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The Effect of Seed inoculation with different bacterial strains on some morphological traits and essential oil of Medicinal plant Dill (*Anethum graveolens L.*) underwater stress

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ABSTRACT
In order to investigate the effect of different bacterial strains on some morphologic properties of dill, under water stress conditions in a field study, a split plot experiment based on complete randomized block design with three replicates was used, in 2013 and 2014. Water stress as the main factor in three levels of irrigation with 40, 80 and 120 mm evaporation from pan, and bacterial strains in 9 levels as sub factors were used. The results indicate that all bacterial strains worked significantly for the improvement of performance in dill, under stress, moderate stress and water deficit. Based on composite ANOVA, the effect of stress was significant on number of umbels, stem diameter, root dry weight, stem dry weight and leaf dry weight at 1%, so was the effect of stress and strain on the number of umbels, root dry weight, and stem diameter. The strains significantly changed the number of umbels, stem diameter and root dry weight. The three factors had significant effects on the essential oil percentage. Finally, bacterial inoculation seed alone could improve the quality and quantity of dill. Therefore, it is advisable to use biological inputs instead of chemical fertilizers as a means towards sustainable agriculture.
Keywords: bio-fertilizers, essential oil, bacterial strains, Dill, drought, medicinal plants

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INTRODUCTION

Dill (*Anethum graveolens L.*) is a short lived perennial herb native to Mediterranean countries and southeastern Europe. Its fruit is used as flavoring in sauces, vinegars, pastries, and soups. The leaves are used primarily as a condiment. Dill also has medicinal application as a diuretic, stimulant, and a carminative [1]. At present, application of organic fertilizers and bio-stimulants such as nitrogen fixing bacteria containing Azotobacter and Azospirillum has led to a decrease in the use of chemical fertilizers and provided high quality products free of harmful agrochemicals for human safety [2,3].Organic fertilizers have many advantages including increase the uptake of macro elements, such as phosphorous and potassium, and micro elements [4], the ability to stimulate plant growth [3], release phytohormones such as auxin, cytokinin, gibberellin [5]), as well as enhancing water absorption and drought tolerance.
Experiments have shown that a combination of mycorrhiza with growth stimulus bacteria such as Bacillus and Azospirillum could lead to the increase in the quantity of biomass and phosphorus content in lemongrass [6]. Azospirillum also had a positive effect on the germination percentage in *Embilica officinals* plants [7]. The use of fertilizers containing Azotobacter, Azospirillum, Bacillus and 50 percent complete fertilizer, enhanced the growth and quantity of the essential oil of fennel [3]. Azzaz et al. [8] assessed possibility of using organic fertilizers, instead of chemical fertilizers, in fennel and concluded that the growth, yield and quantity of essential oil in fennel increased under treatment of organic fertilizer. Enhancement in vegetative growth and productivity, under treatment with bio-fertilizer, has been reported in other plants. Seed inoculation of wheat with Azospirillium increased the length and dry weight of the roots, which can be effective in absorption of water [9]. In that study, seed treatment with bacteria had mitigated the negative impact of drought.
Water deficit, among other come to be known as abiotic stresses, is a major environmental factor affecting many aspects of plant physiology and biochemistry [10]. The morphological and physiological mechanisms involved in a plant's response to drought stress have been frequently studied in some

research. It has been demonstrated that water stress decreases plant height [11], and has a negative effect on stem number per plant [12], as well as causing modifications in some metabolites pathways [13]. Currently, the use of beneficial microorganisms as sustainable and efficient agricultural inputs has been the focus of attention, with the hope to reduce the adverse effects of drought. Therefore, the main objective of the present field study has been to investigate the role of different strains of bacteria on the growth and productivity of dill plants under different conditions of irrigation.

MATERIALS AND METHODS

In order to determine the effects of different strains of bacteria on the growth and productivity of medicinal plant dill under different irrigation regimes, an experiment was conducted in 2013 and 2014 at Tabriz Branch of the Agricultural Research Station, located 15 kilometers east of Tabriz at an altitude of 1360 m above the sea level and the geographical coordinates 46 degrees and 17 minutes east longitude and 38 degrees and 5 minutes north latitude. In every season, samples from 0-30 cm depth of the soil were taken to determine physical and chemical properties of the soil, as charted in Table 1. Over the course of two years, the experiment was conducted as a split plot in a complete randomized block design with three replicates.

Table 1. Analysis of soil samples for the two-year period

Characteristics of the Sample	clay %	Silt %	Sand %	Available K mg/k	Available P mg/k	Total N	Organic Carbon	Caso4 Me/100g	Acidity of the saturated mud	Electric conductivity ds/m	Saturation Percent	Depth
For 2013	24	22	5	420	8.60	%77	%70	_	7.5	1.02	-	0-30
For 2014	24	22	5	182	11	%59	%68	-	7.92	0.99	-	0-30

Irrigation included 40,80,120 mm from evaporation pan as main factors, and different bacterial strains, as sub-factor, included nine levels of Azosperillium-off (Azoff), Azosperillium 21 (Azos 21), Azatobacter-5 (Azto5), Flavobacter-9 (F9), Flavobacter-40 (F40), Herbasillum (Herbas), Psoudomonas168 (P168), Psoudomonas169 (P169),along with control containing no bacteria. Different strains of bacteria were obtained from the national soil and water research institute. The number of experimental plots for two years totaled 81. The main plot was 11 × 2.5 m,with the distance of 25 cm between the rows. Each plot held four rows. The distances between the plots and replicates were 1.5 meters and 2 meters, respectively. Seeds were planted in soil in early May at a depth of 1-2 cm in both seasons. The soil wasplowed by moldboard in the fall, then, in April,disc was used for crushing hunks and preparation of the soil. Before planting, the seeds were inoculated with various strains of bacteria, according to experimental treatments. To make inoculation of bacteria more effective, inoculum and the seeds were,first, soaked in 200 ml volume of emulsion solution and the seeds were, then, planted after drying in shade for 2 hours. Seeds germinated in 7 to 9 days. Irrigation was kept on regularly every 5 days in all experimental plots until plant establishment was achieved with no stress imposed. The three levels of water deficit included control (irrigation after 40 mm evaporation from pan with a 5-7 day period),limited stress with irrigation periodically about every 8 to 10 days (80 mm evaporation), and severe drought treatment with periodic irrigation about every 12 to 15 days (120 mm evaporation). Irrigation treatments started upon inception of branching and continued to the end of growth. Each time, irrigation was conducted after 40±5, 80±5 and 120±5 mm evaporation from class A pan. The volume of daily cumulative evaporation from the pan, after reaching the expected value for each treatment (40, 80 and 120 mm), marked the time for irrigation. The amount of water given to each treatment was assigned according to the total water need calculated for dill, which was obtained through random sample taken from three different spots in the plots, and determining weight percentage of soil moisture 24 hours prior to irrigation. The $\frac{ETc}{ETo}$ = KC equation was used to determine crop coefficient. Where Etc and E to are plant evapotranspiration and reference evapotranspiration (mm day^{-1}), respectively [14].In this study the excess plants were removed at the 3-4 leaf stage. Weed control was done manually several stages during the growing season. To assess the characteristics of the two central rows of each experimental unit, 10 compatible plants were taken, after removing the marginal effects. Fresh and dry weight measurements of leaves and stems were conducted separately for harvested plants. Characteristics such as the number of umbels per plant and leaves, stem diameter, dry weight of stem, leaf, seed weight and seed yield per plant and the quantity and percentage of the essential oil were determined. To determine the amount of essential oil from the dried seeds obtained from separate treatments, a sample of 50 grams was selected and ground, and, then, poured with 250 ml of distilled water into a flask. The mixture was heated by Clevenger for four hours. The yellow essential oilof the seeds was collected, then, dehydrated using anhydrous sodium sulfate and diethyl ether, and, finally, the essential oil content was calculated. The yield essential oil per plant was calculated by multiplying the quantity of essential oil per each seed, in milliliter, by the number of seeds per plant. Statistical calculations were carried out in SAS and 2010 Excel programs.

RESULTS AND DISCUSSIONS

The number of umbels per plant

Analysis of variance of the data showed that irrigation regime and different bacterial strains, as well as their interaction had a significant effect on the number of umbels in dill (Table 2). EL –Ghaban *et al.* [15], likewise, reported in their study that the number of umbels of fennel plants under the use of these fertilizers had a significant increase. Under irrigation condition, after 40 mm evaporation, strains Herbas, F40, P168, Azoff and F9 significantly contributed 97/43%, 27/35%, 33/31% , 38/28% and 29/20%, respectively, to the enhancement of this trait, compared to the condition in which bacteria were not used. Under irrigation conditions with 80 mm evaporation from pan, all strains, except Herbas, significantly increased the number of umbels in plants, compared to the control. This increase peaked at 52.18% by Azto5 strain and reached the lowest 25.99% by strains P168 and Azos21. Under irrigation with 120 mm evaporation from pan, none of the strains led to a significant increase in the number of umbels in dill (Table 3). The results of reviewing this attribute in other literatures indicated that the ability of different strains of bacteria to render ability to plants to increase the number of umbels is dependent on severity of water deficit. A myriad of responses were observed from various strains in irrigated conditions in a way that Herbas lost its capability under water shortage stress, rendering no significant difference in the number of umbels, despite having the maximum efficiency under irrigation conditions. In the current study, severe water shortages inhibited dill plants from taking advantage of their symbiotic relationship with bacteria strains, a relationship congenial to production of more umbels. The strains of bacteria increased photosynthesis and flowering, and, finally, the number of umbels through improvement of nutrient uptake. Kapoor *et al*. (2004), in their study on fennel, showed that the number of umbels per plant was associated with enhancement of mineral nutrition, especially phosphorus, and improvement of biological function via inoculation with mycorrhiza. In the current experiment, under irrigation with 40 mm evaporation from pan, the highest number of composite umbels was 30.27 after treatment with Herbas, and the lowest average number for all three irrigation conditions not using bacteria was 18.39 (Table 3).

Table 2.ANOVA of the mean squares for the effect of year, strain and stress on morphological traits of dill for the two-year period.

		M.S							
S.O.V.	**d.f.**	**Number of umbels**	**Root dry weight**	**Stem diameter**	**Leaf dry weight**	**Stem dry weight**	**Essential oil percentage**	**Essential oil yield per plant**	**Essential oil yield per area unit**
Year (Y.)	1	0.01	0.176	17.880**	17.49	84.13	0.084	778.49*	1.217
RY.	4	6.74	0.0504	0.405	650.39	20494.7	0.390	88.57	0.176
Stress (S.)	2	486.55**	2.0850**	73.56**	1459.2**	36871.0**	0.705	2377.10	3.668
Y. × S.	2	0.002	0.0000	0.005	0.0002	6.35	9.986**	1441.59**	2.220**
Error 1	8	10.49	0.0062	3.52	5.04	79.91	0.075	16.06	0.028
Strain (St.)	8	48.52**	0.0976**	12.02**	118.93**	4014.46**	0.607	249.64	0.404
St. × Y.	8	0.24	0.0000	0.003	0.0002	12.79	0.100	67.67**	0.106**
St. × S.	16	31.35**	0.0028**	9.09**	30.25	1096.14	0.191	130.26	0.211
Y. × St. × S.	16	0.22	0.0000	0.002	0.0002	15.21	0.551**	114.78**	0.179**
Error 2	96	7.23	0.0003	0.797	35.60	789.22	0.087	14.36	0.026
C.V.%		12.23	4.53	24.89	26.51	28.46	23.47	28.18	30.48

S.O.V., Source of Variation; d.f., Degree of Freedom; C.V., Coefficient of Variation, M.S., Mean Squares.*, **, Significant at P<0.01 and P<0.05, respectively.

Table 3. Comparison of the Means of strain × stress treatments factors for the traits studied

stress	strain	Number of umbels	Stem diameter	Root weight
$S_{1=40mm}$	Azoff	26.99	6.06	0.267
	F_9	25.29	7.85	0.197
	A_0	21.024	2.80	0.167
	Azto5	23.03	4.06	0.220
	F_{40}	28.44	5.79	0.293
	Herbas	30.27	3.57	0.313
	P168	27.61	4.83	0.240
	Azos21	22.71	3.98	0.293
	P169	22.74	2.92	0.347
$S_{2=80mm}$	Azoff	22.16	4.46	0.340
	F_9	20.52	2.82	0.340
	A_0	15.85	1.69	0.267
	Azto5	24.12	5.60	0.353
	F_{40}	23.65	5.57	0.427
	Herbas	19.26	4.92	0.473
	P168	19.97	3.61	0.400
	Azos21	19.97	2.78	0.420
	P169	23.38	2.41	0.527
$S_{3=120mm}$	Azoff	18.80	1.91	0.633
	F_9	19.45	1.77	0.580
	A_0	18.28	2.74	0.487
	Azto5	20	2.32	0.607
	F_{40}	18.07	2.87	0.660
	Herbas	21.62	2.29	0.747
	P168	20.11	3.17	0.633
	Azos21	18.61	1.97	0.700
	P169	21.34	2.02	0.773
LSD		3.77	1.24	0.26

Root dry weight

Analysis of variance of the two years showed that the two irrigation regimes and bacterial strain factors and interaction between these two treatments had a significant effect on root dry weight (Table 2). Root weight increased in direct relationship with water stress. It was seen that, under irrigation treatment with 40 and 80 mm evaporation from pan, using different bacterial strains did not make any difference in root weight. In irrigation with 120 mm evaporation from pan, by comparing root weight influenced by different strains, the highest weight root was attributed to Pseudomonas, which would drop to 58.73 percent in conditions with no bacterial inoculation (Table 3). Researchers have reported that inoculation of lavender herb with Mycorrhiza increased the root dry weight [16]. In various crops such as wheat [17], fresh thyme [19] and peas [20] increase in root dry weight has been reported in relation to inoculation with different bacterial strains. In the current study, the largest increase in phosphorus absorption belonged to *Pseudomonas putida* and, then, *Azospirillum lipoferum*. Control had scored the lowest absorption. The use of bio-fertilizers in wheat led to increase in absorption of calcium, phosphorus and potassium and, thus, the root dry weight [18]. The use of bio- fertilizers, such as Azotobacter, Azospirillum and Pseudomonas, in marjoram plant led to dissolving phosphate, which, in turn, increased growth indices in shoots, roots and quantity of essential oil [21].

Stem diameter

The results of ANOVA of the means showed that the factors, stress and different strains of bacteria, and their interaction had significant effects on stem diameter (Table 2). Comparison of the means of the two years indicates that the severity of water deficit deterred the growth of stem diameter (Table 3). Under these circumstances, the use of bacterial strains could partially mitigate the inverse effects of drought stress. In irrigation with 40 mm evaporation from pan, using F9, Azoff, Azto5, F40 and P168 strains attributed, respectively, to 180, 116, 45, 106 and 72 percent significant increase in stem diameter.While in irrigation with 80 mm evaporation from pan, using Azoff, Azto5, F40, Herbas and P168 respectively made 164, 231, 229, 191 and 113 significant increases in stem diameter. Under irrigation with 120 mm evaporation from pan, none of the strains could increase the stem diameter significantly (Table 3).When water is scarce, biological fixation of phosphorus by bacteria existent in the *rhizosphere* such as Flaviobacterium [22], which are capable of dissolving phosphorus, will be inhibited. Therefore, availability of phosphorus reduces in clay soils under these conditions.

Stem dry weight

Water shortage stress significantly lowered shoot dry weight. In a way that, for each unit reduction in water available to the plant, dry weight shrunk by 0.65 units. Maximum dry weight of 125.89 gr and the minimum of 73.78 gr were obtained, respectively, by irrigation levels with 40 and 120 mm evaporation from pan (Figure 1).

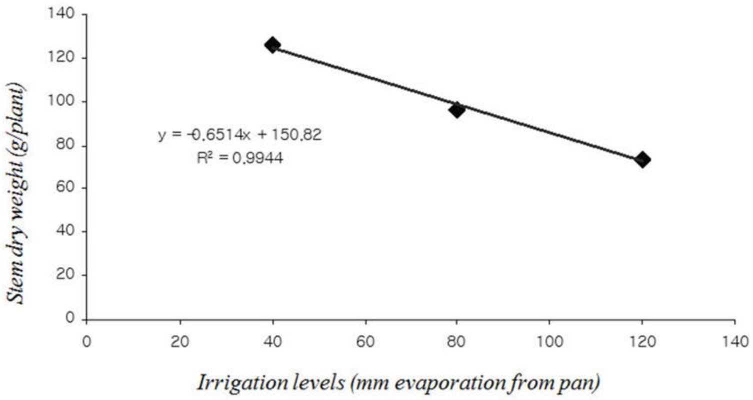

Fig. 1. The effect of different levels of irrigation on the stem dry weight (mean of two)

All strains made a significant contribution to stem weight,which was 83.33, 54.99, 47.33, 36.39, 42.56, 60.22 and 48.57 percent for strains Azos21, P168, Herbas, F40, Azato5, F9, Azoff and P169, respectively,as opposed to the no-use of bacteria (Figure 2). The results are in compliance with studies on cereals; positive effects of inoculation with bacteria on plant height, leaf size, stem length and the quantity of dry matter. Allnoaim and Hamad [18]reported that the use of bio-fertilizers yielded the maximum plant height and seed production in rice plants inoculated with bacteria. Bacteria can increase plant's resistance to stress conditions, by enhancing uptake of elements and release of hormones such as auxin. The first sign of water shortage is the fall of turgor pressure and, thereby, growth of cells in specific stems and leaves. Reduction in cellular growth limits the size of the organ. And that is why the first tangible effect of dehydration on plants can be seen on retarded leaves or stunted plants. Drought stress affects at a cellular level or the whole plant. The results of research by Youssef et al. [23] on sage (*Saliva officinalis L.*) indicated that the use of bio-fertilizers containing Azospirillum and Azotobacter increased the height, fresh and dry weight of the shoots in the first and second harvests during two seasons.

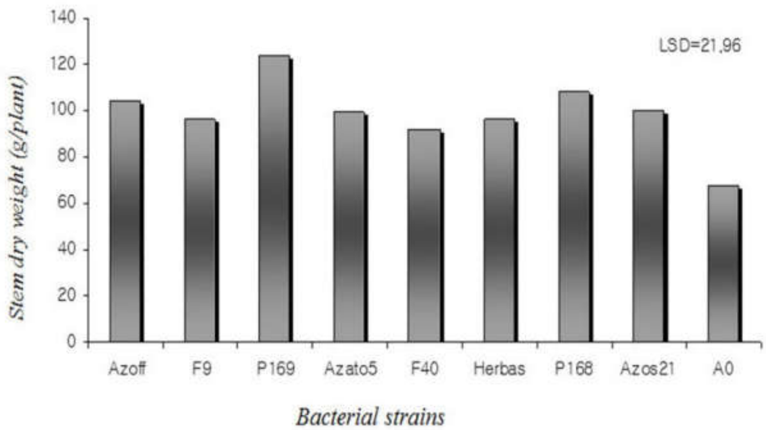

Fig. 2. The effect of bacterial strain on the stem dry weight (mean of two years)

Leaf dry weight

Water shortage stress leads to loss of weight in leaves.Results of the ANOVA showed that water stress and bacterial strains had a significant effect on leaf dry weight at the level of 1%. Maximum dry weight of 27.96gr and the lowest of 17.61gr were, respectively, obtained in irrigation treatment with 40 and 120 mm of evaporation (Figure 3).Some bacterial strains had a positive impact on the dry weight of leaves, compared to the conditions with no use of bacteria, and with some effects significant. In this study, the use of different bacterial strains, except for Herbas and P169, could not significantly increase leaf dry weight. The highest leaf dry weight was achieved by treatment with strain Herbas, and lowest by control.

Accordingly, dill treatment with strain Herbas contributed to about 27 percent increase in leaf dry weight, in comparison to control. The amount of increase was not significant when using other strains, despite increasing the effect (Figure 4).

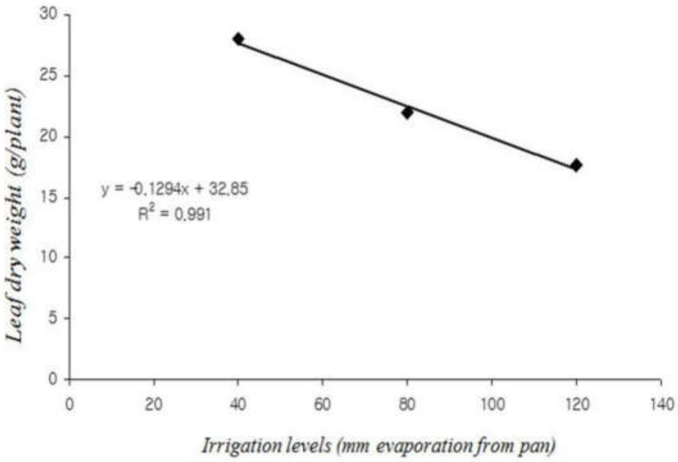

Fig. 3. The effect of different irrigation levels on leaf dry weight (mean of two years)

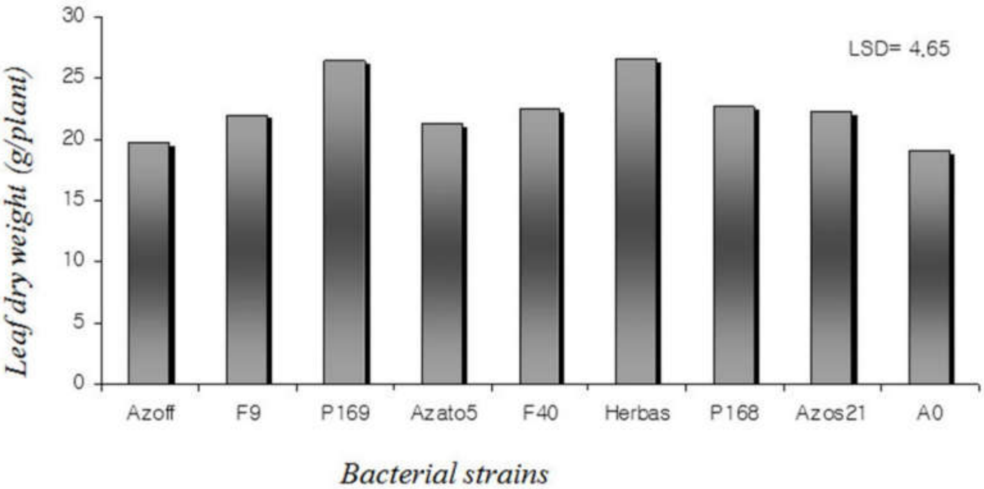

Fig. 4. The effect of bacterial strain on leaf dry weight (mean of two years)

Other researches have shown that inoculation with growth inducing bacteria caused an increase in shoot dry weight and nutrient uptake by plants [24].Water deficit, however, reduced the number of leaves. Fallof the amount of leaf area rate and expansion, due to impaired photosynthesis and reduction in cellular inflammation for water defect,has been reported in other studies, too [25]. Dehydration stress,in addition to leaf area, reduces the number of leaves, which culminate in the fall of dry weight. Water stress, by reducingstem height, on one hand, and hampering the growth of young leaves and desiccation of old leaves, on the other hand, reduces the number of leaves on the plant [25].

Essential oil percentage of the seed

Combined variance analysis of the two-year period showed that the quantity of essential oil was significantly influenced by irrigation treatment and the interaction of year, stress and bacterial strain (Table 2). In 2013, the use of bacterial strains had an increasing effect on quantity of the essential oil in dill.Under no stress and moderate stress conditions, under irrigation with 40 mm evaporation from pan, strains F9, Azato5, Herbas, P168 and P169 significantly increased quantity of the essential oil, as 118, 95.5, 184, 151.4 and 75.30 percent, respectively. In 2014, treatment with any of the strains could not lead to a significant change in the essential oil content. In 2013, under irrigation with 80 mm evaporation from pan, only Azos 21 could significantly increase the amount of essential oil in comparison to no use of bacteria, which was 66.7%. In 2014, strains of bacteria were ineffective in changing the quantity of the essential oil. In 2013, under irrigation after 120 mm evaporation from pan, none of the strains led to a significant increase in the percentage of essential oil. In 2014, treatment with strains of herbas and P169 were the most effective in increasing the essential oil (Table 4).

In general, growth stimulating bacteria present in nitrogen fixing bio-fertilizers were capable of producing auxin hormone and secretion of some bioactive compounds such as vitamin B, acid nicotinic and biotin (). Accordingly, the use of Azospirillum strains had a positive impact on nitrogen absorption, and increased the amount of essential oil. Combined application of nitrogen-fixing bio-fertilizers along with applying stress increased the percentage of essential oil in dill.

Table 4. The comparison of the means of combination of year × strain × stress for the traits studied

stress	strain	**Essential oil percentage**		**Essential oil yield per plant**		**Essential oil yield per unit area**	
		2013	2014	2013	2014	2013	2014
S_1	Azoff	1.290	1.336	19.16	19.01	0.76	0.76
	F_9	1.706	0.713	10.53	25.91	0.42	1.03
	A_0	0.973	0.930	10.27	11.38	0.41	0.45
	Azto5	2.446	1.230	21.69	43.55	0.86	1.74
	F_{40}	1.346	0.756	9.40	17.24	0.37	0.68
	Herbas	2.763	0.573	10.85	53	0.43	2.12
	P168	1.906	0.516	7.59	28.62	0.30	1.14
	Azos21	1.306	0.840	13.80	21.88	0.55	0.87
	P169	2.130	0.656	11.46	38.97	0.45	1.44
S_2	Azoff	1.030	1.030	6.82	7.15	0.27	0.28
	F_9	1.213	1.210	12.66	12.90	0.50	0.51
	A_0	0.960	0.936	6.80	7.09	0.27	0.28
	Azto5	1.380	1.366	16.62	16.89	0.66	0.67
	F_{40}	1.183	1.166	12.56	13.40	0.50	0.53
	Herbas	1.140	1.026	9.56	11.10	0.38	0.44
	P168	0.840	1.120	9.01	6.88	0.35	0.27
	Azos21	1.600	1.333	17.61	21.48	0.70	0.95
	P169	0.886	0.970	10.42	9.70	0.41	0.38
S_3	Azoff	1.086	1.416	10.64	11.96	0.42	0.47
	F_9	0.973	1.440	7.74	5.58	0.30	0.22
	A_0	0.963	1.466	7.86	5.54	0.31	0.22
	Azto5	1.360	2.050	16.97	9.75	0.70	0.39
	F_{40}	0.916	1.820	9.26	6.39	0.37	0.25
	Herbas	0.853	2.486	8.88	4.11	0.35	0.16
	P168	0.623	1.686	6.48	2.40	0.25	0.9
	Azos21	1.103	1.256	6.91	6.14	0.27	0.24
	P169	0.703	2.113	12.04	3.66	0.48	0.14
LSD		0.634		8.14		0.34	

Generally, production and accumulation of essential oil increases in plants under dry conditions (Abreu and Mozzafera, 2005). The percentage of essential oil decreases in inverse relationship with available water in all plant organs.

Treatments not experiencing drought stress accumulated the lowest percentage of essential oil. There is no proven reasons as to how secondary metabolites of medicinal plants response to drought stress. There are only two hypotheses developed on the effects of environmental conditions on secondary metabolites.

The second hypothesis, growth-differentiation balance, states that carbon will be consumed for growth, as long as conditions permit for cell division and expansion. With incidence of drought, growth ceases, cells start to differentiate, storages create secondary metabolites, and plant allocates carbon to the creation of effective pharmaceuticals [26].

Essential oil yield per plant

Essential oil yield per plant in dill is also influenced by some bacterial strains under no stress, moderate stress and shortage of water, the same as the percentage of essential oil per seed. The increasing effect was especially noticeable under moderate stress and shortage of water conditions. In 2013, under irrigation with 40 mm evaporation from pan, strains Azato 5 and Azoff caused an increase, in comparison to no use of bacteria condition, which was 86.56 and 111 percent, respectively. In 2014, all strains, except for F40 and Azoff, caused a significant increase in the essential oil yield, compared to control. In 2013, under irrigation with 80 mm evaporation from pan, only Azoto5 and Azos 21 could cause a significant increase in the essential oil production, compared to control, in which each caused 143.6 and 58 percent increase, respectively. In 2014, strains were not effective on the essential oil production.

In 2013, under irrigation with 120 mm evaporation from pan, bacterial strains did not render any significant increase in production of essential oil. In 2014, the treatment of bacterial strains was found ineffective on the essential oil production (Table 4).

Two-year compound analysis showed that plant essential oil to be significantly affected by levels of irrigation for this period (Figure 5). Velmurugan et al. [27], in their study on turmeric, concluded that the use of Azotobacter and Azosprillum led to the improvement of attributes including plant performance. Since the performance of essential oil in seed is obtained as multiplying essential oil percentage by seed yield, in this study, both components of multiplication (essential oil content and grain yield per plant) were grown as a result of applying bacterial strains. Thus, increase in the essential oil yield per plant was not unexpected.

Essential oil yield per unit areaData analysis of two years showed that irrigation regime, strain and year and bilateral interaction effects had significant effects on essential oil yield per unit area (Table 2). Irrigation with 40 mm evaporation from pan, in 2013, even when treated with bacteria, did not make a difference in yield. In 2014, using bacteria strains of F9 and Azato 5, Herbas, P168 and P169 and Azos 21, respectively, brought about 128, 286,371, 153,220 and 93 percent significant increase in yield. In irrigation with 80 mm evaporation from pan, strains Azato5 and Azos21, respectively, caused 159 and 144 percent significant increase in 2013, while the same strains left a significant effect, in that regard, in 2014. Treatment with irrigation with 120 mm evaporation from pan, had no significant effect in both years (Table 4).

Plants need variety of nutrients for growth and development, which they mainly uptake from soil or obtain from chemical fertilizers. For many years, chemical fertilizers have been the keystone of any agricultural production, and are currently considered as the most important input in agriculture. Following major changes in policies of food production, and research in agriculture has been the shift from seeing increase in food production to the highest possible amount as the final goal to the point where any effort toward more production should be in accomplice with the basic principles and the goals of sustainable ecology and agriculture, which also constitute the objectives of the current study. Here, the results amply proved the affectivity of using organic fertilizers (micro-organisms enhancing plant growth) on dill plants. Drought and bacterial strains inducing plant growth significantly affected most of the physiological traits, indicating plants opt to use different options in dealing with stress. Due to the demands for medicinal plants, on one hand, and the requirements for production of these plants under the low cost regulation, on the other hand, organic fertilizers can be the best alternative for chemical fertilizers.

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