INCREASING YIELD AND ITS QUALITY OF POTATO BY SPRAYING WITH NANOCHITOSAN LOADED WITH NPK, NETTEL AND GREEN TEA EXTRACTS

Z. R. J. AL- Malikshah* I. J. Abdulrasool**
Researcher Professor
Dept. Horti. and Landscape Gardening, Coll. Agric. Eng. Sci., University Baghdad.
Zainab.Rahman1105a@coagri.uobaghdad.edu.iq eimanjabir@coagri.uobaghdad.edu.iq

ABSTRACT

This study was aimed to effect of spraying nano chitosan loaded with NPK and nettle leaf extracts and green tea on yield and its quality of potato for the spring and autumn seasons of 2021 in Al-Suwaira district of Wasit Governorate, It was conducted as a factorial experiment (5 × 5) within randomized complete block design with three replicates. The first factor included spraying with four concentrations of Nano chitosan loaded with NPK fertilizer at concentrations 0, 10. 15 and 20% in addition to chemical fertilization treatment, the second factor was spraying nettle leaf extract 25 and 35 gL^{-1} and green tea extract at 2 and 4 $g.L^{-1}$, in addition to the control treatment, spraying with distilled water only. The results showed a significant superiority of the interaction between spraying with Nano chitosan loaded with NPK at a concentration of 15% and spraying green tea extract at a concentration of 4 g L^{-1} in producing the highest value for the leaf area of the plant amounted to 9973 and 9742 m^2 $plant^{-1}$ and the highest yield per plant reached 1055.7 and 967.9 $g.plant^{-1}$ for both seasons respectively, and the highest percentage of dry matter in tubers (24.31 and 22.77% for both seasons, respectively. The tuber content of the amino acid Arginine increased significantly. (324.1 and 318.8 mg 100g $D.W.^{-1}$) and Glutamine (94.70 and 9453 mg 100g $D.W.^{-1}$) for both seasons respectively.

Keywords: ***Solanum tuberosum*** **L, foliar feeding, nano elements, plant extracts, safety.**

***Part of Ph.D of the 1st author.**

زيادة حاصل البطاطا ونوعيته بالرش بالكيتوسان النانوي المحمل NPK ومستخلص اوراق القريص والشاي الاخضر

زينب رحمن جاسم الملك شاه ايمان جابر عبد الرسول
باحث استاذ
قسم البستنة وهندسة الحدائق/ كلية علوم الهندسة الزراعية / جامعة بغداد

المستخلص

نفذت الدراسة في مزرعة خاصة في قضاء الصويرة التابع لمحافظة واسط/ العراق بهدف دراسة تأثير الرش بالكيتوسان النانوي المحمل بالسماد NPK ومستخلصي أوراق القريص والشاي الاخضر في الحاصل و جودته للبطاطا للموسمين الربيعي والخريفي للعام 2021. نفذت تجربة عاملية (5×5) ضمن تصميم القطاعات الكاملة المعشاة RCBD وبثلاث مكررات تضمن العامل الاول الرش بأربع تراكيز من جسيمات الكيتوسان النانوية المحملة بالأسمدة NPK (0, 10, 15 و 20 % فضلاً عن معاملة التسميد الكيميائي) اما العامل الثاني فقد تضمن الرش بمستخلص أوراق القريص بتركيزين 25 و 35 غم.لتر$^{-1}$ ومستخلص الشاي الاخضر بتركيزين 2 و 4 غم لتر$^{-1}$ فضلاً عن معاملة القياس الرش بالماء المقطر فقط . اظهرت النتائج تفوق معنوي لمعاملة التداخل بين الرش بجسيمات الكيتوسان النانوية المحملة بالأسمدة NPK بالتركيز 15% مع رش مستخلص الشاي الاخضر بالتركيز 4 غم لتر$^{-1}$ في اعطاء اعلى قيمة للمساحة الورقية للنبات بلغت 9973 و 9742 م^2 نبات$^{-1}$ واعلى حاصل للنبات بلغ 1055.7 و 967.9 غم نبات$^{-1}$ للموسمين على الترتيب كما زاد معنويا فيها محتوى الدرنات من الاحماض الامينية Arginin (324.1 و 318.8 ملغم 100غم مادة جافة$^{-1}$) و Glutamine (94.70 و 9453 ملغم 100غم مادة جافة$^{-1}$) للموسمين على الترتيب.

الكلمات المفتاحية: *Solanum tuberosum* L, التغذية الورقي، عناصر نانوية، مستخلصات نباتية، سلامة الغذاء.

البحث مستل من اطروحة دكتوراه للباحث الاول

Received: 27/1/2023, Accepted:5/4/2023, Published:30 June.

INTRODUCTION

potato (*Solanum tuberosum* L.) stands as a globally significant food crop, ranking fourth in production after maize, rice, and wheat. Its ability to produce high yields within a short growth cycle and to thrive across a wide range of environmental conditions makes it indispensable to both small-scale and commercial agriculture (10). As a rich source of carbohydrates, essential vitamins, and minerals, potato contributes substantially to human nutrition and dietary energy. It plays a pivotal role in strengthening food security, particularly in areas with constrained land and water resources, due to its efficient input use and high caloric output per unit area. Moreover, potato farming supports rural economies by generating employment and income. Its wide applicability in food processing further enhances its economic value. Consequently, advancing sustainable potato production is critical to bolstering agricultural sustainability and ensuring global food security (6). Addition of Nano-fertilizers recently applied to some crops and contributed to improving their growth and productivity, including potato (8, 14), tomato (32), broccoli (25), basil (26) and others .The integrated management of nutrients leads to better plant in terms of yield, quality and economic return through balanced use of organic fertilizers with inorganic fertilizers (22 and 31) showed that biocatalysts have a role in producing high-quality and nutritious food that can help protecting against hunger and malnutrition. Its role is not limited to important crops only, but includes all sectors of horticulture. In fact; using plant extracts in agriculture has gained considerable attention as a sustainable alternative to synthetic agrochemicals. These natural substances, derived from various plant parts, possess bioactive compounds that can promote plant growth, enhance resistance to pests and diseases, and improve soil health. Consequently, the application of plant extracts supports environmentally responsible agriculture and helps reduce chemical residues in food and the environment (19, 33). Kisvarga *et al.,* (21) and Shahbaz et al., (29) found that the use of plant extracts, including lemon, aloe vera and neem extract, is a natural alternative to chemical pesticides and preservatives to maintain post-harvest quality of fruits and vegetables, moreover they enhance their shelf life and protect them from damage, and biostimulants based on plant extracts were also used to control salinity (5). Hakim et al. (18) showed that the addition of compost tea solution to drip irrigation system at a ratio of 4:1, respectively, by following two irrigation methods (the traditional full irrigation and partial irrigation on one side of the plant) led to an increase in yield and an improvement in tomato fruits quality after harvest. Great interest in the quality of food that free from fertilizers and pesticides residues by using organic nutrients from plant origin through foliar fertilization. Garcia *et al.,* (16) noted in a study conducted on the starch of seven potato cultivars that the starch had a high degree of purity, but showed different percentages in terms of mineral content, amylose content, starch resistance, heat and adhesive properties in different cultivars.Differences in the physicochemical and starch percentage of different potato cultivars can be directly related to the use of potato making them useful for industrial applications. This study was aimed to verify the response of the potato crop to the above study factors, each alone, and their interaction effects on the quality of potato tubers.

MATERIALS AND METHODS

The experiment was conducted in a private farm in Al-Suwayrah district of Wasit Governorate (32.92°N, 44.77°E) about 55 km south of Baghdad / Iraq. With studying the effect of spraying with Nano chitosan loaded with NPK fertilizer and nettle leaf extracts and green tea on the growth and productivity of potatoes for the spring and fall seasons of 2021.The Burren hybrid potato plant, rank Elite, of Dutch origin, was selected. At the end of the season, part of the tubers produced from the spring season 2021 were stored in refrigerated private warehouses at a temperature of 4 °C, and where's as seeds later used for the fall season 2021. A furrows was made with a width of 0.75 m. The furrows were divided into experimental units. The experimental unit included a 5-m long furrow in the spring season 2021 and a 2.5-m long furrow in fall 2021 season, an area of 3.75 m^2. Planting took place at a distance of 0.25 m between one tuber and another, an average of 20 plants per experimental unit, and for both seasons. The tubers were planted on January 19, 2021 for the spring season, and for the fall season, on September 17, 2021. The untreated tubers of the same hybrid of rank A that produced from spring season of the same field experiment, untreated tubers were planted and stored in refrigerated private warehouses for the period from May 22, 2021 to September 9, 2021 at a temperature of 4 °C ± 2 °C. Nano Chitosan (factor I) were prepared in laboratory according to the mentioned method (13 and 23).It included spraying with four concentrations of Nano chitosan loaded with NPK (15). C 50% Half of the chemical fertilizer recommendation plus Spray with distilled water only (control treatment), Spray NanoNPK1 with a concentration of 10%, Spray NanoNPK2 with a concentration of 15%, Spray NanoNPK3 with a concentration 20%. In addition to chemical fertilization treatment according to the fertilizer recommendation C100% addition of complete chemical fertilizer recommendation. Spraying was conducted in three stages, the first spraying after the completion of emergence, the second spraying in the vegetative growth stage, and the third in the tuber enlargement stage. Half of the chemical fertilizer recommendation was added to the spraying treatments with Nano chitosan. The fertilizer recommendation for potato crop was K_2O 300, $P_2O_5$300, N 300. The addition was made in three times, the first at planting, the second after 45 days of planting (vegetative growth stage), and the second after 60 days of planting (tubers growth stage). The second factor included spraying nettle leaf extract, symbol N (2) and green tea extract, symbol GT with two concentrations of each, in addition to the control as follows: C0 (Control) - spray distilled water only, N1 – Spraying nettle leaf extract with a concentration of 25g.L^{-1}, N2 – Spraying nettle leaf extract with a concentration of 35 g.L^{-1}, GT1 – Spraying green tea extract with a concentration of 2g.L^{-1}, GT2 – Spraying green tea extract with a concentration of 4 g.L^{-1}. Spraying was conducted two times of each extract during the cultivation period, leaving a time interval of three days after spraying the first factor, where the first spray was after 45 days of cultivation and the second spray after 60 days of cultivation. The experiment was conducted for both seasons as a factorial experiment with two factors (5 × 5) within the RCBD, with three replicates. The results were analyzed using analysis of variances and means compared using LSD level 0.05 (7). Leaf area was measured (cm^2 $plant^{-1}$) The yield of one plant (g $plant^{-1}$) and the quality indicators of the yield, which are the percentage of dry matter in tubers (%), the hardness of the tubers (kg cm^{-2}), the percentage of total soluble solids (TSS), and the content of the tubers of amino acids (mg.100 g D.$W.^{-1}$)and the percentage of Amylose and Amylopectin in starch and the concentration of nutrients in the tubers, which are the percentage of nitrogen (%), the percentage of phosphorus (%) and the percentage of potassium (%).

RESULTS AND DISCUSSION

Leaf area (cm^2 $plant^{-1}$): The results in Table (1) indicate that spraying with Nano chitosan loaded with NPK had a significant effect on plant leaf area for both seasons. NanoNPK2 treatment achieved the highest (9189 and 9051 cm^2 $plant^{-1}$ respectively, for both seasons). C100% treatment which also produced an increase in total leaf area (7436 and 6359 cm^2 $plant^{-1}$) for both seasons respectively compared to C50% treatment, which recorded the lowest mean of leaf area, which reached 6097 and 5990 cm^2, $Plant^{-1}$ for both seasons respectively. Foliar application with green tea extract GT2 superior in giving the highest average of total leaf area, which reached 8620 and 8312 cm^2 $plant^{-1}$ for both seasons, respectively while the lowest leaf area average for the control treatment (C0) was 7227 6869 cm^2 $Plant^{-1}$ for both seasons, respectively. Data in Table 2 shows a significantly superiority of the interaction treatment NanoNPK2 GT2 (9973 and 9742 cm^2 $plant^{-1}$) for both seasons, respectively, compared to C050%, which produced the lowest rate of total leaf area amounting to 5432, 5368 cm^2 $plant^{-1}$ for both seasons, respectively. The foliar application of the plant, especially when using polymer-based Nano-fertilizers as a fertilizer carrier, has helped in providing the plant with the basic elements nitrogen, potassium and phosphorus, which led to improve the nutritional status of the plant and thus preventing the loss of nutrients in the soil, water and air through direct entry, and avoiding the interaction of nutrients with the soil. microorganisms, water and air (4).The extreme smallness of the particles loaded with fertilizers played an important role due to their high ability to penetrate cellular walls, stomata openings and wounds on the leaf surfaces with a large entry of nanoparticles into the cytoplasm and may be associated with different organelles in it (1). As a result of the biocompatibility between chitosan and the medium it passes through, it contributes to the delivery of fertilizers to the manufacturing sites in a ready-made manner, and to achieve a nutritional balance within the plant by enhancing the various physiological processes of the plant, raising the efficiency of carbon metabolism process, increasing the amount of manufactured materials, and activating a number of enzymes, including oxidation and reduction enzymes and the manufacture of protein as well as the accompanying enzymes and the increase in cell differentiation and division, and this leads to an improvement in the growth of the plant structure and as a result a better growth represented by an increase in the total leaf area (Tables 1 and 2) These results are consistent with what was mentioned by Elshamy et al. (15), who concluded that spraying Nano chitosan loaded with NPK on potato plants led to an improvement in the vegetative indicators of the plant, As for the reason for the excelled of spraying green tea extract treatments in increasing the leafy area of the plant, it may be due to its high content of biologically active compounds such as phenols, carotenoids, vitamins and organic acids that act as natural antioxidants, as well as a wide and different spectrum of nutrients that play a vital role in building plant tissues (11),The extracts under study encouraged the promotion of vegetative growth and the improvement of plant structure due to their effects on cell walls by capturing free radicals resulting from vital processes within the plant and protecting cell walls from internal damage. Thus strengthening the cuticle layer and reducing water loss as well as resisting pathogens as well as contributing to provide raw materials for vital processes within the plant organelles and thus increasing metabolism products such as carbohydrates and proteins and their accumulation as a result of increasing the number of leaves, the positive basis for increasing the leaf area. These results are consistent with what was stated by Garmendia et al., (17), and with what was reached by Abdulrasool and AL-Malikshah, (3) when spraying green tea extract on pepper plants.

Plant yield (g plant^{-1}): The plant yield is the final yield of all the vital physiological processes that took place throughout the growing season and a reflection of the good vegetative growth of a single plant. Data in Table 1 shows that CS-NPK2 produced the highest significant plant yield (972.8 and 920.4 g plant^{-1}) for both seasons, respectively while the C50% treatment recorded the lowest mean for this trait, which reached 510.0 and 566.8 g. plant^{-1}) for both seasons, respectively. The green tea extract excelled in producing the highest results for this traits for both seasons, the highest value was recorded in the GT2 treatment, which amounted to 839.8, 793.4 g plant^{-1} for both seasons, respectively, compared to control treatment C0, which provided the lowest value (735.6, 685.4 g plant^{-1}) for both seasons. Respectively. Spraying with nettle leaf extract also led to a significant increase in yield per plant, N1 recorded the highest value (777.3 and 739.1 g plant^{-1}) for both seasons, respectively. The results of the interaction for this trait (Table 2) showed that the combination NanoNPK2 GT2 produced the highest significant plant yield, which amounted to 1055.7 and 967.9 g plant^{-1} for both seasons, respectively, compared to C50% C0 for the spring season only and to C100% C0 for fall season only which produced the lowest rate for this trait (510.0 and 466.4 g plant^{-1}, respectively).The superiority of foliar nutrition treatments of different types in plant yield by changing levels, perhaps due to the superiority of spraying treatments with Nano chitosan loaded with NPK and extracts of nettle leaves and green tea as a complementary fertilization of the ground addition to the role of the nutrients included in the mixture of solutions and their positive multifaceted effect in achieving a nutritional balance within the plant structure as it affects internally the various biochemical processes such as cell division and hormonal and nutritional balance, which is reflected externally on the morphology of the plant.The study factors, whether individually or in combination, improved the state of the plant, starting from the improvement in vegetative growth indicators to the yield of the plant and the creation of particles characterized by the characteristics of safe and high penetration of cell walls due to their small size and the occurrence of a kind of food homeostasis within the plant directly affected the efficiency of the carbon metabolism process and increased the manufacture of energy-rich compounds and the activation of enzymes necessary for vital processes within the plant, which was reflected in the increase in plant tissues as well as the role of nitrogen in building proteins and enzymes that increase plant growth. As well as the participation of nitrogen in the formation of amino acids and an increase in the effectiveness of GA_3 gibberellins, which are responsible for the formation of stolons before emergence, which increases the number of tubers formed (34) in addition to the role of potassium and phosphorus in raising the efficiency of metabolizing carbohydrates synthetized in leaves And stored in the tubers in the form of starch, which helped to raise the rate of plant yield, The results of the response to foliar fertilization with Nano chitosan loaded with NPK were consistent and in the same direction as the results of Elshamy et al.(15), which showed that spraying with Nano chitosan loaded with nitrogen, phosphorus and potassium contributed to increasing the yield of potato plants and it agrees with what was mentioned by a number of researchers in the field of nanofertilizers (15 and 24). These results are consistent with what was reached by (2 and 3) from spraying organic nutrients on plants.

Dry mater and N, P, K % in tubers: Data in Table 1 shows that NanoNPK2 superior in dry matter in the tubers (22.22, 21.64%) respectively for both seasons, than C100%, (16.94 , 16.53%) respectively for both seasons and C50% which produced the lowest value (15.86, 15.59%) respectively for both seasons, spraying green tea extract was significantly superior in GT2 which produced the highest results for this trait (20.35, 19.53%) respectively for both seasons, and superior than nettle leaf extract N1 (19.04 and 18.78%) respectively for both seasons compared to C0, which produced the lowest values reached 17.70% and 17.60% respectively for both seasons. Data in Table 2 shows that the interaction between the two study factors had a significant effect on the percentage of dry matter in tubers for both seasons. C100% C0 produced highest values (15.44 and 15.99%) respectively for both seasons while C50% C0 produced the lowest percentage for this trait (15.24 and 14.97%) respectively for both seasons. The results of Table 1 indicate the significant superiority of NanoNPK2 in producing the highest percentage of nitrogen, phosphorus and potassium in the tubers which amounted 0.451, 0.370 and 0.480%, respectively for the spring season, and 0.452, 0.380 and 0.477%, respectively for fall season, compared to C50% which produced the lowest values (0.241, 0.260, and 0.340%, respectively) for spring season, and (0.253, 0.250, and 0.329%, respectively) for fall season. Also, spraying with GT2 was significantly superior in giving the highest percentage of nitrogen, phosphorus and potassium in the tubers (0.424, 0.350 and 0.450%, respectively) for spring season and (0.411, 0.330 and 0.439%, respectively) for fall season, compared to C0, which gave the lowest values (0.346, 0.280, and 0.380%, respectively) for spring season and (0.345, 0.280, and 0.375%, respectively) for fall season. Data in table 2 shows that there was no significant effect in interaction between the two study factors for N% in the spring season and for P% in fall season, and P% for both seasons, the highest N% in tubers appeared for fall season by NanoNPK2GT2, NanoNPK2GT1, NanoNPK1GT1, NanoNPK3GT2, NanoNPK3GT1 and NanoNPK2N1, which did not differ significantly between them (0.480, 0.473. , 0.447, 0.457, 0.440 and 0.450%, respectively) but they were significantly superior to C100% C0 (0.273%) and to C50%C0 which produced 0.250%. The highest P% in tubers appeared in NanoNPK2 GT2 (0.430 %,) which superior than C100% C0 (0.260%) and C50%

C0, which gave the lowest value (0.240 %) for spring season. It is clear from the results of tables (1 and 2) that there is a significant increase in dry matter and nitrogen, phosphorus and potassium in tubers when spraying with the study factors perhaps due to the role of these factors in increasing the content of the leaves of these elements and then their transmission and accumulation in the tubers It also led to an increase in the products of carbon metabolism and a better accumulation of manufactured compounds such as carbohydrates, soluble amino acids and organic acids, so they are transported from the source in the leaves to the final sink in the tubers and stored in the form of dry matter, which is the final product of the processes of carbon metabolism which leading to an increase in dry matter in tubers, as it means an increase in the percentage of nitrogen, phosphorus, and potassium in the tubers, which is one of the important indicators that indicating the high nutritional value of tubers and an increase in their storage capacity.

Table 1. Effect of spraying with chitosan nanoparticles loaded with NPK fertilizer, nettle leaf extract, and green tea extract on the Leaf area, Yield, Dry matter and nutrient concentration in tubers of potato in the spring and fall seasons 2021.

Treatment	Leaf area (m2. plant-1)		Plant yield (g plant-1)		Dry weight % tubers		Tubers (%) N		Tubers (%) P		Tubers (%) K	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Chitosan nanoparticles loaded with NPK fertilizer (%)												
$C_{100\%}$	7436	6359	604.3	574.6	16.94	16.53	0.36	0.32	0.28	0.26	0.36	0.36
$C_{50\%}$	6097	5990	580.2	566.8	15.86	15.59	0.24	0.25	0.26	0.25	0.34	0.33
Nano NPK $_1$	7977	7814	846.6	829.2	18.67	18.28	0.44	0.41	0.31	0.30	0.43	0.42
Nano NPK $_2$	9189	9051	972.8	920.4	22.22	21.64	0.45	0.45	0.37	0.38	0.48	0.47
Nano NPK $_3$	8998	8891	930.4	838.5	21.77	21.33	0.43	0.43	0.35	0.35	0.46	0.46
LSD $_{0.05}$	160	55	2.7	9.4	0.02	0.11	0.02	0.02	0.01	0.02	0.02	0.02
Plant extracts (g L^{-1})												
C_0	7227	6869	735.6	685.4	17.70	17.60	0.35	0.45	0.28	0.28	0.38	0.38
N_1	7885	7551	777.3	739.1	19.04	18.78	0.37	0.37	0.31	0.30	0.41	0.41
N_2	7583	7258	766.6	733.6	18.71	18.30	0.36	0.35	0.30	0.29	0.40	0.40
GT_1	8382	8115	814.9	778.1	19.65	19.17	0.41	0.39	0.33	0.32	0.44	0.43
GT_2	8620	8312	839.8	793.4	20.35	19.53	0.42	0.41	0.35	0.33	0.45	0.44
LSD $_{0.05}$	160	55	2.7	9.4	0.02	0.11	0.02	0.02	0.01	0.02	0.02	0.02

***C100% = ground addition to the recommendation chemical fertilizer, C50% = ground addition to half of the recommendation chemical fertilizer, NanoNPK$_1$ = chitosan nanoparticles loaded with NPK fertilizer at a concentration of 10%, NanoNPK$_2$ = chitosan nanoparticles loaded with fertilizer NPK at a concentration of 15%, NanoNPK$_3$=chitosan nanoparticles loaded with NPK fertilizer 20%, C0 = control treatment (spray with distilled water only), N1 = 25g L^{-1} nettle leaf extract, N2 = 35g L^{-1} nettle leaf extract, GT1 = Green tea extract at a concentration of 2g L^{-1}, GT2 = green tea extract at a concentration of 4g L^{-1}**

Table 2. Effect of the interaction between spraying chitosan nanoparticles loaded with NPK fertilizer and nettle leaf extract, and green tea extract on the Leaf area, Yield, Dry matter and nutrient concentration in tubers of potato in the spring and full seasons 2021

Interaction	Leaf area (m^2. $plant^{-1}$)		Plant yield (g $plant^{-1}$)		Dry weight % tubers		Tubers (%) N		P		K	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
$C_{100\%}$ C_0	6898	5849	585.0	466.4	15.99	15.44	0.31	0.27	0.26	0.24	0.34	0.33
$C_{100\%}$ N_1	7379	6052	598.0	582.6	16.78	16.66	0.35	0.31	0.28	0.27	0.35	0.36
$C_{100\%}$ N_2	7253	5959	594.4	592.7	16.37	16.22	0.32	0.29	0.27	0.25	0.35	0.35
$C_{100\%}$ GT_1	7662	6825	610.0	611.8	17.65	16.99	0.39	0.36	0.28	0.27	0.36	0.37
$C_{100\%}$ GT_2	7989	7108	634.1	619.6	17.89	17.35	0.41	0.38	0.29	0.28	0.38	0.37
$C_{50\%}$ C_0	5432	5368	510.0	508.9	15.24	14.97	0.21	0.25	0.24	0.23	0.31	0.30
$C_{50\%}$ N_1	5712	5654	570.5	554.7	15.99	15.65	0.23	0.24	0.26	0.25	0.34	0.33
$C_{50\%}$ N_2	5509	5509	563.0	540.2	15.94	15.18	0.22	0.23	0.25	0.25	0.33	0.32
$C_{50\%}$ GT_1	6816	6547	615.3	605.4	16.00	16.01	0.26	0.25	0.27	0.26	0.35	0.34
$C_{50\%}$ GT_2	7017	6870	642.0	625.0	16.13	16.15	0.27	0.29	0.28	0.27	0.36	0.35
Nano NPK_1 C_0	7525	7056	811.0	782.7	17.13	17.60	0.39	0.37	0.28	0.26	0.38	0.37
$NanoNPK_1$ N_1	7822	7736	823.7	809.4	18.52	18.03	0.43	0.42	0.30	0.28	0.42	0.42
$NanoNPK_1$ N_2	7739	7683	854.2	829.5	18.47	17.90	0.42	0.40	0.29	0.27	0.41	0.40
$NanoNPK_1$ GT_1	8240	8199	866.0	854.7	19.44	18.72	0.46	0.43	0.33	0.32	0.45	0.44
$NanoNPK_1$ GT_2	8560	8396	878.0	869.5	19.78	19.14	0.46	0.45	0.36	0.34	0.47	0.46
$NanoNPK_2$ C_0	8196	8121	902.0	877.8	20.01	20.06	0.41	0.43	0.31	0.34	0.43	0.44
$NanoNPK_2$ N_1	9283	9223	987.0	921.5	22.12	21.79	0.44	0.45	0.37	0.37	0.48	0.47
$NanoNPK_2$ N_2	8712	8525	923.4	886.4	21.64	21.45	0.42	0.43	0.36	0.37	0.46	0.46
$NanoNPK_2$ GT_1	9782	9646	995.7	948.2	23.01	22.12	0.48	0.47	0.40	0.40	0.52	0.50
$NanoNPK_2$ GT_2	9973	9742	1055.7	967.9	24.31	22.77	0.50	0.48	0.43	0.41	0.53	0.52
$NanoNPK_3$ C_0	8084	7952	870.2	791.1	20.12	19.91	0.40	0.41	0.30	0.33	0.42	0.42
$NanoNPK_3$ N_1	9230	9089	907.2	827.1	21.81	21.75	0.42	0.43	0.35	0.34	0.45	0.46
$NanoNPK_3$ N_2	8704	8613	898.0	818.9	21.13	20.77	0.41	0.41	0.33	0.33	0.44	0.45
$NanoNPK_3$ GT_1	9410	9359	987.3	870.5	22.14	22.00	0.46	0.44	0.38	0.36	0.50	0.47
$NanoNPK_3$ GT_2	9560	9441	989.4	885.0	23.64	22.22	0.47	0.46	0.40	0.37	0.51	0.49
L.S.D $_{0.05}$	357	122	6.1	21.1	0.05	0.25	NS	0.04	0.03	NS	NS	NS

Quality tubers traits

The results in Table 3 show that spraying with Nano chitosan loaded with NPK had a significant effect on tuber hardness for both seasons, where the spraying treatment NanoNPK2 achieved the highest degree of hardness, which reached 11.11 and 11.0 kg cm^{-2} for both seasons, respectively, and the highest percentage of total soluble solids (TSS), (6.35 and 6.34%) for both seasons, respectively compared to the lowest degree of hardness and the percentage of total soluble solids (TSS), which reached 9.87 kg cm^{-2} for both seasons and 5.68 and 5.57% when treating C50% for both seasons, respectively. also spraying with green tea extract GT2 excelled in producing the highest hardness (10.86 and 10.82 kg cm^{-2}) respectively for both seasons compared to the lowest hardness of tubers in C0 reached 10.11 and 10.06 kg cm^{-2} for both seasons respectively. The same applies to TSS for both seasons, where GT2 was significantly excelled in producing the highest TSS (6.38% and 6.35%) for both seasons respectively compared to C0, which produced the lowest percentage (5.86% and 5.67%) for both seasons respectively. The results showed in Table 3 the significant superiority of NanoNPK2 by producing the highest tuber content for each of the amino acid Arginine, which reached 296.2 and 292.3 mg 100 g^{-1} for both seasons respectively compared to C50% which produced the lowest content (235.1, 233.9 mg 100 g^{-1}) respectively for both seasons, and glutamate amino acid, which reached 78.33 mg 100 g^{-1} for the spring season, which did not differ significantly from NanoNPK3 for the same season and 79.25 mg 100 g $^{-1}$ for fall season, It was superior to C100% treatment, which reached 45.85 and 44.88 mg $100g^{-1}$ for both seasons, and C50% which achieved the lowest content (38.64 and 38.50 mg $100g^{-1}$) for both seasons respectively. It was also significantly excelled on GT2 by producing the highest Arginine content (282.3 and 279.3 mg 100 g^{-1}) for both seasons respectively, and the highest Glutamate content amounted to 72.11 and 71.56 mg 100 g^{-1} for both seasons respectively compared to C0 which produce the lowest values in Arginine content (245.3 and 243.5 mg $100g^{-1}$ for both seasons, respectively and in Glutamate content (47.06 and 45.99 mg $100g^{-1}$) for both seasons respectively. Data in table 3 also showed that NanoNPK3 produce the highest percentage of Amylose (25.88% and 25.63%) for both seasons respectively while C100% produce a percentage of 19.76% and 18.95% for both seasons respectively which did not differ significantly from C50% which produce the lowest percentage (19.24% and 18.84%) for both seasons respectively. As for amylopectin polymers forming starch granules with a percentage of 70-80%, which is completed with amylose with a ratio of 20-30% of the total starch, as well as the secondary components of the starch granule (30), and that the ratio of Amylose and Amylopectin to the granules is the starch of potato tubers. The optimal consumption is within the limits of these ratios, as they are considered complementary to one another, and any violation of these percentage will be negatively reflected on the formation of the starch granule (12 and 27). It appears in the results of Table 3 that spraying with Nano chitosan loaded with NPK with all treatments (NanoNPK1, NanoNPK2, NanoNPK3) led to achieving an optimal percentage of Amylopectin, which is completed with the percentage of Amylose from the same treatments in Table 3 to form starch granules, with a value of 78.00%, 76.70%, and 74.00%, respectively for the spring season, for each treatment, and for fall season 77.74%, 76.66%, and 74.27%. Respectively, compared with C100% which achieved a percentage of 80.20% and 80.95% for both seasons, respectively while C50% achieved the highest percentage of 80.70% and 81.06% for both seasons respectively. Spraying green tea extract GT2 achieved the highest Amylose percentage (24.07% and 23.49%) respectively for both seasons compared to C0, which achieved the lowest Amylose percentage (20.31% and 20.41%) for both seasons respectively also spraying nettle leaf extract and green tea extract significantly affected the percentage of amylopectin for spring and fall seasons, and despite the significant differences between the values of each treatment, all treatments of both extracts in addition to the control achieved a percentage within the limits of the percentage of amylopectin for both seasons. The results for interaction (Table 4) showed that the highest hardness of tubers in the spring season was with NanoNPK2 GT2, NanoNPK2 GT1, NanoNPK3 GT2, NanoNPK3 GT1, NanoNPK1 GT2 and NanoNPK1 GT1 which did not differ significantly among them and reached 11.40, 11.34, 11.39, 11.32, 11.22 and 11.20 kg cm^{-2} respectively, It excelled C100% C0 value of 9.87 kg cm^{-2} and C50% C0 with the lowest tuber hardness of 9.56 kg cm-2. In fall season, the highest hardness of tubers was recorded at NanoNPK2 GT2, NanoNPK2 GT1, NanoNPK3 GT2 and NanoNPK3 GT1, which did not differ significantly between them and reached 11.34, 11.32, 11.31, 11.25 kg cm^{-2} respectively, it excelled C100% C0 (9.81 kg cm^{-2}) and C50% C0 which recorded the lowest tuber hardness (9.64 kg cm^{-2}). As for the percentage of total soluble solids (TSS), the interaction was superior in NanoNPK2 GT2 producing the highest percentage (6.66% and 6.65%) respectively for both seasons while the lowest percentage of total soluble solids

(TSS), was at C50% C0 (5.41%) for spring season, and in C100% C0 (4.92%) for fall season. NanoNPK2 and NanoNPK3 (which did not differ significantly between them) were significantly excelled in producing the highest arginine content (324.1, 323.5 mg $100g^{-1}$) for spring season respectively and producing 318.8, 316.5 mg $100g^{-1}$ for fall season respectively compared to C100% C0, which produce 227.7 and 224.4 mg $100g^{-1}$ for both seasons respectively, and C50% C0, which produce the lowest content of Arginine in the tubers (225.4 and 223.9 mg $100g^{-1}$) for both seasons respectively. NanoNPK2GT2 was superior to all treatments by achieving the highest content of glutamate amino acid, (94.70 mg 100 g^{-1}) for spring season. and in fall season it reached to 94.53 mg $100g^{-1}$, C50%C0 achieved the lowest content of glutamate amino acid (29.29 and 29.22 mg $100g^{-1}$) for both seasons respectively. For interaction between the two study factors it did not show a significant effect on Amylose and Amylopectin for the spring and fall seasons. Increasing yield quality traits represented by tuber hardness and percentage of total soluble solids (TSS) may be due to the significant role of the supplementary fertilizer manufactured according to nanotechnology (chitosan nanoparticles loaded with NPK) in exceeding its effectiveness with traditional methods of fertilization, in addition to its high absorption speed as a result of its small size and high surface area. As well as the role of plant extracts (nettle leaf extract and green tea extract) rich in a wide spectrum of nutrients, proteins and amino acids, Both of them contributed to increasing the readiness of nutrients and their absorption by the plant by repeating the spraying process, leading to an increase in carbon metabolism and a better accumulation of manufactured compounds such as carbohydrates, soluble amino acids and organic acids, so they are transported from the source in the leaves to the final sink in the tubers and stored in the form of dry matter as a final product of carbon metabolism and metabolism leading to an increase in the percentage of both starch (Amylose and Amylopectin).and protein (Arginine and Glutamate), which are directly proportional to the increase in the percentage of dry matter in the tubers, and that the increase in the dry matter in the tubers means an increase in the percentage of total soluble solids (TSS) which is one of the important indicators of the high nutritional value of the tubers and increase their storage capacity. The hardness of the tubers is one of the important quality criteria for potato tubers, and its increase in the tubers is mainly associated with an increase in the percentage of starch and the percentage of dry matter. The physiological effect of the nutrients absorbed, especially nitrogen, phosphorus and potassium with other elements plays a physiological role in activating the enzymatic activity of the pathways of carbon metabolism and increasing the building of amino acids that transport from the leaves to storage places to form proteins through amino acid transporters in the plant which is reflected in the increase in the percentage of protein in the tubers, while phosphorus has a role in the synthesis of organic compounds due to the occurrence of reductive oxidation processes during vital activities such as carbon metabolism, respiration, and carbohydrate metabolism (28).Phosphorus also contributes to stimulating the growth and development of the plant and is involved in the formation of starch granules and increasing the percentage of starch in tubers, as well as its role with potassium in transporting manufactured materials from leaves to tubers. Potassium also has a role in representing nitrogen and converting it into basic units of amino acids to form protein. Potassium also has an impact on the process of protein synthesis itself, as it helps separate the newly formed protein from the ribosome and provides an opportunity for the formation of a new protein (20) as for the effect of spraying with chitosan nanoparticles loaded with NPK, chitosan has a role in increasing the hardness of tubers. The results, in their general framework, are consistent with what the researchers by (9) found in potato tubers. As for the effect of the interaction between the factors of the study, it is only a reflection of its effect, which is reflected in a positive way in increasing the qualitative yield indicators represented by the percentage of dry matter in tubers, starch components, amino acids, tuber hardness, and the percentage of total soluble solids (TSS). We recommend the use of spraying chitosan nanoparticles loaded with NPK at a concentration of 15% and 20% and spraying with green tea extract at a concentration of 4g L^{-1} and nettle leaf extract at a concentration of 35g L^{-1} because their role in improving the quality of potato tubers by increasing its nutritional value for consumption or increasing the marketing capacity of the yield.

Table 3. Effect of spraying chitosan nanoparticles loaded with NPK fertilizer, nettle leaf extract, and green tea extract on the quality traits of potato tubers in the spring and full seasons 2021.

Treatments	Hardness (Kg cm^{-2})		TSS %		Arginine (mg 100g $D.Wt^{-1}$)		Glutamate (mg 100g $D.W.^{-1}$)		Amylose %		Amylopectin %	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Chitosan nanoparticles loaded with NPK fertilizer (%)												
C100%	10.02	10.00	5.81	5.63	237.9	234.3	45.85	44.88	19.76	18.95	80.20	80.95
C50%	9.87	9.87	5.68	5.57	235.1	233.9	38.64	38.50	19.24	18.84	80.70	81.06
NanoNPK1	10.76	10.70	6.22	6.18	264.8	260.2	61.75	61.47	21.88	22.16	78.00	77.74
NanoNPK2	11.11	11.10	6.35	6.34	296.2	292.3	78.33	79.25	23.15	23.24	76.70	76.66
NanoNPK3	11.05	10.88	6.31	6.30	291.0	287.6	77.17	76.86	25.88	25.63	74.00	74.27
LSD 0.05	0.10	0.04	0.03	0.05	3.1	3.4	1.80	2.21	1.09	0.96	1.09	0.96
Plant extracts (g L-1)												
C0	10.11	10.06	5.86	5.67	245.3	243.5	47.06	45.99	20.31	20.41	79.60	79.49
N1	10.54	10.46	5.94	5.88	262.0	257.6	59.97	59.03	21.25	21.05	78.60	78.85
N2	10.50	10.42	5.97	5.92	260.1	256.5	55.33	57.24	21.65	21.51	78.30	78.39
GT1	10.81	10.78	6.22	6.19	275.3	271.4	67.28	67.14	22.63	22.37	77.30	77.53
GT2	10.86	10.82	6.38	6.35	282.3	279.3	72.11	71.56	24.07	23.49	75.90	76.41
LSD 0.05	0.10	0.04	0.03	0.05	3.1	3.4	1.80	2.21	1.09	0.96	1.09	0.96

***C100% = ground addition to the recommendation chemical fertilizer, C50% = ground addition to half of the recommendation chemical fertilizer, $NanoNPK_1$ = chitosan nanoparticles loaded with NPK fertilizer at a concentration of 10%, $NanoNPK_2$ = chitosan nanoparticles loaded with fertilizer NPK at a concentration of 15%, $NanoNPK_3$=chitosan nanoparticles loaded with NPK fertilizer 20%, C0 = control treatment (spray with distilled water only), N1 = 25g L^{-1} nettle leaf extract, N2 = 35g L^{-1} nettle leaf extract, GT1 = Green tea extract at a concentration of 2g L^{-1}, GT2 = green tea extract at a concentration of 4g L^{-1}**

Table 4. Effect of the interaction between spraying chitosan nanoparticles loaded with NPK fertilizer and nettle leaf extract, and green tea extract on the quality traits of potato tubers in the spring and full seasons 2021.

Interaction	Hardness (Kg cm^{-2})		TSS %		Arginine (mg 100g D.W^{-1})		Glutamate (mg 100g D.W^{-1})		Amylose %		Amylopectin %	
	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
$C_{100\%}$ C_0	9.87	9.81	5.47	4.92	227.7	224.4	40.00	36.93	18.08	17.60	81.80	82.30
$C_{100\%}$ N_1	10.02	10.00	5.68	5.53	239.7	235.5	45.60	44.77	19.20	18.53	80.70	81.37
$C_{100\%}$ N_2	9.98	9.99	5.57	5.40	236.0	234.4	42.09	42.85	19.90	18.80	80.10	81.10
$C_{100\%}$ GT_1	10.10	10.07	6.13	6.13	240.4	236.7	48.63	48.76	20.70	19.63	79.30	80.27
$C_{100\%}$ GT_2	10.14	10.13	6.19	6.17	245.7	240.7	52.95	51.10	20.90	20.17	79.10	79.73
$C_{50\%}$ C_0	9.56	9.64	5.41	5.08	225.4	223.9	29.29	29.22	17.90	17.30	82.00	82.60
$C_{50\%}$ N_1	9.82	9.78	5.47	5.36	234.7	231.6	38.59	38.31	18.83	18.83	81.10	81.07
$C_{50\%}$ N_2	9.79	9.73	5.47	5.44	234.3	233.0	35.71	37.05	18.83	18.70	81.10	81.20
$C_{50\%}$ GT_1	10.07	10.07	5.92	5.85	238.1	237.0	42.14	42.04	20.00	19.47	79.90	80.43
$C_{50\%}$ GT_2	10.13	10.11	6.14	6.12	243.0	243.8	47.49	45.90	20.63	19.90	79.30	80.00
$NanoNPK_1$ CT_0	10.27	10.17	6.08	6.06	249.5	245.5	49.76	48.48	20.47	21.80	79.40	78.10
$NanoNPK_1$ N_1	10.60	10.52	6.15	6.12	265.2	255.6	60.12	57.63	21.30	20.97	78.60	78.93
$NanoNPK_1$ N_2	10.51	10.43	6.19	6.16	261.3	250.6	54.16	57.94	21.50	21.40	78.40	78.50
$NanoNPK_1$ GT_1	11.20	11.17	6.27	6.25	272.6	272.8	69.39	69.15	22.27	22.90	77.60	77.00
$NanoNPK_1$ GT_2	11.22	11.20	6.40	6.30	275.4	276.5	75.35	74.14	23.87	23.73	76.00	76.17
$NanoNPK_2$ C_0	10.53	10.51	6.16	6.16	268.3	269.2	58.85	58.56	21.93	21.83	78.00	78.07
$NanoNPK_2$ N_1	11.15	11.18	6.21	6.19	287.2	284.1	79.80	79.54	22.80	22.00	77.10	77.90
$NanoNPK_2$ N_2	11.11	11.14	6.33	6.32	286.3	282.5	69.38	74.53	22.97	23.67	76.90	76.23
$NanoNPK_2$ GT_1	11.34	11.32	6.40	6.36	315.3	306.9	88.92	89.10	23.60	23.97	76.30	75.93
$NanoNPK_2$ GT_2	11.40	11.34	6.66	6.65	324.1	318.8	94.70	94.53	24.47	24.73	75.40	75.17
$NanoNPK_3$ C_0	10.33	10.19	6.16	6.15	255.5	254.6	57.42	56.75	23.17	23.50	76.70	76.40
$NanoNPK_3$ N_1	11.11	10.82	6.18	6.18	283.2	281.2	75.73	74.91	24.13	24.90	75.80	75.00
$NanoNPK_3$ N_2	11.09	10.81	6.28	6.27	282.5	281.8	75.31	73.85	25.03	24.97	74.90	74.93
$NanoNPK_3$ GT_1	11.32	11.25	6.38	6.37	310.2	303.6	87.33	86.67	26.60	25.87	73.30	74.03
$NanoNPK_3$ GT_2	11.39	11.31	6.54	6.50	323.5	316.5	90.06	92.11	30.47	28.93	69.40	70.97
L.S.D $_{0.05}$	0.23	0.09	0.07	0.12	7.0	7.6	4.01	4.95	NS	NS	NS	NS

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

REFERENCES

1. Abdel-Aziz, H.M.M.; M.N.A. Hasaneen and A.M. Omer. 2018. Effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of wheat grains. Egyptian Journal of Botany. 58(1):87-95.

2. Abdulraheem S. M. and J. I. Estefo. 2018. Effect of seeds, leaves, and roots extract plants on growth and yield of pea. Tikrit Journal for Agricultural Sciences. 18 (2): 60 – 67.

3. Abdulrasool, I.J. and Z.R.J. Al-Malikshah. 2022. Effect of adding fulzyme plus and spraying with green tea extract on vegetative growth and yield of pepper cv.california wonder. Basrah Journal of Agricultural Sciences. 35(2): 302-312.

4. Adisa, I.O.; V. L. R. Pullagurala; J. R. Peralta-Videa; Ch.O. Dimkpa; W. H. Elmer; J. L. Gardea-Torresdey and J. C. White. 2019. Recent advances in nano-enabled fertilizers and pesticides: A critical review of

mechanisms of action', Environmental Science: Nano. 6 (7): 2002 -2030.
5. Ahmad, A.; B. Blasco and V. Martos. 2022. Combating salinity through natural plant extracts based biostimulants: A Review. Frontiers in Plant Science. 13:862034.
6. Al-jubouri, K. D. H., I. J. Abdul Rasool, Aseel M.H. H. Al-Khafaji, A. J. Abdulsada, F. Y. Baktash, W. H. Hasoon, and Z. J. Al-Mousawi. 2025. Unraveling prolonged irrigation intervals and some sustainable treatments on potato starch composition, growth, and productivity in iraq. Iraqi Journal of Agricultural Sciences, 56(1), 321-329. https://doi.org/10.36103/s9q1w418
7. AL Mohammadi, S. M. and F.H. AL Mohammadi. 2012. Statistics and Experimental Design. Dar Osama for publication and distribution / Amman, Jordan. pp. 376.
8. Al-Mousawi, Z. J., I. J. Abdul Rasool, A. M.H. H. Al-Khafaji, F. Y. Baktash, and K. D. H. Al-jubouri. 2025. Ecofriendly treatments and drought conditions as a tool for the induction of medicinally active compounds on potatoes. Iraqi Journal of Agricultural Sciences, 56(2), 648-656. https://doi.org/10.36103/qzwfkw53
9. Al-Zebari,Y.I.; A.MS. Kahlel and S.Y.H. AL-Hamdany. 2021. Response of four potato (*Solanum tuberosum* L.) varieties to four nano fertilizers. Earth and Environmental Science.761:012060.
10. Abd El-Azeim, M. M., Sherif, M. A., Hussien, M. S., Tantawy, I. A. A., and Bashandy, S. O. 2020. Impacts of nano-and non-nanofertilizers on potato quality and productivity. Acta Ecologica Sinica, 40(5), 388-397. https://doi.org/10.1016/j.chnaes.2019.12.007
11. Barreca, D. 2021. Mechanisms of Plant Antioxidants Action. Plants. 10(1):35.
12. Choi,I.; J. Chun; H.-S. Choi; J. Park; N.-G. Kim; S.-K. Lee; C.-H. Park; K.-H. Jeong; J.-W. Nam; J. Cho and K. Cho. 2020. Starch characteristics, sugars and thermal properties of processing potato (*Solanum tuberosum* L.) cultivars developed in korea. American Journal of Potato Research.97: 308 - 317.
13. Corradini, E.; M. R. Moura, and L. H. Mattoso, 2010. A preliminary study of the incorparation of NPK fertilizer into chitosan nanoparticles. Express Polymer Letters 4: 509–515.
14. Dheyab, N. S., A M.H. H. Al-Khafaji, I. J. Abdul Rasool, F. Y. Baktash, K. D. H. Al-jubouri, Z. J. Al-Mousawi, and D. A. Hanoon. 2025. Reducing water consumption and improving soil, root quality of potato via environmentally sustainable treatments. Iraqi Journal of Agricultural Sciences, 56(Special), 1-9. https://doi.org/10.36103/przef771
15. Elshamy,M.T.; S.M. Elkhallal; Sh.M. Husseiny and K.Y. Farroh. 2019. Application of nano-chitosan NPK fertilizer on growth and productivity of potato plant. Journal of Scientific Research in Science. 36 (1): 424-441.
16. Garcia,E.L.; E.L.do Carmo; J.G.de Pádua; C.M.L.Franco and M. Leonel. 2019. Potato cultivars as a source of starch in Brazil: physicochemical characteristics of the starches and their correlations. Australian Journal of Crop Science.13 (11):1786-1792.
17. Garmendia,A.; M.D. Raigón; O. Marques; M. Ferriol; J. Royo and H. Merle. 2018. Effect of nettle slurry (*Urtica dioica* L.) used as foliar fertilizer on potato (*Solanum tuberosum* L.) yield and plant growth. PeerJ.6:e4729.
18. Hakim, A.; M. Khatoon and S. Gullo. 2019. Effect of compost tea and partial root zone drying on tomato productivity and quality. Advances in Horticultural Science.33 (4):511-518.
19. Han, M., S. Kasim, Z. Yang, X. Deng, N. B. Saidi, M. K. Uddin, and E. M. Shuib, 2024. Plant Extracts as Biostimulant Agents: A Promising Strategy for Managing Environmental Stress in Sustainable Agriculture. Phyton (0031-9457), 93(9). 10.32604/phyton.2024.054009
20. Kavoosi,G.; S. Balotf; H. Eshghi and H. Hasani. 2014. Analysis of nitrate reductase mRNA expression and nitrate reductase activity in response to nitrogen supply. Molecular Biology Resesrch Communications.3 (2):75-84.
21. Kisvarga, S.; D. Farkas; G. Boronkay; A. Neményi and L. Orlóci. 2022. Effect of biostimulants in horticulture, with emphasis on ornamental plant production. Agronomy. 12:1043.
22. Kumar, H.D. and P. Aloke. 2020. Role of biostimulant formulations in crop production:

A Overview. International Journal of Agricultural Sciences and Veterinary Medicine. 8 (2): 38-46.
23. Márcia, R. de Moura.; F. A. Aouada. and L.H.C. Mattoso. 2008. Preparation of chitosan nanoparticles using methacrylic acid. Journal of Colloid and Interface Science 321: 477–483.
24. Mariush, A.H.K. and M.Z.K. AL-Mharib, 2020. Effect of nano-fertilizers and amino acids on the growth and yield of broccoli. International Journal of Agricultural and Statistical Sciences.16 (1):1661-1665.
25. Salman,A.D. and A.H. Abdulrazzaq. 2022. Effect of cultivation dates and different sources of soil fertilization on vegetative characteristics, Quality and Yield of Broccoli. International Journal of Agricultural and Statistical Sciences. 18(1):165-171.
26. Shahrabadi, F., Abbasifar, A., & ValizadehKaji, B. (2020). Effects of green synthesized zinc and copper nano-fertilizers on the morphological and biochemical attributes of basil plant. Journal of Plant Nutrition, 43(8), 1104-1118. https://doi.org/10.1080/01904167.2020.1724305
27. Sanchez-González ,J.A; C. Echeverria; L. Lescano; G. Linares; H.L .Arteaga-Miňano ;J. Soriano-Colchado and G. Barraza-Jáuregui. 2019. Physico-chemical, thermal and rheological characteristics of starch isolated from four commercial potatoes cultivars. Scientia Agropecuaria. 10 (1): 63-71.
28. Sawicka, B.; A.H. Noaema; T.S. Hameed and B. Bienia. 2019. The role of magnesium in the growth and development of the potato XVIII of magnesium conference in Lublin. The Role of Element in the Biosphere: 115-116.
29. Shahbaz, M. U.; M. Arshad; K. Mukhtar; B. G. Nabi; G. Goksen; M. Starowicz; A. Nawaz; I. Ahmad; N. Walayat; M.F. Manzoor and R.M. Aadil. 2022. Natural plant extracts: An update about novel spraying as an alternative of chemical pesticides to extend the postharvest shelf life of fruits and vegetables. Molecules. 27: 5152.
30. Siddiqui,S.; N. Ahmed and N. Phogat. 2021."Potato Starch as Affected by Varieties, Storage Treatments and Conditions of Tubers" In Starch: Evolution and Recent Advances, edited by Martins Ochubiojo Emeje. London: IntechOpen pp: 63 - 77.
31. Tiwari,A.; R. Kumar; R. Sachan; H. Tiwari and S.R. Pandey. 2022. Effect of organic and inorganic manure on yield, quality trait and economics of potato (*Solanum tuberosum* L.) under indo gangetic plain of eastern uttar pradesh. Journal of Experimental Agriculture International. 44 (3): 10-14.
32. Turk, H. A. M. and R. M. A. AL-Ubiady. 2022. Effect of spraying with nano-elements and selenium under water stress conditions on vegetative traits and yield of tomato plants. Indian Journal of Ecology. 49 (20):10-16.
33. Zulfiqar, F., Casadesús, A., Brockman, H., & Munné-Bosch, S. (2020). An overview of plant-based natural biostimulants for sustainable horticulture with a particular focus on moringa leaf extracts. Plant Science, 295, 110194. https://doi.org/10.1016/j.plantsci.2019.110194
34. Zainaldeen, M. A. and I. J. Abdulrasool. 2017. Response growth and production of potato plant Var. Rodolof for spraying with gibberellin and nutrients. Euphrates Journal of Agriculture Science. 9 (4):525 – 536.