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PERFORMANCE OF SAFFRON GROWTH ON DIFFERENT SOILS UNDER HOMOGENEOUS ENVIRONMENTAL CONDITION

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ABSTRACT

Soil is the major factor determining saffron yield. Although saffron tolerates different soil types, some soils with specific characteristics perform better than others. This work was conducted to evaluate the performance of saffron crop on different soil types under homogeneous environmental conditions. Four soil types sampled from different regions were tested: Rendzic Leptosols, Anthropic Regosols, Hypercalcaric Fluvisol and Eutric Cambisols. Soil samples were put in large plastic pots (radius=0.27 m, height=0.44 m) and organized in complete block design with four replicates. Combined analysis for four years revealed significant differences between soil types regarding most yield parameters. Saffron corms performed better on calcareous clayey Rendzic Leptosols soil with respect to plant height(PL), flowers per plot, flowers per corm cluster, total stigmas fresh and dry weights, fresh and dry weight of single stigmas and total number of corms. Corms grown on Hypercalcaric Fluvisol soil produced the largest content of Crocin, Picrocrocin and Safranal. A regression analysis was used to evaluate the performance of soil types on the number of flowers per mother corm through four years of the study. In this regard, a positive significant higher slope was obtained for Rendzic Leptosols ($y = 4.23x - 8514.3$, $R^2 = 0.69$, $p<.0001$). Quantitative yield attributes such number of flowers per corm cluster was significantly correlated with organic matter t (r = .60, p=.016) and calcium (r =.52,p.041) contents. Correlation analysis showed that the soil parameters most attributed to the saffron yield were organic matter, phosphorus, potassium and calcium. For soils with limiting factors (Eutric cambisols and anthropic regosols) further studies should focus on improving their performance under saffron crop.

Keywords: *Rendzic Leptosols, Anthropic Regosols ,Crocin, Corm cluster.*

INTRODUCTION

As a new and promising crop, Saffron cultivation in Lebanon was initiated approximately two decades ago to replace Cannabis sativus. Besides its cultivation in traditional farming, saffron can be accepted as a family business. Other attractive features of Saffron cultivation is that saffron yield could be stored for a long period without losing its essential values. Furthermore, the high price of dried stigmas and the low cultivation requirements (fertilization, irrigation and pest management) make Saffron very promising and an alternative to many crops especially in marginalized areas (Dar et al.,2007, Gresta *et al.,* 2007,Birouk *et al.,*2011,Chaouqi *et al.,*2016). The biological cycle of saffron in main producing areas displays relatively similar stages starting from sprouting and flowering in autumn till corm dormancy in summer. Six stages were reported by (Lopez-Corcoles *et al.,* 2015). Yasmin and. Nehvi (2018), Gresta et al.,(2007) reported that timing of the phenological stage is observed to be closely related to weather parameters in particular air temperatures. Saffron grows within a wide range of geographical zones from Irano-Touranian , east Asia to the Mediterranean regions. Saffron is cultivated in a wide range of climate zones (from temperate to dry climates) (Gresta *et al.,* 2007). These climatic conditions ensure high saffron yield (Fernández, 2004). Annual rainfall in the cultivated areas in Spain ranges from 250 to 500mm,in Sardinia from 300 to 600 mm while in Greece is about 560mm(Tammaro ,2017). Average annual precipitation in Lebanon ranges from very low (< 300 mm/year) in Hermel region to very high (>1200 mm/year) in Mount Lebanon (Darwish, 2012). Despite its small territory (10452 m^2), Lebanon as a mountainous country is featured by a diverse and complex geography. Land forms, climate, soils, and vegetation differ markedly within short distances (Wikipedia).The fertile Bekaa valley separates the two mountain chains: Mount Lebanon (stretching from north to south facing Mediterranean sea) and anti-Lebanon(bordering Lebanon with Syria) (Geography of Lebanon). In addition to climatic factors, Soil plays an important role in determining quantitative and qualitative parameters of saffron yield. The role of some soil properties is essential in enhancing and increasing yield (Emami ,2015). Amoon *et al.,*(2013), reported that Saffron yield parameters respond significantly on the degree of soil fertility. Although Saffron tolerates various soil types, deep and well drained clay-calcareous soils with a loose texture are the appropriate for better growth and root penetration(Dar *et al.,* 2017). Light and moderate soils rich in nutrient enhance the performance of Saffron (Tammaro,2017). Clayey soils with poor drainage causes corm decay. These soils are low in organic matter (> 1%)(Skinner *et al.,* 2017). The Lebanese land is characterized by a wide range of soils (from good to poor soils) which have a typical Mediterranean nature (LIDO, (2014) (Vogiatzakis in Mediterranean mountains environments)]. Terra-Rossa (Red Mediterranean soils) and the Rendzinas represent 70 percent of Lebanese soils (LIDO ,2014). Several small-scale trials were established by the Lebanese agricultural research institute in 5 stations located in different regions for evaluating saffron production. The yield varied among these trials. Because of the scarce researches on Saffron in Lebanon, this study was conducted to evaluate the relationship between Saffron yield and some soil types and properties under homogeneous environment.

MATERIALS AND METHODS

Site description

The study was conducted for four years from 2013 to 2017 at The Lebanese Agricultural Research Institute in Lebaa station ,Jizzin province at altitude 350 m asl. Soils were collected from four regions. The main characteristics of sites are shown in table 1. Soil samples were put in large plastic pots (radius=0.27 m, height=0.44 m) and organized in complete block design with four replicates. 6 homogeneous corms allocated to each experimental unit.

Site sampling

Flowers were collected early in the morning. The yield parameters recorded in the study included plant height(PL), number of flowers per pot(FP) ,number of flowers per corm cluster (FCC), fresh (FWS) and dry (DWS) weight of stigmas, length of stigma(LS),total number of corms per pot(CP), dry leaf biomass(DLB), crocin, picrocrocin and safranal content. The separated stigmas (red part of stigmas) were dried under ambient lab temperature. Fresh and dry weight of single stigma were weighted on a precise digital balance up to 0.000g accuracy. The components of air-dried stigmas (Crocin , Picrocrocin and Safranal) were determined according to ISO 3632-2 :2010 test method by using UV-vis spectrophotometer. The results for these three compounds were obtained by direct reading of the specific absorbance at three wavelengths (257nm-picrocrocin,330nm –Safranal,440nm crocin). Soil analysis was done at Lebaa laboratory using ISO 10390:2005, 11265: 1994, 11263:1994 for pH,electrical conductivity , and phosphor parameters respectively. For organic matter Walkley-black method was used. Combined analysis was performed in SAS 9.2 for Windows (SAS Institute Inc., Cary, NC, USA) to evaluate the effect of treatments (soils), time (year) and their interaction on saffron yield parameters . Tukey's multiple comparisons test of significance at p= 0.05 was used to evaluate differences between these groupings

Table 4 .Geographic and weather characteristics of the sites and their soil types.

Site	Altitude (m)	Latitude	Longitude	Rainfall[1] (mm)	Temperature[1] (C^0)	Soil type
Lebaa	354	33°32.68N	35°27.08E	852	Min:9.7 Max:30.2	Rendzic Leptosols[2]
Nabatieh	508	33°21'50N	35° 29'33E	800	Min:9.6 Max:31.5	Anthropic Regosols
Sour	7	33°15'54N	35°13'03E	697	Min:13.7 Max:26.4	Hypercalcaric Fluvisol
Tel-Amara	915	33 º28'N	36º30'E	503	Min: -3.6 Max:43	Eutric Cambisols

[1] Weather data were obtained from weather stations of the Lebanese agricultural research institute

[2] Soils were named based on soil map of Lebanon (Darwish et al., 2006)

RESULTS AND DISCUSSION

Summary results for the physic-chemical analysis of soils samples are shown in table 2.

Table 5.Physico-chemical analysis of the selected four soil samples

Soil type*l*	pH	EC	Ca^{++}	Mg^{++}	P2O5	Total CaCO3	Active CaCO3	O.M	Na	K	Texture
		ms/m	ppm	ppm	ppm	%	%	%	ppm	ppm	
Rendzic Leptosols	8.2	98.3	9044a	261.1	70.5	54.5	15.8	2.4	79	450.2	Clay
Hypercalcaric Fluvisol	8.8	94.4	3500	401.7	42.4	71	7.2	1.7	33.5	287.9	Sandy loam
Anthropic Regosols	7.5	63	6972	341.5	37.3	2.75	0.9	0.5	360.5	350.1	Clay
Eutric Cambisols	8.4	99.8	6300	361.5	21.8	17.5	18.4	1.6	213.1	488	Clay
P η^2	.001 .71	.18 .33	<.0001 .96	.73 .10	.0002 .80	<.0001 .99	<.0001 .99	<.0001 .89	<.0001 .92	<.0001 .9	

The soils were named based on the soil map of Lebanon 1:50000 (Darwish et al., 2006). Sampled soils of Sour region were sandy loam whereas the other three soils have a clay texture. The highest organic matter content was measured in soils of Lebaa region (Rendzic leptosols)(Darwish et al., 2006). Significant differences between tested soils were observed in regard to main soil parameters except for electrical conductivity and magnesium content. Further analysis was explored to examine the effect of soil attributes on saffron yield.

The combined analysis over four years of the study revealed that the soil samples affected all studied saffron yield component. The Length of stigma, number of flowers per pot(F/P), number of flower per corm cluster(F/CC), stigmas fresh(SFW) and dry(SDW) weights were significantly affected by soil type and year respectively (Table 3). The greatest values of these parameters were recorded from Rendzic leptosols soil samples. Soil type and year interaction with a marginal significance was observed only for number on flowers per pot. Fresh weight of single stigma was affected by soil type and did not differ significantly from year to year.

Table 6. Means and (SD) of the main yield parameters as affected by soil type over four years (2014-2015-2016-2017) of the study.

Soil type/Location	Stigma length,cm	#Flower	# of flower/mother corm	Stigma fresh weight,g	Stigma dry weight,g	Fresh weight of stigma	Dry weight of stigma,g
Rendzic Leptosols(Lebaa)	3.4[a] (0.3)	64.5[a] (34.2)	11.2[a] (5.9)	1.507[a] (0.84)	0.277[a] (0.155)	0.024[a] (0.005)	0.0041[a] (0.0006)
Hypercalcaric Fluvisol (Sour)	3.1a[b] (0.5)	43[ab] (36.6)	8.0[ab] (5.9)	0.911[b] (0.93)	0.167[b] (0.178)	0.022[ab] (0.005)	0.0040[a] (0.0011)
Eutric Cambisols (Tel-Amara)	3.1[b] (0.3)	30.4[b] (14.9)	5.4[b] 92.6)	0.585[b] (0.27)	0.112[b] 90.055)	0.020[bc] (0.003)	0.0036[ab] (0.0011)
Anthropic Regosols(Nabatieh)	2.9[b] (0.5)	31.2[b] (23.8)	6.7[b] (6.0)	0.565[b] (0.42)	0.107[b] 90.090	0.018[c] (0.004)	0.0032[b] (0.0008)
Year	.0004	<.0001	<.0001	.003	<.0001	.479	.011
Soil type	.04	<.0001	.0004	<.0001	<.0001	.002	.014
Year*soil type	.60	.062	.123	.223	.223	.369	.516
η^2	.656	.78	.78	.72	.74	.52	.53
CV	11.0	45.9	44.8	59.9	58.3	20.8	24.3

On the fourth year, the stigmas dry weight obtained from rendzic leptosol soils was twice greater than that obtained from hypercalcaric fluvisol and three times from Anthropic regosols and Eutric combisols. These changes in the main yield components may be attributed to some soil properties in particular organic matter. This was supported by the relatively high significant positive correlation between organic matter and number of flowers per corm cluster(r=0.60, p=.0016) .Moreover, the number of flowers/CC was also positively correlated with phosphor and calcium content respectively(r=.46,p=.075; r=.52,p=.042). A regression analysis was used to evaluate the performance of soil types on the number of flowers per corm cluster(CC) through four years of the study.In this regard, a positive significant higher slope was obtained for Rendzic Leptosols(4.23,SE=0.79,t=5.55,R^2=.69 p<.0001)(4.23±2.145*.79=1.69) (Figure 1).

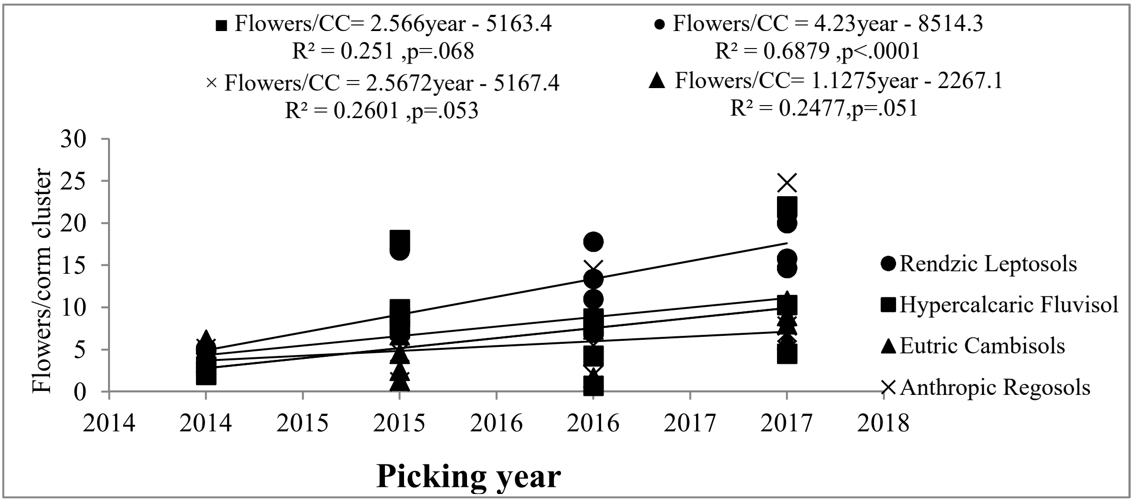

Figure 5.Scatter plot of the flowers/corm cluster as affected by soil type through four years of the study.

Hypercalcaric fluvisol with a sandy loam texture presented an intermediate performance showing no significance with other three tested soils for most yield parameters. This was agreed with the results obtained by Turhan H., et al., (2007) which stated that sandy soils had a positive effect on saffron yield. But their findings were contrary to our results which indicated that Rendzic soils with a clayey texture showed a better results.

The quality of dried stigmas related to the color (Crocin),bitterness(Picrocrocin) and aroma (Safranal) was also affected by soil type. The better results were obtained from hypercalcaric fluvisol soil samples. These sandy loam soils with moderate organic matter content (1.7%) have a high content of total calcium bicarbonate (71%) and the lower calcium concentration (3500 ppm) compared to the other tested soil samples. Crocin and picrocrocin were positively correlated with total calcium bicarbonate respectively *(r=.55, p=.035;r=.6, p=.018)*. Negative correlation between soil sodium and calcium content and saffron quality (crocin and picrocrocin) was distinct respectively *(picrocrocin:r=.52 ,p=.045; crocin:r=.51,p=.05) , (picrocrocin:r=.45 ,p=.077; crocin:r=.68,p=.034)*.Yarani ,(2016) reported a negative correlation between saffron quality and leaf calcium and sodium content.

Table 7. Analysis of variance for the effect of soil type on saffron quality attributes

Soil type	Picrocrocin	Saftanal	Crocin
Rendzic Leptosols	73.6(4.3ab	24.7(1.2)b	128.5(8.9)b
Hypercalcaric Fluvisol	84.6(15.9)a	37.1(3.1)a	187.3(26.5)a
Eutric Cambisols	70.8(12.4)b	27.7(3.5)b	145.1(12.7)ab
Anthropic Regosols	66.9(4.4)b	25.9(8.1)b	127.1(20.7)b
P	.0189	.001	.007
η^2	.65	.82	.72
cv	10.9	8.7	8.7

Corms were pulled and categorized into three classes. First class contained corms less than 2g, the second class ranged from 3 to 4g and the third class was more than 4 g. No significance differences between soil types were observed among the first and third classes. A significant total number of corms was recorded from Rendzic soil samples. These soils were rich in organic matter (2.4%) as compared with other tested soil samples. A significant positive correlation between corm yield and organic matter content was recorded (r=.68,p=.005).This was agreed with the results obtained by Turhan *et al.,* (2007).

Table 8. Analysis of variance of the effect of soil type on the total corm number and corm classes.

Soil type	Total corms	Corm classes		
		≤2	**3-3.9**	**≥4**
Lebaa	320a	.72	.13a	.15
Sour	181b	.79	.05b	.16
Nabatieh	193b	.72	.15a	.14
Tel amara	189b	.80	.10ab	.10
p	.025	.469	.0425	.679
η^2	.52	.18	.48	.11

At the last year of the study plant height ranged from 31.2 to 48.8 cm and was highly correlated with leaf biomass (r=.87, p<.0001). The highest values were observed in Randzic soils for both plant length (Mean =48.8±4.3 df (3,12),F=15.1,p=.0002, η^2=.79) and biomass (Mean =14.3±3.6 df(3,12),F=5.42, p=.0156, η^2= .6) respectively. Since the study was carried out in homogeneous condition (climate condition) but different soil samples, the observed differences in saffron yield parameters are most likely associated with soil characteristics. Outside the scope of this study, other conditions such as geographical location, temperature and rain may have an impact on the quality of saffron.

CONCLUSION

Results of the study showed that the most of saffron yield attributes were affected by some soil parameters. Soil samples of Lebaa region (Rendzic leptosols) demonstrated the best results regarding quantitative yield characteristics. This superiority was consistent from year to year. This differentiation in soil performance was supported by the positive significant correlation between main quantitative yield parameters and some of the soil components such organic matter and calcium content. The quality of saffron yield in regard to the coloring, taste and aroma was affected positively by calcium bicarbonate. Soils with relatively high sodium content resulted in low saffron quality. The soils with limiting factors can be managed to improve their performance under saffron crop.

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