UNRAVELING PROLONGED IRRIGATION INTERVALS AND SOME SUSTAINABLE TREATMENTS ON POTATO STARCH COMPOSITION, GROWTH, AND PRODUCTIVITY IN IRAQ

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ABSTRACT

The study aimed to reveal the effect of some sustainable treatments under prolonged irrigation intervals on potato plant growth, yield, and starch properties. The experiment carried out at vegetable field of the College of Agricultural Engineering Sciences - University of Baghdad during spring season 2023. The experiment was conducted using split arrangement within Randomized Complete Block Design with two factors and three replicates (2X6X3). Applying TiO_2-NPs represented the first factor (main plot) (10 $mg.L^{-1}$), which symbolized (T_0, T_1). six treatments were included to represent subplots (regular irrigation interval (I) prolonged irrigation interval (D), fungal biofertilizers (D_B), fungal biofertilizers + mannitol (D_{BM}), fungal biofertilizers +xanthan (D_{BZ}), fungal biofertilizers + mannitol+ xanthan (D_{BMZ}). Results exhibited the superiority plants that grew under prolonged irrigation periods in amylose percent over regular irrigated plants. In contrast, amylopectin exhibits the opposite behavior. i.e., plant that grew under regular water conditions revealed superiority in amylopectin percent, and that for sole treatments and interactions.

Keywords: amylose/amylopectin; responsible consumption and production; mannitol; climate action, biofertilizers, xanthan gum

تحري تأثير الري المتباعد وبعض المعاملات المستدامة في مكونات النشا ونمو وانتاجية نبات البطاطا في العراق

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المستخلص

هدفت التجربة الى معرفة تاثير بعض المعاملات المستدامة تحت نظام الري المتباعد في نمو وانتاجية وخصائص النشا في نبات البطاطا ، نفذت تجربة حقلية في حقول كلية علوم الهندسة الزراعية/جامعة بغداد للموسم الربيعي 2023. طُبقت التجربة باستعمال تصميم القطاعات الكاملة المعشاة على وفق ترتيب القطع المنشقة بعاملين وثلاث مكررات (3X6X2)، فيما يخص العامل الاول فتم اضافة TiO_2–NPs بمستويين (0، 10مل.لتر$^{-1}$) والذي رُمز له (T_0 وT_1)، اما العامل الثاني فتضمن ست معاملات وزعت كقطع ثانوية كالاتي (ري طبيعي I، ري بمدة متباعدة D، اسمدة احيائية تحت ظرف الري المتباعد D_B، اسمدة احيائية تحت ظرف الري المتباعد+ مانيتول D_{BM} ، اسمدة احيائية تحت ظرف الري المتباعد+ صمغ الزنثان D_{BZ} ، اسمدة احيائية تحت ظرف الري المتباعد+ مانيتول+صمغ الزنثان D_{BMZ}) . اظهرت النتائج ان جميع النباتات النامية تحت ظروف الري المتباعد نسبا اعلى من الاميلوز في درناتها مقارنة بالنباتات النامية تحت ظروف الري المنتظم ولجميع المعاملات الفردية والتداخلات. وعلى العكس من ذلك تفوقت نباتات الري المنتظم في اعطاء اعلى نسبة من الاميلوبكتين والتي اختلفت معنويا عن جميع النباتات النامية تحت نظام الري المتباعد.

الكلمات المفتاحية: اميلوز/اميلوبكتين، الاستهلاك والانتاج المسؤولان، مانيتول، العمل المناخي، الاسمدة الاحيائية، صمغ الزانثان

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INTRODUCTION

Functional food notion has gained traction over the past ten years, alongside highlighting food safety prioritization within the United Nations Sustainable Development Goals (12, 17, 44, 48). As a result, agricultural experts have shifted towards implementing farming methods that minimize harmful build-ups in food and are eco-friendly, aiming to create safe food while protecting the environment, particularly in light of global warming, climate change, and limited water resources (37, 38). Potatoes (*Solanum tuberosum*) represent a widely consumed crop around the world and have made significant inroads into the industrial sector (15, 33, 51). This has led stakeholders to explore more lucrative methods of altering starch properties to meet industrial needs. Consequently, practices such as developing zero-amylose potato varieties (42, 47, 45), high-yield production using intensive chemical fertilizers and pesticides (8, 35, 36, 39, 50), and other related techniques have surfaced. Amylose potato starch improves its nutritional value, since it is resistant starch and does not spike blood sugar (14, 22, 52), however; it is not appropriate for the crop's processing uses. Conversely, when there is a high concentration of amylopectin, potato starch industrial properties such a gelatinous and stable texture find it more enticing (21, 34, 49). Simulating the Iraqi environment is crucial. Researches undertaken under drought conditions offer a future scenario on how to deal with such conditions by merging many sustainable technologies to combat drought (7, 32), for using them to determine the best possible scenario (27). Titanium dioxide is one of the most common and effective substances for drought resistance. In an attempt to mitigate the effects of water and salt stress, the aforementioned chemical has been the subject of multiple research (31). For various crops, TiO2-NPs have been demonstrated to increase growth metrics including shoot biomass and chlorophyll concentration under stress (18, 24, 25). TiO2-NPs have been associated with a reduction in oxidative stress markers in plants under stress (3, 23). Additionally, by increasing the activity of its essential enzymes, such as Rubisco, TiO2-NPs increase the efficiency of photosynthesis (30, 40). Since biofertilizers gradually increase the soil microbial community, which in turn affects crops yield (6, 11, 20, 46). It is clear that they produce sustained improvements for soil resources. By making nutrients more soluble (4), encouraging the biodegradation of organic matter (10), and releasing vigorous hormones (5), Khosravifar et al (26) found that mycorrhizal fertilization for potatoes had noteworthy results in terms of leaf area index by 60%, shoot dry weight by 40%, and tuber production by 36%.It has been shown that mannitol influences photosynthetic capacity (19). Under drought conditions, Mahdy et al. (29) discovered that applying mannitol and mycorrhiza biofertilizers to maize plants resulted in notable increases in dry matter, chlorophyll concentration, and N concentration. Using xanthan gum, which increases soil water retention, is an environmentally acceptable and biodegradable method of combating drought (13). According to (41); xanthan gum is classified as a polysaccharide (biopolymer) with physical and microbiological properties that make it resistant to drought. Adding xanthan gum to soil improved its water retention and made lawns more resistant to water shortages (43). Consequently; this study seeks to mitigate the lack of water by biofertilizers, biopolymers, mannitol and titanium dioxide , and enhancing potato drought tolerance by improving nutrient absorption, and physiological resilience, and promote environmentally sustainable strategies for potato cultivation and simulate arid regions in Iraq.

MATERIALS AND METHODS

Field preparation, planting, harvest

This experimental study is part of a project deals with sustainable potato production under prolonged irrigation conditions (7, 20). It took place at the research unite (A) / College of Agricultural Engineering Sciences, University of Baghdad (Al-Jadiryah), during the spring of 2023. Table (1) presents the chemical and physical characteristics of the soil. Santana hybrid class (Elite) potato tubers were planted in a single row in the center of the furrows on January 28, 2023. There was drip irrigation installed in the field. Plants were spaced 0.25 meters apart from one another and 0.75m among rows. Planting density was 53333 $plant.ha^{-1}$. After 120 days of planting, every plot was harvested.

Experimental design

The experiment was implemented by using split plot arrangement within Randomized Complete Block Design with three replicates (2X6X3), in which titanium dioxide represented the main factor with two concentrations (0, and 10 $mg.L^{-1}$) which symbolized (T_0, T_1), six treatments were included to represent subplots (drought mitigation strategies DMS) (regular irrigation interval (I) (as control) (4 days), prolonged irrigation interval (D) (8 days) according to Al-Rubaie recommendation (9), fungal biofertilizers under (D), (D_B), fungal biofertilizers + mannitol under (D) (D_{BM}), fungal biofertilizers +xanthan under (D) (D_{BZ}), fungal biofertilizers + mannitol+ xanthan under (D) (D_{BMZ}). Titanium dioxide (nano-anatase) was applied three times following the growth cycle of the potato plant; specifically, the initial application occurred during the vegetative growth phase, the second application took place at the tuber initiation stage, and the final application was done during the tuber enlargement stage. Fungal biofertilizers (mycorrhizae *Glomus intraradices* + trichoderma *Tricoderma asperellum*) mixed with corn cobs residues (50 $spores.1g^{-1}$) and positioned as a pad beneath the tuber during planting in the soil at a dosage of 20g for each tuber. Xanthan gum mixed with the soil at 1% percent before planting. Mannitol injected three times at a concentration ($30mM.L^{-1}$) according to the mentioned potato growth cycle in rhizosphere zone.

The studied traits: Vegetative growth traits were determined as follows: leaves number, vegetative branches number, magnesium leaves concentrations (16), starch traits were fixed as follows; tuber starch percent **(%) (1),** tubers amylose and amylopectin percents (%) (2). Starch traits were determined in the laboratories of Agricultural Researches center/ Scientific Research Commission. The yield traits that determined were tubers $number.plant^{-1}$ and plant yield (g). The data were analyzed through analyses of variance and the means were compared using L.S.D. test under 5% probability.

Table 1. Physical and chemical properties of the soil

Character	Value
pH	6.16
$EC_{1:1}$ ($ds.m^{-1}$)	390.8
Total N ($mg\ kg^{-1}$)	53.8
P ($mg\ kg^{-1}$)	12.5
K ($mg\ kg^{-1}$)	168.8
Ca ($mg\ kg^{-1}$)	185.8
Mg ($mg\ kg^{-1}$)	168.8
Fe ($mg\ kg^{-1}$)	1.4
Na ($Meq\ L^{-1}$)	59.8
Cl^- ($Meq\ L^{-1}$)	49.8
SO_4^{-2} ($Meq\ L^{-1}$)	205.8
HCO_3^- ($Meq\ L^{-1}$)	475.8
O.M. (%)	9.1
Gypsum (%)	318.8
Sand (%)	10.8
Silt (%)	38.8
Clay (%)	46.8
Texture	**Clay loam**

RESULTS AND DISCUSSION

Vegetative growth traits

As illustrated in table (2); there is a significant impact on spraying titanium dioxide (nano-anatase) on Magnesium concentration of potato plants leaves (17254_{ppm}) contrasted with T_0 (15720_{ppm}). However; spraying TiO_2 doesn't have any significant results to the other traits (Table 2). The statistical analysis of Table 2 confirms that drought mitigation treatments have a potent impact on the entire potato vegetative growth traits, (I) treatment produced the highest (66 leaves $number.plant^{-1}$, 5.5 branches $number.plant^{-1}$, 18349_{ppm}) respectively. However; D_{BMX} treatment doesn't show any significant differences in comparing with (I) treatment (64.3 leaves $number.plant^{-1}$, 5.5 branches $number.plant^{-1}$, 18314_{ppm}). While a notable decline could be observed in all vegetative growth traits at (D) treatment (45.5 leaves $number.plant^{-1}$, 3.5 branches $number.plant^{-1}$, 13411_{ppm}) respectively. The data documented in Table 2 also approved that the interaction has an impact on leaves number and magnesium concentration, the highest leaves number found in T_1I treatment (68.3), while the highest Magnesium concentration found in T_1D_{BMX} (18609_{ppm}). In compare with the lowest traits that found in T_0D (43 $leaves.plant^{-1}$, 11533_{ppm}) respectively.

Starch components traits

Regarding starch percent in potato tubers (Table 3); T_1 reveals superiority (17.7%) over T_0 (16%). As for drought mitigation treatment; (D_{BMX}) treatment produced the highest starch percent (18.9%) opposed to (D) treatment (14.2%). However; interaction treatments demonstrated non-significant results. Concerning amylose and amylopectin percents; TiO_2-NPs spraying exhibit no considerable variation. Regarding drought mitigation treatments; the entire plants that grew under water deficit conditions displayed superiority in favor of amylose in compare with irrigated treatment (I), similarly, the inverse is valid for amylopectin. i.e. (I) treatment reveals superiority over all drought treatments. The interaction between TiO_2-NPs and DMS treatments reveals the superiority of the plants that grew under prolonged irrigation periods in amylose percent over regular irrigated plants. In contrast, amylopectin exhibits the opposite behavior. i.e., plant that grew under regular water conditions revealed superiority in amylopectin percent.

Yield traits

Table (4) presents the superiority of T_1 in producing the highest plant yield (1592 g) over T_0 (1357 g). Regarding DMS treatments; D_{BMX} produced the highest plant yield (1688 g) comparing to (D) treatment that produced the lowest (1128 g). The interaction between TiO_2-NPs and DMS treatments exhibit significant findings in the favor of T_1I (1877 g) in compare with the lowest plant yield that found in T_0D treatment (930 g). However; T_1D_{BMX} produced plant yield (1788 g) doesn't significantly differ from T_1I treatment. Tubers number trait doesn't reach to the significant level in all sole factors and the interaction.

Table 2. Effect of titanium dioxide (T), and drought mitigation strategies (DMS): biofertilizers (B), mannitol (M), and xanthan gum (X) on vegetative growth traits of potato plant under drought conditions

traits / treatments	leaves number.$plant^{-1}$	Branches number.$plant^{-1}$	Magnesium conc. (ppm)
		T	
$T_{0\ (control)}$	53.8	4.33	15720
T_1	55.9	4.72	17254
$LSD_{(0.05)}$	N.S.	N.S.	628.4
		DMS	
I [irrigated (control)]	66.0	5.50	18349
D [drought]	45.5	3.50	13411
D_B	45.8	3.83	15261
D_{BM}	51.3	4.33	16266
D_{BX}	56.2	4.50	17321
D_{BMX}	64.3	5.50	18314
$LSD_{(0.05)}$	3.485	0.756	922.5
		T X DMS	
T_0I (control)	63.7	5.00	18424
T_0D	43.0	3.33	11533
T_0D_B	43.7	3.67	13900
T_0D_{BM}	51.3	4.00	15822
T_0D_{BX}	53.0	4.33	16622
T_0D_{BMX}	68.0	5.67	18019
T_1I	68.3	6.00	18274
T_1D	48.0	3.67	15289
T_1D_B	48.0	4.00	16622
T_1D_{BM}	51.3	4.66	16709
T_1D_{BX}	59.3	4.67	18019
T_1D_{BMX}	60.7	5.34	18609
$LSD_{(0.05)}$	4.737	N.S.	934.2

Table 3. Effect of titanium dioxide (T), and drought mitigation strategies (DMS): biofertilizers (B), mannitol (M), and xanthan gum (X) on starch traits of potato tubers under drought conditions

traits treatments	Starch (%)	Amylose (%)	Amylopectin (%)
		T	
$T_{0\ (control)}$	16.0	27.1	72.9
T_1	17.7	27.2	72.8
$LSD_{(0.05)}$	0.769	N.S.	N.S.
		DMS	
I [irrigated (control)]	18.7	26.3	73.7
D [drought]	14.2	27.4	72.6
D_B	15.8	27.4	72.6
D_{BM}	16.3	27.4	72.6
D_{BX}	17.2	27.4	72.6
D_{BMX}	18.9	27.3	72.7
$LSD_{(0.05)}$	0.864	0.358	0.358
		T X DMS	
T_0I (control)	19.3	26.2	73.7
T_0D	13.3	27.0	73.0
T_0D_B	15.0	27.7	72.3
T_0D_{BM}	15.3	27.2	72.8
T_0D_{BX}	16.0	27.6	72.4
T_0D_{BMX}	18.3	27.2	72.8
T_1I	18.0	26.3	73.7
T_1D	15.0	27.7	72.3
T_1D_B	16.7	27.2	72.8
T_1D_{BM}	17.3	27.6	72.4
T_1D_{BX}	18.3	27.3	72.7
T_1D_{BMX}	19.5	27.3	72.7
$LSD_{(0.05)}$	N.S.	0.504	0.504

Table 4. Effect of titanium dioxide (T), and drought mitigation strategies (DMS): biofertilizers (B), mannitol (M), and xanthan gum (X) on yield traits of potato plant under drought conditions

Traits Treatments	Tubers number.plant^{-1}	plant yield (g)
	T	
$T_{0\ (control)}$	9.28	1357
T_1	9.56	1592
$LSD_{(0.05)}$	N.S.	31.9
	DMS	
I [irrigated (control)]	8.67	1680
D [drought]	9.50	1128
D_B	8.50	1229
D_{BM}	10.0	1481
D_{BX}	10.5	1641
D_{BMX}	9.33	1688
$LSD_{(0.05)}$	N.S.	149.6
	T X DMS	
T_0I (control)	8.67	1483
T_0D	8.67	930
T_0D_B	8.00	1108
T_0D_{BM}	10.3	1480
T_0D_{BX}	10.6	1493
T_0D_{BMX}	9.33	1648
T_1I	8.67	1877
T_1D	10.3	1327
T_1D_B	9.00	1350
T_1D_{BM}	9.67	1482
T_1D_{BX}	10.3	1729
T_1D_{BMX}	9.33	1788
$LSD_{(0.05)}$	N.S.	193.7

From noticing results in tables 2, 3, and 4; it's obvious that prolonged irrigation statistically affected plant growth, productivity, and starch components percents in compare with regular irrigation. However; drought mitigation treatments reduced this effect, which improved outcomes that frequently came close to the outcomes of standard irrigation. In fact; biofertilizers enhance nutrients availability in soil. Biofertilizers aid in the solubilization of nutrients that plants would not otherwise be able to access. They improve nutritional bioavailability by decomposing complicated molecules into simpler forms. This procedure makes it possible for essential elements, which are essential for plant growth, to be absorbed more effectively and that aids in maintain growth and physiological functions (27). Moreover; Biofertilizers (mycorrhizae and trichoderma) showed resilience and excellent performance in whole plant traits under water stress situations. This could be because they help plants obtain water and nutrients in soil pores that are inaccessible to plant roots alone by expanding the root system through their hyphal networks. This feature greatly enhances the plant's capacity to absorb moisture, especially when water supplies are few (10). When xanthan gum is added to stressed soil, it strengthens the bonds between the particles. When water content is decreased to specific levels, xanthan gum can dramatically improve soil cohesiveness, up to three times that of untreated soils. This rise is explained by xanthan gum's gel-like qualities, which form a network that holds soil particles together (41). Mannitol's important results seemed to be brought on by its function as an osmotic agent, which simulates drought stress by causing a water deficit. Plants' physiological and biochemical reactions are triggered by this system, which encourages the buildup of suitable solutes that sustain cellular function under stressful situations. Actually, mannitol can increase the synthesis of osmolytes, which are essential for plants to survive when there is a shortage of water (19). Plant traits were clearly improved by the use of titanium dioxide nanoparticles. Its ability to modify the expression of numerous proteins linked to photosynthesis, energy metabolism, and antioxidant systems may be the cause of this. Furthermore, TiO_2 nanoparticles improve the absorption of vital nutrients like iron, magnesium, and nitrogen. This promotes the production of chlorophyll and the general health of plants (43). In conclusion; this research provides insights into optimizing water management strategies for sustainable potato production.

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