Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 2, p. 456-463, 2014
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Investigation on density, cover and production changes and the effect of soil texture on these factors in sagebrush steppe rangelands of Esfahan province

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Article published on August 24, 2014

Key words: density, cover, production, soil texture, Isfahan.

Abstract

In order to study the vegetation changes of Esfahan sagebrush rangelands and the role of environmental factors on these changes, four sites located in the steppe region were selected. Alavijeh and Charmshahr had a light soil texture, while the soil texture of Dorr and Baghsorkh was heavy. The quantities of density, canopy cover and plant production on these sites were measured over eight years. According to the results, the correlation between rainfall and production for Alavije, Charmshahr, Baghsorkh and Dorr was calculated to be 67, 51, 40, and 48%, respectively. On the other hand, the average production of each sagebrush in the sites was 8.1, 10.7, 3.4, and 4.8 g , respectively. This difference is due to the differences in soil texture of the study sites as well as differences of water storage and loss. Also, the higher water-holding capacity of heavy textured soils caused reduced variability in density, cover and the production of range species compared to light textured soils during the years of the project. Variation coefficients of the density were calculated to be 36.4, 40.4, 22.8, and 8.7%, for Alavije, Charmshahr, Baghsorkh and Dorr, respectively. Variation coefficients of the cover were calculated to be 37.4, 47.6, 24.6 and 12% for Alavije, Charmshahr, Baghsorkh and Dorr, respectively. Finally, variation coefficients of the production were calculated to be 26.3, 45.9, 24.3, and 17.5% for Alavije, Charmshahr, Baghsorkh and Dorr, respectively.

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Introduction

From over ninety-one million hectares of rangelands in Iran, the habitats of *Artemisia sieberi* consist more than 35000000 hectares i.e. 38.5% of the country. This habitat is the most widespread plant community in the province with an area of 3092774 ha, covering about 53% of the rangelands of Isfahan (Feizi *et al.*, 2013). This plant species does play a significant role in providing forage requirements of livestock in arid regions of the country; therefore, understanding the behavior of this species against environmental factors can help range managers of the country for planning, conservation and proper utilization of these rangelands. Rangeland ecosystems always undergo changes in terms of vegetation composition, vegetation cover and production. These changes primarily occur under the influence of environmental and management factors.

Soil is one of the most important factors, affecting the response of species to climatic factors including precipitation. It is confirmed by the studies performed by various researchers. Soil texture is the main factor in controlling the distribution, abundance and production of plant species through affecting the available water (Sperry *et al.,* 1998; Fravolini *et al.,* 2003; Jafari, 2006; Noymeir, 1973). Robertson *et al.,* (1966) studied vegetation and soil in two adjacent regions in Colorado and found that *Artemisia longiloba* with shallow roots in hard pan clay had an annual production of 510 pounds per acre and a canopy cover of 20%. Root growth in this soil encounters some difficulties due to swelling of clay particles and insufficient moisture in soil pores. Shown *et al.,* (1969) in a study on Artemisia communities of a western state of the United States with annual rainfall of 200 to 350 mm found that grass establishment and production were more in light-textured soils. Mutz and Scifres (1975) showed that the number of regeneration in light-textured soils was more than that of heavy-textured soils but the size of each individual in heavy-textured soils was more than that of light-textured soils; they pointed out to the greater ability of clay soils to maintain water as a reason. Hart and Samuel (1985) assessed the relationship between seasonal rainfall and grass production in Wyoming State of US with mixed grass cover. Results showed that there was a good correlation between production and precipitation close to the growing season in sandy soils. In loamy soils, precipitation of growing season had less importance and prediction of production from precipitation was more complicated. They concluded that the main variations of vegetation production were resulted from difference in water-holding capacity due to the soil texture and the depth of soil horizons. LeHoureou (1984) showed that olive production in sandy soils in arid region of Tunisia with rainfall less than 300 mm was more than that of silty soils while an inverse trend was observed in regions with more than 300 mm rainfall. Sala *et al.,* (1988) investigated the effect of precipitation on production in relation to soil at 9498 sites across central grasslands of the United State. Results of this study showed that in areas with rainfall less than 370 mm, sandy soils had more production than loamy soils. Perez and Frangi (2000 concluded that total biomass dry matter and litter were the most in the light loamy sandy soils in Airaventana region in Argentina. On the other hand, the ratio of below ground biomass to above ground biomass was the lowest in loamy clay soils. Dodd *et al.,* (2002), while studying on short steppe grasslands in Colorado State found significant relationship between vegetation variables and soil texture. Fravolini (2003), characteristics concluded that *Prosopis velutinna* had deeper roots in light-textured soils than heavy ones. Also, soil texture had a major role on plant growth and production. Eshraghi *et al.,* (2003), while studying on Haloxylon communities of Natanz and Badrud, concluded that Haloxylon had more regeneration and freshness in light-textured soils but density was more in heavy-textured soils. English *et al.,* (2005) investigated the effect of soil texture and vegetation on soil moisture in semi-arid grasslands in southern Arizona. They concluded that in sandy soils, plant access to water was more in the lower soil layers whereas in clay soils it was higher in soil surface.

In this paper we intend to study the trend of changes in density, cover, production, and the relation among them and rainfall . Then the effect of soil texture on the mentioned factors in sagebrush steppe rangelands of Esfahan province is investigated for 8 years.

Materials and methods

Study area and data sampling

This study was conducted in four regions of Artemisia communities of Isfahan province(table1). One site was established in each region and data sampling was carried out within them. In each site, density, canopy cover percentage and production of *Artemisia sieberi* were measured along four transects of 400 m within 60 plots of two m^2. Density was measured through the counting of the shrubs and canopy cover was determined based on the estimation of canopy cover percentage. For measuring the plant production, species were harvested randomly in 25% of the plots by the method of cutting and weighing. Data collection was performed in three sites during 8 years from 1997 to 2005 and in one site during 6 years until 2001. Also, soil characteristics in each site were determined based on the description and experiment of the samples obtained from present horizons of excavated soil profiles.

Table 1. The studied sites characteristics.

Site name	Species type	Level from sea (m)	Latitude and longitude
Alavijeh	Artemisia sieberi-Anabasis aphylla	1600	"30' 09 51° "22 ' 02 33°
Charmshahr	*Artemisia sieberi*	1495	" 04' 32 51° "12' 00 33°
Dorr	*Artemisia sieberi*	1995	" 14' 43 50° " 30' 33° 14
Baghsorkh	*Artemisia sieberi*	1870	" 34' 02 52° " 51' 31° 56

To classify the sites based on soil texture, the sum of clay and silt of A and B horizons, having the highest density of plant root, was used (Subrahmanyam, 2000). The evaluation of grazing intensity was conducted as visual and in respect to the exploitation level of species during grazing season. After data collection was completed, they were entered into a computer for analysis.

Statistic analysis

Firstly, normality test of cover, density and production data was conducted in SAS software and the obtained curves indicated that most data followed a normal distribution. In order to calculate the production of each species, the data of cut and weighed plots were used. The same was done for the ratio of production to cover. Duncan's multiple range test was used for mean comparisons. Experimental design was a randomized complete block design. Correlation test, regression analysis and estimation of production equations were conducted in SAS software. Then, based on the significance of equation ($p>0.05$) and determination coefficient (R^2) the best equation was fitted.

Results

Average precipitation during project execution, soil texture and grazing intensity of the study sites are presented in table 2. As can be seen, all sites had relatively similar average rainfall except for the Dorr site. In terms of soil texture, Alavijeh and Charmshahr sites were classified in same group and Dorr and Baghsorkh were classified in another group. Both Alavijeh and Dorr and Charmshahr and

Baghsorkh were also classified in the same groups in terms of grazing intensity. On the basis of conducted measurements, the information obtained from each site was evaluated separately as follows.

Table 2. Climate, soil and grazing intensity of the study sites during project execution.

Site name	Eighteen years average precipitation	Silt and Clay percent average in both of A and B horizons	Soil texture	Grazing intensity
Alavijeh	132	35	light	Moderate
Charmshahr	113	35.5	light	light
Dorr	264	75	Heavy	Moderate
Baghsorkh	136	65	Heavy	light

Relationship between precipitation, density and cover

The average of density, canopy cover percentage and production of Artemisia during the years of data collection as well as rainfall, is presented in table 3 to 6. In Alavijeh and Charmshahr the correlation between precipitation and cover were 34% and 43%, which was significant at 5 percent level of probability. In Dorr this correlation was 45% that was significant at 1%. And in Baghsorkh it was 31% that was not significant. Also, correlation between precipitation and production in Alavijeh, Charmshahr and Baghsorkh were 67%, 51% and 48% which was significant in level of 1% and in Dorr it was 40% which was significant at 5 %(table7-10).

Table 3. Density, canopy cover percentage, production of Artemisia sieberi and average annual precipitation of Alavijeh during 1998 to 2005.

Year	Density Mean (in hectare)	Cover mean (%)	Yield mean (Kg/ha)	Precipitation mean(mm)
1998	5700	1.8	101.1	193
1999	9100	2.5	63.2	119
2000	6000	1.5	19	46
2001	6900	2.8	21.3	124
2002	4300	1.8	82.9	112
2003	4400	1.9	75.9	111
2004	5400	3.1	147.8	178
2005	5000	3	123.7	172
Average	5800	2.29	79.4	132

Table 4. Density, canopy cover percentage and yield of *Artemisia sieberi*, and also average annual precipitation of Charmshahr during 1998 to 2003.

Year	Density mean (in hectare)	Cover mean (%)	Yield mean (Kg/h)	Precipitation mean(mm)
1998	4800	2.09	116.9	144
1999	5100	1.93	103.4	89
2000	4400	1.28	63.6	36
2001	3600	2.24	101.1	117
2002	5300	2.38	153.2	151
2003	4700	3.23	160.6	142
Average	4700	2.19	116.5	113.2

Table 5. Density, canopy cover percentage and production of *Artemisia sieberi*, and average annual precipitation of Dorr during 1998 to 2005

Year	Density Mean (in hectare)	Cover mean (%)	Yield mean (Kg/ha)	Precipitation mean(mm)
1998	54600	13.96	534	291
1999	58400	9.22	500	165
2000	53400	9.89	138.5	133
2001	46900	15.2	398.1	233
2002	50300	11.95	220.2	401
2003	48200	14.32	500	302
2004	39500	15.29	325.8	293
2005	39200	16.12	261.4	294
average	48800	13.24	311.8	264

Table 6. Density, canopy cover percent age and yield of *Artemisia sieberi*, and also average annual precipitation of Baghsorkh during 1998 to 2005.

Year	Density Mean (in hectare)	Cover mean (%)	Yield mean (Kg/ha)	Precipitation mean(mm)
1998	25900	8.56	210.3	192
1999	24400	5.30	211.4	130
2000	23100	6.47	191.7	75
2001	24100	7.37	166.3	95
2002	22400	9.79	226.7	185
2003	15300	6.43	164.5	112
2004	21100	7.52	221.2	214
2005	20000	7.95	129.2	85
average	22000	7.42	190.1	136

Table 7. Correlation coefficient among density, cover and production in Alavijeh site.

Quantity	Density	Cover	Yield	Rainfall
Density	1.00			
Cover	0.53	1.00		
Yield	0.11	0.61	1.00	
Rainfall	0.08	0.34	0.67	1.00

Coefficients more than or equal 53% and 34% are significant at 1 and 5%, respectively.

Table 8. Correlation coefficients among the traits of density, cover, and yield in Charmshahr site.

Quantity	Density	Cover	Yield	Rainfall
Density	1.00			
Cover	0.41	1.00		
Yield	0.32	0.74	1.00	
Rainfall	0.090	0.43	0.51	1.00

Coefficients more than or equal 41% and 51% are significant at 5 and 1% level of probability, respectively.

Table 9. Correlation coefficients among traits of density, cover, and yield in Dorr site

Quantity	Density	Cover	Yield	Rainfall
Density	1.00			
Cover	0.57	1.00		
Yield	0.14	0.68	1.00	
Rainfall	0.36	0.45	0.40	1.00

Coefficients more than or equal 36% and 45% are significant at 5 and 1% level of probability, respectively.

Table 10. Correlation coefficients among the traits of density, cover, and yield in Baghsorkh site.

Quantity	Density	Cover	Yield	Rainfall
Density	1.00			
Cover	0.49	1.00		
Yield	0.63	0.65	1.00	
Rainfall	0.12	0.31	0.48	1.00

Coefficients more than or equal 48% are significant in 1% level of probability.

Mean comparisons

Table 11 shows the variance analysis of density, cover and production and also the ratio between these parameters in the study sites. Results indicated that density, cover, production, ratio of production to number of Artemisia, and ratio of production to cover of Artemisia were significant among different sites and years at 1% level of probability. Also, mean comparisons of parameters are presented in table12.

Table 11. Summary of variance analysis of density, cover percentage, production, ratio of production to number and ratio of production to cover in study sites during 1998 to 2005.

Source of variation	Mean of squares(year)	Mean of squares(site)
Density	$^{**}1.19$	$^{**}130.02$
Cover percent	$^{**}17.31$	$^{**}794.71$
Production	$^{**}367.58$	$^{**}3219.56$
Production /number ratio	$^{**}54.63$	$^{**}331.20$
Production /cover ratio	$7.55^{n.s}$	$^{**}89.33$

**significant in 1% level of probability.

n.s: not significant.

Table 12. Mean comparison of study sites based on density, cover, production, ratio of production to number and ratio of production to cover of Artemisia.

Site	Density	Cover	Production	Production /number ratio	Production /Cover ratio
Alavijeh	0.58[c]	2.29[c]	79.4[c]	8.09[b]	4.33[b]
	0.04±	0.17±	0.92±	0.86±	0.46±
Dorr	4.88[a]	13.24[a]	311.8[a]	3.45[c]	2.27[c]
	0.13±	0.50±	2.76±	0.28±	0.14±
Charmshar	0.47[c]	2.19[c]	116.5[c]	10.71[a]	6.31[a]
	0.04±	0.22±	1.19±	1.01±	0.64±
Baghsorkh	2.20[b]	7.42[b]	190.2[b]	4.81[c]	2.79[c]
	0.09±	0.37±	0.92±	0.23±	0.11±

As can be seen, the mean comparison of density, cover and production of Artemisia in study sites, at 5 percent level of probability, indicates the lack of significant difference between Alavijeh and Charmshahr sites. While, there was a significant difference between these sites and other two sites. Also, there was a significant difference between Dorr and Alavijeh sites. Results of the ratios of production to number and cover of *Artemisia sieberi* showed that there was no significant difference between Dorr and Bagh Sorkh sites. While, a significant difference was found between Alavijeh and Charmshahr, and also with two other sites.

Coefficient of variations of density, cover and production

The coefficient of variations of density was calculated to be 40.4 and 36.4 in Charmshahr and Alavijeh sites, respectively while it was 22.8 and 8.7 percent in Baghsorkh and Dorr sites, respectively. The coefficient of variations of cover was obtained to be 37.4, 47.6, 24.6, and 12 percent in the study sites Alavijeh, Charmshahr, Bagh Sorkh, and Dorr, respectively. Finally, the coefficient of variations of production was obtained to be 26.3, 45.9, 24.3, and 17.5 percent in Alavijeh, Charmshahr, Bagh Sorkh, and Dorr, respectively.

Discussion and Conclusion

As Table 2 shows, four study sites were categorized in two classes of light and heavy soil textures. This classification was based on sum of clay and silt percentage in B and A horizons. It was about 35 and 35.5 percent in Alavijeh and Charmshahr sites, respectively, classified in light-textured soils. This level was 75 and 65 in two sites of Baghsorkh and Dorr, classified in heavy-textured soils. To investigate the effects of soil texture on the Ar.si production variation during 8 years data collection, there was an acute need for a suitable index by minimum variability. Hence, the average production of each bush was selected. This ratio was accurate since it was a measurable parameter and estimation had a minimal role in it. Also, it shows the productivity potential of an area better than other parameters. As can be seen, the average production of Ar.si in light-textured soils was much more than that of heavy-textured soils. The average production of each bush of Ar.si was calculated to be 8.1 and 10.7 g in Alavijeh and Charmshahr sites, respectively wich the soil texture were light. This amount was 3.4 and 4.8 g in two sites of Dorr and Baghsorkh, respectively wich the texture of soil were heavy. This behavioure may be due to less water loss as surface evaporation and run off in sandy soils because of more and fast infiltration to the lower layers of the soil (Buckman and Brady, 1960; Le Houerou ,1984; Sala *et al.,* 1988; Perez and Frangi, 2000; Eshraghi *et al.,* 2003).

Clay particles of the heavy-textured soils with a strong ionic bonds with water molecules, provide conditions that the release of these molecules and their

absorption by plant encounter a problem. These conditions are not significant in sandy soils (Foth and Turk, 1980).

The pores of heavy-textured soils are smaller and its discharge is much difficult compared to clay soils. Fig. 1 shows soil water release curve in clay and sandy soils. As it is seen, water release in sandy texture is by far higher than clay texture (Foth and Turk, 1980).

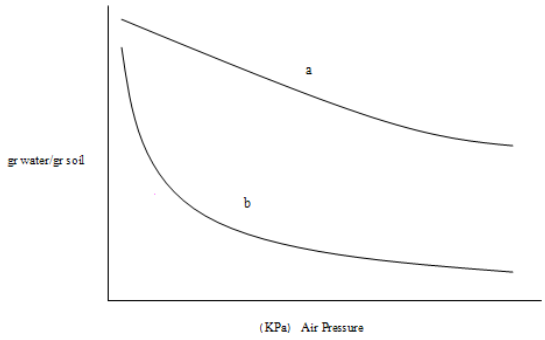

Fig. 1. Water release curves in heavy (a) and light (b) textured soils (Foth and Turk, 1980).

Also as it can be inferred from the results, the response of study sites to the soil texture variations is not the same and it does not follow a linear trend. It seems that in the sites under light grazing, there is a clear variation between light and heavy-textured soils as it expected; whereas there are smaller difference in the sites under moderate grazing. This behavior is obvious especially in Alavijeh site. In this site, the obtained results of average production or coefficient of variation of parameters slightly differed with what expected.

On the other hand, high water holding capacity of heavy-textured soils has led to reduction in variability of density, cover and production of range species during the project execution. For this purpose, the coefficient of variations was used during different years. Results showed that fluctuations of density, cover and production in heavy-textured soils were less than that of light-textured soils. In the two sites with light-textured soils, the coefficient of variation of density, cover and production was more than that of the two sites with heavy-textured soils.

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