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FIELD PERFORMANCE OF POTATO TREATED WITH ECO-FRIENDLY FERTILIZERS TECHNIQUES

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ABSTRACT

A field experiment was conducted during the spring growing season of 2022–2023 at the research stations, College of Agricultural Engineering Sciences, University of Baghdad. The study aimed to evaluate the impact of foliar application of eco-friendly fertilisers on the field performance and the quantitative and chemical yield characteristics of potato plants (Arizona hybrid). The experiment included two factors: the first involved foliar spraying with four treatments—water only, 5 mL L^{-1} shrimp shell extract, 5 mL L^{-1} dried fish extract, and 5 mL L^{-1} sardine extract—coded as F_0, F_1, F_2, and F_3, respectively. The second factor included spraying with three concentrations of organic silicon: 0, 1, and 2 mL L^{-1}, coded as Si_0, Si_1, and Si_2, respectively, along with their interactions. The research was implemented as a factorial experiment following a Randomized Complete Block Design (R.C.B.D.) with three replications. The results indicated that treatment (F_1) resulted in the highest values for the number of aerial branches, marketable plant yield, number of tubers, tuber weight, and total soluble solids (T.S.S.).Treatment Si_1 resulted in tubers with the highest yield, dry matter content, and specific gravity. The interaction treatment F_1Si_2 produced the highest number of tubers, while F_2Si_2 yielded the firmest tubers.

INTRODUCTION

Food security, both local and global, is facing a new challenge as a food crisis that puts at risk the ability to feed millions of people. This crisis is driven by daily population growth, rising prices of staple foods, and increased dependence on agricultural products, which account for 70% of consumption. These challenges extend beyond the existing crises, including climate change, water shortages (Khalaf, 2024), desertification, soil degradation, and increased carbon emissions from certain agricultural practices. Excessive use of chemical inputs has led to vulnerability to environmental pollution, reduced productivity, and increased consumption of farm products (FAO, 2022; V, 2022; Wu, 2022; 2022; Zhang et al., 2024). On the other hand, potatoes (*Solanum tuberosum* L.), as a strategic crop that is almost always present on Iraqi dining tables throughout the year, can serve as the foundation for a sustainable agricultural system and a future pillar of food security(Alzubaidi, 2024) , especially for developing countries(Abdullah et al.,2025 and Sulaiman *et al*.,2024). This is due to its short growth cycle, low carbon emissions, minimal water requirements, and high productivity, yielding four times as much as wheat, rice, and corn per hectare. Additionally, potatoes provide excellent nutritional value, serving as an affordable and rich source of carbohydrates, proteins, minerals, and vitamins (Liu *et al*., 2021).

The application of affordable organic alternatives in fertilisation systems can enhance agricultural productivity and facilitate a shift towards a sustainable green economy.By using environmentally safe organic and bio-nutrients with foliar fertilisation systems, they improve both the productivity and the qualitative content of potato tubers (Al-jubouri *et al*., 2025 and Jaafar and Abdulrasool, 2025). Hence, sustainable nutrient management has been shown to cause a considerable improvement in vegetative growth markers and potato yield parameters (Al-Zaidi and Al-Jumaili, 2022). On the other hand, potato crop production was strongly associated with the availability of NPK (nitrogen, phosphorus, and potassium) used to improve growth conditions, which increases nutrient absorption and physiological activity in the potato crop. Thus, a steady and efficient increase in quantitative and qualitative indicators of production (Banjare, 2007; Baniune and Zekaitis, 2008; Sasseea and Al-Amry, 2024).

Aligned with sustainability on food and natural resources, recycling fish, fungi, and their residues can be an economically and environmentally relevant agricultural practice, moving towards cleaner production, especially since the continuous increase in the price of chemical fertilisers. This is especially significant, as their production is based on the conversion and recovery of natural waste products into high-nutrient products containing nitrogen (N) and phosphorus (P) (Ahuja *et al*., 2020 and Jaies *et al*., 2024). Fish waste is also commonly used in organic farming systems, as the special fertiliser can help increase the marketable yield of the respective crop. Moreover, the use of dried fish can meet the nutritional needs of plants and thus increase future productivity. Similarly, shrimp shells can be used as a cheap and safe substitute for fertilisers, a great offender in traditional farming systems, and potentially an accelerator of the climate crisis through the rise of carbon footprints. The high nitrogen, organic carbon, protein, and amino acid content of shrimp shells has been reported (Revathi, 2013; Yan and Xi, 2015 ;IIIera-Vives *et al*, 2017; Ahuja *et al*., 2020; Jaies *et al*., 2024). Moreover, Chitin (Chitosan) is a physiological stimulus for plants(Ibrahim *et al*.,2024), which has a safe and environmentally clean advantage, can be attributed to low emissions of CO_2 and N_2O into the atmosphere after Chitin (Chitosan) application on agricultural fields (Mansyur et al. 2020; Anwar *et al*. 2024 and Munda *et al*., 2024). Additionally, these residues can be readily, effectively absorbed, and utilized by plants – even byeconomically important ones – with physiological effects that are superior to those of mineral fertilisers. A study found that the addition of fish waste increased potato tuber productivity as well as qualitative and marketable tuber plants in organic farming systems (Banjare et al., 2014; Marpanng *et al*., 2023). One treatment type had a positive effect on potato plants: treating potato plants with a 1% fish extract concentration increased quantitative production measures while also reducing their susceptibility to scab disease (Abbasi *et al*., 2010). On the other hand, compost derived from shrimp shells promoted the growth parameters of pepper plants (Abirami *et al.,* 2016). Indratmi et al. (2024) reported increases in leaf production, bulb dry weight, and the percentage of dry matter in shallot bulbs when shrimp shells were added as organic waste.

With the introduction of silicon, one of the sustainable potato production practices to achieve more marketable produce is provided, as it amplifies the yield potential by enhancing the plant's responses to biotic and abiotic stressors. Silicon acts as a carbon assimilation stimulant, an enzymatic regulator, and a scavenger of free radicals because of its reductive role in oxidative stress (Wadas, 2022). Besides its regulatory function, silicon also increases water and nutrients uptake, their mineralisation, and incorporation by cells, therefore becoming one of the most relevant elements to introduce in environmentally clean fertilization regimes, especially for root and tuber species (Sotani *et al*., 2018; Artyszak et al., 2019; Wang, 2021; Khan *et al*., 2023). According to Crusciol et al. (2009), silicon fertilization resulted in a 34% increase in the weight of potato tubers. The marketable yield of silicon-treated potato varieties can be increased from 15 to 50% (Khan *et al*., 2017). Moreover, the use of organosilicate increased growth and yield characteristics and potato tuber production (Hussein *et al*., 2025).

Therefore, this research aimed to assess the field performance of Arizona hybrid potato plants and to enhance tuber production and their chemical and physical characteristics by using environmentally sustainable fertilisers.

MATERIALS & METHODS

The study was conducted in the spring season of 2022-2023 in Research Station A, College of Agriculture, Engineering Sciences, Baghdad University, Al-Jadriyah. The experiment included the cultivation of a potato hybrid, Arizona, produced by the Dutch company Agrico. To study the effect of treatments on the characteristics such as plant height (cm), number of aerial branches (branches plant^{-1}), total number of leaves (leaves plant^{-1}), marketable yield plant (g plant^{-1}), marketable tuber weight (g tuber^{-1}), number of marketable tubers (tubers plant^{-1}), dry matter (%), total soluble solids (T.S.S. %), firmness (kg cm^{-2}), specific gravity (A.O.A.C. 1990). The experiment was laid out as a factorial experiment arranged in a Randomised Complete Block Design (RCBD).

The first factor involved four levels of eco-friendly fish-based fertilizers: water only (F_0); shrimp shell extract (manually prepared) containing Ca = 7.64%, Mg = 0.59%, O.M. = 17.45%, N = 3.26%, P = 2.27%, and K = 8.13% at a concentration of 5 mL L^{-1} (F_1); dried fish extract (manually prepared) containing N = 7.7%, P = 9%, K = 8.70%, and Ca = 5.6% at a concentration of 5 mL L^{-1} (F_2); and commercial sardine fertilizer containing N = 9%, P_2O_5 = 6%, K_2O = 3%, and O.M. = 60% at a concentration of 5 mL L^{-1} (F_3).

The second factor consisted of foliar spraying with three concentrations of commercial organic silicon 0, 1, and 2 mL L^{-1}, containing Si = 2%, K = 1%, and O.M. = 70%, coded as Si_0, Si_1, and Si_2, respectively. The treatments were applied in three spraying intervals, with two weeks between applications, starting at full emergence. Data were collected and statistically analyzed using GenStat software, and means were compared using the Least Significant Difference (LSD) test at a 5% probability level (Elsahooki and Wahib, 1990).

RESULTS AND DISCUSSION

Vegetative Growth Characteristics

Table (1) demonstrates the statistically significant effects of the studied treatments on the vegetative growth traits of potato plants. Foliar spraying with dried fish extract (F_2) led to the highest plant height and the greatest number of leaves. In contrast, shrimp shell extract treatment (F_1) resulted in the highest number of aerial branches, relative to the control treatment sprayed with water only (F_0). The respective values were 86.9 cm plant height, 68.50 leaves $plant^{-1}$, and 6.333 aerial branches $plant^{-1}$ for F_2 and F_1, compared to 71.7 cm, 55.31 leaves $plant^{-1}$, and 3.4 aerial branches $plant^{-1}$ in the F_0 treatment.

Regarding the effect of organic silicon, the Si_3 treatment significantly increased both plant height and number of aerial branches compared to the control (Si_0), reaching 94.52 cm and 5.725 branches $plant^{-1}$ versus 60.4 cm and 3.475 branches $plant^{-1}$, respectively. The Si_1 treatment produced the highest number of leaves (69.21 leaves $plant^{-1}$), while the lowest number was recorded under the Si0 treatment (52.11 leaves $plant^{-1}$).

As for the interaction between the two factors, the F_2Si_3 treatment achieved the tallest plants (101.2 cm), while the shortest plants were recorded in the F_0Si_0 treatment (40.8 cm). The greatest number of aerial branches (5.725 branches $plant^{-1}$) was recorded in the F3Si3 interaction treatment, compared to the lowest (3.475 branches $plant^{-1}$) in the F_0Si_0 treatment. Additionally, the highest number of total leaves was observed in the F3Si1 treatment (78.75 leaves $plant^{-1}$), while the lowest (35.59 leaves $plant^{-1}$) was recorded under the F0Si0 control.

Table 1. Effect of foliar spraying with fish-based fertilizers and organic silicon on vegetative growth characteristics of the Arizona potato hybrid

F.	**Plant height (cm) Si**			Mean F.
	Si0	Si1	Si2	
F0	40.8±1.04	81.7±1.17	92.6±1.31	71.7±1.07
F1	78.5±1.12	83.5±1.21	89.6±1.27	83.93±1.21
F2	62.6±1.08	94.2±1.23	101.2±1.18	86.10±1.19
F3	59.7±1.10	91.2±1.11	94.7±1.08	81.86±1.11
Mean Si	60.4±1.08	87.65±1.17	94.52±1.21	
L.S.D.5%	Si	F	F * Si	
	9.28	10.72	18.57	
F.	**branches plant^{-1} Si**			Mean F.
	Si0	Si1	Si2	
F0	1.5±0.62	4.2±0.53	4.5±0.42	3.4±0.48
F1	6.2±0.73	6.5±0.64	6.3±0.63	6.3±0.67
F2	2.5±0.81	4.3±0.55	5.5±1.02	4.1±0.93
F3	5.1±0.59	6.1±0.73	6.6±0.53	5.9±0.63
Mean Si	3.475±1.02	5.275±0.62	5.725±0.66	
L.S.D.5%	Si	F	F * Si	
	1.22	1.41	2.45	
F.	**leaves plant^{-1} Si**			Mean F.
	Si0	Si1	Si2	
F0	35.59±1.76	55.07±2.10	75.32±0.67	55.33±1.40
F1	69.71±2.03	69.66±1.69	56.59±0.78	65.32±1.21
F2	57.38±2.11	73.35±1.02	74.76±1.01	68.50±1.31
F3	45.76±1.46	78.75±0.95	63.96±1.03	62.82±1.13
Mean Si	52.11±1.96	69.21±1.21	67.66±0.92	
L.S.D.5%	Si	F	F * Si	
	9.427	10.88	18.85	

Yield Characteristics

From Table (2), the results indicated a significant effect of fish-based fertilisers on yield characteristics. Treatment F_1 resulted in plants producing the highest marketable yield, number of tubers, and tuber weight compared to the control treatment F_0, with values of (1329 g plant^{-1}, 8.2 tubers plant^{-1}, 178.2 g tuber^{-1} for F_1) and (1092 g plant^{-1}, 6.6 tubers plant^{-1}, 150.2 g tuber^{-1} for F_0), respectively. Meanwhile, treatment Si_1 produced the highest marketable yield per plant, reaching (1289 g plant^{-1}), compared to the lowest yield recorded by the control treatment Si_0, which was (1060 g plant^{-1}). The highest number of tubers was achieved by treatment Si_3, with (8.45 tubers plant^{-1}), compared to the lowest number recorded by the control treatment Si_0, which was (6.6 tubers plant^{-1}). However, foliar spraying with organic silicon did not have a statistically significant effect on average marketable tuber weight.

As for the interaction between the two factors, the combination $F_1 \times S_1$ resulted in the highest marketable yield per plant compared to the lowest yield recorded by the control treatment $F_0 \times S_0$, with values of (1393 g plant^{-1} and 724 g plant^{-1}), respectively. The interaction $F_1 \times S_2$ produced the highest number of marketable tubers compared to the lowest number recorded by the interaction $F_0 \times S_0$, with values of (9.8 and 5.6 tubers plant^{-1}), respectively. However, the interaction between the two experimental factors was not statistically significant for average tuber weight, as indicated in Table 2.

Physical Characteristics of Tubers

The results indicate the effects of fish-based fertilisers on tuber physical traits (Table 3). Tubers produced from treatments F_2 and F_3 exhibited the highest firmness and specific gravity. At the same time, the lowest values for these traits were recorded in tubers from the control treatment F_0, with values of 10.4 kg cm^{-2}, 1.074 (F_2 & F_3) and 8.333 kg cm^{-2}, 1.055 (F_0), respectively.

Regarding foliar spraying with organic silicon, treatments Si_1 and Si_2 achieved the highest mean tuber firmness and specific gravity. At the same time, the lowest values were observed under the control treatment Si_0 at 8.625 kg cm^{-2} and 1.054, respectively, compared to 10.00 kg cm^{-2} and 1.071 for Si_1 and Si_2.

As for the interaction between factors, the combination $F_2 \times Si_2$ produced tubers with the highest firmness (10.8 kg cm^{-2}), whereas the lowest firmness was recorded under $F_0 \times Si_0$ (7.5 kg cm^{-2}). The highest specific gravity (1.085) was observed in the $F_3 \times Si_2$ treatment, while the lowest value (1.029) was recorded under $F_0 \times Si_0$, as shown in Table (3).

Table 2. Effect of foliar spraying with fish-based fertilizers and organic silicon on yield characteristics of the Arizona potato hybrid

F.	Marketable yield (g) **Si**			Mean F.
	Si0	Si1	Si2	
F0	724±20.84	1322±30.11	1230±21.11	1092±22.31
F1	1253±23.18	1393±27.12	1334±12.18	1327±19.25
F2	1118±19.11	1160±16.32	1158±9.12	1145±14.12
F3	1245±16.25	1282±11.12	1337±16.24	1288±14.12
Mean Si	1060±20.23	1289±19.22	1264±18.34	
L.S.D.5%	Si	F	F * Si	
	165.2	190.7	330.3	
F.	Number of tubers plant^{-1} **Si**			Mean F.
	Si0	Si1	Si2	
F0	5.6±0.91	7.2±0.9	7.1±1.1	6.6±0.92
F1	6.5±0.72	8.3±0.61	9.8±0.61	8.2±0.65
F2	7.5±0.52	7.2±0.58	8.2±0.96	7.6±0.74
F3	7.0±1.2	8.0±0.49	8.7±0.63	7.9±0.82
Mean Si	6.6±0.81	7.7±0.62	8.45±0.84	
L.S.D.5%	Si	F	F * Si	
	0.91	1.06	1.83	

F.	Tuber weight (g tuber^{-1}) Si			Mean F.
	Si0	Si1	Si2	
F0	137.9±22.32	141.8±21.12	170.9±18.96	150.2±21.09
F1	172.7±19.74	179.4±26.19	182.6±25.12	178.2±22.67
F2	149.5±22.33	162.1±12.92	176.4±27.12	162.7±20.19
F3	170.9±18.34	173.9±31.25	180.3±19.56	175.0±23.19
Mean Si	157.9±24.12	173.9±24.53	180.3±19.20	
L.S.D.5%	Si	F	F * Si	
	N.S	25.95	N.S	

Table 3. Effect of foliar spraying with fish-based fertilizers and organic silicon on the physical characteristics of tubers of the Arizona potato hybrid.

F.	Tuber firmness (kg cm^{-2}) **Si**			Mean F.
	Si0	Si1	Si2	
F0	7.5±0.76	8.7±0.31	8.8±0.09	8.3±0.18
F1	8.5±0.43	9.8±0.05	10.5±0.63	9.6±0.42
F2	10.3±1.1	10.2±0.06	10.8±0.62	10.4±0.24
F3	8.2±0.03	9.4±0.26	9.9±0.32	9.2±0.26
Mean Si	8.625±0.61	9.52±0.23	10.00±0.78	
L.S.D.5%	Si	F	F * Si	
	0.57	0.65	1.13	
F.	specific gravity **Si**			Mean F.
	Si0	Si1	Si2	
F0	1.029±0.03	1.071±0.01	1.066±0.2	1.055±0.02
F1	1.052±0.01	1.078±0.03	1.071±0.03	1.067±0.03
F2	1.062±0.01	1.071±0.02	1.047±0.04	1.060±0.2
F3	1.071±0.02	1.063±0.01	1.085±0.04	1.740±0.03
Mean Si	1.054±0.02	1.071±0.02	1.067±0.02	
L.S.D.5%	Si	F	F * Si	
	0.003	0.004	0.008	

Chemical Characteristics of Tubers

The results indicate that tubers produced from plants treated with F_3 recorded the highest dry matter percentage (18.70%) compared to the lowest value (15.00%) observed in tubers from the control treatment F_0 (Table 4). Similarly, treatment Si_1 resulted in tubers with the highest dry matter content (17.83%) relative to the lowest percentage (14.62%) recorded in the Si_0 control treatment. The interaction between F_3 and Si_2 produced tubers with the highest dry matter percentage (21.32%), whereas the lowest value for this trait (9.54%) was recorded in tubers from the $F_0 \times Si_0$ treatment.

The results show that treatment F1 yielded the highest total soluble solids (T.S.S.) percentage in the tubers, compared with the lowest value recorded in tubers from the control treatment F0, at 7.00% and 5.2%, respectively. Similarly, tubers from treatment Si2 achieved the highest T.S.S. value (6.6%), while the lowest was recorded under the control treatment Si0 (5.45%). The interaction between F1 × Si2 resulted in the highest T.S.S. percentage (7.4%), whereas the lowest value (4.3%) was observed in tubers from the F0 × Si0 interaction treatment.

Table 4. Effect of foliar spraying with fish-based fertilizers and organic silicon on the chemical characteristics of tubers of the Arizona potato hybrid.

F.	Marketable yield (g) **Si**			Mean F.
	Si0	Si1	Si2	
F0	9.54±0.07	18.25±0.09	17.21±0.02	15.00±0.06
F1	14.35±0.05	18.07±0.08	18.24±0.01	16.89±0.04
F2	16.53±0.04	18.31±0.04	13.34±0.03	16.06±0.04
F3	18.06±0.08	16.71±0.6	21.32±0.01	18.70±0.05
Mean Si	14.62±0.06	17.83±0.04	17.53±0.02	
L.S.D.5%	Si	F	F * Si	
	0.995	1.149	1.990	
F.	Number of tubers plant^{-1} **Si**			Mean F.
	Si0	Si1	Si2	
F0	4.3±0.01	5.6±0.02	5.7±0.01	5.2±0.02
F1	6.5±0.01	7.1±0.03	7.4±0.004	7.0±0.02
F2	5.9±0.01	6.6±0.01	6.8±0.01	6.3±0.01
F3	5.1±0.02	6.1±0.02	6.5±0.02	5.9±0.02
Mean Si	0.82±0.01	0.95±0.02	1.64±0.02	
L.S.D.5%	Si	F	F * Si	
	0.82	0.95	1.64	

The positive effects of fish-based fertilisers on all the studied traits can be attributed to their ability to supply plants with essential nutrients from a natural organic source, which are crucial for growth and metabolic processes during the vegetative stage (Table 1). This beneficial impact enhances carbon assimilation by promoting the translocation of carbohydrates and proteins from sites of synthesis to storage organs such as tubers. This is achieved by activating numerous enzymes and increasing the synthesis of carbon compounds within cells (Al-Amry *et al*., 2017; Mansyur *et al*., 2020; Marpanng *et al*., 2023; Anwar *et al*., 2024).

Moreover, the regulatory role of catalytic action through enzymatic activity enhancement would also support the improvement at photosynthetic indices, allowing to reach the superior scores in organs and leaves for field and laboratory traits with silicon-based nutritional treatments. This was primarily attributed to the elevated Na/K ratio, which is essential for the development of various physiological processes, contributing to cellular osmotic equilibrium, preserving membrane integrity, and decreasing transpiration. Consequently, these effects improved tubers firmness, as well as chemical and physical properties (Khan *et al*., 2007; Wang *et al*., 2021; Wadas, 2022).

CONCLUSION

This study indicates that both eco-friendly fish-based fertilisers and organic silicon enhance vegetative growth, yield components and quality traits of Solanum tuberosum L. (Arizona hybrid). Among the treatments, the foliar application of shrimp shell extract and dried fish extract significantly increased plant height, branch number, leaf production, marketable yield, and tuber quality. Dry matter content, total soluble solids, tuber firmness, and specific gravity were significantly affected, particularly at moderate to high concentrations of organic silicon.

- Moreover, the synergistic effects from the co-appearing of them had also further improved such utilities, ensuring that the combined application of organic marine-based fertilisers and silicon could be an eco-efficient approach in sustainable fertilisation systems to promote potato productivity and quality, decrease reliance on chemical inputs and improve resource-use efficiency and environmental safety
- The findings of this study indicate that shrimp shell and dried fish extracts, as fish-based eco-friendly formulated fertilisers, can be advocatedin combination with organic silicon-based foliar applications as effective strategies for sustainable fertilisation practices in potato. The application of these treatments increased vegetative growth and marketable yield and improved the physical and chemical descriptors of tubers. So, they can be a good substitute for traditional fertilisers because they are effective at providing crucial nutrients, boosting enzymatic activity, & minimizing environmental stress. Consequently, the integration of these organic inputs into potato production systems has the potential to contribute to the development of environmentally sustainable agricultural models without compromising the yield and quality of the production crop.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

الاداء الحقلي للبطاطا المعاملة بتقنيات الاسمدة الصديقة للبيئة

مها علي حسين و بيان حمزة مجيد

كلية علوم الهندسة الزراعية \ جامعة بغداد\بغداد\العراق \ قسم البستنة وهندسة الحدائق

الخلاصة

اجريت تجربة حقلية في احد المحطات البحثية التابعة لكلية علوم الهندسة الزراعية \ جامعة بغداد اثناء العروة الربيعية 2022–2023, لدراسة مدى تأثر الاداء الحقلي ومواصفات الحاصل الكمية والكيميائية

لنباتات البطاطا هجين Arizona بالمعاملة الورقية بالأسمدة نظيفة بيئيا , اذ تضمنت التجربة دراسة عاملين الاول الرش الورقي باربع تراكيز من الاسمدة السمكية الرش بالماء فقط , 5 مل لتر−1 من مستخلص قشور الروبيان, 5 مل لتر−1 من مستخلص السمك المجفف و 5 مل لتر−1 من سمك السردين ورمز لها (F0,F1,F2,F3) , والرش بثلاث تراكيز من السليكون العضوي 0 و1و2 مل لتر−1ورمز لها (Si0,Si1,Si2)والتداخل بينهما , ونفذ البحث كتجربة عاملية باتباع تصميم القطاعات الكاملة المعشاة R.C.B.D.كررت ثلاث مرات . ابرزت النتائج التجربة تفوق المعاملة (F1) من بلوغ نباتاتها اعلى القيم لعدد الافرع الهوائية , حاصل النبات التسويقي , عدد الدرنات ووزن الدرنة ونسبة , .T.S.S اما المعاملة (Si1)فتوفقت بانتاج درناتها لاعلى انتاجية , نسبة مادة جافة وكثافة نوعية في حين تمكنت معاملة التداخل (F1S2) من انتاج اعلى عدد من الدرنات اما درنات المعاملة (F2S2) فكانت الاعلى صلابة .

الكلمات المفتاحية : انبعاث كاربوني , قشور روبيان , غذاء مستدام

REFERENCES

Abbasi, P. A., Conn, K. L., & Lazarovits, G. (2010). Effect of fish emulsion used as a preplanting soil amendment on verticillium wilt, scab, and tuber yield of potato. *Canadian Journal of Plant Pathology*, *28*(4), 509–518. https://doi.org/10.1080/07060660609507328

Abdullah , N., M. Zolkafli and M. Omar .(2025). Advancements and integration of biophysical , socio-economic , and local knowledge in agricultural land suitability assessments : Asystematic literature review. *Mesopotamia Journal of Agriculture , 53(1)*,168-192. https://doi.org/10.33899/mja.2025.156944.1531.

Abirami, S. K., Yogalsakshmi, K., Pushpa, A. S. R., & Kannan, M. (2016). Screening and identification of chitin-degrading bacteria from shrimp shell waste dumping soil environment and its media optimization for chitinase production. *World Journal of Pharmacy and Pharmaceutical Sciences*, *5*(11), 743–757.. https://doi.org/10.20959/wjpps201611-7713.

Ahuja, I., Dauksas, E., Remme, J. F., Richardsen, R., & Loes, A. K. (2020). Fish and fish waste–based fertilizers in organic farming with status in Norway. https://doi.org/10.1016/j.wasman.2020.07.025 .

Al-Amry, N. K., Hussein, M. A., & Mahmood, A. H. (2017). The effect of spraying with two different sources of calcium in vegetative growth characteristics and yield of potato. *IOSR Journal of Agriculture and Veterinary Science*, *10*(7), 1–5. https://doi.org/10.9790/2380-100720105

Al-Jubori, K. D. H. , Abud Rasool I. J. ,Al-Khafaji A. M. H. H. , Abdulsada A. J. , Baktash F. Y. ,Hassan W.H. & Al-Mousawi Z. J. . (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)* ,329-321. https://doi.org/10.36103/s9qlw418.

Al-Zaidi, M. A. H. & Al-Jumaili M. A. H. (2022). Impact safe nutrientents in rasing production and chemical contentents of potato. *Iraqi Journal of Agricultural Sciences ,53* (6), 1397- 1406. https://doi.org/10.36103/ijas.v53i6.1655

Alzubaidi , E.F.M.(2024).The reality of sustainable development in developing countries and the prospects for achieving it in 2030. *Mesopotamia J. of Agriculture,52(2)*,27 -45. https://doi.org/10.33899/mja.2024.145075.1311.

Anuradha, V., & Revathi, K. (2013). Purification and characterization of bacterial chitinase isolated from crustacean shells. *International Journal of Pure and Applied Bioscience*, *1*(4), 1–11.

Anwar, R., Rahman, A., Usmini, R., Aryono, D., & Uporno, S. (2024). Physical and chemical characteristics of liquid organic fertilizer from shrimp shell waste and coconut water. *International Journal of Life Science and Agriculture Research*, *3*(3), 118–123. https://doi.org/10.55677/ijlsar/V0313y2024-01

AOAC. (1990). *Official methods of analysis* (15th ed., Vol. 1). Association of Official Analytical Chemists. https://law.resource.org/pub/us/cfr/ibr/002/aoac.methods.1.1990.pdf

Artyszak, A. (2018). Effect of silicon fertilization on crop yield quantity and quality: A literature review in Europe. *Plant*, *7*(54), 1–17. https://doi.org/10.3390/plants7030054.

Artyszak, A., Gozdowski, D., & Kucinska, K. (2019). Impact of foliar fertilization on the content of silicon and macronutrients in sugar beet. *Plants*, *8*(5), 136. https://doi.org/10.3390/plant38050136

Baniuniene, A., & Zekaite, V. (2008). The effect of mineral and organic fertilizers on potato tuber yield and quality. *Latvian Journal of Agronomy*, *11*, 202–206. https://llufb.llu.lv/conference/agrvestis/content/n11/AgrVestis-Nr11-202-206.pdf.

Crusciol, C. A., Pulz, A. L., Lemos, L. B., Soratto, R. P., & Lima, G. P. P. (2009). Effect of silicon and drought stress on tuber yield and leaf biochemical characteristics in potato. *Crop Science*, *49*, 944–954. https://doi.org/10.2135/cropsci2008.04.0233.

El-Sahookie, M., & Wahab, K. N. (1990). *Application in the design and analysis of experiments* (p. 488). University of Baghdad, Higher Education and Scientific Research Publishing.

FAO. (2022). *FAO strategy on climate change 2022–2031*. Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/f6270800-eec7-498f-9887-6d937c4f575a/content

Hussein, M. A., K.Al-amry N. J. & Mohmmed R. R. (2025). Field and storage performance of industrial potatoes treated with cobalt and silicon . *Iraqi Journal of Agricultural Sciences , 56 (2)* : 817 – 826. https://doi.org/10.36103/7p19dy09

Ibrahim , B.Y. , Aljuboori F.K., Mheedi R.N. & Baker S.M. (2024).Control of green mold disease in oranges in oranges caused by Penicillium digitatum by using chitosan and salicylic acid. *Mesopotamia J. of Agriculture,52(1)*,48-59. https://doi.org/10.33899/mja.2024.144845.130.8.acid

Iiiera-Vives , S. Seoane Labanderia , L. Iglesias Loureiro &M. E.Lopez-Mosquera (2017) Agronomic assessment of a compost consisting of seaweed and fish waste as an organic fertilizer for organic potato crops . Journal of Applied Phycology, *29 (3)*. https://doi.org/10.1007/s10811-017-1053-2.

Indratmi, D., Pangestika, P., Tuzzahra, D. A. R., & Wachid, M. (2024). Utilization of shrimp shells waste and golden snails to increase the yield of shallots. *The 3rd and 4th International Conference on Bioenergy Environmentally Sustainable Agriculture Technology (ICON BEAT 2022 and 2023)*. https://doi.org/10.1051/bioconf/20241040006.

Jaafar, A.A. and K. J. Abdulrasool. (2025). Effect of organic and mineral fertilizers and agricultural sulfur on concentration of N,P and K in soil and potato tubers. *Journal of Agricultural Sciences, 56(2)*: 838-849. https://doi.org/10.361031/ganqdh03

Jaies, I., Qayoom, I., Khan, S., & Sab, F. (2024). Fish wastes as a source of fertilizers and manures. In S. Maqsool *et al.* (Eds.), *Fish waste to valuable products: Sustainable material and technology* (pp. 329–338). https://doi.org/10.1007/978-981-99-8593-7_15

Khalaf, A.B.(2024). Using geospatial technigues to analysis the impact of climate change onwater and agriculture resource : case study khanaqin district in Diyala , Iraq . *Basrah Journal of Agricultural Sciences ,37 (1)* : 55-70 https://doi.org/10.37077/25200860.2024.37.1.05

Khan, M. A., Vinod, G., & Neeru, J. (2017). Impact of ortho silicic acid formulation on yield and disease. In *Proceedings of the 7th International Conference on Silicon in Agriculture*, Bengaluru, India, October 24–28, p. 137. https://scholar.google.com/scholar?hl=en&as_sdt=0,5&cluster=530902219877445937.

Khan, I., Awan, S. A., Rizwan, M., Brestic, M., & Xie, W. (2023). Silicon: An essential element for plant nutrition and phytohormone signaling mechanism under stressful conditions. *Plant Growth Regulation*, *100*, 301–319. https://doi.org/10.1007/s10725-022-00872-3

Liu, B., Gu, W., Yang, Y., Wang, F., Zhang, B., & Bi, J. (2021). Promoting potato as a staple food can reduce the carbon–land–water impacts of crops in China. *Nature Food*. https://doi.org/10.1038/s43016-021-00337-2

Mansyur, N. I., Hanudin, E., Purwanto, B. H., & Utami, S. N. H. (2021). The nutritional value of shrimp waste and its response to growth and N uptake efficiency by corn. *IOP Conference Series: Earth and Environmental Science*, *748*, 012013. https://doi.org/10.1088/1755-1315/748/1/012013

Marpaung, A. E., Karo, B., Barus, S., Hutabarat, R. C., & Tarigan, R. (2023). Increasing the quality and quantity of potatoes by utilizing seed size and fish organic fertilizer. *E3S Web of Conferences*, *373*, 03001. https://doi.org/10.1051/e3sconf/202337303001

Munda , D. , F. Laekemariam and Y.Abrham(2024). Roles of foliar fertilization on growth , yield and quality of tomato (Solanum lycopersicon L.) cultivar (Review). . *Basrah J. of Agricultural Sciences* , 37(2),381-404. https://doi.org/10.37077/25200860.2024.37.2.27.

Singh, P., Sharma, P., Sarkar, B., Sengupta, A., Singh, C., & Ibrahim, M. H. (2014). Biological response of agricultural soils to fly-ash amendment. In *Sustainable Biochar for Bioenergy Production* (pp. 45–60). https://doi.org/10.1007/978-3-319-06746-9_2

Saaseea, K. G., & Al-Amry, N. J. K. (2023). Effect of nitrogen and potassium levels on the productivity of industrial potatoes. *Iraqi Journal of Agricultural Sciences*, 54(6), 1726–1736. https://doi.org/10.36103/ijas.v54i6.1871.

Sotani, M., Kafi, M., Nezami, A., & Taghiyari, H. R. (2018). Effects of silicon application at nano and micro scales on the growth and nutrient uptake of potato minitubers (*Solanum tuberosum* var. Agria) under greenhouse conditions. *BioNanoScience*, *8*, 218–228. 31.

Sulaiman , A. S. S., Wayayok A. , Aziz S. A., Yun W. M. & Leifeng G. (2024) . Advancements in crop water modellling : Agorithmic developments and parameter optimization strategies for sustainable agriculture: A Review. *Basrah J. of Agricultural Sciences* , 37(2), 310-325. https://doi.org/10.37077/25200860.2024.37.24

Wadas, W. (2022). Effect of foliar silicon application on nutrient content in early crop potato tubers. *Agronomy*, *12*(11), 2706. https://doi.org/10.3390/agronomy12112706

Wang, M., Wang, R., Mur, A. J., Rugn, J., Shen, Q., & Guo, S. (2021). Functions of silicon in plant drought stress response. *Horticulture Research*, *8*, 254. https://doi.org/10.1038/s41438-021-00681-1

Yau, N., & Xi, C. (2015). Sustainability: Do not waste seafood waste. *Nature*, *524*(7564). https://doi.org/10.1038/524027a

Zhang, T., Li, C., Wang, S., Cheng, Z., Li, Z., Xu, T., Zhou, X., Chen, W., & Hong, J. (2024). Promoting sustainable potato production – insights from an integrated life cycle environmental–economic assessment. *Agricultural Systems*, *291*, 104029. https://doi.org/10.1016/j.agsy.2024.10402