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POTATO (*SOLANUM TUBEROSUM* L.) RESPONSE IN TERMS OF GROWTH AND YIELD TO FOLIAR APPLICATION OF NANOCOMPOSITE FERTILIZER

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SUMMARY

The study on potato (*Solanum tuberosum* L.) took place during the cropping season of 2019–2020 at the Babil Governorate, Abu Gharq Region, Iraq. This study aimed to determine the response of five potato cultivars, Burren (control), Everest, Arizona, Argos, and Evora, to foliar application of Loenergy Plus Nano-nutrient solution with three concentrations (0, 1.5, and 2.5 ml^{-1}) and three replicates. The results showed the Loenergy Plus Nano-nutrient solution's spraying significantly affected the potato cultivars' vegetative and yield characteristics, especially when used at a concentration of 2.5 ml L^{-1}. It resulted in the highest average values compared with the lower concentration and the control (distilled water). The potato Argos cultivar expressed the maximum values in vegetative traits among the studied potatoes. The research showed the different potato cultivars behaved differently to the same factor in the Iraqi environmental conditions.

Keywords: Potato (*S. tuberosum* L.), solanaceae, nano-materials, foliar application, tuber

Key findings: Foliar spraying of Loenergy Plus Nano-nutrient solution (2.5 ml L^{-1}) resulted in increased potato (*S. tuberosum* L.) growth and yield regardless of the cultivar type**.** Some potato cultivars showed suitability to grow in Iraqi environmental conditions much better than the Burren cultivar as the most commonly cultivated variety in local farms.

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INTRODUCTION

The potato (*Solanum tuberosum* L.) belongs to the plant family Solanaceae, with its origin in South America, the Andes Mountains, on the border between Peru and Bolivia. The potato's transfer from South America to Europe transpired by the first Spanish exploratory of America in the 16th century, then quickly spread in Western Europe, becoming one of the most valuable crops of vegetables that people depended on as staples. It moved from Europe to North America, South Africa, and Australia, then spread to the rest of the world (Bohl and Johnson, 2010).

With the excessive population increase and the great nutritional importance of potatoes and their rising consumption, the need has become intense to raise production by extending the cultivated area. This can be through the selection of cultivars appropriate for the environmental conditions of the region. The method of import and insertion of varieties is one of the easiest and cheapest ways to obtain types with good specifications. The items' further testing under the conditions of the importing country could result in choosing and adopting the most suitable type for the prevailing environmental conditions (Al-Shammari, 2015; Devaux *et al.*, 2021).

Potato needs specific environmental requirements to stabilize varieties and growth features and maintain consumption quality in different environmental conditions (TomasieWicz *et al.*, 2003; Haase *et al.*, 2005). The choice of varieties and qualitative attributes in different environmental settings is an influential factor in choosing appropriate varieties of diverse regions. The production of potatoes incurs effects from many factors, including the category response to prevailing environmental conditions in the region and the genetic expression of the category (Haase *et al.*, 2005).

Nutrition is an essential and significant factor in the production and quality of tubers. It is from the vicinity crops that need large quantities of nutrients, and this may be due to the large size of the vegetative total and the period of growth of tubers taking about 90 to 120 growing days to harvest. The stages of tubers' formation and maturation are critical stages in the crop plant's life. In these stages, the plant will need the most nutrients. The nutrients usually absorbed from the soil may be insufficient during this stage and therefore require a speedy and easy-to-absorb formula, as provided by foliar fertilization compared with ground fertilization (Fageria *et al.*, 2009).

In addition, the foliar application of plant nutrition provides fast-growing and less fertilization usage, which, in turn, increases crop income (Heyland and Werner, 2000). This research materialized to compare and choose the best potato varieties for their suitability for cultivation in the Iraqi environment and evaluate the efficiency of foliar spraying with commercial nano-nutrients at different concentrations.

MATERIALS AND METHODS

The experiment commenced in a private vegetable farm in Babil Governorate, Abi Gharq area, during the crop season of 2019–2020. Potato seed tubers came from the Euphrates Valley Services Company. Before planting, the land and planting preparations comprised plowing twice perpendicularly, with the land smoothed and leveled (Table 1). The land, divided into three replicates, had tubers planted on September 10, 2019 on 80-cm wide furrows and 25-cm planting spacing.

The experiment included two factors. The first consisted of five potato cultivars: Burren (control), Everest, Arizona, Argos, and Evora. The second factor was spraying the plants with nanoparticle nutrient Loenergy Plus solution (produced by Turkish Agri Sciences), containing nutrients NPK at rates of 12:12:10 and sprayed at three concentrations (0, 1.5, and 2.5) ml L^{-1}. The first spraying with the Loenergy Plus Nano-nutrient solution transpired 45 days post-cultivation, while the second application was 15 days after the first spray (the stage increasing tuber size). Cultivation operations and services (irrigation, weeding, hilling, and control) continued according to the recommendations for the crop cultivation (Matloob *et al.*, 1989).

Table 1. Physical and chemical properties of the experimental soil before planting.

Properties	Physical properties				Chemical properties					Organic matter
Property	Clay	Silt	Sand	Texture	N	P	K	pH	EC	
Unit		g Kg^{-1}			mg L^{-1}				dSms m^{-1}	g Kg^{-1}
	70	130	800	Sandy loam	10.5	2.5	21	7.3	2.8	1.2

When the crop reached maturity on January 10, 2020, six random plants from each experimental unit were uprooted. For all the 15 treatments, the study measurements were collected, where experiment measurements included plant height (cm), the number of main stems (stems $plant^{-1}$), the number of leaves (leaves $plant^{-1}$), shoot dry weight (g $plant^{-1}$), and the number of tubers (tubers $plant^{-1}$). In addition to the average tuber weight (g $tuber^{-1}$), the calculation dividing the plant yield (g) by the number of plant tubers provided the average yield per plant (kg $plant^{-1}$) and the marketing yield (t ha^{-1}). Excluding the infected and damaged tubers, the remaining tubers' computation as a marketable yield was by multiplying the average yield of one plant (kg $plant^{-1}$) by the total number of plants (44,000).

Experimental design and data analysis

The experiment proceeded as a factorial experiment according to RCBD, with three replications. The means' comparison was according to the Duncan's multiple range test at a probability level of 0.05 (Al-Rawi and Khalafallah, 2000). The data analysis used the GenStat software (VSN International Gen Sat12.1, 2009).

RESULTS AND DISCUSSION

The results showed significant differences among the cultivars for most growth characteristics under study (plant height, the number of total leaves, and the shoot dry weight), while the cultivars did not differ in the number of main stems (Table 2). The Burren cultivar had the highest average plant length (100.33 cm $plant^{-1}$) and the lowest average number of total leaves (42.89 leaves $plant^{-1}$). Meanwhile, the Argos cultivar had the topmost average number of total leaves and dry weight of shoots, amounting to 99.33 leaves $plant^{-1}$ and 81.56 g $plant^{-1}$, respectively, and the lowest average plant length at 59.44 cm $plant^{-1}$. The least average shoot dry weight (34.44 gm) was in the Arizona cultivar.

The outcomes indicated spraying the plants with Loenergy Plus had a significant effect on the vegetative growth characteristics (plant height, the number of main stems, the number of total leaves, and shoot dry weight). The concentration of 2.5 ml L^{-1} resulted in the highest average of the mentioned traits (78.80 cm $plant^{-1}$, 3.55 stems $plant^{-1}$, 66.53 leaves $plant^{-1}$, and 61.13 g $plant^{-1}$, respectively). Meanwhile, spraying with distilled water showed the lowest rates of vegetative growth characteristics (72.07 cm $plant^{-1}$, 2.78 stems $plant^{-1}$, 57.53 leaves $plant^{-1}$, and 54.13 g $plant^{-1}$, respectively).

The interaction between the Burren cultivar and foliar spray at a concentration of 2.5 ml L^{-1} gave the tallest plant height and the most number of main stems (103.00 cm $plant^{-1}$ and 3.55 stems $plant^{-1}$). Similarly, the cultivar Argos at the same concentration led to the highest mean of the total number of leaves and shoot dry weight (103.33 leaves $plant^{-1}$ and 85.33 g $plant^{-1}$). Regardless of cultivar, spraying treatment with distilled water (control) provided the lowest parameters for all the traits under study, with a significant difference from all treatments.

As for the yield indicators, results, as shown in Table 3, reveal the cultivars differed, as the Argos cultivar had the maximum average in yield characteristics (the number of

Table 2. Effect of foliar spray with nano-nutrient (Loenergy Plus) on growth indicators of five potato cultivars.

Potato cultivars	Plant height (cm)				Stems plant^{-1}				Leaves plant^{-1}				Shoot dry weight (g)			
	Nano-fertilizer Loenergy Plus (ml L^{-1})															
	0	1.5	2.5	Means	0	1.5	2.5	Means	0	1.5	2.5	Means	0	1.5	2.5	Means
Burren	96.00	102.00	103.00	100.33	3.15	3.05	3.55	3.25	40.00	43.00	45.67	42.89	66.00	67.33	72.67	68.67
Everest	62.00	61.00	67.33	63.44	2.40	3.30	3.69	3.13	52.00	58.00	62.33	57.44	43.33	43.67	48.00	45.00
Arizona	86.67	92.33	92.67	90.56	2.81	3.29	3.53	3.21	46.00	51.67	54.33	50.67	32.00	35.33	36.00	34.44
Argos	56.33	59.00	63.00	59.44	2.59	3.49	3.40	3.16	94.67	100.00	103.33	99.33	76.67	82.67	85.33	81.56
Evora	59.33	64.33	68.00	63.89	2.96	2.83	3.57	3.12	55.00	62.33	67.00	61.44	52.67	60.33	63.67	58.89
Means	72.07	75.73	78.80		2.78	3.19	3.55		57.53	63.00	66.53		54.13	57.87	61.13	

Values are means of 3 replications, means within a measurement or within Means column followed by different letter(s) are significantly different according to Duncan's multiple range test ($P \leq 0.05$).

Table 3. Effect of foliar spray with nano-nutrient (Loenergy Plus) on potato yield components of five potato cultivars.

Potato cultivars	Tubers plant^{-1}				Tuber weight (g)				Plant yield (g plant^{-1})				Marketable yield (t ha^{-1})			
	Nano-fertilizer Loenergy Plus (ml L^{-1})															
	0	1.5	2.5	Means	0	1.5	2.5	Means	0	1.5	2.5	Means	0	1.5	2.5	Means
Burren	7.33d	8.00	8.00	8.11	109.1	111.9	115.8	112.3	809.0	902.2	932.2	881.1	18.39	20.00	22.68	20.36
Everest	8.00cd	8.00	10.667	8.88	101.8	107.2	110.0	106.3	830.9	867.8	1187.0	961.9	24.73	26.63	27.71	26.36
Arizona	5.66e	7.66	11.33	8.22	99.5	105.6	113.9	106.3	574.1	815.6	1298.8	896.2	17.91	21.60	24.41	21.30
Argos	7.66d	9.66	10.33	9.22	117.2	125. 1	127.7	123.3	915.9	1212.5	1331.9	1153.4	29.53	32.47	35.39	32.46
Evora	7.33 d	9.00	8.00	7.77	98.1	106.7	108.9	104.6	722.2	963.7	881.6b	855.8	16.62	17.75l	18.89	17.75
Means	7.20 c	8.46	9.66		105.1	111.3	115.3		770.4	952.4	1126.3		21.44	23.69	25.82	

Values are means of 3 replications, means within a measurement or within Means column followed by different letter(s) are significantly different according to Duncan's multiple range test ($P \leq 0.05$).

tubers, the average weight of the tuber, the average yield of one plant, and the marketing yield), while the cultivar Evora showed the lowest average for the same traits. Findings also displayed (Table 3) a significant effect of spraying the plants with the nano-nutrient solution (Loenergy Plus) in increasing the characteristics of the crop under study, especially at a concentration of 2.5 ml L^{-1}. It led to the highest values compared with the control treatment sprayed with distilled water. Outcomes exhibited the highest yield standards resulted in the Arizona overlap treatment, and the concentration was 2.5 ml L^{-1} for the most number of tubers (11.33 tubers plant^{-1}). Meanwhile, the massive average tuber weight was 127.7 tubers plant^{-1}), and the average yield per plant was 1331.9 g plant^{-1}. Moreover, the marketing yield of 35.39 t ha^{-1} appeared in Argos with the same concentration of the nutrient solution.

The results, as available in the tables, indicate differences existed between the cultivars in the indicators under study (growth and production traits). This may be due to the different genetic factors between the varieties, i.e., these differences are under the control of genes. The varying effects of the interaction between genetic and environmental factors may have led to such a difference between cultivars in growth and yield characteristics (Ngailo *et al.*, 2019; Ali *et al.,* 2021; Ebem *et al.*, 2021). The Argos cultivar was distinct in growth and production indicators, which signifies the adaptation of this cultivar to the environmental conditions of the region.

A good environment contributes to showing the distinctive traits of cultivars, or this cultivar may possess good genetic traits for successful cultivation in various environments, giving superior results (Affleck *et al.*, 2008). In general, the existence of differences between cultivars in growth and yield characteristics as a result of their response to spraying with nutrient solution refers to the cultivars' variance in their ability to absorb nutrients. Genetic control may be the reason for differing responses of cultivars to foliar feeding, since the nutrients' absorption and transfer are under the control of several genes (Abu-Dahi and El-Younes, 1988).

Conversely, the treatments of spraying with nutrient solution were superior and resulted in the highest values of growth and production characteristics. This is mostly because of the contribution of the nutrient solution in providing the necessary needs of nutrients required for plant growth. The nutrient solution contains the main elements crucial in the process of photosynthesis and respiration, especially the macro-elements. Major elements, such as nitrogen and phosphorous, are part of the composition of nucleic acids, DNA, and RNA. These are necessary for cell division, increasing the number of phalanges, plant height, the number of leaves, and thus increasing the dry weight of the shoot.

The nutrient solution also contains potassium, critical in transporting nutrients synthesized in the leaves to the rest of the plant. It plays a vital role in the process of photosynthesis through its participation in regulating the opening and closing of stomata (Naseem *et al.*, 2019). Providing nutrients in a balanced manner to the plant increases the activity of gibberellins within the plant tissues, which works to increase the elongation of cells (De Lucas *et al.*, 2008), and hence positively influencing improved growth and increased production in quantity and quality.

CONCLUSIONS

Findings in general showed the potato cultivar Argos was superior in most vegetative and all yield indicators. Foliar application with 2.5 ml L^{-1} of the Loenergy Plus Nano-nutrient solution was the best, which resulted in the highest increase in potato growth and yield, regardless of the cultivar type. Some potato cultivars displayed suitability to grow in Iraqi environmental conditions much better than Burren, as the most commonly cultivated variety in local farms. Said cultivars are reliable and recommendable for cultivation.

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