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Effects of Water Stress and Mulch on Grean Bean Yield and Yield Components in Greenhouse Condition

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Abstract: In this research, effects of water stress levels (I_{100}, I_{66}, I_{33} and I_0) and mulch types (gray-Mg; black-Mb- and mulchless-Mo) on green bean yield and yield components in greenhouse condition were studied. The irrigation levels applied in this study significantly affected the yield and almost all yield parameters. The irrigation at I_{100} level gave the highest green bean yield. Un-irrigated treatment (I_0) gave the lowest values for yield and yield parameters. The irrigation level × mulch treatment interactions were significant on pod width, length of pod and branch number per plant. The yield and almost all of yield components were not affected by mulch types. However, the yields for the mulch treatments of Mg and Mb were higher than the mulchless treatment (Mo) under the water stress condition. The yield was not significantly affected by the mulch types, but gray mulch type (Mg) has the highest yield. The highest WUE was obtained in $I_{0\,X}$Mg conditions.

Key words: Bean, water stress, WUE, irrigation, mulch

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is known under different names (french bean, kidney bean, snap bean, runner bean and string bean). In Turkey, it is known as green bean or fresh bean. Annual World green bean production is about 2.2 million tons. In Turkey, it is about 515,000 tons of which 23% is produced in the Mediterranean region[1]. It is generally consumed as fresh product. However, to decrease the quality losses during the exportation, nowadays it has been processed into frozen product.

Growing of green bean in greenhouse conditions is very important for growers due to high income. Also, irrigation program of green bean is very important because of the short vegetation period and rapid growing in greenhouse condition. Bean water requirement for maximum production of a 60 to 120 day crop varies between 300 and 500 mm depending on climatic conditions. For fresh produce, water supply needed for maximum yield during much of the growing period is similar to the above addressed values, but varies during the ripening period. When water supply is limited, some water savings could be made during the vegetative and also ripening period without great affect in yield, whereby provided water deficits are moderate. If the full crop water requirements are met over a limited area total production is higher than the production in extended cultivated area under limited supply conditions. Frequency of irrigation varies between 3 and 12 days depending on climate, crop development and soil type. Furrow and trickle irrigations are the commonly used irrigation practices for bean growing[2].

To be more competitive in today's vegetable markets, vegetable growers strive for high quality, superior yield and early spring production. Plasticulture is helping many growers reach these goals and, subsequently, acreage on plastic continues to increase each year. As a result, snap bean, sweet corn, tomato and cucumber are high-value vegetables crops that show significant increases in earliness, yield and fruit quality when grown on plastic mulch. Black and white plastic and white-on-black are the types most often used plastic mulch in vegetable growing[3].

There is one research examining the effect of irrigation methods on bean yield under Center Anatolia Region in Turkey. Trickle irrigation resulted in a yield increase of 1.9 and 2.4 fold over sprinkler and furrow irrigation, respectively [4].

A study was carried out in Çukurova Region of Turkey on the yield and quality of snap beans. Results showed that average yields were 23% higher in shorter irrigation. However, it is reported that there was no significant difference in the quality[5].

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Table 1: Some physical and chemical properties of the experimental soil

Soil depth (m)	Texture	FC ($g\ g^{-1}$)	Bulk density ($g\ cm^{-3}$)	$CaCO_3$ (%)	pH
0.0-0.3	CL	41.0	1.56	20.8	7.4
0.3-0.6	CL	33.0	1.62	20.9	7.5

Sezen *et al.*[6] examined the effects of different irrigation regimes on yield and water use of green beans irrigated with a trickle system under the Mediterranean region of Turkey. The maximum yield of 20,558 kg ha^{-1} has been obtained from short irrigation interval and crop-pan coefficient of the 1.00 values.

The objectives of this research were to determine optimum irrigation level to maximize yield and quality of green bean and to evaluate the effect of mulch types on green bean yield and yield parameters in greenhouse conditions in the Mediterranean region of Turkey.

MATERIALS AND METHODS

This research was carried out at the experimental greenhouses of Samandag Higher Vocational school of Mustafa Kemal University located in Hatay, Turkey. Samandag is located at 36° 08′ N latitude, 35 °54′ E longitude and altitude 3.1 m above sea level. The study was conducted during spring growing period of 2003 year. Some physical and chemical properties of the experimental soil in relation to irrigation are shown in Table 1. The soil of the experimental area has clay loam texture and deep profile. Ground water was also characterized under 90-120 cm soil profile.

Samandag town has typical Mediterranean climate conditions with hot-dry summers and mild-rainy winters. Some important climatic data of Samandag town during the experimental periods are given in Table 2. The mean temperatures during the experimental period ranged between 12.3 and 24.8°C. The mean relative humidity during the experimental period changed from 62-75% at Samandağ.

The effective root zone of green bean was considered as 0.60 m[2]. A split-plot design with three replications was used with irrigation levels as main plots and mulch types as subplots. Each subplot had 36 m^2 planting area having four rows with 3.0 m width and 12.0 m length. The rows has double planting system namely, one row is 0.50 m and other one 1.0 m apart from each other. The grean bean variety "Alman Ayse" which was traditional variety was planted with 0.3 m row spacing by hand on 15 March in 2003. Plots were fertilized with 60 kg N, P, K per ha before planting and an additional nitrogen dose of 30 kg per ha was injected by irrigation system at the beginning of irrigation and the beginning of flowering periods. The two rows in each plot were harvested by hand on between 12 May and 26 June in 2003.

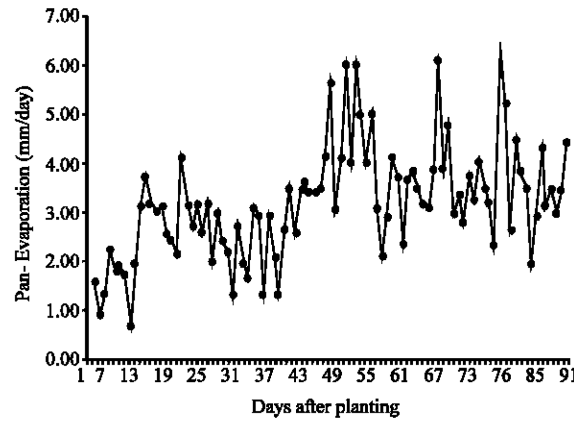

Fig. 1: The class A pan evaporation values during experimental period

The green bean yield components; number of seeds in each pod, bean length and width, were determined from 10 randomly selected plants in each subplot prior to harvest.

The gravimetric method was used to determine the soil moisture content. Soil samples for moisture content determination were taken at 0.60 m depth from the middle row of every plot at the begging periods of irrigation event (one day before irrigation). When the irrigation programme started, irrigation amount calculated according to cumulative pan evaporation.

The amount of irrigation water was calculated using Eq. 1:

$$IR = Epan.Kc.Kp \quad (1)$$

Where, IR is the amount of irrigation water (mm), Epan (mm) is the cumulative evaporation from Class-A pan during an irrigation interval, Kp is the pan coefficient and Kc is the crop coefficient. Class-A pan is located at the center of greenhouse. Daily water level changes in the Class-A pan were measured with a special gage. The Class A pan evaporation values during experimental period are given in Fig 1. Water is obtained from the deep well near the greenhouse. Quality of water is classified as "C_3S_1" and average electrical conductivity is 1.526 dS m^{-1}. The pan coefficient (Kp) and the crop coefficient (Kc) was taken from Doorenbos and Kassam[2].

The field experiments were consisted of four different irrigation levels and tree mulches treatments. The irrigation levels were full irrigation (I_{100}), 66% of full irrigation (I_{66};33% deficit), 33% of full irrigation (I_{33}; 66% deficit) and un-irrigated (I_0) treatments. The mulches were

Table 2: Some climatic data of the experimental area

Month	Mean temperature (°C) Maximum 2003	Maximum Long term	Minimum 2003	Minimum Long term	Average 2003	Average Long term	Relative humidity (%) 2003	Relative humidity (%) Long term	Precipitation (mm) 2003	Precipitation (mm) Long term
March	23.0	28.0	3.7	-1.0	12.3	13.8	71	74	213.5	122.0
April	29.4	34.4	8.4	1.0	17.4	17.6	75	77	24.8	78.2
May	36.5	40.0	10.8	8.8	23.6	20.9	62	80	27.1	45.1
June	36.3	38.6	17.4	14.6	24.8	24.4	75	82	1.4	26.6

* 1981-2001.

Table 3: Variance analyses of the yield and yield components

Source of variation	df	Yield ($kg\ ha^{-1}$)	Number of pod per plant (unit pL^{-1})	Pod weight ($g\ pod^{-1}$)	Pod thickness (mm)	Pod width (mm)	Length of Pod (cm)
Replication	2	5.97	4.62	6.32	1.08	2.26	2.61
Irr. Level, IL	3	25.64**	25.33**	38.32**	3.18	3.59	4.08
Mulches, M	2	0.72	0.58	0.49	0.009	3.81	1.85
IL×M	6	1.57	1.75	0.82	0.42	3.90**	5.52**

*p<0.05, **p<0.01

grey mulch (Mg), black mulch (Mb) and mulchless (Mo). Irrigation treatment levels were based on the amount of water applied with respect to full irrigation treatment (I_{100}). It is calculated by using the corresponding percentage of water deficit (66 and 33%) based on the water amount of I_{100} treatment.

The refreshing water applied at the beginning of planting process for starting of irrigation program. On 27 March, soil water deficit in the 60 cm depth was replenished to the field capacity in all treatment. The first irrigation programme was applied on 10 April and final application was made on 18 June, 2003. All of the treatments were irrigated between 4 and 12 days intervals according to growing periods.

The drip lateral lines were installed on the surface with one drip line for two crop line after planting. The drip irrigation laterals were 16 mm in diameter. The drippers were inline type and placed 0.20 m apart from each other and had 2.75 $L.h^{-1}$ flow rate at 1.0 atm pressure.

Total crop evapotranspiration (Et) for irrigations was calculated using water balance approach (Eq. 2):

$$Et = (P+I) \pm \Delta S - Dp - Ro \qquad (2)$$

Where, P is the rainfall, I is the irrigation amount, ΔS is change in the soil water content, Dp is deep percolation and Ro is run-off amount. The units of all parameters in this equation were millimeters. In this study, Ro was assumed to be zero because the amount of irrigation was controlled. Deep percolation was calculated from the difference between the field capacity moisture level and total soil moisture level at 0.60 m soil depth in the observed period.

Variance Analysis (ANOVA) was used to evaluate the effects of the treatments on the yield and yield components and to determine the significance of the main effects and interactions for the variables measured. MSTATC program was used to carry out statistical analysis.

RESULTS AND DISCUSSION

Yield and yield components: The irrigation levels significantly affected yield and almost all yield parameters (Table 3 and 4). However, the mulch types had no significant effect on yield and the yield parameters. These results are in good agreements with the findings of Cevik *et al.*[7] and Mozumder *et al.*[8] reporting no significant differences in the yield and the yield components depending on the mulches types.

The irrigation levels × mulches interactions were also significant on pod width, length of pod and number of branch per plant (Table 5 and 6).

The irrigation at I_{100} level gave the highest green bean yield. On the other hand, un-irrigated treatment (I_0) gave the lowest values for yield and yield parameters. The yield of un-irrigated treatment was 64% of the most yielding treatment (I_{100}). The pod number per plant, pod weight, string, length of plant significantly increased with increasing amount of water. In the experiment, pod thickness, pod width, length of pod and thickness of root throat increased with increasing amount of water. But such increases in these parameters were not significant, statistically (Table 5 and 6). Increasing the amount of irrigation water resulted in a significant reduction in number of leaf per the plants.

Similar relationships between irrigation amount and bean yield were also reported by Calvache *et al.*[9], Ustun *et al.*[10], Soyergin[11], Ozekici[5], Sezgin *et al.*[6], Sezen *et al.*[12] and Mozumder *et al.*[8].

Table 4: Variance analyses of the yield and some yield components

Source of variation	df	String	Length of plant (cm)	Thickness of root throat (mm)	Number of branch per plant (unit)	Number of leaf per plant (unit)
Replication	2	2.38	3.63	1.926.32	1.61	0.39
Irr. Level, IL	3	7.43**	8.86**	2.01	4.82	10.54**
Mulches, M	2	3.01	0.91	8.50**	3.14	0.84
IL×M	6	1.73	1.57	0.23	4.41**	0.94

*p<0.05, **p<0.01

Table 5: The effects of different irrigation levels and mulch types on yield components*

		Yield (kg ha^{-1})	Number of pod per plant (unit pl^{-1})	Pod weight (g pod^{-1})	Pod thickness (mm)	Pod width (mm)	Length of pod (cm)
Irrigation level	I_0	23400c	59.6c	5.12c	7.71	10.53	19.67
	I_{33}	30380b	75.6b	5.99b	7.97	11.18	19.89
	I_{66}	31470b	79.6b	6.60a	7.71	10.93	20.34
	I_{100}	36550a	93.3a	6.56a	8.00	10.91	20.24
	LSD (%5)	3701	9.5	0.39	ns	ns	ns
Mulch types	M_o	29105.7	74.9	5.91	7.84	10.74	19.88
	M_g	31447.6	79.6	6.24	7.84	10.88	20.21
	M_b	30801.8	76.6	6.05	7.86	11.04	20.01
	LSD (%5)	ns**	ns	ns	ns	ns	ns

*Means shown with the same letter (s) in the same column are not significantly different at 0.05 probability level, **ns: non significant

Table 6: The effects of different irrigation levels and mulch types on some yield components*

		String	Length of Plant (cm)	Thickness of root throat (mm)	No. of branch per plant (unit)	No. of leaf per plant (unit)
Irrigation level	I_0	1.03b	313.3b	10.33	10.67	15.67a
	I_{33}	1.22a	311.9b	10.59	11.14	14.39b
	I_{66}	1.20a	328.6a	10.75	10.64	14.08b
	I_{100}	1.17a	329.2a	10.85	9.28	14.33b
	LSD (%5)	0.11	10.9	ns	ns	0.76
Mulch types	M_o	1.20	324.6	10.20b	9.94	14.40
	M_g	1.16	320.4	11.05a	10.69	14.75
	M_b	1.10	317.3	10.63ab	10.67	14.71
	LSD (%5)	ns**	ns	0.44	ns	ns

*Means shown with the same letter (s) in the same column are not significantly different at 0.05 probability level, **ns: non significant

Table 7: Interaction effects of irrigation levels and mulch types on green bean*

		Yield (kg ha^{-1})	No. of pod per plant (unit pL^{-1})	Pod weight (g pod^{-1})	Pod thickness (mm)	Pod width (mm)	Length of pod (cm)
I_0	Mo	19791.0	54.0	4.56	7.62	10.06d	18.81d
	Mg	28521.0	68.3	5.91	7.79	10.48cd	20.20ab
	Mb	21886	56.5	4.88	7.72	11.05ab	20.00bc
I_{33}	Mo	29434.0	74.3	5.98	8.07	11.05ab	19.89bc
	Mg	29298.0	73.1	5.67	7.80	11.51a	20.47ab
	Mb	32416.7	79.3	6.33	8.03	10.97b	19.31cd
I_{66}	Mo	33674.7	85.6	6.59	7.71	10.94bc	20.76a
	Mg	32348.7	84.4	6.81	7.74	10.78bc	20.07ab
	Mb	28397.3	68.8	6.41	7.68	11.06ab	20.20ab
I_{100}	Mo	33523.0	85.7	6.52	7.96	10.90bc	20.07ab
	Mg	35622.7	92.4	6.57	8.05	10.76bc	20.11ab
	Mb	40507.0	101.9	6.57	7.99	11.08ab	20.53ab
	LSD (%5)	ns**	ns	ns	ns	0.468	0.732

*Means shown with the same letter(s) in the same column are not significantly different at 0.05 probability level, **ns: non significant

There were different results on the effect of irrigation on yield parameters. Calvache *et al.*[9], Sezen *et al.*[6] reported that irrigation frequency and amount of applied water significantly effected some yield qualities. Ozekici[5] reported no significant differences in yield quality between water amounts. Mozumder *et al.*[8] reported that increase of irrigation amount increased plant height, number of pod and pod yield. The yield and almost all of yield components were not significantly affected by mulch types (Table 5 and 6). Only, the grey type mulch resulted in higher root throat thickness, significantly (Table 6). Both the grey mulch (Mg) and the black mulch (Mb) produced higher pod number per plant, pod weight, pod thickness, pod width, length of

Table 8: Interaction effects of irrigation levels and mulch types on some yield components*

		String	Length of Plant (cm)	Thickness of root throat (mm)	No. of branch per plant (unit)	No. of leaf per plant (unit)
I_0	Mo	1.11	330.0	9.82	9.50de	15.5
	Mg	1.01	310.0	10.69	11.50ab	16.0
	Mb	0.96	300.0	10.47	11.00a-c	15.5
I_{33}	Mo	1.20	317.5	10.17	10.83b-d	14.2
	Mg	1.28	307.5	11.09	10.25b-d	14.0
	Mb	1.18	310.8	10.52	12.33a	15.0
I_{66}	Mo	1.33	322.5	10.21	11.25a-c	13.8
	Mg	1.16	337.5	11.27	10.83b-d	14.7
	Mb	1.10	325.8	10.76	9.83cd	13.8
I_{100}	Mo	1.14	328.3	10.61	8.17e	14.2
	Mg	1.20	326.7	11.16	10.17b-d	14.3
	Mb	1.17	332.5	10.77	9.50de	14.5
	LSD (%5)	ns**	ns	ns	1.45	ns

*Means shown with the same letter(s) in the same column are not significantly different at 0.05 probability level, **ns: non significant

Table 9: Irrigation amount, seasonal evapotranspiration and water use efficiency

Treatments	Total irrigation Amount (mm)	Seasonal evapotranspiration (mm)	IWUE (kg ha^{-1} mm^{-1})	TWUE (kg ha^{-1} mm^{-1})
$I_{100}M_0$	485	531	15.6	14.2
$I_{100}M_g$	471	552	17.0	14.5
$I_{100}M_b$	488	546	18.7	16.7
$I_{66}M_0$	419	429	18.1	17.7
$I_{66}M_g$	352	417	20.7	17.5
$I_{66}M_b$	342	413	18.7	15.5
$I_{33}M_0$	297	346	22.3	19.1
$I_{33}M_g$	306	364	21.6	18.1
$I_{33}M_b$	279	362	26.1	20.2
I_0M_0	124	300	36.0	14.9
I_0M_g	125	301	51.5	21.4
I_0M_b	123	299	40.1	16.5

pod, number of branch per plant and number of leaf per plant (Table 5 and 6). In the experiment, string and length of plant increased with mulchless (Mo) condition, although no significant differences were found (Table 5 and 6). Mozumder *et al.*[8] also reported mulch application increased yield, plant height and number of pods per plant. But, the researchers concluded that no significant effect on pod size, length of pod and width of pod. Irrigation levels significantly increased mean green bean ($p<0.01$), while the effects of mulch types and irrigation level×mulch interaction on mean green bean yield were insignificant (Table 7 and 8). The interaction of irrigation level and mulch types on the pod width, length of pod and number of branch per plant were also significant. The highest values were obtained in I_{33}Mg, I_{66}Mo and I_{33}Mb on pod width, length of pod and number of branch per plant, respectively. There was also an inconsistency on the effects on the irrigation levels on green bean yield and yield components. Mozumder *et al.*[8] reported almost all yield and yield attributes significantly influenced by irrigation level × mulch interactions.

Results showed that, the mulch treatments (Mg, Mb) has higher yields from the mulchless treatment (Mo) under the water stress condition. excepting I_{100} treatment, mulch applications decreased the yield when irrigation amount increased, Excessive moisture reduced the affectivity of mulches as reported in Mozumder *et al.*[8]. Although the mulch type has no significant effect on the yield, gray mulch type (Mg) has the highest yield.

The irrigation amounts, evapotranspiration and water use efficiencies: Depending on irrigation levels and mulch types, the total amount of irrigation water was varied between 123 and 488 mm (Table 9). This results are similar results of some researchers. It is reported that the water requirements of green bean was between 300 and 500 mm depending on climate[2]. Sezen *et al.*[12] found seasonal water requirement of green bean ranging from 253 to 338 mm under Tarsus conditions which is located in Mediterrenian region. Soyergin[11] also reported similar amounts namely, 219.8 and 245 mm under Egean Sea region. Although, the differences were small (Table 8), the grey mulches (Mg) was required less water than black mulches (Mb). Deep percolation was not obtained from calculation values of treatments.

Seasonal evapotranspiration (Et) changed between 299 and 552 mm (Table 9). The Et values increased with the amount of irrigation water and the mulch types. Hence, the lowest Et values obtained in IoMb treatment were possibly due to the lower irrigation water during the growing season. The highest evapotranspiration (552 mm) was in I_{100} treatment at full irrigation (I_{100}) (Table 9). The grey mulch type caused higher evapotranspiration compared to black mulch and mulchless treatment except $I_{66}M_0$ (Table 9). There is no significant difference in evapotranspiration values of the mulch types.

The irrigation water use efficiency (IWUE) varied between 15.6 and 51.5 kg ha^{-1} mm^{-1} (Table 9) depending on irrigation levels and mulch types. On the other hand, the TWUE changed between 14.2 and 21.4 kg ha^{-1} mm^{-1}. Stansel and Smittle[13], reported green bean WUE of 40-60 kg ha^{-1} mm^{-1} in USA. The highest TWUE and IWUE were obtained in I_0Mg. The lowest TWUE and IWUE were calculated in $I_{100}M_0$ treatment. In this type of studies, generally, the lower the amount of water received, the higher the water use efficiency obtained[9].

WUE of mulchless treatment (Mo) of the I_0 and I_{100} treatments was lower than grey and black mulches.

As a result of this study, it can be concluded that green bean does not allow to water stress under greenhouse growing in the Mediterranean climatic conditions in Turkey. Because, without stress condition, the irrigation at I_{100} level resulted in the highest green bean yield. It is clear that green bean very sensitive to water level. Some yield parameters such as the pod number per plant, pod weight, string, length of plant significantly increased with amount of water. The mulch types had no significant effect on the yield and almost all of yield components of green bean in greenhouse conditions in Turkey. The yield was not significantly affected by mulch types, but gray mulch type (Mg) has the highest yield. On the other hand, the grey mulch (Mg) was required less water than black mulch (Mb). WUE of -mulchless treatment (Mo) of the I_0 and I_{100} treatments was lower than both grey and black mulches. As a result, grey mulch system can be recommended for green bean growing in greenhouse in Mediterrannean.

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