EFFECT OF NITROGEN, PHOSPHOROUS AND POTASSIUM LEVELS ON THE PRODUCTIVITY OF INDUSTRIAL POTATOES

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ABSTRACT

The experiment was conducted using Potato(*Solanum tuberosum* L.) at the eastern Radwaniyah at private field during fall season 2020/2021 and spring 2021 to study the effect of nitrogen levels to 350, 275, 200 kg N h^{-1} (N_1, N_2, N_3) and phosphorous to 100, 180, 360 kg P_2O_5 h^{-1} (P_1, P_2, P_3) and potassium to 100, 200, 300 kg K_2O h^{-1} (K_1, K_2, K_3) to vegetative growth and yield of industrial potato, The seeds of the hybrid potato Sinora, Class A, were planted in the fall season on 15/9/2020 and Elite in the spring season on 31/1/2021. The experimental fertilizers were added in four batches and in proportions according to the stages of plant age, Factorial experiment with RCBD using three replications. The results showed that changing the levels of the elements used to N_3, P_3, K_3 led to a significant increases in most traits of vegetative growth for both seasons, while the change of phosphorous and potassium levels to P_2 and K_3 had a significant effect on the quantitative and qualitative yield for both seasons. The $N_1P_2K_3$ interaction gave the highest marketable tuber weight, marketable yield $plant^{-1}$, total yield for the fall and spring seasons, and the highest percentage of dry matter in tubers in the fall season.

Key words: *Solanum tuberosum* L., Macro nutrients, ground addition, Manufacturing.

تأثير مستويات النتروجين والفسفور والبوتاسيوم في انتاجية البطاطا الصناعية

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المستخلص

نفذت التجربة باستعمال البطاطا (*Solanum tuberosum* L.) في منطقة الرضوانية الشرقية في أحد الحقول الخاصة خلال الموسمين الخريفي2020/2021 والربيعي 2021 لدراسة تأثير تغير مستويات النتروجين الى 200 ,275 ,350 كغمN هـ$^{-1}$ (N_1 ,N_2 ,N_3) والفسفور الى100, 180, 360 كغمP_2O_5 هـ$^{-1}$(P_1, P_2, P_3) والبوتاسيوم الى 100, 200, 300 كغمK_2O هـ$^{-1}$ (K_1, K_2, K_3) في بعض مؤشرات النمو الخضري والحاصل لنباتات البطاطا الصناعية, زرعت تقاوي هجين البطاطا سينورا رتبة A في الموسم الخريفي بتاريخ 2020/9/15 ورتبة Elite في الموسم الربيعي بتاريخ 2021/1/31 وأضيفت الاسمدة أعلاه على اربعة دفعات وبنسب حسب مراحل عمر النبات, نفذت كتجربة عاملية بثلاثة عوامل(3×3×3) ضمن تصميم القطاعات تامة التعشية وبثلاث مكررات. أظهرت النتائج أن تغير مستويات العناصر الى N_3 وP_3 وK_3 قد أدى الى زيادة معنوية في معظم صفات النمو الخضري لكلا موسمي التجربة, بينما كان لتغير مستويات الفسفور والبوتاسيوم الى P_2 وK_3 تأثير معنوي واضح في صفات الحاصل الكمية والنوعية ولكلا موسمي التجربة. واعطت معاملة التداخل$N_1P_2K_3$ اعلى وزن درنة قابل للتسويق وحاصل قابل للتسويق للنبات الواحد وحاصل كلي للموسمين الخريفي والربيعي واعلى نسبة مئوية للمادة الجافة في الدرنات في الموسم الخريفي.

الكلمات المفتاحية: *Solanum tuberosum* L., العناصر الكبرى, الاضافة الارضية, التصنيع.

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INTRODUCTION

Potato crop (*Solanum tuberosum* L.) is considered one of the important vegetable crops in the world, belonging to the Solanaceae family, and it ranks fourth among the important food crops (17, 30), It is a rich source of carbohydrates, starch, protein and amino acids (20), and it provides raw materials for many food industries, as part of its production is used for home consumption, while the other part goes to the manufacturing process (32). Due to the substantial market need for potatoes in Iraq, this country has become a fruitful field for scientific research (5, 6, 14, 15, 16, 36, 37). Recent researchers efforts have been concentrated on processing potato varieties since the enormous market for chips and potato snacks (11, 12, 34). Mineral fertilizers are the best solution to increase production and overcome the global food problem, and three of the most important mineral fertilizers that potato plants need are nitrogen, phosphorous and potassium (18). Nitrogen contributes blocks in building and producing the protoplasm. It takes part in protein constructer (1). It also contributes in building enzymes and nucleic acids and some hormones. Phosphorous enters the composition of nucleic acids and energy-rich compounds (ATP) and has a role in activating the process of carbon metabolism and enters in the formation of enzymatic companions as it encourages root growth and then improves the absorption of nutrients. Potassium is one of the most abundant elements in the soil but It exists in an unfree form combined with other ions (27) It has a big role in regulating the providing nutrients and processed food from roots to vegetative growth and vice versa. It also help on regulating the osmotic effort of cells, which contributes to the process of root absorption of water, nutrients, and plays a prominent role in the process of opening and closing stomata, which affects the transpiration process (24), Several studies were showed that fertilizing potato plants with NPK fertilizers had led to a significant increases in most vegetative growth, such as plant height, number of leaves and leaves area (4, 8, 13, 21, 28, 29, 35). It also led to an increase in the quantitative and qualitative traits of the yield (26, 31). This study was aimed to obtain the best growth, yield and quality of industrial potato tubers ender NPK fertilizers.

MATERIALS AND METHODS

After preparing the land and carrying out the required agricultural operations, the field was divided into 81 agricultural plots (experimental units) with a length of 2.5 and a width of 1.0 m. Each agricultural plot contains 20 plants distributed on both sides of the agricultural board, the distance between one plant and another is 0.25 m, leaving a distance of 0.5 meters between the experimental units and 1.0 meters Between sectors to ensure that transactions do not overlap by planting the Senora hybrid in one of the private fields in the eastern Radwaniyah region within the work area of the Baghdad Agriculture Directorate – Al-Karkh on 15 / September 2020 for the fall season using class A seeds, and on January 31/2021 for the spring season using class E seeds. The experiment was carried out using factorial experiment with RCBD with three replications. This experiment included three factors and each factor had three levels, where the first level for each factor is according to the recommendation of Ali (2) and as the following: Nitrogen levels: 200, 275, 350 kg N hectare^{-1} and has the symbols N_1, N_2 and N_3. Phosphorous levels: 100, 180, 360 kg P_2O_5 hectare^{-1} and symbolized by the symbols P_1, P_2 and P_3. Potassium levels: 100, 200, 300 kg K_2O hectare^{-1} and symbolized by the symbols K_1, K_2 and K_3, The fertilizers were added in four stages and in proportions according to the stages of plant stage and as shows in Table1, where urea fertilizer (46% N) was used as a source of nitrogen and MAP fertilizer (52% P_2O_5) as a source of phosphorous and potassium sulfate (50% K_2O) as a source of potassium, and the compared using LSD with probating 0.05 (3). Vegetative Growth traits were measured as plant height (cm) and number of leaves (leaves plant^{-1}) and leaves area (dm^2 plant^{-1}) according to Sadik et al. (33), and traits of quantitative and qualitative yield such as marketable tuber weight (gm tuber^{-1}) and marketable yield of one plant (kg plant^{-1}), the total yield (ton h^{-1}) and the percentage of dry matter (%).

Table 1. shows the percentage of fertilizer used according to the stages of plant life

fertilizer type	The percentage of fertilizer from the total amount before planting	After of the plant emergence	Vegetative growth stage	tuber growth stage
N	20	40	30	10
P_2O_5	40	30	20	10
K_2O	10	20	20	50

RESULTS AND DISCUSSION

Plant height (cm): Results in Table 2 show that the average plant height was not significantly affected by the change in the levels of the mineral elements used in the study in the fall season, although the higher level of them gave the largest value of this trait, while in the spring season, the effect of changing the levels of the used elements was In the study, significantly in this trait, in nitrogen, the N_3 level gave the highest plant height of 76.85 cm, compared to the lowest height, which was 70.85 cm at the N_1 level. Length (72.03 cm), while potassium, the higher level (K_3) gave the highest plant height of 59.75% compared to K_1, which gave the lowest length of 70.96%. The results of the binary interaction between the study factors showed a significant effect on plant height for both seasons In the fall season, the interaction treatments N_2P_2, N_3K_1 and P_2K_2 gave the highest plant height, which was 86.88, 86.44 and 87.77 cm, respectively, compared to the treatments N_1P_2, N_1K_1 and P_1K_2, which gave the lowest plant height, which was 79.88, 75.66 and 76.88 cm, respectively. N_3P_3, N_1K_3 and P3K2 had the highest plant height at 78.44, 78.66 and 78.66 cm, respectively, while the treatments N_1P_2, N_1K_1 and P_1K_1 gave the lowest plant height at 67.33, 64.55 and 66.88 cm, respectively. In the same direction, there was a significant triple interaction between the study factors for both seasons, as the treatment $N_2P_2K_2$ excelled in the fall season by giving the highest plant height of 89.00 cm compared to the treatment $N_1P_2K_1$ which gave the lowest length of 74.33 cm, while the treatment of the interaction $N_1P_1K_3$ excelled in the spring season by giving the highest height For potato plants, it was 87.33 cm compared to the treatment $N_1P_1K_1$, which gave the shortest length of 61.00 cm.

Table 2. Effect of changing nitrogen, phosphorous and potassium levels and their interaction on the height of potato plants (cm) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
	P_1	77.67	75.00	88.67	80.44	61.00	61.33	87.33	69.89
N_1	P_2	74.33	86.67	78.67	79.89	66.67	63.33	72.00	67.33
	P_3	75.00	88.33	84.33	82.56	66.00	83.33	76.67	75.33
	P_1	82.67	79.33	87.33	83.11	66.33	75.67	72.67	71.56
N_2	P_2	83.33	89.00	88.33	86.89	76.67	70.67	69.33	72.22
	P_3	76.67	85.67	78.33	80.22	72.00	74.00	72.00	72.67
	P_1	84.00	76.33	84.67	81.67	73.33	77.33	73.33	74.67
N_3	P_2	87.00	87.67	75.67	83.44	82.67	75.33	74.33	77.44
	P_3	88.33	83.67	82.33	84.78	74.00	78.67	82.67	78.44
L.S.D 0.05			9.64		5.57		11.65		6.72
K		81.00	83.52	83.15		70.96	73.30	75.59	
L.S.D 0.05			N. S				3.88		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		75.67	83.33	83.89	80.96	64.56	69.33	78.67	70.85
N_2		80.89	84.67	84.67	83.41	71.67	73.44	71.33	72.15
N_3		86.44	82.56	80.89	83.30	76.67	77.11	76.78	76.85
L.S.D 0.05			5.57		N. S		6.72		3.88
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		81.44	76.89	86.89	81.74	66.89	71.44	77.78	72.04
P_2		81.56	87.78	80.89	83.41	75.33	69.78	71.89	72.33
P_3		80.00	85.89	81.67	82.52	70.67	78.67	77.11	75.48
L.S.D 0.05			5.57		N. S		6.72		3.88

Number of leaves plant^{-1}

Results in Table3 shows that the number of leaves of potato plants was significantly affected by the change in the levels of the experimental factors for both seasons, as the use of nitrogen at the level N_3, which gave the highest number of leaves of potato plants, with to 44.82 and 35.83 leaves plant^{-1} for both seasons. respectively, compared to 40.45 leaves plant^{-1} at the N_1 level for the fall season and 28.40 leaves plant^{-1} at the N_2 level for the spring season. It was also noted that the increase in the level of phosphorous used to P_3 in the fall season led to a significant increases in the number of leaves plant^{-1}, reaching 46.49 leaves plant^{-1}. compared to the level P_1, which gave 41.05 leaves plant^{-1}, while the change in the level of phosphorous led to a non-significant increase in this trait, as for potassium, we note that the K_3 level gave the highest number of leaves, which reached44.33 and 33.19 leaves plant^{-1} for the two seasons, respectively. Compared to the K_2 level, which gave 42.28 and 30.05 leaves plant^{-1}, respectively. As for the effect of the binary interaction between the factors of the study, we notice a significant effects on the number of plant leaves for both seasons, if the interaction between nitrogen and phosphorous leads to the appearance of significant differences in this trait and for both seasons, if the treatment N_3P_3 (47.42 leaves plant^{-1}) gave the highest number of leaves for the fall season, Treatment N_3P_2 (37.03 leaves plant^{-1}) gave the highest number of leaves in the spring season compared to treatment N_1P_1 (36.69 leaves plant^{-1}) in the fall season and treatment N_2P_2 (26.85 leaves plant^{-1}) in the spring season. The same applies to the interaction between nitrogen and potassium, as the treatment N_3K_3 excelled in the fall season with the highest number of leaves that reached 46.14 leaves plant^{-1} compared to the treatment N_1K_1 which gave 39.08 leaves plant^{-1} and the treatment N3K2 in the spring season (36.92 leaves plant^{-1}) compared to the treatment N_2K_2 (26.19). leaves plant^{-1}), and there was a significant interaction between phosphorous and potassium for both seasons, the treatment P_3K_2 (46.67 leaves plant^{-1}) in the fall season and the treatment P_2K_3 (34.73 leaves plant^{-1}) in the spring season compared to treatments P_2K_1 and P_2K_2 (37.67 and 27.69 leaves plant^{-1}) for the two seasons respectively, and the triple interaction showed the superiority of treatment $N_3P_3K_3$ in the fall season and treatment $N_3P_2K_2$ in the spring season by giving them the highest number of leaves reached 47.92 and 37.71 leaves plant^{-1} respectively compared to treatments $N_1P_2K_1$ and $N_2P_2K_2$, which gave the lowest number of leaves 33.17 and 20.88 leaves plant^{-1} for the two seasons, respectively.

Table 3. Effect of changing nitrogen, phosphorous and potassium levels and their interaction on the number of leaves of potato plants (leaves plant^{-1}) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
	P_1	38.50	36.00	35.58	36.69	27.96	25.42	31.58	28.32
N_1	P_2	33.17	40.42	44.83	39.47	27.31	24.50	34.23	28.68
	P_3	45.58	45.67	44.33	45.19	29.96	31.60	34.81	32.13
	P_1	45.67	39.67	43.50	42.94	31.25	31.50	30.25	31.00
N_2	P_2	38.33	41.25	44.93	41.51	25.56	20.88	34.13	26.85
	P_3	46.42	46.83	47.33	46.86	31.15	26.19	24.67	27.33
	P_1	46.00	40.50	44.00	43.50	30.35	35.58	36.67	34.20
N_3	P_2	41.50	42.67	46.50	43.56	37.54	37.71	35.83	37.03
	P_3	46.83	47.50	47.92	47.42	34.77	37.46	36.58	36.27
L.S.D 0.05			4.98		2.88		5.93		3.42
K		42.44	42.28	44.33		30.65	30.09	33.19	
L.S.D 0.05			1.66				1.98		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		39.08	40.69	41.58	40.45	28.41	27.17	33.54	29.71
N_2		43.47	42.58	45.26	43.77	29.32	26.19	29.68	28.40
N_3		44.78	43.56	46.14	44.82	34.22	36.92	36.36	35.83
L.S.D 0.05			2.88		1.66		3.42		1.98
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		43.39	38.72	41.03	41.05	29.85	30.83	32.83	31.17
P_2		37.67	41.44	45.42	41.51	30.14	27.69	34.73	30.85
P_3		46.28	46.67	46.53	46.49	31.96	31.75	32.02	31.91
L.S.D 0.05			2.88		1.66		3.42		1.98

Leaves area (dm^2 $plant^{-1}$)

Results in Table 4 shows that the leaves area was significantly affected by the increase in the levels of experimental factors for both seasons, as the increase in nitrogen level to N_3 gave the highest leaves area amounted to 120.43 and 116.07 dm^2 $plant^{-1}$ for the two seasons, respectively. Compared to the level N_1, which gave 111.55 dm^2 $plants^{-1}$ in the fall season, and the level N_2 which gave the least leaves area in the spring season, which amounted to 91.34 dm^2 $plants^{-1}$. The P_2 level reached 110.83 and 99.36 dm^2 $plant^{-1}$ for the two seasons, respectively. As for the effect of potassium in this trait, it was also significant, as the K_3 treatment in both seasons gave the highest leaves area of 118.01 and 106.37 dm^2 $plant^{-1}$, respectively, compared to the treatment. K_2 which gave 114.09 dm^2 $plant^{-1}$ in the fall season and 96.40 dm^2 $plant^{-1}$ in the spring season. As for the binary interaction between the studied factors, the treatments N_2P_3, N_3K_3 and P_3K_1 gave the highest leaves area of 129.25, 126.89 and 129.12 dm^2 $plants^{-1}$ in the fall season, compared to the lowest area of N_1P_1, N_1K_1 and P_1K_2 which was 100.55, 108.42 and 99.57 dm^2 $plants^{-1}$ for the same season, while the treatments N3P2, N_3K_3 and P_1K_3 recorded in the spring season the highest leaves area amounted to 118.25, 120.42 and 112.65 dm^2 $plant^{-1}$ compared to the treatments N_2P_2, N_1K_2 and P_2K_2 which gave the lowest leaves area amounted to 85.33, 87.19 and 92.90 dm^2 $plant^{-1}$. The same applies to the triple interaction between the factors of the study, as the treatment of the interaction $N_3P_1K_3$ excelled in the fall season with the highest leaves area of 138.42 dm^2 $plant^{-1}$ compared to the treatment $N_1P_2K_1$ which gave the lowest leaves area of 88.78 dm^2 $plant^{-1}$, while in the spring season the treatment $N_3P_1K_3$ excelled with the highest The leaves area was 138.51 dm^2 $plant^{-1}$ compared to the lowest leaves area which was at $N_2P_2K_2$ which was 74.8 dm^2 $plant^{-1}$.

Table 4. Effect of changing nitrogen, phosphorous and potassium levels and their interaction on the leaves area of potato plants (dm^2 $plant^{-1}$) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
N_1	P_1	102.29	99.05	100.30	100.55	88.78	78.27	106.75	91.27
	P_2	88.78	112.75	118.45	106.66	93.88	80.94	108.71	94.51
	P_3	134.19	122.39	125.72	127.43	104.55	102.36	118.20	108.37
N_2	P_1	127.20	100.96	111.72	113.29	104.48	96.06	92.69	97.74
	P_2	105.22	122.77	102.17	110.05	87.70	74.88	93.41	85.33
	P_3	128.56	136.03	123.17	129.25	104.60	91.97	76.32	90.96
N_3	P_1	136.20	98.72	138.42	124.45	107.81	107.69	138.51	118.00
	P_2	109.52	116.02	121.79	115.78	119.57	122.88	112.32	118.25
	P_3	124.61	118.13	120.44	121.06	112.92	112.54	110.43	111.96
L.S.D 0.05			10.31		5.95		10.04		5.80
K		117.39	114.09	118.02		102.70	96.40	106.37	
L.S.D 0.05			3.44				3.35		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		108.42	111.40	114.82	111.55	95.74	87.19	111.22	98.05
N_2		120.32	119.92	112.35	117.53	98.93	87.64	87.47	91.34
N_3		123.44	110.96	126.88	120.43	113.43	114.37	120.42	116.07
L.S.D 0.05			5.95		3.44		5.80		3.35
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		121.89	99.57	116.81	112.76	100.36	94.01	112.65	102.34
P_2		101.17	117.18	114.14	110.83	100.38	92.90	104.81	99.36
P_3		129.12	125.52	123.11	125.91	107.36	102.29	101.65	103.77
L.S.D 0.05			5.95		3.44		5.80		3.35

Marketable tuber weight (gm $tuber^{-1}$)

Results in Table 5 shows that the marketable tuber weight rate was not significantly affected by increasing nitrogen level, despite giving the second level the highest weight for the tuber and for the two seasons of the experiment. As for the effect of changing phosphorous levels in this trait, it was Significantly for both seasons, the highest marketable weight of the tuber was 96.72 and 134.56 gm. $tuber^{-1}$ at the P_2 level and for the two seasons of the experiment, respectively, compared to the lowest weight of 88.99 and 128.00 gm $tuber^{-1}$ at the P_1 level. In a similar way, the effect of potassium was significant. In this trait, the level K_3 gave the highest rate of 96.06 and

135.50 gm. tuber^{-1} for the two seasons respectively, compared to the lowest rate of 88.39 and 128.68 g tuber^{-1} at the level of K_2 for the two seasons of the experiment respectively. It appears from the data of the same table that the binary interaction between the study factors was significant in this trait and for both seasons, as the interaction treatment N_1P_2 in the fall season gave the highest weight of tuber 103.55 gm. tuber^{-1} compared to the lowest marketable weight of 86.02 gm. tuber^{-1} at N_1P_3, In the spring season, the N_2P_2 interaction gave the highest weight of 145.48 gm. tuber^{-1}, compared to the lowest weight of N_2P_1 which amounted to 125.66 gm. tuber^{-1}, and with the same effect, the interaction between nitrogen and potassium at the level N_2K_1 in the fall season N_1K_3 in the spring season led to the highest rate of tuber weight. The marketable value reached 100.80 and 136.61 gm. tuber^{-1}, respectively, compared to treatment N_2K_2 (83.42 gm. tuber^{-1}) in the fall season and treatment N_1K_2 (125.56 gm. tuber^{-1}) in the spring season. Fall season by giving the highest rate of 102.93 gm. tuber^{-1} compared to treatment P_1K_1 which gave 84.40 gm. of tuber^{-1}, and in the spring season treatment P_2K_3 excelled with the highest weight of 148.46 gm. tuber^{-1} compared to 125.97 gm. tuber^{-1} when treated P_2K_2. The triple interaction treatments for the study factors showed significant differences in the marketable tuber weight, as the treatment $N_1P_2K_3$ in the fall season topped the rest of the treatments by giving it the highest rate of marketable tuber weight of 127.95 gm. tuber^{-1} compared to the lowest rate of 79.91 gm Tuber^{-1} in the treatment $N_2P_3K_2$ and in the spring season Treatment $N_2P_2K_3$ had the highest marketable weight of tuber 160.10 gm. tuber^{-1}, which did not differed significantly from treatment $N_1P_2K_3$ which recorded 152.71 gm. tuber^{-1}, compared to the lowest weight of 113.86 gm. tuber^{-1} when treatment $N_2P_3K_3$.

Table 5. Effect of changing nitrogen, phosphorous and potassium levels and their interaction on the marketable tuber weight of potato plants (gm. tuber^{-1}) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
N_1	P_1	85.94	93.00	83.85	87.60	133.58	128.75	116.29	126.20
	P_2	84.59	98.11	127.96	103.55	126.13	114.47	152.71	131.11
	P_3	85.59	81.95	90.55	86.03	141.98	133.47	140.85	138.77
N_2	P_1	85.16	86.16	101.08	90.80	120.80	120.40	135.80	125.67
	P_2	118.83	84.20	97.47	100.17	136.66	139.67	160.11	145.48
	P_3	98.43	79.92	92.07	90.14	134.38	141.98	113.87	130.08
N_3	P_1	82.13	88.52	95.09	88.58	128.50	129.14	138.82	132.15
	P_2	87.78	88.16	83.39	86.44	124.99	123.77	132.56	127.11
	P_3	97.19	95.29	93.15	95.21	146.19	126.54	128.55	133.76
L.S.D 0.05			22.12		12.77		13.70		7.91
K		91.74	88.37	96.07		132.58	128.69	135.51	
L.S.D 0.05			7.37				7.37		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		85.37	91.02	100.79	92.39	133.90	125.56	136.62	132.03
N_2		100.81	83.42	96.87	93.70	130.62	134.02	136.59	133.74
N_3		89.03	90.66	90.54	90.08	133.23	126.48	133.31	131.01
L.S.D 0.05			12.77		n. s		7.91		n. s
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		84.41	89.22	93.34	88.99	127.63	126.09	130.30	128.01
P_2		97.07	90.16	102.94	96.72	129.26	125.97	148.46	134.57
P_3		93.73	85.72	91.92	90.46	140.85	134.00	127.76	134.20
L.S.D 0.05			12.77		7.37		7.91		7.37

Marketable plant yield (kg plant^{-1})

Results in Table6 shows that there is no significant effect of the change in nitrogen levels on the marketable yield of the plant, despite giving the highest yield with the increase in the levels used, while the same table shows that the increase in phosphorous and potassium levels led to increasing the yield of one plant, as the level P_2 and K_3 gave the highest yield of 0.474 and 0.495 kg plant^{-1}

for the fall season, respectively, and 0.576 and 0.590 kg plant^{-1} for the spring season, respectively, compared to the lowest yield, which was at the level P_1, which was 0.446 and 0.545 kg plant^{-1} for the two seasons in a row, and at K_2 it was 0.416 and 447 kg plant^{-1} for the both seasons of the experiment Sequentially. The results in the same table show that the interactions between the study factors led to significant differences in this trait, as the interaction treatments N_3P_3, N_1K_3 and P_2K_1 and in the fall season gave the highest value of 0.506, 0.523 and 0.505 kg plant^{-1}, respectively, compared to the lowest value of the treatments N_1P_1, N_1K_2 and P_1K_2 reached 0.420, 0.391 and 0.404 kg plant^{-1} respectively, while in the spring season, the binary interactions N_2P_2, N_1K_3 and P_1K_3 gave the highest yield of 0.599, 0.642 and 0.618 kg plant^{-1}, respectively, compared to 0.521, 0.522 and 0.503 kg plant^{-1} at N_1P_1, N_1K_2 and P_1K_1 treatments, respectively. With regard to the triple interaction between the levels of the studied factors, treatment $N_1P_2K_3$ excelled with the highest value of 0.584 and 665 kg plant^{-1} for the two seasons respectively compared to treatment $N_1P_3K_2$ (0.367 kg plant^{-1}) in the fall season and treatment $N_1P_1K_1$ (0.436 kg plant^{-1}) in the spring season.

Table 6. Effect of changing nitrogen, phosphorous and potassium levels and their interaction on the marketable yield of potato plants (kg plant^{-1}) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
	P_1	0.426	0.398	0.436	0.420	0.437	0.504	0.623	0.521
N_1	P_2	0.502	0.408	0.584	0.498	0.588	0.498	0.666	0.584
	P_3	0.425	0.368	0.549	0.447	0.549	0.563	0.638	0.583
	P_1	0.447	0.438	0.568	0.484	0.480	0.492	0.623	0.532
N_2	P_2	0.553	0.400	0.490	0.481	0.652	0.580	0.565	0.599
	P_3	0.458	0.392	0.419	0.423	0.541	0.616	0.573	0.577
	P_1	0.448	0.378	0.483	0.436	0.592	0.548	0.610	0.583
N_3	P_2	0.462	0.450	0.425	0.446	0.611	0.522	0.511	0.548
	P_3	0.492	0.519	0.509	0.506	0.533	0.601	0.509	0.548
L.S.D 0.05			0.045		0.026		0.043		0.025
K		0.468	0.417	0.496		0.554	0.547	0.591	
L.S.D 0.05			0.013				0.014		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		0.451	0.391	0.523	0.455	0.525	0.522	0.642	0.563
N_2		0.486	0.410	0.492	0.463	0.558	0.563	0.587	0.569
N_3		0.467	0.449	0.472	0.463	0.579	0.557	0.543	0.560
L.S.D 0.05			0.026		N. S		0.025		N. S
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		0.441	0.405	0.496	0.447	0.503	0.515	0.619	0.545
P_2		0.506	0.419	0.500	0.475	0.617	0.533	0.581	0.577
P_3		0.459	0.426	0.492	0.459	0.541	0.594	0.573	0.569
L.S.D 0.05			0.026		0.013		0.025		0.014

Total yield (ton h^{-1})

Results in Table7 shows that there is no significant effect of the change in nitrogen levels in the total yield for both seasons, while significant effects show when changing phosphorous levels in this trait, as the P_2 treatment gave the highest total yield of 26.12 and 33.37 ton h^{-1} for the fall and spring seasons, respectively. The lowest yield was produced from using P_1 which amounted to 24.84 and 31.76 ton h^{-1}, respectively, and the increases in potassium levels to K_3 led to a significant increases of the total yield, 27.38 and 34.13 ton h^{-1} for the both seasons, respectively, compared to the lowest yield, which was at the K_2 level. 23.07 and 31.91 ton h^{-1} for the two seasons, respectively. The two interactions also showed a significant effect on the total yield for both seasons, as the interaction treatments N_3P_3, N_1K_3 and P_2K_1 excelled in the fall season with the highest yield of 27.81, 29.25 and 27.76 ton h^{-1}, respectively, compared to the lowest total yield, 23.29, 21.92 and 22.47 ton h^{-1} for treatments N_2P_3, N_1K_2 and P_1K_2 respectively, and from the same Table shows the superiority of the triple interaction treatment $N_1P_2K_3$ by producing the highest total yield of 32.44 and 37.64 ton h^{-1} for the fall and spring seasons, respectively, compared to the $N_1P_3K_2$ in the fall season (21.06 ton h^{-1}) and the treatment $N_1P_1K_1$ in Spring season (27.43 ton h^{-1}).=

Table 7. Effect of changes in nitrogen, phosphorous and potassium levels and the interaction between them on the total yield of potato plants (ton per hectare) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
	P_1	24.08	22.34	24.54	23.65	27.44	28.73	36.86	31.01
N_1	P_2	27.51	22.36	32.45	27.44	34.94	29.43	37.64	34.00
	P_3	23.87	21.06	30.77	25.24	31.41	33.61	36.41	33.81
	P_1	24.64	23.98	31.18	26.60	29.24	28.28	35.42	30.98
N_2	P_2	30.15	22.05	26.79	26.33	36.93	33.26	32.64	34.28
	P_3	25.18	21.83	22.88	23.30	31.27	36.34	33.16	33.59
	P_1	25.14	21.11	26.56	24.27	33.35	31.76	34.81	33.31
N_3	P_2	25.65	24.65	23.51	24.60	35.43	30.17	29.92	31.84
	P_3	27.37	28.32	27.77	27.82	30.42	35.63	30.02	32.02
L.S.D 0.05			3.37		1.94		4.00		2.30
K		25.95	23.08	27.38		32.27	31.91	34.10	
L.S.D 0.05			1.12				1.33		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		25.15	21.92	29.25	25.44	31.26	30.59	36.97	32.94
N_2		26.66	22.62	26.95	25.41	32.48	32.63	33.74	32.95
N_3		26.05	24.69	25.95	25.56	33.07	32.52	31.58	32.39
L.S.D 0.05			1.94		n. s		2.30		n. s
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		24.62	22.48	27.43	24.84	30.01	29.59	35.70	31.77
P_2		27.77	23.02	27.58	26.12	35.77	30.95	33.40	33.37
P_3		25.47	23.74	27.14	25.45	31.03	35.19	33.20	33.14
L.S.D 0.05			1.94		1.12		2.30		1.33

The percentage of dry matter in the tubers (%): Results in Table8 shows that the percentage of dry matter in tubers decreased with the increases in the level of nitrogen used in the study, as the level N_1 gave the highest percentage for both seasons, amounting to 21.10 and 21.30% for the two seasons, respectively, compared to the level N_3, which gave the lowest percentage, 19.13 and 20.45%, respectively. On the contrary, the increases in phosphorous and potassium levels led to an insignificant increases for phosphorous and a significant increase for potassium in this percentage, as the level P_3 gave the highest percentage of 20.55 and 20.90% for the two seasons, respectively, compared to the lowest percentage of 20.01% at P_2 in the season Fall and 20.58% at P_1 in the spring season, and K_3 gave the highest percentage of 20.73 and 21.18% for the two seasons, respectively, compared to the lowest percentage of 19.91 and 20.14% for K_1 for both seasons, respectively. The results of the same table showed the significant effect of the binary interactions between the studied factors in this trait. In the fall season, treatment N_1P_2 gave the highest percentage of 21.81% compared to treatment N_3P_2 that gave 17.95%, and in the spring treatment N_1P_3 excelled with the highest rate of 21.49% compared to the lowest percentage of 19.74 % when treatment N_3P_1, and treatment N_1K_3 gave the highest percentage of 21.39 and 21.63% for the two seasons, respectively, compared to the factor N_3K_1 which gave 18.71 and 19.33% for the two seasons respectively, and the treatment P_2K_3 in the fall season with the highest rate of 21.08% compared to 19.28% for P_2K_2 while it outperformed P_3K_2 treatment in the spring season had the highest rate of 21.39% compared to the lowest rate of 19.77% at P_1K_1. The triple interaction between the studied factors showed a clear significant superiority of the treatment $N_1P_2K_3$ in the fall season with the highest percentage of 22.13%, compared to the lowest percentage of 16.03% at $N_3P_2K_2$, and in the spring season $N_3P_2K_3$ outperformed with the highest percentage of dry matter amounted to 21.96%, which did not differed significantly with most of the interaction treatments, especially treatment $N_1P_2K_3$ compared to treatment $N_3P_1K_1$, which gave the lowest percentage of 18.54%. Perhaps the reason for the increases in vegetative growth indicators (Table 2, 3, 4) is the role of these elements in contributing to all the physiological processes necessary for plant growth, as nitrogen activates the vegetative growth of the plant by entering into the formation of proteins that are the basic compounds The amino acids, enters in the compounds of some growth hormones such as gibberellins and cytokinins (7) and in the synthesis of nucleic acids necessary for cell division, which leads to an increases widening and thus increases vegetative growth (25) as well as its role in increasing the process of carbon metabolism and respiration (20). Phosphorous also has a role in the formation of energy compounds necessary for vital processes, and it has a role in activating hormones and enzyme companions, increasing the ability of roots to absorb nutrients from the soil, and facilitating the transfer of the products of the carbon metabolism process to effective growth areas, which contributes to increasing and revitalizing vegetative growth (9), and that potassium has a role in increasing the growth of plants through its important role in the processes of cell division and elongation, and it activates several enzymes responsible for building the basic materials in the plant structure (23). As for the reason for a significant increases in the quantitative and qualitative yield indicators by changing the levels of mineral fertilizers used, it may be due to the role of these elements in increasing of vegetative growth (Tables 2, 3, 4) through the increase in cell division and elongation, the formation of energy-rich compounds and the activation of enzymes necessary for biological processes within the plant (10), which encouraged the plant to increase the process of carbon metabolism and the formation of carbohydrates, and this reflected positively on the quantitative and qualitative characteristics of the yield.

Table 8. Effect of changes in nitrogen, phosphorous and potassium levels and their interaction on the percentage of dry matter in potato tubers (%) for the fall season 2020/2021 and spring 2021

Chemical fertilizers		Fall season 2020/2021				Spring season 2021			
		K_1	K_2	K_3	N*P	K_1	K_2	K_3	N*P
	P_1	21.98	19.98	20.23	20.73	20.83	21.25	21.66	21.25
N_1	P_2	21.84	21.47	22.14	21.81	20.85	21.24	21.44	21.18
	P_3	19.48	21.00	21.82	20.77	21.13	21.57	21.80	21.50
	P_1	18.29	19.36	21.69	19.78	19.95	20.86	21.48	20.77
N_2	P_2	20.07	20.36	20.43	20.29	20.65	20.47	20.64	20.59
	P_3	21.43	21.52	20.57	21.18	19.86	21.58	19.35	20.26
	P_1	19.22	20.76	19.23	19.74	18.55	20.06	20.62	19.74
N_3	P_2	17.13	16.03	20.69	17.95	19.36	20.67	21.97	20.67
	P_3	19.80	19.48	19.84	19.71	20.09	22.04	21.72	21.28
L.S.D 0.05			2.09		1.20		2.09		1.21
K		19.92	20.00	20.74		20.14	21.08	21.19	
L.S.D 0.05			0.69				0.69		
N*K		K_1	K_2	K_3	N	K_1	K_2	K_3	N
N_1		21.10	20.82	21.40	21.10	20.94	21.36	21.63	21.31
N_2		19.93	20.42	20.90	20.42	20.15	20.97	20.49	20.54
N_3		18.71	18.76	19.92	19.13	19.33	20.92	21.44	20.56
L.S.D 0.05			1.20		0.69		1.21		0.69
P*K		K_1	K_2	K_3	P	K_1	K_2	K_3	P
P_1		19.83	20.03	20.38	20.08	19.78	20.72	21.25	20.58
P_2		19.68	19.29	21.09	20.02	20.29	20.80	21.35	20.81
P_3		20.24	20.67	20.74	20.55	20.36	21.73	20.95	21.01
L.S.D 0.05			1.20		n. s		1.21		n. s

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