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Effect of Pulse Irrigation and Pulse Fertigation on the Yield, Water Productivity and Quality of Cucumber Under the Dry Environmental Conditions of Sandy Soil

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Abstract

Consideration of the use of the pulse technique for irrigation and fertigation is one of the irrigation management methods to enhance crop production, water productivity, and lower deep percolation. An experiment was carried out using three pulse irrigation "PI" levels [PI1: Continues irrigation (control), PI2: 2 pulses/day and PI3:3 pulses/day] with five cases for pulse fertigation "PF" per season [PF4: 4 pulses/season (control), PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season] to inspect the impact of those treatments for increasing water productivity and productivity and improvement of the quality traits for cucumber crop under the dry environment conditions of sandy soil. To meet the study's objectives, two greenhouse experiments had been carried out in Al-Nubariya Region, Al-Buhayrah Governorate, Egypt, during the seasons 2021 and 2022. Our results demonstrated a general decrease in water stress inside the root zone area with the increase of the irrigation pulses number under pulse fertigation treatments during the seasons 2021 and 2022. Pulsed irrigation led to a higher value for water application efficiency when contrasted with continuous irrigation under pulse fertigation treatments of cucumber crop for the two seasons. According to this study, pulse irrigation and pulse fertigation improved crop yield and water productivity over the two seasons. The highest cucumber yield values were (34.1 and 33 tons $ha.^{-1}$), and water productivity were (5.6 and 5.4 kg m^{-3}) using 3 pulses/day of pulse irrigation with 8 pulses/season for pulse fertigation for seasons 2021 and 2022, respectively. As per our results for impact of pulse irrigation and pulse fertigation on yield, water productivity and quality traits indicated that, adopting 3 pulses/day of pulse irrigation with 8 pulses/season for pulse fertigation is the perfect condition in light of the fact that under these conditions was happened the highest worth of yield, water productivity and the quality traits for cucumber crop contrasted with other treatments during seasons 2021 and 2022. Finally, these treatments condition is beneficial to improve nitrogen utilization efficiency. In addition, it can raise the density of root length and the zone of root surface in the layers of deep soil, especially at 20-35 cm of soil depth, and partially increase root growth in depth.

Keywords: Pulse technique, Irrigation management, Deficit irrigation, Water productivity, Water stress.

1- Introduction

The problem and crisis of worldwide water resources have attracted concentration and consideration in most countries of the world on expanding the efficiency of utilizing and rationalizing scarce water resources, particularly water utilized through agriculture, in order to achieve and provide food security and increase the production of many crops. The agriculture sector is under a lot of pressure to use less fresh water for irrigation and its use in other non-agricultural sectors in places that experience drought problems, notably semi-arid and arid areas with high population density and limited water resources (Abdelraouf et al., 2020a,b; Hozayn et al., 2016). In Egypt, which has arid parts, the issue of water scarcity is a really very serious problem facing food production. It is crucial to reduce consumption and preserve irrigation water through the modernization and improvement of environmentally friendly techniques (El-Metwally et al., 2015). The Arab Republic of Egypt's agriculture sector is faced with the difficult and significant challenge of

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discovering ways for improving crop yield through irrigation while using less water, a concept known as increasing the water productivity of the crops (Abdelraouf and Abuarab, 2012). In order to meet the rising demand for food caused as a result by the growing populations growth, it is crucial and significant to raise the water productivity unit used to irrigate crops (Bakry et al., 2012; Okasha et al., 2013; Abdelraouf and Ragab, 2018a,b,c; Eid and Negm, 2018). Egypt's water resources are suffering from extreme shortages and scarcity, and this suffering is getting more and more as the population growth rate rises. Most modern irrigation techniques are competing to improve water productivity as well as yield and crop quality due to turbulent and growing competition for scarce water resources (Marwa et al., 2017). Given the scarcity of available water resources, their limited availability, and Egypt's low annual rainfall rate, the productivity of water units are used to irrigate agricultural crops is regarded as a highly essential issue (Hozayn et al., 2013). One of the central concepts that have to be considered, followed, and put into practice in semi-arid and arid regions, such as Egypt, in order to supply a large volume of irrigation water, is the adoption of new irrigation techniques and the various related techniques (El-Habbasha et al., 2014).

Due to their high yield production and water use efficiency, drip irrigation systems are among the acceptable and effective irrigation methods, especially in semi-arid and arid areas, where fresh water is a scarce resource (Liu and Xu, 2018; Karimi et al., 2020). Accurate knowledge of the wetting patterns is necessary for the proper design and installation of drip irrigation systems (Yao et al., 2011; Kandelous and Simunek, 2010; Moncef and Khemaies, 2016). In order to reduce deep percolation as well as the leaching of nutrients and also other chemicals through the root zone, high-frequency drip irrigation management involves controlling the drip discharge rate in accordance with the hydraulic parameters of soil (Cote et al., 2003).

The development of intense and sustainable agriculture requires the adoption of techniques and equipment that encourage the rationalizing of inputs and increase in agricultural productivity. However, use of the low discharge rates is difficult due to several technical limitations (such as discharge, operation pressure and clogging). However, pulsed method, a theory with current findings that has the possibility for increasing the usage of nutrients and water, can be used to generate soil moisture levels similar to those resulting from continuous limited water application rates. Each irrigation cycle in the pulsed irrigation process consists of an irrigation stage and a resting stage (Assouline et al., 2006). Recent investigations have supported the development of the pulse irrigation technique. It entails applying a daily irrigation depth divided into cycles made up of one quick irrigation period, followed by a resting stage, and another quick irrigation period. These cycles are repeated until the entire water volume is supplied in several on-off cycles (Almeida et al., 2015; García-Prats and Guillem-Picó, 2016). However, pulsed drip irrigation at larger discharge rates can provide soil moisture regimes that are comparable to those that come from continuous limited water application rates (Phogat et al., 2013). Several recent studies deal with various management strategies in a mix of pulsed and continuous irrigation in an effort to find the optimal management method to optimize drip irrigation (Assouline, 2002; Cote et al., 2003; Segal et al., 2006; Elmaloglou and Diamantopoulos, 2007; Skaggs et al., 2010; Phogat et al., 2012b, 2013; Elnesr et al., 2015; Elnesr and Alazba, 2015).

According to Cote et al. (2003), in comparison to continuous irrigation, pulsed irrigation significantly raised the wetted depth and radius, but Elmaloglou and Diamantopoulos (2007) found that the vertical component of its wetting front was larger with pulsed irrigation. Various soil physical properties, like as structure and texture, are among the factors influencing the distribution of water via drip sources (Thorburn et al., 2003; Gardenas et al., 2005). According to Eid et al. (2013), this encourages water to flow in a horizontal direction, enhancing soil moisture distribution and increasing volume of wet soil in root zone. Skaggs et al. (2010) found a little increase in the horizontal distribution of moisture content under pulsing irrigation compared to continuous irrigation under lower application rates, However, this increase was quickly lost during the redistribution period that followed irrigation. According to Phogat et al. (2012a), pulsing had a negligible effect on salt removal, leaching fraction, and salinity and moisture distribution in the soil almond trees during the profile early stages. However, given plant water intake and interaction among all fluxes over soil boundaries across the entire season, it is unclear from any of these experiments whether the influence of pulsing would have any practical significance over the long term. Elmaloglou and Diamantopoulos (2009) reached a conclusion that pulse the irrigation technique significantly reduced deep percolation loss.

Pulse irrigation has produced successful and attractive results, including increases in product quantity and quality, water savings, and enhanced nutrient absorption (Assouline et al., 2006; Elnesr et al., 2015). However, methods of pulsed drip fertigation with soil water depletion are still rare, although, few studies have been done with pulsed ripping on coriander (Zamora et al., 2019; Menezes et al., 2020; Zamora et al., 2021), potato (Abdelraouf et al., 2012, 2013), soybean (Eid et al., 2013), tomato (Elnesr et al., 2015; Elshamlyet al., 2016), cucumber

(Maller et al., 2016; Abdelraouf et al., 2020c; El-Shawadfy et al., 2020; El-Shafie et al., 2021), lettuce (Almeida et al., 2015), green beans (Almeida et al., 2018), almond (Phogat et al., 2013) and eggplant (Arriero et al., 2020). These studies found that pulse irrigation outperformed continuous irrigation in terms of water savings, enhanced yield, and the quality of the product.

Wetting redistribution, which typically occurs after stopping the irrigation operation in both vertical and horizontal directions, is one of the crucial factors for precisely estimating the moisture dimensions with drip irrigation systems. In the case of horizontal redistribution, taking into account moisture redistribution values can decrease wetting front overlap between laterals and emitters, and in the case of vertical redistribution, it can decrease water deep percolation, both of which can completely reduce the applied water volume (Mohammadbeigi et al., 2017). Since high efficiency is the consequence of all the efficiencies achieved from the existing network (storage, conveyance, distribution, application, etc.), pulsed and continuous irrigation are supporting fields that should be taken into consideration in order to obtain more efficient usage of the irrigation water, but not only from the farms themselves (García-Prats and Guillem-Picó, 2016).

Having sufficient knowledge of the likelihoods of the various yield outcomes would be very helpful in choosing a fertilizing program. Researchers would then be able to compute the most cost-effective fertigation rate as a result. Also, the achievable yield at a given rate of fertigation may be estimated when this optimal rate is used. Various researchers have utilized the quantitative method for evaluating and expressing quantitatively how crops' yields respond to nitrogenous fertilizers (Atia et al., 2009). N requirement maximum plant growth rate is not met by plant N uptake when N availability is low. Plants may lengthen their roots to discover a larger soil volume and/or improve their N-uptake activity in order to get enough N (Liu et al., 2009). Therefore, an ideal quantity of N is required, based on volume of water available, for increasing crop production (Azizian and Sepaskhah, 2014). Water use efficiency, which is correlated with nutrient and water usage, is expected to improve under partial management (Almeida et al., 2015). Abdelraouf et al. (2012) found a 63.90% improvement in water productivity, indicating water savings of up to 25% every crop cycle.

Following the popular Egyptian crops of tomato, cabbage, and onion, cucumber is the fourth most significant vegetable crop. It is used for pickling and salad in addition to fresh eating. It is a principal source of minerals and vitamins in the diet of people (El-Atawy, 2010). One of the vegetables that are most frequently consumed off the table that is cultivated in greenhouses in Egypt is cucumber. Water shortages have a significant impact on fresh fruit production, hence scheduling irrigation throughout growing season is preferred (Abdelraouf et al., 2020c). The cucumber crop is rich in lipids, antioxidants, minerals, vitamins, and fibers. It also has a low sugar content (Abbey et al., 2017). Many investigations revealed that the total volume of irrigation water throughout all stages of growth has a significant effect on production of fresh cucumber fruit (Wang and Zhang, 2004). Because of their surface fibrous root system, cucumbers are sensitive to the water stress (Kirnak and Demirtas, 2006). For production of the crops, nitrogen (N) availability is just as crucial as water. Application of N fertilizer has a good effect on cucumber crop (Mansouri-Far et al., 2010).

Due to their low organic content, low water-holding capacity, and high infiltration rate, sandy soils are particularly important for the water management since they may result in limit water usage efficiency (Al-Omran et al., 2005). On the other hand, sandy soils suffer from a lack of water, and mineral fertilizing that is concentrated through irrigation water supply puts the environment in danger. To fight world hunger, it is therefore necessary to cultivate sandy soils using a minimal volume of irrigation (Saleh and Ozawa, 2006). Given the foregoing and the scarcity of available data, the study's objective was to inspect the effects of pulse drip irrigation at various pulse fertigation levels on water productivity, productivity and the quality traits of the cucumber crop under the dry environment conditions of sandy soil.

MATERIALS AND METHODS

Location and climate of the experimental site: Field experiments were carried out during 2021 and 2022 seasons on cucumber and the farm was located in north Cairo–Egypt on sandy soil in Al-Nubariya Region, (latitude 30º 26` 28``N, longitude 30º 18` 0`` E, and mean altitude above sea level 21 m), Al Buhayra governorate, Egypt. The chosen region has a dry climate with cool winters and hot dry summers as shown in Figure (1). The average air temperatures were 16.37 and 17.29, with average air relative humidity of 65.21 and 68.90%, for two seasons 2021 and 2022, respectively.

Physical and chemical properties of soil and irrigation water: The irrigation water source was a channel that passed across the experimental area and had an average pH of 7.6 and an electrical conductivity (EC) of 0.55 dS m^{-1}. At the start of the experiment, the major physical and chemical properties of the soil, as shown in Table 1, were determined on-site and in a lab. Soil samples had been taken from depths (0-15, 15-30 and 30-45) at the start of the experiment, and analyzed for physical and chemical properties. The analyses revealed that soil was sand.

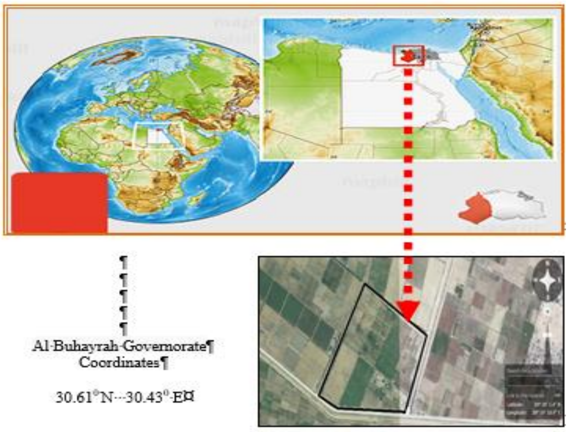

Figure (1): Location of the study site, Al-Nubariya Region, Egypt

Experimental design: The experimental layout was a split-plot design using three replicates. Three **P**ulse **I**rrigation (PI) levels: Continues (control), 2 pulses/day, and 3 pulses/day (PI1, PI2 and PI3) were assigned as main plots. Each main plot was then divided into sub main plots subjected to five cases for pulse fertigation (PF) per season [PF4: 4pulses/season (control), PF5: 5pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season] as shown in table (I)

Irrigation system description: The irrigation network consists of a centrifugal pump with a discharge of 45 $m^3 h^{-1}$ with other components of a main control unit. It was the main line of PVC pipes with a diameter of 110 mm. The branch lines of PVC pipes with a diameter of 75 mm were also directly connected to the main line. Manifold lines were made from Polyethylene pipes with a diameter of 63 mm connected to the laterals. Emitters were built in the laterals with a diameter of 16 mm and a length of 30 m and the emitter discharge was 4 liters per hour at an operating pressure of 1.0 bar and a distance of 25 cm between the emitters.

Table (1): Physical and chemical characteristics of soil for experimental area

Soil Characteristics	Soil depth (cm)		
	0–15	15-30	30-45
Physical parameters			
Field capacity		15	
Wilting point		4	
Available water		11	
Texture	Sandy	Sandy	Sandy
Course sand (%)	48.00	56.24	40.71
Fine sand (%)	49.42	40.60	55.55
Silt + clay (%)	2.58	3.16	3.74
Bulk density (g cm^{-3})	1.66	1.66	1.68
Organic matter (%)	0.45	0.42	0.27
Chemical parameters			
EC (dS m^{-1})	0.68	0.59	0.61
pH (1:2.5)	8.4	8.7	8.8
Total CaCO3 (%)	7.05	2.49	4.60

Irrigation requirements for cucumber: Equation (1) was used for measuring daily irrigation water and the seasonal irrigation water was 6120 m^3/ha./season for 100% full irrigation "FI" for 2021 and 6080 m^3/ha./season for 2022 using drip irrigation system following Savva and Frenken (2002). Because the volume of rainfall was so small and the duration was only a few minutes, there was no rainfall that was included across the two seasons.

$$IRg = \left[\frac{ETO \times Kc \times Kr}{Ei}\right] - R + LR \ldots\ldots\ldots (1)$$

Where, IRg is the gross irrigation requirements (mm/day); ET_O is reference evapotranspiration (mm/day); Kc is crop factor "FAO-56"; Kr is a factor of ground cover reduction; Ei is the irrigation efficiency (%); R is water received by plant from sources other than irrigation (mm) "for example rainfall"; and LR is amount of the water needed for leaching of salts (mm).

Cucumber crop: Regardless of the experimental treatments, all experimental plots were treated by the normal and recommended cucumber growing requirements (Cucumissativus L.) as recommended by the instructions of the official agricultural bulletins. The date of cultivation was at first September 2021 for the first season and first February 2021 for the second season. The seasonal fertigation amount for cucumber crop was 343 kg N/ha./season. Fertigation was attributed to the application of nutrient solution via irrigation water. All field practices were done as usually recommended for cucumber cultivation in sandy soil. Harvesting was begun after 30 days from planting.

Evaluation Parameters

The water stress of cucumber plant in the root zone: Soil moisture was measured in effective roots zone before and after irrigation. As evaluation parameters for the exposure range of plants to water stress, field capacity and wilting point were taken into consideration according to Abdelraouf et al. (2020b). Measurements were taken at soil depths at mid-growth stage. Soil moisture values were measured using profile probe device. Water contents equivalent to field capacity was 14% and permanent wilting point was 4%.

Table (I): Distribution of experimental design factors

PI1															
							PF4	PF5	PF6	PF7	PF8				
PI2															
									PF4	PF5	PF6	PF7	PF8		
PI3															
											PF4	PF5	PF6	PF7	PF8

Application efficiency of irrigation water "AEIW": In order to meet crop's water requirements in relation to water applied to the area; application efficiency refers to the actual storage of water inside root zone. Pulse irrigation treatments were defended with a 60-minute-rest period between the two successive applications. As was already mentioned, pulsed irrigation uses the same water volume and runs for the same length of time as continuous drip irrigation, but in a number of stages. On the other hand, continuous irrigation treatment was applied as one continuous event until the required amount of irrigation water was applied. According to El-Meseery (2003), application efficiency "AE_{IW}" was calculated with the following Equation (2):

$$\mathrm{AEIW} = \frac{\mathrm{Ds}}{\mathrm{Da}} \text{.........} (2)$$

Where, AEIW is application efficiency of the irrigation water (%); Ds is depth of stored water in root zone (cm); and Da is depth of the applied water (cm). Ds were determined using equation (3) (El-Meseery, 2003):

$$\mathrm{Ds} = (\theta_1 - \theta_2) * d * \rho \text{.........} (3)$$

Where, d is soil layer the depth (cm), θ_1 is average of soil moisture content after irrigation (%); θ_2 is average of soil moisture content before irrigation (%); and ρ is relative bulk density of soil (dimensionless).

Yield of cucumber: At harvest time, total weight of fruits in each treatment were collected at time intervals when they were about 10 cm in length, weighed and then fruit yield was calculated as kg per 1 m^2. The total yield as ton ha^{-1} was determined.

Water productivity of cucumber "$WP_{cucumber}$": According to James (1988), $WP_{cucumber}$ was determined by Equation (4) as follows:

$$\mathrm{WP}_{cucumber} = \frac{\mathrm{Ey}}{\mathrm{Ir}} \text{...........} (4)$$

Where, $WP_{cucumber}$ is water productivity of the cucumber crop ($kg_{cucumber}/m^3_{water}$); Ey is economical yield (kg/ha.); and Ir is applied volume of the irrigation water (m^3_{water} /ha./season).

Quality traits of cucumber: Representative samples of cucumber crop were randomly chosen from each treatment at the third picking to determine some of quality parameters of cucumber fruits (i.e. Vitamin C and total soluble solids (T.S.S.)) using a hand refractometer according to the method described by Singh (1988).

Statistical Analysis: All the obtained data in the two seasons of study were statistically analyzed using the standard analysis of variance procedure

(ANOVA) of split plot design using three replications according to Snedecor and Cochran (1980). All data were processed with the assistance of statistical program COASTAT for Windows. However, meansof treatments were distinguished by the Duncan's multiple range test (Duncan, 1955). Differences were considered significant at $p \leq 0.05$.

RESULTS AND DISCUSSION

The water stress in the root zone

Our results indicated a general reduction in water stress within the root zone area with the increase in the number of irrigation pulses under pulse fertigation treatments of cucumber crop for the two seasons as shown in Figure (2). The lowest water stress values were reported in 3 pulses/day of pulse irrigation "PI3" and the highest values were at continuous irrigation "PI1" with all pulse fertigation treatments for the two seasons. This result showed the advantage of pulse technique, for reducing the deep percolation of water under the crop root zone, while obtaining a wide horizontal spread of wetting. As a result, the same quantity of water could be used with a highly discharge emitter. The experiment's split irrigation made sure there was enough water available to minimize the impact of water stress. Pulse-irrigated plants developed more quickly and maintained better health than plants that were stressed every day because they tended to accrue less water stress each day. It can be established that pulse drip irrigation increased moisture in the 0–30 cm layer while decreasing the depth and increasing the diameter of the wet-bulb. Increasing soil moisture distribution and the wet soil size in the root propagation area by increasing number of irrigation pulses may be due to increasing number of pulses will increase from water movement in horizontal direction than vertical direction inside the soil root zone. All this reduces the water stress on the roots of cucumber plant. These results are in agreement with those obtained by Abdelraouf et al. (2019) and El-Shawadfy et al. (2020). On this topic, Almeida et al. (2018) state that pulse drip irrigation helped to reduce water stress within the root zone area, probably because the irrigation depth was split, which keeps maintaining soil moisture for a longer period.

Application efficiency of irrigation water "AEIW"

Figure (3) exhibits the effect of pulse irrigation and pulse fertigation on AE_{IW} for the two seasons. Comparing pulsed irrigation to continuous irrigation, a greater value of AE_{IW} was obtained under pulse fertigation treatments of cucumber crop for the two seasons. The highest values of AE_{IW} were 99 and 98% for seasons 2021 and 2022, respectively when applying PI3 with PF8, while the lowest values of AE_{IW} were 84 and 80% for seasons 2021 and 2022, respectively when applying PI1 with PF4. Applying irrigation water in pulses rather than giving it at one time can save or prevent from losses by giving enough time to media to moisten and consequently, it will be better able to absorb subsequent irrigation, requiring less water overall. In general, the applied of pulse irrigation system gave regularity in water distribution, which leads to a high water application efficiency as mentioned by Vázquez et al. (2006) and Zotarelli et al. (2009). These findings indicate that this irrigation technique improves the use of nutrients and water throughout the fertigation cycle, as also confirmed by Assouline et al. (2012), who explained this result with the high nutrient availability and water absorption. Assouline et al. (2006) indicate that the high frequency of irrigation promotes fertigation availability and absorption, corroborating this finding.

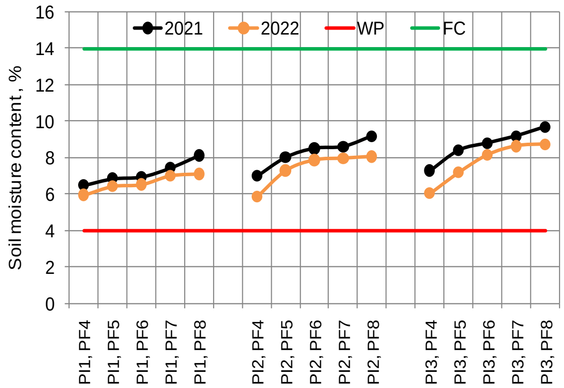

Figure (2): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the water stress of cucumber plants in the roots zone at the peak of water requirements and before irrigation during seasons of 2021 and 2022. (PI1: Continues irrigation, PI2: 2 pulses/day and PI3: 3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season).

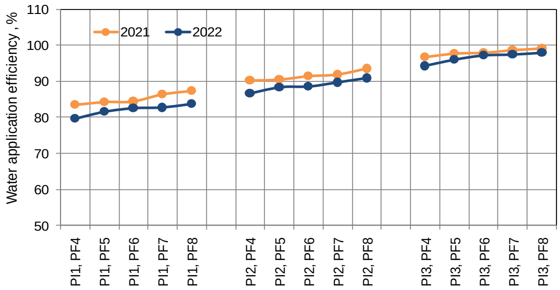

Figure (3): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the water application efficiency during seasons of 2021 and 2022. (PI1: Continues irrigation, PI2: 2 pulses/day and PI3:3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season).

Yield of cucumber

Table 2 shows the effect of pulse irrigation and pulse fertigation on yield of cucumber for the two seasons. When analyzing the factors separately, the first factor (pulse irrigation) had a positive and significant effect on cucumber yield, which was also significantly affected by the second factor (pulse fertigation) for seasons 2021 and 2022. For the pulse irrigation treatments, the highest yield values were under PI3 followed by PI2 and the lowest values were under PI1 for the two seasons. The highest values of cucumber yield were 29.27 and 28.16 ton/ha. occurred by using PI3 for seasons 2021 and 2022, respectively and there are significant differences between using PI3 and other treatments, while the lowest values of cucumber yield were 20.36 and 19.5 tons/ha. occurred by using PI1 for seasons 2021 and 2022, respectively. The maximum yield under pulse technique described here, even if these results were produced under various experimental variables and harvesting intervals, provides as a guideline for the development of management strategies to maximize water and nutrient consumption. (Assouline et al., 2012).

For the pulse fertigation treatments, the increase in the number of fertigation pulses per season led to an increase in yield of cucumber. The highest values of cucumber yield were 29.1 and 28.13 ton/ha. occurred by using PF8 for seasons 2021 and 2022, respectively and there is a significant differences between using PF8 and other treatments, while the lowest values of cucumber yield were 20.23 and 19.43 ton/ha. occurred by using PF4 for seasons 2021 and 2022, respectively. Pulse fertigation effect on nitrogen transport inside soil and root distribution, thus affecting root water and nitrogen uptake. These results from pulse fertigation may encourage the maintenance of more consistent fertigation throughout the growing season, which may have helped to increase the stability of the soil solution and, as a result, increased nutrient absorption.

Table (2): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the on the yield and water productivity of cucumber during seasons 2021 and 2022.

Pulse Irrigation, pulses/day	Pulse Fertigation, pulses/season	Yield of fruits, (ton ha.$^{-1}$)		Water productivity (kg $_{cucumber}$ m^{-3}$_{water}$)	
		2021	2022	2021	2022
PI1		20.36	19.5	3.36	3.24
PI2		23.94	23.1	3.9	3.8
PI3		29.27	28.16	4.78	4.64
LSD $_{5\%}$		0.42	0.53		
	PF4	20.23	19.43	3.33	3.2
	PF5	23.48	22.53	3.83	3.73
	PF6	24.13	23.17	3.93	3.83
	PF7	25.67	24.67	4.2	4.07
	PF8	29.1	28.13	4.77	4.63
LSD $_{5\%}$		0.71	0.74		
	PF4	16.8	16.1	2.8	2.7
	PF5	19.5	18.6	3.2	3.1
	PF6	20	19.2	3.3	3.2
PI1	PF7	21.3	20.5	3.5	3.4
	PF8	24.2	23.1	4	3.8
	PF4	19.6	18.9	3.2	3.1
	PF5	22.8	21.9	3.7	3.6
	PF6	23.4	22.5	3.8	3.7
PI2	PF7	24.9	23.9	4.1	3.9
	PF8	29	28.3	4.7	4.7
	PF4	24.3	23.3	4	3.8
	PF5	28.14	27.1	4.6	4.5
PI3	PF6	29	27.8	4.7	4.6
	PF7	30.8	29.6	5	4.9
	PF8	34.1	33	5.6	5.4
LSD $_{5\%}$		1.25	1.26		

PI1: Continues irrigation, PI2: 2 pulses/day and PI3:3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season.

The analysis of variance showed a significant effect of the interaction between pulse irrigation and pulse fertigation on yield of cucumber for the two seasons as indicated in Figure (4) and Table (2). The highest values of cucumber yield were 34.1 and 33 ton ha^{-1} occurred under PI3 with applying PF8 for seasons 2021 and 2022, respectively and there are significant differences between using these conditions and other treatments, while the lowest values of cucumber yield were 16.8 and 16.1 ton ha^{-1} occurred by using PI1 with applying PF4 for seasons 2021 and 2022, respectively. Increasing the value of cucumber yield on 3 pulses/day of pulse irrigation with 8 pulses/season for pulse fertigation might be brought on by an increase in the nutrients that are available to plants in the root zone, which will be made more so by efficient fertigation use, better soil moisture distribution in the root zone, and an increase in the volume of wet soil in the root zone relative to field capacity. Better water availability conditions and lower evaporation and deep percolation losses ensure a constant wet bulb in the root zone. When the capacity of the field is exceeded by the amount of wetted soil, more water and nutrients are made available to the root zone. These nutrients would be more readily available to plants if the root zone's moisture content and wetted soil volume were both increased. These results are agreement with those obtained by Wang et al. (2006).

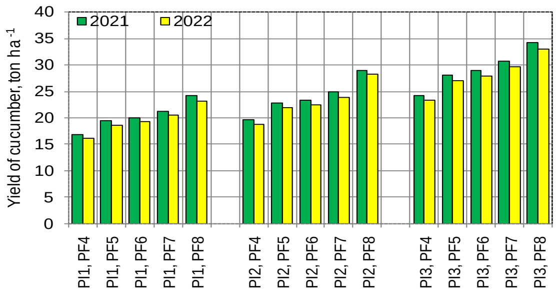

Figure (4): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the yield of cucumber during seasons of 2021 and 2022. (PI1: Continues irrigation, PI2: 2 pulses/day and PI3:3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season).

Water productivity of cucumber

Data presented in Table 2 illustrated the effect of pulse irrigation and pulse fertigation on water productivity of cucumber crop for the two seasons. The yield and water productivity of the cucumber crop follow a similar pattern.

The first factor (pulse irrigation) had clearly effect on water productivity. The highest water productivity values were under PI3 followed by PI2 and the lowest values were under PI1 for the two seasons. The highest values of water productivity were 4.78 and 4.64 kg m^{-3} occurred by using PI3 for seasons 2021 and 2022, respectively and there are significant differences between using PI3 and other treatments, while the lowest values of water productivity were 3.36 and 3.24 kg m^{-3} occurred by using PI1 for seasons 2021 and 2022, respectively.

The second factor (pulse fertigation) also had clear effect on water productivity. The highest values of water productivity were 4.77 and 4.63 kg m^{-3} occurred by using PF8 for seasons 2021 and 2022, respectively and there are significant differences between using PF8 and other treatments, while the lowest values of water productivity were 3.33 and 3.2 kg m^{-3} occurred by using PF4 for seasons 2021 and 2022, respectively.

The interaction between the two factors also effect on water productivity for the two seasons as shown in Figure (5) and Table (2). The highest values of water productivity were 5.6 and 5.4 kg m^{-3} occurred under PI3 with applying PF8 for seasons 2021 and 2022, respectively and there are significant differences between using these conditions and other treatments, while the lowest values of water productivity were 2.8 and 2.7 kg m^{-3} occurred by using PI1 with applying PF4 for seasons 2021 and 2022, respectively. If the drip irrigation system drains after each irrigation, cut the irrigation to the longest possible pulses to reduce rain loss and the area of the wet zone could be increased if irrigation was pulsing, the benefits of pulsed irrigation, such as reducing soil water evaporation, reducing fertilizer filtration and yield improvement. The fact that the water application happens at about the same rate as the crop's evapotranspiration during the day is one potential reason for the technique's benefit on water productivity in dry and fresh matter (Abdelraouf et al., 2012).

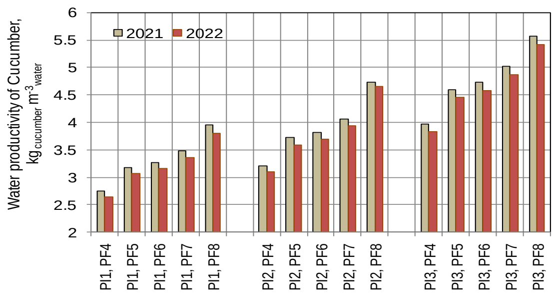

Figure (5): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the water productivity of cucumber during seasons of 2021 and 2022. (PI1: Continues irrigation, PI2: 2 pulses/day and PI3:3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season).

Quality traits of cucumber

Figure (6) shows the effect of pulse irrigation and pulse fertigation on vitamin C of cucumber crop for the two seasons. Vitamin C values under PI3 were higher that PI2 and followed by PI1 with all pulse fertigation treatments for the two seasons. The highest values of vitamin C occurred by using PF8 for seasons 2021 and 2022, respectively, while the lowest values of vitamin C were occurred by using PF4 for seasons 2021 and 2022, respectively with all pulse irrigation treatments. The highest values of vitamin C were 120.4 and 115.1 occurred under PI3 with applying PF8 for seasons 2021 and 2022, respectively, while the lowest values of vitamin C were 73.3 and 70 occurred by using PI1 with applying PF4 for seasons 2021 and 2022, respectively.

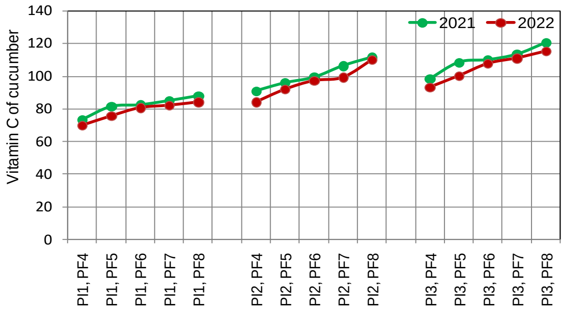

Figure (6): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the vitamin C of cucumber during seasons of 2021 and 2022. (PI1: Continues irrigation, PI2: 2 pulses/day and PI3:3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season).

Figure (7) shows the effect of pulse irrigation and pulse fertigation on the total soluble solids "T.S.S." of cucumber crop for the two seasons. T.S.S. values under PI3 were higher that PI2 and followed by PI1 with all pulse fertigation treatments for the two seasons. The highest values of T.S.S. were occurred by using PF8 for seasons 2021 and 2022, respectively, while the lowest values of T.S.S. were occurred by using PF4 for seasons 2021 and 2022, respectively with all pulse irrigation treatments. The highest values of T.S.S. were 6.6 and 6.3% occurred under PI3 with applying PF8 for seasons 2021 and 2022, respectively, while the lowest values of T.S.S. were 2.5 and 2.2% occurred by using PI1 with applying PF4 for seasons 2021 and 2022, respectively. The experiment's split irrigation made sure there was enough water present to maintain crop quality. Such an increase in quality traits may have resulted from the higher mass flow brought on by the increase of the applied fertigation depth, which in turn increased the amount of N in the soil solution and the rate at which plants absorbed the nutrient. This increase was also brought about by pulse fertigation's beneficial impact on roots' increased capacity to absorb nutrients.

In irrigated vegetable crops, drip pulse irrigation management can increase efficiency while also reducing nutrient losses. It is possible to divide irrigation of the required daily depth since it offers a good method for conserving water, energy, and nutrients. Our findings show that adopting a pulse irrigation strategy of 3 pulses per day with 8 pulses per season for pulse fertigation is a successful irrigation management technique for cucumber crops grown in greenhouses.

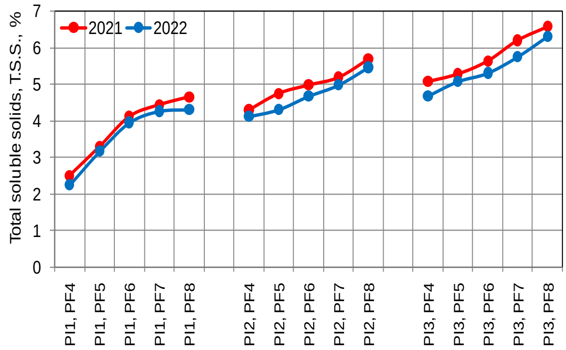

Figure (7): Effect of pulse irrigation "PI" and pulse fertigation "PF" on the total soluble solids "T.S.S." of cucumber during seasons of 2021 and 2022. (PI1: Continues irrigation, PI2: 2 pulses/day and PI3:3 pulses/day; PF4: 4 pulses/season, PF5: 5 pulses/season, PF6: 6 pulses/season, PF7: 7 pulses/season and PF8: 8 pulses/season).

However, more research is required to determine the procedure and/or methodology to determine the interval between two successive pulses, taking into account dripper flow, crop, soil, and regional climate. Additionally, consider whether similar management may be used with different crops, brackish water, fertigation, and multiple cycles of deficit irrigation with the application of a leaching depth between cycles.

CONCLUSIONS

The increase in the size of the wet soil within the root zone was caused by adding water in three pulses per day as opposed to one, increased irrigation water application efficiency and reduced water stress on the roots of the cucumber crop. Additionally, the positive effect of increasing the fertigation pulses to eight pulses per season indicates an improvement in yield, water productivity, and the quality traits for the cucumber crop when compared to other treatments during the growing season. Pulse irrigation was not much popular, but it became more popular in recent years as aeration in irrigation water became a reality. The productivity of crops benefits greatly with pulse irrigation.

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