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The physiological role of potassium and calcium spraying on vegetative characteristics of two potato varieties

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Abstract--An experiment was carried out in the forest area during the spring growing season 2021 to study the physiological role of calcium and potassium spraying on some vegetative growth characteristics in two potato varieties. The experiment included two potato varieties, calcium in three concentrations (0, 500 and 1000 mg.L⁻¹) and potassium in three concentrations (0, 2.5 and 5 gm. L⁻¹), thus it included 18 treatments (2 x 3 x 3). The experiment was carried out in the field using the Split-Split Plots system within the RCBD design, each treatment was repeated three times. The results showed that Fandango cultivars were significantly superior than as compared to cultivar Sifra in all the studied traits. The plants which treated with both concentrations of calcium 500 and 1000 mg. L⁻¹ achieved a significant increase in most of the studied traits compared to the untreated plants. The plants which treated with concentrations of 2.5 and 5 g.L⁻¹ of potassium achieved a significant increase in the relative chlorophyll content of leaves, while using the concentration of 2.5 g. L⁻¹ led to a significant increase in plant height. On the other hand, the leaf area was significantly increased when using the concentration 5 g. L⁻¹.

Keyword--physiological, potassium, calcium spraying, vegetative.

Introduction

Potato (*Solanum tuberosum* L.) belongs to the solanaceae family and is among the four most important crops in the world after wheat, corn and rice. It considers one of the vegetable crops rich in nutrients and easily digestible. The percentage

of dry matter in the tubers ranges from 15-29%, the starch from 10-24%, proteins 1- 2%, carbohydrates 15%, and the percentage of mineral salts 1% consisting mainly of potassium salts, phosphorous, magnesium and calcium (Hassan, 1999). The potato crop is also the first alternative to cereal crops in solving the global food problem (Aldouri and Zanzal, 2017). Plant growth and production are affected by many factors, including choosing the appropriate variety for the environmental conditions which prevailing in the production area (Daoud, 2013). Nasser (2020) studied three cultivars of potato Barcelona, La Perla and Montreal, the cultivar La Perla was significantly superior in the number of stems, leaf area and the percentage of chlorophyll compared to the other two cultivars. Al-Ajili (2021) in a study of two cultivars of potato Arizona and Flores, found that the Arizona cultivar was significantly superior in the number of stems and leaf area of the plant. Khudair (2022) in his study on three cultivars of potato Fandango, Montreal and Taurus, the Fandango variety was significantly superior in the relative content of chlorophyll in comparison with the other two cultivars Montreal and Taurus, while the plants of the Montreal and Fandango variety were significantly superior in the plant height, Furthermore, the plants of the variety Fandango were distinguished with the highest percentage of dry matter in the leaves.

Bahar et al. (2021) showed that the addition of potassium nitrate at three levels of 50,75,100 kg. ha⁻¹ at all levels led to a significant increase in vegetative characteristics such as plant height, number of stems and percentage of dry matter in the leaves in comparison with non-fertilized plants. Stone et al. (2021) showed that foliar spraying with potassium sulfate K₂SO₄ at concentrations 0,1800,2200 and 2600 mg. L⁻¹ led to a significant increase in plant height, number of stems, leaf area and percentage of dry matter, and the significant superior was increased with increasing concentration which used in comparison with the untreated plants.

Potassium is one of the necessary elements for plant growth and development, Yakimenko and Naumova (2021) concluded that potassium chloride has been added at a rate of 15 and 10 g. m², where 10 g. m² led to a significant increase in plant height, leaf area and percentage of dry matter in leaves compared to the level of 15 g. m² and the control. As per Ibrahim's study (2012) which was conducted during two seasons, the application of calcium chloride (25% Ca) at concentrations of 400 and 800 mg. L⁻¹ of Ca led to a significant increase in the total chlorophyll content of leaves in both seasons. Whereas the leaf area significantly increased in the second season only. Helal et al. (2015) explained in a study of the effect of calcium in potato fields for two seasons in the form of calcium sulfate CaSO₄ at a rate of 25,50,75 kg. ha⁻¹ where all levels led to a significant increase in plant height, number of stems and total chlorophyll in leaves and leaf area and the percentage of dry matter in the leaves. As for EL-Hadidi et al. (2017), they found a significant increase in plant height, number of aerial stems, leaf area, chlorophyll content in leaves and percentage of dry matter in leaves when spraying Salany potato plants with calcium nitrate (17% Ca) at concentrations of 0.6% and 0.8%. The purpose of the study is:

- Improving the vegetative characteristics of plants by using foliar spraying with calcium and potassium.

- Finding the best concentration of calcium and potassium and which the plants respond to it and thus positively reflected on the vegetative characteristics.
- Finding the best interference between the cultivars and calcium and potassium concentrations.

Materials and Methods

The experiment was carried out in the research field of the College of Agriculture and Forestry/Mosul University/Forest Area during the spring growing season 2021. The land was prepared for cultivation then ploughed the field. The experimental unit included three seedbeds with a length of 2.10 m and a width of 75 cm. Thus, the area of the experimental unit reached 4.725 m². The tubers were manually planted at a distance of 30 cm between one tuber and another, with 7 tubers per seedbed (21 plants per experimental unit). The tubers were planted at a depth of 12-15 cm, and surface irrigation was selected to irrigate the plants in the field. Agricultural service operations were conducted for all experimental units, including fertilization, weeding, export, preventive and curative control of diseases, insects and bushes. Urea fertilizer (46% N) was added at a rate of 400 kg. ha⁻¹ and triple superphosphate (45% P₂O) at a rate of 600 kg. ha⁻¹ Potassium sulfate (48% K₂O) at a rate of 400 kg. ha⁻¹ (Al-Obaidi, 2005).

The fertilizer was added in three batches, the first after 15 days of planting and included all the phosphate fertilizer, the second after emergence and included half of the nitrogen fertilizer and all the potassium fertilizer, and the third after a month from the second and included the remaining half of the nitrogen fertilizer and the addition was in a trench under the plant. Experimental treatments included three factors, the first factor included two imported potato cultivars (Fandango and Sifra), the second factor included calcium chloride Ca (27.3%) with three concentrations (0, 500, 1000) mg. L⁻¹. The third factor included potassium sulfate K₂SO₄ (50%) K₂O in three concentrations (0, 2.5, 5) g. L⁻¹. The plants were treated with calcium and potassium in three stages of plant growth: the first after completion of field emergence, the second and the third with an interval of 20 days between phase and another. As a result of the interference between the levels of the studied factors, the number of treatments is 18 (2 x 3 x 3). The experiment was implemented in the field using the split-plot system within the RCBD design, where the cultivars were placed in the main plots and calcium chloride concentrations in the secondary sub-plots where the sub-sub-plots included potassium concentrations, and each treatment was repeated three times. The results were analyzed statistically by SAS program. The studied characteristics: relative chlorophyll content of leaves, plant height, number of stems, leaf area and dry matter in leaves %.

Results and Discussion

Tables (1-5) indicate that the plants of the cultivar Fandango were significantly superior to the plants of the cultivar Sifra in the relative content of chlorophyll in leaves, plant height, number of stems, leaf area of the plant and percentage of dry matter in the leaves. As for the effect of calcium, the tables (1-5) show that both concentrations of 500 and 1000 mg. L⁻¹ of calcium had a significant effect on all

studied traits compared to control plants. Furthermore, the superior concentrations of calcium did not differ significantly between them, except the percentage of dry matter in the leaves. The results showed that the addition of potassium at concentration of 5 g.L^{-1} led to a significant increase in the chlorophyll content and leaf area of the plant, while the use of potassium at a concentration of 2.5 g.L^{-1} led to a significant increase compared to the control treatment and a concentration of 5 g.L^{-1} for plant height. As for the effect of potassium, it has been noticed that there are no significant differences between potassium concentrations and the control treatment for the two characteristics which are the number of stems and the percentage of dry matter in the leaves.

The results of the effect of the dual interference between cultivars and calcium were as follows; the relative chlorophyll content of leaves in plants of the cultivar Fandango treated and untreated with calcium were significantly superior to all treatments of plants of the cultivar Sifra. There was a significant increase for the following traits: number of stems, plant height and leaf area in plants of the cultivar Fandango with concentration of 500 mg.L^{-1} of calcium. As for the percentage of dry matter in the leaves the highest significant value was 21.97% in plants of the cultivar Fandango which untreated with calcium. As for the dual interference between the cultivars and potassium, the highest significant values were recorded in the plants of the cultivar Fandango sprayed at a concentration of 2.5 g.L^{-1} of potassium as the following characteristics; plant height and relative chlorophyll content of leaves, which is 32.73. Using the concentration 5 g.L^{-1} of potassium with plants of the variety Fandango gave the highest significant value in the number of stems, which was $3.66 \text{ stem.plant}^{-1}$. The percentage of dry matter in the leaves that all the treatments of the Fandango cultivar differed significantly with all the treatments of the plants of the cultivar Sifra.

The results of the dual interference between calcium and potassium and its effect on the studied traits were as follows: the relative chlorophyll content of the leaves was the highest significant value in this trait 31.98 found in the case of interference between the concentration treatment 1000 mg.L^{-1} of calcium with 5 g.L^{-1} of potassium. As for the plant height trait, the highest value was $86.50 \text{ cm.plant}^{-1}$ in the case of interface between the treatment 1000 mg.L^{-1} of calcium with 2.5 g.L^{-1} of potassium. Spraying calcium at concentration of 500 mg.L^{-1} without potassium gave the highest significant increase in the two characteristics which are the number of stems and leaf area per plant, which were $3.68 \text{ stem.plant}^{-1}$ and $11987.5 \text{ cm}^2.\text{plant}^{-1}$ respectively for the two mentioned traits. The highest significant value in the percentage of dry matter in the leaves was 21.47 which recorded in the dual interference between the concentration of 500 mg.L^{-1} calcium and 5 g.L^{-1} potassium.

Triple interference of the three studied factors (varieties, calcium and potassium). The results show that the highest value in the relative chlorophyll content of leaves was 33.21 found in plants of the cultivar Fandango treated with a concentration of 1000 mg.L^{-1} of calcium and 2.5 g.L^{-1} of potassium. The highest value of the height of the plant was $100.18 \text{ cm.plant}^{-1}$ found in plants of the cultivar Fandango with concentration 500 mg.L^{-1} of calcium and 2.5 g.L^{-1} of potassium. The plants of the cultivar Fandango treated with a concentration of 500 mg.L^{-1} of calcium and not treated with potassium the two highest significant

values were recorded in the characteristics of the number of stems and leaf area of the plant, which were 4.30 stem. plant⁻¹ and 15460.6 cm².plant⁻¹, respectively for the two mentioned traits. The highest value of dry matter in leaves 22.24 was obtained in plants of the cultivar Fandango when using 500 mg. L⁻¹ of calcium and 5 g.L⁻¹ of potassium.

Table 1
Effect of cultivar, calcium and potassium and the interference between them on the relative chlorophyll content of leaves (SPAD)

Cultivars	Calcium Con. (mg.L ⁻¹)	Potassium Con. (g.L ⁻¹)			Cultivar × Calcium	Average effect of cultivar
		0	2.5	5		
Fandango	0	29.46 bc	31.89 ab	32.81 a	31.39 a	31.93 a
	500	30.33 ab	33.08 a	32.33 ab	31.91 a	
	1000	31.32 ab	33.21 a	32.96 a	32.50 a	
Sifra	0	25.96 d	26.94 cd	26.55 cd	26.48 c	27.71 b
	500	27.20 cd	27.54 cd	30.38 ab	28.38 b	
	1000	27.03 cd	26.78 cd	31.00 ab	28.27 b	
Cultivar × Potassium	Fandango	30.37 b	32.73 a	32.70 a	Average effect of Calcium	
	Sifra	26.73 c	27.08 c	29.31 b		
Calcium × Potassium	0	27.71 d	29.41 b-d	29.68 b-d	28.94 b	
	500	28.77 cd	30.31 a-c	31.35 ab	30.14 a	
	1000	29.18 cd	29.99 bc	31.98 a	30.38 a	
Average effect of Potassium		28.55 c	29.91 b	31.00 a		

Table 2
Effect of cultivar, calcium and potassium and the interference between them on plant height (cm. plant⁻¹)

Cultivars	Calcium Con. (mg.L ⁻¹)	Potassium Con. (g.L ⁻¹)			Cultivar × Calcium	Average effect of cultivar
		0	2.5	5		
Fandango	0	86.93 d	97.13 ab	92.83 bc	92.30 b	94.60 a
	500	98.70 a	100.18 a	95.45 a-c	98.11 a	
	1000	92.47 bc	96.70 ab	91.00 cd	93.39 b	
Sifra	0	67.12 g	71.10 e-g	70.32 fg	69.51 d	72.03 b
	500	70.37 fg	70.05 fg	74.56 ef	71.66 cd	
	1000	75.25	76.30	73.20	74.92	

		ef	e	ef	c	
Cultivar × Potassium	Fandango	92.70 b	98.00 a	93.09 b	Average effect of Calcium	
	Sifra	70.91 c	72.48 c	72.70 c		
Calcium × Potassium	0	77.03 c	48.21 ab	81.58 b	80.91 b	
	500	84.53 ab	85.21 ab	85.01 ab	84.89 a	
	1000	83.86 ab	86.50 a	82.10 b	84.15 a	
Average effect of Potassium		81.81 b	85.24 a	82.90 b		

* The averages that share the same alphabetic letter for each factor and each interference do not differ significantly among themselves according to Duncan's polynomial test at the probability level ($P \leq 0.05$).

Table 3
Effect of cultivar, calcium and potassium and the interference between them on the number of stems (stem. plant⁻¹)

Cultivars	Calcium Con. (mg.L ⁻¹)	Potassium Con. (g.L ⁻¹)			Cultivar × Calcium	Average effect of cultivar
		0	2.5	5		
Fandango	0	2.93 de	3.00 de	3.82 ab	3.25 b-d	3.53 a
	500	4.30 a	3.53 b-d	3.50 b-d	3.78 a	
	1000	3.53 b-d	3.50 b-d	3.67 bc	3.57 ab	
Sifra	0	2.48 e	3.18 b-d	3.20 b-d	2.95 c	3.09 b
	500	3.07 c-e	3.10 c-e	2.92 de	3.03 cd	
	1000	3.45 b-d	3.15 cd	3.30 b-d	3.30 bc	
Cultivar × Potassium	Fandango	3.59 a	3.34 ab	3.66 a	Average effect of Calcium	
	Sifra	3.00 b	3.14 b	3.14 b		
Calcium × Potassium	0	2.71 c	3.09 bc	3.51 ab	3.10 b	
	500	3.68 a	3.32 ab	3.21 b	3.40 a	
	1000	3.49 ab	3.33 ab	3.48 ab	3.43 a	
Average effect of Potassium		3.30 a	3.24 a	3.40 a		

Table 4
Effect of cultivar, calcium and potassium and the interference between them on leaf area ($\text{cm}^2.\text{plant}^{-1}$)

Cultivars	Calcium Con. (mg.L^{-1})	Potassium Con. (g.L^{-1})			Cultivar \times Calcium	Average effect of cultivar
		0	2.5	5		
Fandango	0	8261.4 e	9225.3 e	11535.0 d	9673.9 b	12479.8 a
	500	15460.6 a	14147.6 a-c	12891.3 b-d	14166.5 a	
	1000	12650.2 cd	13730.5 bc	14416.2 ab	13599.0 a	
Sifra	0	7454.7 e	7678.4 e	8154.6 e	7762.6 b	8163.7 b
	500	8514.5 e	7882.0 e	8981.0 e	8459.2 b	
	1000	8035.5 e	8188.1 e	8584.3 e	8269.3 b	
Cultivar \times Potassium	Fandango	12124.1 a	12367.8 a	12947.5 a	Average effect of Calcium	
	Sifra	8001.6 b	7916.2 b	8573.3 b		
Calcium \times Potassium	0	7858.1 d	8451.9 d	9844.8 c	8718.2 b	
	500	11987.5 a	11014.8 a-c	10936.1 a-c	11312.8 a	
	1000	10342.8 bc	10959.3 a-c	11500.3 ab	10934.1 a	
Average effect of Potassium		10062.8 b	10142.0 ab	10760.4 a		

* The averages that share the same alphabetic letter for each factor and each interference do not differ significantly among themselves according to Duncan's polynomial test at the probability level ($P \leq 0.05$).

Table 5
Effect of cultivar, calcium and potassium and the interference between them on dry matter in leaves %

Cultivars	Calcium Con. (mg.L^{-1})	Potassium Con. (g.L^{-1})			Cultivar \times Calcium	Average effect of cultivar
		0	2.5	5		
Fandango	0	21.65 ab	22.27 a	21.99 a	21.97 a	21.66 a
	500	21.41 a-c	21.32 a-d	22.24 a	21.66 a	
	1000	21.21 a-d	21.10 a	20.93 a-e	21.34 a	
Sifra	0	19.46	19.73	19.86	19.70	19.79

		ef	d-f	c-f	b	b
	500	20.02 c-f	19.03 f	20.71 a-e	19.20 b	
	1000	19.82 c-f	19.73 ef	20.06 b-f	19.75 b	
Cultivar × Potassium	Fandango	21.42 a	21.83 a	21.72 a	Average effect of Calcium	
	Sifra	19.77 b	19.83 b	20.21 b		
Calcium × Potassium	0	20.56 ab	21.00 ab	20.93 ab	20.83 a	
	500	20.72 ab	20.17 b	21.47 a	20.79 a	
	1000	20.52 ab	20.64 ab	20.49 ab	20.55 a	
Average effect of Potassium		20.59 a	20.60 a	20.96 a		

* The averages that share the same alphabetic letter for each factor and each interference do not differ significantly among themselves according to Duncan's polynomial test at the probability level ($P \leq 0.05$).

An overview of the results of the vegetative characteristics that were presented, it was found that the plants of the cultivar Fandango were significantly superior in all the studied vegetative characteristics in comparison with the plants of the cultivar Sifra Tables (1-5). The reason for this may be due to the difference in the genetic structure of each variety and the extent of the interference of these genes with the environmental conditions. As a result, discrepancies between the varieties for each of these traits. Our significant results are consistent with what was mentioned (Al-Qaisi and Al-Bayati, 2010 and Ibrahim, 2018 and Al-Hayali, 2019) in the presence of significant differences in some vegetative characteristics among the cultivars used in their studies.

The significant increase achieved when calcium was used at both concentrations of 500 and 1000 mg. L⁻¹ in most of the vegetative characteristics such as the relative chlorophyll content, plant height, number of stems and leaf area Tables (1-4). The reason for this may be due to the role of calcium in building the wall, forming cell membranes and maintaining cell swelling (Bangerth, 1979), where this element works to regulate osmotic effort and regulate the process of osmosis and maintain hormonal balance within the plant and to the continuity of vital processes at high rates and stability of the forming cell membranes, including the formation of Chlorophyll (Nakata, 2003). In addition, calcium has a positive and effective role in increasing the efficiency of the photosynthesis process, in addition to its effect in regulating chromosomes in spindle alignment, which helps in cell division, and it also helps in cell growth and increase in size and thus affects the development of meristematic cells and works to regulate the work of plant hormones such as indole acetic acid IAA by Plant (David, 2007). Thus, these physiological roles of calcium will be reflected in the form of significant increases in the vegetative characteristics that were mentioned. It inhibits the activity of several oxidative enzymes (Wei et al., 2008). Also, calcium has an important role in increasing growth speed by stimulating the growth of the largest number of

sprouts in potato tubers (Davies and Ros, 1985). These findings are consistent with Tawfik (2001), El-Beltagy et al (2002), and EL-Hadidi et al (2017).

As for the significant effect of potassium when using a concentration of 2.5 and 5 g.L⁻¹ on some vegetative characteristics represented by the relative chlorophyll content of leaves Table (1) and the concentration of 2.5 g. L⁻¹ in the characteristic of plant height Table (2) and the concentration of 5 g.L⁻¹ in the characteristic of leaf area Table (4) this can be explained by the fact that the addition of potassium as a spray to the vegetative led to an increase in its absorption and thus an increase in its concentration in the guard cells, thus increasing the stomata area and keeping the cells in a state of fullness and thus aiding the gaseous exchange between the outer atmosphere and the vegetative stomata, which leads to activating physiological processes and providing the energy needed for vital activities (Krauss, 2004). The physiological role of potassium can be attributed to the activation of many enzymes, especially those responsible for building the chlorophyll molecule, and thus increasing the amount of chlorophyll content in the leaves, as the lack of potassium leads to the destruction of the chloroplast (Abu Dahi and Younis, 1988) and it has an important role in plant nutrition and its role in many vital processes (Havlin et al., 2005) it regulates the action of hormones that increase the division and elongation of cells (Adrian, 2004) and thus an increase in the height of the plant and the leaf area of the plant.

The availability of the appropriate amounts of potassium for the plant has a great importance in increasing the efficiency of the photosynthesis process as the decrease in potassium leads to a slowdown in the photosynthesis process. In addition to its active role in building the energy compound ATP, which is the carrier and storage of energy in the plant as it transports the products of the process photosynthesis to the areas that the plant needs (Al-Amri, 2005 and Al-Zoba'i, 2008), therefore this will be significantly reflected in the vegetative factors that were mentioned. As per the above that the plants of the cultivar Fandango were significantly superior in most of the vegetative characteristics compared to the plants of the cultivar Sifra. Using calcium at both concentrations of 500 and 1000 mg. L⁻¹ led to a significant increase in many vegetative characteristics with the recommendation of conducting future studies using concentrations of 250 and 750 mg. L⁻¹ and comparing them with the mentioned concentrations.

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