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Effect of Drip Irrigation Systems, Water Regimes and Irrigation Frequency on Growth and Quality of Potato under Organic Agriculture in Sandy Soils

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Abstract: Drip irrigation frequency is a recent concept where small frequent irrigation applications are applied to saturate the soil and meet the plant water requirements. A field experiment was carried out during the two summer growing seasons 2006 and 2007, it was executed in Abo-Ghaleb farm, Cairo- Alex. Rood, 60 Km away from Cairo in sandy soil. Seed tubers were planted on 2 th of February and harvested on 28 th of May in the two seasons, and a well water was used as irrigation source having EC 1.9 ds/m. Soil samples were taken up to 45 cm depth. Diameter of the lateral line was 16 mm, with dripper discharge of 2 l/h. The present investigation aimed to study the effect of drip irrigation systems, water regimes and irrigation frequency on the growth and quality of potato under organic agriculture. The following parameters were studied to evaluate the performance of the studied factors; and the interaction between them (1) growth of potato, (2) quality of potato. The results indicated that growth and quality of potato were improved by increasing irrigation frequency under 100% and 75% from water requirements and decreased at 50 % from water requirements where**:** growth (shoot/Plant and Leaves area/Plant) where improved by increasing number of irrigation pulses especially at (100% and 75% from water requirements) at all sampling dates. Shoot/Plant increased from 38.22 (gm) under continuous drip irrigation to maximum value, where it became 46.12 (gm) after applying pulse technique with 4 pulses at 100 % from water requirements under subsurface drip irrigation at 100 days from sowing, Also, leaves area/plant increased from 1668 (cm^2) under continuous drip irrigation to maximum value, where it became 1875 (cm^2) under the same conditions. Dry matter, specific density and total carbohydrates of tubers increased from 14.73%, 1.0540 gm/cm^3, 40.52% under continuous drip irrigation to maximum values, where it become 18.99%, 1.0742 gm/cm^3, 45.58% respectively after applying drip irrigation frequency with 4 times/day at 100% from water requirements under subsurface drip irrigation.

Kew words: Drip irrigation, water regimes, irrigation frequency, potato, organic agriculture and sandy soils

INTRODUCTION

Potato *(Solanum tuberosum L.)* is considered one of the most important vegetable crops grown in Egypt as well as in the whole world. It occupies a great figure in local consumption and export. The performance of any crop depends not only on its genetic characteristics but also on the surrounding environmental conditions particularly methods of irrigation and water supply. Therefore, growers have to adopt modern techniques of cultivation. Irrigation systems such as surface drip irrigation (SDI) and subsurface drip irrigation (SSDI) are practiced for increasing yield and quality of most vegetable crops.

Using modern irrigation systems (surface and subsurface drip) in growing vegetable crops led to increase in growth and quality of fruits (Gengoglan et al., 2006 and El-Shawadfy, 2008).

Increasing number of irrigations, levels of field capacity, irrigation amounts, pan evaporation ratios and/ or potential evapotranspiration (ETo) up to the maximum level increased growth parameters; i.e. leaf area, total plant dry matter (Fatthallah and Gawish, 1997& Mahmoud, 2000 on peas, and Abdel-Mawgoud, 2006 & El-Shawadfy, 2008 on beans). Moreover, Increasing irrigation level increased pod quality of beans (Al – Kaisi et al., 1999; Amer et al., 2002; Metin et al., 2005, Abdel-Mawgoud, 2006; El-Shawadfy, 2008 and El-Noemani et al., 2009).

Irrigation frequency is one of the most important factors in drip irrigation scheduling. Due to the differences in soil moisture and wetting pattern, crop yields may be different when the same quantity of water

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is applied under different irrigation frequencies. High irrigation frequency might provide desirable conditions for water movement in soil and for uptake by roots (Segal *et al*., 2000). Several experiments have shown positive responses in some crops to high frequency drip irrigation (Freeman *et al*., 1976; Segal *et al*., 2000; Sharmasarkar *et al*., 2001). The benefits of Irrigation frequency method, such as reducing surface soil water evaporation, decreasing fertilizers leaching, enhancing yield and so on, have been documented by different researchers . Drip irrigation with over irrigation, valuable nutrients may be leached out of the root zone and become unavailable for the plants, while contaminating the groundwater (Zin El-Abedin, 2006). The advantages of frequency are that plant growth is generally greater than with standard irrigation and lower fertilizer rates can be used (Dole, 1993). To schedule irrigation, we have to compare the amount of water available in the crop root zone with the tree's daily water requirement. If the daily water requirement exceeds the amount of water that can be held in the root zone, you will need to irrigate more than once a day. If the soil can hold more than the daily water requirement there is an option of irrigating when the available water is depleted (this may be every second or third day), daily or several times a day (Helen, 2007). Using drip irrigation frequency with organic agriculture if we want to get a major utilization from organic agriculture. Based on reports from other states (where soil types are different), it is often believed that the size of the wetted zone can be increased if irrigation is frequent. (Eric *et al*., 2004). Pulse irrigation system, irrigating amount and timing are the objectives for reducing run off, decreasing percolation of water beneath the root zone and reducing water evaporation after irrigation. (El-Gindy and Abdel Aziz, 2001). High frequency irrigation enhanced potato tuber growth and water use efficiency. (Feng-Xin *et al*., 2006). Total potato tuber yield was highest for the Soil Water Balance scheduling method. Irrigation frequency influenced yield differently for the different scheduling methods. Tuber relative density was improved by pulse irrigation**.** Potatoes are largest horticultural export crop in Egypt. In most recent years the European Union has accounted for about 70% - 90% of Egyptian potato exports. (Brian, 2001). The aim of the present work was study the effect of drip irrigation systems, water regime and drip irrigation frequency under organic agriculture for improving growth and quality of potato under Egyptian growing conditions. To achieve the aim of present study the effect of drip irrigation frequency was studied on: (1) growth of potato plants and (2) quality of potato tubers.

MATERIALS AND METHODS

Materials:

Physical Properties of Soil and Chemical Analysis of Soil and Irrigation Water:

Some physical and chemical characters of soil and analysis of irrigation water for experimental site, were determined, i.e.; soil texture, field Capacity, wilting point, bulk density, pH and EC and were sandy, 10 %, 3.5 %, 1.57 g/cm^3, 7.6 and 3.5 (ds/m), respectively and pH and EC were 7.55, 1.9 (ds/m) for irrigation water, respectively.

b. Potato Variety:

Spunta variety Netherland production was used as an experimental material.

2. Methods:

a. Experimental Site:

The field experiments were carried out during two summer growing seasons 2006 and 2007 they it executed in Abo-Ghaleb farm, Cairo- Alex. Rood, 60 km away from Cairo and the soil was sandy. Seed tubers were planted on 2 nd of February and harvested on 28 th of May in the two seasons.

b. Fertilization Method and Bio-fertigation:

Three kinds of fertilizers were used in the experiments . The First was Microbin **(**bio fertilizers). It was a commercial product purchased by the General Authority of Agriculture Funds and Equalization. The second was compost which contented, 0.91 % nitrogen, 0.85% phosphorus and 0.90% potassium in addition to other elements. The third was compost tea. Fertilizer requirements of potato crop were added according to the recommendation of Ministry of Agriculture and Land Reclamation. The recommended dose of fertilizer for potato as a Microbin was 11 kg from Microbin mixed with one ton from seed tubers directly before planting. Actual amount from applied compost were 24.72 ton/fed. The compost was applied 20 days before planting. Bio-fertigation, adding compost tea which was prepared by using water at a rate of 100 litter of water for each 20 kg of compost and stored for 48 hrs then compost tea was taken and injected in drip irrigation network weekly.

c. Experimental Design and Treatments:

The experimental design was split-split plot with three replications. Irrigation systems, water regime treatments, and pulse irrigation treatments were put in main plots, sub main plots and sub-sub main plots, respectively. Two irrigation systems were selected to irrigate potato plants. The first was surface drip irrigation "SDI" built-in drip lines system (2 l/h emitter's discharge) with 30 cm emitters spacing. Polyethylene laterals with diameter of 16 mm were used at 70 cm spacing the second system is subsurface drip irrigation "SSDI", the same practices used for laterals but they were fixed at 15 cm depth under soil surface. Three water application rates were applied for irrigating potato crop: 50, 75 and 100% from crop water requirements "Etc". Fig.(1) shows the layout of irrigation systems with the experimental design. Three types of frequency irrigation or pulse irrigation (2 times per day, 3 times per day and 4 times per day and time-off between pulses was 30 minutes) with continuous drip irrigation (one time per day).

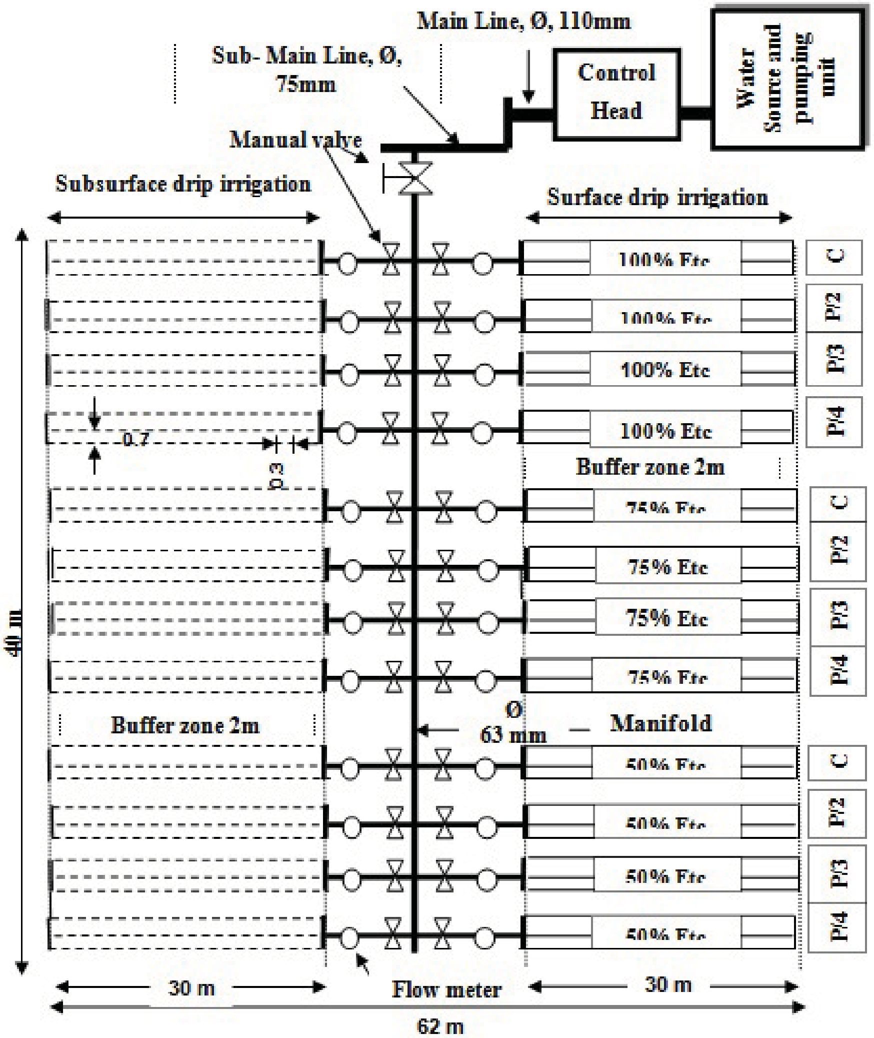

Fig. 1: Layout of irrigation systems with experimental design.

d. Estimation of the Total Irrigation Water:

The total irrigation water for potato crop was estimated according to the meteorological data of the Central Laboratory for Agricultural Climate (CLAC) as shown in fig. (2), the volume of applied water increased with the growth of the plant then declined at the end of the growth season. The seasonal irrigation water applied was 3476 m^3/fed.

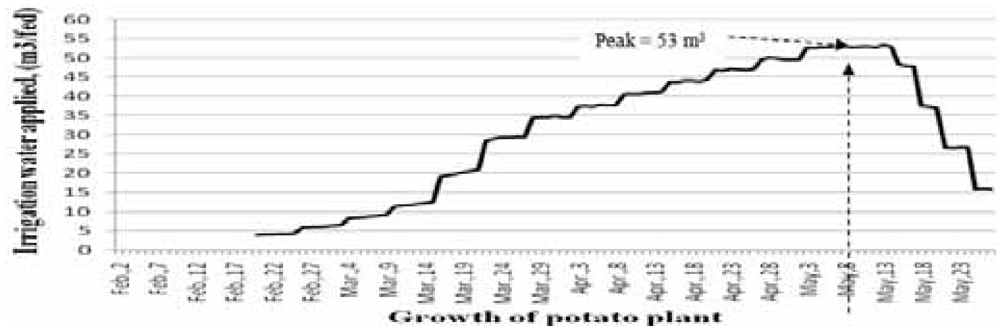

Fig. 2: The relation between growth of potato plant and irrigation water applied

e. Plant Growth Characters:

A random samples of plants were taken at 60, 80 and 100 day after planting for determination of the following growth characters; shoot dry weight /plant and leaves area/plant.

f. Determination of Quality of Potato Tubers:

A random sample of 20 tubers was selected from each experimental unit then washed, dried and cut into small pieces, for determination of dry matter content, specific density and total carbohydrates, as following: Tuber dry matter content was determined after drying in an oven at $70C^0$ for 72 hours using the standard methods as illustrated by A.O.A.C. (1990). Tuber specific density "TSD" was measured according to Burton(1984) method and was calculated from following equation: TSD, (g/cm^3) = ((Dry matter content-24.182)/211.04)+1.0988 while tuber total carbohydrates "TTC" was determined (as glucose) after acid hydrolysis and spectro photometrically measured using phenol sulfuric acid reagent according to Dubbois *et al*. (1956).

RESULTS AND DISCUSSION

Effect of Drip Irrigation Systems:
Growth of Potato:

Table (1) showed the effect of drip irrigation systems on growth of potato. There are significant differences in values of growth parameters of potato under SDI and SSDI. dry Shoot/plant under SSDI is better than SDI. It was 36.19 and 38.32 (g) under SDI and SSDI respectively at 100 days after sowing. In addition, leaves area /plant under SSDI was better than SDI. It was 1625 and 1672 (cm^2) under SDI and SSDI, respectively at 100 days after sowing. There are significant differences in values of growth parameters of potato under SDI and SSDI and this may be due to the salt distribution in the soil profile in the SSDI which was better than that of the SDI in the sandy soil since it decreased the salt harmful effect in the root zone and the evaporation from the soil surface. These results are agreement with those obtained by El-Tantawy (2000); Gengoglan et al.(2006) and El-Shawadfy(2008) who concluded that using modern irrigation systems (surface and subsurface drip) in growing vegetable crops led to increase in growth parameters.

Table 1: Effect of drip irrigation systems on Growth of potato average of the two growing seasons.

Irrigation Systems	Dry weigh / plant (g)			Leaves area/plant (cm^2)		
	60 days after sowing	80 days after sowing	100 days after sowing	60 days after sowing	80 days after sowing	100 days after sowing
surface drip irrigation	20.11	28.15	36.19	971	1297	1625
subsurface drip irrigation	21.39	29.86	38.32	1001	1336	1672
L.S.D. at 5%	0.17	0.15	0.23	18	N.S.	21

Quality of Potato:

Table (2) showed the effect of drip irrigation systems on quality of potato. There are significant differences in values of quality parameters of potato under SDI and SSDI. Dry matter and specific density under SSDI were higher than SDI. Dry matter, specific density and total carbohydrates were 14.89 (%), 1.0547 (g/cm^3) and 40.84 (%) ,respectively under SDI but they were 15.44 (%), 1.0573 (g/cm^3) and 40.56 (%) under SSDI. This means that the effect of SSDI on quality of potato is better than SDI and this may be also, due to higher salt accumulation under SDI compared with SSDI, which resulted from increasing of evaporation from soil surface.

The present results are in agreement with those of Gengoglan et al.(2006) and El-Shawadfy, (2008) in beans who reported that applying modern irrigation systems (surface and subsurface drip) in growing vegetable crops led to increase in the quality of fruits.

Table 2: Effect of drip irrigation systems on quality of potato average of the two growing seasons.

Irrigation Systems	Dry matter, (%)	Specific density, (g/cm3)	Total carbohydrates, (%)
surface drip irrigation	14.89	1.0547	40.84
subsurface drip irrigation	15.44	1.0573	40.56
L.S.D. at 5%	0.14	0.0071	0.1

Effect of Water Regimes:

Growth of Potato:

Table (3) showed the effect of water regimes on growth of potato. Shoot dry weight /plant is increased by increasing the quantity of applied water. It were 41.71, 41.37and 28.69 (g) under 3476, 2707and 1938 (m^3/season), respectively at 100 days after sowing. In addition, LA / plant is increased by increasing the quantity of applied water. It wase 1773, 1744and 1429 (cm^2) under 3476, 2707and 1938 (m^3/season) respectively at 100 days after sowing. The obtained results were previously confirmed by those of Fatthallah and Gawish(1997) & Mahmoud(2000) on peas, and Abdel-Mawgoud(2006) & El-Shawadfy(2008) on beans), who revealed that increasing number of irrigations, levels of field capacity, irrigation amounts, pan evaporation ratios and/ or potential evapotranspiration (ETo) up to the maximum level increased growth parameters; i.e. leaf area, total plant dry matter.

The significantly higher in values of growth parameters of potato under 3476 (m^3/fed season) may be due to taller plants grown under irrigation at high available soil moisture which may be contribute to the promoting role of enough watering for cell division, expansion and enlargement and consequently internode length, El-Ganayni, (2000). Ezzo (2004) mentioned that reductions in leaf area which were obtained under conditions of low irrigation level, may be due to the relatively severe reductions pertaining to plant tissues, in cell size, number of cells per unit area or intercellular spaces. In addition, he concluded that the increase of vegetative growth with medium and high irrigation levels may be due to the high levels of acidic auxins, acidic and basic gibberellins and low levels of inhibitors within the plant tissues. The increase in the levels of both auxins and gibberellins, within the biological concentrations, promote cell division and cell enlargement and hence, increased vegetative growth.

Table 3: Effect of water regimes on Growth of potato average of the two growing seasons.

Water regimes (m^3/fed./season)	Shoot dry weight/plant, (g)			Leaves area/plant (cm^2)		
	60 days after sowing	80 days after sowing	100 days after sowing	60 days after sowing	80 days after sowing	100 days after sowing
3476	23.42	32.57	41.71	1060	1416	1773
2707	23.22	32.30	41.37	1044	1394	1744
1938	15.61	22.15	28.69	855	1140	1429
L.S.D. at 5%	0.25	0.30	0.38	20	39	33

Quality of Potato:

Table (4) showed the effect of water regimes on quality of potato. There are significant differences in values of quality parameters of potato under 3476**,** 2707 and 1938 m^3/fed./season. The Quality of potato is increased by increasing the quantity of applied water. Dry matter, specific density and total carbohydrates were 11.88 (%), 1.0405 (g/cm^3) and 37.07 (%) respectively under 1938 m^3/fed./season but they were 17.10 (%), 1.0652 (g/cm^3) and 43.33 (%) under 3476 m^3/fed./season. This may be due to that the reduction in the quantity of applied water led to high water stress for plant hence, reduction in quality parameters of potato under 1938 m^3/fed./season compared with 3476**,** 2707 m^3/fed./season. Similar results in other vegetable crops were detected by Al – Kaisi et al.(1999); Amer et al.(2002); Metin et al.(2005); Abdel-Mawgoud(2006); El-Shawadfy(2008) and El-Noemani et al.(2009)who showed that increasing irrigation level increased pod quality of beans.

Table 4: Effect of water regimes on Quality of potato average of the two growing seasons.

Water regimes (m3fed./season)	Dry matter (%)	Specific density (g/cm3)	Total carbohydrates (%)
3476	17.1	1.0652	43.33
2707	16.51	1.0624	41.7
1938	11.88	1.0405	37.07
L.S.D. at 5%	0.14	0.007	0.04

Effect of Irrigation Frequency:
Growth of Potato:

Table (5) showed the effect of irrigation frequency (number of irrigation pulses) on growth of potato. Shoot dry matter/plant is increased by increasing the number of irrigation pulses at all sampling dates. It was 34.68, 37.09, 38.55 and 38.71 (g) under continuous drip irrigation "CDI", 2 pulses, 3 pulses and 4 pulses respectively at 100 days after sowing. similarly, LA /plant was increased by increasing the number of irrigation pulses at all sampling dates. It was 1599, 1657, 1673and 1676 (cm^2) under CDI, 2 pulses, 3 pulses and 4 pulses respectively at 100 days after sowing. In general, There are significant differences in values of growth parameters of potato under the different irrigation frequencies, this may be due to differences in the soil moisture content in the root zone after applying pulse technique compared with CDI, moreover, increasing number of pulses caused increases in water movement in horizontal direction than vertical direction. These results are agreement with those obtained by Bouma *et al*. (2003), Shock *et al.* (2006), Zin El-Abedin and (2006)Helen (2007). Not only soil moisture content in the root zone increased by increasing number of pulses but also pulse technique made enhancement in soil moisture distribution inside root zone.

Table 5: Effect of irrigation frequency on growth of potato average of the two growing seasons.

Number of pulses	Shoot dry weight/plant (g)			Leaves area/plant (cm^2)		
	60 days after sowing	80 days after sowing	100 days after sowing	60 days after sowing	80 days after sowing	100 days after sowing
CDI	19.20	26.94	34.68	957	1278	1599
2 Pulses	20.65	28.87	37.09	992	1323	1657
3 Pulses	21.53	30.04	38.55	1000	1334	1673
4 Pulses	21.62	30.17	38.71	997	1331	1676
L.S.D. at 5%	1	0.15	0.18	12	14	10

CDI = Continuous Drip Irrigation

Quality of Potato:

Table (6) showed the effect of irrigation frequency on quality of potato**.** There are significant differences in values of quality parameters of potato under CDI, 2 pulses, 3 pulses and 4 pulses. The quality of potato increased by increasing the number of irrigation pulses. Dry matter, specific density and total carbohydrates were 14.17 (%), 1.0513 (g/cm^3) and 39.48 (%) respectively under CDI but they were 15.71 (%), 1.0592 (g/cm^3) and 41.33 (%) under 4 pulses this may be due to the positive effect of pulse irrigation on increasing TDM, SD and TC compared with continuous irrigation. This may be due to two reasons. The first is that pulse irrigation increased moisture content in root zone, which increased the ability of roots to absorb more nutrients. The second reason is that pulse irrigation increased air water balance inside root zone.

Table 6: Effect of irrigation frequency on Quality of potato average of the two growing seasons

Number of pulses	Dry matter (%)	Specific density (g/cm3)	Total carbohydrates (%)
CDI	14.17	1.0513	39.48
2 Pulses	14.95	1.055	40.94
3 Pulses	15.81	1.0591	41.06
4 Pulses	15.71	1.0592	41.33
L.S.D. at 5%	0.29	0.0014	0.27

CDI = Continuous Drip Irrigation

Effect of the Second Order Interaction:
Growth of Potato:
4.1.1. Shoot Dry Weight/plant(SDW/plant):

Table (7) showed influence of interaction between the three studied factors on shoot dry weight/plant. I was clear that shoot dry weight / plant increased by increasing the number of pulses with 100% Etc under SDI at 60, 80 and 100 days plant age, i.e. SDW/plant increased from 36.46 (g) for CDI to 45.05 (g) under pulse technique with 4 pulses. Moreover SDW/plant increased by increasing the number of pulses at 75% ETC at 60, 80 and 100 days plant age. i.e. SDW/plant increased from 35.87 (g) for CDI to 43.11 (g) under pulse technique with 4 pulses. However,SDW/ plant decreased by increasing the number of pulses at 50% from ETC at 60, 80 and 100 days plant age. i.e. SH/P decreased from 28.33 (g) for CDI to 25.12 (g) using pulse technique with 4 pulses under the same irrigation system .Table (7)also showed the relation between pulse subsurface drip irrigation and SDW/plant under 100%, 75% and 50% ETC. It was obvious that SDW/plant increased by increasing the number of pulses with 100% ETC at 60, 80 and 100 days from plant age., i.e SDW/plant increased from 38.22 (g) for CDI to 46.12 (g) under pulse technique with 4 pulses. Moreover, SDW/plant increased by increasing the number of pulses with 75% ETC at 60, 80 and 100 days plant age, i.e. SDW/plant increased from 37.65 (g) for CDI to 44.00 (g) under pulse technique with 4 pulses. On the contrary, SDW/plant decreased by increasing the number of pulses with 50% ETC at 60, 80 and 100 days plant age, i.e. SDW/plant decreased from 31.55 (g) for CDI to 28.89 (g) under pulse technique with 4 pulses at 100 days after sowing. Maximum value of SDW/plant was 46.12 (g) at 100 days plant age under the following conditions (100% ETC with 4Pulses under SSDI) and minimum value of SDW/plant was 25.12 (g) at 100 days after sowing under the following conditions (50% ETC with 4Pulses under SDI).

Table 7: Effect of the interaction between drip irrigation systems, water regimes and irrigation frequency on Shootdry weight/plant (average of the two growing seasons).

Irrigation systems	ETC (m^3/fed./ season	Irrigation frequency (number of pulses)	Shootdry weight/plant (g)		
			60 days after sowing	80 days after sowing	100 days after sowing
Surface drip irrigation	3476	CDI	20.28	28.37	36.46
		2 Pulses	22.97	31.96	40.95
		3 Pulses	23.09	32.12	41.15
		4 Pulses	25.43	35.24	45.05
	2707	CDI	19.92	27.90	35.87
		2 Pulses	21.62	30.16	38.70
		3 Pulses	24.55	34.06	43.58
		4 Pulses	24.27	33.69	43.11
	1938	CDI	15.40	21.86	28.33
		2 Pulses	15.20	21.60	28.00
		3 Pulses	15.18	21.58	27.97
		4 Pulses	13.47	19.30	25.12
Subsurface drip irrigation	3476	CDI	21.33	29.78	38.22
		2 Pulses	23.19	32.26	41.32
		3 Pulses	25.06	34.75	44.44
		4 Pulses	26.07	36.10	46.12
	2707	CDI	20.99	29.32	37.65
		2 Pulses	24.27	33.69	43.11
		3 Pulses	25.39	35.18	44.98
		4 Pulses	24.80	34.40	44.00
	1938	CDI	17.33	24.44	31.55
		2 Pulses	16.68	23.58	30.47
		3 Pulses	15.91	22.55	29.19
		4 Pulses	15.73	22.31	28.89
L.S.D. at 5%			1.12	0.98	1.51

4.1.2. Leaves Aarea/plant:

Table (8) showed the relation between pulse surface drip irrigation and LA / plant under 100%, 75% and 50% ETC. Data revealed that LA / plant increased by increasing the number of pulses under 100% ETC at 60, 80 and 100 days plant age, i.e. LA / plant increased from 1630 (cm^2) for CDI to 1850 (cm^2) under pulse technique with 4 pulses. In addition, LA / plant increased by increasing the number of pulses with75% ETC at 60, 80 and 100 days plant age,. i.e. LA / plant increased from 1570 (cm^2) for CDI to 1826 (cm^2) under pulse technique with 4 pulses.however LA / plant decreased by increasing the number of pulses at 50% ETC at 60, 80 and 100 days from plant age, i.e. LA / plant decreased from 1539 (cm^2) for CDI to 1231 (cm^2) under pulse technique with 4 pulses. Table (8) showed also the relation between pulse subsurface drip irrigation and LA / plant under 100%, 75% and 50% ETC. Data showed that LA/ plant increased by increasing the number of pulses at 100% ETC at 60, 80 and 100 days plant age, i.e. LA / plant increased from 1668 (cm^2) for CDI to 1875 (cm^2) under pulse technique with 4 pulses. In addition LA / plant increased by increasing the number of pulses with 75% ETC at 60, 80 and 100 days from plant age, i.e. LA / plant increased from 1631 (cm^2) for CDI to 1839 (cm^2) under pulse technique with 4 pulses. Cotrarly, LA / plant decreased by increasing the number of pulses using50% ETC at 60, 80 and 100 days plant age, i.e. LA / plant decreased from 1560 (cm^2) for CDI to 1378 (cm^2) under pulse technique with 4 pulses.

Maximum value of LA / plant was 1875 (cm^2) at 100 days plant age under the following conditions (100% ETC with 4Pulses under SSDI) whereas, minimum value of LA / plantwas 1231 (cm^2) at 100 days plant age under the following conditions (50% ETC with 4Pulses under SDI).

Table 8: Effect of the interaction between drip irrigation systems, water regimes and irrigation frequency on leaves area/plant average of the two growing seasons.

Irrigation systems	ETC (m^3/fed./ season	Irrigation frequency (number of pulses)	Leaves area/plant (cm^2) 60 days after sowing	80 days after sowing	100 days after sowing
Surface drip irrigation		CDI	974	1300	1630
	3476	2 Pulses	1049	1400	1755
		3 Pulses	1085	1450	1817
		4 Pulses	1106	1477	1850
		CDI	940	1255	1570
	2707	2 Pulses	1016	1357	1696
		3 Pulses	1093	1459	1830
		4 Pulses	1094	1461	1826
		CDI	921	1230	1539
	1938	2 Pulses	900	1201	1508
		3 Pulses	750	1000	1256
		4 Pulses	734	980	1231
Sbsurface drip irrigation		CDI	995	1330	1668
	3476	2 Pulses	1050	1400	1754
		3 Pulses	1100	1471	1838
		4 Pulses	1124	1500	1875
		CDI	977	1305	1631
	2707	2 Pulses	1034	1380	1725
		3 Pulses	1100	1468	1841
		4 Pulses	1100	1470	1839
		CDI	938	1250	1560
	1938	2 Pulses	906	1200	1509
		3 Pulses	873	1160	1457
		4 Pulses	824	1100	1378
L.S.D. at 5%			30	42	38

The improving in potato growth may be due to the increasing in the available nutrients in the root zone. These nutrients will be more available for plant by increasing moisture content in root zone and hence increasing fertilizers use efficiency.However at 50% ETC the volume of water stored was un-sufficient for growing potato plant and caused high stress for plant and led to, the harm ful effect of pulse drip irrigation with small amount of water and increasing in time-off. Small amount of irrigation water with more pulses with increasing in time-off will concentrate the salts around the plant which increase osmotic potentional and hence decreasing the yield of potato especially under surface drip irrigation. Growth of potato (SDW/plant and LA / plant)was improved by increasing number of irrigation pulses especially at (100% and 75% ETC). SDW/plant increased from 38.22 (g) under CDI to maximum value, where it become 46.12 (g) after applying pulse technique with 4 pulses at 100 % ETC under subsurface drip irrigation. Also, LA /PLANT increased from 1668 (cm^2) under CDI to maximum value, where it become 1875 (cm^2).

4.2. Quality of Pota:

There are a lot of quality characters for potato tubers. We had chosen the most important characteristics (dry matter, specific density and total carbohydrates) to study the effect of pulse drip irrigation on these characteristics.

4.2.1. Tuber Dry Matter:

Table (9) showed the relation between pulse drip irrigation (PDI) and tuber dry matter(TDM) under 100%, 75% and 50% ETC. Data in Table (9) exhibited the relation between pulse surface drip irrigation (PSDI) and TDM under 100%, 75% and 50% ETC. It was clear that TDM increased by increasing the number of pulses at 100% ETC. TDM increased from 14.83 (g) for CDI to 18.78 (g) under pulse technique with 4 pulses recording an increase of 26.63 %. Moreover, TDM increased by increasing the number of pulses at 75% ETC. TDM increased from 13.98 (g) for CDI to 17.15 (g) under pulse technique with 4 pulses recording an increase of 22.67%.On the apposite TDM decreased by increasing the number of pulses at 50% ETC. TDM decreased from 13.02 (g) for CDI to 10.00 (g) under pulse technique with 4 pulses recording a decrease of 23.2%. Results in Table (9) showed the relation between PSSDI and TDM under 100%, 75% and 50% ETC. It is worthy to mention that TDM increased by increasing the number of pulses at 100% ETC. TDM increased from 14.73 (g) for CDI to 18.99 (g) under pulse technique with 4 pulses recording an increase of 28.92 %. Moreover, TDM increased by increasing the number of pulses at 75% ETC. TDM increased from 14.97 (gm) for CDI to 18.82 (gm) under pulse technique with 4 pulses recording an increase of 25.71%.On the contrary,TDM decreased by increasing the number of pulses at 50% ETC. TDM decreased from 13.52 (g) for CDI to 10.57(g) under pulse technique with 4 pulses recording a decrease of 21.8 %the maximum value of TDM was 18.99 (g) under the following conditions (100% ETC with 4 pulses under SSDI) and the minimum value of TDM was 10 (g) under the following conditions (50% ETC with 4 pulses under SDI).

4.2.2. Tuber Specific Density:

Table (9)) exhibited the relation between pulse drip irrigation and tuber specific density(TSD) under 100%, 75% and 50% ETC. Data showed the relation between pulse surface drip irrigation and TSD under 100%, 75% and 50% ETC.It is obvious that TSD increased by increasing the number of pulses at 100% ETC. TSD increased from 1.0545 (g/cm^3) for CDI to 1.0732 (g/cm^3) under pulse technique with 4 pulses recording an increase of 1.77%. In addition TSD increased by increasing the number of pulses at 75% ETC. TSD increased from 1.0505 (g/cm^3) for CDI to 1.0655 (g/cm^3) under pulse technique with 4 pulses recording an increase of 1.43 %.on the opposite TSD decreased by increasing the number of pulses at 50% ETC. TSD decreased from 1.0459 (g/cm^3) for CDI to 1.0316 (g/cm^3) under pulse technique with 4 pulses recording a decrease of 1.37 %. Data inTable (9) revealed the relation between pulse subsurface drip irrigation and TSD under 100%, 75% and 50% ETC. It is noteworthy that TSD increased by increasing the number of pulses at 100% ETC. TSD increased from 1.0540 (g/cm^3) for CDI to 1.0742 (g/ cm^3) under pulse technique with 4 pulses recording an increase of 1.92%. Similarly, TSD increased by increasing the number of pulses at 75% ETC. TSD increased from 1.0551 (g/cm^3) for CDI to 1.0734 (g/cm^3) under pulse technique with 4 pulses recording an increase of 1.73 %.contrarly; TSD decreased by increasing the number of pulses at 50% ETC. TSD decreased from 1.0483 (g/cm^3) for CDI to 1.0343 (g/cm^3) under pulse technique with 4 pulses recording a decrease of 1.34 %.

Maximum value of TSD was 1.0742 (g/cm^3) under the following conditions (100% ETCwith 4 pulses under SSDI) and minimum value of TSD was 1.0316 (g/cm^3) under the following conditions (50% ETC. with 4 pulses under SDI).

4.2.3. Tuber Total Carbohydrates:

The results of Table (9) showed the relation between pulse drip irrigation and tuber total carbohydrates(TTC) under 100%, 75% and 50% ETC.Moreover, the data in Table (9)exhibited the relation between pulse surface drip irrigation and TTC under 100%, 75% and 50% ETC. It was noticed that TTC increased by increasing the number of pulses at 100% ETC. TTC increased from 39.71 % for CDI to 45.07 % under pulse technique with 4 pulses recording an increase of 13.49%. Additionally, TTC increased by increasing the number of pulses at 75% ETC. TTC increased from 38.79 % for CDI to 42.66 % under pulse technique with 4 pulses recording an increase of 9.98%.However; TTC decreased by increasing the number of pulses at 50% ETC. TTC decreased from 39.00 % for CDI to 37.55% under pulse technique with 4 pulses recording a decrease of 3.72 %. Also, in Table (9) showed the relation between pulse subsurface drip irrigation and TTC under 100%, 75% and 50% ETC. It is noteworthy thatl TTC increased by increasing the number of pulses at 100% ETC. TTC increased from 40.52 % for CDI to 45.58 % under pulse technique on 4 pulses recording an increase of 12.49 %. Moreover, TTC increased by increasing the number of pulses at 75% ETC. TTC increased from 41.29 % for CDI to 43.14 % under pulse technique with 4 pulses recording an increase of 4.48 %.Whereas; TTC decreased by increasing the number of pulses at 50% ETC. TTC decreased from 37.58% for CDI to 34.00 % under pulse technique with 4 pulses recording a decrease of 9.52%.

Maximum value of TTC was 45.58 % under the following conditions (100% ETC with 4Pulses under SSDI) and minimum value of TTC was 34.00 % under the following conditions (50% from WR with 4Pulses under SSDI).

It was clear from the previous results concerning the quality of potato exhibited in Table (9) that there is a positive effect of pulse drip irrigation on increasing TDM, TSD and TTC compared with continuous drip irrigation especially at 100% ETC and 75%ETC. This may be due to two reasons The first is that pulse irrigation increased moisture content in the root zone, which increased the ability of roots to absorb more fertilizer nutrients. The second reason is that pulse irrigation increased air water balance inside theroot zone. It could be concluded that pulse irrigation helped the plants to grow faster and remained healthier than plants exposed to water stress. These results are in agreement with those obtained by Bravdo and Proebsting (1993). The negative effect of PDI on the quality of potato at 50% ETC may be due to that the small amounts of applied water with increasing number of pulses increased salts accumulation inside the root zone. Using statistical analysis for values of TDM, TSD and TTC indicated that, there are significant differences between PDI and CDI especially under 100% and 75% ETC. TDM, TSD and TTC increased by increasing number of

Table 9: Effect of the interaction between drip irrigation systems, water regimes and irrigation frequency on quality characters of potato tuber (average of the two growing seasons).

Irrigation systems	ETC (m^3/fed./ season	Irrigation frequency (number of pulses)	Dry matter (%)	Specific density (g/cm^3)	Total carbohydrates (%)
Surface drip irrigation		CDI	14.83	1.0545	39.71
	3476	2 Pulses	16.14	1.0607	42.93
		3 Pulses	18.21	1.0705	44.46
		4 Pulses	18.78	1.0732	45.07
		CDI	13.98	1.0505	38.79
	2707	2 Pulses	16.2	1.061	41.5
		3 Pulses	16.82	1.0639	42.14
		4 Pulses	17.15	1.0655	42.66
		CDI	13.02	1.0459	39
	1938	2 Pulses	12.11	1.0416	38.19
		3 Pulses	11.44	1.0384	38.11
		4 Pulses	10	1.0316	37.55
Subsurface drip irrigation		CDI	14.73	1.054	40.52
	3476	2 Pulses	16.46	1.0622	43.84
		3 Pulses	18.68	1.0727	44.55
		4 Pulses	18.99	1.0742	45.58
		CDI	14.97	1.0551	41.29
	2707	2 Pulses	16.41	1.062	41.6
		3 Pulses	17.73	1.0682	42.53
		4 Pulses	18.82	1.0734	43.14
		CDI	13.52	1.0483	37.58
	1938	2 Pulses	12.41	1.043	37.56
		3 Pulses	12	1.0411	34.57
		4 Pulses	10.57	1.0343	34
L.S.D. at 5%			0.91	0.0042	0.84

WR_{DI} =Water regime under deficit irrigation

irrigation pulses especially at 100% and 75% ETC. TDM, TSD and TTC increased from 14.73%, 1.0540 $g/cm^3$and 40.52% under CDI to maximum values, where it become 18.99%, 1.0742 $g/cm^3$and 45.58%, respectively after applying pulse technique with 4 pulses at 100% ETC under SSDI. This is in accordance with the data presented in Tables (7 and 8) which, indicate the positive effect of pulse drip irrigation on increasing dry weight of stems and leaves/plant and leaves area/plant. The highest values of dry weight of stems and leaves /plant and leaves area/plant were 46.12 (g) and 1875 (cm^2), respectively under (SSDI + 100% ETC + pulse drip/4). The Increasing in leaves area/plant led to increasing photosynthesis process, this increased yield and enhanced quality characters. Finaiiy, it could be concludes that polat plants can be irrigation at100% ETC with 4 pulse underSSDI to obtain higher growth and tuber quality.

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