Table 6), with the V1 variety outperforming by with an average tuber weight of 5.27 grams per plant, compared to the V2 variety which had a lower average tuber weight of 0.473 grams plant-1. The results of the fertilizer treatments showed a significant differences, with the T6 treatment outperforming and with the highest average tuber weight of 0.714 grams plant-1, while the control treatment T1 recorded the lowest average tuber weight of 0.331 grams plant-1. The results also showed significant interaction between fertilizer treatments and the variety, with the V1T6 treatment outperforming and with the highest average of 0.789 grams plant-1, while the V1T1 treatment had the lowest average of 0.321 grams plant-1.

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Table 6: Effect of variety and fertilizer treatments and interaction on Average tuber weight (g plant-1)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	0.321	0.34	0.331
T2	0.466	0.404	0.435
T3	0.587	0.517	0.552
T4	0.471	0.451	0.461
T5	0.451	0.421	0.436
T6	0.789	0.639	0.714
T7	0.437	0.407	0.422
T8	0.696	0.601	0.648
Mean variety (V)	0.527	0.473	
LSD 0.05	V	T	T x V
	0.0038	0.0077	0.0109

Yield per plant (kg plant-1:(

The results indicate a significant difference between the varieties (Table 7), with the V1 variety outperforming by with an average yield of 0.582 kg plant-1, compared to the V2 variety which had a lower average yield of 0.527 kg plant-1. The results of the fertilizer treatments showed significant differences, with the T6 treatment outperforming and with the highest average yield of 0.769 kg plant-1, while the control treatment T1 recorded the lowest average yield of 0.385 kg plant-1. The results showed significant interaction between the fertilizer treatments and the variety, with the V1T6 treatment outperforming with the highest average of 0.844 kg plant-1, while the V1T1 treatment had the lowest average of 0.376 kg plant-1.

Table 7: Effect of variety and fertilizer treatments and interaction on yield per plant (kg plant-1)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	0.376	0.395	0.385
T2	0.521	0.459	0.49
T3	0.641	0.572	0.607
T4	0.526	0.506	0.516
T5	0.506	0.476	0.491
T6	0.844	0.693	0.769
T7	0.491	0.462	0.477
T8	0.75	0.656	0.703
Mean variety (V)	0.582	0.527	
LSD 0.05	V	T	T x V
	0.0038	0.0077	0.0109

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The qualitative traits showed the highest average hardness value of 11.178 kg/cm², while the T1 control treatment recorded the lowest average hardness value of 5.302 kg/cm². the interaction between the varieties and treatments, the results showed high significance. The V2T8 treatment achieved the highest average value of 11.46 kg/cm², while the V1T1 treatment yielded the lowest average value of 5.183 kg/cm².

Tuber hardness (kg 0.50 cm-²:(

The results revealed a significant differences between the varieties in tuber hardness (Table 8). The V2 variety exhibited the highest average value for tuber hardness (8.334 kg/cm²), compared to the V1 variety which had the lowest average value of 7.93 kg/cm². As for the effect of the studied treatments on this trait, the T8 treatment

Table 8: Effect of variety and fertilizer treatments and interaction on Tuber hardness (kg 0.50 cm-²)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	**5.183**	**5.420**	**5.302**
T2	**6.360**	**6.500**	**6.430**
T3	**6.720**	**6.757**	**6.738**
T4	**7.210**	**7.753**	**7.482**
T5	**9.100**	**9.847**	**9.473**
T6	**7.863**	**8.260**	**8.062**
T7	**10.103**	**10.673**	**10.388**
T8	**10.897**	**11.460**	**11.178**
Mean variety (V)	**7.930**	**8.334**	
LSD 0.05	**V**	**T**	**T x V**
	0.0578	**0.1157**	**0.1636**

Tuber dry matter:(%)

The results showed no significant differences between the two varieties (Table 9). However, the results of the fertilizer treatments demonstrated clear significant differences. The T6 treatment outperformed with tuber dry matter of 22.443% higher than the control treatment T1 (19.942%). The results of also showed significant interaction between the fertilizer treatments and the variety. The V2T6 interaction treatment outperformed with the highest average of 22.750%, while the V2T1 treatment recorded the lowest average of 19.857%.

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Table 9: Effect of variety and fertilizer treatments and interaction on tuber dry matter (%)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	20.027	19.857	19.942
T2	20.427	20.233	20.330
T3	21.547	21.720	21.633
T4	21.193	21.337	21.265
T5	21.053	21.183	21.118
T6	22.137	22.750	22.443
T7	21.940	21.870	21.905
T8	22.270	21.987	22.128
Mean variety (V)	21.324	21.367	
LSD 0.05	V N.S	T 0.1569	T x V 0.2218

Total sugar concentration(%)

The results revealed a significant difference between the varieties in sugar content (Table 10). The V1 variety had the highest average of 1.74%, compared to the V2 variety, which had the lowest average of 1.45%. The results of the fertilizer treatments showed significant differences, with the T1 treatment yielded the highest sugar content with an average of 1.94%, compared to T8 treatment with the lowest average of 1.19%. Regarding the interaction between the varieties and the fertilizer treatments, the results revealed a highly significant. The V1T1 interaction treatment achieved the highest average of 2.01%, compared to the lowest average obtained by the V1T8 treatment at 1.13%.

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Table 10: Effect of variety and fertilizer treatments and interaction on Total sugar concentration (%)

Fertilizer treatments	Varieties (T) V1	V2	Mean T
T1	2.01	1.87	1.94
T2	1.95	1.81	1.88
T3	1.41	1.28	1.35
T4	1.96	1.51	1.73
T5	1.86	1.69	1.77
T6	1.73	1.03	1.38
T7	1.89	1.20	1.54
T8	1.13	1.25	1.19
Mean variety (V)	1.74	1.45	
LSD 0.05	V 0.0188	T 0.0375	T x V 0.0531

Discussion

The variation between varieties in the vegetative growth traits may be attributed to the genetic factors specific to each variety. It is worth noting that all the tested combinations in this study, at their recommended concentrations, increased the vegetative growth traits of potatoes for both studied varieties. This is because they provided the plants with the necessary nutrients involved in carbon assimilation, respiration, protein synthesis, and the formation of essential nucleic acids (RNA and DNA) required for cell division [3].Providing plants with essential elements, particularly phosphorus, potassium, and calcium, enhances the vigor and activity of the vegetative biomass in plants, which positively reflects on increased yield. Additionally, these elements play a crucial role in the transport of manufactured nutrients in leaves to their storage sites in the tubers [11].On the other hand, organic fertilizers contain various water-soluble organic compounds, such as sugars, proteins, amino acids, and organic acids, which directly or indirectly contribute to plant growth and development. They can act as growth promoters through enzymatic or hormonal activities, as they contain nutrients required by the plant. They can also enhance the availability of existing nutrients in the soil or added to it, thereby increasing production and improving its quality [2.[

Tables (7, 8, and 9) clearly indicate a significant increase in most quality characters of industrial potato tubers with the increase in the studied factors' concentrations. This may be attributed to the role of these factors in various physiological processes within the plant, such as controlling transpiration by regulating stomatal opening and closure, nutrient absorption, and enhancing the plant's resistance to unfavorable environmental conditions [8].This improves carbon assimilation and increases carbohydrate production, resulting in positive effects on the vegetative growth characters. Alternatively, the increase in vegetative growth characters

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may be attributed to the role of these factors in promoting carbon assimilation, increasing the production of manufactured substances, and their subsequent transfer to the tubers, leading to positive effects on the yield's quality characters.

The use of these fertilizer combinations, rich in a wide range of nutrients and organic acids, contributed to increasing the availability and absorption of nutrients by the plant, resulting in an increase in vegetative growth characters such as plant height (Table 1), the number of main stems (Table 2), and the dry weight of the vegetative mass (Table 3). This led to an increase in carbon assimilation and a better accumulation of manufactured compounds such as carbohydrates, soluble amino acids, and organic acids, which are transported from the source sites in the leaves to the final sink sites in the tubers, where they are stored as dry matter, the ultimate product of carbon assimilation and metabolism. This results in an increase in the percentage of all quality characters for the studied yield (Table 7, 8, and 9), and all these traits are considered important quality criteria for potato tubers [1]. These traits are positively correlated with each other, as the physiological effect of absorbed nutrients, especially phosphorus, potassium, and calcium, plays a synergistic role in activating the enzymatic activity of carbon assimilation pathways and increasing the synthesis of amino acids. These amino acids are transported from the leaves to storage sites for protein formation through amino acid transporters in the plant [13 .[

Conclusion

The variety Arsenal produced the highest number of main stems, while the variety Acria excelled in the trait of dry weight of the vegetative group. The treatment of 1/2 fertilizer recommendation + phosphoric acid + humic acid + potassium + calcium resulted in superior plant height. Additionally, the treatment of 1/2 fertilizer recommendation + phosphoric acid + humic acid + potassium outperformed in both quantitative and qualitative yield traits.

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