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Effect of Pine Needle Mulch and Irrigation Frequency on the Yield of *Origanum syriacum* under Open Field Condition

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Authors' contributions

This work was carried out in collaboration among all authors. Author EHAK designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MN, VT, NT, SO and MH managed the analyses of the study. Author HR managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Due to the intensive harvest from natural habitat and increasing competition as a source of food, *O. syriacum* was introduced into cultivation and soon became one of the promising crops for many farmers in rural areas. The aim of the study is to investigate the effect of pine needle mulch(PN) and irrigation frequency(IF) at 5, 10 and 15 days on the yield under open field conditions. The study was conducted at the Lebanese agricultural research institute (LARI) in Lebaa station (33°32.681′ North, 35°27.088′ East, 354 m a.s.l.), south Lebanon, province of Jizzin, under open field condition for two seasons during 2016. Treatments were organized in randomized complete block design (RCBD) with three replicates. The results indicated a significant effect of mulch in both spring and fall seasons $F (1, 172) = 59.34$, $p < .0001$, $\eta^2=.24$, $F (1, 172) = 77.71$, $p < .0001$, $\eta^2=.30$

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respectively. The two-way anova showed no significant effect of irrigation frequency on the average and total plant fresh weight (PFW) across two seasons F (2, 349) = .80, p= .4522, η^2=.0038, F (2, 159) = 1.07, p= .3460, η^2=.007 respectively. Very little variance of the plant fresh weight ,(0.2% – spring and 3.1 %- fall) was attributed to the interaction of mulch and irrigation frequency .In a comparison between percent weight contribution(PWC) of a different plant part, leaves formed the highest proportion (48.6%) compared to the inflorescence and stem. The fresh weight of weeds(g/ m^2) was significantly less in plots mulched with pine needles compared to the control (F(1,66)=24.43, p<.0001, η^2=.75).
Applying pine needle mulch enhanced most of the yield parameters. Under calcareous clayey soil *O. syriacum* could be irrigated at10 or 15 days frequencies without remarkable decrease in the yield.

Keywords: Intensive harvest; fresh weight; Lebaa; percent weight contribution.

1. INTRODUCTION

O. syriacum (Fig. 1) belongs to the Labiatae family, genus Origanum. Along with other species, *O. syriacum is* native to Palestine, Jordan and Syria [1]. In Lebanon*, O. syriacum* is spread as a wild subshrub in different areas, especially on west-facing slopes of Mount Lebanon mountain chain from north to south between 200 and 600 m above sea level. *O. syriacum* is characterized by its multiple benefits and diverse use.

Their leaves and inflorescence contain essential oil rich in phenolic monoterpenoids mainly thymol and carvacrol [2,3,4,5,6,7]. They are used in traditional medicine as a remedy for cold, flu and cough and also as a food and flavor (spice). Extracts from *O. syriacum* show an antifungal activity [4] and they are used as an insecticidal agent against agricultural pests and diseases [8,9,10,11]. The production of *O. syriacum* from the wild habitat in Lebanon varies annually from 700 to 800 t (dry weight) [12]. This production is considered high compared to the small territory of Lebanon and may pose a serious threat to *O. syriacum* as a herbal wild plant. The domestication of *O. syriacum* was initialized several decades ago in response to the unsustainable over exploitation from its wild and also to its high market potential. The climate is characterized by the dry summer which constrains the cultivation of many crops unless the supply of irrigation water. Under natural habitats, one harvest is obtained annually. Without irrigation program, the cultivation of *O. syriacum* will fail to produce a high reasonable and sustainable yield under the prevailing hot and dry weather conditions during the summer period in Lebanon. Another limiting factor of irrigated *O. syriacum* is the weed management. Polyethylene mulch is the main treatments used to control weeds in agricultural crops. The use of chemical herbicides is not advisable on aromatic perennial plants since it is associated with series drawbacks [13]. However some herbicides have shown a selective weed control in *O. syriacum* [14]. Straw and pine needle mulch may offer an alternative method to the use of herbicides. The objective of this study is to investigate the effect of irrigation frequency and pine needle mulch on the herbage yield of *O. syriacum* under field conditions.

Fig. 1. *Origanum sp.* grown at Lebaa station within the mother plots

2. MATERIALS AND METHODS

2.1 Site and Treatments

The study was conducted at the Lebanese agricultural research institute (LARI) in Lebaa station (33°32.681′ North, 35°27.088′ East, 354 m a.s.l.), south Lebanon, province of Jizzin, under open field condition. Cuttings of Rmeich ecotype were rooted in propagating units on December 2015 and then planted in the field on March 2016. Based on the soil analysis (Clay texture), the method of planting on raised ridges was adopted to avoid the water logging during

rainy period. Plant spacing was 75cm between ridges, 40cm between plants (Net plot size 3 m^2). Drip irrigation system with flow meter was used to deliver the right amount of water to the plants. The irrigation of 1 and 0.6 l/plant/day at 5, 10 and 15 days frequency were assigned to both organic mulch (pine needle)and control plots (bare soil) respectively.

2.2 Experimental Design and Statistical Analysis

A total of 6 treatments were organized in complete block design with three replicates (blocks). The experimental unit consisted of 12 plants. Two-way analysis of variance was performed for testing the effect of treatments and their interaction on yield parameters by using SAS for windowsV8. A post hoc Tukey's test ($p < 0.05$) was used to discriminate among means of treatments. Wolcoxon signed-rank test was used for comparison two paired samples of spring and fall plant fresh weight.

2.3 Data Recordings

Plant weight was recorded on 10 plants cut at10 cm above soil level .Four plants were assigned for measuring the plant proportion parts (leaves, flowers and stem).Plant height was measured from the soil level to the highest point of the plant. 6 plants from each experimental plot were photographed at 1.5 m height and then the images were processed through the ImageJ program for evaluating canopy area. Weed biomass (fresh weight) were recorded at two harvesting dates.

3. RESULTS AND DISCUSSION

3.1 Weather Data

Two cuts were obtained through the implementation of drip irrigation during the hot dry period which lasted from late spring to the mid of autumn. The average daily reference evapotranspiration (ET0) was 4.1mm for the period from May till the end of September. Max reference evapotranspiration (ET0) was recorded on June, July and August months (Fig. 1).

3.2 Yield Parameters

Analysis of variance showed a significant difference between treatments in regard to plant fresh weight in both spring ($F(5,172)=14.63$, $p<.0001$, $\eta^2=0.30$)and fall ($F(5,172)=17.40$, $p<.0001$, $\eta^2=34$) harvests respectively (Table 1). A Wilcoxon Signed-ranks test indicated that the plant fresh weight was higher in fall harvest (Mn=142.2, SD=42.6) than in spring (Mn=78.4, SD=27.8), $p<.0001$. The longer growing period, the higher amount of irrigation water received and development of root system [15] caused the plants cut in fall to have a higher biomass as compared to the plants harvested in late spring. The results for two-way ANOVA indicated a significant main effect for mulch in both spring and fall seasons F (1, 172) = 59.34, $p < .0001$, $\eta^2=.24$, F (1, 172) = 77.71, $p < .0001$, $\eta^2=.30$ respectively (Table 1). Therefore the soil coverage with pine needle increased the average plant fresh weight as compared with bare soil regardless the implementation of irrigation frequency. This may be due to the positive effect of mulch on the total uptake of N P K [16]. Other studies also showed a significant effect of pine needle mulch on plant growth [17]. The results obtained by [18] showed the improving effect of organic mulches mainly pine needle mulch on the vegetative characters of squash. Regarding irrigation frequency, the two-way ANOVA showed no significant effect on the average and total plant fresh weight across two seasons F (2, 349) = .80, $p= .4522$, $\eta^2=.0038$, F (2, 159) = 1.07, $p= .3460$, $\eta^2=.007$ respectively (Table 1). The same results were obtained by Khaazaie, H.R and Uçan, K [19,20] which showed no significant effect of irrigation frequency on the herbal biomass. However, the results obtained by Gerami F [21] showed a negative effect of increasing irrigation intervals on morphological traits while it did not affect the oil production and yield of *Origanum vulgare*. In spring season, the observed variation in the fresh weight that was attributed to the irrigation frequency did not exceed 6%($\eta^2=.055$). Additionally, the results showed no significant interaction between mulch and irrigation frequency on the total $F(2, 159) = 1.22$, $p= .2969$, $\eta^2=.009$, and average plant fresh weight $F(2, 349) = 1.25$, $p= .2891$, $\eta^2=.006$ indicating that the effect of mulch does not depend on irrigation frequency. Very little variation in the plant fresh weight, (0.2%, $\eta^2=..002$– Spring and 3.1 %-, $\eta^2=.031$ fall) (Table 1) was attributed to the interaction of mulch and irrigation frequency.

Air dried plant weight comprised in average about 36% of the total yield biomass and did not differ significantly between treatments. In a comparison between percent weight contribution of a different plant part, leaves formed the

highest proportion compared to the inflorescence and stem (Table 2). In fall harvest, neither mulch nor irrigation frequency and their interaction significantly affected the percent weight contribution of the leaf, inflorescence and stem. In spring harvest, a two-way ANOVA indicated a significant effect of mulch on the percent contribution of leaves. The effect of mulch on percent contribution of inflorescence showed a marginal significance (p=*0.0971)*. Plants irrigated at 15 days frequency had a slightly more inflorescence as compared with plants irrigated at 5 days frequency (marginal significance *p*=.0887).

The effect of treatments was examined on the canopy area, plant height and number of shoots per plant. The results showed a significant difference between treatments on the three parameters. These parameters were positively affected by pine needle mulch. The irrigation frequency had a significant effect on the number of shoots/plant (*p*=0.0222) (Table 3) whereas no significant effect was observed on the plant length and plant canopy area respectively (*p*=0.5997, *p*=0.3351). The highest number of shoots per plant was recorded in plots irrigated at 5 days frequency (Table 3).

3.3 Weeds

In regards to the weed biomass (fresh weight/m^2), the overall analysis of variance indicated a significant difference between treatments (*F* (5, 66) =6.52, *P*<.0001, η^2=0.33) (Fig. 2). Control plots accumulated significantly more weed biomass (Mn=328.7/m^2, SD=246.7) than plots mulched with pine needles (Mn=123.6/$m^{2,}$ ^{SD}=69.7), (F (1, 66) =24.43, *p*<.0001, η^2=.75). Our results regarding the suppression effect of pine needle mulch on weed growth agree with the results obtained by Burkhard Nel [22]. Irrigation frequency showed a marginal significant effect on weed biomass. Plots irrigated at high frequency (5 days frequency) yielded a higher weed biomass (Mn=280.9, SD=257.4) as compared with plots irrigated at low frequency (15 days frequency) (Mn=164.8, SD=121.1), (F (2, 66) =2.64, *p*=.0792, η^2=.16).

Table 1. Two–way analysis of variance for the main effect of mulch, irrigation frequency and their interaction on the fresh plant weight and its average percent air dried weight

	Total	Average	Spring harvest	Fall harvest	Plant air dried weight,%
Treatments					
PN5	261.6(50.1)^a	130.1(42.4)^a	104.9(28.3)^a	153.6(39.9)^a	36.1(5.9)
PN10	261.3(57.2)^a	133.1(54.5)^a	92.1(27.5)^b	169.9(45.8)^a	35.8(5.2)
PN15	262.3(35.4)^a	131.7(52.2)^a	87.6(25.3)^b	175.9(29.7)^a	36.4(4.3)
Ctrl5	198.6(46.3)^b	101.2(39.5)^b	73.9(23.1)^c	125.7(35.0)^b	37.4(8)
Ctrl10	188.7(31.1)^b	92.0(36.3)^b	66.0(18.4)^c	121.9(27.8)^b	35.9(5.2)
Ctrl15	174.2(34.4)^b	85.4(52.2)^b	62.6(18.4)^c	111.9(28.3)^b	37.1(4.8)
P	<.0001	<.0001	<.0001	<.0001	.85
Mulch(m)					
Pine needle	261.8(47.4)^a	131.6(49.7)^a	94.7(27.7)^a	166.5(39.7)^a	36.1(5.1)
Bare soil	186.7(38.6.)^b	92.5(37.0)^b	67.0(20.2)^b	119.8(30.8)^b	36.8(6.1)
P	<.0001	<.0001	<.0001	<.0001	.40
(IF)					
5 days	229.5(57.4)	115.8(43.3)	89.7(30.1)^a	139.6(40.0)	36.8(7)
10 days	224.3(58.3)	112.4(50.5)	78.2(26.4)^b	147.2(45.0)	35.8(5.2)
15 days	217.5(56.3)	107.6(49.4)	74.1(25.0)^b	143.9(43.2)	36.7(4.5)
P	.34	.45	.001	.61	.62
Interaction (M*IF)					
P	.29	.28	.76	.02	.85

Note. Columns with different letters are significantly different (Tukey's test, p < 0.05).
Means are reported with standard deviation (SD) in brackets.

Table 2. Two–way analysis of variance for the main effect of mulch, irrigation frequency and their interaction on the percent weight contribution of plant parts of *Origanum syriacum* (Leaves, Inflorescence, and Stems) measured at spring and fall seasons

	Spring harvest			Autumn harvest			Average		
	Leaves	**Infl.**	**Stem**	**Leaves**	**Infl.**	**Stem**	**Leaves**	**Infl.**	**Stem**
Treatments									
PN5	39.3(7.7)	30.3(7.0)	29.9(3.5)	57.5(3.6)	17.9(3.7)	24.7(2.0)	46.6(13.8)	26.1(12.1)	27.3(3.8)
PN10	37.7(7.1)	33.5(8.9)	28.8(3.3)	59.5(5.4)	15.6(8.1)	24.9(3.8)	48.6(12.9)	24.5(12.4)	26.8(3.9)
PN15	33.3(3.0)	38.6(1.5)	27.1(2.9)	63.0(6.7)	13.4(5.1)	23.5(3.6)	46.3(19.1)	28.4(17.8)	25.3(3.2)
Ctrl5	43.4(9.7)	28.1(7.6)	28.6(2.4)	55.5(5.2)	21.6(6.0)	23.0(1.0)	49.4(9.7)	24.8(7.3)	25.8(3.4)
Ctrl10	44.0(6.7)	27.9(7.5)	28.2(2.5)	59.6(6.6)	17.2(5.7)	23.1(2.6)	51.8(10.3)	22.5(8.4)	25.7(3.6)
Ctrl15	39.7(6.6)	33.5(8.7)	26.8(3.6)	60.7(8.8)	16.7(8.2)	22.6(2.8)	50.2(13.2)	25.1(11.9)	24.7(3.8)
P	*.13*	*.14*	*.56*	*.47*	*.45*	*.64*	*.92*	*.92*	*.61*
Mulch									
PN	36.8(6.5)[b]	34.1(7.2)	28.6(3.2)	60.0(5.6)	15.6(5.9)	24.4(2.8)	47.2(15.1)	26.3(14.0)	26.5(3.7)
CTRL	42.8(7.4)[a]	29.9 (7.9)	27.8(2.8)	58.7(7.0)	18.3(6.7)	22.9(2.2)	50.5(11.0)	24.1(9.3)	25.4(3.5)
P	*.02*	*.09*	*.48*	*.56*	*.22*	*.13*	*.32*	*.46*	*.21*
Irrigation frequency									
5 days	41.3(8.5)	29.2(7.0)	29.3(3.0)	56.6(4.3)	19.6(5.0)	23.9(1.8)	47.9(11.9)	25.5(10.0)	26.6(3.7)
10 days	40.9(7.4)	30.7(8.4)	28.5(2.8)	59.5(5.7)	16.4(6.8)	24.0(3.2)	50.2(11.5)	23.5(10.4)	26.3(3.7)
15 days	36.8(6.0)	35.8(6.7)	26.9(3.1)	61.9(7.6)	15.1(6.7)	23.1(2.7)	48.3(16.2)	26.7(14.9)	25.0(3.4)
P	*.22*	*.08*	*.20*	*.15*	*.24*	*.66*	*.83*	*.67*	*.31*
Interaction (Mulch*Frequency)									
P	*.70*	*.69*	*.95*	*.84*	*.83*	*..93*	*.98*	*.96*	*.96*

Note. Columns with different letters are significantly different (Tukey's test, $p < 0.05$).
Means are reported with standard deviation (SD) in brackets

Table 3. Two–way analysis of variance for the main effect of mulch, irrigation frequency and their interaction on the canopy a, number of shoots and plant height of *Origanum syriacum*

	Canopy area, cm^2	Number of shoots	Plant length, cm
Treatments			
PN5	1727.4(360.3)^a	39.0(12.7)^a	55.7(8.1)^a
PN10	1721.4(350.9)^a	29.5(10.7)^{bc}	55.5(7.2)^a
PN15	1689.2(166.2)^a	32.9(9.2)^{ab}	54.4(5.4)^a
Ctrl5	1248.8(340.4)^b	26.6(9.3)^c	49.5(7.4)^b
Ctrl10	1318.5(268.6)^b	26.0(13.1)^c	49.7(5.5)^b
Ctrl15	1128.1(144.6)^b	23.6(9.4)^c	50.3(7.0)^b
P	*.04*	*<.0001*	*.006*
Irrigation frequency(if)			
5 days	1474(418.7)	32.8(12.7)^a	52.6(8.3)
10 days	1531.8(368.9)	27.7(12.0)^b	52.6(7.0)
15 days	1408.6(328.5)	28.3(10.3)^b	(52.3(6.5)
P	*.33*	*.02*	*.59*
Mulch(m)			
Pine needle	1715.1(304.3)	33.8(11.5)^a	55.2(6.9)^a
Control(Bare soil)	1241.6(274.8)	25.4(10.7)^b	49.8(6.6)^b
P	*.004*	*<.0001*	*.001*
Interaction (m*if)			
P	*.52*	.003	*.10*

Note. Columns with different letters are significantly different (Tukey's test, p < 0.05). Means are reported with standard deviation (SD) in brackets

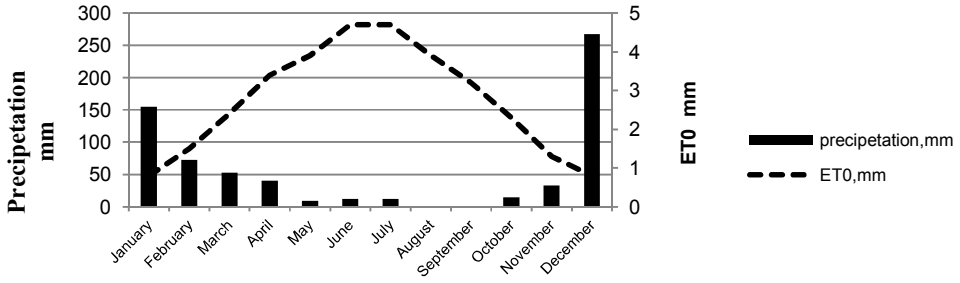

Fig. 2. Reference evapotransperation (ET0) and precipitation for the period from January to December of 2016 in Lebaa station

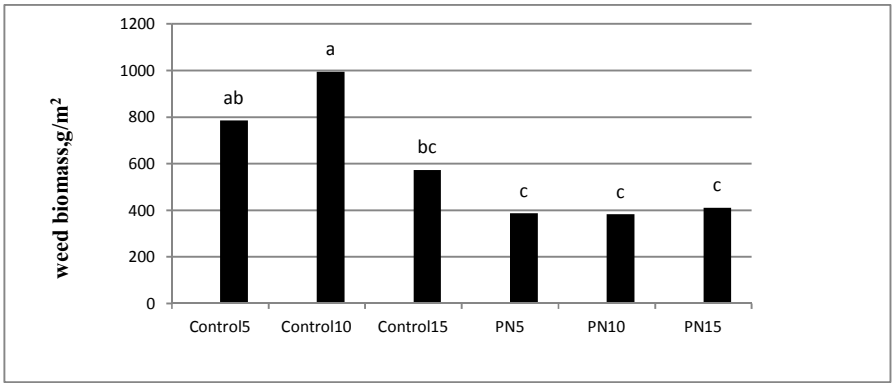

Fig. 3. Means of weed fresh biomass recorded from bare and mulched plots cropped with *O. syriacum* and irrigated at three frequencies (5, 10 and 15 days)

4. CONCLUSION

There was no significant effect between the three adopted frequencies on the fresh plant weight. Applying pine needle mulch enhanced most of the yield parameters except for the percent weight contribution of plant parts. No obvious trend of the interaction between pine needle mulch and irrigation frequency. Under calcareous clayey soil, *Origanum syriacum* could be irrigated at 15 days frequency without remarkable decrease in the yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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