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Effect of Nano Organic Nutrient Application and Boron on Vegetative Growth , Yield, Quality and Mineral Content of Potato (Solanum tuberosum L.)

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Abstract. *A field experiment in spring 2024 at the University of Mosul evaluated potato response to foliar applications of a nano organic nutrient (Optimus Plus) and boron using a factorial RCBD design. Optimus Plus was applied at 0, 2, and 4 ml L⁻¹, and boron at 0, 100, and 125 mg L⁻¹ across three growth stages. To promote growth, fertilizers were applied in three split doses: the first, 15 days after planting, included the full dose of phosphorus fertilizer; the second, at emergence, included half of the nitrogen and the full dose of potassium; and the third, one month after the second. Data were statistically analyzed using the SAS SAS (2017). software package according to the experimental design, and treatment means were compared using Duncan's Multiple Range Test at a significance level of ≥ 0.05.*
Keywords. *Potato, nano fertilizer, boron, foliar spray, vegetative growth, yield components, SPAD, dry matter.*

INTRODUCTION

Potato (*Solanum tuberosum* L.) is a major global food crop belonging to the Solanaceae family. It ranks as the fourth most important staple crop worldwide after wheat, maize, and rice. Potato tubers are nutritionally rich and easily digestible, containing 15–29% dry matter, 10–24% starch, 1–2% protein, 17.5% carbohydrates, and about 1% minerals, primarily potassium, phosphorus, calcium, and magnesium (Hassan,1999). Furthermore, potato serves as a vital alternative to cereal crops in addressing global food security challenges (Aldoury et al., 2019).

Fertilization, whether chemical or organic, plays a crucial role in promoting plant growth and enhancing crop productivity. However, farmers face significant challenges, including high financial costs and the adverse environmental impacts associated with chemical fertilizers. Consequently, many countries worldwide have shifted towards encouraging organic production. Organic matter is utilized without the addition of synthetic chemicals, ensuring the balanced supply of nutrients to plants at degradation rates suited to soil, climate, and crop conditions(Ibraheem and Alsultan,2025 , Taha etal,2025 , Abbas and Ibraheem,2025 , Ibraheem etal.2025 , Ibraheem and Mahmoud,2024 , Ibraheem and Mahmoud,2024 , Hussein and Ibraheem, 2023 , Ibraheem,2023)

In Egypt, Abd El-Aal et al. (2010) evaluated the effect of different concentrations (0, 0.5, 1.0, and 1.5%) of foliar-applied potassium humates on potato plants. They reported that the highest concentration (1.5%) significantly increased studied traits, including dry matter content, chlorophyll concentration in leaves, and dry matter and starch content in tubers compared to lower concentrations.Similarly, Karzoun et al. (2022) conducted a study in Syria assessing the foliar application of the seaweed extract (Amalgerol) at 2.5 ml L^{-1}, applied three times with 20-day intervals, on potato plants. This treatment significantly enhanced plant height, leaf number, and leaf area compared to the untreated control.

Boron is considered an essential micronutrient for plants, playing a crucial role in cell wall formation, the transport of sugars to storage tissues, cell division, and the synthesis of auxins, amino acids, and proteins. It also regulates the translocation of carbohydrates from leaves to other plant organs(Lenka & Das, 2019; Singh & Singh, 2019). In a study conducted Elsadany et al. (2021), the foliar application of boron at concentrations of 0, 50, and 100 mg L^{-1} using boric acid was evaluated for its effect on the growth, yield, and quality of potato tubers. The results showed that the highest concentration (100 mg L^{-1}) significantly improved vegetative growth, qualitative yield, and increased the carbohydrate and starch content of the tubers compared to the other treatments. Similarly, Ilyas et al. (2021) reported that foliar spraying with boric acid at concentrations of 0, 0.02, and 0.04% pure boron showed that the 0.04% treatment resulted in the highest values for marketable tuber number, total yield per unit area, and tuber content of dry matter and starch. Moreover, Malek et al. (2021) found that foliar application of boric acid at concentrations of 0, 10, 20, and 30 mg L^{-1} in Egypt demonstrated that the 30 mg L^{-1} treatment significantly outperformed the others in terms of tuber number per plant, total yield, and tuber content of starch, total soluble solids, specific gravity, firmness, and boron concentration.

Objectives of the Study

- To evaluate the effect of different concentrations of nano organic fertilizer (Optimus Plus) on selected quantitative and qualitative traits of potato, in order to determine the optimal concentration for maximum vegetative response.
- To investigate the impact of multiple foliar-applied boron concentrations on the yield and quality of potato, aiming to identify the most effective concentration.
- To analyze the interactions between nano organic fertilizer and boron concentrations to determine the best treatment combination that improves vegetative growth and yield quality.

MATERIALS AND METHODS

Research Field of the College of Agriculture and Forestry, University of Mosul. Tap water was used as the source of irrigation.

The study aimed to evaluate the effect of foliar application of a nano-organic nutrient (Optimus Plus) and boron on the growth and productivity of potato plants (*Solanum tuberosum* L.). Optimus Plus was applied at three concentrations: 0, 2, and 4 mL L^{-1}. Boron was supplied in the form of boric acid at concentrations of 0, 100, and 125 mg L^{-1}. Foliar spraying was carried out in three stages: the first application occurred 10 days after full plant emergence, followed by two additional applications at 20-day intervals.

The experiment was arranged in a randomized complete block design (RCBD) with three replications, following the methodology of (Al-Rawi and Khalaf Allah,2000)

1.1. Studied Traits

- Leaf chlorophyll content (SPAD)
- Number of aerial stems per plant
- Leaf dry matter percentage
- Marketable tuber yield per plant (g $plant^{-1}$)
- Total marketable yield (t ha^{-1})
- Tuber dry matter percentage
- Tuber starch percentage (after harvest)
- Tuber specific gravity
- Calcium content in tubers (%)
- Boron content in tubers (mg kg^{-1} or as appropriate)

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using SAS software (SAS, 2017). Treatment means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$.

RESULTS

Chlorophyll Content in Leaves (SPAD)

Table 1 results show that foliar application of Optimus Plus at 2 and 4 ml L^{-1} significantly increased leaf chlorophyll content versus the control, with no difference between these two concentrations. Boron at 125 mg L^{-1} also significantly raised chlorophyll levels (34.18 SPAD). The highest chlorophyll content (37.03 SPAD) occurred with the combined treatment of 4 ml L^{-1} Optimus Plus and 125 mg L^{-1} boron, outperforming all other treatments.

Table 1. Effect of foliar application of Optimus Plus, boron, and their interaction on leaf chlorophyll content (SPAD)

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	

0	22.8167 d	32.2667 b	29.4167 c	28.1667 c
100	27.6500 c	33.0333 b	33.7500 b	31.4778 b
125	32.7333 b	33.0333 b	37.0333 a	34.1833 a
Mean effect of Organic Nutrient	27.7333 b	32.6944 a	33.4000 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

The data presented in Table 2 indicate that foliar application of Optimus Plus at 4 mL L^{-1} significantly increased the number of aerial stems, reaching 3.9778 stems per plant and outperforming other concentrations. Similarly, foliar spray with boron at 125 mg L^{-1} significantly enhanced stem number (3.7778 stems) compared to the control. The highest stem count (4.1000 stems per plant) was observed with the combined application of Optimus Plus at 4 mL L^{-1} and boron at 125 mg L^{-1}, significantly exceeding all other treatment combinations.

Table 2. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, and Their Interaction on the Number of Aerial Stems (stems $plant^{-1}$).

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	2.9667 c	3.5000 b	4.0333 a	3.5000 b
100	3.5667 b	3.7667 ab	3.8000 ab	3.7111 ab
125	3.8333 ab	3.4000 b	4.1000 a	3.7778 a
Mean effect of Organic Nutrient	3.4556 b	3.5556 b	3.9778 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

The data in Table 3 indicate that foliar application of Optimus Plus at 4 mL L^{-1} significantly increased the leaf dry matter percentage to 14.1978%, surpassing other concentrations. Foliar spray with boron at 125 mg L^{-1} also significantly enhanced dry matter percentage to 12.8533%. The highest value (16.860%) was recorded from the combined treatment of 4 mL L^{-1} Optimus Plus and 125 mg L^{-1} boron, significantly exceeding all other treatments.

Table 3. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, and Their Interaction on the Percentage of Dry Matter in Leaves.

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	6.632 d	11.807 c	14.190 b	10.8761 b
100	11.057 c	9.832 c	11.543 c	10.8106 b
125	10.615 c	11.085 c	16.860 a	12.8533 a
Mean effect of Organic Nutrient	9.4344 c	10.9078 b	14.1978 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

The results showed that both 2 and 4 ml L^{-1} concentrations of the organic nutrient Optimus Plus significantly improved chlorophyll content, dry matter percentage, and the number of aerial stems, with the 4 ml L^{-1} concentration outperforming 2 ml L^{-1} in most traits. This improvement is attributed to enhanced root efficiency and improved photosynthesis and respiration processes(Ullah etal, 2019). Additionally, the 125 mg L^{-1} boron concentration increased stem number, chlorophyll content, and dry matter percentage compared to the control and 100 mg L^{-1}, due to its role in carbohydrate transport and calcium maintenance (Abu Dhahi and Al-Younis,1988).

Foliar application of 4 ml L^{-1} Optimus Plus raised the marketable yield to 594.01 g per plant, while 100 mg L^{-1} boron increased yield to 657.09 g per plant compared to the control. The combination of no Optimus Plus with 100 mg L^{-1} boron produced the highest yield (692.83 g per plant), outperforming other treatments.

Table 4. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, and Their Interaction on Marketable Yield per Plant (g $plant^{-1}$)

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	439.96 e	513.87 cd	605.05 b	548.67 b
100	692.83 a	596.77 b	681.67 a	557.33 b
125	513.23 cd	561.34 bc	495.30 d	594.01 a
Mean effect of Organic Nutrient	519.63 b	657.09 a	523.29 b	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

The results in Table 5 showed consistent effects of the studied factors, both individually and in combination, across both locations. This aligns with the findings in Table 4 regarding the significant differences in marketable yield per plant, which is expected since marketable tuber yield (ton ha^{-1}) is derived from the yield per plant

Table 5. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, Cultivars, and Their Interaction on Marketable Tuber Yield (ton ha^{-1})

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	19.554 e	22.839 cd	26.891 b	23.0945 b
100	30.792 a	26.523 b	30.297 a	29.2041 a
125	22.810 cd	24.948 bc	22.013 d	23.2573 b
Mean effect of Organic Nutrient	24.3855 b	24.7701 b	26.4003 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

he results in Table 5 confirmed the consistent effects of the studied factors, both individually and in combination, aligning with Table 4 findings on marketable yield per plant, which is expected due to their direct relationship. The interaction between 4 mL L^{-1} of Optimus Plus and 125 mg L^{-1} of boron recorded the highest values for the evaluated traits: 24.1150%, 17.4922%, and 1.0984825, respectively.

Table 6. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, Cultivars, and Their Interaction on Dry Matter Percentage in Tubers.

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	16.0917 g	17.1417 f	19.3350 c	17.5228 c
100	17.1967 f	18.2750 d	20.5433 b	18.6717 b
125	17.8450 e	19.3400 c	24.1150 a	20.4333 a
Mean effect of Organic Nutrient	17.0444 c	18.2522 b	21.3311 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$**)**

Table 7. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, and Their Interaction on Starch Percentage in Tubers After Harvest.

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	10.3514 g	11.2859 f	13.2380 c	11.62507 c
100	11.3348 f	12.2946 d	14.3134 b	12.64758 b
125	11.9119 e	13.2424 c	17.4922 a	14.21547 a
Mean effect of Organic Nutrient	11.19936 c	12.27428 b	15.01449 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

Table 8. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, and Their Interaction on Tuber Specific Gravity

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	1.0604645 g	1.0654398 f	1.0758328 c	1.0672457 c
100	1.0657004 f	1.0708100 d	1.0815584 b	1.0726896 b
125	1.0687725 e	1.0758565 c	1.0984825 a	1.0810372 a

Mean effect of Organic Nutrient	1.0649791 c	1.0707021 b	1.0852912 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

The results showed significant differences in quantitative and qualitative yield traits between the concentrations of 2 and 4 mL L^{-1} of Optimus Plus, with the higher concentration (4 mL L^{-1}) significantly improving marketable yield per plant and tuber yield, as well as enhancing all quality traits. This improvement is attributed to the positive interactions between elements and organic compounds in nano-formulations, which enhance growth and productivity (Abu Dhahi and Al-Younis,1988).
Regarding boron, the 100 mg L^{-1} concentration had the most significant effect on yield compared to the control and 125 mg L^{-1}, while the higher concentration (125 mg L^{-1}) showed superior performance in improving quality traits. This may be due to boron's role in regulating the function of macronutrients such as nitrogen, phosphorus, potassium, and calcium, whose functions are disrupted in its absence (Al-Mosuli,2011).
Table (9) shows that foliar application of the organic nutrient at a concentration of 2 mL L^{-1} significantly increased calcium content in tubers compared to the control (1.43556%). Additionally, interactions at the first location revealed that applying 2 mL L^{-1} of the organic nutrient without boron resulted in the highest calcium content (1.6233%), outperforming other treatments.

Table 9. Effect of Foliar Application of Optimus Plus Organic Nutrient, Boron, and Their Interaction on Calcium Percentage in Tubers

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	1.0717 D	1.6233 a	1.4733 ab	1.38944 a
100	1.4167 ab	1.3250 bc	1.4883 ab	1.41000 a
125	1.1417 cd	1.3583 bc	1.2383 b-d	1.24611 b
Mean effect of Organic Nutrient	1.21000 b	1.43556 a	1.40000 a	

Means sharing he same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).
Table 10 shows that foliar application of the organic nutrient at 4 mL L^{-1} significantly increased tuber boron content to 49.380 mg L^{-1}, outperforming other treatments. Boron at 125 mg L^{-1} also significantly raised boron content to 45.526 mg L^{-1}, surpassing the 100 mg L^{-1} treatment. The interaction of 4 mL L^{-1} organic nutrient with 0 mg L^{-1} boron yielded the highest boron content at 56.330 mg L^{-1}, significantly exceeding all other combinations.

Table 10. Effect of foliar application of organic nutrient Optimus Plus, boron, cultivars, and their interactions on boron content in tubers (mg L^{-1}) .

Boron concentrations mg/L^{-1}	Organic Nutrient concentrations ml L^{-1}			Mean effect of Boron
	0	2	4	
0	26.148 c	44.828 b	56.330 a	42.436 a
100	25.657 c	45.502 b	43.842 b	38.333 b

125	42.275 b	46.333 b	47.968 b	45.526 a
Mean effect of Organic Nutrient	31.360 c	45.554 b	49.380 a	

Means sharing the same letter within each factor and interaction are not significantly different according to Duncan's multiple range test at the probability level of ($P \leq 0.05$).

Tables (9, 10) show that foliar application of the organic nutrient at both concentrations significantly increased tuber calcium content. This effect is likely due to the rich macro- and micronutrient composition of the organic nutrient, which enhances plant growth and nutrient uptake efficiency, thereby improving tuber chemical composition (O-Dell,2003).

The significant increase in tuber boron content may be due to the foliar application of boron, which provided the plant with sufficient amounts to enhance key physiological processes such as sugar and auxin transport, cell membrane formation, and root development. These improvements likely stimulated vegetative growth and nutrient accumulation in the tubers, aligning with the findings of (Rai etal, 2021).

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