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Effects of Different Irrigation Levels with Bio-stimulant Applications on Plant Growth in 'Kabarla' Strawberry Variety

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Abstract: In this study, the effects of different irrigation levels with bio-stimulant applications on leaf area, crown diameter, number of crown, leaf number and plant width were investigated in a variety of *Kabarla*. The trail was implemented as a 4×2 factorial scheme (irrigation levels and bio-stimulant use), in split plot design with 6 consequent months at 4 replicates, totaling 32 plots. Bio-stimulant applications were designed as main plot and different irrigation levels were arranged as sub plot. Strawberry plant was subjected to four irrigation water levels (Ir125, 1.25 Ep; Ir100, 1.0 Ep; Ir75, 0.75 Ep; Ir50, 0.50 Ep). Bio-stimulant applications were investigated on morphological parameters with compared by control plot. As a result of the experiment, irrigation levels and growing period influenced the leaf area, crown diameter, plant width, number of crown and leaf number. Bio-stimulant application just positively affected the number of leaf, while other parameters were not affected by the application. All examined parameters were taken same statistical group except of IR50 which negatively affected plant growth. Also as expected, all plant vegetative part increased with time and this increase was determined statistically significant among months. As a result of these data, IR75 irrigation level could be recommended in terms of optimal vegetative growing combined with bio-stimulant applications.

Keywords: Drought Stress, High Tunnel, Class A pan, Leaf Area, Crown Diameter

1. Introduction

Strawberry is one of the major horticultural crops of Turkey in terms of economy. The country is the processor strawberry cultivator in Europe and the fourth after China, United States and Mexico at worldwide [9] with production of 415.150 metric tons in 2016 [27]. One of the practices for increasing yield comprises from the high tunnel system, low-cost and by using fittest technical economic optimization ratio [11]. Besides, Plastic mulches over drip irrigation systems are remarkably used on the raised-bed culture of strawberry to save water and cut down on weeds together with promote the fruit size, yield and quality [2]. Turkey, especially the Mediterranean region, is one of the countries most affected by global warming related climatic changes. Drought is one of the common environmental factors affecting plant growth and productivity. Reductions in world water resources require focus on saving strategies in irrigation water and ways to increase water use efficiency. Reduced water availability induces innumerable physiological changes in all plant organs [13]. Excessive irrigation decreases yield; at the same time, insufficient irrigation causes also water stress and less production [2]. Thus, the optimal use of irrigation can be characterised as the supply of adequate water corresponding to plant needs in the rooting area [2, 7]. Moreover, to determine the optimal amount of irrigation water use and new agricultural practices like the application of bio-stimulants, the increase of the yield and quality could play a major role in improving the performance of strawberry under high tunnels. These products can increase the efficiency of the use of mineral nutrients decreasing the leaching and ensuring a production more sustainable [20, 21]. Bio-stimulants have increasingly been considered as production materials as demonstrated by the increase in scientific publications [21]. Bio-stimulants have been gaining interest for sustainable agriculture because their application enables several physiological processes that increase nutrient use efficiency, encouraging plant development and allowing the reduction of fertilizers consumption [8, 21].

The objectives of this study were: [1] to determine the response of strawberry growth under different irrigation levels through drip irrigation under high tunnels in the Mediterranean region of Turkey [2] to find relationship between the water requirements of strawberry and the effectiveness of bio-stimulants on the plant growth under drought stress and excessive irrigated water.

2. Materials and Methods

The field experiment was conducted inside the high tunnel at the experimental farm of the Cukurova University (latitude: 36°59'N, longitude 35°27'E and altitude 20 m above sea level). The soils at the site were classified as heavy clay texture (16) and the soil water content at field capacity and permanent wilting point are 34 g/g and 18 g/g respectively. Strawberry (Fragaria Xananassa Duch. Kabarla cv.) was planted on November 10 in 2015 and harvesting continued till June 8 in 2016. The berries were planted in trapezoidal raised beds measuring 0.70 m from the base, 0.50 m at the top, with a height of 0.30 m. The distance among each bed was 0.4 m and covered by 0.05 mm thick two-sided polyethylene mulch cover with a grey upper side and black under side according to the conventional cultural practices in the area. After planting, equal amount water was applied to all treatments until the plants were reached 3 trifoliate (28 January 2016). Fertilizer was applied uniformly to all treatments during the trial through drip irrigation and foliar spraying. Plant protection was carried out by controlled with timely spraying of agricultural pesticides.

The trail was implemented as a 4×2 factorial scheme (irrigation levels and bio-stimulant use), in split plot design with 6 consequent months at 4 replicates, totaling 32 plots. Bio-stimulant applications were designed as main plot and different irrigation levels were arranged as sub plot. Strawberry plant was subjected to four irrigation water levels as Ir50, Ir75, Ir100, Ir125 in which the water quantities applied were 0.5, 0.75, 1.00 and 1.25 times the pan evaporation measured by the US Weather Service Class A pan with a standard 120.7 cm diameter and 25 cm depth placed over the crop canopy in the center of the high tunnel. The content of the bio-stimulant which was named Com Cat was certified by the BCS Öko-Garantie GMBH, Nurnberg, Germany as seaweed extract; organic matter (67%), K_2O (1.5%), alginic acid (18%) and gibberellic acid (250 ppm). The bio-stimulant was applied as foliar spraying on strawberry four times. The amount applied at each treatment was 40 gr extract in 30 L water da^{-1}. Irrigation water (salinity 0.18 dS/m) was applied using the drip tube with emitters spaced every 0.3 m, with a flow rate of 2.7 l h^{-1} and the amount of irrigation water was calculated by using Eq (1).

$$t = (A \times Ep \times Pc \times Kcp) / (q \times n) \quad (1)$$

where, t is the irrigation time (hours), A the area of plot (m^2), Ep the cumulative free surface water evaporation at irrigation interval (mm), Pc the plant cover (%), Kcp the crop-pan coefficient which is taken 0.7 throughout the trial as mentioned in (23), q the flow rate of emitters and n the number of emitters in the plot. In order to evaluate the morphological responses of strawberry, several samplings were taken from plants on DAP (Day after Planting) 79, 107, 137, 164, 192 and 209 in the trail.

Leaf area (LA), crown number (CN), crown diameter (CD), leaf number (LN) and plant width (PW) was evaluated to characterize the vegetative growth of strawberry at each sampling time. Three plants were cut from each plot, their leaflets were separated from the petioles and LA was measured by a leaf area meter (model 3050A; Li-Cor Lincoln, NE, USA).

The experiment was conducted as two factors randomized complete block design with split plot combined with 6 consequent months at with three replications. The obtained data were analyzed with the statistical program JMP version 5.0.1 (SAS Institute Inc., Cary, NC). The results are evaluated by ANOVA to determine the effects of the different irrigation levels and bio-stimulant application at growing period with monthly on examined morphological parameters. A least significant difference test was done to examine the differences among groups. Comparisons that yielded $P \leq 0.05$ were considered to be statistically significant. In addition, correlation among all the obtained results was carried out through multivariate methods with the statistical program JMP version 5.0.1, with $P \leq 0.05$ as threshold.

3. Results and Discussion

3.1. Weather Conditions and the Amount of the Irrigation Water Applied

The 2015-2016 strawberry growth season temperature and humidity reflects the long term averages. Inside the high tunnel the average growth season temperature varied from 2 to 4.4°C higher than the outside with an approximately the same humidity. This result in harmony with [6], which is the high tunnels maintained temperatures about 4°C and 3°C higher than the outside respectively. Water requirements of the plants were supplied with merely irrigation water and Figure 1 reflects the cumulative irrigation water of the all treatments. After planting, the crops received equal amounts of water until set in the application of different irrigations (28 January 2016). From the inception of the treatment to the end of the trial, a total of 357, 285, 214 and 143 mm water were applied to Ir125, Ir100, Ir75 and Ir50 respectively. In the previous studies connected to drip irrigation in strawberries a great variety of irrigation water use has been reported varying from 250 mm to 825 mm [2, 5, 14, 22, 24, and 26]. And in our study the irrigation water amounts were compatible with those of [2] and [22] who were both designed on the same growing conditions and methods for irrigation water calculations varying from 254 to 414 mm and 424 mm, respectively.

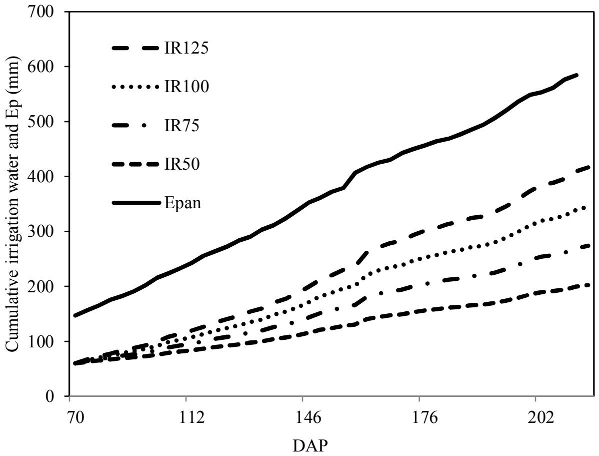

Figure 1. *Cumulative irrigation water (Ir) and evaporation (Ep) during the trial period submitted to different irrigation treatments.*

3.2. Plant Growth

In terms of the sampling time, the vegetative development of the strawberry was completed at approximately DAP 192 and this date harmony with [15] with DAP 199 under almost the same conditions. The LA, LN, PW, CD and CN with values per plant under different irrigation and bio-stimulant applications are presented in Table 1. According to this Table, Ir50 treatments caused a significant decline in morphological parameters. The diminishment of growth is one of the earliest responses of plants against water deficiency which was also stated by [12] and [25]. Similarly, [10], [17], [18], and [19] found decreases in LA in consequence of water stress. On the other hand, different irrigation applications was found statistically important although excessive irrigation water was determined to not enhance the LA, LN, CD, CN and PW in our experiment. And at the same time, Ir75, Ir100 and Ir125 remained similar as statistically for all of parameters. Although previous studies had revealed that the higher amounts of irrigation water applied to the crops caused a significant increase in LA [2, 7, 15, 18, 19], highest values was reached from Ir100 applications in our study. Furthermore, the effect of the bio-stimulant was not found significant in PW, CN, CD and LA excluding LN. Under drought stress conditions (Ir50 and Ir75), bio-stimulant applications were found to reduce the harmful effects on vegetation in generally. Some studies are similar with our experiment that the seaweed extract bio-stimulants promoted plant growth and tolerance to abiotic stress such as drought [4]. Correlations among the variables evaluated in the Kabarla cultivar until 209 days after planting under different irrigation levels and bio-stimulant applications was reflected in Table 2. The all morphological variables (PW, CN, CD, LN and LA) were positively correlated with each other as we expected. Similarly, [3] found that there was positive correlation among the leaf area, crown numbers and leaf numbers. Furthermore; the results obtained in our research were in agreement with the findings [1], indicating that there was positive correlation between LA and LN.

Table 1. *Effect of the different irrigation levels and bio-stimulant applications on plant growth throughout the growing period.*

	App	**Irrıgat levels**	**Growth period**						**AppxIrr**	**Av. Of App**	**Irrıgat. levels**	**Av. of Irr. levels**
			1	**2**	**3**	**4**	**5**	**6**				
Plant Width	Biosti.	50	18.8	23.5	30.7	35.5	36.2	37.0	30.3		50	30.7 B
		75	18.8	24.2	35.0	39.9	41.3	40.0	33.2	32.4		
		100	18.8	23.7	34.7	40.3	39.9	40.3	33.0		75	33.4 A
		125	18.8	24.2	35.3	39.5	40.0	42.3	33.7			
	Control	50	18.8	22.2	30.7	38.0	38.6	38.3	31.1		100	33.7 A
		75	18.8	24.5	33.1	39.0	43.2	43.0	33.6			
		100	18.8	27.0	35.7	41.7	41.6	41.7	34.4	33.1		
		125	18.8	25.5	33.7	40.4	40.6	40.8	33.3		125	33.7 A
	Average of periods		18.8E	24.3D	33.6C	39.3B	40.2AB	40.4A				
LSDapp= N. S. LSDper***= 1.14 LSDirr***= 0.93 LSDappxirrxper= N. S												
	App	**Irrıgat. levels.**	**Growth period**						**AppxIrr**	**Av. Of App**	**Irrıgat. levels**	**Av. of Irr. levels**
			1	**2**	**3**	**4**	**5**	**6**				
Crown number	Biosti.	50	1.00	1.67	2.00	1.67	2.00	2.33	1.78		50	1.72 B
		75	1.00	1.67	2.00	2.00	3.00	3.33	2.17	2.03		
		100	1.00	1.33	2.33	2.33	2.67	3.33	2.17		75	2.03 A
		125	1.00	1.67	2.00	2.00	2.67	2.67	2.00			
	Control	50	1.00	1.00	1.67	2.00	2.00	2.33	1.67		100	2.19 A
		75	1.00	1.00	2.00	2.33	2.33	2.67	1.89			
		100	1.00	1.67	2.33	2.67	2.67	3.00	2.22	1.94		
		125	1.00	1.33	2.00	2.33	2.67	2.67	2.00		125	2.00 A
	Average of periods		1.00D	1.42C	2.04B	2.17B	2.50A	2.79A				
LSDirr***= 0.25 LSDper***= 0.30 LSDappxirr= N. S. LSDappxirrxper= N. S.												

	App	Irrıgat levels	Growth period 1	2	3	4	5	6	AppxIrr	Av. Of App	Irrıgat. levels	Av. of Irr. levels
	App	Irrıgat. levels	Growth period 1	2	3	4	5	6	AppxIrr	Av. Of App	Irrıgat. levels	Av. of Irr. levels
Crown diameter	Biosti.	50	12.3	17.6	26.4	28.5	31.5	33.4	25.0	27.0	50	25.2 B
		75	12.3	18.6	29.1	29.8	39.0	38.9	28.0			
		100	12.3	19.6	29.1	29.6	36.4	37.2	27.4		75	27.7 A
		125	12.3	18.6	28.9	30.0	38.1	39.4	27.9			
	Control	50	12.3	15.4	25.6	27.0	34.7	37.3	25.4		100	28.0 A
		75	12.3	18.3	26.3	28.4	40.0	39.4	27.4			
		100	12.3	18.5	26.1	32.5	39.3	43.4	28.7	27.3		
		125	12.3	17.2	27.8	28.7	38.2	41.1	27.5		125	27.7 A
	Average of periods		12.3D	18.0C	27.4B	29.3B	37.1A	38.8A				
LSDirr***= 1.87 LSDper***= 2.30 LSDappxirr= N. S. LSDappxirrxper= N. S.												
	App	Irrıgat. levels	Growth period 1	2	3	4	5	6	AppxIrr	Av. Of App	Irrıgat. levels	Av. of Irr. levels
Leaf Number	Biosti.	50	6.67	10.0	10.2	11.7	18.0	18.2	12.4	14.1A	50	11.5 B
		75	6.67	12.0	10.3	13.3	21.3	25.6	14.9			
		100	6.67	10.7	12.3	12.0	23.7	25.7	15.2		75	13.7 A
		125	6.67	10.0	11.0	12.3	21.7	22.3	14.0			
	Control	50	6.67	8.0	9.3	11.0	13.0	15.3	10.6		100	14.8 A
		75	6.67	9.0	11.3	12.3	17.2	18.4	12.5			
		100	6.67	10.7	12.0	13.3	21.5	22.3	14.4	12.7B		
		125	6.67	10.3	11.0	14.3	14.3	18.7	13.3		125	13.7 A
	Average of periods		6.67D	10.1C	10.9BC	12.5B	19.4A	20.8A				
LSDapp*= 0.92 LSDper***= 1.60 LSDirr***= 1.30 LSDappxper*= 2.26												
	App	Irrıgat. levels	Growth period 1	2	3	4	5	6	AppxIrr	Av. Of App	Irrıgat. levels	Av. of Irr. levels
Leaf area	Biosti.	50	132	254	716	755	1242	1451	758	1073	50	756 B
		75	132	327	832	1140	2338	2089	1143			
		100	132	293	785	1050	2085	2735	1180		75	1158 A
		125	132	313	780	938	2606	2489	1210			
	Control	50	132	298	675	779	1072	1571	754		100	1244 A
		75	132	347	756	1054	2155	2593	1173			
		100	132	354	804	1297	2304	2958	1308	1109		
		125	132	347	770	979	2092	2889	1201		125	1205 A
	Average of periods		132F	317E	765D	999C	1987B	2347A				
	LSDirr***= 131 LSDper***= 160 LSDperxirr***= 320 LSDappxirrxper= N. S.											

(1): Differences between the means were showed with different letters
(2): N. S.: Not Significant, ***: p<0.001; **: p<0.01; *: p<0.05

Table 2. *Correlation coefficients of several morphological characteristics under different irrigation levels and bio-stimulant applications throughout growing period. (P ≤ 0.05).*

Trait	v2	v3	v4	v5
Plant Width (v1)	0.75*	0.73*	0.88*	0.79*
Crown Number (v2)		0.76*	0.74*	0.72*
Leaf Number (v3)			0.77*	0.82*
Crown Diameter (v4)				0.89*
Leaf Area (v5)				1

*Significant coefficients, at 0.05, are shown in bold.

4. Conclusions

The results of the study indicated that, for strawberry *Kabarla cv*., was effected from drought stress since Ir50 had the significantly lowest values for all the plant growth parameters in comparison to Ir75, Ir100 and Ir125. These differences were found statistically important for all of the parameters. On the other hand, the LA, LN, CD, CN and PW were not enhanced by excessive irrigation water in our experiment. Although Ir100 treatments had highest values, they were in same statistically group with Ir75 and Ir125 treatments.

Bio-stimulant applications affected the leaf number significantly. Although the seaweed bio-stimulant extracts were not found statistically important for CN, it was determined that CN values were encouraged. Besides, it had been determined that the seaweed bio-stimulant extracts alleviated to drought stress for especially LN and CN.

Consequently, for optimal plant growth under current conditions, Ir75 coupled with bio-stimulant application will lead to remarkable water saving in strawberry production considering the large production areas of the Mediterranean countries. That's why the optimal amount of irrigation water was found around 274 mm (Ir75) inside the high tunnel for the current strawberry cultivar in Mediterranean climate conditions.

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