# Role of nano-fertilization and Organic Fertilizer Application to the Soil in potato growth and yield

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## Abstract

A field experiment was conducted in Al-Kifl, Babylon, to study the effect of organic fertilizers (A) and nano-fertilizers (N) on some quantitative and qualitative yield traits of potato plants (*Solanum tuberosum* L.). A split-plot design (R&B) was used, with two treatments: organic fertilizer (compost) applied in the main plots at three levels (20, 40, and 60 tons $ha^{-1}$), and a control treatment (recommended NPK fertilizer) (A1, A2, A3 and A4, respectively). Nano-fertilizer (macro- and micronutrients) was applied in the subplots at three concentrations (0, 1, and 2 g $L^{-1}$) (N1, N2, and N3). The mean values of the treatments were compared using the least significant difference (LSD) test at a probability level of 0.05.

The results of the experiment were compared using the LSD test. The results showed that organic fertilizer at a level of 40 tons.ha-1 (A3) achieved a significant increase in chlorophyll content, plant height, total plant yield, and tuber protein compared to the level of 20 tons. The application of A2 (n-1) resulted in a significant increase in total soluble solids (TSS) and fructose content. Similarly, spraying the nano-fertilizer at a concentration of 1 g.L resulted in a significant increase in plant height, tuber dry matter, tuber protein, TSS, and tuber starch content. A concentration of 2 g.L resulted in significant differences in chlorophyll content, total plant yield, and fructose content. The interaction between organic fertilizers and nano-fertilizers showed significant differences in some of the studied indicators. The interaction of 60 tons . $ha^{-1}$ + 1 g.L (N2×A4) gave the highest values for fructose content, while the interaction of 60 tons . $ha^{-1}$ + 2 g.L (N3×A4) gave the highest values for chlorophyll content, total plant yield, and TSS. The interaction of 40 tons .$ha^{-1}$ gave the highest values for TSS. The highest rate of plant height and tuber protein content is observed when 1 g.L is 1 $g/h^{-1}$ ($N_2 \times A_3$ ).

## Introduction:

Potatoes (*Solanum tuberosum* L.) are among the most important tuber vegetable crops in the world, including in Arab countries. Their economic importance ranks fourth after wheat, corn, and rice. The global average production is estimated at approximately 19.9 $tons/ha^{-1}$, while Iraq's potato production is 402,302 $tons/ha^{-1}$ across an estimated 25,745 hectares [10]. This production is insufficient to meet local market demands, leading to reliance on imported potato seeds to bridge the gap. The low quality of disease-carrying seeds and the neglect of various agricultural practices, which reduce the availability of essential nutrients, are among the reasons for the decreased productivity per unit area. This necessitates attention to soil and plant management practices and the adoption of the latest developments in this field, including the introduction of modern agricultural machinery and the use of fertilizers with beneficial effects on the soil. Plants benefit from reduced pollution from fertilizers such as nano-, organic, and bio-fertilizers.Organic fertilization is an ancient method used by the Chinese, who fermented plant residues and added them to the soil. The world's shift towards chemical and mineral fertilizers in the

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last century led to negative side effects on the environment and human health. This prompted a more extensive study of organic materials than before, considering them natural substances that increase the organic content and activity of soil microorganisms, restoring its natural balance and aiding plant growth and production[4,11]. Increasing the level of animal organic fertilizer (poultry manure) applied to potato plants from 5 tons/ha to 10 tons/ha resulted in an increase in most vegetative, quantitative, and qualitative traits.

This refers to the technology that controls matter at the 1-100 nanometer scale. Nanotechnology, which represents one billionth of a meter, is important because of the different methods used to create materials derived from it. These methods increase the surface area per unit volume and enhance chemical reactivity, leading to increased crop yields and improved soil quality [15]. Using nano-fertilizers offers several advantages over traditional fertilizers due to their lower application rate, high efficiency, and longer retention of nutrients. This results in increased benefit to the plant, primarily through faster absorption of nano-fertilizers compared to traditional fertilizers [9,20] . The increased activity of plant biological processes through nano-fertilization depends on the successful application of nanotechnology. For example, nanoparticles enable the soil to retain nutrients, increasing productivity while simultaneously improving environmental security. This aligns with the plant's needs for absorbable nutrients, offering greater efficiency than traditional materials. Furthermore, nanomaterials containing plant nutrients can be easily stored within the plant [16] adding different concentrations of nano-fertilizers (1) $g.L^{-1}$ to potato plants caused an increase in vegetative traits, and a concentration of (2) $g.L^{-1}$ increased qualitative and quantitative traits. The use of nano-fertilizers led to an increase in soluble solids [17].

**Materials and Methods:**

A field experiment was conducted in the Al-Kifl area on the Arizona potato variety, grade E, to demonstrate the effect of soil application of organic fertilizer and spraying with nano-fertilizer. The soil was prepared for planting (plowing, harrowing, and leveling) and divided into three sections, each containing 12 experimental units (2.5m x 2.5m) with a total area of 6.25 $m^2$, consisting of three rows per experimental unit. The treatments were randomly distributed within the experimental units in each section. Each experimental unit contained 24 tubers (8 tubers per row) planted at a depth of 10-15 cm.The first treatment in the experiment was organic compost, applied at four levels (NPK, 20, 40, and 60 $tons.ha^{-1}$ (A1, A2, A3, A4) respectively, and the organic fertilizer levels were mixed well with the soil before the planting process and in one go. The second factor included spraying with nano fertilizer at three concentrations (0, 1, 2) g. The potato plants were sprayed with three applications of nano-fertilizer (N1, N2, N3) in the early morning, ensuring uniform coverage until complete saturation. The first application was 45 days after emergence, while the second and third applications were spaced 15 days apart. The GenStat 2009 software was used to analyze the experimental data using a randomized complete block design (RCBD). Treatment means were compared using LSD with a significance level of 0.05 [5]. The following parameters were measured: total chlorophyll content, total plant yield, total soluble solids (TSS), fructose, plant height, tuber protein content, tuber dry matter content, and tuber starch content.

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**Table 1: Some chemical and physical properties of the research soil before planting.**

| Properties and Unit of Measurement | **Autumn Season 2018** |
|---|---|
| Soil pH | 7.8 |
| Electrical Conductivity (EC) ($dc/m^{-1}$) | 3.30 |
| Organic Matter % | 1.60 |
| Nitrogen % | 0.45 |
| Phosphorus % | 0.18 |
| Potassium % | 1.11 |
| Sand % | 27 |
| Silt % | 60 |
| Clay % | 29 |

**Results**:

Table 2 shows that the addition of organic fertilizer (A) significantly affected plant height. The 40 $ton.ha^{-1}$ (A4) level outperformed the other levels, gave the highest height of 53.00 cm, while the average plant height in the control unit was lower (41.10 cm). The table also reveals a significant difference between the concentrations of nano-fertilizer (N). A concentration of 1 $g.L^{-1}$ (N2) resulted in the highest plant height of 48.23 cm, while a concentration of 2 $g.L^{-1}$ resulted in the lowest average height of 45.28 cm. Regarding the interaction (A×N), the table below shows a significant interaction between organic fertilizer levels and nano-fertilizer concentrations in this trait. The interaction of (40 $ton.ha^{-1}$ + 1 $g.L^{-1}$) (A4×N2) resulted in the highest height of 57.15 cm, while the lowest average plant height was recorded at a concentration of 2 $g.L^{-1}$. (35.90 cm).The table shows significant differences in the percentage of dry matter between the concentrations of organic fertilizer used. The control treatment (NPK) gave the highest percentage at 15.242%, which did not differ significantly from the levels of 20 and 40 tons $ha^{-1}$. The 60 tons $ha^{-1}$ level gave the lowest percentage at 14.593%.However, the effect of nano-fertilizer on the percentage of dry matter showed significant differences. The 1 g $L^{-1}$ concentration resulted in the highest percentage at 15.417%, while the control treatment gave the lowest at 14.656%.The table also indicates significant differences between the interactions. The interaction between nano-fertilizer and organic fertilizer (1 g $L^{-1}$ + NPK) resulted in the highest percentage at 16.250%, while the percentage decreased with the 0 g $L^{-1}$ + 60 tons $ha^{-1}$ interaction, reaching 13.932%. The results in the table show significant differences between the levels of organic fertilizer. The highest percentage of protein in the tubers was achieved at the 40 $ton.ha^{-1}$ level, reaching 13.77%, while this percentage decreased to 11.787% at the 60 $ton.ha^{-1}$ level. When nano-fertilizer was used, the highest percentage of protein in the tubers was achieved at a concentration of 1 $g.L^{-1}$, reaching 14.093%, while the control treatment gave the lowest value at 10.665%.Regarding the interaction between nano-fertilizer concentrations and organic fertilizer levels, the interaction of 1 g $L^{-1}$ + 40 $ton.ha^{-1}$ resulted in the highest protein percentage in tubers, reaching 17.68%, while the interaction of 0 + NPK resulted in the lowest protein percentage, at 9.940%.The results in the table indicate significant differences between organic fertilizer levels in the percentage of soluble solids. The 20 $ton.ha^{-1}$ level achieved the highest percentage at 7.546%, while the control treatment (NPK) gave the lowest percentage at 7.35%.When using nano-fertilizer, the highest percentage was achieved at 7.519% at a concentration of 1 g $L^{-1}$, while the percentage decreased to 7.311% in the control treatment. As for the effect of the interaction between the studied fertilizers (nano fertilizer + organic fertilizer), the results indicated significant differences between the interactions, with the highest percentage reaching 7.917% when the interaction was 2 g.L-1 + 60 $ton.ha^{-1}$, while the interaction 2 $g.L^{-1}$ + 20 $ton.ha^{-1}$ gave the lowest percentage, which was 7.1%.The table shows significant differences in the percentage of starch in tubers depending on the level of added organic fertilizer. The highest starch percentage, 9.585%, was achieved with the control treatment (NPK), and this percentage did not differ significantly from the 20 and 40 $ton.ha^{-1}$ levels. However, the starch percentage decreased to 9.007% at the 60 $ton.ha^{-1}$ level.while, the nano-fertilizer, at a concentration of 1 $g.L^{-1}$, resulted in the highest starch percentage in tubers, reaching 9.741%. The control treatment (no application) gave the lowest percentage at 9.063%.

Regarding the interaction, the same table reveals significant differences between fertilizer applications. The 1 g.L/2 + NPK treatment resulted in the highest starch percentage in tubers, reaching 10.483%, while the 0 g.L + 60 $ton.ha^{-1}$ treatment resulted in the lowest starch percentage, at 8.417%. The same table indicated a significant advantage of organic fertilizer at the 60 $ton.ha^{-1}$ level over the other levels, gave the highest chlorophyll content at 38.1 SPAD, while the 20 $ton.ha^{-1}$ application level resulted in the lowest chlorophyll content at 36.2 SPAD.Regarding the effect of the nano-fertilizer concentrations used, a concentration of 2 $g.L^{-1}$ showed a significant advantage, gave the highest chlorophyll content at 37.4 SPAD, while the control treatment resulted in the lowest chlorophyll content at 36.8 SPAD. The interaction between the two types of fertilizer used (nano-fertilizer + organic fertilizer) showed significant differences in the average percentage of the studied trait. The interaction of 2 $g.L^{-1}$ + 60 $ton.ha^{-1}$ gave the highest average relative chlorophyll content, reaching 38.7 SPAD, while the interaction of 1 $g.L^{-1}$ + 20 $ton.ha^{-1}$ gave the lowest average chlorophyll content, reaching 35.6 SPAD.The organic fertilizer used significantly impacted the total plant yield. The 60 $ton.ha^{-1}$ treatment outperformed other organic fertilizer levels, gave the highest total plant yield of 940.60 g $plant^{-1}$, while the control (NPK) treatment resulted in the lowest yield of 562.94 g $plant^{-1}$.The table also shows significant differences between the nano-fertilizer concentrations. The 2 g $L^{-1}$ concentration resulted in the highest total plant yield of 768.06 g $plant^{-1}$, while the 1 g $L^{-1}$ concentration resulted in the lowest total plant yield of 735.53 g $plant^{-1}$. The table indicated significant differences between the interventions. The interaction between nano-fertilizer and organic fertilizer (2 g $L^{-1}$ + 60 $ton.ha^{-1}$) outperformed the other interventions, achieving the highest yield per plant (1000.55 g $plant^{-1}$), while the interaction with 1 g + NPK gave the lowest yield (470.76 g $plant^{-1}$).

The results in the table also indicate that the use of organic fertilizer (compost) led to significant differences between the levels. The 20 $ton.ha^{-1}$ level resulted in a high fructose percentage of 0.612%, which did not differ significantly from the 60 $ton.ha^{-1}$ level. However, the fructose percentage decreased with the NPK control treatment, reaching 0.411%. The nano-fertilizer used significantly affected the fructose percentage, reaching its highest level of 0.673% at a concentration of 2 $g.L^{-1}$, excelled on all other concentrations. However, control treatment gave the lowest fructose percentage at 0.364%.Regarding the interaction between nano-fertilizer and organic fertilizer, the table above shows significant differences between the interactions. The interaction of 1 $g.L^{-1}$ + 60 $ton.ha^{2}$ resulted in the highest fructose percentage at 0.860%, while the interaction of 1 $g.L^{-1}$ + NPK gave a low percentage of 0.149%.

**Table 2: Effect of Nano-Fertilizer, Organic Fertilizer, and Their Interaction on Some Vegetative, Quantitative, and Qualitative Traits of Potato Plants.**

| traits / treatments / organic fertilizer | Plant height (cm/plant) - 1 | Dry matter of tubers (%) | Protein in tubers (%) | TSS percentage in tubers | Starch in tubers % | Chlorophyll in leaves SPAD | Yield per plant kg.plant$^{-1}$ | Fructose percentage in tubers % |
|---|---|---|---|---|---|---|---|---|
| A1 | 41.10 | 15.242 | 13.100 | 7.350 | 9.585 | 37.1 | 562.94 | 0.411 |
| A2 | 42.06 | 15.224 | 11.834 | 7.546 | 9.568 | 36.2 | 757.56 | 0.612 |
| A3 | 53.00 | 15.152 | 13.772 | 7.375 | 9.504 | 36.7 | 750.27 | 0.446 |
| A4 | 51.20 | 14.593 | 11.787 | 7.399 | 9.007 | 38.1 | 940.60 | 0.583 |
| **LSD 0.05** | 0.55 | N.S | 0.153 | 0.110 | 0.137 | 0.23 | 29.66 | 0.046 |
| **nano fertilizer** | | | | | | | | |
| N1 | 47.01 | 14.656 | 10.665 | 7.311 | 9.063 | 36.8 | 754.94 | 0.364 |
| N2 | 48.23 | 15.417 | 14.093 | 7.519 | 9.741 | 36.9 | 735.53 | 0.503 |
| N3 | 45.28 | 15.085 | 13.112 | 7.422 | 9.444 | 37.4 | 768.06 | 0.673 |
| **LSD 0.05** | 0.54 | 0.171 | 0.270 | 0.054 | 0.152 | 0.20 | 17.76 | 0.030 |

| traits / treatments / Organic x Nano | Plant height (cm/plant ) - 1 | Dry matter of tubers (%) | Protein in tubers (%) | TSS percentage in tubers | Starch in tubers % | Chlorophyll in leaves SPAD | Yield per plant kg.plant$^{-1}$ | Fructose percentage in tubers % |
|---|---|---|---|---|---|---|---|---|
| A1*N1 | 44.50 | 15.337 | 9.940 | 7.174 | 9.669 | 35.8 | 644.34 | 0.240 |
| A2*N2 | 42.90 | 16.250 | 15.942 | 7.324 | 10.483 | 37.5 | 470.76 | 0.149 |
| A3*N3 | 35.90 | 14.139 | 13.417 | 7.550 | 8.602 | 37.9 | 537.72 | 0.846 |
| A2*N1 | 38.20 | 14.851 | 10.331 | 7.733 | 9.236 | 36.6 | 750.27 | 0.634 |
| A2*N2 | 43.27 | 15.442 | 10.873 | 7.793 | 9.763 | 35.6 | 730.92 | 0.630 |
| A2*N3 | 44.70 | 15.379 | 14.297 | 7.111 | 9.707 | 36.5 | 791.51 | 0.571 |
| A3*N1 | 53.36 | 14.505 | 11.672 | 7.222 | 8.928 | 36.8 | 673.70 | 0.412 |
| A3*N2 | 57.15 | 15.333 | 17.681 | 7.790 | 9.666 | 36.8 | 870.63 | 0.371 |
| A3*N3 | 48.50 | 15.617 | 11.964 | 7.112 | 9.918 | 36.6 | 706.48 | 0.554 |
| A4*N1 | 51.97 | 13.932 | 10.716 | 7.113 | 8.417 | 38.2 | 951.46 | 0.168 |
| A4*N2 | 49.62 | 14.644 | 11.877 | 7.167 | 9.051 | 37.5 | 869.81 | 0.860 |
| A4*N3 | 52.02 | 15.205 | 12.769 | 7.917 | 9.551 | 38.7 | 1000.55 | 0.720 |
| LSD 0.05 | 0.99 | 0.303 | 0.455 | 0.130 | 0.270 | 0.38 | 38.22 | 0.062 |

Discussion:

Plant height can be increased because organic fertilizers added to the soil are rich in nutrients, which stimulate the production of auxins in the plant. This also activates many vital and physiological processes, encouraging the activity of several enzymes that play a major role in food production within the plant. This is achieved by promoting cell division and cell elongation, thus increasing plant height [1,6,7 ].

The increase in relative chlorophyll content and dry matter percentage may be attributed to the added organic fertilizers, which contain many nutrients essential for plant growth. These fertilizers provide an opportunity for increased accumulation of manufactured materials (proteins and carbohydrates) and nutrients in plant tissues through photosynthesis. This leads to an increase in leaf area and chlorophyll, and consequently, an increase in the dry weight of the vegetative growth. Furthermore, these fertilizers increase the availability of nitrogen and magnesium, which play a crucial role in chlorophyll production because they are located at the center of the chlorophyll molecule. In addition, these fertilizers contain nitrogen, which increases protein and nucleic acid synthesis. This, in turn, leads to increased division of chloroplasts and consequently enhances the activity of enzymes in plant cells responsible for chlorophyll synthesis[2,14].The reason for the increase in total plant yield is the decomposition of organic fertilizers in the soil by microorganisms. These microorganisms improve the soil's physical, chemical, and biological properties, providing essential nutrients and elements for plant growth, such as nitrogen and potassium. These nutrients lead to increased activity, strength, and growth of the vegetative system. This is due to the good nutrition and abundance of nutrients in the root zone, which are then absorbed by the plant. This improves the plant's ability to perform its vital functions and store the synthesized food compounds in the tubers after their production in the leaves. Furthermore, the accumulation of dry matter in the tubers increases tuber weight and the number of tubers, leading to a positive increase in plant yield, marketable yield, and ultimately, total yield per unit area. This is the conclusion reached by [8,13.

The increased percentage of starch may be attributed to the decomposition of organic matter in the soil solution, which increases the availability of nutrients and their absorption by the roots. This, in turn, leads to greater efficiency in the vegetative parts' absorption of nitrogen and potassium, which are then stored in the leaves. These nutrients play a crucial role in several vital processes, most importantly activating enzymes involved in photosynthesis and increasing carbohydrate synthesis in the form of dry matter, thus increasing the starch percentage, as it is directly proportional to dry matter [12].

The increase in total soluble solids (TSS) and fructose percentage may be attributed to the role of calcium, which enhances photosynthesis. This leads to increased carbohydrate production, which is then transported from its synthesis sites to the tubers, resulting in higher TSS and fructose levels. Alternatively, the increase may be due to improved membrane permeability caused by calcium, which enhances metabolism and carbohydrate accumulation, resulting in higher TSS and fructose levels [23].

The high percentage of protein in tubers may be attributed to the fact that organic fertilizers increase the levels of organic carbon and total nitrogen in the soil [18]. This means that the organic matter is more decomposed and provides more nutrients, i.e., its components are better broken down. This helps stimulate the plant's biological and enzymatic activity, thus increasing the efficiency of nutrient absorption from the soil resulting from these organic fertilizers, which contain good amounts of nutrients. This is reflected in the quantity of these elements in the leaves and tubers. The high nitrogen percentage caused an increase in the plant's vegetative growth (plant height, number of leaves, number of aerial stems, leaf area, and chlorophyll), which was reflected in an increase in the products of photosynthesis and subsequent food production and transfer to the tubers, thus increasing the protein percentage in the tubers. The increase in the nitrogen percentage may also be attributed to increased plant growth resulting from the role of potassium and its efficiency in absorbing nutrients to meet the needs of vital activities, including nitrogen. The high nitrogen percentage is reflected in the protein percentage, as nitrogen is the essential element that Potassium is a component of amino acids, which are the building blocks of protein. It also plays a vital role in improving vegetative growth traits in plants, as well as in transporting manufactured materials from the leaves to their storage sites in the tubers. Furthermore, it activates the nitrate reductase enzyme, which reduces nitrates to ammonia, the precursor to amino acids necessary for protein synthesis. Similarly, boron plays a crucial role in transporting the products of photosynthesis to storage sites or utilizing them in plant growth [3,14].

Borone is a component of amino acids, which are the building blocks of protein. The increased plant height may be explained by the role of nano-fertilizers in improving plant growth. Nanoparticles possess a large surface area due to their small particle size, thus increasing the effective surface area for reaction. This leads to increased enzyme efficiency and, consequently, more biochemical reactions, which in turn lead to increased cell division. Furthermore, these particles reduce or inhibit the formation of free radicals and decrease the activity of existing free radicals, thereby reducing their oxidation and damage. This delays the aging process and promotes vegetative growth [22].

The increased relative chlorophyll content may be attributed to the role of nanoparticles in enhancing the activity of enzymes that inhibit the production of ethylene, a key component of chlorophyll oxidation. This oxidation process destroys chloroplasts, leading to increased chlorophyll division and longer chloroplast survival, thus delaying senescence. Furthermore, nanoparticles stimulate photosynthetic enzymes [24].

The increased dry matter percentage, starch percentage, total soluble solids (TSS), and fructose content in tubers can be attributed to the large surface area and small size of nanoparticles. This accelerates biochemical reactions and stimulates enzyme activity, resulting in enhanced vegetative traits, increased carbohydrate accumulation, higher dry matter, and consequently, increased protein and starch production, which are directly proportional to dry matter levels[25]). Or it may be due to the use of nano-fertilizers by spraying, which directly increases the absorption of nutrients (micro- and macro-elements) by the leaves, which increases physiological activities, leading to an increase in the activity of enzymes involved in photosynthesis and an increase in carbohydrates produced in the vegetative system, i.e., an increase in the percentage of starch in the leaves, which leads to an increase in the efficiency of the vegetative system (plant height, number of leaves, leaf area, and chlorophyll). After that, it is stored in the tubers as a dry substance, which increases its concentration in the tubers, which is directly proportional to the increase in the percentage of starch. Or perhaps the reason is due to the different integrated roles that the nutrients play. This is to achieve a state of nutritional equilibrium where the dry matter content in the tubers increases. The increase in photosynthetic byproducts is also due to magnesium, which plays a crucial role in the synthesis of chlorophyll molecules. This leads to increased translocation of chlorophyll from its production sites to the tubers, thus increasing dry matter and starch content. Potassium also plays a vital role for potato plants, improving the quality of their tubers, both in terms of starch and protein content. This is particularly important for potatoes intended for human [1]. Boron also plays a role in many different biological processes, activating numerous enzymes and thus improving the overall condition of the plant and promoting optimal growth. This ensures the plant's nutrient requirements are met and easily absorbed, increasing the efficiency of

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photosynthesis and consequently increasing dry matter [23] An increase in dry matter means an increase in the total soluble solids (TSS) percentage, including an increase in fructose content, which means an increase in sugars. Because the dissolved solids represent organic acids, mineral salts, and other substances dissolved in the tuber juice [12] Or perhaps the reason is due to the role of nano-fertilizers in improving plant growth and quality while increasing the efficiency of nutrient utilization. These fertilizers give the metabolic reactions in the plant more space, which increases the rate of photosynthesis, resulting in more dry matter and thus an increase in total dissolved solids (TSS) and an increase in fructose content [21].

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