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  Semimonthly
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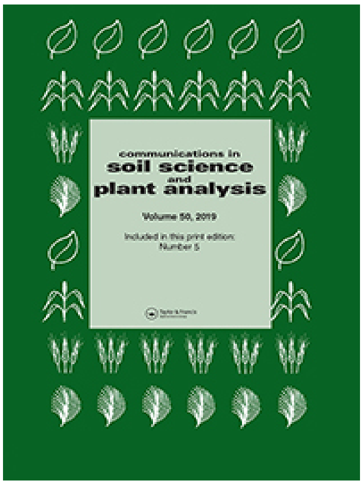

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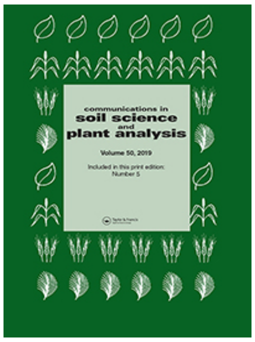

Communications in Soil Science and Plant Analysis

ISSN: 0010-3624 (Print) 1532-2416 (Online) Journal homepage: https://www.tandfonline.com/loi/lcss20

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To cite this article: M. Cüneyt Bağdatli & Oktay Erdoğan (2019) Effects of Different Irrigation Levels and Arbuscular Mycorrhizal Fungi (AMF), Photosynthesis Activator, Traditional Fertilizer on Yield and Growth Parameters of Dry Bean (*Phaseolus Vulgaris* L.) in Arid Climatic Conditions, Communications in Soil Science and Plant Analysis, 50:5, 527-537, DOI: 10.1080/00103624.2019.1566919

To link to this article: https://doi.org/10.1080/00103624.2019.1566919

Published online: 04 Mar 2019.

COMMUNICATIONS IN SOIL SCIENCE AND PLANT ANALYSIS
2019, VOL. 50, NO. 5, 527–537
https://doi.org/10.1080/00103624.2019.1566919

Effects of Different Irrigation Levels and Arbuscular Mycorrhizal Fungi (AMF), Photosynthesis Activator, Traditional Fertilizer on Yield and Growth Parameters of Dry Bean (Phaseolus Vulgaris L.) in Arid Climatic Conditions

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ABSTRACT

A field experiment has been conducted to determine the effects of different irrigation water and AMF (Arbuscular Mycorrhizal Fungi) biofertilizer, photosynthesis activator and traditional fertilizer dry bean (*Phaseolus vulgaris L.)* on yield and growth parameters in Nevsehir Province of Turkey in 2015. The experiment has been carried out using three replications in a split plot design with three different irrigation types as main plots and AMF biofertilizer (ERS), photosynthesis activator (Multigreen-Mg), traditional fertilization (TF-Control), ERS + Mg, ERS + TF and TF + Mg applied as subplots. The number of pods per plant, the length of pods, the number of grains per pod, the weight of grains per plant, the yield of grains, 1000 seed weight, the number of grains per plant, protein yield, arbuscular mycorrhizal fungi rate have been evaluated as yield and growth criteria in the study. In the experiment, as well as the treatment x irrigation interaction, the plant height, pod number per plant, pod lenght, grain number per pod, grain weight per plant, grain yield, 1000 seed weight, grain number per plant, protein rate/grain, protein yield, root weight and AMF colonization parameters, were the other studied properties that were found to be significant. The results obtained were 877.6 mm for I_{100} irrigation treatment, 512.2 mm for I_{50} irrigation treatment and 40.19 mm water for I_{30} irrigation treatment. Regarding the growth parameters of dry bean, the highest PH was in ERS + Mg (67.66 cm), the lowest PH was in ERS (54.33 cm); In I_{50}, the highest Plant Height (PH) was in ERS + Mg (65.66 cm), the lowest PH was in TF-Control (53.00 cm); and in I_{30}, the highest PH was in TF-Control (50.66 cm), and the lowest PH was again in ERS + Mg (44.33 cm). For protein yield (PY) value, ERS + Mg, ERS + TF, TF + Mg have been placed in the same group, in I_{100} and I_{50} irrigation treatment. The highest value was ERS + TF (34.90 kg da^{-1}) in I_{100}, The lowest value was TF-control (19.90 kg da^{-1}) in I_{30} irrigation treatment. In terms of mycorrhiza colonization ratio, ERS has been ranked first in all irrigation treatments, while the highest mycorrhiza colonization has been observed in I_{30} irrigation treatment (26.30%). ERS was followed by ERS + Mg (23.33%). As expected, the lowest mycorrhiza colonization ratio in all irrigation treatments have been observed in TF-control treatment, while the highest mycorrhiza colonization ratio has been respectively observed in I_{30} and I_{50} irrigation topics. The highest root weight (RW) in I_{100} irrigation treatment was observed in ERS (15.06 g $plant^{-1}$) and it was observed in ERS (19.05 g $plant^{-1}$; 26.30 g $plant^{-1}$) in I_{50} and I_{30} irrigation treatments. The lowest RW in all irrigation treatments has been observed in TF + Mg (4.43 g $plant^{-1}$, 6.40 g $plant^{-1}$, 10.26 g $plant^{-1}$), respectively.

ARTICLE HISTORY
Received 30 October 2017
Accepted 1 March 2018

KEYWORDS
Different irrigation levels; *Phaseolus vulgaris*; AMF; seed yield

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Introduction

Dry beans are one of the most important agricultural products among field crops in the world. Beans, which are a member of the legumes family, are ranked third in Turkey in terms of their cultivation area and production, after chickpeas and lentils (Çalı kan 2014). While the world production level of dry beans is 28.5 million tons on an average area of 30.6 million hectares, Turkey produces 235.000 tons of dry beans on an area of 93.5 hectares. In the province of Nev ehir in Turkey, where the experiment was carried out, approximately 21.400 tons of beans are produced per year in an area of 6.3 hectares, which corresponds to about 9% of Turkey's dry bean production (Tüik 2015; Foastat 2015). Beans are the most selective edible legume species in terms of ecological conditions. The yield and quality of a bean in a region is affected by physical (rainfall, temperature, day length, topography, soil type, etc.), biological (diseases and pests) and various socio-economic factors (Woelley et al. 1991).

The world's water resources are seriously exposed to uncontrolled use and pollution of drinking water, as well as agricultural water constraints due to global climate change, industrial and population growth, and uncontrolled use of clean water resources. The area where the experiment was conducted for this study is a low rainfall area due to global climate change and the average rainfall of Turkey is below 623 mm. According to the average of many years, the province of Nev ehir receives an average annual rainfall of 421 mm and in July, when the plants need the most water, it receives 9.3 mm rainfall (Ba datlı, Bellitürk, and Jabbari 2015). The desired water conservation is not possible through the use of traditional irrigation. It is possible to prevent environmental pollution with drip irrigation as less water is used and fertilizer and other plant nutrients are deeply infiltrated into the soil to ensure the washing is minimized (Ertek and Kanber 2000; Faostat 2015).

Deficient irrigation inevitably induces a small decrease in the yield due to a lack of water (Biber and Kara 2006). A study was conducted in Mediterranean climatic conditions, to study the development parameters of dwarf beans under different irrigation regimes, I_{100} irrigation treatment; 250 mm; 200 mm in May, I_{50}; 187.5; 150.0 mm in June and I_{25} treatment; 62.5 mm; 50 mm in July applied irrigation water for dry bean for 2008 and 2009 years, respectively (Ninou et al. 2013). Shaozhong, Wenjuan, and Jıanhua (2000) determined that the increase or decrease of the yield of the bean plant due to variety, rainfall, the amount of evaporation, soil hydraulic conductivity, especially irrigation deficits in beans caused a decrease in yield in areas with limited water, contrary to increases in water use efficiency.

Glomeromycota phylum, the symbiosis between plant roots and mycorrhizal fungi, is the most important arbuscular mycorrhizal fungi (AMF) in terms of agricultural production (Schussler, Schwarzott, and Walker 2001).

Mycorrhizal fungi play a key role in the terrestrial ecosystem, functioning along with various environmental factors such as climate, disturbances, food web interactions, mutualism and ecological history (Wardle and Van Der Putten 2002). The mycorrhizal infected roots of the plant make important contributions to extracting minerals from the soil and using water more efficiently (Entry et al. 2002). The AMFs increase the resistance of the plants to drought, soil pathogen and salinity-heavy metal soils (Mohammad, Malkawi, and Shibli 2003; Pozo et al. 2002; Smith and Read 2008).

In recent years, drought and water shortages have been observed in many regions in Turkey. In this context, the total annual rainfall in the Central Anatolia region, in which the province of Nev ehir is located, is considered a low-arid climates. This is limiting the amount of water used in the agricultural irrigation in the area. To achieve high efficiency and high quality products it is necessary to know the water-production function well. The aim of this study was to determine the effect of different irrigation levels, AMFs, photosynthesis activators, traditional fertilizers on the growth yield of the dry bean in the province of Nev ehir, Turkey.

Materials and methods

The dry bean cultivar Canada Alberta (dry grain) was used as the crop material in the study area. This specific bean matures 106–116 days after planting (FAO maturity group). Also AMF (Glomus intraradices, G. mosseae, G. aggregatum, G. clarum, G. monosporum, G. deserticola, G. brasilianum, G. etunicatum and Gigaspora margarita) containing Endo Roots Soluble® and Multigreen (Photosynthesis activator) biofertilizer were used. Endo Roots Soluble® (Novozymes) and Multigreen were obtained from the company Bioglobal.

A field experiment was conducted in Nev ehir, a province in the Central Anatolia Region of Turkey. The location of the study area was 38°44′17.10"N – 34°46′19.85"E and 1045 m above sea level (Figure 1).

The soil type of the study area was clay loam and loam and contained 0.57% organic material according to soil depth (90 cm). In terms of physical properties the soil bulk density was 1.51 g cm^{-3}, field capacity was 21.76%, and wilting point was 9.25% on average in all depths. (0–30; 30–60 and 60–90 cm). The pH level of the soils was a value of 7.58. The climate of the study area was semi-arid with a total annual rainfall of 423 mm and average temperatures of 17.1°C in May throughout the dry bean cultivation period and 26.7°C in August. In addition the total rainfall was recorded as 104.5 mm from May to September.

Seeds were sown at depths of 5–6 cm using a dibbler in 70 × 25 cm row space on 1 May 2015. Each plot area was 10.5 m^2 and consisted of 4 rows. The intervals between the plots and blocks were two meters and three meters, respectively. The photos of the harvest, morphological parameters, and irrigation treatment equipments are given Figures 2 and 3 and the experiment design of the study area is given Figure 4.

The experiment was carried out using three replications in a split plot design with different irrigation levels as main plots and AMF biofertilizer (ERS), Multigreen (Mg-Photosynthesis activator), Traditional Fertilization (TF-Control), ERS + Mg, ERS + TF and Mg + TF applied as subplots. The main plots had deficit irrigation levels (I_{30} treatment: 30% of Full irrigation treatments was supplied; I_{50} treatment: 50% of Full irrigation treatments was supplied; I_{100} Full irrigation: The total irrigation water requirement is met). When 50% of the applied irrigation waters of all of the applied irrigation water treatments are consumed the irrigation treatment are carried out and AMF applications (10 spores g^{-1}) were applied to bean seed coatings (5 g kg^{-1} seed). Magnesium was applied to the leaves at a rate of 2 g L^{-1}, when the plants were 15 cm tall and within two weeks after the first application.

Fertilizer was applied with drip irrigation in 200 kg ha^{-1} N, 100 kg ha^{-1} P, and 100 kg ha^{-1} K to the rows in the form of ammonium nitrate, triple super phosphate and potassium chloride, respectively. The drip irrigation method was used to irrigate the beans during the study. Drip

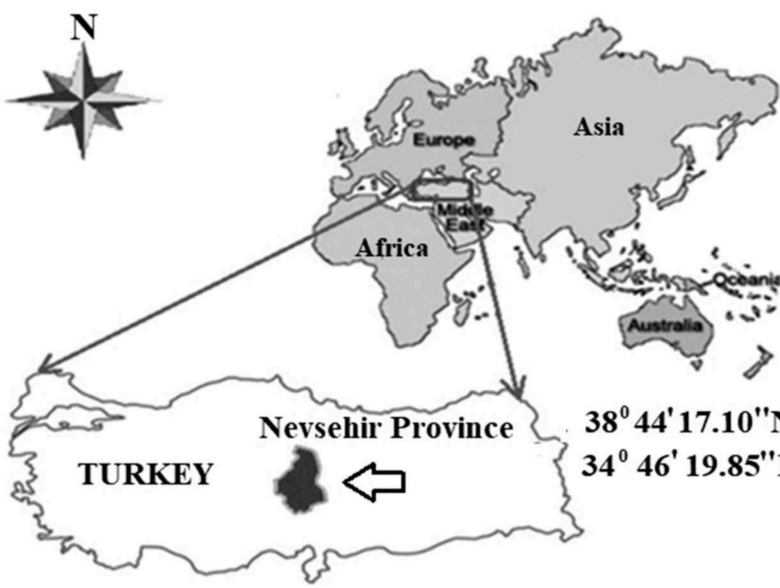

Figure 1. The location of the study area (Nevşehir Province of Turkey).

Figure 2. The harvest of the dry bean and irrigation treatments.

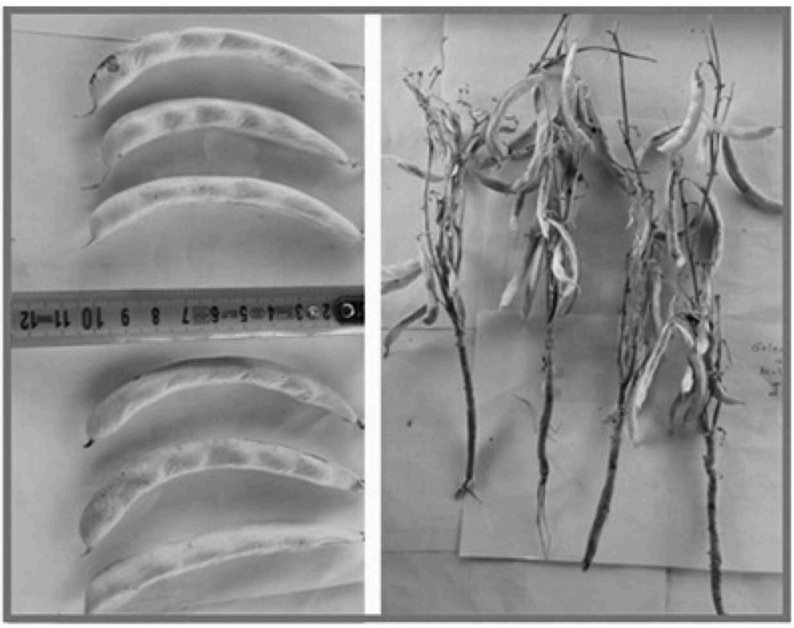

Figure 3. Evaluated morphological parameters of the dry bean.

irrigation system, with each plant rows facing a lateral plan and 25 cm intervals on the inline-type emitter 16 mm diameter lateral PE plastic flat pipes were used. The rate of the dripper flow at 1 atmosphere pressure was 2 L h^{-1}. Following germination and post-emergence periods of the plant, the drip irrigation system was laterally applied to the parcels, in accordance with the principles set forth by Güngör and Yıldırım (1989).

These principles were used when determining irrigation time and water was applied by the help of Eq. (1) (Doorenbos and Kassam 1979; Güngör and Yıldırım 1989).

$$d_n = \frac{(TK - MN)}{100} \gamma_t D\, P \tag{1}$$

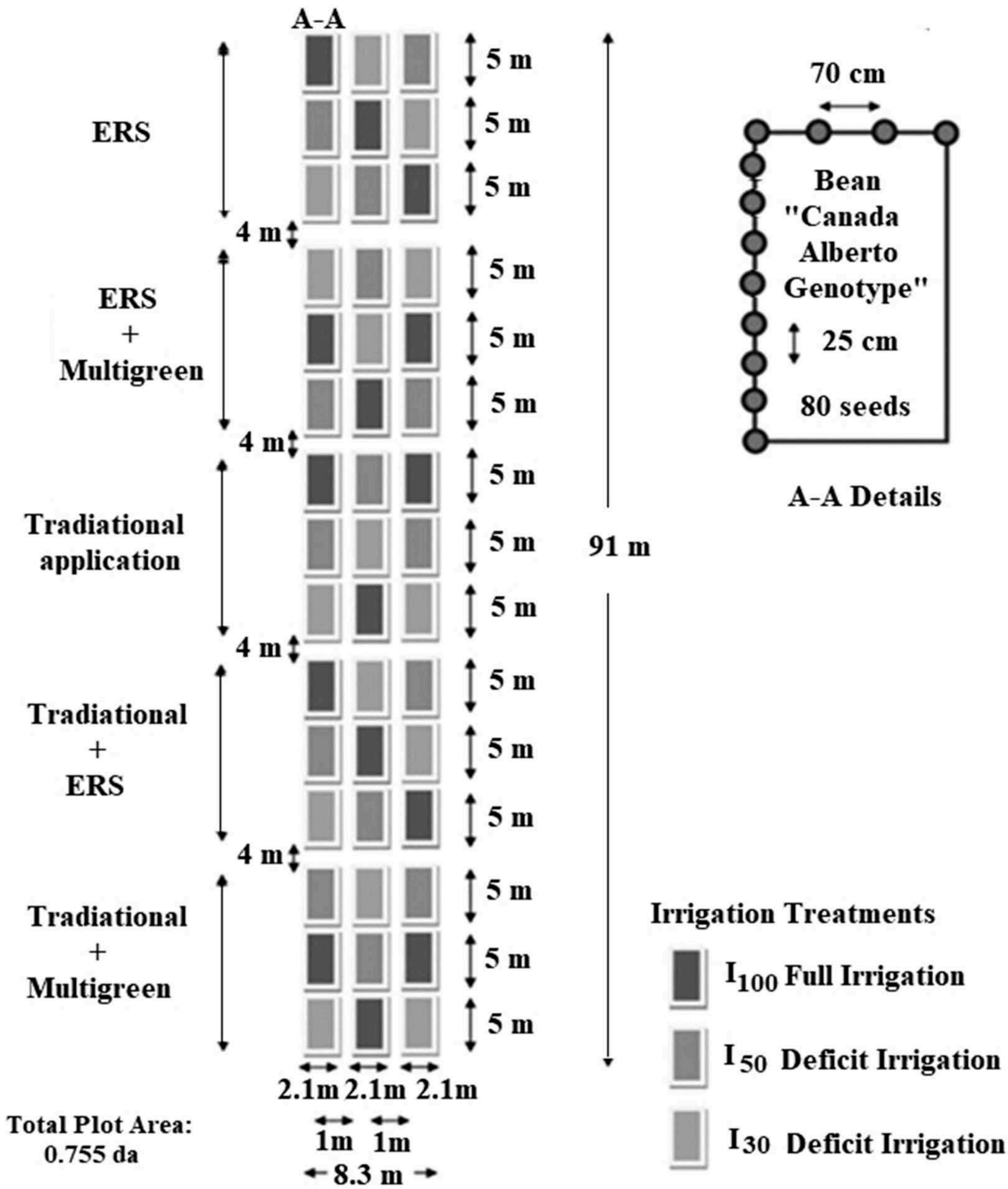

Figure 4. Experiment design in the study area.

dn: Net irrigation water amount to be applied in every irrigation(mm); TK: Field capacity (%); MN: Existing moisture (%); γ_t: Soil bulk density (g cm^{-3}); D: Effective root depth (mm); P: Percentage of wetted area (%).

In this study, the irrigation water amount to be applied was calculated for a 90 cm effective root depth, but in order to be able to monitor any possible deep seepages, water consumption values were calculated by considering water budget for 120 cm soil depth and using Eq. (2) (Walker and Skogerboe 1987).

$$ET = I + P + Cp - Dp \pm Rf \pm \Delta S \tag{2}$$

ET: Plant water consumption (mm); I: Amount of irrigation water applied throughout the period (mm); P: Precipitation throughout the period (mm); Cp: Amount of water entering the root area by capillary elevation (mm); Dp: Deep seepage losses (mm); Rf: Amountof runoff entering and exiting trial parcels (mm); S: Changes in soil moisture in the root area (mm).

Based on the irrigation water applied to the trial subjects, measured plant water consumption, acquired harvest yields, irrigation water usage efficiency (IWUE) and water usage performance (WUE) values were calculated by the use of Eq. (3) (Zhang et al. 1999).

$$IWUE = Y/ET_a \qquad WUE = Y/I \tag{3}$$

IWUE: Irrigation water usage efficiency (kg m^{-3}); WUE: Water usage efficiency (kg m^{-3}); Y: Harvest yield measured from the trial subjects where irrigation waterhas been applied (kg ha^{-1}); I: Amount of irrigation water applied (mm); ET_a: Evapotranspiration (mm).

Harvesting was carried out during milk production period on the 3 September in 2015. To minimise the border/side effect between the plots, the samples were collected by removing a row from all sides of each plot and by cutting the 10 plants in the middle of the plots 5 cm above the soil.

In this study, plant height, pod number per plant, grain number per pod, grain weight per plant, pod length, root weight, grain yield, thousand grain weight, grain number per plant, protein rate/ grain, protein yield and AMF were examined (Akçin 1974).

Ten plants in the AMF inoculated plots were randomly removed and dried after harvesting, then the roots were dyed to detect AMF presence, and the percentage of mycorrhizal colonization was estimated by applying the Grid Line Intersect Method (Giovannetti and Mosse 1980). Data collected on different parameters were analysed statistically by using XLSTAT statistical software program for variance analysis and means were compared using Fisher's protected least significance difference (LSD) test at 5% probability level.

Results and discussion

The mean square values acquired through the variance analysis for the morphological and quality parameters of the study are given in Table 1. Furthermore, the grain number per pod parameter, subjecting to the treatment and irrigation and various other parameters were also found to be significant at the level of 95%.

Treatment x irrigation interaction was found to be significant at the level of 95% in the plant height (PH), pod number per plant (GN), pod length (PL), grain number per pod (PGN), grain weight per plant (GW), grain yield (GY), 1000 seed weight (SW), grain number per plant (GNP), protein rate/grain (PR), protein yield (PY), root weight (RW) and AMF parameters (Table 1) and the mean values of some morphological measurement results for different irrigation applications and other treatments are summarized in Table 2. The findings of this study comply with the results obtained by Karasu, Ku cu, and Öz (2015b).

According to the results, in I_{100} the highest PH was in ERS + Mg (67.66 cm) and the lowest PH was in ERS (54.33 cm); in I_{50} the highest PH was in ERS + Mg (65.66 cm) and the lowest PH was in TF-Control (53.00 cm); and in I_{30}, the highest PH was in TF-Control (50.66 cm) and the lowest PH was again in ERS + Mg (44.33 cm). The highest GN in the I_{100} irrigation treatment was the ERS + Mg (25 number pod^{-1}) and TF + Mg (21 number pod^{-1}), ERS (20 number pod^{-1}) treatments and statistically placed in the same group. In the I_{50} irrigation treatment, the highest GN treatment was the ERS treatment (19.33 number pod^{-1}), ERS + Mg and TF + Mg statistically placed in the same group.

Table 1. Mean squares from the analysis of variance for some morphological and quality parameters of the dry bean.

Source of variation	d.f.	PH (cm)	GN (number pod^{-1})	PL (cm)	PGN (number pod^{-1})	GW (g plant^{-1})	GY (kg da^{-1})
Replication	2	57.00	17.60	8.13	3.33	16.07	284.87
Treatments (T)	4	56.20*	16.20*	7.29*	3.11ns	15.95*	279.12*
Irrigation (I)	2	55.80*	15.32*	6.26*	3.13ns	14.01*	264.10*
T x I	8	*	*	*	ns	*	*
Error	15	138.00	15.33	9.00	5.83	13.83	14.33
Total	31						

Source of variation	d.f.	1000 SW (g)	GNP (number plant^{-1})	PR (% grain^{-1})	PY (kg da^{-1})	RW (g plant^{-1})	AMF (%)
Replication	2	511.87	69.53	17.15	27.99	13.16	9.94
Treatments (T)	4	510.78*	67.16*	15.01*	28.10*	12.98*	10.90*
Irrigation (I)	2	509.98*	68.49*	16.90*	26.48*	14.05*	8.87*
T x I	8	*	*	*	*	*	*
Error	15	220.50	23.83	0.10	0.11	1.82	2.27
Total	31						

*Significant at the 0.05 probability level; ns: not significant; PH: plant height; GN: pod number per plant; PL: pod lenght; PGN: Grain number per pod; GW: grain weight per plant; GY: grain yield; 1000 SW: 1000 seed weight; GNP: Grain number per plant; PR: protein rate/grain; PY: Protein yield, RW: Root weight; AMF: Arbuscular mycorrhizal fungi

Table 2. Average values of the effects of different irrigation and treatments on some morphological parameters of dry bean.

	PH (cm)			GN (pod number plant^{-1})			PL (cm)		
Treatments/Irrigation	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}
ERS	57,33c	53.00d	49.00bc	20.00bc	19.33a	10.33c	8.66c	7.33c	5.66c
ERS + Mg	67.66a	65.66a	44.33c	25.00a	18.66ab	15.66a	10.00b	9.50a	7.00a
ERS + TF	63.00b	60.00b	46.66bc	23.66b	16.00c	9.66cd	11.33a	8.33b	6.66b
TF + Mg	62.66b	56.66c	50.00b	21.00bc	17.33b	13.66b	10.33b	7.66c	5.66c
TF-control	54.33c	53.00d	50.66a	18.66d	16.66c	9.66cd	8.33c	7.33c	5.33c
Mean	61.00	58.33	47.50	21.66	17.59	11.79	9.73	8.03	6.06

	GW (g plant $^{-1}$)			RW (g plant^{-1})			GY (kg da^{-1})		
Treatments/Irrigation	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}
ERS	17.66b	14.66b	9.66c	15.06a	19.05a	26.30a	284.66b	274.33b	260.00c
ERS + Mg	25.50a	20.00a	13.5b	11.65b	13.14b	23.00ab	318.00a	301.00a	297.00a
ERS + TF	26.66a	19.66a	11.66a	8.40c	10.36c	20.23b	308.00a	300.00a	285.00b
TF + Mg	15.00c	11.00c	9.66c	4.43d	6.40d	10.26d	297.00b	276.66b	263.00c
TF-control	17.33b	13.00bc	8.00d	6.23c	8.5cd	12.08c	273.00c	261.66c	251.66d
Mean	20.40	15.66	10.49	9.15	11.49	18.37	296.13	282.73	271.33

	1000 SW (g)			GNP (grain number plant^{-1})			PR (% grain^{-1})		
Treatments/Irrigation	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}
ERS	530.33c	493.66c	395.00c	86.00b	82.00b	44.00b	18.38b	17.02c	11.01c
ERS + Mg	611.00a	595.00a	429.00a	87.00b	87.00a	59.00a	21.77a	20.40a	15.36a
ERS + TF	607.00a	554.66b	405.33b	90.00a	81.00b	45.00b	20.47a	18.30bc	14.35b
TF + Mg	600.66b	543.66bc	397.66c	85.00b	73.00c	57.00a	20.90a	19.80b	14.96b
TF-control	542.33c	510.00c	419.33a	63.00c	44.00d	36.00c	17.88b	15.01d	10.76c
Mean	578.26	539.39	409.26	82.20	73.40	48.20	19.88	18.11	13.29

	PY (kg da^{-1})			AMF (%)		
Treatments/Irrigation	I_{100}	I_{50}	I_{30}	I_{100}	I_{50}	I_{30}
ERS	29.55b	26.32b	20.02c	15.23a	19.20a	26.30a
ERS + Mg	34.75a	34.10a	22.00a	11.30ab	13.30b	23.33ab
ERS + TF	34.90a	33.08a	21.80b	8.36b	10.16c	20.13b
TF + Mg	34.09a	33.08a	20.00c	0.60c	0.30cd	0.60c
TF-control	28.10b	26.9b	19.90d	0.70d	0.09d	0.10d
Mean	32.27	30.69	20.74	7.24	8.61	14.09

Means within column for each experiment by the same latter (s) are not significantly different according to Duncan Multiple Tests ($P < 0.05$); PH: plant height; GN: pod number per plant; PL: pod length; GW: grain weight per plant; RW: Root weight; GY: grain yield; 1000 SW: 1000 seed weight; GNP: Grain number per plant; PR: protein rate/grain; PY: Protein yield, AMF: arbuscular mycorrhizal fungi.

In terms of PL treatment in the I_{100} and I_{50} irrigation treatments are ERS + TF and ERS + Mg (11.33 cm; 9.50 cm) were placed among the top, while in I_{30}, ERS + Mg (7.00 cm) was ranked first. In the I_{100} treatment lowest value was in Tf-Control (8.33 cm), while in the I_{50} and I_{30} irrigation treatments, the lowest value was observed in TF-Control and ERS (7.33 cm) and TF-Control (5.33 cm).

The highest GW in all irrigation treatments was observed in ERS + Mg (26.66 g plant^{-1}), while the lowest GW in the I_{100} and I_{50} irrigation treatments were in TF + Mg (15.00 g plant^{-1}; 11.00 g plant^{-1}) respectively, and in I_{30} it was in TF-Control (8.00 g plant^{-1}). The highest RW in the I_{100} irrigation treatment was observed in ERS (15.06 g plant^{-1}) and it was also observed to be in ERS (19.05 g plant^{-1}; 26.30 g plant^{-1}) in the I_{50} and I_{30} irrigation treatments. The lowest RW in all of the irrigation treatments was observed in TF + Mg (4.43 g plant^{-1}, 6.40 g plant^{-1}, 10.26 g plant^{-1}) respectively. In the GY values, some treatments were placed statistically in the same group. The highest GY was observed in I_{100}, I_{50}, I_{30} irrigation treatments in ERS + Mg (318.00 kg da^{-1}, 301.00 kg da^{-1}, 297.00 kg da$^{-1,}$ respectively).

For the I_{100} and I_{50} irrigation treatments, ERS + Mg and ERS + TF were placed statistically in the same group. For the 1000 SW values, ERS + Mg with ERS + Tg and ERS with TF-control were placed in same group in I_{100} irrigation treatment, ERS with TF-control in same group in I_{50}, ERS with TF + Mg and ERS + Mg with TF-control in same group in I_{30} irrigation treatment. The highest 1000 SW value was ERS + Mg (611.00 g) in I_{100}, ERS + Mg (595.00 g, 429.00 g) in I_{50}, $I_{30,}$ respectively.

In this study, the highest GNP was observed in ERS + TF (90.00 grain number plant^{-1}) in the I_{100} irrigation treatment, while the lowest GNP was observed in TF-control (36.00 grain number plant-1) in the I_{30} irrigation treatment in other similar studies, the highest PH was observed in I_{100} irrigation application, while the lowest PH was observed in limited irrigation treatment (Çakır 2004; Erdo an and Ba datlı 2017; Kang et al. 2000; Sylvia et al. 1993).

As a result of the measurement of PR value obtained in the study, the highest value is ERS + Mg (21.77% grain^{-1}) in I_{100}, The lowest value is TF-control (10.76% grain^{-1}) in I_{30} irrgiation treatment. ERS + Mg, ERS + TF, TF + Mg take placed in same group in I_{100}, ERS with TF-control and ERS + TF with TF + Mg is same group in I_{30} irrigation treatment. For PY value, ERS + Mg, ERS + TF, TF + Mg take placed in same group in I_{100} and I_{50} irrigation treatment. The highest value is ERS + TF (34.90 kg da^{-1}) in I_{100}, The lowest value is TF-control (19.90 kg da^{-1}) in I_{30} irrigation treatment. In terms of mycorrhiza colonization ratio, ERS has been ranked first in all irrigation treatments, while the highest mycorrhiza colonization has been observed in I_{30} irrigation application (26.30%). ERS was followed by ERS + Mg (23.33%).

As expected, the lowest mycorrhiza colonization ratio among all irrigation treatments was observed in TF-control treatment, while the highest mycorrhiza colonization ratio was observed in I_{30} and I_{50} irrigation treatments, respectively. In his study ehirali (2005) reported that PH was 34 cm for I_{100} irrigation treatment and 30.6 cm for I_{50}. 100 seed weight was 442.3 g for I_{50} irrigation treatment and GN was determined 14.1 number pod^{-1} for I_{100} irrigation treatment.

Mycorrhiza colonization ratio varied in irrigation subjects. It was higher in limited irrigation conditions and under arid conditions and was associated with the shortening of plant height in bean plants with AMF (Erdo an and Ba datlı 2017; Sylvia et al. 1993; Zhang et al. 2011).

The EW and ST values acquired in this study were in direct proportion to the different irrigation water amounts applied and the highest was observed in I_{100} ERS + TF (233.5 g/208.6 cm) and TF-control (232.6 g/207.7 cm) treatments. In similar studies, it has been reported that in bean plant, in direct proportion to the amount of water applied, there is a change in ST, and in limited irrigation treatments, ST was lower when compared to I_{100} irrigation treatment (Akçin 1974; Ku çu and Demir 2013).

Depending on the irrigation treatments, the highest FRW was observed in I_{30} in ERS (220.3 g), while the lowest FRW value was observed in TF-control (41.6 g). GHY and FEH values varied depending on the irrigation treatments, and the highest GHY was observed in I_{100} in ERS + TF (6060.5 kg ha^{-1}), while the lowest GHY was observed in I_{100} in ERS (3120.1 kg ha^{-1}).

Similarly, the highest FEH was observed in ERS + TF (134.5 cm), while the lowest FEH value was observed in ERS (85.7 cm). In this study, GHY and FEH values in limited irrigation treatments were

Table 3. Green herbage yield, total irrigation water applied, irrigation water use efficiency (IWUE), water use efficiency (WUE), Evapotranspiration (mm)(ET_a) for dry bean under different irrigation treatments.

Irrigation Treatments	Green herbage yield (kg da^{-1})	Total Irrigation Water applied (mm)	ET_a (mm)	WUE (kg m^{-3})	IWUE (kg m^{-3})
I_{100}	340.17	821.60	877.60	0.39	0.41
I_{50}	301.45	456.20	512.20	0.59	0.66
I_{30}	210.62	345.90	401.90	0.52	0.61

ET_a: evapotranspiration; IWUE: irrigation water usage efficiency; WUE: water usage performance.

defined to be lower than I_{100} irrigation treatment. Studies reported that in the bean plant the highest GHY was acquired in I_{100} irrigation treatment, while the lowest GHY was observed in limited irrigation treatment (Genço lan 1996; Kızılo lu et al. 2009; Ku çu and Demir 2013; ehirali et al. 2005).

In the I_{30} treatment, ERS, in addition to PH and EW characteristics, ST, FRW, GHY and FEH values were observed to be high. Similarly, Çelebi et al. (2010) reported that in all of the irrigation treatments, yield, stem ratio and leaf ratio in bean plants with mycorrhiza application increased when compared to plants without mycorrhiza application.

Ba datlı, Bellitürk, and Jabbari (2015) reported that applying mycorrhiza to bean plants increased the PH and dry matter amount. In contrast to the findings acquired in relation to mycorrhiza, Genço lan (1996) reported that irrigation has positive effects on GHY and total weight in bean plants both with and without mycorrhiza. The irrigation treatment based on total water amount, evapotranspiration, water use efficiency and green herbage yield values of this study are given in Table 3.

In this study, WUE was found to be 0.52 kg m^{-3} for the I_{30} irrigation treatment, 0.59 kg m^{-3} for the I_{50} irrigation treatment and 0.39 for the I_{100} irrigation treatment. IWUE was found to be 0.41 kg m^{-3} for the I_{100} irrigation treatment, 0.66 kg m^{-3} for the I_{50} irrigation and 0.61 kg m^{-3} for the I_{30} irrigation treatment.

Total water application was 877.6 mm for the I_{100} treatment during the training season as IWUE, 512.2 mm in I_{50} deficit irrigation treatment and 401.9 mm irrigation for the I_{30} treatment. Contrary to the findings of this study, it was reported by another study that the IWUE value was higher than 1.62 kg $m^{-3}$and the IWUE value was between 1.11–1.72 kg m^{-3} (Karasu et al. 2015a; Ku çu and Demir 2013). In his study ehirali et al. (2005) reported that the IWUE of bean plants ranged from 0.34 to 0.41 kg m^{-3} and the WUE ranged from 0.20 to 0.37 kg m^{-3}.

The water use efficiency results of this study displayed similarities to findings of other studies, however it should not be ignored that water usage efficiency may be affected by soil, climate and the employed irrigation method.

Conclusion

The results of the study, treatment x irrigation interactions, were found to be significant at a level of 95% for the properties of PH, GN, PL, PGN, GW, GY, 1000 SW, GNP, PR, PY, RW and AMF. It was determined that as the amount of applied irrigation water increased, the plant height, the weight of the bean and the average plant height also increased. It should not be forgotten that the dry bean is a hereditary feature influenced by the plant, environment and breeding technique. In all irrigation treatments, the I_{100} irrigation treatment came to the forefront, with the 1000 SW and mean value of bean yield being close to each other. The mean values of wet root weight were found to be higher in the I_{30} irrigation treatment than in other irrigation treatments.

Considering that the total annual rainfall (423 mm) is low in the Nev ehir province, where the survey was conducted, less irrigation treatments applied less than field capacity may not provide the necessary washings for salt balancing. In this context, irrigation practices should also consider the need for washing water. While the highest WUE (0.59 kg m^{-3}) and IWUE (0.66 kg m^{-3}) values were obtained for I_{50} irrigation, IWUE values can vary depending on soil, climate and irrigation method. While the ERS application was the last rank in all the features examined for I_{100} irrigation, ERS and ERS + Mg applications in the characteristics of GY, PY, 1000 SW, PL and GN in the I_{30} irrigation were statistically in the same group with other applications.

As expected, mycorrhiza colonization in the roots of dry bean plants and photosynthetic activator (ERS + Mg) applied to the leaves of plants with AMF resulted in ERS application under conditions of irrigation (I_{30}) from which better results were obtained compared to the applications.

As a result, this study demonstrated that in dry bean cultivation it is necessary to avoid irrigation practices in cases of sufficient water resources and cases of irregularity of irrigation and water resources in the world and in Turkey and that it may be possible to obtain successful results from ERS and ERS + Mg applications. In addition, the obtained data will shed light on studies conducted by plant breeders and agronomists.

Acknowledgment

The authors thank to The Governor of Avanos District in Nev ehir Province of Turkey and Bioglobal Company.

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References

Akçin, A. 1974. *Erzurum Şartlarında Yetiştirilen Kuru Fasulye Çeşitlerinde Gübreleme, Ekim Zamanı ve Sıra Aralığının Tane Verimine Etkisi İle Bu Çeşitlerin Bazı Fenolojik, Morfolojik ve Teknolojik Karakterleri Üzerine Bir Araştırma*. Atatürk Üniv. Zir. Fak. Yayın No: 157, s.112 (in Turkish).

Ba datlı, M. C., K. Bellitürk, and A. Jabbari. 2015. Possible effects on soil and water resources observed in Nev ehir Province in long annual temperature and rainfall changing. *Eurasian Journal of Forest Science* 3 (2):19–27. doi:10.31195/ejejfs.333091.

Biber, Ç., and T. Kara. 2006. Evaporatranspiration and restricted irrigation applications of corn. *Journal of Agriculture Faculty Ondokuz Mayıs University* 21 (1):140–46.

Çakir, R. 2004. Effect of water stress at different development stages on vegetative and reproductive growth of corn. *Field Crops Research* 89 (1):1–16. doi: 10.1016/j.fcr.2004.01.005.

Çalı kan, S. 2014. Current situation, problems and solutions of bean in TR71 region. *Turkish Journal of Agriculture - Food Science and Technology* 2:60–65. doi:10.24925/turjaf.v2i2.60-65.98.

Çelebi, S. Z., S. Demir, R. Celebi, E. D. Durak, and I. H. Yilmaz. 2010. The effect of arbuscular mycorrhizal fungi (AMF) applications on the bean (*Zea mays* L.) yield in different irrigation regimes. *European Journal of Soil Biology* 46:302–05. doi:10.1016/j.ejsobi.2010.06.002.

Doorenbos, J., and A. H. Kassam. 1979. *Yield response to water*. Rome: United Nations Food and Agriculture Organization. Publication No 33, 193.

Entry, J. A., P. T. Rygiewicz, L. S. Watrud, and P. K. Donelly. 2002. Influence of adverse soil conditions on the formation and function of Arbuscular mycorrhizas. *Advances in Environmental Research* 7:123–38. doi:10.1016/S1093-0191(01)00109-5.

Erdo an, O., and M. C. Ba datlı. 2017. The effects of arbuscular mycorrhizal fungi (AMF) and deficit irrigation levels on yield and growth parameters of the silage maize (Zea mays L.). *Fresenius Environmental Bulletin* V.26 (4):2948–55.

Ertek, A., and R. Kanber. 2000. Determination of the amount of irrigation water and interval for cotton with the pan evaporation method. *Turkish Journal of Agriculture and Forestry* 24:293–300.

Faostat. 2015. Dünya Tarımsal statsitikleri, Dünya Gıda ve Tarım Organizasyonu Verileri. Accessed September 15, 2015. http://www.fao.org/faostat/en/#data/QC.

Genço lan, C. 1996. Water-yield relationships of bean, determining between the root distribution and plant water stress index and investigation of CEREZ-bean the plant growth model of local compliance. PhD thesis, Cukurova University (in Turkish).

Giovannetti, M., and B. Mosse. 1980. An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. *The New Phytologist* 84:489–500. doi:10.1111/j.1469-8137.1980.tb04556.x.

Güngör, Y., and O. Yıldırım. 1989. *Field irrigation systems*. Vol. 1155, 371. Ankara: Ankara University, Faculty of Agriculture Press (in Turkish).

Kang, S., Z. Liang, Y. Pan, P. Shi, and J. Zhang. 2000. Soil water distribution, uniformity and water-use efficiency under alternate furrow irrigation in arid areas. *Irrigation Science* 19:181–90. doi:10.1007/s002710000.

Karasu, A., H. Ku cu, and M. Öz. 2015b. Yield and economic return response of bean to different levels of irrigation water in a sub-humid zone. *Zemdirbyste-Agriculture* 102 (3):313–18. doi:10.13080/z-a.2015.102.040.

Karasu, A., H. Ku cu, M. Öz, and G. Bayram. 2015a. The effect of different irrigation water levels on grain yield, yield components and some quality parameters of bean (*Zea mays indentata* Sturt.) in marmara region of Turkey. *Notulae Botanicae Horti Agrobotanici Cluj* 43 (1):138–45.

Kızılo lu, F. M., U. ahin, Y. Ku lu, and T. Tunç. 2009. Determining water–Yield relationship, water use efficiency, crop and pan coefficients for bean in a semiarid region. *Irrigation Science* 27 (2):129–37. doi:10.1007/s00271-008.

Ku çu, H., and A. O. Demir. 2013. Yield and water use efficiency of bean under deficit irrigation regimes in a sub-humid climate. *Philippine Agricultural Scientist* 96 (1):32–41.

Mohammad, M. J., H. I. Malkawi, and R. Shibli. 2003. Effects of mycorrhizal fungi and phosphorus fertilzation on growth and nutrient uptake of barley grown on soils with different levels of salts. *Journal of Plant Nutrition* 26:125–37. doi:10.1081/PLN-120016500.

Ninou, E., J. T. Tsıaltas, C. A. Dordas, and D. K. Papakosta. 2013. Effect of irrigation on relationship between leaf gas exchange related traits and yield dwarf dry bean grown under mediterranean conditions. *Agricultural Water Management Journal* 116:235–41. doi:10.1016/j.agwat.2012.08.002.

Pozo, M. J., C. Cordıer, D. E. Gaudot, S. Gıanınazzı, J. M. Barea, and A. C. Aguilar. 2002. Localized versus systemic effect of arbuscular mycorrhizal fungi on defence responses to Phytophthora infection in tomato plants. *Journal of Experimental Botany* 53:525–34. doi:10.1093/jexbot/53.368.525.

Schussler, A., D. Schwarzott, and C. Walker. 2001. A new fungal phylum, the Glomeromycota: Phylogeny and evolution. *Mycological Research* 105:1413. doi:10.1017/S0953756201005196.

ehirali, S., T. Erdem, Y. Erdem, and D. Kenarı. 2005. Damla Sulama Yöntemi ile Sulanan Fasulyenin (Phaseolus vulgaris L.) Su Kullanım Özellikleri. *Tarım Bilimleri Dergisi* 11 (2):212–16 (in Turkish).

Shaozhong, K., S. Wenjuan, and Z. Jıanhua. 2000. An improved water-use efficiency for bean grown under regulated deficit irrigation. *Field Crops Research* 67 (3):207–14. doi:10.1016/S0378-4290(00)00095-2.

Smith, S., and D. J. Read. 2008. *Mycorrhizal Symbiosis*. In ed. S. Smith and D. I. Read, 605. London: Academic Press Publishers.

Sylvia, D. M., L. C. Hammond, J. M. Bennet, J. H. Hass, and S. B. Linda. 1993. Field response of bean to a VAM fungus and water management. *Agronomy Journal* 85:193–98. doi:10.2134/agronj1993.00021962008500020006x.

Tüik (Turkish Statistical Institute) 2015. Agricultural structure and production. Government Statistic Institute of Prime Minister Publ. Accesed October 20, 2015. https://biruni.tuik.gov.tr/bitkiselapp/bitkisel.zul

Walker, W. R., and G. V. Skogerboe. 1987. *Surface irrigation. teory and practice*, 375. Englewood Cliffs, NJ: Prentice- Hall.

Wardle, D. A., and W. H. Van Der Putten. 2002. Biodiversity, ecosystem functioning and above-ground- below-ground linkages. In *Biodiversity and ecosystem functioning: Synthesis and perspectives*, ed. M. Loreau, S. Naeem, and P. Inchausti, 155–68. New York: Academic Press.

Woolley, J. R. L., T. D. Ildefonso, and J. V. Castro. 1991. Bean cropping systems in the tropics and subtropic and their determinants. *Field Crops Abstracts* 44.

Zhang, G. Y., L. P. Zhang, M. F. Wei., Z. Liu, Q. L. Fan, Q. R. Shen, and G. H. Xu. 2011. Effect of arbuscular mycorrhizal fungi, organic fertilizer and soil sterilization on bean growth. *Acta Ecologica Sinica* 31:192–96. doi:10.1016/j.chnaes.2011.04.005.

Zhang, H., X. Wang, M. You, and C. Liu. 1999. Water–Yield relations and water use efficiency winter wheat in the North China Plain. *Irrigation Science* 19 (1):37–45. doi:10.1007/s002710050.