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A NEW AND INNOVATIVE METHOD FOR SAVING WATER, ENERGY, FERTILIZERS, REDUCING OF SOIL SALTS ACCUMULATION AND WEEDS GROWTH UNDER GREENHOUSES CONDITIONS

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Abstract

Sustainable management of irrigation water encourages the application of water in an amount that meets the need of the growing plant in a manner which avoids extensive soil saturation and runoff. Through increasing application precision and reducing unneeded applications, water can be conserved and energy can be saved as well as reducing soil salts accumulation and weeds growth especially under drip irrigation system. Two greenhouse experiments were carry out at Al-Nubariya Region, Al-Buhayrah Governorate, Egypt, during seasons 2017 and 2018 to explore the impact of Cultivation methods [Cultivation into Small Pieces of PVC Pipes (CSPPP) method and Traditional Cultivation (TC) method] and deficit irrigation (100% FI, 75 % FI and 50 % FI) using pulse irrigation technique under irrigation system on water stress into roots zone, application efficiency of irrigation water "AE_{IW}" at initial growth stage, soil salts accumulation "SSA", weeds growth, yield of cucumber, and water productivity "$WP_{cucumber}$". There were significant effects for applying CSPPP method compared to TC method under drip irrigation. Where, the highest values of yield and $WP_{cucumber}$ were improved and increased under CSPPP method. The AE_{IW} also increased due to the addition of water quantity within the root propagation area, while in TC method, the amount of water ran horizontally and vertically out of the root zone. In addition to the use of the CSPPP method resulted in a decline in weeds growth due to the lower surface wet area of sandy soils compared with TC method that increased wet soil area around the roots of plant. The values of cucumber yield and WP were decreased by decreasing amount of applied irrigation water under TC method. Meanwhile, this may have resulted in increasing the fertilizer elements and concentrating them with less water quantities and not leaving part of them outside the root spread area. In conclusion, the use of the new method (CSPPP method) led to creating and creating a very healthy environment for plant growth, (Minimum water stress inside root zone, soil salts accumulation and weeds growth around cucumber Plant - Maximum application efficiency of irrigation water at initial growth stage of cucumber plant,) which reflected positively on the ability of plant roots to increase the absorption of major nutrients and store a large part of them in the leaves of cucumber plants in addition to increasing of leaves area and chlorophyll content and as a result increasing the productivity and saving 50% of the water needs, and as a result, saving 50% of the energy needed for pumping irrigation water when producing cucumbers under greenhouses conditions.

Keywords: Drip irrigation, Cultivation methods, Deficit irrigation, Soil moisture content, Weeds growth, PVC Pipe, Cucumber.

Introduction

Water shortage and scarcity are one of the major and serious problems facing crops cultivation and production in the Arab Republic of Egypt, and it is important and necessary to reduce irrigation water consumption through developing and improving new and innovative technologies that can be an effective tool and affect effectively (Abdelraouf *et al*., 2013b; El-Metwally *et al*., 2015). In arid and semi-arid countries with large population growth and limited fresh water, there is significant stress and pressure on the agricultural sector to reduce and limit fresh water consumption for irrigation for the urban and industrial sectors (Abdelraouf and Abuarab 2012; Hozayn, *et al*., 2016). The agricultural sector faces a serious challenge in increasing food production with less irrigation water, which can be accomplished by increasing crop water productivity (Abdelraouf *et al*., 2013c; Dewedar *et al*., 2019). Increasing crop water productivity is an important goal and is to increase demand while increasing high population growth (Bakry *et al*., 2012) and (Abdelraouf and Ragab 2018). The limited water resources in Egypt suffer from severe water scarcity, which increases with the increasing population. The increasing competition for scarce water resources is competing for innovative and new application of new irrigation techniques to increase water productivity and improve crop productivity and quality (Abdelraouf and Habasha, 2014; El-Shafie *et al*., 2017; Marwa, *et al*. 2017). The water productivity of crops in the Arab Republic of Egypt is extremely important because water resources are limited and precipitation is a very limited and low factor (Hozayn *et al*., 2013). The application of modern irrigation methods, accompanying technologies and increasing the water efficiency is an important concept that you must do in arid and semi-arid areas as in Egypt for providing part of irrigation water due to limited water resources (El-Habbasha *et al*., 2014; Abdelraouf *et al*., 2012; Hussein *et al*., 2016). Irrigation water is becoming scarce progressively not only in arid and semi-arid regions, but also in the regions which rainfall is much. Therefore, water saving and water conservation are the main goal to support activities of agricultural (El-Shafie *et al*., 2018; Hozayn *et al*., 2020). On the other hand, sandy soils suffer due to water shortage, while condensing mineral fertilization through irrigation water supply exposes the environment to endanger. Therefore, there is need to cultivate the sandy soils to fight against hunger in the world, but with the least amount of irrigation (Saleh and Ozawa, 2006). In Egypt, water is an essential factor in agriculture production. In arid and semi-arid regions where, irrigation water is required for production of crop, growers are looking for methods to save water by increasing irrigation efficiency (Youssef *et al*., 2018). Scheduling of optimum irrigation based on water use patterns and crop response to deficit of water can possibly improve water use efficiency (Wahba *et al*., 2016; Marwa *et al*., 2020). Apply of drip irrigation system uses water less than sprinkler and surface systems since only a portion of the soil surface area is irrigated (Amer *et al.*, 2009). Drip irrigation system with its ability to provide small and frequent water application directly in the plant root zone has proved to be a success in terms of water and increased yield in a wide range of crops (Rahil and Antonopoulos, 2007; Janat, 2003; Bhardwaj, 2001).

Cucumber (*Cucumis sativus* L.) crop contain on antioxidants, vitamins, minerals and fibers, contain also lipids and are low in sugar (Abbey *et al*., 2017). Cucumber is sensitive to stress of water due to its surface fibrous root system (Kirnak and Demirtas, 2006; Hashem *et al.*, 2011). Water is an important limiting factor in production and quality of cucumber because it has a sparse root system; about 85% of root length is concentrated in upper 30 cm top layer of soil (Janoudi and Widders, 1993). Many studies showed that fresh fruit of cucumber yield were highly affected by the total amount of irrigation water at all growth stages (Hasandokht, 2005; Wang and Zhang, 2004; Castilla *et al.*, 1991). Water use efficiency (WUE) relates to how much yield is obtained from a unit of applied water (Howell, 2003). Water use efficiency determining is essential to obtain optimum of irrigation level. In general cucumber irrigation water use efficiency (IWUE) was the lowest under unstressed irrigation water (Kirnak and Demirtas, 2006; Hashem *et al.*, 2011). While, Wang *et al.* (2009) and Zhang *et al.* (2011) shown that IWUE was the lowest under water stress conditions. Similarly, (Ayas and Demirtaş, 2009) determined that IWUE increased with increase applied of irrigation water for cucumber. Sandy soils are especially critical for water management due to it's low capacity of water-holding, low organic matter and high infiltration rate, which may induce low water use efficiency (Al-Omran *et al.* 2005). High frequency water management by drip irrigation system provides daily requirement of water to a part of the root zone for each plant and preserve a high soil matric possibility in the rhizosphere to decrease plant water stress (Nakayama and Bucks, 1986).

Accordingly, the aim of the study was to evaluate the performance of a new method under conditions of water stress on water productivity and productivity and the quality of the cucumber crop under sandy soil and dry areas conditions with the aim of providing irrigation water, mineral fertilizers and energy consumed in the process of pumping water, accumulation of salts in the soil and weed growth.

Materials and Methods

Location and climate of experimental site: The field experiments were conducted during 2017 and 2018 seasons at the research farm station of National Research Centre (NRC) (latitude 30° 30' 1.4"N, longitude 30°19' 10.9" E, and 21 m + MSL (mean sea level) at Al-Nubariya Region, Al-Buhayrah Governorate, Egypt. The experimental area has an arid climate with cool winters and hot dry summer. The data of average temperature, relative humidity and wind speed were obtained from the meteorological data of the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center for El-Nubaryia region, as shown in Figure 1.

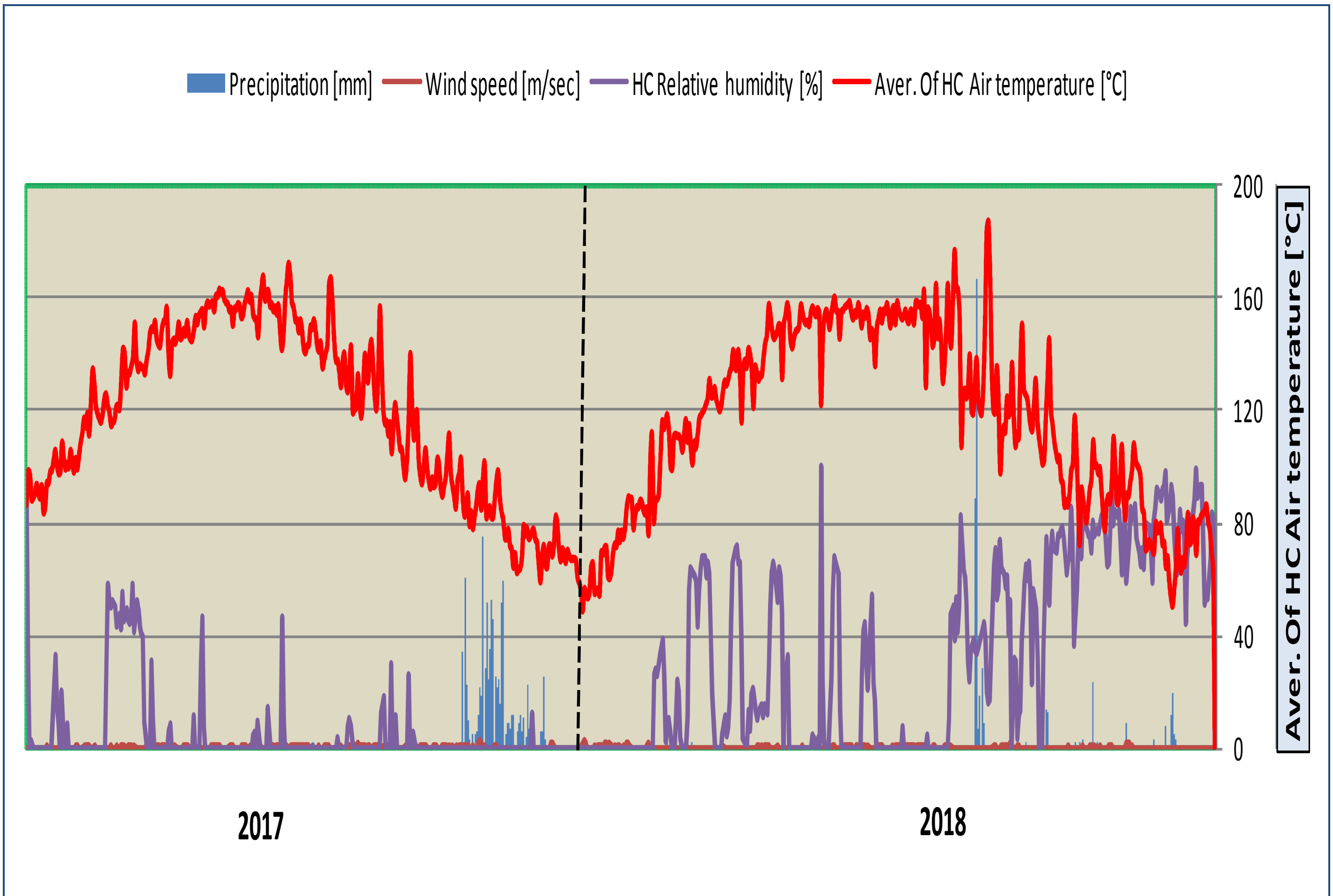


Fig. 1 : The daily data of temperature, relative humidity and wind speed were obtained from the meteorological data of the Central Laboratory for Agricultural Climate (CLAC), weather station for El-Nubaryia region.

Physical and chemical properties of soil and irrigation water: Irrigation water source was an irrigation channel passing through the experimental area, with an average pH of 7.36 and 0.42 dS m^{-1} as electrical conductivity (EC). The main physical and chemical properties of the soil are shown in Table 1.

Table 1: Physical and chemical properties of the soil of the experimental area

Physical properties			
Soil layer depth (cm)	0–15	15-30	30-45
Texture	Sandy	Sandy	Sandy
Course sand (%)	48.62	54.77	42.64
Fine sand (%)	48.80	41.55	53.46
Silt+ clay (%)	2.58	3.68	3.90
Bulk density (t m^{-3})	1.68	1.66	1.65
Chemical properties			
$EC_{1:5}$ (dS m^{-1})	0.46	0.50	0.65
pH (1:2.5)	8.51	8.50	8.82
Total $CaCO_3$ (%)	7.11	2.44	4.65

*EC = Electric Conductivity

Experimental design: Two trials were conducted to reach the study objective.

The first experimental design was without cultivating, it was for determining the best dimensions for the small PVC pipes that will be cultivated. Also, for determining the adding method of irrigation water (continuous drip irrigation or pulsed drip irrigation) to ensure that part of the added irrigation water does not come out of the small PVC pipe pieces as shown in Figure 2.

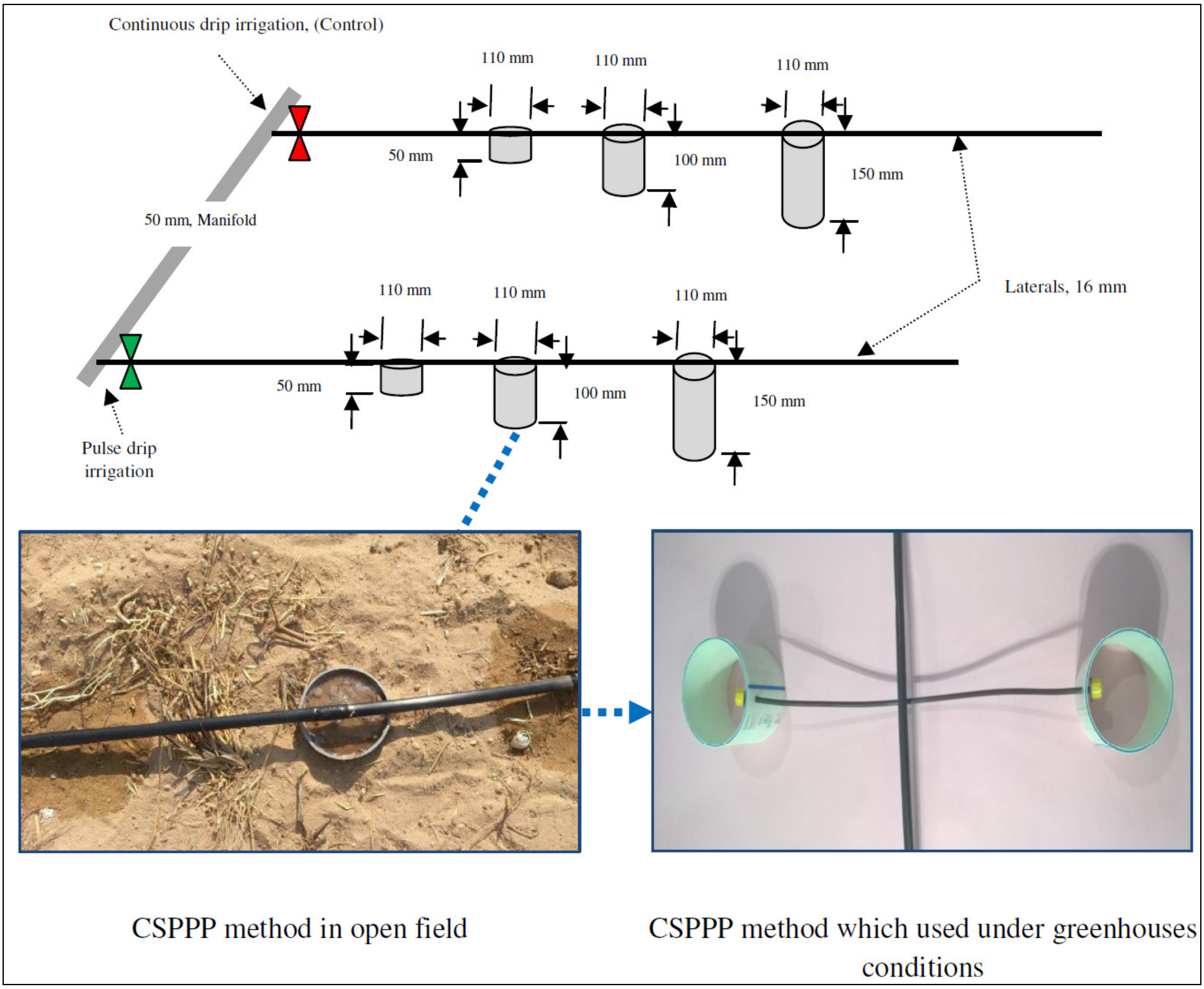


Fig. 2 : Layout of the first experimental design.

The second experimental design: Experimental design and treatments was split plot with three replications. Deficit irrigation [100%Full Irrigation"100%FI", 75% FI and 50%FI] were used in main plots and method of irrigation [cultivation in small pieces of PVC pipes" CSPPP method" and traditional method of drip irrigation, TM (control) and the both methods were applied with pulse irrigation system] were used in sub main plots as shown in Figure (3).

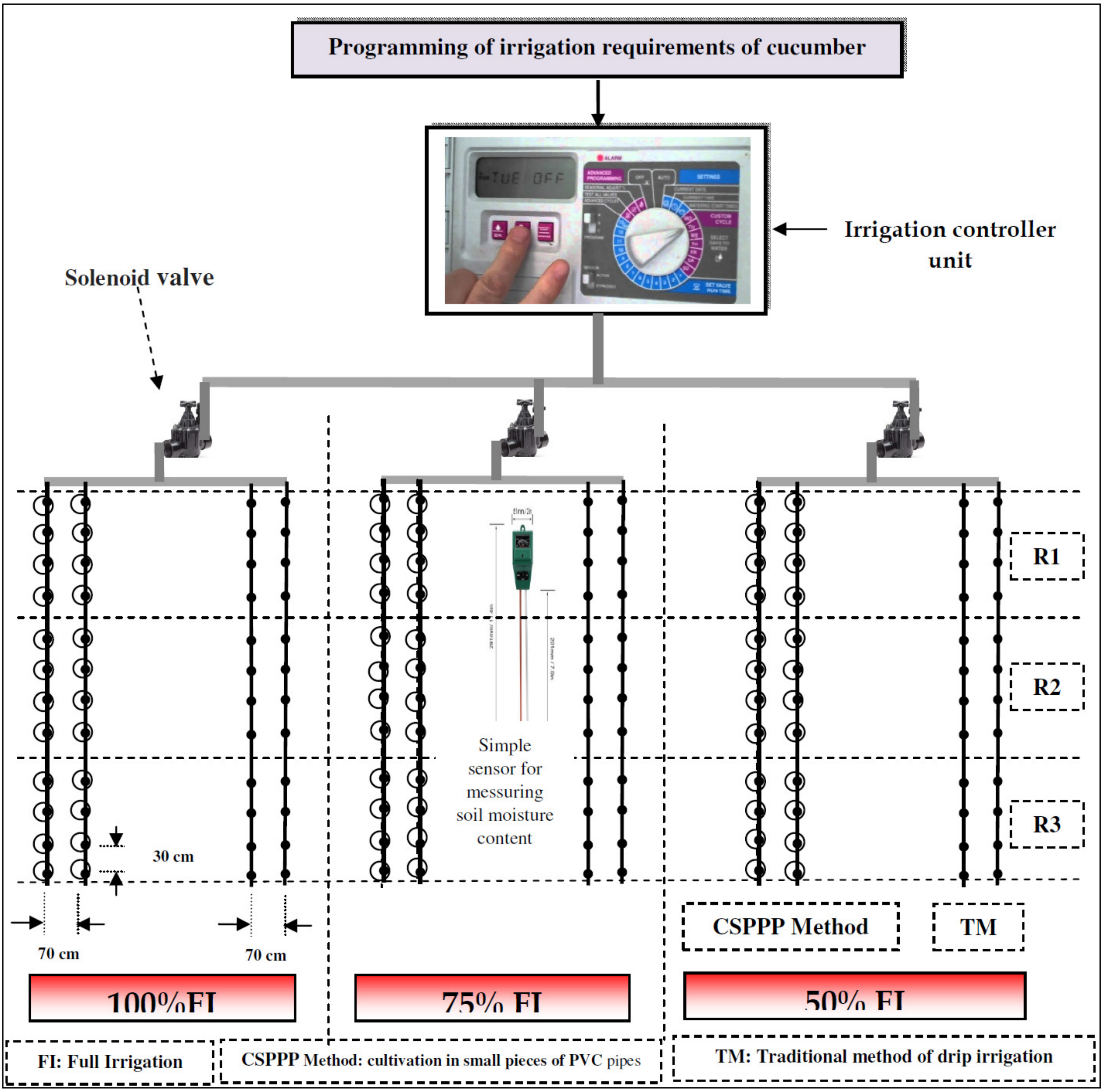


Fig. 3 : Layout of the second experimental design.

Estimation the seasonal irrigation water for cucumber: Seasonal irrigation water was estimated according to the meteorological data of the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Dokki, Egypt depending on Penman-Monteith equation. Seasonal irrigation water requirement for cucumber crop were 6000 m^3. ha^{-1} for season 2017 and 6100 m^3 ha^{-1} for season 2018. Daily irrigation water was calculated by the following equation (1) for two seasons, 2017 and 2018 under drip irrigation system:

$$IRg = [(ET_o \times Kc \times Kr) / Ei] - R + LR \qquad ...(1)$$

Where: IRg = Gross irrigation requirements, mm/day, ET_o= Reference evapotranspiration, mm/day, Kc = Crop factor (FAO-56), Kr = Ground cover reduction factor, Ei = Irrigation efficiency, %, R = Water received by plant from sources other than irrigation, mm (for example rainfall), LR = Amount of water required for the leaching of salts, mm. Gross irrigation requirements were converted from mm/ha/day to m^3/ha/day.

All agricultural practices were carried out according to the recommendations of Ministry of Egyptian Agriculture for cucumber production in El-Nobaria region.

Evaluation parameters

Water stress inside root zone: Measuring the soil moisture content in the effective root zone before and after irrigation and taking field capacity and wilting point as evaluation lines were considered as an evaluation parameter for exposure range of the plants to water stress "WS" (Abdelraouf, 2014). Soil moisture content was measured by simple sensor device.

Application efficiency of irrigation water "AE_{IW}" at the initial growth stage of cucumber plant: Soil moisture content "SMC" was determined and it was taken at maximum actual water requirements at the initial growth stage of cucumber plant by simple sensor device before and 2 hours after irrigation and from different locations inside effective root zone (20 cm depth). According to El-Meseery, (2003) application efficiency "AE_{IW}" was calculated using the following relation (2):

$$AE_{IW} = Ds/ Da \qquad ...(2)$$

Where: AE_{IW} = Application efficiency of irrigation water, (%), Ds = Depth of stored water in root zone (cm) and it was calculated by equation (3)

$$Ds = (\theta_1 - \theta_2) * d * \rho \qquad ...(3)$$

where: Da = Depth of applied water (cm), d = Soil layer depth (cm), θ_1 = Soil moisture content after irrigation (%), θ_2 = Soil moisture content before irrigation (%), ρ = Relative bulk density of soil (dimensionless).

Salt accumulation in the root zone: measuring the total soil salts in the root zone before cultivation and after harvesting the cucumber.

Weeds growth: Weeds were pulled by hand from 1 m^2 of each experimental unit at 80 days after sowing, and then the collected weeds were dried by air in the sun and then in an electric oven for 72 hours, maintaining a constant temperature of 70°C. Consequently, the dry weights of weeds were recorded.

Yield of cucumber: At harvest time of cucumber, total weights of fruits in each treatment were recorded by harvesting cucumber, as Kg per 1 m^2 were calculated, fruits twice weekly and then the total yield as ton/hectare was calculated.

Water productivity of cucumber: "$WP_{cucumber}$" was calculated according to James (1988) by equation (4) as follows:

$$WP_{cucumber} = Ey/Ir \qquad ...(4)$$

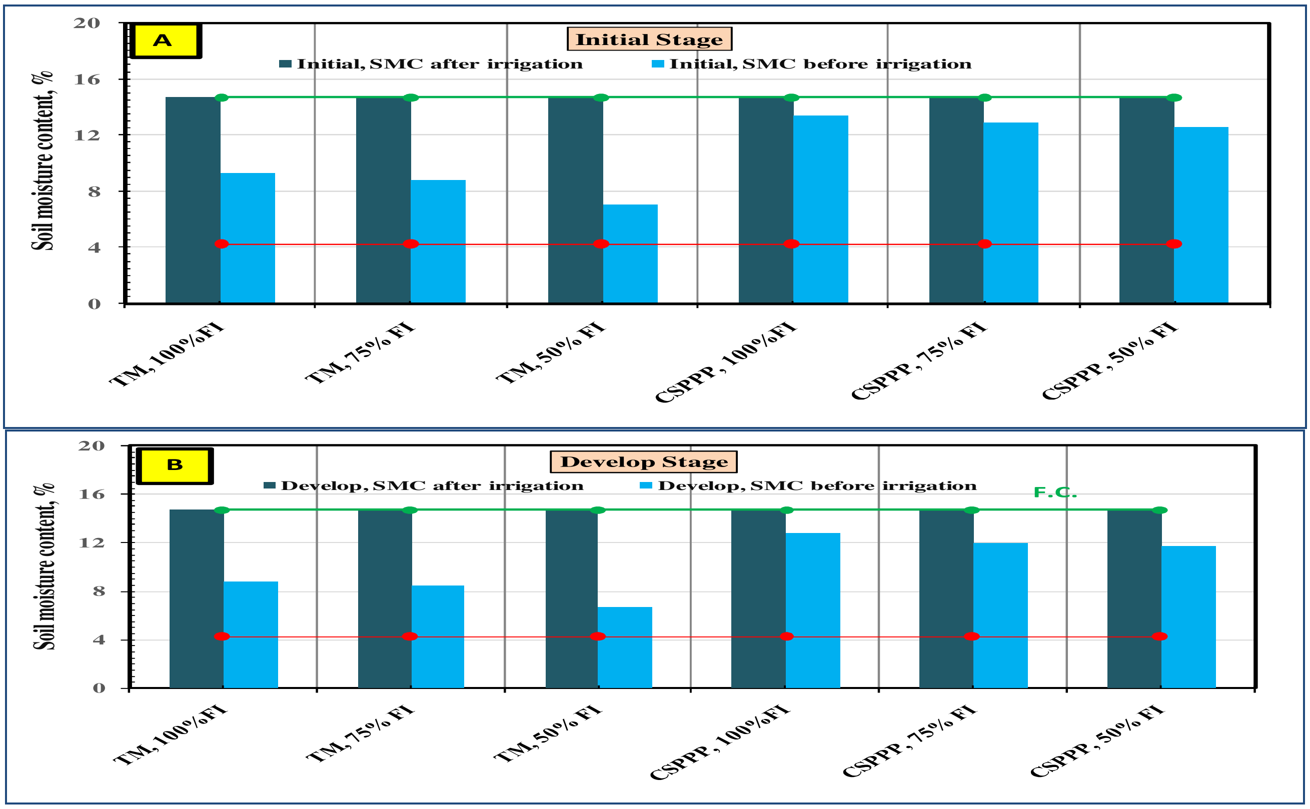
Where: $WP_{cucumber}$ is water productivity of cucumber ($kg_{cucumber}$ / $m^3_{irrigation\ water}$), Ey is the economical yield ($kg_{cucumber}$ / hectare/season); Ir is the applied amount of irrigation water ($m^3_{irrigation\ water}$ /hectare/season).

Statistical analysis: All the obtained data from two seasons of the study were statistically analyzed using the analysis of variance method according to Snedecor and Cochran (1980) while, the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

Results and Discussion

Water Stress Inside Root Zone

Effect of cultivation methods [Cultivation into Small Pieces of PVC Pipes (CSPPP) method and traditional cultivation (TC) method] and deficit irrigation (100%FI, 75 % of FI and 50 % of FI) using pulse irrigation technique under irrigation system on the water stress inside roots zone for cucumber crop at different growth stages is illustrated in Figure 4. (A, B, C and D). Data demonstrated that the lowest values of water stress occurred under CSPPP method compared to TC method in all growth stages generally. This resulted from adding irrigation water, whether a large or small amount in a small and specific area when using the new method, as the movement of added irrigation water within the soil sector shifted from three-dimensional movement to one-dimensional movement, especially in the initial stages of plant growth. Meanwhile, the highest values of water stress inside roots zone were recorded with using 50%FI followed by 75%FI and 100%FI respectively. The volume of water stress under deficit irrigation using CSPPP method was much higher compare with using TC method. So, the treatments were arranged in ascending order from the lowest water stress to the higher ones CSPPP, 100% FI> CSPPP, 75%FI> CSPPP, 50%FI> TC, 100%FI> TC, 75%FI> TC, 50%FI respectively as shown in Figure 4 (A, B, C and D).



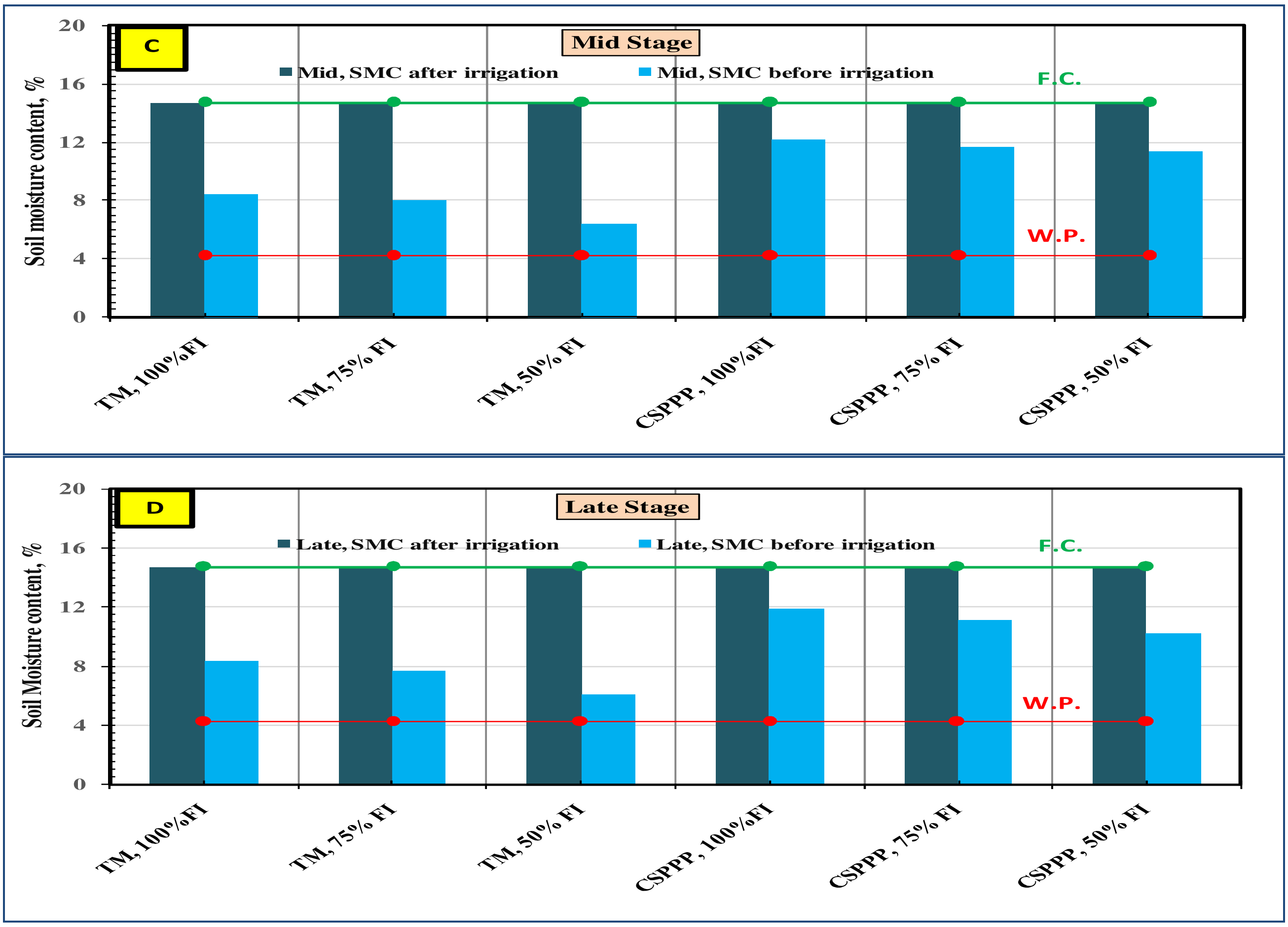


Fig. 4 (A, B, C and D). Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on water stress within the root zone of the cucumber plant during all growth stages 2017 and 2018 seasons.

Application Efficiency of Irrigation Water at Initial Growth Stage of Cucumber Plant

Application efficiency of irrigation water "AE_{IW}" is a term which using to measurement the effective of irrigation system to store the water into plants roots zone. It is expressed as a percentage of total volume for irrigation water delivered to the field and which stored in the roots zone to meet crop evapotranspiration (ET) needs. Figure (5) exhibited the effect of cultivation methods and deficit irrigation using pulse irrigation technique under drip irrigation system on the AE_{IW} at the initial growth stage of cucumber plants. This resulted from adding irrigation water, whether a large or small amount in a small and specific area when using the new method, as added irrigation water was stored inside the soil sector, especially in the initial growth stage of the plant. Minimum AE_{IW} occurred under TC compared to CSPPP method. AE_{IW} values were increased with decreasing in amount of irrigation water where, the highest values of AE_{IW} were obtained at 50%FI followed by 75%FI and 100%FI respectively. Consequently, the treatments were arranged in ascending order from the smaller AE_{IW} to the higher ones TC, 100%FI> TC, 75%FI> TC, 50%FI> CSPPP, 100%FI> CSPPP, 75%FI> CSPPP, 50%FI as illustrated in Figure 5.

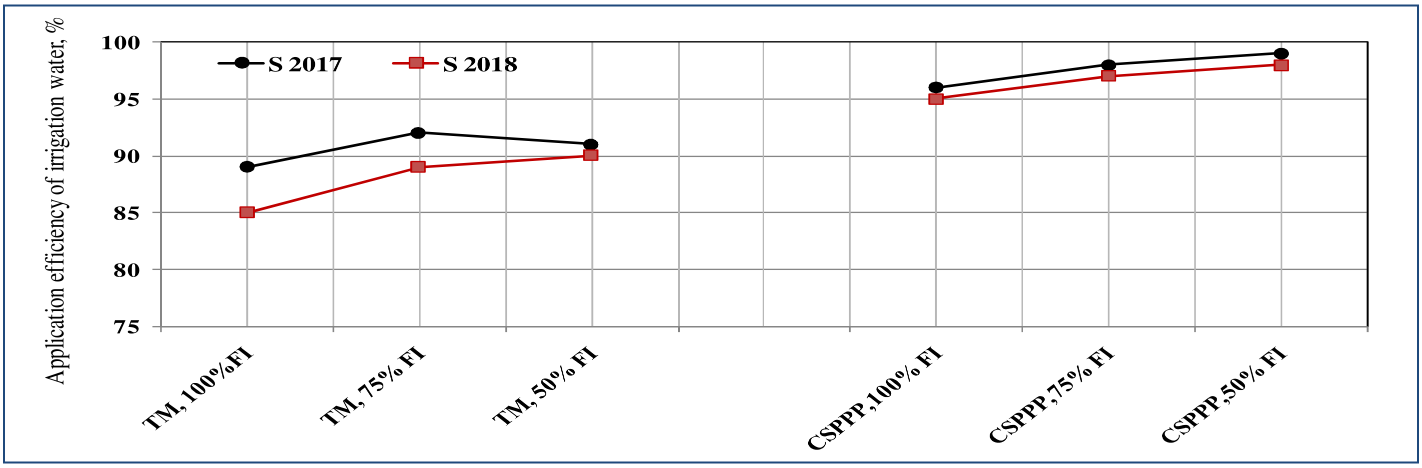


Fig. 5 : Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on application efficiency of irrigation water at the initial growth stage of plant for seasons 2017 and 2018.

Soil Salts Accumulation

Though the drip irrigation system is the most efficient system comparable with other systems to supply the water, it has some disadvantages; the most common problem in this system is accumulation of salts on soil surface. The effect of cultivation methods and deficit irrigation using pulse irrigation technique under drip irrigation system on the soil salts accumulation "SSA" into roots zone of cucumber plants is shown in Figure 6. Where that the maximum values of SSA were recorded under TC method compared to CSPPP method. This resulted from an increase in the wet surface area exposed to sunlight, which of course experienced a higher rate of evaporation, which was reflected in the increase in the accumulation of salt in the soil under the conditions of the traditional method, while the opposite happened completely when applying the new method. Meanwhile, the values of SSA were decreased by decreasing in the amount of irrigation water under CSPPP method where, SSA values at 50% of FI and 75% of FI were lower than at 100%FI respectively, but there was a slight increase in values of SSA by decreasing of an irrigation water amount which added under CSPPP method. Consequently, the treatments were arranged in ascending order from the smaller values of SSA to the higher ones CSPPP, 100%FI> CSPPP, 75%FI> CSPPP, 50%FI> TC, 50%FI> TC, 75%FI> TC, 100%FI as exhibited in Figure 6.

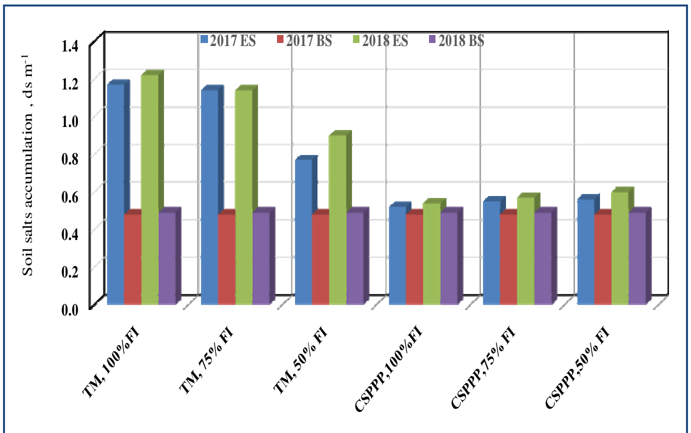


Fig. 6 : Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on the soil salts accumulation for seasons 2017 and 2018.

Weeds Growth around Cucumber Plant

It is known that increases of weeds growth with the increase in the wet surface of the soil, as confirmed by results of some research and the following study. Figure 7 represents the effect of cultivation methods and deficit irrigation with pulse irrigation technique under drip irrigation system on the dry weight of total weeds "DWTW" during growth stages of cucumber plants. Minimum values of DWTW occurred under CSPPP method compared to TC method. On the other hand DWTW values were increased by increasing the amount of irrigation water under TC where, values of DWTW at 100%full irrigation were higher than 75%FI and 50%FI respectively but there were a slight increase in DWTW values with decreasing of irrigation water amount which added under CSPPP method. The decrease in the wet surface area with the new method reduced the opportunities for weed growth compared to the traditional method with a large wet surface area, which is a source of absorbing water and nutrients encouraging the growth of weeds in this large area. Consequently, the treatments were arranged in ascending order from the smaller DWTW values to the higher ones, CSPPP, 100%FI˙ CSPPP, 75% FI> CSPPP, 50% FI> TC, 50% FI> TC, 75% FI> TC, 100%FI as illustrated in Figure 7.

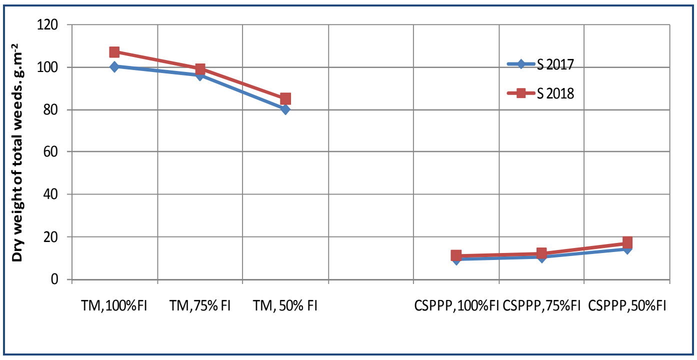


Fig. 7 : Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on the dry weight of total weeds during growing of cucumber plant for seasons 2017 and 2018.

NPK Contents on Cucumber Leaves

Data in Table 2 indicated clearly that cultivation methods [Cultivation into Small Pieces of PVC Pipes (CSPPP) method and Traditional Cultivation (TC) method] affected significantly cucumber NPK content in 2017 and 2018 seasons. It is noteworthy to mention that CSPPP method exhibited similar effects on N, P and K of cucumber plants; compare with another traditional cultivation (TC) method in 2017 and 2018 seasons. It is clear from data in Table 2 there are significant differences due to variation of deficit irrigation (100%FI, 75 % of FI and 50 % of FI) in N and P of cucumber plants except for K content in both seasons. In the first and the second seasons, when cucumber plants were irrigated with 100%FI followed by 75 % of FI led to significant increases in N and P of cucumber plants where irrigation with 50 % of FI showed significant decreases in N and P of cucumber plants. In both experimental seasons, the effect of interaction showed significantly the highest values for N, P and K content of cucumber plants as illustrated in Table 2. Whereas, significant increases in N, P and K content of cucumber were observed by using CSPPP method at 50 %FI followed by using CSPPP method at 75%FI in all studied parameters compare with other treatments in 2017 and 2018 seasons. Briefly, the use of the new method led to creating and creating a very healthy environment for plant growth, which reflected positively on the ability of plant roots to increase the absorption of major nutrients and store a large part of them in the leaves of cucumber plants.

Table 2: Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on NPK contents on cucumber leaves during growing of cucumber plant for seasons 2017 and 2018.

Method of irrigation	Deficit irrigation	2017			2018		
		N %	P %	K %	N %	P %	K %
Effect of cultivation methods on NPK contents of cucumber leaves							
TM, (control)		4.156 b	0.6733b	2.990 b	4.031 b	0.660 b	2.840 b
CSPPP method		6.156 a	1.016 a	4.514 a	5.972 a	0.996 a	4.289 a
LSD at 5%		0.5983	0.06414	0.2222	0.5773	0.06414	0.2222
Effect of deficit irrigation on the fruit quality of cucumber leaves							
	100%FI	5.350 a	0.877 a	3.772	5.190 a	0.857 a	3.583
	75% FI	5.217 a	0.830 b	3.695	5.062 a	0.815ab	3.512
	50% FI	4.900 b	0.827 b	3.790	4.753 b	0.812 b	3.598
LSD at 5%		0.2793	0.04210	N.S	0.2696	0.04210	N.S
Effect the interaction of CSPPP method and deficit irrigation on the fruit quality of cucumber leaves							
TM, (control)	100%FI	4.967 d	0.790 c	3.420 d	4.817 d	0.770 c	3.250 d
	75% FI	4.300 e	0.663 d	2.930 e	4.173 e	0.653 d	2.783 e
	50% FI	3.200 f	0.567 e	2.620 e	3.103 f	0.557 e	2.487 e
CSPPP method	100%FI	5.733 c	0.963 b	4.123 c	5.563 c	0.943 b	3.917 c
	75% FI	6.133 b	0.997 b	4.460 b	5.950 b	0.977 b	4.240 b
	50% FI	6.600 a	1.087 a	4.960 a	6.403 a	1.067 a	4.710 a
LSD at 5%		0.3949	0.05954	0.3315	0.3812	0.05954	0.3151

Leaves Area and Chlorophyll Content

Data found in Table 3 contain the effect of cultivation methods on Leaves area and chlorophyll content in leaves of cucumber plants. It is clear from data that a quite similar trend was obtained in both experimental seasons regarding the effect of cultivation methods on Leaves area and chlorophyll content in leaves. In both seasons, leaves area and chlorophyll content were increased significantly by using CSPPP method. Moreover, traditional cultivation method exhibited the lowest values of Leaves area and chlorophyll content in leaves in the two seasons. Effect of deficit irrigation on Leaves area and chlorophyll content in leaves is exhibited in Table 3. Significant differences due to deficit irrigation were attained in both experimental seasons. The highest significant values of Leaves area and chlorophyll content in leaves were recorded when plants of cucumber crop were irrigated with 100%FI and 75% FI in 2017 season as well as the highest significant values of Leaves area and chlorophyll content in leaves were recorded when plants of cucumber crop were irrigated with 100%FI in 2018 season, Meanwhile, the lowest significant values of leaves area and chlorophyll content in leaves were obtained under irrigation treatment at 50% FI in the first and second seasons. Data regarding the interaction between cultivation methods and deficit irrigation and its effect on leaves area and chlorophyll content in leaves is found in Table 3. Significant differences due to cultivation methods and deficit irrigation in both experimental seasons, from data table the highest values of Leaves area and chlorophyll content in leaves were given with irrigated at 50 %FI under CSPPP method followed by 75 %FI under CSPPP method. While the lowest interaction values of leaves area and chlorophyll content in leaves of cucumber crop were recorded when irrigated with 75%FI and 50 %FI under traditional cultivation (TC) method in the two seasons.

Table 3 : Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on the leaves area and chlorophyll content of cucumber leaves during growing of cucumber plant for seasons 2017 and 2018.

Method of irrigation	Deficit irrigation	Leaves area, cm^2		Chlorophyll content, SPAD	
		2017	2018	2017	2018
Effect of the CSPPP method on the leaves area and chlorophyll content of cucumber leaves					
TM, (control)		9240 b	32.72 b	9056 b	31.74 b
CSPPP method		12660 a	46.19 a	12400 a	44.80 a
LSD at 5%		540.7	1.872	529.9	1.814
Effect of deficit irrigation on the leaves area and chlorophyll content of cucumber leaves					
	100%FI	11080 a	41.02 a	10860 a	39.79 a
	75% FI	11030 a	39.40 b	10810 a	38.22 b
	50% FI	10730 b	37.95 c	10520 b	36.81 c
LSD at 5%		272.2	0.9990	266.7	0.9665

Effect the interaction of CSPPP method and deficit irrigation on the leaves area and chlorophyll content of cucumber leaves					
TM, (control)	100%FI	10110 d	37.63 d	9904 d	36.50 d
	75% FI	9549 e	32.67 e	9358 e	31.69 e
	50% FI	8066 f	27.87 f	7905 f	27.03 f
CSPPP method	100%FI	12060 c	44.40 c	11820 c	43.07 c
	75% FI	12510 b	46.13 b	12260 b	44.75 b
	50% FI	13400 a	48.03 a	13130 a	46.59 a
LSD at 5%		384.9	1.413	377.2	1.367

Cucumber Yield

It is clear from Table 4 that yield of cucumber was significantly affected by cultivation methods in the two seasons. Where, using CSPPP method surpassed significantly on traditional cultivation method (TC) in yield of cucumber. Data shown in Table 4 illustrated the significant relationships among deficit irrigation on yield of cucumber, where that the higher value was obtained under FI treatment compared with either 75 % or 50 % of FI. Effect of interaction between cultivation methods and deficit irrigation on Productivity of cucumber is exhibited in Table 4 and Figure 8. Significant differences due to interaction were attained on yield of cucumber in both experimental seasons. The highest significant interaction values of cucumber yield were recorded when cucumber plants irrigated at 50 % of FI followed by 75 % and FI under CSPPP method in both seasons. Meanwhile, the lowest significant interaction values of cucumber yield were shown under traditional cultivation method with irrigated at 50 and 75 % of FI in 2017 and 2018 seasons. In conclusion, the use of the new method (CSPPP method) led to creating and creating a very healthy environment for plant growth, (Minimum water stress inside root zone, soil salts accumulation and weeds growth around cucumber Plant - Maximum application efficiency of irrigation water at initial growth stage of cucumber plant,) which reflected positively on the ability of plant roots to increase the absorption of major nutrients and store a large part of them in the leaves of cucumber plants in addition to increasing of leaves area and chlorophyll content. All of the above has resulted in increased water productivity and productivity using the new method of producing cucumbers under greenhouse conditions.

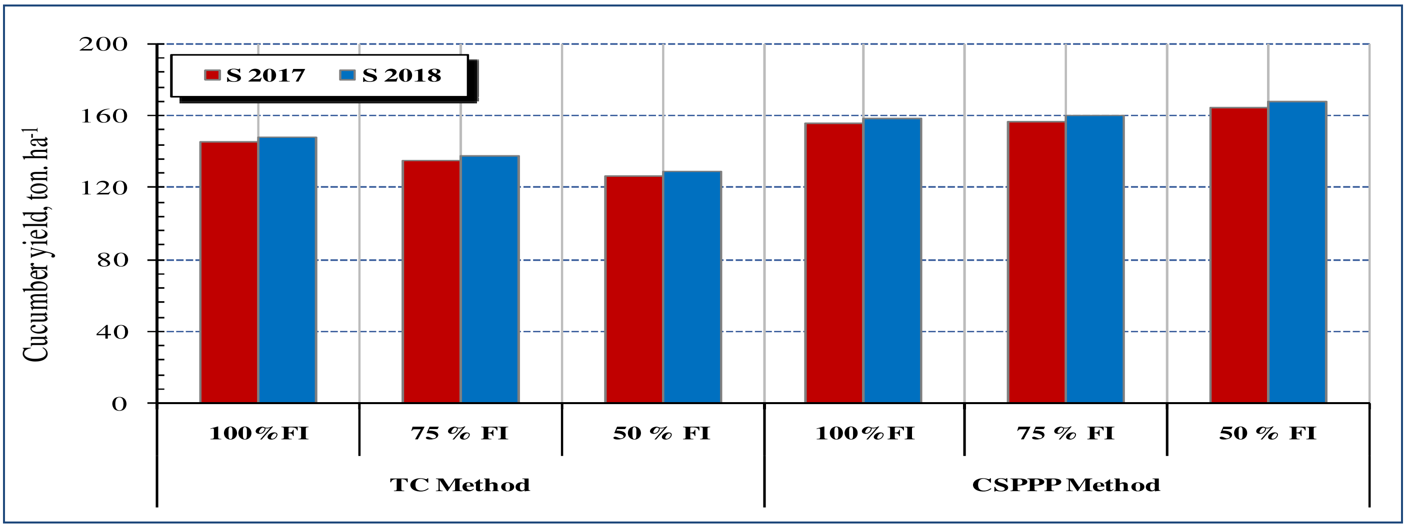


Figure 8. Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on the cucumber yield during growing of cucumber plant for seasons 2017 and 2018.

Water Productivity of Cucumber

Figure 9 and Table 4 shown the effect of cultivation methods and deficit irrigation using pulse irrigation technique under drip irrigation system on the water productivity "$WP_{cucumber}$". Maximum value of $WP_{cucumber}$ was occurred under CSPPP method compared to TC method. $WP_{cucumber}$ value was increased by decreasing in irrigation water amount under both TC and CSPPP method where, $WP_{cucumber}$ value at full irrigation and 75% of FI was smaller than at 50% of FI. Consequently, the treatments were arranged in descending order from the higher $WP_{cucumber}$ to the smaller ones, CSPPP, 50% FI> TC, 50% FI> CSPPP, 75% FI> TC, 75% FI> CSPPP, FI>TC, FI. The use of the new method (CSPPP method) resulted in providing 50% of the water needs when producing cucumbers under greenhouse conditions, and as a result, providing 50% of the necessary water for pumping irrigation water.

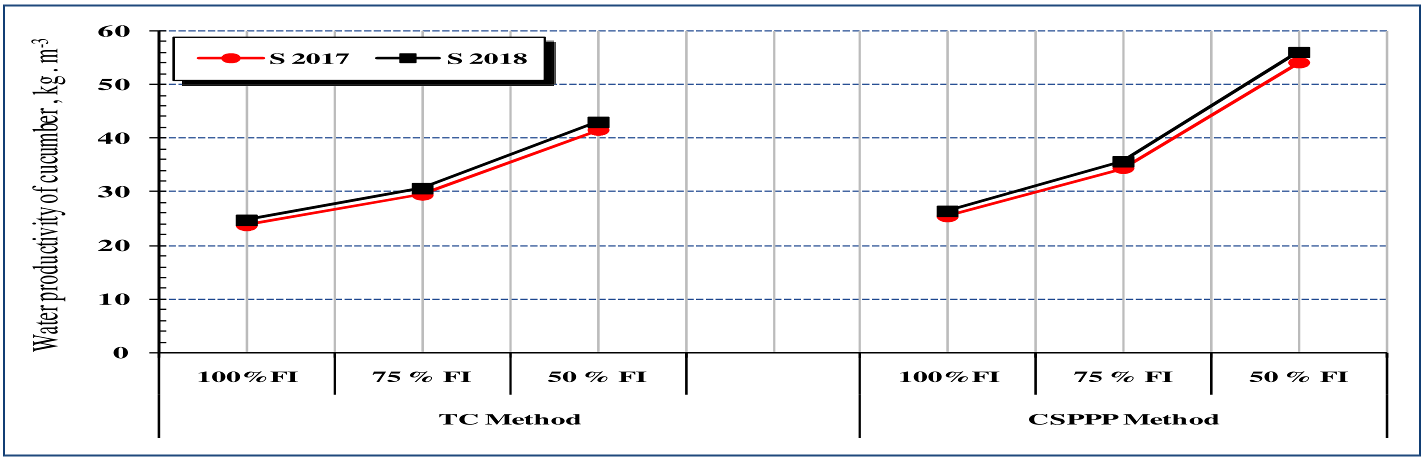


Fig. 9 : Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on the water productivity of cucumber during growing of cucumber plant for seasons 2017 and 2018.

Table 4: Effect of CSPPP method (cultivation in small pieces of PVC pipes), traditional method of drip irrigation "TM (control)" and deficit irrigation (100%Full irrigation "100%FI", 75%FI and 50% FI) with pulse irrigation technique on the yield and water productivity of cucumber during growing of cucumber plant for seasons 2017 and 2018.

Method of irrigation	Deficit irrigation	Yield of cucumber, ton ha^{-1}		WP cucumber, kg m^{-3}	
		2017	2018	2017	2018
Effect of the CSPPP method on the yield and water productivity of cucumber					
TM, (control)		138.4 b	135.7 b	32.80 b	31.62 b
CSPPP method		162.4 a	159.2 a	39.38 a	37.96 a
LSD at 5%		9.519	9.333	2.371	2.291
Effect of deficit irrigation on the yield and water productivity of cucumber					
	100%FI	153.5 a	150.4 a	25.58 c	24.66 c
	75% FI	149.1 b	146.2 b	33.15 b	31.95 b
	50% FI	148.6 b	145.7 b	49.54 a	47.76 a
LSD at 5%		2.295	2.248	0.6644	0.6399
Effect the interaction of CSPPP method and deficit irrigation on the yield and water productivity of cucumber					
TM, (control)	100%FI	148.1 c	145.2 c	24.69 f	23.80 f
	75% FI	138.0 d	135.2 d	30.67 d	29.56 d
	50% FI	129.1 e	126.6 e	43.05 b	41.49 b
CSPPP method	100%FI	158.8 b	155.6 b	26.47 e	25.51 e
	75% FI	160.3 b	157.1 b	35.62 c	34.34 c
	50% FI	168.1 a	164.8 a	56.04 a	54.02 a
LSD at 5%		3.246	3.179	0.9395	0.9049

Conclusion

The use of the new method (Cultivation into Small Pieces of PVC Pipes "CSPPP method") led to creating and creating a very healthy environment for plant growth, (Minimum water stress inside root zone, soil salts accumulation and weeds growth around cucumber Plant - Maximum application efficiency of irrigation water at initial growth stage of cucumber plant). Which reflected positively on the ability of plant roots to increase the absorption of major nutrients and store a large part of them in the leaves of cucumber plants. In addition to increasing of leaves area and chlorophyll content and as a result, increasing the productivity and saving 50% of the water needs, and as a result, saving 50% of the energy needed for pumping irrigation water when producing cucumbers under greenhouses conditions.

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