EFFECT OF DIFFERENT IRRIGATION INTERVALS AND TREATMENTS ON YIELD QUANTITY AND QUALITY OF POTATO (*SOLANUM TUBEROSUM* L.) UNDER FIELD CONDITIONS IN SULAIMANI, IRAQI KURDISTAN REGION

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Abstract. This study was carried out in two growing spring seasons 2017 and 2018 at Kanipanka Agricultural Research Station (Lat. 35°13’12”, Long. 45°25’48”, 550 MASL) in Shahrazoor valley 35 km east of Sulaimani. The aim was to investigate the effect of two irrigation intervals (5 and 10 days) and thirteen biotic and abiotic treatments on yield quantity and quality of potato under field condition. The results showed that the 5 days irrigation intervals gave the maximum values of total yield, Total Soluble Solute percentage, while 10 days of irrigation intervals obtained the highest values of tuber hardness and all of the amino acids in the tuber seasons 2017 and 2018, while the maximum values of total yield were acquired through mycorrhizal inoculation. Total Soluble Solute and tuber hardness were achieved by potassium chloride treatment. Whereas the maximum values of all amino acid in the tuber were given by the mycorrhizal inoculation treatment with (6 g L^{-1}) of *Glycyrrhiza glabra* extract in the first season 2017. Concerning the second season 2018, the maximum total yield gave by treatment of potassium chloride and (6 g L^{-1}) of *Glycyrrhiza glabra* extract, while the potassium chloride treatment gave the maximum values of Total Soluble Solute in the tuber.
Keywords: *watering period, T.S.S and starch percentage, proline, glycine, lucien, lysine*

Introduction

Potato (*Solanum tuberosum* L.), which belonging to the Solanaceae family, is the fourth most important agronomical feed crop worldwide after winter wheat, maize, and rice. The total world production of potatoes was 388 million t in 2017, (FAOSTA, 2019). The potato production in Iraq was more than 190,000 t with a total cultivated area of 7950 ha on average 23.996 t h^{-1} (Central Statistical Organization, 2016). Regarding the Kurdistan Region, the potato production was estimated to be over 150,000 t in 2016 data to the Ministry of Agriculture and Water Resources in the Iraqi Kurdistan region.

Irrigation aimed for supplying water totally or partially for crop requirements, decreasing soil and plant temperature, leach excess salts, increase storage of groundwater, facilitate continuous cropping, and to enhance fertilizer application. Some other benefits of irrigation include the direct cut on water stress, increasing the investment in inputs such as fertilizers and improving cultivars affected by uncertain crop production under rained conditions (Zotarelli et al., 2009).

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Muthoni and Kabira (2016) reported that water is the most important limiting factor for potato production and it is possible to increase production levels by well-scheduled irrigation programs throughout the growing season in Tigoni, Kenya. Water stress limits crop productivity by affecting photosynthetic processes at the canopy, or by feedback, inhibition if the transport of photosynthesis to sink organs is limited (Murchie et al., 2009). Moisture stress first causes stomatal closure thus reducing CO_2 uptake for photosynthesis; this leads to reduced plant growth and yield (Mafakheri et al., 2010). Sugar concentration within the leaf tissue increases to increase the osmotic potential of the plant, these clues to response inhibition of photosynthesis (Basu et al., 1999). Finkel and Holbrook (2000) found that the water stresses affected to increased accumulation of reactive oxygen species (ROS) in plants such as (O_2^-, H_2O_2). Overproduction of ROS can disrupt normal plant metabolism through impaired enzyme activity due to oxidative damage, protein degradation.

The natural plant extracted can be achieved easily, safely and cheaply. Furthermore, it is considered as highly eco-friendly compounds. Sarby et al. (2009) reported that licorice root extract contains some compounds, which have similar effect to the growth promoters. Also have a wide range of minerals (P, K Zn, Mg, Fe, and Ca), amino acids (alanine, lysine, arginine), vitamins (B_1, B_2, B_6), with carbohydrate and nitrogen addition, It also contains mevalonic acid that can be used in gibberellins synthesis. Matar et al. (2012) found that the spray (5 g L^{-1}) of licorice extract significantly increased protein percentage in tubers with the maximum values of the total and marketable yield of the potato plant. 5% foliar application with licorice extracts resulted in significant increases total tube, and marketable yields and in addition to decreases in physiological disorders and mechanical injury of tomato plants (Fan et al., 2016). EL-Sagan (2015) reported that the mechanism of action of licorice extract in plants is similar to the gibberellic acid action in stimulating of vegetative growth of plants. Moreover, the licorice extract is available, low cost and effective easy to apply. In addition licorice, foliar applications increase the percentages of N, P, and K in plant's leaves, chlorophyll content in the leaves of cucumber (Khalel and Hado, 2011).

The role of potassium in molecular mechanisms and physiological stress resistance, furthermore, ROS damage would be justifying by K under water stress conditions that resulting in the cell death (Wang et al., 2013). Potassium foliar application is another factor that has been used for improved nutrient management and increasing potato growth and yield (Fageria et al., 2016). Asmaa and Magda (2010) concluded that the total yield of potato tubers significantly with the increases of potassium level in tow season growth. In addition, they concluded that the potassium application significantly affected tubers nutritive values. Maximum tuber yield 36.65 t ha^{-1} was obtained from 600 kg K_2SO_4 ha^{-1} for trickle irrigation and 35.23 t ha^{-1} for furrow irrigation. Interaction between irrigation and potassium fertilization were significantly affected in relation to leaf area, the relative water content in leaves, water potential, stomatal resistance and number of the tiny and marketable tuber of potato (Khosravifar et al., 2008). Zelelew et al. (2016) reported that potato needs different plant nutrients for both growth and developments lacking such nutrients caused the reduction in both qualities and quantities of tubers. AL-Alousi (2013) Studied the effect of potassium fertilizer with three levels (0, 200 and 400 kg potassium ha^{-1}) in form of K_2SO_4, also spray with two levels of potassium sulfate (0 and 5000 mg potassium L^{-1}) and spray with organic extract (0 and 10 ml L^{-1}). The results show the addition and spraying of potassium gave the highest values of vegetative day weight, total tuber yields, number of tuber $plant^{-1}$, tuber weight and percentage of starch

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in tuber with 6243.33 kg h^{-1}, 36.07 t h^{-1}, 6.45 tuber $plant^{-1}$,140.33 g $tuber^{-1}$ and 12.41% for treatments K400, F5000 and M10 respectively.

Tuber dry matter is a varietal character; however, growing location, season, climatic conditions and cultural practices greatly affect the accumulation of dry matter in tubers, a dry matter content of more than 20% is considered ideal for making chips (Saran and Chhabra, 2014). As a food, potato ranks second to soybean in protein amount produced per hectare, and second to sugarcane in carbohydrate production (Alavijeh and Yaghmaei, 2016). Chakraborty et al. (2010) showed that potato tuber proteins have been found to be of high nutritional value.

The mycorrhiza's function is enhancing the processes of nutrient absorption from the soil and increase the plant resistance against drought and diseases. Microorganisms are an essential component of the agricultural system. Mycorrhizae are a global soil microbe, can subordinate with the roots of most native crop species (Duc, 2017). Several benefits were observed when arbuscular mycorrhizal (AM) fungi is colonized crops including; increased growth and yield, enhanced plant resistance to environmental adversities, increase the plant resistance to abiotic stress (Birhane et al., 2012). ROS production, and thus antioxidant enzyme activity, is enhanced when plants are exposed to various abiotic stresses, such as drought (Caverzan et al., 2012). Osmosis is a mechanism for maintaining water relations under osmotic pressure. It involves the accumulation of a group of active/osmotic molecules/ions including dissolved sugars, sugar alcohol, proline, glycine betaine, organic acids, calcium, potassium, chloride ions and others under water shortage and due to the dissolved accumulation of the cell, which attracts water to the cell and helps maintain the turgor. Potatoes respond to dehydration and salts accumulated through the accumulation of proline which acts as an endoscopy device (osmoprotector), osmoregulator and ROS scavenger (Vahdati and Lotfi, 2013), they study the effects of different irrigation systems during two stages of growth on total chlorophyll in, total soluble sugars content and antioxidant activity in potato leaves.

The aim of this study was to evaluate the effect of irrigation intervals and some biotic and abiotic treatments on potato yield and quality in two growing spring seasons 2017 and 2018, as well as studding the possibility to reducing water requirements of potato while maintaining the tuber quantities and qualities under the field conditions in Sulaimani – Iraqi Kurdistan region.

Material and methods

This study carried out in two growing spring seasons 2017 and 2018 in Kanipanka Agricultural Research Station which located in North-East of Iraq (Lat. 35°13'12", Long. 45°25'48", 550 MASL) in Shahrazoor valley 35 km east of Sulaimani. GIS software was used to create the study sites shown in *Figure 1*. Generally, the elevation of this region ranges between 5 and 2368 m above sea levels. This study includes the interaction effect of two irrigation intervals (5 and 10 days) and thirteen treatments such as *Glycyrrhiza glabra* extract, potassium chloride (KCl), and mycorrhiza inoculation and their interaction on yield quantity and quality of potato plant under field condition. The climate of the study area is generally characterized by warm, dry summer and cold winters (Najmaddin et al., 2017). Thus, the meteorological data of Kanipanka during both growing seasons are shown in *Table 1*. Some physical and chemical properties of Kanipanka soil are shown in *Table 2*.

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Bio inoculation

The fungal inoculants *Glomus mosseae* was obtained from Al-Zaefaraniya Agricultural Research Station/Ministry of Science and Technology/Baghdad. The inoculants were consisting of mycorrhiza spore with 47 spores g^{-1} dry soil and the residual of the infected roots. Potato tubers were inoculated with the mycorrhiza spores by using 20 g from the mixture of the inoculums and the pet moss inside the pores, which specified for inoculation treatment before planting the tubers where the pad method was used to ensure the infection by touching the inoculums during planting.

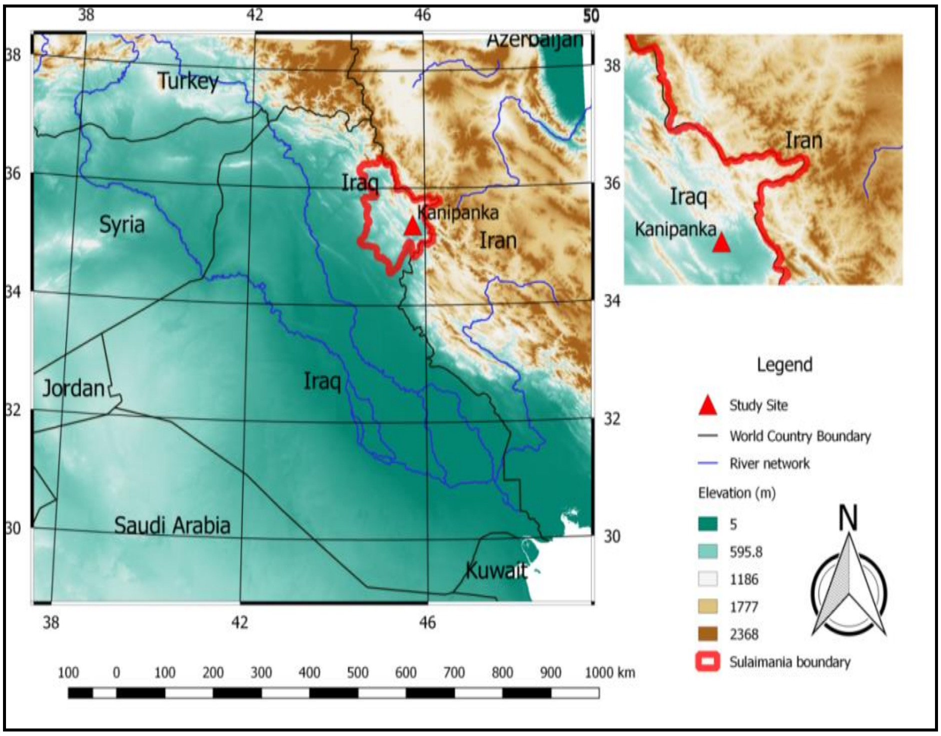

Figure 1. *Regional and local location of the study site*

Table 1. *Meteorological data of Kanipanka location during both growing seasons (2017 and 2018)*

Months	Air temp. (°C)			Humidity (%)			Prec. (mm)	Pan eva. (mm)	Soil temp. (°C)
	Avg.	Max.	Min.	Avg.	Max.	Min.			
First season 2017									
March	12.2	23.0	4.0	49.7	84.0	22.0	107.1	70.2	12.0
April	17.4	31.1	7.0	42.0	79.0	17.0	39.6	119.9	17.6
May	24.6	39.3	12.2	30.3	75.0	16.0	19.3	164.4	23.9
June	30.4	45.7	15.2	21.4	32.0	14.0	0.0	216.0	29.4
Second season 2018									
March	14.7	30.0	2.5	42.3	78.0	18.0	15.5	98.7	11.7
April	17.1	29.7	6.2	38.4	80.0	17.0	82.7	110.5	17.4
May	22.2	37.8	10.0	36.1	84.0	17.0	51.8	135.1	20.6
June	30.3	45.5	17.0	21.7	30.0	13.3	0.0	211.3	27.1

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Table 2. *Some physical and chemical properties of Kanipanka soil*

Soil components	Quantities	Unit
Sand	308.0	g kg^{-1}
Silt	340.0	g kg^{-1}
Clay	352.0	g kg^{-1}
Textured class	Clay loam	
pH	7.10	
EC	0.38	dS m^{-1}
Field capacity	290.0	g kg^{-1}
Wilting point	180.0	g kg^{-1}
Organic matter	8.5	g kg^{-1}
Available nitrogen	32.0	g kg^{-1}
Available phosphate	8.0	g kg^{-1}
Available potassium	73.11	g kg^{-1}
Carbonate minerals	201.2	g kg^{-1}
Bulk density	1.32	g cm^{-3}
CEC	33.0	$cmol_c$ kg^{-1}
Calcium (Ca++)	2.29	meq L^{-1}
Magnesium (Mg++)	2.53	meq L^{-1}
Potassium (K+)	0.93	meq L^{-1}
Sodium (Na+)	2.10	meq L^{-1}
Carbonate (CO3=)	Nil	meq L^{-1}
Bicarbonate (HCO3-)	0.90	meq L^{-1}
Chloride (Cl-)	2.49	meq L^{-1}
Sulfate (SO4=)	2.16	meq L^{-1}

Preparation of Glycyrrhiza glabra extraction

Glycyrrhiza glabra roots powder (3 and 6) g was soaked separately in one litter hot distilled water at 50 °C for 24 h in dark colure bottles with shaking continuously. The solution filtered through several layers of filter papers, to obtained two concentrations of the extraction 3 and 6 g L^{-1} and several drops of Twin20 were added as a spread material to reduce the surface tension. The plants were sprayed two times 45 and 60 days after planting date, after the sun seat in both years 2017 and 2018 (Lazim and Sulaiman, 2012).

Preparation of potassium fertilizer (KCl)

Two half five gram of potassium chloride (KCl) was dissolved in one liter hot distilled water at 40 °C with shaking the potassium completely dissolved and several drops of Twin20 were added as a spreading material to reduce the surface tension. The plants were sprayed at the morning trice 40, 55 and 70 days after planting in both years 2017 and 2018.

Addition of chemical fertilizer

Six hundred kilograms per hectare of Di-Ammonium Phosphate (DAP) 18:18:0 fertilizer was added in two times. The first was during the cultivation of the tubers (spares on the furrows) and the second addition was after one month from the first

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addition as recommended for the chemical fertilizer treatment only (Esho et al., 2009), while half of the recommended were added for the rest of the treatments.

Field practices

Potato tubers (Acterice varieties) which produced by the Agro-plant's Company/Nederland, used in the study, each experimental unit (furrow) was 3 m long and 0.8 m apart (2.4 m^2), each furrow consists of 12 plants in one side. Planting dates were 10 March 2017 and 5 March 2018 at the first and the second season respectively, while the harvesting was accomplished after 100 days on 20 June 2017 and 15 June 2018 at the first and the second season respectively. The land was plowed perpendicularly at 30 cm depth by using moldboard plow then the soil was smoothed by disc harrow then leveled the all the divisions were made to furrow according to the experimental layout (*Fig. 2*). Each experimental units (furrows) within the blocks were divided into four groups, each group consists of four furrows the last one was one furrow, each group were conducted with a 10 cm diameter plastic pipes to feeding them with water from the mainstream. Watering timing from the mainstream to the furrows was calculated according to the field design for furrow irrigation system (*Fig. 3*).

The irrigation timing was computed until the water reached the standardized line in each furrow in order to measure the amount of water that entered each furrow through the plastic pipes in the irrigation intervals (5 and 10 days). The amount of water and its operation time were calculated to estimate the discharge of sub main irrigation pipe. Depending on the knowledge discharge, Furrow area, number of furrow, and operation times for irrigation, the depth of irrigation was calculated as well as it can be used to estimate the amount of irrigation (*Eq. 1*). In 2017, the depth and the amount of irrigation were 369 mm and 0.885 m^3 $furrow^{-1}$ respectively for $\mathbf{I_5}$, while the values were 228 mm and 0.547 m^3 $furrow^{-1}$ respectively for $\mathbf{I_{10}}$. In 2018, the values were 363 mm and 0.871 m^3 $furrow^{-1}$ respectively for $\mathbf{I_5}$, and 287 mm and 0.668 m^3 $furrow^{-1}$ respectively for $\mathbf{I_{10}}$.

$$Q\,t = n\,A\,d \qquad \text{(Eq.1)}$$

where: Qt: the amount of irrigation (L), Q: discharge of sub main (L s^{-1}), t: operation time (s), n: No. of the furrows, A: area of the furrow (2.4 m^2), d: depth of irrigation water (mm).

Statistical analysis

A factorial experiment was conducted in a split-plot design with three replicates; the first factor (Irrigation intervals) was implemented in the main plots and conducted with Randomized Complete Block Design (RCBD), while the second factor (Treatments) was implemented in the subplots. All possible comparisons among the means were carried out by using Least Significant Difference (L.S.D) test at a significant level of 5% after they show their significance in the general test (AL-Rawi and Khalafallah, 1980). The study included treatments as specified in *Table 3*.

Quantitative and qualitative yield characters

After tubers maturity harvested were performed manually (100 days from planting date), the yield was calculated (*Eq. 2*).

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$$\text{Total Yield } (t\ ha^{-1}) = \frac{\text{Yield of the Experimental Unit } (t)}{\text{Area of the Experimental Unit } (m^2)} \times 10000\ m^2 \qquad \text{(Eq.2)}$$

Total soluble solid (%)

Total soluble solids were measured by Refractometer (LCD DIGITAL BENCH MODEL). In order to measure T.S.S. (%), a drop of the tuber extract was placed on the prism of the digital Refractometer and the total soluble solids were read in Brix (A.O.A.C, 1986).

Tuber starch percentage (%)

The percentage of starch was estimated based on the dry weight of the tuber (A. O. A. C. 1970), according to *Equation 3*.

$$\text{Tuber starch } (\%) = 17.55 + 0.891(\text{Tuber dry matter percentage} - 24.18) \qquad \text{(Eq.3)}$$

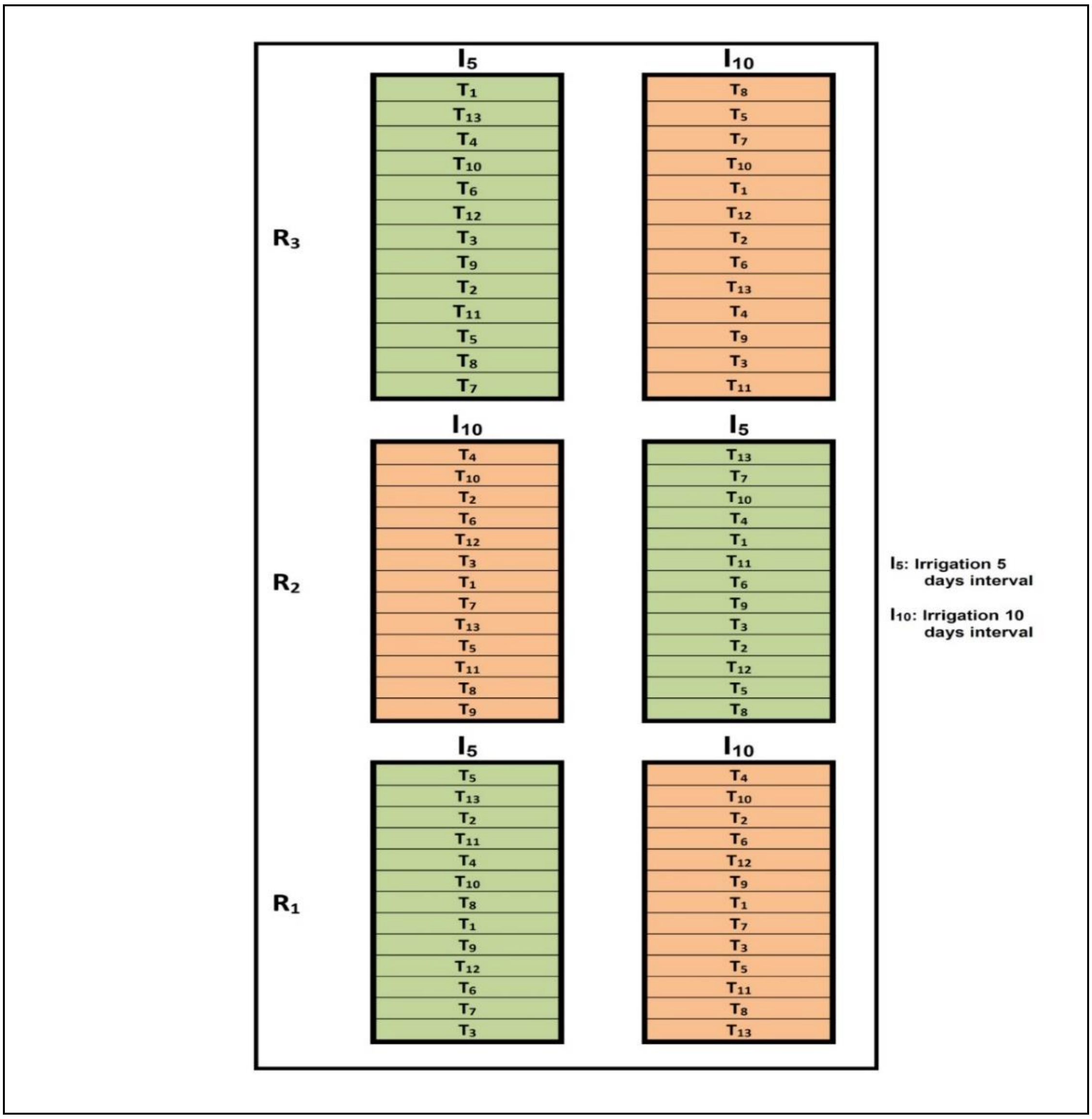

***Figure 2.** The experimental layout*

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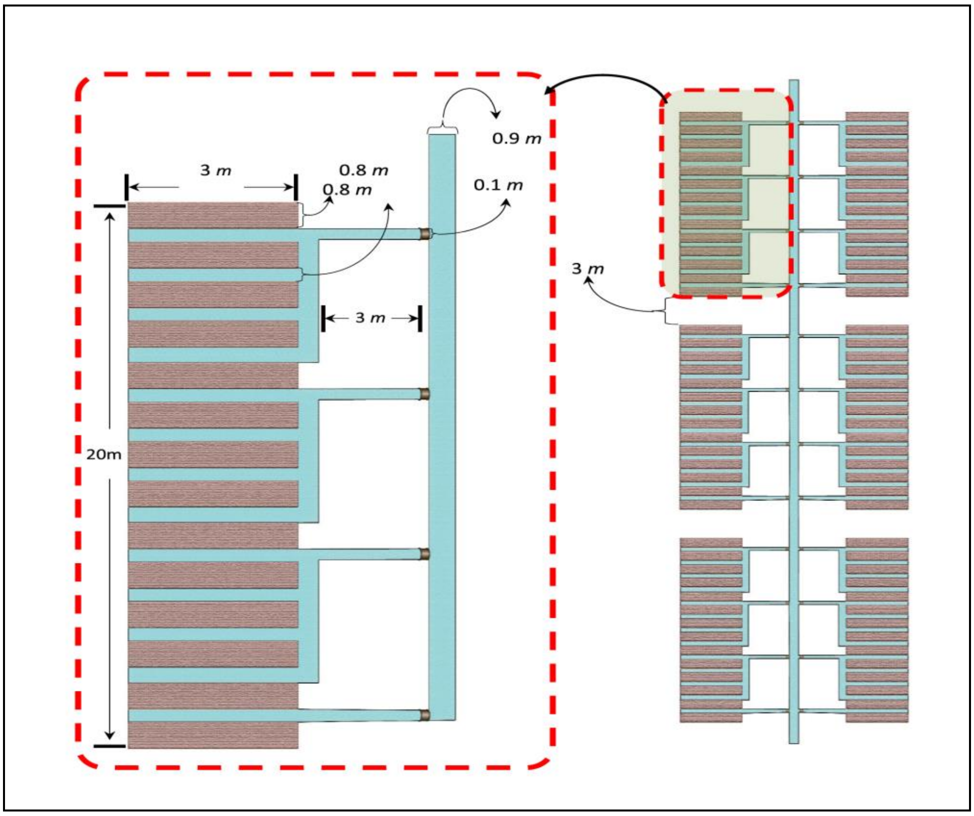

Figure 3. *The field design for furrow irrigation system*

Table 3. *The experimental factors used in the study*

No.	Factors	Levels	Descriptions
First	Irrigation intervals	I_5	5 days
		I_{10}	10 days
Second	Treatments	T_1	Control (spray with distilled water)
		T_2	Di-Ammonium phosphate (DAP)
		T_3	Mycorrhizal inoculation
		T_4	Spraying with (2.5 g L^{-1}) KCl
		T_5	Spraying with (3 g L^{-1}) *Glycyrrhiza glabra* extract
		T_6	Spraying with (6 g L^{-1}) *Glycyrrhiza glabra* extract
		T_7	Mycorrhizal Inoculation + spraying with (2.5 g L^{-1}) KCl
		T_8	Mycorrhizal Inoculation + spraying with (3 g L^{-1}) *Glycyrrhiza glabra* extract
		T_9	Mycorrhizal Inoculation + spraying with (6 g L^{-1}) *Glycyrrhiza glabra* extract
		T_{10}	Spraying with (2.5 g L^{-1}) KCl + spraying with (3 g L^{-1}) *Glycyrrhiza glabra* extract
		T_{11}	Spraying with (2.5 g L^{-1}) KCl + spraying with (6 g L^{-1}) *Glycyrrhiza glabra* extract
		T_{12}	Mycorrhizal Inoculation + spraying with (2.5 g L^{-1}) KCl + spraying with (3 g L^{-1}) *Glycyrrhiza glabra* extract
		T_{13}	Mycorrhizal Inoculation + spraying with (2.5 g L^{-1}) KCl + spraying with (6 g L^{-1}) *Glycyrrhiza glabra* extract

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Analysis and estimation of some amino acids in potato tubers

Amino acids in tubers were estimated and analyzed using High-Performance Liquid Chromatography (YL9100 HPLC System, Model: YL9101 Vacuum Degasser, S/N: D2714120911, YL: instrument CO. LTD, made in Korea) device in potato tubers. Five grams from the tubers mixed with the methanol and water in 10:40 ratio respectively. The mixture was filtered using fine Tapestry cloth, then the precipitated leach was stored in a sterile bottle (-20 °C) (Itakura et al., 2001). It is worth to mention that the Orethophthalheide derivative (OPA) was prepared according to (Graser et al., 1985). Approximately 5 mg of the sample was weighed into a 10 ml headspace glass vial with crimp cap and 3 ml hydrochloric acid (6 M with 0.1% w/v phenol) was added. The vial was sealed and placed in a preheated oven at 110 °C for 24 h. After hydrolysis, the samples were allowed to cool to handling temperature then neutralized with 3 ml sodium hydroxide (6 M) mixed thoroughly and left to cool to handling temperature. After cooling, an aliquot was filtered through a 0.45 µm, 13 mm diameter nylon filter (*Figs. 4* and *5*).

Mobile phase = acetonitrile: buffer (30: 70), Flow = 1 ml min^{-1}
Injection: injection program, including derivatization steps with OPA
Injected volume = 100 uL
Column = ZORBAX Eclipse-AAA; 3.5 µm; L × i.d. = 150 × 4.6 mm
Detector: fluorescence (Ex = 360 nm, Em = 450 nm)

Results

Table 4 shows the effects of irrigation intervals on yield quantitative and qualitative characters. The irrigation intervals were significant effects on total yield, total soluble solid (T.S.S%) in the tuber and all amino acids in the tuber with an exception for Lucien in the first season 2017. The **I$_5$** gave the highest values of total yield and T.S.S% in the tubers with 40.418 t ha^{-1} and 9.536%, while the **I$_{10}$** gave the minimum values of total yield and T.S.S% in the tuber with 32.205 t ha^{-1} and 5.872%, but the **I$_{10}$** gave the highest values for Proline, Glycine, and Lysine with 2.707, 2.681 and 2.861 mg g^{-1} respectively, and the **I$_5$** gave the lowest values with 2.060, 2.091, and 1.882 mg g^{-1} respectively.

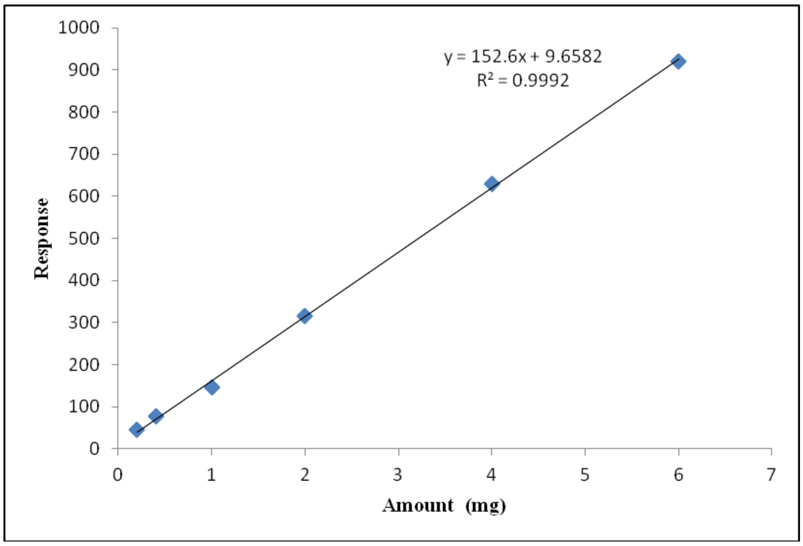

Figure 4. *Calibration standard curve of amino acids*

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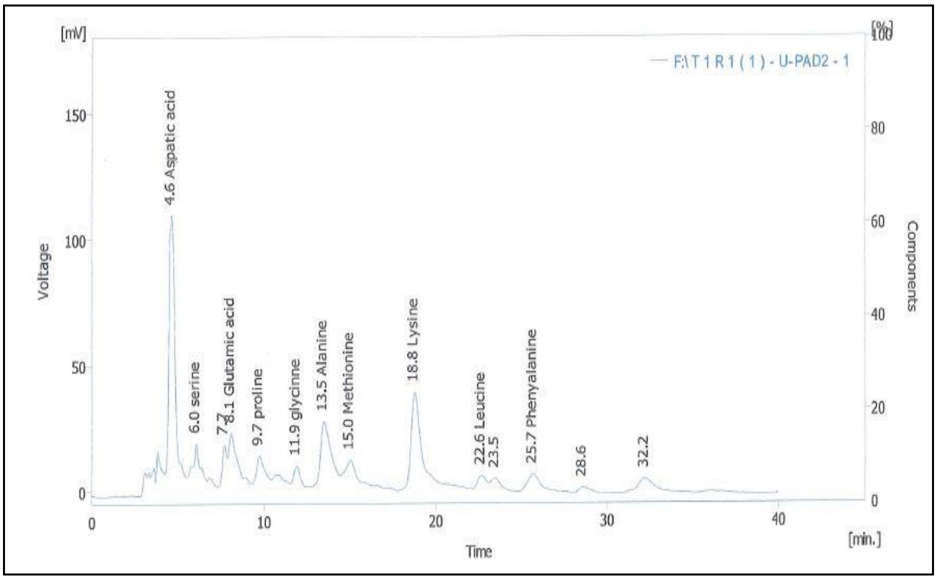

Figure 5. *An example of HPLC chromatogram of amino acid profile in potato tubers*

Table 4. *Effect of irrigation intervals on yield quantitative and qualitative characters at both growing seasons 2017 and 2018*

Irrigation interval (A)	Total yield (t ha^{-1})	T.S.S (%)	Starch (%)	Proline	Glycine	Lucien	Lysine
First season 2017							
I_5	40.418 a	9.536 a	21.392 a	2.060 b	2.091 b	2.659 a	1.882 b
I_{10}	32.205 b	5.872 b	23.570 a	2.707 a	2.681 a	2.778 a	2.861 a
L.S.D ($p \leq 0.05$)	**2.012**	**2.856**	**n.s**	**0.202**	**0.209**	**n.s**	**0.220**
Second season 2018							
I_5	42.886 a	8.479 a	21.751 a	2.091 b	1.991 b	2.656 a	1.942 b
I_{10}	31.431 b	6.954 a	22.281 a	2.681 a	2.988 a	2.816 a	2.951 a
L.S.D ($p \leq 0.05$)	**4.117**	**n.s**	**n.s**	**0.209**	**0.311**	**n.s**	**0.191**

Concerning the second season 2018, the irrigation intervals had a significant effect on total yield, Proline, Glycine, and Lysine character. The **I_5** gave the highest values for total yield with 42.886 t ha^{-1}, while the lowest values gave by **I_{10}** with 31.431 t ha^{-1}. The **I_{10}** achieved the highest values for Proline, Glycine, and Lysine with 2.681, 2.988, and 2.951 mg g^{-1} respectively. The lowest values achieved by **I_5** with 2.091, 1.991 and 1.942 mg g^{-1} respectively.

Table 5A illustrates the effects of treatments on yield quantitative and qualitative characters in the first season 2017; data shows the treatments were significant effect for all characters with the exception of starch% in the tuber. The highest values of total yield gave by **T_3** with 44.912 t ha^{-1}. The minimum values obtained by **T_1** with 25.984 t ha^{-1}**.** And the maximum values of T.S.S% in the tube achieved in **T_4** with 8.925%. The minimum values of T.S.S% in tuber were achieved in **T_{10}** with 6.592%. The highest values of Proline, Glycine, Lucien, and Lysine in the tuber gave by **T_9** with 5.906, 5.823, 6.104 and 6.143 mg g^{-1} respectively. The minimum values were recorded by **T_1** with 0.241, 0.211, 0.293 and 0.126 mg g^{-1} respectively.

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Table 5A. *Effect of the treatments on yield quantitative and qualitative characters in the first season 2017*

T_i	**Total yield ($t\ ha^{-1}$)**	**T.S.S (%)**	**Starch (%)**	**Proline**	**Glycine**	**Lucien**	**Lysine**
T_1	25.984 d	7.017 d	23.178 a	0.241 j	0.211 h	0.293 h	0.126 h
T_2	38.984 b	7.875 bc	23.101 a	0.506 hi	0.360 gh	0.462 gh	0.267 h
T_3	44.912 a	8.292 ab	22.359 a	0.559 gh	0.546 gh	0.536 gh	0.408 h
T_4	37.634 b	8.925 ab	20.402 a	0.289 ij	0.286 h	0.414 gh	0.165 h
T_5	31.654 cd	8.658 ab	25.498 a	2.774 e	2.629 e	3.727 d	3.027 e
T_6	37.812 b	7.075 d	23.404 a	3.257 d	3.426 d	4.397 c	3.672 d
T_7	39.331 ab	6.908 d	22.407 a	0.747 g	0.811 g	0.896 g	0.720 g
T_8	36.033 bc	7.225 cd	22.426 a	4.044 c	4.269 c	5.596 b	5.087 b
T_9	33.924 bc	7.892 bc	23.131 a	5.906 a	5.823 a	6.104 a	6.143 a
T_{10}	36.347 bc	6.592 d	23.135 a	1.667 f	1.553 f	1.419 f	1.358 f
T_{11}	36.856 bc	6.992 d	20.470 a	2.279 e	2.184 e	2.256 e	1.620 f
T_{12}	36.293 bc	8.408 ab	21.253 a	4.050 c	4.107 c	3.834 d	3.667 d
T_{13}	36.284 bc	8.292 ab	21.484 a	4.665 b	4.814 b	5.406 b	4.567 c
LSD ($p \leq 0.05$)	**5.940**	**0.799**	**n.s**	**0.225**	**0.453**	**0.496**	**0.305**

Table 5A illustrates the effects of treatments on yield quantitative and qualitative characters in the first season 2017; data shows the treatments were significant effect for all characters with the exception of starch% in the tuber. The highest values of total yield gave by **T_3** with 44.912 $t\ ha^{-1}$. The minimum values obtained by **T_1** with 25.984 $t\ ha^{-1}$**.** And the maximum values of T.S.S% in the tube achieved in **T_4** with 8.925%. The minimum values of T.S.S% in tuber were achieved in **T_{10}** with 6.592%. The highest values of Proline, Glycine, Lucien, and Lysine in the tuber gave by **T_9** with 5.906, 5.823, 6.104 and 6.143 $mg\ g^{-1}$ respectively. The minimum values were recorded by **T_1** with 0.241, 0.211, 0.293 and 0.126 $mg\ g^{-1}$ respectively.

Table 5B shows the effect of the treatments on yield quantitative and qualitative characters in the second season 2018, the statistical analysis reveals a significant difference for all of the characters. The highest values of total yield gave by **T_{11}** with 42.106 t/ha. The minimum values obtained by **T_1** with 29.678 $t\ ha^{-1}$**.** And the maximum values for T.S.S% were given by **T_4** with 9.083%. The minimum values were given by **T_5** with 6.450%. Regarding the starch% in the tuber, the **T_1** gave the highest values with 26.948%. The lowest values obtained by treatments **T_{13}** with 18.222%. The maximum values of Proline, Lucien and Lysine were obtained by **T_9** with 5.823, 4.971 and 6.096 $mg\ g^{-1}$ respectively. Whereas the maximum values for Glycine were recorded by **T_8** with 5.596 $mg\ g^{-1}$. The minimum values were recorded by **T_1** with 0.211, 0.222, 0.289 and 0.106 $mg\ g^{-1}$ for Proline, Glycine, Lucien, and Lysine respectively.

Table 6A shows the interaction effects of irrigation intervals and treatments on yield quantitative and qualitative characters at the first season 2017, the statistical analysis reveals significant difference for T.S.S% and amino acid in the tubers (Proline, Glycine, Lucien, and Lysine). The highest values for T.S.S% was obtained in the interaction of **$I_5 \times T_{13}$** with 11.200%. The lowest values obtained in interaction **$I_{10} \times T_8$** with 4.250%, and the highest values of Proline, Glycine, and Lysine gave by interaction **$I_{10} \times T_{13}$** with 6.724, 6.912 and 7.525 $mg\ g^{-1}$ respectively. But the

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maximum values of Lucien recorded by $\mathbf{I_5} \times \mathbf{T_9}$ with 6.148 mg g^{-1}. The minimum values were recorded by $\mathbf{I_5} \times \mathbf{T_1}$ with 0.143, 0.126, 0.284 and 0.080 mg g^{-1} respectively for Proline, Glycine, Lucien, and Lysine.

Table 5B. *Effect of the treatments on yield quantitative and qualitative characters in the second season 2018*

T_i	Total yield (t ha^{-1})	T.S.S (%)	Starch (%)	Proline	Glycine	Lucien	Lysine
T_1	29.678 e	7.217 cd	26.948 a	0.211 h	0.222 h	0.289 h	0.106 h
T_2	39.809 abc	7.983 bc	23.174 b	0.360 gh	0.371 h	0.477 h	0.290 h
T_3	41.453 ab	8.500 ab	23.725 ab	0.546 gh	0.528 h	0.599 gh	0.385 h
T_4	33.424 cde	9.083 a	21.741 b	0.286 h	0.284 h	0.373 h	0.176 h
T_5	34.799 b-e	6.450 d	21.621 bc	2.629 e	3.317 d	3.759 d	2.855 e
T_6	38.924 a-d	7.833 bc	22.256 b	3.426 d	3.601 d	4.375 c	3.652 d
T_7	41.351 ab	7.367 cd	20.429 bc	0.811 g	0.876 g	0.966 fg	0.865 g
T_8	34.564 b-e	7.367 cd	21.045 bc	4.269 c	5.596 a	5.757 ab	5.458 b
T_9	32.142 de	7.567 bc	22.638 b	5.823 a	5.448 a	6.021 a	6.096 a
T_{10}	40.014 abc	7.850 bc	21.807 b	1.553 f	1.388 f	1.442 f	1.244 g
T_{11}	42.106 a	7.700 bc	21.904 b	2.184 e	2.047 e	2.291 e	1.844 f
T_{12}	36.089 a-e	7.650 bc	20.699 bc	4.107 c	4.079 c	3.842 d	3.916 d
T_{13}	38.709 a-d	7.750 bc	18.222 c	4.814 b	4.604 b	5.376 b	4.918 c
LSD $(p \leq 0.05)$	**7.318**	**0.961**	**3.474**	**0.453**	**0.435**	**0.486**	**0.450**

Data in *Table 6B* illustrates the interaction effects of irrigation intervals and treatments on yield quantitative and qualitative characters at the second season 2018, the interaction had the significant effect on T.S.S, starch and amino acid in the tuber. The highest values of T.S.S were obtained by interaction $\mathbf{I_5} \times \mathbf{T_4}$ with 10.767%. But the lowest values obtained by interaction I_{10} × with 6.167%. Regarding on percentage of starch in the tuber, the highest values were achieved by $\mathbf{I_5} \times \mathbf{T_1}$ with 28.226%, the minimum values achieved by $\mathbf{I_{10}} \times \mathbf{T_{13}}$ with 15.964%. The highest values gave by interaction $\mathbf{I_{10}} \times \mathbf{T_9}$ Proline, and Lysine with 6.912 and 7.290 mg g^{-1} respectively. And the maximum values for Glycine recorded by interaction with $\mathbf{I_{10}} \times \mathbf{T_8}$ with 7.181 mg g^{-1}. The maximum values of Lucien gave by interaction $\mathbf{I_5} \times \mathbf{T_9}$ with 6.094 mg g^{-1}, while the minimum values for all amino acid with exception Glycine were recorded by interaction $\mathbf{I_5} \times \mathbf{T_1}$ with 0.126, 0.252 and 0.079 mg g^{-1} respectively. But the minimum values of Glycine gave by interaction $\mathbf{I_{10}} \times \mathbf{T_1}$ with 0.198 mg g^{-1}.

Table 7 shows the effect of seasons on yield quantitative and qualitative characters. The season had no significant effects on yield qualitative characters.

Discussion

Water is one of the most essential elements in growing plants, which constitutes more than 80% of the active cells. Thereby, the amount of applied water during crop irrigation, added time, irrigation methods, quality of added water, and prevailing micro-meteorological conditions have found to play limited roles in yield quality and quantity. In Asia, statistics showed that the yields for most crops have increased 100–400% after

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irrigation. In the first season of irrigation intervals (5 and 10 days) were applied after 50 days from sowing and were ended at 96 days after sowing, since, the amount of irrigation water for 5 days interval was cover the most of depleted water at this time. The cumulative depth of irrigation for 5 and 10 days from (10 May 2017 to 15 June 2017) were practically measured and formed to be (369 and 228 mm) respectively. Since the numbers of irrigation were 10 and 6 times for 5 and 10 days of irrigation intervals respectively, while the amount of actual evapotranspiration for 2017 and 2018 was (529, 423, 515 and 440 mm) respectively, while the cumulate depth of irrigation and precipitation were (535 and 394 mm) respectively.

Table 6A. *Interaction effects of irrigation intervals and treatments on yield quantitative and qualitative characters in the first season 2017*

$I_i \times T_i$ (A×B)	**Total yield ($t\ ha^{-1}$)**	**T.S.S (%)**	**Starch (%)**	**Proline**	**Glycine**	**Lucien**	**Lysine**
$I_5 \times T_1$	28.472 a	8.033 fg	23.013 a	0.143 n	0.126 n	0.284 l	0.080 n
$I_5 \times T_2$	44.353 a	9.233 cde	23.473 a	0.228 n	0.186 n	0.388 kl	0.226 mn
$I_5 \times T_3$	52.324 a	10.000 bcd	20.229 a	0.382 mn	0.394 mn	0.502 jkl	0.452 mn
$I_5 \times T_4$	42.859 a	10.500 ab	19.357 a	0.151 n	0.159 n	0.310 l	0.126 mn
$I_5 \times T_5$	33.840 a	9.800 bcd	23.569 a	2.400 h	2.298 ij	3.844 e	2.317 g
$I_5 \times T_6$	43.307 a	9.700 bcd	23.147 a	3.306 f	3.530 fg	4.696 cd	3.476 f
$I_5 \times T_7$	43.763 a	9.000 def	19.040 a	0.592 klm	0.624 mn	0.774 jkl	0.528 lm
$I_5 \times T_8$	38.931 a	10.200 abc	21.967 a	4.114 d	4.334 cde	5.670 a	4.072 e
$I_5 \times T_9$	37.284 a	11.200 a	19.135 a	5.088 bc	4.734 cd	6.184 a	4.762 d
$I_5 \times T_{10}$	38.657 a	8.467 efg	22.443 a	1.837 i	1.772 jk	1.108 ij	0.930 jk
$I_5 \times T_{11}$	45.077 a	8.900 def	21.206 a	1.766 ij	1.869 ijk	1.814 h	1.358 ij
$I_5 \times T_{12}$	39.642 a	9.067 def	20.862 a	3.118 f	3.274 fg	3.104 fg	2.502 g
$I_5 \times T_{13}$	36.923 a	9.867 bcd	20.651 a	3.656 e	3.886 ef	5.894 a	3.632 f
$I_{10} \times T_1$	23.496 a	6.000 jk	23.344 a	0.338 mn	0.296 n	0.302 l	0.172 mn
$I_{10} \times T_2$	33.615 a	6.517 ij	22.730 a	0.784 k	0.534 mn	0.536 jkl	0.308 mn
$I_{10} \times T_3$	37.500 a	6.583 ij	24.489 a	0.736 kl	0.698 lmn	0.570 jkl	0.364 mn
$I_{10} \times T_4$	32.410 a	7.350 ghi	21.447 a	0.428 lmn	0.412 mn	0.518 jkl	0.204 mn
$I_{10} \times T_5$	29.467 a	7.517 ghi	27.426 a	3.147 f	2.960 gh	3.610 ef	3.738 ef
$I_{10} \times T_6$	32.318 a	4.450 l	23.661 a	3.208 f	3.322 fg	4.099 de	3.868 ef
$I_{10} \times T_7$	34.900 a	4.817 l	25.774 a	0.902 k	0.998 lm	1.018 jk	0.912 kl
$I_{10} \times T_8$	33.134 a	4.250 l	22.885 a	3.974 d	4.204 de	5.521 ab	6.102 b
$I_{10} \times T_9$	30.564 a	4.583 l	27.128 a	6.724 a	6.912 a	6.024 a	7.525 a
$I_{10} \times T_{10}$	34.037 a	4.717 l	23.827 a	1.498 j	1.334 kl	1.730 hi	1.786 hi
$I_{10} \times T_{11}$	28.635 a	5.083 kl	19.734 a	2.792 g	2.498 hi	2.698 g	1.882 h
$I_{10} \times T_{12}$	32.943 a	7.750 gh	21.645 a	4.981 c	4.940 c	4.564 cd	4.832 d
$I_{10} \times T_{13}$	35.646 a	6.717 hij	22.318 a	5.674 b	5.742 b	4.918 bc	5.502 c
L.S.D ($p \leq 0.05$)	**n.s**	**1.130**	**n.s**	**0.318**	**0.641**	**0.701**	**0.431**

In the season 2018 the irrigation intervals (5 and 10 days) was applied from the sowing date and were ended at 95 days after sowing, the amount of irrigation water for 5 days interval which cover the most of depleted from (5 March 2018 to 10 June 2018) were practically measured (363 and 287 mm) respectively. Since the numbers of

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irrigation were 9 and 5 times for 5 and 10 days of irrigation intervals respectively, while accumulate depth irrigation and precipitation were (513 and 437 mm) respectively. These results are in agreement with the findings of several other kinds of research (Ati et al., 2013; Ati and Nafaou, 2012). Gander and Tanner (1976) showed that mild water stress of -3 to -5 bars greatly reduce leaf expansion in potatoes, and for best tuber yields, a 120-150 day potato crop requires 508-698.5 mm of the water.

Table 6B. *Interaction effects of irrigation intervals and treatments on yield quantitative and qualitative characters in the second season 2018*

$I_i \times T_i$ (A×B)	Total yield (t ha^{-1})	T.S.S (%)	Starch (%)	Proline	Glycine	Lucien	Lysine
$I_5 \times T_1$	30.886 a	8.267 bcd	28.226 a	0.126 n	0.246 ij	0.252 j	0.079 m
$I_5 \times T_2$	41.377 a	9.167 bc	22.812 b-f	0.186 n	0.365 hij	0.373 j	0.188 m
$I_5 \times T_3$	50.598 a	9.167 bc	22.569 b-f	0.394 mn	0.614 hij	0.526 ij	0.349 lm
$I_5 \times T_4$	38.109 a	10.767 a	19.088 fgh	0.159 n	0.282 ij	0.280 j	0.100 m
$I_5 \times T_5$	37.928 a	6.067 g	17.412 gh	2.298 ij	2.683 de	3.788 e	2.218 gh
$I_5 \times T_6$	46.156 a	9.200 b	20.216 d-h	3.530 fg	2.990 de	4.926 cd	3.578 f
$I_5 \times T_7$	51.678 a	8.233 bcd	20.172 d-h	0.624 mn	0.854 ghi	0.818 hij	0.572 klm
$I_5 \times T_8$	38.385 a	7.933 b-e	22.530 b-f	4.334 cde	4.012 c	5.952 a	4.358 de
$I_5 \times T_9$	35.996 a	8.133 b-e	22.691 b-f	4.734 cd	4.122 c	6.094 a	4.902 cd
$I_5 \times T_{10}$	48.668 a	8.833 bc	22.547 b-f	1.772 jk	1.315 fg	1.276 gh	0.898 jkl
$I_5 \times T_{11}$	48.619 a	8.933 bc	23.130 b-f	1.869 ijk	1.683 f	1.663 g	1.469 ij
$I_5 \times T_{12}$	40.223 a	7.400 d-g	20.890 c-g	3.274 fg	3.032 d	2.954 f	2.658 g
$I_5 \times T_{13}$	48.900 a	8.133 b-e	20.481 d-h	3.886 ef	3.682 c	5.624 ab	3.876 ef
$I_{10} \times T_1$	28.470 a	6.167 g	25.671 abc	0.296 n	0.198 j	0.326 j	0.134 m
$I_{10} \times T_2$	38.241 a	6.800 efg	23.536 a-f	0.534 mn	0.376 hij	0.582 ij	0.392 lm
$I_{10} \times T_3$	32.309 a	7.833 c-f	24.881 a-d	0.698 lmn	0.442 hij	0.672 hij	0.422 klm
$I_{10} \times T_4$	28.739 a	7.400 d-g	24.394 a-e	0.412 mn	0.286 hij	0.466 ij	0.252 m
$I_{10} \times T_5$	31.669 a	6.833 efg	25.830 ab	2.960 gh	3.952 c	3.730 e	3.492 f
$I_{10} \times T_6$	31.692 a	6.467 g	24.296 a-e	3.322 fg	4.212 c	3.824 e	3.726 ef
$I_{10} \times T_7$	31.024 a	6.500 fg	20.686 d-h	0.998 lm	0.898 gh	1.114 ghi	1.158 ijk
$I_{10} \times T_8$	30.742 a	6.800 efg	19.559 e-h	4.204 de	7.181 a	5.562 abc	6.558 b
$I_{10} \times T_9$	28.288 a	7.000 d-g	22.585 b-f	6.912 a	6.774 a	5.948 a	7.290 a
$I_{10} \times T_{10}$	31.360 a	6.867 efg	21.066 b-g	1.334 kl	1.462 fg	1.608 g	1.590 hi
$I_{10} \times T_{11}$	35.594 a	6.467 g	20.678 d-h	2.498 hi	2.412 e	2.920 f	2.218 gh
$I_{10} \times T_{12}$	31.955 a	7.900 b-e	20.508 d-h	4.940 c	5.126 b	4.730 d	5.174 c
$I_{10} \times T_{13}$	28.518 a	7.367d-g	15.964 h	5.742 b	5.526 b	5.128 bcd	5.960 b
L.S.D$_{(p \leq 0.05)}$	**n.s**	**1.360**	**4.913**	**0.641**	**0.615**	**0.688**	**0.637**

Table 7. *The effect of seasons on yield quantitative and qualitative characters*

Seasons	Total yield (t ha^{-1})	T.S.S (%)	Starch (%)	Proline	Glycine	Lucien	Lysine
First season 2017	36.311 a	7.704 a	22.481 a	2.383 a	2.386 a	2.718 a	2.371 a
Second season 2018	37.159 a	7.717 a	22.016 a	2.386 a	2.489 a	2.736 a	2.447 a
L.S.D$_{(p \leq 0.05)}$	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**	**n.s**

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The treatment of mycorrhizae inoculation gave the highest values for water use efficiency; this may be due to its high ability to produce the glomalin compound, which binds the soil minutes to each other and to the aggregation of aggregates. as well as the mycelium hypha played a major role by increasing the soil mass and stability (Fokom et al., 2012) indicates that there are positive correlations of correlations between organic matter and chlorine associated with Glomalin Related Soil Protein (GRSP). Peng et al. (2013) recorded that the fertilized soil with mycorrhizae increases the stability of its aggregates as a result of the action of the mycorrhizae hypha and the result of its production of glomalin, a watery and insoluble molybdenum protein compound that contributes to the formation and increase stability of the soil complexes where it is released to them and reduce their hydration because it is a glue-absorbing composite. (Martin et al., 2012 and Wu et al., 2013) reported that organic matter also plays an important role in improving the properties of physical, chemical and biological soil. The Glycyrrhiza glabra extract contains various elements such as calcium, iron, silicon, aluminum, magnesium, sulfur, potassium, zinc, and phosphorus, which play an important role in growth (Vispute and Khopade, 2011). Licorice extract also contains mevalonic acid, which enters the synthesis of gibberellins (Moses et al., 2002). AL-Hamdani and AL-Zuhairy (2017) nitrogen enter the formation of chlorophyll as well as the formation of amino acids in the formation of Chloroplast, which increases the leaves content of chlorophyll. Myint et al. (2010) showed that chlorophyll was directly related to the plant content of nitrogen.

Potassium is also associated with many other important phylogenetic functions, including activation of enzymes, regulation of opening and closing of stents, as well as its important role in the synthesis of ATP, where the electrostatic charge in the ATP production sites is closely related to the K^+ (Prajapati and Modi, 2012) and sugars (Van Brunt and Sultenfnss, 1998), water and nutrient transport (Thomas and Thomas, 2009) and protein synthesis and starch (Patil, 2011).

The combination of the licorice extract and the inoculation of the mycorrhizae on the composition of amino acids, especially in the case of a lack of irrigation or dehydration, and the interference of the element nitrogen and potassium religions reduce the presence of amino acids in potato tubers.

Conclusion and recommendation

The 5 days irrigation interval had highly effect on the total yield, while 10 days irrigation period had a significant effect on the tuber hardness, and most of the amino acid content in the tubers. The treatments were significantly affected on all of the studied characters with the exception of starch% in the tubers. The interaction of the 10 days irrigation interval with both of the Mycorrhizal inoculation and Spraying with (2.5 g L^{-1}) KCl + Spraying with (6 g L^{-1}) *Glycyrrhiza glabra* extract recorded significant effects on total soluble solid percentage, tuber hardness and all of the amino acid in the tuber.

Carrying out more investigation on different irrigation intervals as well as more biotic and abiotic treatments to determine their effect on the quantitative and qualitative traits in in different locations and for different years in Sulaimani region to generalize the results and to ensure the potato yield stability. Reduce the use of chemical fertilizers and replace them by increasing the use of different plant extracts at different concentrations according to the recommendations of specialists in that field. The use of

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fungal, bacterial, bio inoculators, and transpiration compounds and potassium salts on potato is recommended to increase the resistance to abiotic stress.

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