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Phenological Effects on Forage Quality of *Salsola arbuscula*, *Salsola orientalis* and *Salsola tomentosa* in Three Habitats in the Central Part of Iran

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Abstract: Information on forage quality of plant species adapted to drylands in each phonological stage is essential not only in determining grazing capacity and reaching the best exploitation of range forage but also in recognising probable deficiencies in the nutrition of livestock grazing there. Thus, some forage quality traits such as dry matter digestibility (DMD), water-soluble carbohydrate (WSC), crude protein (CP), crude fiber (CF), metabolizable energy (ME), acid detergent fiber (ADF) and neutral detergent fiber (NDF) were investigated in three phonological stages (vegetative, flowering and seed ripening) in three species of *Salsola arbuscula*, *Salsola orientalis* and *Salsola tomentosa* using near infrared spectroscopy. These species were harvested from three rangelands in the central part of Iran: Esfahan, Markazi and Semnan provinces. Collected data were analyzed using a factorial experiment for locations, phenological stages and interaction effects between locations and phenological stage with three replicates in each location. Results showed that in *Salsola arbuscula*, phonological stage of growth had a significant effect ($P<0.01$) on all forage quality traits except CP but there was no significant effect of location on traits. In *Salsola tomentosa*, phonological stage of growth had no significant effect on all traits except CF but significant effect of location on all traits was obtained. In *Salsola orientalis*, phonological stage had a significant effect ($P<0.01$) on CP, ADF and NDF and also location had a significant effect on all traits. Results also showed that there was a relationship between forage traits. Species and stages with more ME, DMD and CP which specify the nutritive value of plant had less ADF, CF and NDF. Among species, *Salsola arbuscula* had less forage quality in comparison with two other species and the first stage of growth, vegetative stage, had higher quality and was the best time for grazing and reaching more desirable livestock response.

Key words: Phenological stage · *Salsola arbuscula* · *Salsola orientalis* · *Salsola tomentosa* · Forage quality

INTRODUCTION

Dryland salinity is one of the most serious and significant environmental problems facing arid and semi-arid environments on a global scale [1]. About one-third of the world's land area is drought affected [2] with potential evapotranspiration rates exceeding precipitation. Information on forage quality of plant species adapted to such environments, their chemical composition and factors affecting on them such as climate and maturity stage are essential not only in determining grazing capacity and reaching the best exploitation of range forage but also in recognising probable deficiencies in the nutrition of livestock grazing there.

Forage quality can be defined as the extent to which a forage has the potential to produce a desired animal response [3]. Forage quality varies considerably due to several factors. Factors that affect forage quality include species, leaf-to-stem ratio, stage of growth, soil agents, climate, harvesting, disease and pests [4, 5]. The most important factor influencing forage quality is herbage maturity [6]. Information on nutritive value of plant species in each phonological stage could help range managers choose suitable grazing time to achieve higher animal performance without detriment to vegetation [7]. Graza and Fulbright [8], Khalil *et al.* [9], Arzani [10], Rhodes and Sharrow [11] introduced CP (Crude Protein), DMD (Dry Matter Digestibility) and ME (Metabolizable

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Energy) as the most appropriate factors for forage quality evaluation. Forage quality declines with advancing maturity which also influences forage consumption by animals [3]. As plants mature and become more fibrous, the cell wall concentration increases, the proportion of cell soluble content decreases [6]. The percentage of ADF (Acid Detergent Fiber) increases, cellulose and other structural carbohydrates will be collected in cell wall (this process is called lignification). With increasing of CF (Crude Fiber), the percentage of digestibility and plant energy will decrease [12] and forage intake drops dramatically [3]. Goorchi [13] and Ghadaki *et al.* [14] reported reduction of CP when plants matured; however, percentages of ADF and NDF (Neutral Detergent Fiber) increased. NDF approximates the total cell wall constituents including hemicelluloses, whereas ADF primarily represents cellulose, lignin and ash. ADF is often used to calculate digestibility and NDF is used to predict intake potential. As fiber increases, forage quality declines [3].

The main objective of this paper is to determine the effect of phonological stages on some forage quality traits: DMD, ADF, CP, CF, ME, NDF and WSC (Water Soluble Carbohydrate) in three plant species, *Salsola arbuscula*, *Salsola orientalis* and *Salsola tomentosa* collected from three provinces of Iran: Esfahan, Semnan and Markazi.

MATERIALS AND METHOD

Study Area and Plant Species Choice: As best result of salt tolerance screening can be expected from species that grow naturally in saline environments and within a species, that provenance of plant that grows in the most extreme saline conditions [15] has been chosen. Three native and palatable species of *Salsola arbuscula*, *S.orientalis* and *S.tomentosa* have been selected in their natural habitats. These Irano-Turanian species of Chenopodiaceae family which are mostly characteristic for arid to semiarid and/or saline habitats have great importance in livestock grazing and also in salty and dry range improvement. They form an important component of the flora and vegetation of desert environments. Chenopodiaceae are, however, taxonomically not well-investigated due to the limitation of practical taxonomical characters, the fleshy nature of many species, late flowering and fruiting time and the fact that they are aesthetically not attractive for most collectors and botanists [16-25].

Data Collection: In each site, three 200 meter transects were put. Three separate plant samples have been harvested from transects at three phonological stages (vegetative, flowering and seed ripening). Before chemical analyses, plant samples were dried and ground. Then the

Table 1: Characteristics of the stations in three provinces of Iran, 2010

Province	Species	Location	Altitude	Rainiest month	Mean annual rainfall	Mean annual temperature	Average maximum temperature	Soil Characteristics
Esfahan	*S. arbuscula*	34°4'24" N 51°46'11.8" E	910 m	January 38.3 mm	120.3 mm	18.8°C	41°C - July	EC : 2.18 - 3.74 ds/m pH: 7.4 - 7.9
Esfahan	*S. orientalis*	33°37' N 50°59'15" E	2000 m	November 19.4 mm	83.6 mm	12.2°C	33.6°C - July	EC: 0.73 - 1.09 ds/m pH: 7.7 - 7.9
Esfahan	*S. tomentosa*	33°37'15" N 50°59'15" E	1950 m	November 19.4 mm	83.6 mm	12.2°C	33.6°C - July	EC: 2.88 - 33 ds/m pH: 7.6 - 8.1
Semnan	*S. arbuscula*	35°55' N 53°58' E	1250 m	December 19 mm	58.1 mm	18.6°C	38.5°C - July	EC: 0.43 - 4.74 ds/m pH: 8 - 8.1
Semnan	*S. orientalis*	35°41'35.3" N 53°56'40.3" E	1765 m	December 19 mm	58.1 mm	18.6°C	38.5°C - July	EC: 1.27 - 8.79 ds/m pH: 7.08 - 8.5
Semnan	*S. tomentosa*	35°47' N 53°47' E	1670 m	December- 19 mm	58.1 mm	18.6°C	38.5°C - July	EC: 0.47 0 1.49 ds/m pH: 7.8 - 8
Markazi	*S. arbuscula*	33°46' N 50°50' E	1650 m	January 67.8 mm	191.1 mm	13.6°C	36.2°C - July	EC: 0.47 - 5.21 ds/m pH: 8 - 9.2
Markazi	*S. orientalis*	35°27'09" N 50°38'56" E	1545 m	December 38 mm	140.8 mm	18.3°C	38.7°C - July	EC: 0.38 - 2.39 ds/m pH: 7.8 - 8
Markazi	*S. tomentosa*	33°46'52" N 50°50'26" E	1680 m	January- 67.8 mm	191.1 mm	13.6°C	36.2°C - July	EC: 3.86 - 16.77 ds/m pH: 7.6 - 8.2

quality traits (DMD, WSC, ADF, NDF, CP, CF and ME) were estimated using near infrared spectroscopy (NIR). Details of the methodology and calibrations of NIR are given by Jafari *et al*. [26]. Collected data were analyzed using a factorial experiment for locations, phenological stages and interaction effects between locations and phenological stage with three replicates in each location. All statistical analyses were conducted by SAS Inst [27]. Phenological stages and species in each location means were compared by DMRT method. The characteristics of all sites are presented in Table 1.

RESULTS AND DISCUSSION

The percentage of different traits showed different values in three regions and three species.

CP% of *Salsola arbuscula* decreased with the progress of growth stages in Esfahan and Semnan (Fig.1). Results showed that it was significantly different (P<0.01) in three sites (Table 2) with the higher mean rate of Semnan. It should be noted that low rates of the first stage in Esfahan may be because of the high intolerable temprature for optimum plant function. White [28], Akbarinia and Koocheki [29], Arzani *et al.* [7, 30] and Zandi [31] pointed to the reduction of CP% when plants matured. This trend was reverse for *Salsola orientalis* in Markazi province, *Salsola tomentosa* in Esfahan and also for *Salsola tomentosa* and *Salsola orientalis* in Semnan. Maybe it was due to the seeds harvested with plant sampling in the maturity stage. Results agreed with the results of Zandi [31]. He declared that this increase in CP% with advanced maturity is caused by the protein of seeds in the third stage. The results also showed that the percentage of crude protein was highest for *Salsola tomentosa* in Markazi province and the minimum rate of CP% belonged to *Salsola orientalis* in Esfahan. There was also significant difference (P<0.01) between growth stages in *Salsola orientalis* and between sites in all three species (Table 2, 3, 4).

WSCs depend on different factors. It differs in various habitats for different species in different stages of growth [32]. Results showed that WSC% has the maximum value in flowering stage in *Salsola orientalis* in all three regions (Fig. 2). This trend was also obtained by Arzani [32] for *Salsola orientalis.* WSC% decreased in *Salsola arbuscula* in Esfahan (Fig. 2). Zandi [31] also obtained this trend for *Atriplex leucoclada* and *Suaeda vermiculata*. But the trend was reverse in *Salsola arbuscula* in Semnan and Markazi and also in *Salsola orientalis* in Semnan and Esfahan (Fig. 2). There was a significant difference (P<0.01) between growth stages in *Salsola arbuscula* (Table 3) and between locations in all three species (Table 2, 3, 4). In addition, the maximum rate of WSC% belonged to Esfahan for *Salsola tomentosa* and *Salsola orientalis* and to Markazi for *Salsola arbuscula*. *Salsola arbuscula* had the lowest mean rate of WSC% between three species (Fig. 2).

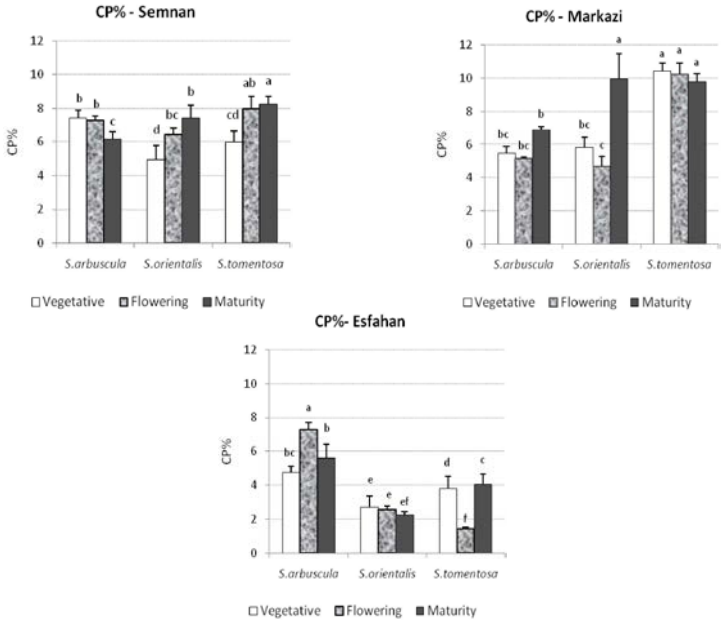

Fig. 1: The effects of phenological stages on CP% in *Salsola arbuscula*, *Salsola orientalis and Salsola tomentosa* in three provinces Iran in 2010.

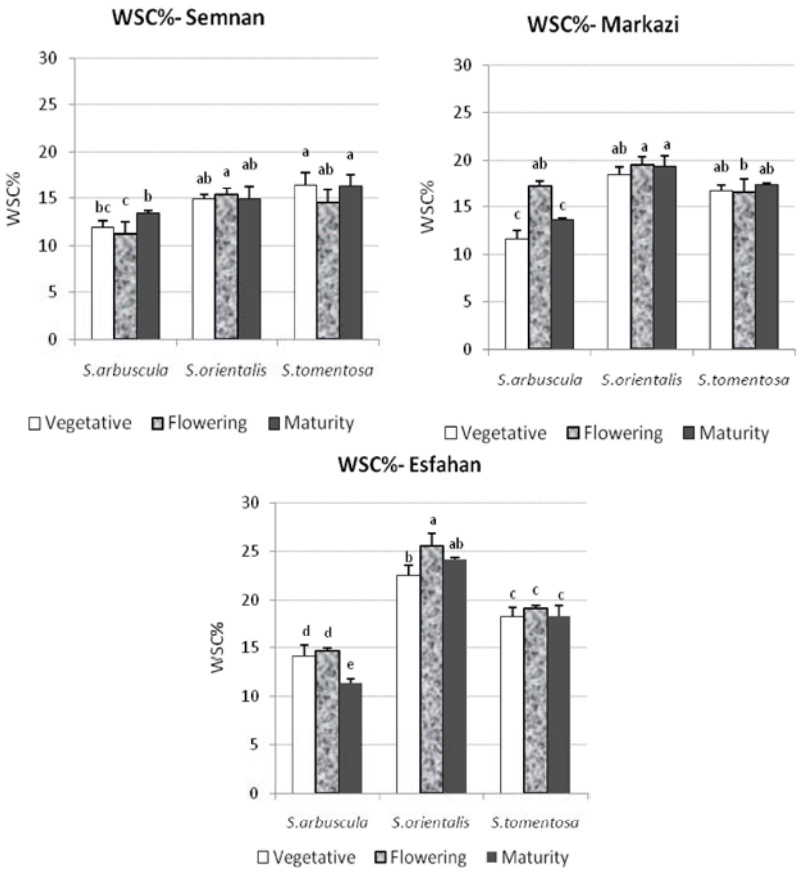

Fig. 2: The effects of phenological stages on WSC% in *Salsola arbuscula*, *Salsola orientalis and Salsola tomentosa* in 3 provinces Iran in 2010.

Table 2: Results of analysis of variances for 7 quality traits in *Salsola tomentosa* in 3 phenological stages in 3 locations

Source	df	CP	WSC	DMD	ADF	CF	NDF	ME
loc	2	112.43**	31.15**	92.30*	64.54*	65.27**	309.82**	2.51*
stage	2	1.12^{ns}	0.48^{ns}	3.17^{ns}	0.61^{ns}	37.46**	35.06^{ns}	0.18^{ns}
loc*stage	4	6.67**	1.25^{ns}	80.72*	51.60*	31.62**	178.96**	2.54*
Error	27	1.22	2.72	28.26	19.49	5.87	35.26	0.77
CV%		16.44	9.94	15.93	10.20	5.76	13.27	23.58

Table 3: Results of analysis of variances for Salsola arbuscula in 3 phenological stages in 3 locations

Source	df	CP	WSC	DMD	ADF	CF	NDF
loc	2	3.54**	8.59**	8.73^{ns}	11.12^{ns}	31.76**	64.45^{ns}
stage	2	1.02	8.81**	89.47**	19.65*	145.39**	303.86**
loc*stage	4	3.96**	14.24**	13.26^{ns}	6.92^{ns}	29.36**	95.81*
Error	27	0.53	1.5	12.06	5.94	5.88	27.13
CV%		11.7	9.27	17.56	4.64	5.19	8.32

Table 4: Results of analysis of variances for *Salsola orientalis* in 3 phenological stages in 3 locations

Source	df	CP	WSC	DMD	ADF	CF	NDF	ME
loc	2	49.69**	182.84**	98.56**	98.96**	99.65**	617**	2.85**
stage	2	8.67**	5.08^{ns}	40.35^{ns}	69**	3.44^{ns}	342.45**	1.17^{ns}
loc*stage	4	9.77**	1.67^{ns}	70.53**	73.66**	16.35*	269.26**	2.03**
Error	27	1.62	2.52	16.3	13.45	4.35	27.2	0.48
CV%		24.51	8.18	11.75	8.97	5.02	12.17	17.89

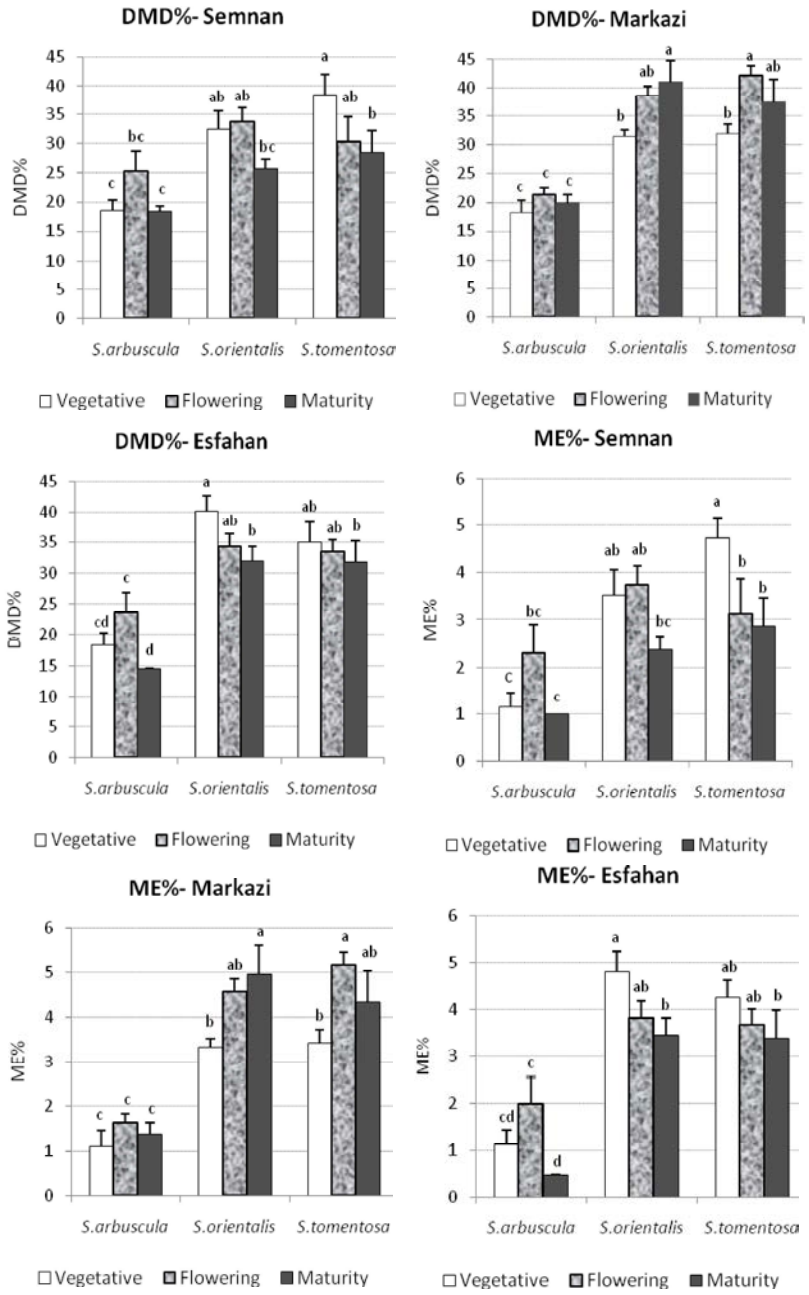

Fig. 3: The effects of phenological stages on DMD%, ME% in *Salsola arbuscula*, *Salsola orientalis and Salsola tomentosa* in three provinces Iran in 2010.

DMD% and ME% decrease was observed with the progress of plant growth in all three species in all three sites except for *Salsola orientalis* in Markazi (Fig. 3) and there was significant difference between sites in *Salsola orientalis* ($P<0.01$) and *Salsola tomentosa* ($P<0.05$) and between stages in *Salsola arbuscula* in both traits (Table 2, 3, 4). According to Arzani *et al*. [7] report, reduction of DMD% and ME% with maturity of plants is due to increasing structural tissues in stems. It was also confirmed by Akbarinia and Koocheki [29], Linn and Kuehn [33], Rayburn [34], Kashki [35], Erfanzadeh [36] and Zandi [39] who pointed to the reduction of digestibility in matured plants. For *Salsola orientalis* in Markazi province, overgrazing of the chosen site in the first stages of growth and as a result not to have high ME% or DMD% in the vegetative stage could be a reason

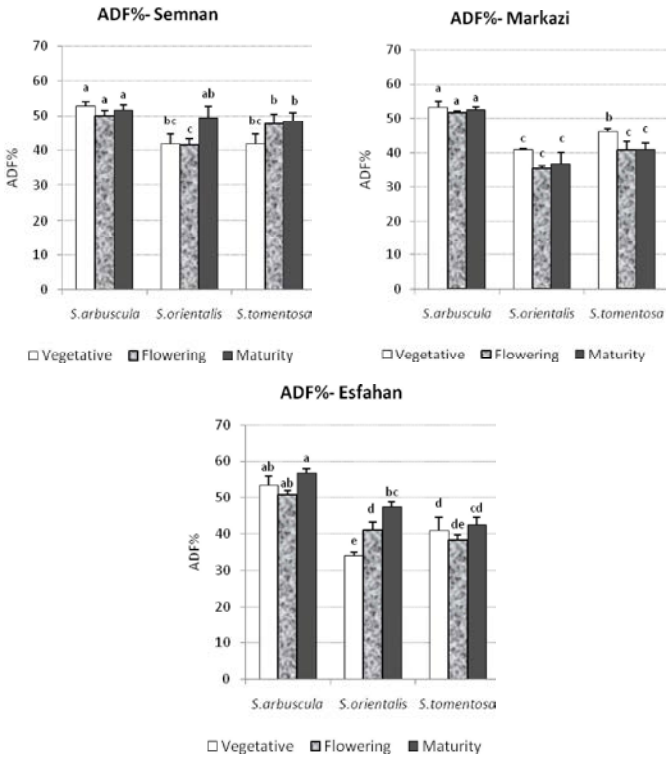

Fig. 4: The effects of phenological stages on ADF% in *Salsola arbuscula*, *Salsola orientalis and Salsola tomentosa* in three provinces Iran in 2010.

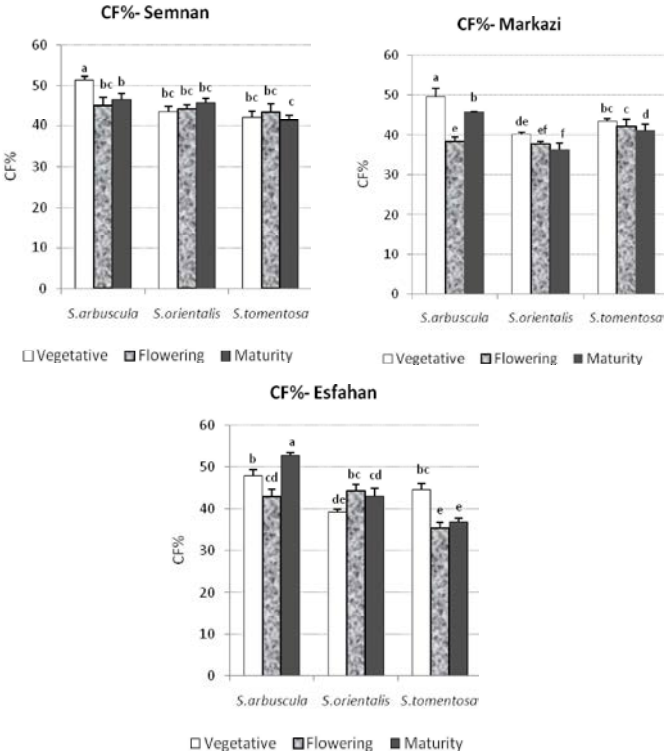

Fig. 5: The effects of phenological stages on CF% in *Salsola arbuscula*, *Salsola orientalis and Salsola tomentosa* in three provinces Iran in 2010.

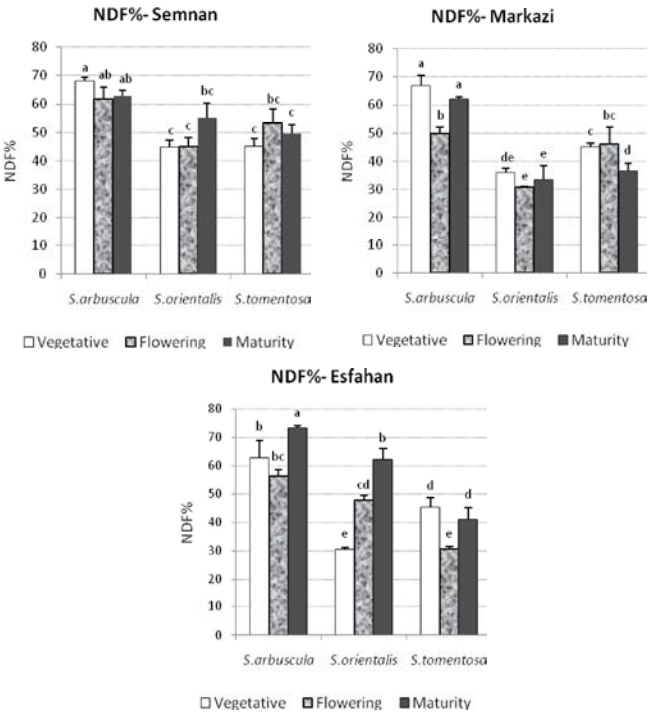

Fig. 6: The effects of phenological stages on NDF% in *Salsola arbuscula*, *Salsola orientalis and Salsola tomentosa* in three provinces Iran in 2010.

for such increasing trend. Arzani *et al*. [7] and Akbarinia and Koocheki [29] also stated that increasing DMD% and ME% in some species when seeds are matured is due to relatively high amounts of digestible carbohydrates in seeds. This trend was also confirmed by Zandi [31] and Pinkerton [37]. Pinkerton [37] showed a close relationship between digestibility and cell wall characteristics and declared that cell contents could be 100% digestible and will not reduce even when the plant becomes mature. In contrast, as plant growth continues, fiber content increases and digestibility decreases. It needs to be said that the minimum mean rate of ME% and DMD% belonged to *Salsola arbuscula* (Fig. 3).

ADF%, NDF% and CF% increased with plant growth in all three species in Esfahan (Fig. 4, 5, 6). It agreed with the results obtained by George *et al*. [38] and Arzani *et al.* [4]. Arzani *et al*. [7] declared that because of storage tissues in seeds, ADF and NDF contents varied with plant maturity between phenological stages and species. Arzani *et al*. [4] also reported that with progress of plant growth, ratios of protector and firm tissues, which mostly consist of structural carbohydrates such as celluloses, hemicelluloses and lignin, are increased. Therefore, maturity of plants and an increase in structural carbohydrates cause higher fiber amounts in forage late in the growing season. In Semnan and Markazi, the trend was somehow different or even reverse in some cases. This might be due to the higher amount of seeds which had low amount of ADF% in the maturity stage. It was obvious for *Salsola tomentosa* and *Salsola orientalis* in Markazi province.

Results showed that there was a relationship between forage traits. Species and stages with more ME, DMD and CP that specifies the nutritive value of plant and forage quality had less ADF, CF and NDF. Among species, *Salsola arbuscula* had less forage quality in comparison with two other species and the first stage of growth had higher quality and was the best time for grazing and reaching more desirable livestock response.

Finally, it has to be mentioned that nature is unpredictable and observing unexpected trends under specific conditions is not impossible and there is the probability of observing various reactions of species in different climates and nartural conditions. Ofcourse reaching the best results in this field, various studies on the species of this familly is needed and as Baba Dioum, a conservationist from Sengal in Africa, said: “We will conserve only what we love, we will love only what we understand and we will understand only what we are taught”.

REFERENCES

1. Szabolcs, I., 1994. Soils and salinization. In: Pessarakli, M. (ed). Handbook of plant and crop stresses. Dekker, New York, Basel, Hong Kong.
2. Kozlowski, T.T., 2002. Acclimation and adaptive responses of woody plants to environmental stresses. Bot. Rev., 68(2): 270-334.
3. Ball, D.M., M. Collins, G.D. Lacefield, N.P. Martin, D.A. Mertens, K.E. Olson, D.H. Putnam, D.J. Undersander and M.W. Wolf, 2001. Understanding Forage Quality. American Farm Bureau Federation Publication 1-01, Park Ridge, IL.
4. Arzani, H., J. Torkan, M. Jafari and A. Nikkhah, 2001. Investigation on effects of phenological stages and environmental factors (soil and climate) on forage quality of some important range species. Journal of Agricultural Science, 32: 385-397.
5. Harrocks, D. and J.F. Valentine, 1999. Harvested Forage. San Diego, Academic Press, CA, pp: 425.
6. Buxton, D.R., D.R. Mertens and D.S. Fisher, 1996. Forage quality and ruminant utilisation. In Moser, L.E. *et al.* (eds.). Cool-season Forage Grasses. ASA, CSSA and SSSA, Madison, USA, pp: 229-266.
7. Arzani, H., M. Zohdi, E. Fish, G.H. Zahedi Amiri, A. Nikkhah and D. Wester, 2004. Phenological effects on forage quality of five grass species. Journal of Range Management, 57: 624-629.
8. Graza, A.JR. and T.E. Fulbright, 1988. Comparative chemical composition of armed saltbush. Journal of Range Management, 41(5): 401-403.
9. Khalil, J.K., *et al.*, 1986. Nutrient composition of *Atriplex* leaves grown in Saudi Arabia. Journal of Range Management, 39(2): 104-107.
10. Arzani, H., 1994. Some aspects of estimating short-term and long-term rangeland carrying capacity in the Western Division of New South Wales, Ph.D.Thesis, University of New South Wales, Australia.
11. Rhodes, B.D. and S.H. Sharrow, 1990. Standing Committee on Agriculture. Feeding standards for Australian livestock ruminants. CSIRO. Australia.
12. Hoffman, P.C., K.M. Lundberg, L.M. Bauman and R.D. Shaver, 2003. The effect of maturity on NDF digestibility. Focus on Forage. 5:1-3.
13. Goorchi, T., 1995. Determination of chemical composition and dry matter digestibility of dominate species in Isfahan Province, M. S. thesis. Industrial University of Isfahan, Iran.
14. Ghadaki, M.B., P.J. Vansoest, R.C. Mcdowel and B. Malekpour, 1974. Composition and in-vitro digestibility of some arid zone forage from Iran. 12th International Grassland Congress. Moscow. Russia, 3(1): 542-549.
15. Niknam, S.R. and J. McComb, 2000. Salt tolerance screening of selected Australian woody species—a review. For Ecol Manage., 139: 1-19.
16. Freitag, H., 1989. Contributions to the Chenopod Flora of Egypt. - Flora, 183: 149-173.
17. Freitag, H., 1991a. The distribution of some prominent Chenopodiaceae in SW Asia and their phytogeographical significance. -In Engel, T., W. Frey, H. Kurschner, (eds.): Contribution selectae ad Florum et Vegetationem Orientis. - Flora et Vegetatio Mundi, IX:281-292. -Berlin, Stuttgart: Cramer.
18. Freitag, H., 1997. *Salsola* L. (Chenopodiaceae). - In Rechinger K.N. (Eds.): Flora Iranica.- Graz: Akadesche Druck-u. Verlagsanstalt, 173: 154-255.
19. Hedge, I., H. Akhani, H. Freitag, G. Kothe-Heinrich, S. Rilke and A.P. Uotilla, 1997. Chenopodiaceae. In: Rechinger KN (ed) Flora Iranica 172. Academische Druck und Verlagsanstalt, Graz, Austria, pp: 371.
20. Kothe-Heinrich, G., 1993. Revision der Gattung *Halothamnus* (Chenopodiaceae)- Biblioth. Bot., pp: 143.
21. Pratov, U.P., 1987. Chenopodiaceae Vent of the Middle Asia and the northern Africa (systematics, phylogenesis and botanical-geography analysis) Summary of boil. Science doctor degree thesis. Academy of Science of USSR, Leningrad: pp: 48. (in Russian).
22. Scott, A.J., 1977. Proposal to conserve the family name Salsolaceae. Moquin-Tandon (1849) (Caryophyllales) when it is treated as a separate family from the Chenopodiaceae Ventenat (1799). Taxon., 26: 246.
23. Scott, A.J., 1978. A revision of the Camphorosmioideae (Chenopodiaceae). - Feddes Repert., 89: 101-119.
24. Townsend, C.C., 1980. Contributions to the Flora of Iraq: XIII. Notes of some genera of Chenopodiaceae.- Kew Bull., 35: 291-296.
25. Williams, J.T. and B.V. Ford Lloy, 1974. The systematics of the Chenopodiaceae. Taxon., 23: 353-354.

26. Jafari, A., V. Connolly, A. Frolich and E.J. Walsh, 2003. A note on estimation of quality parameters in perennial ryegrass by near infrared reflectance spectroscopy. Irish Journal of Agricultural and Food Research, 42: 293-299.
27. SAS Manual, 2004. Copyright (c) 2002-2003 by SAS Institute Inc., Cary, NC, USA.
28. White, L.M., 1983. Seasonal changes in yield, digestibility and crude protein of vegetative and floral tillers of two grasses. Journal of Range Management, 36: 402-405.
29. Akbarinia, A. and A. Koocheki, 1992. Investigation on effects of different harvesting stages on growth, productivity and quality of some barley's varieties. Journal of Pajouhesh and Sazandegi, 15: 40-43.
30. Arzani, H., A. Nikkhah and Z. Arzani, 1998. Forage quality in three provinces of Semnan, Markazi and Lorestan Rangelands, Final report, Determining Economic Property Size Project. College of Natural Resources, University of Tehran, Tehran, Iran.
31. Zandi Esfahan, E., M.H. Assareh, M. Jafari, A.A. Jafari, S.A. Javadi and Gh. Karimi, 2010. Phenological effects on forage quality of two halophyte species *Atriplex leucoclada* and *Suaeda vermiculata* in four saline rangelands of Iran. Journal of Food, Agriculture & Environment, 8(3&4): 999-1003.
32. Arzani, H., 2009. Forage quality and daily requirement of grazing animal. 1st ed. University of Tehran Press. pp: 58.
33. Linn, J. and C. Kuehn, 1994. The effects of forage quality on performance and cost of feeding lactating dairy cows. University of Minnesota. Department of Animal Science. St. Paul, MN, pp: 9.
34. Rayburn, E.B., 1997. Forage quality-fiber and energy. West Virginia University Cooperative Extension Service, Morgantown, WV. Available at http: www.caf.wvu.edu/forage/5012.htm.
35. Kashki, V., 2001. Determination of chemical composition of 7 *Atriplex* species in Sabzevar Research Station. Proceeding of the 1st National Livestock and Rangeland Management Congress, Research Institute of Forests and Rangelands of Iran, pp: 30.
36. Erfanzadeh, R., 2001. Investigation on qualitative indices changes of rangeland species during two phenology stages. Proceeding of the 1st National Livestock and Rangeland Management Congress. Research Institute of Forests and Rangelands of Iran, pp: 60.
37. Pinkerton, B., 1996. Forage Quality. Crop and Soil Environment Science Department, College of Agriculture, Forest and Life Science, Clemson University, Clemson, SC., pp: 998.
38. George, R. and Ph. Ogdeh, 1993. What is an A.U.M.? Rangeland Management Specialists, School of renewable Natural Resources, College of Agriculture and University of Arizona, pp: 33.