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Effect of Different Irrigation Treatments on Yield, and Quality of Potato under North Sinai Conditions

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ABSTRACT

The experiments were conducted to evaluate the effect of two different irrigation treatments, Irrigation levels and Irrigation methods on yield, quality and chemical composion of potato plant (Spunta cultivar), during the seasons of 2020 and 2021. The experiments were conducted at Baloza Research Station, Desert Research Center, North Sinai Governorate, Egypt. The experimental design was a split plot design with three replicates, every replicate included 8 treatments which were the combinations between two drip irrigation mthods (subsurfac drip irrgation SSD and surface drip irigation SD) and four irrigation levels (40%, 60%, 80% and100% of ETo) . The results in the two experimental seasons showed that application of different irrigation levels and irrigation methods treatments affected significantly potato yield, quality and chemical composion. The use of irrigation level 100% of ETo resulted in significantly higher values of potato yield quality and tuber chemical composition, also using subsurface drip irrigation method treatment increase the potato tuber yield quality and tuber chemical composition. Regarding the interaction between irrigation levels and, the highest results of potato tuber yield, quality and tuber chemical composition were obtained by the irrigation level 100% combined with subsurface drip irrigation. The irrigation level 80% treatment was obtained the highest WUE followed by irrigation level 100% treatment, on the other side the sub-surface drip irrigation method SSD was obtained the highest WUE than surface drip irrigation method SD. Regarding the interaction between irrigation levels and irrigation methods treatments, the highest WUE were obtained by SSD with 80% followed by SSD with 60 % treatments.

KEYWORDS: potato, yield, quality, irrigation Levels and subsurface drip irrigation.

1. INTRODUCTION

Potato (*solanum tuberosum* L.) is considered one of the most important vegetables in all over the world. The global cultivated area of potatoes reached amounts to 18132694 hectares, with a total production of 376 million tons (FAO 2021). In Egypt potatoes is classified the fourth vegetable production and potatoes are considered the second most important vegetable crop after tomatoes in terms of cultivated area. The cultivated area of the potato crop 392 thousand acres, with an average production of 11 thousand tons and 600 kilograms, with a total production of 4 million and 200 thousand tons annually including a winter loop of 211 thousand acres, a summer loop of 150 thousand acres, and an indigo loop of 40 thousand acres (Ministry of Agriculture and Land Reclamation 2021).

In general, policies should aim to provide irrigation water in excess of the need for crops. One of the factors for this is the use of drip irrigation, as it helps in rationalizing the excessive use of irrigation water, fertilizers, and pesticides, and thus reduces economic depletion and environmental pollution (Al-Omran and Luki, 2012), (Mattar et al. 2021), and (Abdelhady et al, 2017) indicated that it was possible to save 20% of the irrigation water when growing tomatoes in open fields and using full fertilization rates for the plant in addition to improving production and fruit quality. It is possible to control and rationalize the quantities of fertilizers and slurry added by installing injection units through which fertilizers and slurry are injected into the water network, where one unit or several units can be installed at the head of the irrigation system and before the filters. Chemical fertilizers must also be injected into the center of the water flow slowly to ensure rates dilution and thus the regular distribution of fertilizers (Evans and Waller, 2007), (Jimenez-Bello et al., 2011) El-(Sawy et al. 2022) and (Shrestha et al. 2023). Indicated that it is necessary to understand the hydraulic processes that occur in the central fertilization system in order to obtain the best fertilization management, which helps to improve the distribution of fertilizers.

The study in our hands aims to know the effect of use of different irrigation water treatments on the production and quality of the potato crop and the efficiency of using irrigation water.

2. MATERIALS AND METHODS

This research was conducted at the Experimental Farm of Baloza Research Station (Latitude 31 01 42.01 N; Longitude 32 35 27.89 E); Desert Research Center, North Sinai Governorate, Egypt, during two successive summer growing seasons of 2020 and 2021 to study the effect of irrigation levels and irrigation methods on tuber yield and its quality as well as chemical composition of tubers of potato crop (*Solanum tuberosum* L.) C.V. Spunta.

2.1. Materials

2.1.1. Irrigation

2.1.1.1. Irrigation Source

The irrigation water was from El-salam Canal injected in Trickling system for drip irrigation. One – L was made of several samples taken during first irrigation after 15 days from planting for chemical analysis. The mechanical and chemical analysis of irrigation water were tabulated in Tables (1&2).

Table 1. Chemical analysis of the experimental irrigation water.

	Soluble Cations (meg/100g)				Soluble Anions (meg/100g)				PH	EC (ds/m^2)	SAR	ESP
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Co_3^{2-}	Hco_3^{-}	Cl^{-}	So_4^{2-}				
*Water	8.2	3.5	13.9	0.43	-	6	15.2	4.8	7.23	2.6	5.75	6.73

*Irrigation water source is El-Salam Conduit, North Saini, Egypt.

Table 2. The Local meteorological data and water quantities during 2020 and 2021 growing r seasons.

Month	Temp.	Wind	Rain	ETo	Irrigation Requirement
Unit	Avg.	Speed	Total	Total	100 %
2020	C	m/s	mm	Mm	m^3
January	14	7.05	16.10	1.47	290
February	15	5.92	13.15	1.84	560
March	17	6.30	13.68	2.69	870
April	19	5.61	1.45	3.41	660
Total water irrigation requirements					2380
Month	Temp.	Wind	Rain	ETo	Irrigation Requirement
Unit	Avg.	Speed	Total	Total	100 %
2021	C	m/s	mm	Mm	m^3
January	18	6.22	23.80	1.36	320
February	16	5.92	56.50	1.6	587
March	17	5.97	0.00	2.75	890
April	20	4.80	0.00	3.58	712
Total water irrigation requirements					2509

Irrigation water quantities were about 952 and 1003.6 m^3 for 40 % ETc , 1428 and 1505.4 m^3 for 60 % ETc, 1904 and 2007.2 $m^3$for 80 % Etc and 2380 and 2509 m^3in the 1st and 2nd seasons, respectively.

2.1.1.2. Irrigation systems:-

The irrigation was through drip irrigation network with discharge 4L/h and 30 cm apart between drippers. Two irrigation systems were done, the first, subsurface irrigation system, the network was expended at depth of 30 cm under soil surface. The second was surface irrigation system, the irrigation network was expended on soil surface.

2.1.1.3. Irrigation Requirement:-

The second factor in this experiment was four irrigation water quantity treatments, 40, 60, 80 and 100 % of reference evapotranspiration of crop (ETc) which calculated according to penman - Monteith method (FAO Penman – Monteith equation No.56, 1994), to calculate the irrigation water requirement(IR) by the equation:

$$IR = (ETo * Kc) + LR * 4.2/ Ea$$

Where: -

IR = Irrigation requirement for crop (m^3 $Feddan^{-1}$ day^{-1})

Kc = Crop coefficient (dimensionless).

ETo = Reference crop evapotranspiration (mm day^{-1}).

LR = Leaching requirement (%), assumed 20% of the total applied water.

Ea = Efficiency of the irrigation system, assumed 85% of the total applied water.

4.2 = to convert IR from mm day^{-1} to m^3 $Feddan^{-1}$ day^{-1} (Feddan = 4200 m^2).

According to FAO (1982) the Water Use Efficiency (WUE) was calculated by the equation:-

WUE (Kg m^{-3}) = Yield (kg) / IR (m^3)

2.1.1.4. Soil preparation:

The soil of the experimental field was prepared with two vertical tillage then soil fag with 40cm depth, chicken manure mixed with calcium super phosphate and agricultural sulfur at a recommended dose were applied within fags at depth of 10cm and 10cm of soil had been covered the fertilizers mixture(Table 3).

This experiment concluded 8 treatments which were the combinations between two methods irrigation and four irrigation levels. The treatments were arranged in a split plot design with three replicates. Irrigation methods were arranged in main plot and irrigation methods were arranged in sub plots .The experimental plot was 10.5 m2 (0.6 m width and 17.5 m length). The hoses in the sub-surface treatment

Table 3. Chemical analysis of the experimental Chicken manure.

Sample	pH at 1:10	EC (dS/m) at1:10	O.M (%)	C (%)	C/N	N %	P %	K %	ppm			
									ss	CO	Ni	Pb
Chicken manure	8.10	9.98	35.60	17.80	6.49	2.74	0.763	2.68	*	*	5.85	1.15

were at the 30 cm depth and covered with the soil before the irrigation. After the experimental field was prepared and the irrigation hoses extended whereby the treatment, the whole experiment field was irrigated for one week to organic manure analyzing. The divided sterilized potato tubers were planted on January 15th 2020 and 2021 at 20cm depth and with 30cm apart between hales in wet soil. The experiment field irrigated until sport emergence. Every plot content 52 plants. After 10 days of emergence, the traditional practices was done, i.e. recommended dose of mineral fertilizers, disease and pest control and weed resistance.

3.1. Methods:

3.1.1. Data recorded:-

3.1.1.1. Yield measurement:-

A- Average number of tuber per plant.
B- Average weight of tuber (g).
C- Average tuber weight/plant (kg).
D- Total yield/feddan (ton)- feddan = 4200 m2= 0.42 hectare.

3.1.1.2. Quality measurements:-

A- Average tuber dry weight (g).
B- Average tuber size (cm3).
Which measured by liquid displacement as follow. .

$$V = V_t - V_o$$

Where:-

V = tuber size, V_t = tuber size + liquid size, V_o = liquid size.

C- Average tuber length (cm).
D- Average tuber diameter (cm).

3.1.1.3. Chemical composition of tubers:

E- Total soluble solids (TSS), determinate by refractometer.
F- Total carbohydrates percentage it was determined in tuber dry mater according to Shaffer and Hartman as described in A.OA.C. (1970).
G- Total proteins percentage in tuber was calculated from previously determined total nitrogen content in tuber by multiplying N-values by 6.25.

3.2.2.2 . Experimental design and Statistical analysis:-

The collected data were statistically analyzed by the analysis of variance using Costat package. The Comparison among means was done using ANOVA test the p=0.05 level of significance. The data were statistically analyzed according to Sendecor & Corchran (1980).

3. RESULTS AND DISCUSSION

Illustrated data in Table (4) shows that the different drip irrigation methods (subsurface (SSD) and surface (SD) drip irrigation systems) treatments affected significantly on the potato yield parameters (average number of tubers/plant, average weight of tuber, average tuber weight/plant and total yield/feddan), where the highest data of potato yield parameters were recorded with subsurface (SSD) drip irrigation system treatment. On the other hand, the lowest data were recorded with the surface (SD) drip irrigation system treatment, this data found in the two cultivated seasons with significant differences between all the treatments.

The potato plant yield parameters under different drip irrigation methods in the second season were higher than the first season; the maximum average number of tubers of potato plant was 7.57 tubes/plant in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average number of

Table 4. Effect of the different drip irrigation methods on yield parameters of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrigation Methods	Average number of Tubers		Average weight of tuber (g)		Tuber weight/plant (kg)		Total yield/fed (ton)		Water Use Efficiency (Kg/m3)	
	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
SD	4.77 b	4.79 b	53.07b	65.69b	0.253b	0.315b	5.06b	6.29 b	2.13b	2.51b
SSD	7.45 a	7.57 a	78.82a	83.27a	0.587a	0.630a	11.74a	12.61a	4.93a	5.03a

tuber of potato plant was 4.79 tubes/plant by the surface drip irrigation method (SD) treatment.

The maximum average weight of tuber of potato plant was 83.27 g/tuber in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average weight of tuber of potato plant was 65.69 g/tuber by the surface drip irrigation method (SD) treatment.

The potato plant yield parameters under different drip irrigation methods in the second season were higher than the first season; the maximum average number of tubers of potato plant was 7.57 tubes/plant in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average number of tuber of potato plant was 4.79 tubes/plant by the surface drip irrigation method (SD) treatment.

The maximum average weight of tuber of potato plant was 83.27 g/tuber in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average weight of tuber of potato plant was 65.69 g/tuber by the surface drip irrigation method (SD) treatment.

The maximum average tuber weight/plant of potato plant was 0.630 kg/plant in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average tuber weight/plant of potato plant was 0.315 kg/plant by the surface drip irrigation method (SD) treatment.

The maximum total yield/feddan of potato plant was 12.61 tons/fed in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest total yield of potato plant was 6.29 tons/fed by the surface drip irrigation method (SD) treatment.

Using subsurface drip irrigation method SSD treatment increase the value of WUE than surface drip irrigation method SD treatment in the two growing seasons.

Presence data in Table (5) reveal the different drip irrigation methods (subsurface (SSD) and surface (SD) drip irrigation systems) treatments affected significantly on potato tubers quality parameters (average tuber dry weight, tuber average size, tuber average length and tuber average diameter), where the highest data of potato tubers quality parameters were recorded with subsurface (SSD) drip irrigation system treatment. On the other hand, the lowest data were recorded with the surface (SD) drip irrigation system treatment, this data found in the two seasons with significant differences between all the treatments.

The potato tubers quality parameters under different drip irrigation methods in the second season were higher than the first season; the maximum average potato tuber dry weight was 21.88 g/tuber in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average potato tuber dry weight was 21.24 g/tuber by the surface drip irrigation method (SD) treatment.

The maximum average potato tuber size was 82.47 cm^3/tuber in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average potato tuber size was 80.61 cm^3/tuber by the surface drip irrigation method (SD) treatment.

Table 5. Effect of the different drip irrigation methods on the potato tubers quality parameters (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrigation methods	Average Tuber Dry Weight (g)		Average Tuber Size (cm^3)		Average Tuber Length (cm)		Average Tuber Diameter (cm)	
	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
SD	19.27 b	21.24 b	71.50 b	80.61 b	7.23 b	7.78 b	5.17 b	6.19 b
SSD	19.84 a	21.88 a	77.00 a	82.47 a	8.27 a	8.98 a	6.21 a	7.70 a

The maximum average potato tuber length was 8.98 cm in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average potato tuber length was 7.78 cm by the surface drip irrigation method (SD) treatment.

The maximum average potato tuber diameter was 7.70 cm in the second season by the subsurface drip irrigation method (SSD) treatment while the lowest average potato tuber diameter was 6.19 cm by the surface drip irrigation method (SD) treatment.

Illustrate data in Table (6) shows that the different drip irrigation methods (subsurface (SSD) and surface (SD) drip irrigation systems) treatments affected significantly on the tuber chemical quality of potato plant (% of carbohydrate in tuber, tuber content of TSS, and total protien), the tuber chemical quality of potato plant under different drip irrigation methods in the second season were higher than the first season.

The highest values of carbohydrate % in tuber and content of TSS on potato tubers were recorded by using surface drip irrigation method (SD) while the lowest values were by using subsurface drip irrigation method (SSD) with significant differences between them, the same results were found in the second season. Similar results have been reported by DU Ya-dan et al. (2017).

Table 6. Effect of the different drip irrigation methods on tuber chemical quality of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrig. Meth.	Total carbohydrate contents in dry tubers (%)		TSS		Total protein (%) in tubers	
	1st. S	2nd S	1st. S	2nd S	1st S	2nd S
SD	19.01 a	20.81 a	5.06 a	5.96 a	1.40 b	1.63 b
SSD	18.89 b	20.66 b	4.95 b	5.89 b	1.77 a	2.08 a

The maximum carbohydrate % in tuber of potato plant was 20.81 % in the second season by the surface drip irrigation method (SD) treatment while the lowest % of carbohydrate in tuber of potato plant was 20.66 % by the subsurface drip irrigation method (SSD) treatment with significant difference between the treatments.

The maximum tuber content of TSS of potato plant was 5.96 in the second season by the surface drip irrigation method (SD) treatment while the lowest tuber content of TSS of potato plant was 5.89 by the subsurface drip irrigation method (SSD) treatment with significant difference between the treatments. Similar results have been reported by DU Ya-dan et al. (2017).

Data in Table (7) reveal that the effect of different irrigation levels (40%, 60%, 80% and 100% of ETo) on the potato yield parameters (average number of tubers/plant, average weight of tuber, average tuber weight/plant and total yield/feddan). It is clear from the data that different irrigation levels treatments affected significantly on potato yield parameters in the two successful growing seasons, where the highest values of yield parameters were recorded by the irrigation level 100% of ETo treatment, followed by irrigation level 80% of ETo treatment and irrigation level 60% of ETo

Table 7. Effect of the different irrigation levels on yield parameters of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrigation levels (%)	Average number of Tubers		Average weight of tuber (g)		Average tuber weight/plant (kg)		Total yield/fed (ton)		Water Use Efficiency (Kg/m3)	
	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
40	4.09d	4.61d	45.54d	48.77d	0.186d	0.225d	3.73 d	4.48 d	4.03 d	4.46 d
60	5.62c	5.47c	58.63c	63.70c	0.330c	0.348c	6.59 c	6.97 c	4.60 c	4.62 c
80	7.18b	6.95b	77.05b	82.79b	0.553b	0.575b	11.06b	11.51b	5.80 a	5.73 a
100	7.56a	7.68a	82.55a	84.66a	0.624a	0.650a	12.48a	13.00a	5.24b`	5.18 b

respectively, and the lowest values recorded with the irrigation level 40% of ETo treatment

The potato plant yield parameters under different irrigation levels in the second season were higher than the first season; the maximum average number of tubers of potato plant was 7.68 tubes/plant in the second season by the irrigation level 100% of ETo treatment while the lowest average number of tubers of potato plant was 4.61 tubes/plant by the irrigation level 40% of ETo treatment. Moderate responses the average number tubers of potato plant were recorded by the irrigation levels 60% and 80% of ETo (5.47 and 6.95 tubers/plant) respectively.

The maximum average weight tuber of potato plant was 84.66 g/tuber in the second season by the irrigation level 100% of ETo treatment while the lowest average weight tuber of potato plant was 48.77 g/tuber by the irrigation level 40% of ETo treatment. Moderate responses the average weight of tuber of potato plant were recorded by the irrigation levels 60% an 80% of ETo (63.70 and 82.79 g/tuber) respectively.

The maximum average tuber weight/plant of potato plant was 0.650 kg/plant in the second season by the irrigation level 100% of ETo treatment while the lowest average tuber weight/plant of potato plant was 0.225 kg/plant by the irrigation level 40% of ETo treatment. Moderate responses the average tuber weight/plant of potato plant were recorded by the irrigation levels 60% and 80% of ETo (0.348 and 0.575 kg/plant) respectively.

The previous table shows that increasing irrigation quantity over irrigation level 80% led to decrease in WUE for all irrigation levels treatments. The highest WUE was obtained by irrigation level 80% followed by irrigation level 100% treatment, with significant differences between the all treatments. The lower WUE recorded by the irrigation level 40% treatment.

The maximum total yield of potato plant was 13.00 tons/fed in the second season by the irrigation level 100% of ETo treatment while the lowest total yield of potato plant was 4.48 tons/fed by the irrigation level 40% of ETo treatment. Moderate responses the total yield of potato plant were recorded by the irrigation levels 60% and 80% of ETo (6.97 and 11.51 tons/fed) respectively. Similar results have been reported by Shrestha et al. (2023), Juan Yin et al. (2023), El-Sawy et al. (2022), Mattar et al. (2021), Robert et al. (2020), Elzner et al. (2018), Dash et al. (2018), Badr et al. (2010) and Hiekal (2009).

Table (8) shows the effect of different irrigation levels (40%, 60%, 80% and 100% of ETo) on potato tubers quality parameters (average tuber dry weight, tuber average size, tuber average length and tuber average diameter), It is clear from the data the different irrigation levels treatments affected on potato tubers quality parameters in the two growing seasons, where the highest values of potato tubers quality parameters recorded by the irrigation level 100% of ETo treatment, followed by irrigation level 80% of ETo treatment and irrigation level 60% of ETo respectively, and the lowest values recorded with the irrigation level 40% of ETo treatment with significant differences between all the treatments in both growing seasons.

Table 8. Effect of the different irrigation levels on the potato tubers quality parameters (*Solanum tuberosum* L.), during the two successive cultivated seasons.

Irrigation levels (%)	Average Tuber Dry Weight (g)		Average Tuber Size (cm^3)		Average Tuber Length (cm)		Average Tuber Diameter (cm)	
	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
40	17.75 d	19.41 d	64.08 d	71.03 d	6.63 d	7.16 d	4.56 d	5.34 d
60	19.16 c	21.10 c	73.25 c	78.00 c	7.29 c	7.86 c	5.24 c	6.26 c
80	20.45 b	22.59 b	78.05 b	87.63 b	8.29 b	8.99 b	6.22 b	7.73 b
100	20.89 a	23.15 a	81.63 a	89.50 a	8.79 a	9.50 a	6.73 a	8.44 a

The potato tubers quality parameters under different irrigation levels in the second season were higher than the first season; the maximum average potato tuber dry weight was 23.15 g/tuber in the second season by the irrigation level 100% of ETo treatment while the lowest average potato tuber dry weight was 19.41 g/tuber by the irrigation level 40% of ETo treatment. Moderate responses of the average potato tuber dry weight were recorded by the irrigation levels 60% and 80% of ETo (21.10 and 22.59 g/tuber) respectively.

The maximum average potato tuber size was 89.50 cm3/tuber in the second season by the irrigation level 100% of ETo treatment while the lowest average potato tuber size was 71.03 cm3/tuber by the irrigation level 40% of ETo treatment. Moderate responses the average potato tuber size were recorded by the irrigation levels 60% an 80% of ETo (78.00 and 87.63 cm3/tuber) respectively.

The maximum average potato tuber length was 9.50 cm in the second season by the irrigation level 100% of ETo treatment while the lowest average potato tuber length was 7.16 cm by the irrigation level 40% of ETo treatment. Moderate responses the average potato tuber length was recorded by the irrigation levels 60% an 80% of ETo (7.86 and 8.99 cm) respectively.

The maximum average potato tuber diameter was 8.44 cm in the second season by the irrigation level 100% of ETo treatment while the lowest average potato tuber diameter was 5.34 cm by the irrigation level 40% of ETo treatment. Moderate responses the average potato tuber diameter was recorded by the irrigation levels 60% an 80% of ETo (6.26 and 7.73 cm) respectively.

Similar results have been reported by Al-Hamed et al. (2017) and El-Sawy et al. (2022).

Data in Table (9) reveal that the effect of different irrigation levels (40%, 60%, 80% and 100% of ETo) on the tuber chemical quality of potato tubers (% of carbohydrate in tuber, tuber content of TSS and protien). It is clear from the data the different irrigation levels treatments affected significantly on the tuber chemical quality of potato plant in the two successful growing seasons, where the highest values of the tuber chemical quality of potato were recorded in the second season than the first season.

The highest values of carbohydrate % in tuber and content of TSS of potato were recorded with the irrigation level 40 % of ETo followed by the irrigation level 60 % of ETo while the lowest values were by using the irrigation level 100 % of ETo treatments with significant differences between them, the same results were found in the second season.

The maximum results of carbohydrate % in tuber of potato plant was 22.28 % in the second season by the irrigation level 40 % of ETo treatment while the lowest carbohydrate % in tuber of potato plant was 19.04 % by the irrigation level 100 % of ETo treatment with significant difference between the treatments.

Table 9. Effect of the irrigation levels on tuber chemical quality of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrigation levels (%)	Total carbohydrate contents in dry tubers (%)		TSS		Total protein (%) in tubers	
	1st. S	2nd S	1st. S	2nd S	1st S	2nd S
40	20.25 a	22.28 a	6.00 a	6.94 a	1.22 d	1.49 d
60	19.51 b	21.40 b	5.08 b	6.03 b	1.42 c	1.72 c
80	18.51 c	20.22 c	4.80 c	5.66 c	1.74 b	1.95 b
100	17.54 d	19.04 d	4.14 d	5.05 d	1.96 a	2.26 a

The maximum tuber content of TSS of potato plant was 6.94 in the second season by the irrigation level 40 % of ETo treatment while the lowest tuber content of TSS of potato plant was 5.05 by the irrigation level 100 % of ETo treatment with significant difference between the treatments.

The maximum chlorophyll content of potato plant was 43.66 in the second season by the irrigation level 100 % of ETo treatment while the lowest chlorophyll content of potato plant was 36.88 by the irrigation level 40 % of ETo treatment with significant difference between the treatments.

Concerning the effect of the interaction between different drip irrigation methods (subsurface SSD and surface SD drip irrigation systems) and different irrigation levels (40%, 60%, 80% and 100% of ETo) on the potato yield parameters (average number of tubers/plant, average weight of tuber, average tuber weight/plant and total yield/fed) illustrated in Table (10).

Table 10. Effect of the interaction between different drip irrigation methods with different irrigation levels on yield parameters of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrig. Sys.	Irrigation levels (%)	Average number of Tubers		Average weight of tuber (g)		Average tuber weight/plant (kg)	
		1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
SD	**40**	2.79 h	3.25 h	32.98 g	48.88 h	0.092 h	0.159 h
	60	4.18 g	4.20 g	46.23 f	66.06 g	0.193 g	0.277 g
	80	5.80 e	5.39 f	61.92 d	72.69 e	0.359 e	0.392 e
	100	6.20 d	6.34 d	71.15 c	75.15 c	0.441 d	0.476 d
SSD	**40**	5.39 f	5.98 e	58.11 e	60.66 f	0.313 f	0.363 f
	60	7.05 c	6.74 c	71.03 c	81.35 d	0.501 c	0.548 c
	80	8.55 b	8.52 b	92.19 b	92.89 b	0.788 b	0.791 b
	100	8.81 a	9.02 a	93.95 a	94.17 a	0.828 a	0.849 a

Irrig. Sys.	Irrigation levels (%)	Total yield/fed (ton)		Water Use Efficiency (Kg/m^3)	
		1st. S	2nd S	1st. S	2nd S
SD	**40**	1.84 h	3.18 g	1.99 c	3.17 d
	60	3.86 g	5.55 f	2.70 b	3.69 c
	80	7.18 e	7.84 e	3.77 a	3.91 a
	100	8.82 d	9.53 d	3.71 a	3.80 b
SSD	**40**	6.26 f	7.25 e	6.77 d	7.23 b
	60	10.02 c	10.97 c	7.02 b	7.29 b
	80	15.76 b	15.83 b	8.28 a	7.89 a
	100	16.55 a	16.99 a	6.95 c	6.77 c

Data show that the highest values of average number of tubers/plant recorded by the interaction between the subsurface SSD and surface SD drip irrigation methods combined with the irrigation level 100 % treatments respectively, following by the interaction between the subsurface SSD and surface SD drip irrigation methods combined with the irrigation levels 80 % treatments respectively, following by the interaction between the subsurface SSD and surface SD drip irrigation methods combined with the irrigation levels 60 % treatments respectively, with significant differences in the two cultivated seasons, while the lowest results recorded by in the interaction among surface drip irrigation method with the irrigation level 40% of ETo treatment in the both cultivated seasons. On the other hand, the combination between SSD with the irrigation levels treatments gave the highest values of WUE, the highest value of WUE recorded by th combination between irrigation method SSD with irrigation level 80% followed by the irrigation method SSD with 60% with significant differences in the first season while ws no significant differences between hem in the second season.

These results are in harmony with the findings of other researches Mustafa et al. (2017), Abuarab et al. (2019), Abdelshafy et al. (2021) and Mattar et al. (2021).

It is clear from the previous table the combination between the different irrigation methods and different irrigation levels on the potato yield parameters resulted that using of the subsurface drip irrigation method (SSD) with the different irrigation levels improved the potato yield parameters especially in the second season than the first season with significant difference between the treatments; Also, the best results of the different irrigation levels treatments obtained by using SSD with 100 % of ETo and using SSD with 80% of ETo, respectively.

Concerning the effect of the interaction between different drip irrigation methods (subsurface (SSD) and surface (SD) drip irrigation systems) and different irrigation levels (40%, 60%, 80% and 100% of ETo) on potato tubers quality parameters (average tuber dry weight, tuber average size, tuber average length and tuber average diameter), were illustrated in Table (11).

Data obtain that the highest values of yield parameters recorded by the interaction among subsurface drip (SSD) irrigation method combined with irrigation level 100% of ETo and irrigation level 80% of ETo treatments respectively, followed by surface drip (SD) irrigation method with irrigation level 100% of ETo and irrigation level 80% of ETo treatments respectively, followed by subsurface (SSD) and surface (SD) irrigation methods with irrigation level 60% of ETo treatments respectively, while the lowest results recorded by in the interaction among surface drip irrigation method with the irrigation level 40% of ETo treatment, with significant differences between all the treatments in the two cultivated seasons. These results are in harmony with the findings of other researches Gad et al. (2012).

It is clear from the previous table the combination between the different irrigation methods and different irrigation levels on improved the potato tubers quality parameters, the highest values were resulted by using of the subsurface drip irrigation method (SSD) with the different irrigation levels 100 % of ETo and using SSD with 80% of ETo, respectively especially in the second season than the first season with significant difference between the treatments; Also, the best results of the different irrigation levels treatments obtained by using SSD.

Concerning the effect of the interaction between different drip irrigation methods (subsurface SSD and surface SD drip irrigation systems) and different irrigation levels (40%, 60%, 80% and 100% of ETo) on the tuber chemical quality of potato plant (% of carbohydrate in tuber, tuber content of TSS and total protein) were illustrated in Table (12).

Data show that the highest values of carbohydrate % in tuber, tuber content of TSS recorded by the interaction between the surface drip irrigation method SD and the subsurface

Table 11. Effect of the interaction between the different drip irrigation methods with the different irrigation levels on the potato tubers quality parameters (*Solanum tuberosum* L.), during the two successive cultivated seasons.

Irrig. Sys.	Irrig. levels	Tuber Dry Weight (g)		Tuber Average Size (cm^3)		Tuber Average Length (cm)		Tuber Average Diameter (cm)	
		1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
SD	40	17.56 h	19.23 g	61.77 g	70.16 g	6.16 h	6.63 h	4.09 h	4.70 h
	60	18.72 f	20.58 e	71.47 e	76.92 e	6.46 g	6.98 g	4.40 g	5.04 g
	80	20.13 d	22.26 c	74.51 d	86.90 c	7.84 e	8.47 e	5.78 e	7.09 e
	100	20.68 c	22.90 b	78.27 c	88.48 b	8.46 c	9.03 c	6.40 c	7.95 c
SSD	40	17.94 g	19.59 f	66.39 f	71.90 f	7.09 f	7.69 f	5.04 f	5.99 f
	60	19.60 e	21.62 d	75.03 d	79.08 d	8.13 d	8.74 d	6.07 d	7.49 d
	80	20.76 b	22.92 b	81.58 b	88.35 b	8.73 b	9.52 b	6.67 b	8.38 b
	100	21.10 a	23.40 a	85.00 a	90.53 a	9.13 a	9.98 a	7.06 a	8.93 a

Table 12. Effect of the interaction between the different drip irrigation methods with the different irrigation levels on tuber chemical quality of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Irrig. Sys.	Irrig. levels	Total carbohydrate contents in dry tubers (%)		TSS		Total protein (%) in tubers	
		1st. S	2nd S	1st. S	2nd S	1st S	2nd S
SD	40	20.31 a	22.36 a	6.09 a	6.98 a	1.02 h	1.26 h
	60	19.59 c	21.50 c	5.13 c	6.07 c	1.10 g	1.33 g
	80	18.53 e	20.23 e	4.80 e	5.68 e	1.58 e	1.77 e
	100	17.62 g	19.14 g	4.23 f	5.10 f	1.87 c	2.16 b
SSD	40	20.18 b	22.40 b	5.91 b	6.91 b	1.41 f	1.72 f
	60	19.43 d	21.30 d	5.03 d	6.00 d	1.74 d	2.10 d
	80	18.50 f	20.20 f	4.80 e	5.65 e	1.89 b	2.13 c
	100	17.46 h	18.94 h	4.05 g	5.00 g	2.04 a	2.36 a

drip irrigation method SSD respectively combined with irrigation level 40% of ETo treatments, followed by the interaction between surface drip irrigation method SD and subsurface drip irrigation method SSD respectively combined with irrigation level 60% of ETo treatments, followed by the interaction between surface drip irrigation method SD and subsurface drip irrigation method SSD respectively combined with irrigation level 80% of ETo treatments, while the lowest results recorded by the interaction between surface drip irrigation method SD and subsurface drip irrigation method SSD respectively combined with irrigation level 100% of ETo treatments with significant differences in the two cultivated seasons.

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الملخص العربي

تأثير معاملات الري المختلفة علي محصول وجودة درنات البطاطس تحت ظروف شمال سيناء

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أجريت هذه التجربة لدراسة تأثير مستويات مختلفة من الاحتياجات المائية وطرق الري بالتنقيط في كمبة المحصول وجودته والتركيب الكيميائي لدرنات نبات البطاطس (صنف سبونتا) خلال موسمي ٢٠٢٠ و ٢٠٢١. أجريت التجارب في محطة أبحاث بالوظة مركز بحوث الصحراء، محافظة شمال سيناء، مصر. وكان التصميم التجريبي عبارة عن تصميم قطع منشقة مرة واحدة بثلاث مكررات، تضمنت كل مكررة ٨ معاملات عبارة عن توليفات بين طريقتى رى (الري بالتنقيط تحت السطحي والتنقيط السطحي). و اربع لمستويات ري (٤٠%، ٦٠%، ٨٠% و١٠٠% من البخر نتح المرجعي) أظهرت النتائج في الموسمين التجريبيين أن تطبيق مستويات الري المختلفة ومعاملات طرق الري أثرت بشكل معنوي على إنتاجية البطاطس وجودتها وتركيبها الكيميائي. أدى استخدام مستوى الري ١٠٠% إلى زيادة معنوية في جودة محصول درنات البطاطس والتركيب الكيميائي للدرنات، كما أدى استخدام طريقة الري بالتنقيط تحت السطح إلى زيادة جودة محصول درنات البطاطس والتركيب الكيميائي للدرنات. وفيما يتعلق بالتفاعل بين مستويات الري ومعاملات طريقة الري، فقد تم الحصول على أعلى النتائج في محصول درنات البطاطس وجودتها وتركيبها الكيميائي عند مستوى الري ١٠٠% مع الري بالتنقيط تحت السطحي.
مستوى الري ٨٠% اعطت أعلى قيمة من كفاءة استخدام المياه تليها مستوى الري ١٠٠%، ومن ناحية اخري اعطت طريقة الري بالتنقيط تحت السطحي اعلي قيمة من كفاءة استخدام المياه عن طريقة الري بالتنقيط السطحي. فيما يتعلق بالتفاعل بين مستويات الري ومعاملات طرق الري، تم الحصول على أعلى قيمة من كفاءة استخدام المياه بواسطة الري بالتنقيط تحت السطحي مع مستوى الري ٨٠% تليها الري بالتنقيط تحت السطحي مع مستوي الري ٦٠% المعاملات الاخري.

الكلمات المفتاحية: البطاطس، المحصول،جودة الدرنات،مستويات الري،الري بالتنقيط تحت السطحي.