Monthly Changes in Quality of *Calligonum comosum* Grazing Plant and an Estimate of the Maximum Values of Forage Quality by Using the Polynomial Quadratic Equation

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DOI: 10.21608/jalexu.2020.171967

Article Information

Received: November 11th 2020

Revised: December 1st 2020

Accepted:December 22nd 2020

Published:December 31th 2020

ABSTRACT: Follow up the monthly changes of plant quality on *Calligonum comosum* plant which natural grown in the Research and Training Station of King Faisal University, Al-Hassa, Saudi Arabia in season from September/2019 to May/2020 AD were recorded. The results revealed that a significance differences between values of all months. The polynomial quadratic equation indicated that the higher values % of crude protein (Cd, 9.80%), dry matter weight (DW, 40.21%), ash (Ash, 14.71%), crude fiber (CF, 43.19%), acid detergent fiber (ADF, 32.6%), and dry matter digestibility (DMD, 60.52%) were found between December and February.

Keywords: *Calligonum comosum*; Grazing plant, Forage quality, Acid detergent fiber, Polynomial quadratic equation, Alahsa, Kingdom of Saudi Arabia.

INTRODUCTION

In the desert areas of the Kingdom of Saudi Arabia many desert plants are spread as source of feed for wild animals such as camels and livestock. One of these desert plants is *Calligonum comosum* (Shaltout *et al.*, 1996; Al-Rowaily, 1999; Alzarah, 2020). The Using of desert wild plants as a fodder source for grazing animals reduces the costs of importing fodder and saving water consumption (Alzarah, 2020). The natural rangeland in desert dry regions is considered as a source of livestock nutrition (Bidgoli, 2018). The quality of rangeland production varied from time to time, place to place, and species to species, and also by environmental factors (Dongmei *et al.*, 2005).

Wild plants that live in the desert contain food stuffs in addition to their content of various plant compounds that may benefit animals that live in the desert and can be used as feed materials for these animals. The quality of rangelands forage species and determination of rangeland grazing capacity to proper management of rangelands and the establishment of a sustainable balance between livestock and rangeland are very important (Arzani *et al.*, 2009; Kaboli, 2001). The CP, DMD and ME are the appropriative factors for assessing the forage quality (Arzani *et al.*, 2009; Kaboli, 2001).

From between the several components in forage, ADF is important one as indicator of forage quality in different plant species (Graber, 1991). Oddy *et al.* (1993) concluded that the CP rate in plants in the vegetative stage was higher than the flowering and seed maturity stages; also, Larbi *et al.* (2010) showed that the amount of DMD and ME decreased with increasing plant age. Consequently, Bidgoli (2018) concluded that when plant growth is complete, the number of structural carbohydrates in the plant and the ADF percent are more likely to increase while the CP concentration decreases. Hyder and Sneva (2003) mentioned that forage quality can be used to determine the best time of livestock grazing.

Calligonum comosum is one of the *Polygonaceae* families that grow as a resistant to drought and dehydration in difficult desert conditions. This plant has good distribution in different arid and semi-arid climatic conditions, particularly sandy hills, and very widespread. That plant is distributed in sandy soils of Saudi Arabia such as eastern (Shaltout *et al.*, 1996; Alzarah, 2020), western (Migahid, 1978), northern (Migahid, 1978), southern (Migahid, 1978), and central (AlRowaily, *et al.*, 2018) provinces of the Kingdom.

Calligonum comosum L'Her is a large perennial bush found in any climatic region in scrub and waste ~~of~~ desert zone. This plant inhabits and grows in much the desert sands of the North African, the Middle East, as well as the sand dunes in both central and eastern Arabia (Lipscombe Vincent, 1984). This species belongs to the *Polygonaceae* family and is characterized by a tall, evergreen shrub that can reach 3 m in length but is typically found in a 1 to 2 m tall bush. The stem of the plant is woody hard with white to

grayish-white color. Their nodes are swollen. The bush looks as leafless, hard, widely branched plant, but young branches are green and thin with very small caduceus leaves (Chaudhary, 1999). In the early spring months (March and April) the stiff, young green branches produce an abundance of flowers. The pedicels of the flowers are as long as or longer than the perianth. The hairy fruits, which are yellowish-green, yellow, or even shades of red, follow the silvery-white sweet-smelling little blooms (Chaudhary, 1999). The fruits are covered by long hairs that arising from four vertical wing-like narrow ridges. The plant has a long taproot, which enables the plant to collect sand and used as a dune stabilizer (Zoghet and Al-Alsheikh, 1999).

Vegetative period of this plant begins from March, and the emergence of leafy leaves extends to mid-April, its tiny and white flowers begin to form in late March and by the end of May and give a very sophisticated landscape to the faces of the sandstones. Fruits appear in June and the height of the plant varies between 1 to 3 m (Batooli, 2011). Knowledge of the nature of the forages of this species is an efficient way to use them in a timely fashion, expecting food scarcity and needs for livestock dietary supplementation.

Bedouins use this plant a lot; in winter, they use the woody stem as firewood. The long and far-reaching roots make it a strong sand stabilizer and the sand in broad hummocks is always heaped around it. (Lipscombe Vincent, 1984). It is used in hedges, ground cover, landscaping, and windbreaks. Its new flowers can be consumed, as it is rich in sugar and nitrogenous components (Surviva-Appendix B, 2002). The plant has been used to treat stomach ailments by local healers while the stems and leaves are chewed for curing toothache (Liu *et al*., 2001). The result of boiling the roots are used in the sores of gums treatment (Zoghet and Al-Alsheikh, 1999).

Calligonum plant has economic, environmental and medicinal importance (Okla et al., 2014). *Calligonum* plant can be used in purification of polluted water for Zn where Ackacha (2010) in his study on the stem of *Calligonum comosum* indicated that the plant absorbed some heavy elements like zinc and reduces significantly its presence in the aqueous solution.

Inorganic compounds and minerals are required in all living systems for normal life-supporting processes. In addition, minerals are found in all animal tissues and feedstuffs in widely varying quantities and proportions. Unlike other nutrients, living organisms do not synthesize minerals; thus, if survival and development goals are to be maintained, animals must obtain sufficient quantities of necessary elements from their environment (Khan *et al.*, 2012).

Livestock typically derives most of their dietary nutrients from the feed they consume, although it is possible to acquire substantial amounts of minerals from water, soil intake, and contamination of feed. Feed sources of minerals are typically divided into base feedstuffs (e.g., range or pasture plants, harvested forages, concentrates) and mineral supplements (Khan *et al.*, 2012). While, Dost (2001) indicated that a detailed understanding of the supply and availability of mineral nutrients in traditional feedstuffs involves efforts to reduce the cost of mineral supplementation in livestock production.

For sustainability and reducing dependence on importing fodder from abroad or cultivating varieties that consume water with limited resources. It is necessary to search and find natural resources such as wild plants that exist in the desert environment of the Kingdom of Saudi Arabia that can live in harsh conditions from high temperatures, lack and quality of water (Alzarah, 2020). There is a wide gap between the nutritional needs of animal feed and the quantities produced in Saudi Arabia. Therefore, large quantities of feed are imported to reduce the gap between production and consumption.

Seasonal variation influences seasonal livestock production in different regions of the world by influencing the accumulation of forage dry matter. Seasonal forage mineral nutrient content stability can be achieved through active breeding programs for forage plants (Mislevy *et al.*, 1999). It has been widely known that the available energy and protein of the feed is of primary importance to any animal, but optimum efficiency can only be achieved if there is a sufficient supply of minerals (Khan *et al.*, 2004; McDowell, 1985). The pastures are the main source of minerals, and only rarely the forage of pastures fully fulfill all the mineral requirements of livestock (Jones and Tracy, 2013).

For all of these economical uses, the plant has been faced with over grazing and unorganized rural activities that led to the extinction of it. For this and because of the little available information about that species especially its taxonomical plasticity under the arid conditions which it faces and as a step forward to know the ways its internal and external features adapted to the environmental stress, this work has been done (Wafaa, et al., 2006). Wafaa et al. (2006) in study on *Calligonum* comosum L`Her in two desert Locations in Saudi Arabia, Nefoud El-Shakika and the second west El-Dahnaa, showed that great variations within the plant especially plant length and width and minerals content between the two different regions.

The hints referred to by Taia and El-Olayan (2003) confirm the findings of Wafaa *et al.* (2006) that the morphological and mineralogical

differences of the *Calligonum comosum* L`Her plant differ according to the growing habitats.

To maximize the benefits of wild plants such as *Calligonum comosum* that grows in the eastern part of the Eastern Province of Saudi Arabia as animal feed, ~~so~~ this study aims to follow the monthly changes of forage quality and determine the time that gives the maximum quality using the polynomial equation.

MATERIAL AND METHOD:

2.1 Experimental design

Randomized complete block design with three replications (5 plants/replicate) were used in this experiment where aerial sampling monthly time of plant was considered (9 months: September, October, November, December, January, February, March, April and May). The total units of the experiments were (3 replicates × 9 months = 27 units)

2.2 Collection, preparation and analysis of plant samples

The samples of *Calligonum comosum* plants were collected from three different locations as replications inside Research and Training Station of King Faisal University. The Meteorological conditions through two years are summarized in Table 1. From each site five plants were selected monthly almost similar in morphological shape to conduct the test on them. The plant samples were taken through November / 2019 to May 2020 from aboveground growth (aerial parts). The samples were washed with distilled water, dried, crushed, sieved and analyzed according to AOAC methods (2019) for determination of crude protein (CP%= Total nitrogen%*6.25), crude fiber (CF), acid detergent Fiber (ADF), dry matter digestibility (DMD), total energy (TE), metabolic energy (ME) and ash % . The DMD and ME were calculated by the following equations according to Van Soest *et al.* (1991)

$$\text{DMD\%} = 83.58 - 0.824 * \text{ADF\%} + 2.628 * \text{N\%}$$

$$\text{ME (Mj/kg/DM)} = 0.17 * \text{DMD\%} - 2$$

To measure the ADF content of the plants, 1 g of the powdered sample was placed into glass tubes in the Fiber tec. Then, 100 ml ADS (Acid Detergent Solution) was added and boiled for 1 h. For preparation of the ADS, 20 g $BrNH_4(CH_3)_3$ (try methyl bromide) was combined with 10 ml of conc. H_2SO_4. After 1 h, all the substances in the solution will be vanished, except the cellulose, lignin, and the minerals. The samples were then washed with distilled water and acetone in the cold extraction unit, and then put in the oven at 120°C for 2 hours. Afterwards, the sample weights were recorded (W*b*), and the samples were put in an electric furnace at 500°C for 3 h. In the electric furnace, all of the sample's cellulose and lignin were burnt and only the minerals were remained. Then the sample will be weighted (Wa). By comparing the weights of the samples before and after the electric furnace, the ADF was obtained using the following formula

$$\text{ADF\%} = \left(\frac{\text{W}b - \text{W}a}{\text{W}b}\right) * 100$$

Where *Wb* and *Wa* are the weight of the sample before and after the electric furnace

2.3 Calculation

Polynomial quadratic equation were used to predicate DW, Ash, CF, N, ADF, DMD and ME as forage quality of *Calligonum comosum* wild plant:

$Y_i = B_0 + B_1X_i + B_2X_i^2$

Where the Y_i is the expected characteristics of quality corresponding to monthly changes, B_0 is the intercept, B_1 and B_2 are the linear and quadratic coefficients, respectively. The maximum rate (M_{max}) was calculated when the slope (dy/dx_i) of polynomial equation equals zero. The corresponding maximum characters were calculated by substituting the value of M_{max} in the polynomial quadratic equation.

2.4 Statistical Analysis

Data obtained were subjected to statistical analysis of variance (ANOVA) for randomized complete block design by SAS computer program. Treatment means were compared using LSD test as described by Snedecor and Cochran (1998).

2.5 Climatic conditions in studied area

The study area was the Research and Training Station of King Faisal University located in Eastern province of Saudi Arabia. Table 1 showed that the average annual rainfall in the region was 0-7 (in 2019) 0-3.8 mm day^{-1}(in 2020) and air temperature ranged between 6.68-48.6 and 2.2-42.37°C in 2019 and 2020, respectively. The air speed varied from 0-13.56 (in 2019) and 0-14.21 m S^{-1} (in 2020).

Table 1: The minimum, maximum and average of some climatic conditions in the Research and Training Station of King Faisal University, Kingdom of Saudi Arabia from March 2019 to May 2020.

Parameter	Reading	2019	2020	Parameter	Reading	2019	2020
Air Temperature C°	Min	6.68	2.20	Soil temperature at a depth of 30 cm, C°	Min	22.09	20.67
	Max	48.60	42.37		Max	37.18	31.78
	Average	30.69	21.46		Average	32.14	24.35
Relative Humidity %	Min	3.24	5.06	Net solar radiation W m^{-2}	Min	1,305.00	-729.90
	Max	100	100		Max	863.00	1,007.00
	Average	33.85	39.81		Average	63.24	53.34
Mean Wind Speed m S^{-1}	Min	0.00	0.00	air pressure mm Hg	Min	723.90	728.90
	Max	13.56	14.21		Max	742.50	742.70
	Average	2.42	2.96		Average	732.44	736.49
Wind Direction	Min	0.07	0.08	Falling energy Kw m^{-2}	Min	0.00	0.00
	Max	354.50	354.50		Max	1.31	1.21
	Average	217.60	191.09		Average	0.24	0.21
Solar radiation kw m^{-2}	Min	0.00	0.00	Soil temperature at a depth of 20 cm, C°	Min	22.32	21.38
	Max	0.99	0.93		Max	36.49	31.74
	Average	0.19	0.16		Average	31.79	24.78
Rain mm day^{-1}	Min	0.00	0.00				
	Max	7.00	3.80				
	Average	0.001	0.001				

The data were recorded from Meteorological station, research and training station, King Faisal University, Al-Hassa King Kingdom of Saudi Arabia.

3. RESULTS AND DISCUSSION

Forage ***Quality***: Monthly changes of forage quality comprised of DW, Ash, CF, N, ADF, DMD and ME were recorded. The averages of forage quality characteristics mean will be elucidated as follow.

3.1 Analysis of variance of the forage quality

Analysis of variance of the monthly changes of forage quality characteristics are presented in Table (2). Results illustrated that highly significant changes were found between months for DW, DMD and ME ($P<0.001$) and Ash, CF, N, and ADF, $p<0.0001$. These changes are near to the results found by Bidgoli (2018) in his study on the forage quality of *Calligonum comosum* in three phonological growth stages (vegetative, flowering and seedling) where he showed significant effect of phonological stages on CP and TE ($P<0.01$) and DMD and ME ($p<0.05$).

Table 2: Analysis of variance of dry weight % (DW%), ash %, crude fiber% (CF%), crude protein (CP), acid detergent fiber (ADF), dry matter digestibility (DMD), total energy (TE) and metabolic energy (ME) in *Calligonum comosum* through November/2019 to April/2020.

Source of variation	Df	Mean Square						
		DW%	Ash%	CF%	CP%	ADF%	DMD%	ME MJ kg^{-1}
Rep.	2	637.77	54.23	175.73	30.78	27.64	73.21	2.12
Month.	8	214.95***	26.34****	85.36****	28 ****	120.84***	82.41***	2.38***
Error	26	42.23	1.16	3.76	2.48	16.62	9.71	0.28

*** and **** mean significant at 0.001 and 0.0001 probabilities levels.

3.2 The monthly Change of DW, Ash, CF, N, ADF, DMD and ME

The following Table (3) showed the effect of monthly differences of DW, Ash, CF, N, ADF, DMD and ME of *Calligonum comosum* plant. The obtained results revealed that the characters of DW, Ash, CF, N, ADF, DMD and ME were significantly affected by monthly sampling time i.e. September, October, November and December of 2019 and January, February, March, April, May of 2020. Concerning DW%, the highest value (42.69%) was obtained at February, while the lowest value (18.78%) was at the month of May (Table 3). The high ash% value (15.47%) was produced in February, whereas the lowest ash value% (6.81%) was produced in May. Higher CF% (27.84%) was recorded in February, while the lowest CF% (12.25%) was in May. The higher values for DW, Ash and CF were logged between December and February with no significant differences between its values in these months. The highest CP% (19.9%) was obtained at March, while the lowest (9.64%) was in May. This results were consistent with the results of Bidgoli (2018) where he found in his study on forage quality of *Calligonum comosum* in Iran, that CP% decreased with increasing the growth ~~age~~ stages from vegetative to flowering and then to seed maturity. Regarding ADF, the data of Table 3 revealed that ADF increased monthly from September ⁄ 2019 to February ⁄ 2020 and then decreased thereafter to the month May ⁄ 2020. However, higher ADF value was achieved at February (38.97%) and lower value (15.93%) was achieved at May. Bidgoli (2018) indicated that ADF values ranged from 19.1 to 23.6% of *Calligonum comosum.* The values of ADF increased monthly up to February and then decreased to May. The DMD values ranged from 54.90 at February to 71.64 at May. As general DMD results showed that, DMD decreased monthly up to February and then increased monthly afterward . As shown in Table 3, the lowest ME value was in February (7.33) and the highest value was in May (10.18). The results indicated that the values of DW, Ash, CF, N and ADF take the same direction while the values recorded for DMD and ME take the same trend but are opposite to the other parameters. These results are in line with those of Khan *et al.* (2012) in his study of the same plant in Pakistan.

Table 3: Forage quality monthly changes (DW%, Ash, CF, N, ADF, DMD and ME) of *Calligonum comosum* wild plant

Months*	DW%	Ash%	CF%	CP%	ADF%	DMD	ME
September	24.70cd	8.95c	16.10c	10.50de	17.71e	70.71ab	10.02ab
October	28.12cbd	10.18bc	18.33bc	12.69cd	20.16de	69.00abc	9.73abc
November	37.99ab	13.77a	24.78a	14.58bc	27.25bc	64.10cd	8.90cd
December	39.28ab	14.23a	25.61a	14.96bc	26.89bc	64.52cd	9.73abc
January	40.99a	14.85a	26.73a	15.47b	32.07b	60.41d	8.27d
February	42.69a	15.47a	27.84a	15.97b	38.97a	54.90e	7.33e
March	25.18cd	11.00b	19.8b	19.90a	27.72bc	65.91bc	9.20bc
April	32.57abc	10.60bc	19.08cb	14.05bc	24.80cd	66.74abc	9.35abc
May	18.78d	6.81d	12.25d	9.64e	15.93e	71.64a	10.18a
$LSD_{0.05}$	11.25	1.87	3.36	2.73	6.33	5.39	0.92

*Any two means not sharing the same letter in common in a column differ significantly at 5% level of probability.

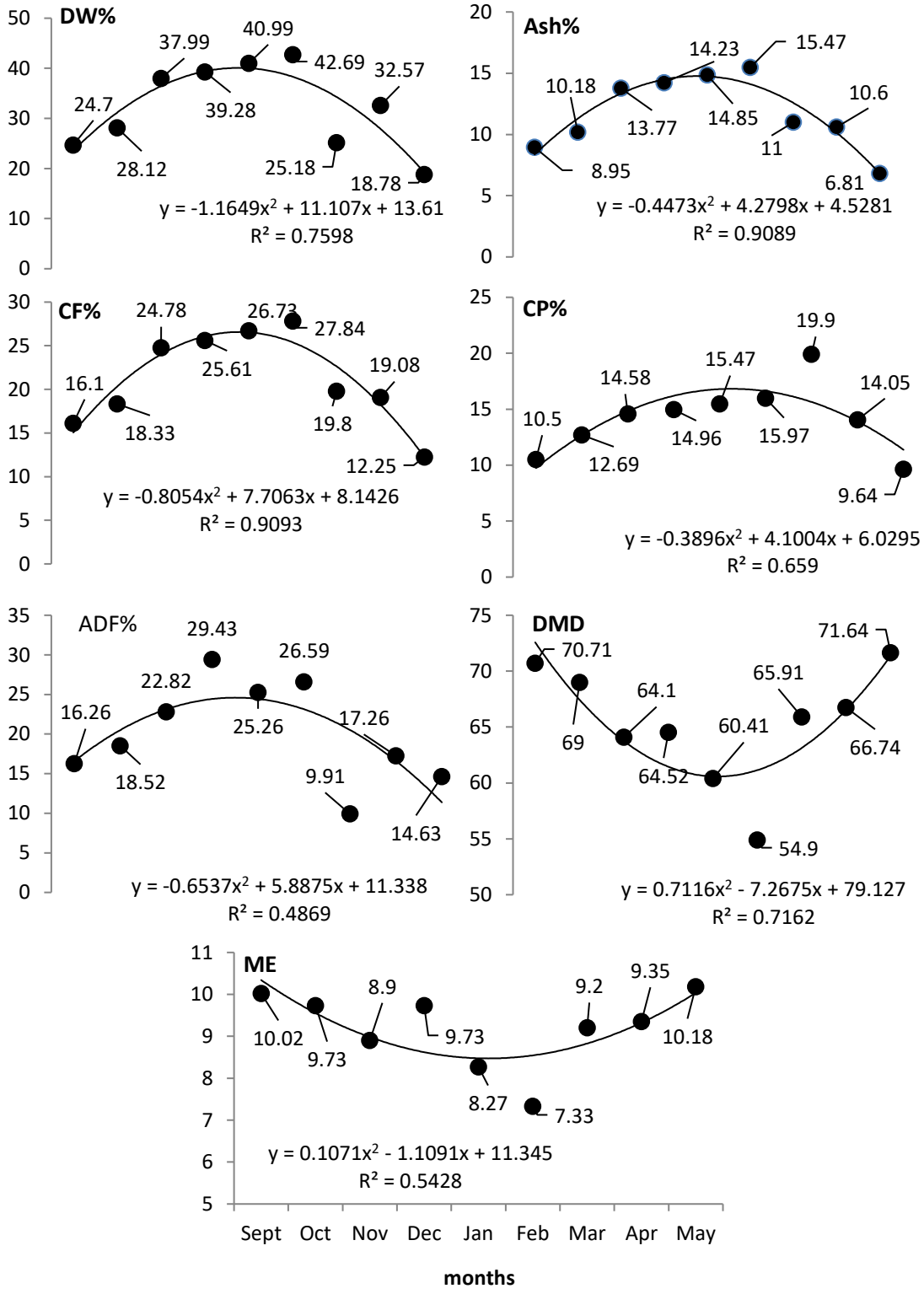

Fig. 1: Monthly changes of some forage quality properties of Calligonum comosum wild plant (DW%, Ash%, CF%, CP%, ADF, DMD and ME). Polynomial quadric equation for y every characters are appeared in the figures.

3.3The maximum ADF as forage quality, CF, CP, and Ash of *Calligonum comosum* wild plant ~~by~~ using polynomial quadratic equation

The polynomial quadratic equations were used to express the characters change (Y_i) through the months (M_i) (September ⁄ 2019 to May ⁄ 2020) under the conditions of the experiment area are illustrated in Table 3. Data in Table 3 designated significant determination coefficients of CF, Ash ($p<0.01$) and CP ($p<0.05$) characters of forage quality with months with no significant value for ADF. Which means that CF, Ash and CP depends mainly on month while ADF is not correlated with the time of sampling (month).

Undersander *et. al* (2019) mentioned that lower ADF indicates a more digestible forage, and ADF values less than 35% are desirable for an alfalfa forage. Whereas ADF can be an indicator of the energy content of a forage and is used in digestibility calculations. Acid Detergent Lignin (ADL) analysis can be performed sequentially on ADF residue.

Table 4: The maximum value (Yi) and time of maximum in month of CF, CP, Ash and ADF by using polynomial quadratic equations

Character (Y_i)	The polynomial quadratic equations	Determination Coefficient (R^2)	Maximum of Y_i %	Time of Maximum (month, M_i)	The month of maximum
CF	$Y_i = -0.805M_i^2 + 7.706M_i + 8.143$	0.909^{**}	43.19	4.79	Dec- Jan
CP	$Y_i = -0.39M_i^2 + 4.100M_i + 6.03$	0.659^{*}	16.81	5.26	Jan-Feb
Ash	$Y_i = -0.447M_i^2 + 4.280M_i + 4.5283$	0.909^{**}	14.71	4.79	Dec- Jan
ADF	$Y_i = -0.653M_i^2 + 5.89M_i + 11.34$	0.487^{NS}	24.62	4.51	Jan-Feb

Mi is the number of month starting from November 2019 to May 2020
NS, *, ** are not significant, significant at $p<0.05$ and $p<0.01$ levels of probability, respectively.

3.4 Comparison between *Calligonum comosum* wild plant and alfalfa as forage for desert animals

Alfalfa is a premier forage legume with potential for high yield and quality so this plant is taken as stander for forage quality (Lacefield, 2004) to compare with the quality of *Calligonum comosum*. The data of table 5 demonstrate the comparison of CP, ash, CF and ADF maximum contents of *Calligonum comosum* wild plant and alfalfa hay as forage guide line. The presented data showed that the maximum value of CP% of wild plant was 16.81%, while the content in alfalfa leaf ~~was~~ ranged between 16 to 26%. This result means that the CP% value of *Calligonum comosum* wild plant is close to alfalfa CP values. In addition ~~to~~ CP% of *Calligonum comosum* plant takes the Fair grade according to Putnam and Undersander (2019) for alfalfa hay. Regarding Ash% in *Calligonum comosum* wild plant and alfalfa leaves were 14.70 and 6-15% respectively, however CF% values were higher in *Calligonum comosum* wild plant than the in alfalfa hay as optimum value (11.8-12%). Concerning ADF% the of *Calligonum comosum* wild plant (24.62%) was lower than the value of alfalfa (<27-35) where the ADF grade for forage quality is supreme when the value is less than 20% according to Putnam and Undersander (2019) and Stivers et al (1983).

Table 5: The comparison of CP, ash, CF, ADF, DW, DMD and ME maximum contents between *Calligonum comosum* wild plant and alfalfa hay as forage.

Characters	*Calligonum* comosum wild plant	Grade according to Putnam and Undersander (2014) for alfalfa hay	Alfalfa
CP%	16.81	Fair	>22 - <16
Ash%	14.70	-	6-15
CF%	26.49	Fair	11.8-12.0
ADF%	24.62	Supreme	<27- >35
DW	40.21	-	-
DMD	60.52	-	-
ME	8.55	-	-

4. CONCLUSION

The *Calligonum comosum* plant is one of the wild plants widely spread in the Kingdom of Saudi Arabia, especially in the Eastern Province. This plant can survive in difficult desert conditions. This plant grows under desert stress such as lack of water, fertilization and high temperatures during growth periods. The components change monthly in the plant body, which affects its quality as feed for wild animals. The results showed that this plant can be used as fodder for the months of January ~~and~~ March, as the values of crude protein are high. From the results of the data obtained we can conclude that *Calligonum comosum* wild plant which grow in difficult stress conditions can be used as forage for wild animals such as Kamal, goats and sheep in desert. This plant grows grow under desert stress due to lack of water, fertilization and high temperatures between months during growth periods.

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الملخص العربى

التغييرات الشهرية في جودة نبات الارطي *Calligonum comosum* للرعي وتقدير القيم القصوى لجودة العلف باستخدام المعادلة التربيعية متعددة الحدود

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متابعة التغييرات الشهرية من حيث الجودة كمادة علفية لنبات الارطى *Calligonum comosum* والذي ينمو بشكل طبيعي في محطة الابحاث والتدريب بجامعة الملك فيصل ، الأحساء ، المملكة العربية السعودية من شهر سبتمبر / ٢٠١٩ إلى شهر مايو / ٢٠٢٠. حيث أظهرت النتائج وجود فروق معنوية بين القيم المسجلة خلال شهور الدراسة. وأشارت المعادلة التربيعية متعددة الحدود إلى أن القيم الأعلى للبروتين الخام (9.80٪) ، وزن المادة الجافة (40.21٪) ، الرماد (١٤,٧١٪) ، الألياف الخام (43.19٪) ، الألياف المهضومة بواسطة المنظفات الحمضية (٣٢,٦٪) ، وهضم المادة الجافة المهضومة (60.52٪) سجلت بين شهري ديسمبر وفبراير.

الكلمات الافتتاحية: *Calligonum comosum*، نبات رعوي، جودة العلف، الالياف المهضومة بالاحماض، المعادلة التربيعية متعددة الحدود، الأحساء، المملكة العربية السعودية