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Effect of Soil Physicochemical Properties on Gum Production in *Astragalus gossypinus* in Tiran Rangelands, Iran

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Abstract: Astragalus legume species have many important applications including production of natural tragacanth gum which is controlled by several climate factors, soil conditions and characteristics. Therefore, identification of major factors for maximizing this invaluable end-product is important for economy goals and plant health. In the present study, the relationship between soil physicochemical properties and gum production in *Astragalus gossypinus* Fisher was investigated. Seven-year-old plants were selected and then the gum and soil samples were taken along transects in a small area having the same specified climate. The soil physicochemical properties such as organic matter (OM) and saturation percentage (SP) showed the highest positive effect on gum production ($P<0.01$), while the amounts of calcium carbonate ($CaCO_3$) and calcium sulfate ($CaSO_4$) had the negative effect on gum production ($P<0.01$).The results showed that habitat soil factors should also be considered to determine the potential of plants for the production of tragacanth gum and its harvesting.

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1. Introduction

The legume family of plants is widely distributed in arid and semi-arid regions having positive effects, including land fertility, nitrogen fixation and production of many industrial products (Zahran, 2001). The *Astragalus* genus belonging to the legume family that includes about 2,500 species in the world is distributed mainly in the near East, the Middle East and also in Southern Europe (Wahhabi, 2005). Tragacanth gum producing species develop in many temperate regions of the world and even in the central parts of Africa (Lee, 1996). The Asiatic species of *Astragalus*, the source of commercial gum, are native to countries of Minor Asia, namely Iran, Turkey, Iraq, Syria, Lebanon, Afghanistan and some parts of Russia (FAO, 1992).

Tragacanth gum is a secondary metabolite that depletes the plant power in production time (Massumi, 2011). It is the dried exudate produced by tapping the tap root and branches of certain shrubby species of *Astragalus*, particularly those which occur wild in Iran and Turkey (FAO, 1992). Tragacanth gum is a viscous, odorless, tasteless, and water-soluble mixture of polysaccharides and absorbs water. The most important applications of tragacanth gum are now in food industry (Hagiwara et al.,1992; Joory and Mahdavi, 2011) and pharmaceuticals (FAO, 1992; Weiping, 2000; Massumi, 2011; Tang and Eisenbrand, 1992; Song et al., 2000; Ionkova et al., 2010; Li et al., 2013).

Several factors such as harvest time and intervals, habitat characteristics, plant characteristics, rainfall (FAO, 1992; Massumi, 2011) and scratching methods (Massumi, 2011) are effective in the gum production. Different applications caused high price and over harvesting in some case, irrespective of the plant potential production in different climate and habitat soil. Generally, plant products depend on the soil properties and fertility and they are directly affected by soil factors. Therefore, knowing the physicochemical properties of soil could help us to determine the potential of gum production and harvesting in different soils with respect to preserving plant health and its regeneration.Relationships between soil factors and plant products have so far been studied by many researchers (Yibinget al., 2004; Wick et al., 2011; Rahimi et al., 2013; De la Rosa et al., 2013; Yao et al., 2013) in different plants and regions.

However, there is no study about the relationship between soil physicochemical properties and gum production in *Astragalus* spp. Therefore, the aim of this study was to investigate the effect and relationship between physicochemical properties of soil and the amount of gum production in *A. gossypinus* Fisher species in Qasem Abad semi-arid rangelands in the west of Isfahan Province (Iran).

2. Materials and Methods

2.1 Study site

The study area located 70 km west of Isfahan, Iran with annual rainfall of 250 mm and average annual temperature of 14°C. The region has topography with mild slopes of about 12% and covered by shrub forms and perennial grass. Tragacanth gum producing *Astragalus* species, especially *A. gossypinus* are the most vegetation element in the studied area.

2.2 Sampling and data collection

24 seven-year-old *A. gossypinus* plants which had not been already utilized were selected. First, the soil on the north side of the plants was set aside (to prevent the effect of sunlight on gum seeping) and the stem of each plant was scratched with traditional tools (Fig. 1A).The process of tapping involved clearing away the soil surrounding the taproot and making one cut in the upper part of the root. The cuts are usually made longitudinally or cross-angled on the root, 2-5 cm long. In the present study, we made a cross-angled cut on the root of *A. gossypinus* forming the ribbon shape (Fig. 1B). The secreted gum was harvested after four days in the morning as there was very little moisture in the gum. The amount of solid material showed the actual gum production by the plant. Finally, it was weighed using a digital scale.

Soil samples were taken at two different depths (0-20 and 20-75 cm according to soil depth, bedrock and length of plant roots) from 24 profiles (in total 48 soil samples) along with the gum samples. Physical and chemical properties of soil influencing plant products were measured as previously reported (Velichkoet al., 2011; Yao et al., 2013; De la Rosa et al., 2013). Physicochemical properties of soil, including acidity (pH), electrical conductivity (EC), gypsum content ($CaSO_4$), calcium carbonate content ($CaCO_3$), organic matter (OM), organic carbon (OC), nitrogen (N) (Kjeldahl, 1883), phosphorus (P) (Olsen,1954), Potassium (K) (Ammonium acetate method), clay, sand, silt and saturation percentage (SP) were measured.

2.3 Statistical analysis

In order to determinate the relationship between soil physicochemical properties and the amount of gum production, data were analyzed by SPSS software. First The Kolmogorov-Smirnov test (KS-test) was used to identify the data normality and then the method of stepwise was used for regression analysis and modeling.

3. Results

Table 1 shows the average amount of gum production per plant in *A. gossypinus* and the results of soil physicochemical properties in the study area. The amount of gum production in *A. gossypinus* was about 1g/plant, which can be more in older plant species.

Fig. 1. Scratching the plant root (A**) and seepage of Tragacanth gum (**B**)**

Table 1. The results of physicochemical properties of soil and gum production.

Factor	Unit	Topsoil (mean ±SE)	Subsoil (mean±SE)
Gravel	%	33.46±9.017	42.791±3.835
pH	-	7.89±0.111	7.917±0.178
Clay	%	33.07±6.176	35.316±5.985
Silt	%	35.82±4.680	33.900±7.229
Sand	%	31.12±7.222	30.783±4.880
EC	(ds/cm)	0.19±0.095	0.179±0.015
Na	(Meq/L)	10.994±2.063	12.343±2.734
OC	%	1.01±0.037	0.854±0.171
OM	%	1.07±0.049	0.994±0.108
SP	%	34.31±6.396	36.033±5.797
N	(Meq/L)	4.41±0.743	4.281±0.682
P	(Meq/L)	17.33±3.215	15.755±3.652
K	(ppm)	727.38±45.469	632.855±32.814
$CaCO_3$	%	22.03±6.619	26.909±7.222
$CaSO_4$	%	3.62±0.855	4.922±0.524
Gum production	(g/plant)	1.008±0.187	

Physicochemical factors such as gravel, saturation percent, sodium, calcium carbonate and calcium sulfate were higher in the subsoil than the topsoil, which could be important in the growth of plants with long and deep roots such as *Astragalus* plant. Table 1 also shows that the amount of calcium carbonate was considerable in the study site both in topsoil and subsoil (22-27%).

Fig. 2 displays the Pearson correlation indicating the relationship between soil physicochemical properties and gum production, which was significant at 95% confidence level ($P<0.05$). Some factors in the subsoil such as OM and Gravel had positive effect on the gum production, while some other factors such as $CaCO_3$ and $CaSO_4$ at both soil depths had negative correlation ($P<0.01$).

Factors including K, P, sand content and pH in both depths had negative impact on the gum production ($P<0.05$).The OM which is closely related to OC had a similar positive effect on the gum production (Fig. 2).

The summary of the predicted models for the relationship between soil factors and gum production is shown in Table 2. The model no. 6 had the highest significant correlation (R^2=0. 928) and the lowest standard error (0.058) which involved6 factors, including: OM (subsoil), K (subsoil), $CaCO_3$ (topsoil), Gravel (topsoil), clay (subsoil) and the total depth of the soil profile. OM and K had the highest and lowest coefficients, respectively in model no 6.Analysis of variance (ANOVA) of the regression equation and the corresponding coefficients of each model are shown in Table3. The high F-value (36.32) of model no. 6 indicated that this model was highly significant ($P<0.01$).

Based on model no. 6, gum production was affected by several physicochemical factors of soil; OM in the subsoil had the highest coefficient. Furthermore, total soil depth had a positive effect on gum production. It is also noteworthy that $CaSO_4$ had a significant negative effect ($P<0.01$) on gum production (Fig 2), but it did not include in the models in Table 2. Therefore, model no. 6 which included some important physicochemical factors of soil was considered as the best model for determining the relationship between gum production and soil factors.

Table 2 **Summary of the predicted models for the relationship between soil factors and gum production.**

Model	R	R^2	ARS	SEE	Change statistics		Predicted models
					RSCh	FCh	
1	0.743	0.551	0.531	0.12856	0.551	27.046	$Y=0.743X_1+0.683$
2	0.827	0.683	0.653	0.11053	0.132	8.761	$Y=0.662X_1+0.372X_2+1.222$
3	0.890	0.792	0.761	0.09176	0.109	10.470	$Y=0.563X_1+0.408X_2-0.344X_3+1.501$
4	0.924	0.854	0.824	0.07882	0.062	8.105	$Y=0.585X_1+0.519X_2-0.370X_3+0.277X_4+1.463$
5	0.952	0.906	0.880	0.06504	0.052	9.906	$Y=0.281X_1+0.001X_2-0.006X_3+0.007X_4+0.006X_5+1.087$
6	0.963	0.928	0.902	0.05874	0.022	5.070	$Y=0.273X_1+0.001X_2-0.004X_3+0.009X_4+0.006X_5+0.006X_6+0.912$

ARS: Adjusted R Square, SEE: Std. Error of the Estimate, RSCh: R Square Change, FCh: F Change, X_1: Subsoil Organic Matter percentage (OM_2), X_2: Subsoil potassium content (K_2), X_3: Topsoil calcium carbonate ($CaCO3_1$), X_4: Topsoil Gravel percentage ($Gravel_1$), X_5: Total soil profile depth (Depth), X_6: Subsoil Clay percentage ($Clay_2$).

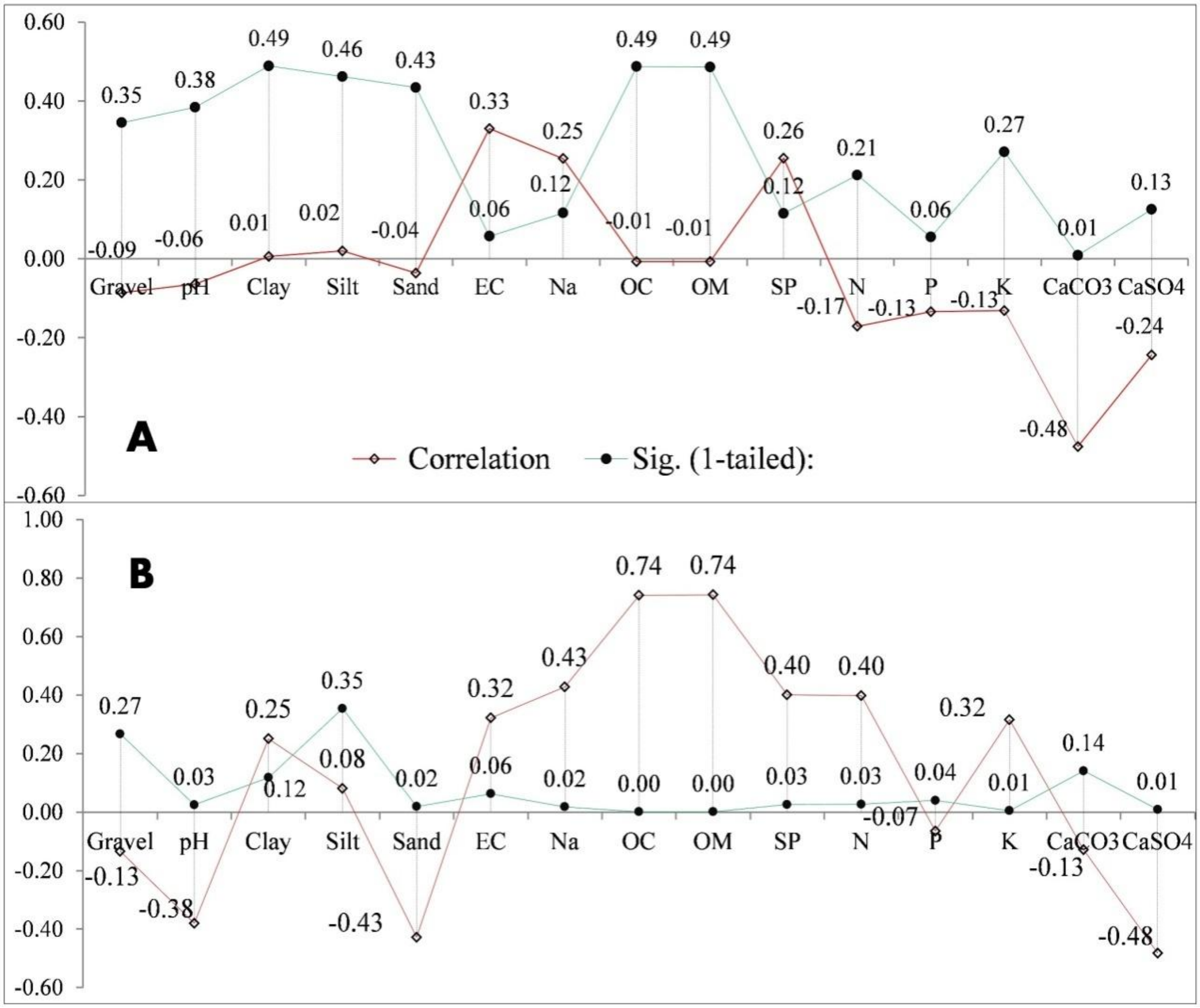

Fig 2. Pearson correlation between gum production and physicochemical properties of topsoil (A) & subsoil (B).

4. Discussion

Tragacanth gum is influenced by several factors like many other plant products. The self-assembly of tragacanth gum is also related to minerals which could be effective on the flow and extraction of gum from the plant root (Hasandokht-Firoozet al., 2012). The physicochemical properties of soil play an important role in the growth and production of plant products. In the present study, the production of tragacanth gum was correlated with some soil physicochemical factors. Among those, OM, $CaCO_3$, $CaSO_4$, K, clay, gravel and total soil depth had the highest correlation with the amount of gum production ($P<0.05$). It is reported that sodium(Na) could affect gum production and/or its properties and some its derivatives such as sodium selenium are available in *Astragalus* gum (Ye et al., 2012), but there was no evidence between Na and gum production in the present study. Physical properties of soil, including the depth of soil profile (Fahimi-Poor et al., 2010),the percentages of gravel, clay and silt (Qian and Schoenaru, 1994; Yibing et al., 2004; Heidari et al., 2011) can affect the growth and distribution of plants root (Pearson et al., 1995).

Soil depth affects the growth of plant roots, nutrient absorption and finally on the plant products. The well-drained deep soils with desirable texture and structure are suitable for the production of plants. Deep soils can hold more plant nutrients and water than the shallow soils. Warm season species that require water later in the season are more dependent upon soil water at depth (Sala and Lauenroth, 1982; Singh et al., 1998). Depth of soil and its nutrients and water capacity determine the yield from plants that grow with little water such as many desert plants. Also the soil texture plays an important role in plant growth and their products. Available water is held in soil pores by forces that depend on the size of the pore and the surface tension of water.

Table Analysis of variance (ANOVA) of regression equation and survey of the significant coefficient.

ANOVA							Coefficients					
	MS.OV	SS	df	MS	F	Sig.	Factor (s)	SC		t	Sig.	CS
								B	SE			VIF$^{\alpha}$
1	Regression	0.447	1	0.447	27.04	0.001**	(Constant)	0.683	0.068	10.100	0.001**	
	Residual	0.364	22	0.017			OM_2	0.743	0.090	5.201	0.001**	1.000
	Total	0.811	23									
2	Regression	0.554	2	0.277	22.67	0.001**	(Constant)	1.222	0.191	6.395	0.001**	
	Residual	0.257	21	0.012			OM_2	0.662	0.079	5.263	0.001**	1.049
	Total	0.811	23				K_2	0.372	0.001	2.960	0.007**	1.049
3	Regression	0.642	3	0.214	25.42	0.001**	(Constant)	1.501	0.181	8.314	0.001**	
	Residual	0.168	20	0.008			OM_2	0.563	0.068	5.175	0.001**	1.139
	Total	0.811	23				K_2	0.408	0.001	3.888	0.001**	1.061
							$CaCO_3^{\alpha}$	-0.344	0.003	-3.236	0.004**	1.088
4	Regression	0.693	4	0.173	27.86	0.001**	(Constant)	1.463	0.156	9.397	0.001**	
	Residual	0.118	19	0.006			OM_2	0.585	0.059	6.238	0.001**	1.147
	Total	0.811	23				K_2	0.519	0.001	5.284	0.001**	1.259
							$CaCO_3^{\alpha}$	-0.370	0.002	-4.032	0.001**	1.099
							Gravel$^{\alpha}$	0.277	0.002	2.847	0.010**	1.235
5	Regression	0.734	5	0.147	34.72	0.001**	(Constant)	1.087	0.175	6.206	0.001**	
	Residual	0.076	18	0.004			OM_2	0.281	0.056	5.039	0.001**	1.512
	Total	0.811	23				K_2	0.001	0.001	6.045	0.001**	1.273
							$CaCO_3^{\alpha}$	-0.006	0.002	-2.813	0.012**	1.417
							Gravel$^{\alpha}$	0.007	0.002	4.247	0.001**	1.362
							Depth	0.006	0.002	3.147	0.006**	2.185
6	Regression	0.752	6	0.125	36.32	0.001**	(Constant)	0.912	0.176	5.169	0.001**	
	Residual	0.059	17	0.003			OM_2	0.273	0.051	5.388	0.001**	1.521
	Total	0.811	23				K2	0.001	0.001	7.018	0.001**	1.551
							$CaCO_3^{\alpha}$	-0.004	0.002	-2.067	0.054^{ns}	1.638
							Gravel$^{\alpha}$	0.009	0.003	5.210	0.001**	1.620
							Depth$^{\beta}$	0.006	0.002	3.196	0.005**	2.216
							$Clay_2$	0.006	0.003	2.252	0.038*	1.791

MS.OV: Model and Sources of variation, SS: Sum of Squares, MS: Mean-Squares, df: Degrees of freedom, SC: Standardized Coefficients, SE: Std. Error, CS: Co-linearity Statistics, **: Significant at 1% confidence, *: Significant at 5% confidence, ns: not Significant, α: VIF more than 10 indicate that factors had self-correlation, β:Depth= total soil depths (topsoil plus subsoil).

Wick et al. (2011) reported that plant productivity was highly dependent on the soil depth. The closer together soil particles or aggregates are, the smaller the pores and the stronger the force holding water in the soil. Because the water in large pores is held with little force and drains out most readily.

In the present study, clay and gravel percentages had a significant correlation with gum production. These factors play an important role in water availability in arid and semi-arid lands, especially for some plants such as gum producing *Astragalus* species. OM has a very high cation exchange capacity, so nutrients retained in plant-available material also helps to develop good soil-air-water relationships. Yibing et al., (2004), Rahimi et al., (2013), De la Rosa et al., (2013) and Yao et al., (2013) also reported that OM had the highest correlation with plant products in the study area. However, Qomshy et al.,(2008) reported that nitrogen content (which is related to OM)was very low in tragacanth gum compared with other compounds.

Calcium plays a very important role in plant growth and nutrition (Tahir et al., 2010) as well as cell wall deposition. Many soils contain high levels of insoluble calcium such as $CaCO_3$, but crops grown in these soils often show a calcium deficiency, which would fail the uptake mechanisms in plants (Epstein, 1961). However, in this research $CaCO_3$ had a significant negative correlation (p<0.01) with gum production. The results also show that $CaSO_4$ had a negative correlation with gum production. Calcium, supplied in the form of $CaSO_4$, is essential to the biochemical mechanisms by which most nutrients are absorbed by plant roots. Messenger et al. (2000) reported that $CaSO_4$ strengthen the plant roots, which could prevent the gum formation and storage in the roots.

The amount of potassium (ppm) had a positive effect on the gum production. K is an essential nutrient for plant growth and increase plant resistance against drought stress. Because large amounts of K are absorbed from the root zone in the production of most agronomic crops and it is required for numerous plant growth processes.

4. Conclusion

The results of this study showed that tragacanth gum production is dependent on both soil physical and chemical factors. OM had the highest positive effect and some other factor such as $CaSO_4$ had a negative correlation on the tragacanth gum production. The results indicated that model no. 6 with six factors, including OM, K, $CaSO_4$, gravel, depth and clay had a most correlation with the amount of gum seepage. Also, the predicted model showed that a factor, depending on the status in soil depth, could affect the gum production.

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