EFFECTS OF MINERAL FERTILIZATION AND SPRAYING WITH SALICYLIC ACID AND AMINO ACIDS ON THE GROWTH AND PRODUCTIVITY OF INDUSTRIAL POTATOES

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ABSTRACT

This experiment was carried out at a private field in the eastern Radwaniyah Baghdad for the fall season 2020/2021 and spring 2021 to study the effects of adding mineral fertilizers, spraying salicylic acid and amino acids on some growth traits and yield of industrial potato plants. 200 kg N h^{-1} , 100 kg P_2O_5 h^{-1}, 100 kg K_2O h^{-1} and F_2 consist of 275 kg N h^{-1}, 180 kg P_2O_5 h^{-1}, 200 K_2O h^{-1} and F_3 consist of 350 kg N h^{-1}, 360 kg P_2O_5 h^{-1}, 300 K_2O h^{-1} and salicylic acid in three concentrations of 0,50 and 100 mg L^{-1} (S_1, S_2, S_3) and amino acids in three concentrations of 0, 1.25 and 2.5 ml L^{-1} (A_1, A_2 , A_3) It was carried out as a factorial split plot experiment, where the fertilizer levels (F_1, F_2 and F_3) are in the main plot and the interaction between salicylic acid and amino acids is in the sub plot with three replications. The results showed the superiority of the F_3 level by giving the highest plant height in the spring season and the largest number of leaves and leaves area for the two seasons, while the F_2 level gave the highest tuber weight and the highest percentage of dry matter for fall seasons, and the concentration S_3 and A_2 was differed in most of the growth indicators and the yield for both seasons of the experiment.

Key words: *Solanum tuberosum* L., macronutrients, ground addition, environmental stress.

تأثير التسميد المعدني والرش بحامض السالسلك والاحماض الامينية في نمو وانتاجية البطاطا الصناعية

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المستخلص

نفذت التجربة في أحد الحقول الخاصة في منطقة الرضوانية_ بغداد للموسمين الخريفي2021/2020 والربيعي 2021 لدراسة تأثير إضافة الاسمدة المعدنية ورش حامض السالسلك والاحماض الامينية في بعض مؤشرات النمو والحاصل لنباتات البطاطا الصناعية, إذ أستعمل السماد المعدني بثلاث مستويات هي F_1 وF_2 وF_3 حيث انF_1 تتكون من 200 كغم N هـ$^{-1}$ و100 كغم P_2O_5هـ$^{-1}$ و100 كغم K_2O هـ$^{-1}$ وF_2 تتكون من 275 كغم N هـ$^{-1}$ و180 كغم P_2O_5هـ$^{-1}$ و200 K_2Oهـ$^{-1}$ وF_3 تتكون من 350 كغم Nهـ$^{-1}$ و360 كغم P_2O_5هـ$^{-1}$ و300 K_2O هـ$^{-1}$ وحامض السالسلك بثلاثة تراكيز هي 0, 50, 100 ملغم لتر$^{-1}$ رمز لها بالرمزS_1 وS_2 وS_3 والاحماض الامينية بثلاث تراكيز هي 0, 1.25 , 2.5 مل لتر$^{-1}$ ورمز لها بالرمز A_1 وA_2 وA_3 . نفذت كتجربة عاملية Split plot حيث مستويات السماد(F_3, F_2 , F_1) تكون في Main plot والتداخل بين حامض السالسلك والاحماض الامينية في Sub plot وبثلاث مكررات. أظهرت النتائج تفوق المستوى F_3 بإعطاء أعلى طول للنبات في الموسم الربيعي وأكبر عدد أوراق ومساحة ورقية للموسمين فيما أعطى المستوى F_2 أعلى وزن للدرنة وأعلى نسبة مئوية للمادة الجافة للموسم الخريفي, وتميز التركيزS_3 وA_2 في معظم مؤشرات النمو والحاصل لكلا موسمي التجربة.

الكلمات المفتاحية: *Solanum tuberosum* L., المغذيات الكبرى, الاضافة الارضية, الاجهاد البيئي.

Received: 11/1/2022, Accepted:13/3/2022

INTRODUCTION

Potato *Solanum tuberosum* L. is important vegetable crops in the world which belongs to Solanaceae family. It ranks fourth among the important food crops. Potato considered rich source of carbohydrate, starch, protein and amino acids. Even more; it provides raw materials for many food industries, as part of its production. It is used for domestic consumption, while the other part goes to the manufacturing process (17). In the last century, several methods were taken to improve the growth of the potato plant and increase its productivity per area unit (5, 6, 14) ;especially potato for processing issues (11, 12, 28). Including increasing the quantities of mineral fertilizers used (29), as they are an important source to secure the crop's need for nutrients (33), so it is necessary to reconsider the applied aspects of current agricultural operations and use methods that improve efficiency of nutrient use (34). Potato plants suffer from the problem of high temperatures at the beginning of the fall season and the end of the spring cycle, as well as the low temperatures at the end of the fall season and the beginning of the spring season, which leads to a significant decreases in yield, Salicylic acid plays a major role in stimulating and increasing plant immunity through its effects on various physiological functions such as respiration and opening and closing stomata (23). Salicylic acid has a major role in increasing resistance plants to environmental stresses (19). And increase their productivity (1, 8) Amino acids are one of the methods used in fertilizing agricultural crops (3, 7) because of their direct and indirect effects on physiological processes, which necessary for plant growth and development (31), as well as improving the absorption and representation of nutrients, and increasing the efficiency of the carbon metabolism process (32), This study was aimed to determine the appropriate quantities of mineral fertilizers and the possibility of reducing the effects of environmental stress on potato plants by spraying salicylic acid and amino acids.

MATERIALS AND METHODS

After preparing the land and carrying out the required agricultural operations, the field was divided into 81 plot (experimental units) with a length of 2.5 and a width of 1.0 m. Each plot contains 20 plants distributed on both sides of the plot, 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 31 January /2021 for the spring season using class elite seeds. It was carried out as a factorial split plot experiment where the fertilizer levels (F_1, F_2 and F_3) are at the main plot and the interaction between salicylic acid and amino acids (9 treatments) in the sub plot and with three replicates. and F_3 where F_1 consists of 200 kg N h^{-1} and 100 kg P_2O_5 h^{-1} and 100 kg K_2O h^{-1} and F_2 consists of 275 kg N h^{-1} and 180 kg P_2O_5 h^{-1} and 200 kg K_2O h^{-1} and F_3 consists of 350 kg N h^{-1}, 360 kg P_2O_5 h^{-1} and 300 kg K_2O h^{-1} and salicylic acid in three concentrations of 0,50,100 mg L^{-1} symbolized by the symbols S_1, S_2 and S_3. Amino acids in three concentrations are 0, 1.25, 2.5 ml L^{-1} and symbolized by the symbol A_1, A_2 and A_3, Fertilizers were added in four stages, in proportions according to the stages of plant age. As for amino acids and salicylic acid, they were sprayed with three sprays each, the first spray 15 days after the emergence and the second spray was 15 days after the first spray, and the third spray 15 days after the second spray also leaving an interval time of three days between the spraying of amino acids and salicylic acid the results were analyses using analysis of variance means were compared according to the LSD test at the probability level of 0.05 (4), the tubers were plucked in the fall season on 20-12-2020 and in the spring season 18-05-2021. Indicators of vegetative growth were measured, such as plant height (cm), number of leaves (leaves $plant^{-1}$) and leaves area (dm^2 $plant^{-1}$) according to Sadik et al.(26), and quantitative and qualitative yield indicators such as marketable tuber weight (gm $tuber^{-1}$) and yield per plant. Marketable (plant kg^{-1}), total yield (ton h^{-1}) and percentage of dry matter (%).

RESULTS AND DISCUSSION

Plant height (cm): Results of Table1 shows that fertilizing potato plants with mineral fertilizers (NPK) did not lead to significant differences in the increases in plant height in the fall season, despite giving the second level the highest plant height. The plant height reached 76.51 cm and did not differed significantly from the F_2 treatment, which reached 75.92 cm, while the lowest plant height reached 69.37 cm in the lower level treatment (F_1), and salicylic acid spray did not significantly affect this trait in both seasons despite giving Spraying treatment (100 mg L^{-1}) had the highest plant height of 81.14 and 75.40 cm for the fall and spring seasons, respectively, compared to the shortest length of 79.59 cm for S_2 treatment in the fall season and 72.18 cm for the no-spray treatment in the spring season. It was noted from the same table that amino acid spraying led to a significant differences in plant height, as a treatment of 1.25 ml L^{-1} (A_2) in the fall season gave the highest height of 84.59 cm and did not differed significantly from the treatment of 2.5 ml L^{-1} which gave 80.11 cm, while the shortest plant height reached 76.44 cm in the comparison treatment, while in the spring season, treatment A_3 excelled by giving the highest plant height reached 76.77 cm compared to the lowest plant height when treatment A_1 was 70.81 cm. As for the binary interaction between mineral fertilizers and amino acids, had a significant effects on plant height, as the interaction F_2A_2 treatment in the fall season had the highest plant height that reached 85.78 cm and did not differed significantly from all the interaction treatments compared to the F_1A_1 treatment which gave the lowest length of 71.33 cm, while in In the spring season, treatment F_2A_3 recorded the highest length of 83.11 cm compared to treatment F_1A_1, which gave 65.11 cm. As for the interaction between mineral fertilizers and salicylic acid, the behavior was the same in both seasons of the experiment, as F_2S_3 treatment recorded the highest length of 85.66 and 78.77 cm for the two seasons respectively, while F_1S_3 treatment in the fall season gave the lowest length of 75.77 cm and F_1S_1 (67.77 cm). In the spring season, as for the interaction between amino acids and salicylic acid, it had a significant effects in increasing plant height, as the highest rate reached 87.55 cm when the interaction A_2S_2 was treated in the fall season, compared to 72.55 cm at A_1S_2, while in the spring season it reached the highest Length 78.00 cm in treatment A_3S_2 compared to 69.11 cm in treatment A_1S_1. With regard to the triple interaction between the experimental factors, it had a significant and clear effects in increasing the plant height, as the treatment $F_2A_2S_2$ excelled with the highest plant height for the fall season, which reached 90.00 cm, and it did not differed significantly from most of the treatments, especially the treatment $F_2A_2S_3$ compared to the treatment $F_1A_1S_3$ which recorded the lowest plant height of66.66 cm and in the spring season.

Table 1. Effects of mineral fertilization and spraying with salicylic acid and amino acids and the interaction between them on the height of potato plants (cm) for the fall season 2020/2021 and spring 2021

mineral fertilization	amino acids	Fall season 2020/2021 salicylic acid				Spring season 2021 salicylic acid			
		S_1	S_2	S_3	F*A	S_1	S_2	S_3	F*A
	A_1	79.00	68.33	66.67	71.33	64.00	64.67	66.67	65.11
F_1	A_2	84.00	83.33	82.67	83.33	68.00	72.00	72.00	70.67
	A_3	76.33	78.33	78.00	77.56	71.33	72.67	73.00	72.33
	A_1	80.00	78.67	83.33	80.67	69.33	70.67	72.67	70.89
F_2	A_2	79.00	90.00	88.33	85.78	70.33	72.00	79.00	73.78
	A_3	80.67	82.00	85.33	82.67	81.33	83.33	84.67	83.11
	A_1	81.33	70.67	80.00	77.33	74.00	76.67	78.67	76.44
F_3	A_2	80.67	89.33	84.00	84.67	76.00	78.00	80.67	78.22
	A_3	82.67	75.67	82.00	80.11	75.33	78.00	71.33	74.89
L.S.D 0.05			11.98		9.06		10.16		6.47
S		80.41	79.59	81.15		72.19	74.22	75.41	
L.S.D 0.05			n. s				n. s		
F*S		S_1	S_2	S_3	F	S_1	S_2	S_3	F
F_1		79.78	76.67	75.78	77.41	67.78	69.78	70.56	69.37
F_2		79.89	83.56	85.67	83.04	73.67	75.33	78.78	75.93
F_3		81.56	78.56	82.00	80.70	75.11	77.56	76.89	76.52
L.S.D 0.05			9.06		n. s		6.47		5.67
A*S		S_1	S_2	S_3	A	S_1	S_2	S_3	A
A_1		80.11	72.56	76.67	76.44	69.11	70.67	72.67	70.81
A_2		81.22	87.56	85.00	84.59	71.44	74.00	77.22	74.22
A_3		79.89	78.67	81.78	80.11	76.00	78.00	76.33	76.78
L.S.D 0.05			6.03		3.48		5.68		3.28

Treatment $F_2A_3S_3$ excelled with the highest plant height of 84.67 cm and did not differed significantly from some of the interaction treatments, especially treatment $F_2A_2S_3$ compared to treatment $F_1A_1S_1$, which gave 64 cm.

Number of leaves (leaves plant^{-1})

Results of Table2 shows the moral superiority of treatment F_3 in increasing the number of leaves to 56.32 and 38.73 leaves plant^{-1} for the two seasons, respectively, compared to the treatment F_1, which gave the lowest number of 48.15 and 30.53 leaves plant^{-1}, Salicylic acid spray had a significant effects on the number of plant leaves, as treatment S_3 recorded the largest number of 54.15 and 36.13 leaves plant^{-1} for the two seasons, respectively, compared to the lowest number of 49.71 and 33.27 leaves plant^{-1} when treatment S_1, and the results show that the spraying of amino acids also led to a significant differences in the studied trait, as the highest rate reached 54.24 leaves plant^{-1}when treated A_2 in the fall season and 37.30 leaves plant^{-1} when treated A_3 in the spring season compared to the lowest rate of 50.39 and 32.23 leaves plant^{-1}when treating A_1 for the two trial seasons sequentially. The binary interaction between mineral fertilizers and amino acids had a significant effects in increasing the number of leaves, as the F_3A_1 treatment in the fall season led to an increase in the number of leaves to 57.97 leaves plant^{-1} and the F_3A_3 treatment in the spring season which gave 41.38 leaves plant^{-1} compared to the F_1A_1 treatment that gave less The number was 46.17 and 28.89 leaves plant^{-1} for the two seasons, respectively. The interaction between the mineral fertilizers and salicylic acid led to the emergence of significant differences in this trait, as the treatment F_3S_1 excelled in the fall season by increasing the number of leaves to 59.25. leaves plant^{-1} and the treatment F_3S_3 for

the spring season by giving 39.61 leaves plant^{-1}, while the treatment F_1S_1 gave the lowest rate It reached 44.83 and 29.02 leaves plant^{-1}for the two seasons, respectively. Also, the interaction between salicylic acid and amino acids showed a significant effects in this trait, as the interaction treatment A_2S_3 in the fall season and A_3S_2 in the spring season gave the highest number of leaves, which reached 57.50 and 37.91 leaves plant^{-1} , respectively, compared to treatment A_1S_1, which recorded the lowest rate. 47.31 and 31.41 leaves plant^{-1} for the two seasons, respectively. As for the triple interaction between the study factors, it had a significant effects in increasing the number of leaves, as the treatment$F_3A_3S_1$ outperformed in the fall season by giving the highest average leaves amounted to 61.00 leaves plant^{-1} compared to the treatment $F_2A_1S_1$ which gave the lowest rate of 37.67 leaves plant^{-1} , and it outperformed The treatment $F_3A_3S_2$ in the spring season gave the highest average leaves amounted to 42.87 leaves plant^{-1} compared to the treatment $F_1A_1S_1$ which gave the lowest rate of 27.47 leaves plant^{-1}.

Table 2. Effects of mineral fertilization and spraying with salicylic acid and amino acids and the interaction between them on the number of leaves of potato plants (leaves of plant^{-1}) for the fall season 2020/2021 and spring 2021

mineral fertilization	amino acids	Fall season 2020/2021 salicylic acid				Spring season 2021 salicylic acid			
		S_1	S_2	S_3	F*A	S_1	S_2	S_3	F*A
F_1	A_1	46.00	43.50	49.00	46.17	27.47	28.07	31.13	28.89
	A_2	44.50	48.75	57.33	50.19	28.40	31.40	32.80	30.87
	A_3	44.00	53.50	46.83	48.11	31.20	32.10	32.27	31.86
F_2	A_1	36.67	44.92	59.50	47.03	30.47	30.77	32.53	31.26
	A_2	53.17	57.58	60.50	57.08	31.67	32.00	37.93	33.87
	A_3	45.33	52.33	51.08	49.58	37.53	38.77	39.67	38.66
F_3	A_1	59.25	55.00	59.67	57.97	36.30	36.37	36.93	36.53
	A_2	57.50	54.17	54.67	55.44	35.27	37.80	41.83	38.30
	A_3	61.00	56.83	48.83	55.56	41.20	42.87	40.07	41.38
L.S.D 0.05			6.00		3.35		5.41		2.99
S		49.71	51.84	54.16		33.28	34.46	36.13	
L.S.D 0.05			2.04				1.84		
F*S		S_1	S_2	S_3	F	S_1	S_2	S_3	F
F_1		44.83	48.58	51.06	48.16	29.02	30.52	32.07	30.54
F_2		45.06	51.61	57.03	51.23	33.22	33.84	36.71	34.59
F_3		59.25	55.33	54.39	56.32	37.59	39.01	39.61	38.74
L.S.D 0.05			3.35		2.28		2.99		1.97
A*S		S_1	S_2	S_3	A	S_1	S_2	S_3	A
A_1		47.31	47.81	56.06	50.39	31.41	31.73	33.53	32.23
A_2		51.72	53.50	57.50	54.24	31.78	33.73	37.52	34.34
A_3		50.11	54.22	48.92	51.08	36.64	37.91	37.33	37.30
L.S.D 0.05			3.54		2.04		3.20		1.84

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

Results in Table3 shows a significant increases in the leaves area of potato plants when fertilized with different levels of mineral fertilizers, as it reached 165.87 and 112.44 dm^2 plant^{-1} when treated with F_3 for the two seasons, respectively, compared to145.26 and 92.71 dm^2 plant^{-1} when treated with F_1. The results in the same table show a significant effects on leaves area when spraying plants with salicylic acid, as the highest value reached 104.08 dm^2 plant^{-1} at concentration S_3 compared to treatment S_1 of 99.52 dm^2 plant^{-1} for the Spring seasons, respectively. The results showed that there were significant differences in the leaves area when spraying amino acids for both seasons, as the concentration A_2 in the fall season gave the highest leaves area, which amounted to 163.49 dm^2 plant^{-1}, compared to the non-spray treatment that gave 147.46 dm^2 plant^{-1}, while in the spring season, the concentration A_3 was superior. The highest area was 107.00 dm^2 plant^{-1}, while the non-additive treatment gave

the lowest percentage (94.81 dm^2 $plant^{-1}$). As for the interaction between fertilizers and amino acids, the F_2A_2 treatment in the fall season was significantly superior. It was recorded the highest area of 177.26 dm^2 $plant^{-1}$, while the F_2A_1 treatment gave the lowest area of 129.98 dm^2 $plant^{-1}$, while the treatment F_3A_3 in the spring season gave the highest leaves area of 118. 90 dm^2 $plant^{-1}$ compared to treatment F_3A_1 which amounted to 85.74 dm^2 $plant^{-1}$, and the interaction between the fertilizers and salicylic acid had a significant effects in this trait. F_2S_1, which amounted to 127.37 dm^2 $plant^{-1}$, while in the spring season the treatment F_3S_2 outperformed with the highest value of 117.24 dm^2 $plant^{-1}$, compared to the lowest value (86.50 dm^2 $plant^{-1}$) when treatment F_1S_2. The interaction between amino acids and salicylic acid significantly affected the studied trait for both seasons, as the treatment A_2S_3 in the fall season recorded the highest leaves area of the plant amounted to 175.03 and 114.38 dm^2 $plant^{-1}$ for the two seasons respectively compared to treatment A_3S_3 in the fall season, which gave the lowest leaves area It reached 137.56 dm^2 $plant^{-1}$ and 92.08 dm^2 $plant^{-1}$ when treated A_1S_1 in the spring season. With regard to the triple interaction, it had a significant effects on the leaves area of potato plants, as the treatment $F_3A_3S_1$ excelled by recording the highest leaves area 209.81 and 128.59 dm^2 $plant^{-1}$ for the fall and spring seasons, respectively, compared to treatment $F_2A_1S_1$ (101.00 dm^2 $plant^{-1}$) in the fall season and the treatment $F_1A_2S_2$ (81.74 dm^2 $plant^{-1}$) in the spring season which gave the least leaves area.

Table 3. Effects of mineral fertilization and spraying with salicylic acid and amino acids and the interaction between them on the leaves area of potato plants (dm^2 $plant^{-1}$) for the fall season 2020/2021 and spring 2021

mineral fertilization	amino acids	Fall season 2020/2021 salicylic acid				Spring season 2021 salicylic acid			
		S_1	S_2	S_3	F*A	S_1	S_2	S_3	F*A
	A_1	141.42	130.17	151.72	141.10	86.99	85.05	98.92	90.32
F_1	A_2	162.79	122.46	179.82	155.02	95.10	81.74	103.80	93.55
	A_3	134.54	150.16	134.24	139.65	98.68	92.71	91.42	94.27
	A_1	101.00	127.49	161.45	129.98	84.04	85.50	87.67	85.74
F_2	A_2	146.05	194.68	191.06	177.26	86.94	112.94	122.32	107.40
	A_3	135.05	144.75	136.29	138.70	109.55	107.26	106.75	107.85
	A_1	171.28	191.43	151.19	171.30	105.19	123.51	96.42	108.38
F_3	A_2	164.15	156.22	154.21	158.19	100.56	112.51	117.04	110.04
	A_3	209.89	152.26	142.16	168.11	128.59	115.70	112.41	118.90
L.S.D 0.05			12.00		6.87		12.38		9.32
S		151.80	152.18	155.79		99.52	101.88	104.08	
L.S.D 0.05			n. s				3.61		
F*S		S_1	S_2	S_3	F	S_1	S_2	S_3	F
F_1		146.25	134.26	155.26	145.26	93.59	86.50	98.05	92.71
F_2		127.37	155.64	162.93	148.65	93.51	101.90	105.58	100.33
F_3		181.77	166.64	149.19	165.87	111.45	117.24	108.62	112.44
L.S.D 0.05			6.87		5.02		9.32		9.18
A*S		S_1	S_2	S_3	A	S_1	S_2	S_3	A
A_1		137.90	149.70	154.79	147.46	92.08	98.02	94.34	94.81
A_2		157.66	157.79	175.03	163.49	94.20	102.40	114.38	103.66
A_3		159.83	149.06	137.56	148.82	112.27	105.22	103.53	107.01
L.S.D 0.05			7.01		4.05		6.26		3.61

Marketable weight of the tuber (g tuber^{-1}):
Results in Table 4 shows that the use of different levels of mineral fertilizers led to a significant increases in the marketable tuber weight rate, as the level F_2 gave the highest tuber weight of 100.55 and 145.60 g tuber^{-1} for the two seasons, respectively. Compared to the F_1 treatment, which gave the lowest weight of the tuber, which was 92.97 and 127.73 g tuber^{-1}, respectively, and the use of salicylic acid had a significant effects on the marketable tuber weight. Whereas, treatment S_3 gave the highest rate of 102.52 and 142.17 gm tuber^{-1} for both seasons, respectively When the comparison treatment S_1 gave the lowest average of 91.66 and 132.29 gm tuber^{-1}, and spraying amino acids led to a significant increases in this trait. Level A_2 gave the highest marketable tuber weight rate of 98.63 and 142.56 gm tuber^{-1} for the two seasons, respectively. Compared to A_1 level, which gave the lowest rate of 94.15 and 134.41 gm tuber^{-1}, respectively. As for the interaction of fertilizers and amino acids, it had a significant effects on the marketable tuber weight rate for both seasons, as the F_3A_2 treatment in the fall season excelled with the highest rate of 102.75 gm tuber^{-1}, while the F_2A_2 treatment in the spring season gave the highest rate of 153.53 gm. tuber^{-1}. Whereas, F_1A_1 treatment gave the lowest tuber weight, which was 88.87 and 123.55 gm tuber^{-1} for the two seasons, respectively. The interaction between mineral fertilizers and salicylic acid had a significant effects on the marketable tuber weight, as treatment F_2S_3 recorded the highest rate of 109.54 and 150.01 g tuber^{-1} for the two seasons, respectively, compared to treatment F_1S_1, which gave the lowest rate of 88.58 and 121.07 gm tuber^{-1} Sequentially, as for the interaction between amino acids and salicylic acid, it had a significant effects on this trait, as the interaction A_2S_3 treatment excelled by giving the highest rate of 103.72 and 149.80 g tuber^{-1} for the two seasons respectively compared to treatment A_1S_1 which gave the lowest rate of 87.38 and130.30 gm tuber^{-1} sequentially. The triple interaction also had a significant effects in increasing the marketable tuber weight, as the interaction $F_2A_1S_3$ treatment in the fall season was characterized by recording the highest weight of the tuber, which amounted to 117.21 gm tuber^{-1}, and the treatment $F_2A_2S_3$ in the spring season gave the highest value of 159.17 gm tuber^{-1} compared to treatment $F_1A_1S_1$. The lowest tuber weight was 83.08 and 119.99 gm tuber^{-1} for the two seasons, respectively.

Table 4. Effects of mineral fertilization and spraying with salicylic acid and amino acids and the interaction between them on the average marketable tuber weight of potato plants (gm tuber^{-1}) for the fall season 2020/2021 and spring 2021

mineral fertilization	amino acids	Fall season 2020/2021 salicylic acid				Spring season 2021 salicylic acid			
		S_1	S_2	S_3	F*A	S_1	S_2	S_3	F*A
	A_1	83.08	90.39	93.15	88.87	119.99	121.17	129.49	123.55
F_1	A_2	88.74	91.72	96.06	92.17	122.51	130.90	146.46	133.29
	A_3	93.93	98.45	101.20	97.86	120.71	127.85	130.48	126.35
	A_1	88.86	97.32	117.21	101.13	140.63	142.19	150.58	144.47
F_2	A_2	96.38	102.59	116.37	100.96	142.27	159.16	159.17	153.53
	A_3	94.16	96.99	107.48	99.54	136.70	139.37	140.29	138.79
	A_1	90.21	92.41	94.76	92.46	130.29	136.60	138.73	135.20
F_3	A_2	92.68	104.39	111.18	102.75	135.60	143.17	143.77	140.85
	A_3	96.87	97.19	97.73	97.26	141.92	144.44	140.58	142.31
L.S.D 0.05			12.72		6.59		14.13		8.16
S		91.66	96.83	102.52		132.29	138.32	142.17	
L.S.D 0.05			4.44				4.75		
F*S		S_1	S_2	S_3	F	S_1	S_2	S_3	F
F_1		88.58	93.52	96.80	92.97	121.07	126.64	135.48	127.73
F_2		93.13	98.97	109.54	100.55	139.87	146.91	150.01	145.60
F_3		93.25	98.00	101.22	97.49	135.93	141.40	141.03	139.45
L.S.D 0.05			6.59		2.78		8.16		6.09
A*S		S_1	S_2	S_3	A	S_1	S_2	S_3	A
A_1		87.38	93.37	101.71	94.15	130.30	133.32	139.60	134.41
A_2		92.60	99.57	103.72	98.63	133.46	144.41	149.80	142.56
A_3		94.99	97.55	102.13	98.22	133.11	137.22	137.12	135.82
L.S.D 0.05			7.70		4.44		8.24		4.75

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

Results in Table 5 shows that the use of different levels of mineral fertilizers led to significant differences in the yield of one marketable plant in the fall season. The F_3 level was superiored by production the highest yield per plant of 0.531 kg Plant^{-1} compared to the lowest yield of 0.445 kg plant^{-1} when treated at F_1 level. In the spring season, there were no significant differences in the levels of mineral fertilizers in this trait. It was also observed that there was a significant increase in the yield of one plant to 0.513 and 0.636 kg plant^{-1} for the two seasons respectively when spraying plants with salicylic acid at concentration S_3 compared to the lowest yield of 0.459 and 0.541 kg plant^{-1} for the two seasons respectively when compared to treatment S_1. For spraying amino acids, it led to an increases in the plant yield A_2 for the two seasons in a row, compared to the treatment of no spray, which gave the lowest yield of the plant was 0.462 and 0.562 kg plant^{-1}.

Table 5. Effects of mineral fertilization and spraying with salicylic acid and amino acids and the interaction between them on the marketable yield of one plant of potato plants (kg plant^{-1}) for the fall season 2020/2021 and spring 2021

mineral fertilization	amino acids	Fall season 2020/2021 salicylic acid				Spring season 2021 salicylic acid			
		S_1	S_2	S_3	F*A	S_1	S_2	S_3	F*A
	A_1	0.416	0.401	0.380	0.399	0.478	0.574	0.565	0.539
F_1	A_2	0.472	0.474	0.485	0.477	0.557	0.597	0.590	0.581
	A_3	0.450	0.396	0.534	0.460	0.534	0.524	0.663	0.574
	A_1	0.404	0.497	0.428	0.443	0.512	0.722	0.521	0.585
F_2	A_2	0.493	0.490	0.590	0.524	0.571	0.557	0.767	0.632
	A_3	0.479	0.528	0.481	0.496	0.528	0.631	0.648	0.602
	A_1	0.444	0.566	0.625	0.545	0.512	0.489	0.688	0.563
F_3	A_2	0.513	0.542	0.551	0.535	0.585	0.549	0.673	0.602
	A_3	0.464	0.532	0.544	0.513	0.593	0.637	0.610	0.613
L.S.D 0.05			0.087		0.059		0.124		N. S
S		0.459	0.492	0.513		0.541	0.587	0.636	
L.S.D 0.05			0.027				0.033		
F*S		S_1	S_2	S_3	F	S_1	S_2	S_3	F
F_1		0.446	0.424	0.466	0.445	0.523	0.565	0.606	0.565
F_2		0.459	0.505	0.500	0.488	0.537	0.637	0.645	0.606
F_3		0.474	0.547	0.573	0.531	0.563	0.558	0.657	0.593
L.S.D 0.05			0.059		0.055		0.103		N. S
A*S		S_1	S_2	S_3	A	S_1	S_2	S_3	A
A_1		0.421	0.488	0.477	0.462	0.501	0.595	0.591	0.562
A_2		0.492	0.502	0.542	0.512	0.571	0.568	0.677	0.605
A_3		0.464	0.485	0.520	0.490	0.552	0.597	0.640	0.596
L.S.D 0.05			0.047		0.027		0.057		0.033

As for the binary interaction between the study factors, it had a significant effects on the marketable plant yield for both seasons of the study. In the fall season, the interaction treatments F_3A_1, F_3S_3 and A_2S_3 outperformed by achieving the highest plant yield of 0.545, 0.573 and 0.542 kg plant^{-1}, respectively, compared to the treatments F_1A_1, F_1S_2 and A_1S_1 which gave the lowest yield of 0.399, 0.424 and 0.421 kg plant^{-1}, respectively, while in the spring season, the interaction between mineral fertilizers with amino acids had no significant effects in this trait, while the interaction treatments F_3S_3 and A_2S_3 achieved the highest yield of 0.657 and 0.677 kg plant^{-1}, respectively, compared to measurement

treatments F_1S_1 and A_1S_1 Which gave the lowest yield of 0.523 and 0.501 kg plant-1, respectively. As well as for the triple interaction between the study factors, it had a significant effect on the marketable plant yield, as the interaction $F_3A_2S_3$ treatment in the fall season gave the highest yield amounting to 0.625 kg plant^{-1} and it did not differed significantly with some of the interaction treatments, especially the treatment $F_2A_2S_3$ which gave 0.590 kg plant^{-1} compared to treatment $F_1A_1S_1$, which gave the lowest yield of 0.380 kg plant^{-1}, and treatment $F_2A_2S_3$ achieved the highest rate in the spring season of 0.767 kg plant^{-1}, compared to the lowest rate of 0.478 kg plant^{-1} when treatment $F_1A_1S_1$.

Total yield (ton h^{-1})

Results in Table6 shows the significant effects of changing the levels of mineral fertilizers in increasing the total yield of the potato crop, as the level F_3 surpassed the highest total yield of 29.16 ton h^{-1} compared to the lowest yield of 24.33 ton ha^{-1} at The F_1 level, while the change in the levels of mineral fertilizers had no significant effects on this trait for the spring season, although the F_2 level gave the highest total yield. As for salicylic acid, it showed a significant effects in this trait, as treatment S_3 was significantly distinguished by recording the highest total yield of 28.23 and 36.15 tons h^{-1} for the two seasons, respectively, compared to treatment S_1 which gave the lowest average total yield of 25.27 and 31.10 ton h^{-1} for the two seasons. Sequentially, as for the amino acids, it also led to a significant increase in the total yield. The A_2 spraying treatment gave the highest rate of 28.20 and 34.42 tons h^{-1} for the two seasons, respectively, compared to the comparison treatment A_1 gave the lowest average of 25.31 and 32.34 tons h^{-1} for two seasons in a row. The interaction between the study factors, it had a significant effects in increasing the total yield, as the treatment F_3A_1 in the fall season gave the highest rate of 29.84 ton h^{-1} compared to the lowest rate of 21.80 ton h^{-1} when treatment F_1A_1, while this interaction had no significant effects in the spring season. The interaction between mineral fertilizers and salicylic acid, F_3S_3 treatment achieved the highest total yield of 31.63 and 37.19 ton h^{-1} for the two seasons, respectively, compared to F_1S_2 treatment in the fall season (23.08 tons h^{-1}) and F_2S_1 treatment in the spring season, which recorded the lowest total yield. Potatoes amounted to 30.45 ton h^{-1}, and that the binary interaction between amino acids and salicylic acid significantly affected the total yield, as the treatment A_2S_3 gave the highest rate of 29.94 and 38.05 ton h^{-1} for the two seasons respectively, while the treatment A_1S_1 recorded the lowest rate of 23.20 and 29.27 ton h^{-1} on straight. The same Table also show a significant effects of the triple interaction between the studied factors on the total yield of potatoes, as the triple interaction $F_3A_1S_3$ treatment in the fall season was characterized by the highest yield of 34.18 ton h^{-1} and did not differed significantly from some of the interaction treatments compared to the treatment of $F_1A_1S_3$ which recorded the lowest yield of 20.85 ton h^{-1} In the spring season, the interference $F_2A_2S_3$ treatment was superior by recording the highest yield of 41.93 ton h^{-1} compared to the lowest yield of 27.78 tons ha^{-1} when treated. $F_1A_1S_1$.

Percentage of dry matter in tubers (%):

Results in Table7 shows that changing the levels of mineral fertilizer significantly affected the percentage of dry matter in potato tubers. In the fall season, the percentage reached 21.00% when treating F_2 and F_3, compared to 19.97% when treating F_1, and in the spring season, treatment F_3 outperformed the highest rate of 22.19% compared to the lowest rate of 20.45% in F_1. The results of the Table indicate that spraying plants with salicylic acid had a significant effects on this trait for both seasons, as the treatment S_3 of the highest concentration excelled by giving the highest percentage of 21.19 and 22.19% for the two seasons, respectively, compared to the lowest percentage of 20.12 and 20.61% at S1. The treatment of amino acid spray with a concentration of 1.25 ml L-1 in the fall season exceeded the highest percentage of 21.15% compared to20.36 % when spraying with water only, and in the spring season, the effects was the same, but it was not significant, as A_2 gave the highest percentage of dry matter amounting to21.52%. The same results showed a significant effects of the interaction between the study factors on the percentage of dry matter in the tubers, the F_3A_2 treatment

was characterized by recording the highest percentage of 21.71 and 22.28% for the two seasons, respectively, compared to the F_1A_1 treatment, which gave the lowest percentage of 19.62 and 20.29% for the two seasons of the experiment. Respectively, treatment F_2S_3 gave the highest value of 21.79 and 22.51% for the two seasons, respectively, compared to 19.76 and 19.06% for F_1S_1, and the interaction A_2S_3 treatment recorded the highest percentage of 21.62 and 22.37% for the fall and spring seasons, respectively, compared to treatment A_1S_1 which gave 19.73 and 20.22%, respectively. With regard to the triple interaction between mineral fertilizers, salicylic acid and amino acids, it had a significant effects on the percentage of dry matter in the tubers. The interaction $F_2A_2S_3$ treatment in the fall season was characterized by giving the highest percentage of 22.58% compared to $F_1A_1S_1$ treatment, which gave the lowest percentage of 19.46%. In the spring season, factor $F_3A_1S_3$ outperformed with the highest percentage of 22.66% and did not differed with most of the overlap coefficients compared to treatment $F_1A_3S_1$ which gave the lowest percentage of 18.78%.

Table 7. The effects of mineral fertilization and spraying with salicylic acid and amino acids and the interaction between them on the percentage of dry matter in potato tubers (%) for the fall season 2020/2021 and spring 2021

mineral fertilization	amino acids	Fall season 2020/2021 salicylic acid				Spring season 2021 salicylic acid			
		S_1	S_2	S_3	F*A	S_1	S_2	S_3	F*A
	A_1	22.83	21.73	20.85	21.80	27.78	32.32	32.00	30.70
F_1	A_2	25.85	26.23	26.53	26.20	33.59	33.84	34.34	33.92
	A_3	24.49	21.26	29.17	24.98	30.54	29.56	37.98	32.69
	A_1	22.28	27.37	23.18	24.28	30.71	41.41	30.69	34.27
F_2	A_2	27.15	27.03	32.24	28.81	31.54	32.15	41.93	35.21
	A_3	26.50	29.15	27.23	27.63	29.11	35.28	36.81	33.73
	A_1	24.50	30.84	34.18	29.84	29.34	28.29	38.57	32.07
F_3	A_2	28.39	29.34	31.07	29.60	33.65	30.86	37.89	34.13
	A_3	25.48	28.99	29.66	28.04	33.60	37.10	35.10	35.27
L.S.D 0.05			4.75		3.16		6.60		N. S
S		25.27	26.88	28.23		31.10	33.42	36.15	
L.S.D 0.05			1.50				1.75		
F*S		S_1	S_2	S_3	F	S_1	S_2	S_3	F
F_1		24.39	23.08	25.52	24.33	30.64	31.91	34.77	32.44
F_2		25.31	27.85	27.55	26.90	30.45	36.28	36.48	34.40
F_3		26.12	29.72	31.63	29.16	32.20	32.08	37.19	33.82
L.S.D 0.05			3.16		2.90		5.48		N. S
A*S		S_1	S_2	S_3	A	S_1	S_2	S_3	A
A_1		23.20	26.65	26.07	25.31	29.27	34.01	33.75	32.34
A_2		27.13	27.53	29.94	28.20	32.93	32.28	38.05	34.42
A_3		25.49	26.47	28.69	26.88	31.08	33.98	36.63	33.90
L.S.D 0.05			2.59		1.50		3.04		1.75

The reason for a significant response in most indicators of vegetative growth and yield of industrial potato plants could be due to the change in the levels of mineral elements used in the study and for both seasons to the role of these elements in contributing to all physiological processes necessary for plant growth (20). In most indicators of vegetative growth, the result of increasing the concentration of salicylic acid and the sprayed

amino acids could be due to the role of salicylic acid in improving the growth of plants by regulating the reactions of the carbonic metabolism process through its effects on the process of opening and closing stomata and controlling the transpiration process (24). Salicylic acid contributes to the formation of chlorophyll pigment and activates the enzymes necessary for growth, which increases cell division and increases their numbers, thus increasing plant growth (2, 18, 35), and improves the health status of plants by increasing the production of oxidants (25). As for the reason for the improvement of the vegetative growth indicators of potato plants when sprayed with amino acids, it may be due to their role in providing the energy that the plant expends in the representation of nitrates and building proteins (22), and amino acids have an important role in the biological construction of carbohydrates, proteins and fats in plant parts. It is a source of nitrogen necessary for its construction, which leads to an increase in the vegetative growth of the plant (15, 21, 30), and perhaps the reason for the improvement in the quantitative and qualitative yield indicators when spraying plants with salicylic acid and amino acids is that spraying plants with these substances leads to an increase in their content. Which leads to affecting the osmotic and water effort of the plant cell and thus increases its ability to absorb water and nutrients necessary for growth (13, 16, 26), which is positively reflected on the quantitative and qualitative yield indicators. These results in agreements with (9, 10)

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