ISSN: 2643-671X

Research Article

Journal of Agriculture and Horticulture Research

Innovating Forage Production System in Kuwait Using Locally Adapted Native Desert Plant Species

Tareq A. Madouh*[1] and Tareq A. Al-Sabbagh[2]

1,2 Desert Agriculture Ecosystems Department, Environmental & Life Sciences Research, Kuwait Institute for Scientific Research, Kuwait

***Corresponding author**
Tareq A. Madouh*, Desert Agriculture Ecosystems Department, Environmental & Life Sciences Research, Kuwait Institute for Scientific Research, P.O. Box 24885, Safat 13109, Kuwait

Submitted: 15 Feb 2021; **Accepted**: 28 Feb 2021; **Published**: 03 March 2021

Citation: *Tareq A. Madouh and Tareq A. Al-Sabbagh (2021).Innovating Forage Production System in Kuwait Using Locally Adapted Native Desert Plant Species. J Agri Horti Res, 4(1):53-61*

Abstract

The native vegetation of Kuwait is well adapted to hyper arid environment and once these naturally vegetated plants are managed properly these may be considered potential candidates as animal feed. Bringing the neglected and underutilized native plant species into animal food chain is promising. Considering the importance of some native plants, five native forage species (Cenchrus ciliaris, Cenchrus setigerus, Lasiurus scindicus, Panicum turgidum and Pennisetum divisum) were compared to widely used exotic forage species Panicum virgatum to measure the effects of fall (October) vs spring (March) planting on the biomass yield and the nutritive value. The results indicate that four species, C. setigerus, C. ciliaris, L. scindicus and P. divisum, showed a higher dry matter production in the spring planting season with relative increase in the nutritive values, i.e., NDF, ADF, fat, protein and ash concentrations as compared to P. virgatum. In general fall season planting, decreased the dry matter production and the nutritive values compared to the spring season. These findings provided opportunities to utilize the natural resources for increasing and or improving livestock feed supply. There is potential for growers to integrate these local forage species into their forage production system.

Key words: Biodiversity, Sustainability Native desert forages integration, Farming system, Planting season, Biomass production, Nutritive value, Livestock feed

Introduction

The impacts of climate change on livestock production as well as quality of feed are much greater in the Arabian Peninsula and many arid regions of the world as compared to those in the rest of the world. Therefore, use of indigenous plant species as alternate animal feed is the main agronomic goal in this region [1]. During the latter half of the 20th century, the Arabian Peninsula, including Kuwait, experienced very rapid economic development that led to dramatic changes in the traditional agricultural systems with major implications on the sustainability of the natural ecosystems. Major limitations for large-scale outdoor production of any crop in this region are drought, salinity and heat stresses. Therefore, forage crops from temperate region are not well adapted to this region due to their lack of tolerance to these abiotic stresses. Availability of water continues to be a critical factor in the Arabian Peninsula as evident from 'Extreme Water Scarcity' classification of this region, i.e. per capita renewable water resources is less than 500 cubic meters per year [2]. Although efforts are underway to promote recycling of treated wastewater (TWW) for forage irrigation, the progress to-date is rather dismal due to infrastructure limitations. Native plants in Kuwait rangelands are well adapted to the abiotic stresses in this region except for their inherent low biomass production per unit area in their native status under extreme low input use. The productivity of these native plants and their feeding quality need to be assessed under low to moderate input uses to evaluate their potential as animal feed to substitute heavy reliance on expensive imported feed.

The native plant biodiversity of the Arabian Peninsula comprises more than 3500 species [3]. The rangelands of Kuwait constitutes approximately 70% of total land area with 374 plant species from 55 families that are recognized, these desert species provides an important source of feed to meet the demands of the livestock raised by herdsmen and Bedouins[4-5]. However, in recent years, the growing conditions and productivity of most rangelands in the country have declined due to over grazing, extreme weather patterns impacted by climate change, and land degradation due to heavy traffic and war activities. Increased biotic stress has disturbed the ecological balance. Increasing aridity is a major factor limiting the regeneration and production potential of native vegetation in Kuwait. In the most recent years a gradual reduction in rainfall and growing temperatures have been observed which have further widened the gap between precipitation amounts and water demand in vegetation [6].

[7-8] prioritized the Arabian Peninsula desert species that have potential for use either for fodder production or for rehabilitation and restoration, and listed 27 species of high priority for forage production. Similarly, [9], in the annual report of 2001/2002 for the International Center for Agricultural Research in the Dry Areas – Arabian Peninsula Regional Program (ICARDA-APRP) reported the importance and priority grass species in most countries of the Arabian Peninsula to obtain large quantities of seeds from these species and lay the grounds for mechanized seed multiplication.

The main objective of this investigation is to evaluate the effects of planting season on the productivity as well as feed quality of five indigenous plant species as potential forage crops to support Kuwait livestock industry and other Arabian Gulf countries.

Materials and Methods

Plant Materials

The native grass species *Cenchrus ciliaris, Cenchrus setigerus, Lasiurus scindicus, Panicum turgidum and Pennisetum divisum* as well as an exotic species *Panicum virgatum* were used in this experiment. The selected test plants were directly sown in the field on October 5th, 2017, and March 4th, 2018, under drip irrigation. The field experiment was designed to investigate the effects of fall (early October) vs spring (early March) seeding dates on the yield, nutritive value and dry matter production of different native forage species.

Plant Establishment

The experiment was conducted in KISR Station for Research and Innovation (KSRI), Sulaibiya area. The field was tilled and the test species were randomly planted in prepared pits of 50 x 50 cm in each plot of approximately 300 x 300 cm. At least six plants were planted in each pit for each species to ensure maximum survival rate. All forage species were irrigated daily, except on rainy days, and were thinned during the fourth leaf stage and the data were recorded. Therefore, the experiment was arranged in a randomized, complete block design with seeding date and species interaction in a split-split plot design. The seeding dates (fall versus spring planting) were the main plots and the different forage species were the subplots.

Plant Growth Parameters

The experimental design consisted of six grass species, two planting dates with four replications. The response parameters included: weekly measurement of plant height, and plant biomass at harvest. The feed quality was evaluated by measuring contents of: ash, crude protein, fat, neutral detergent fiber (NDF), acid detergent fiber (ADF). The biomass samples were ground with a mill (Thomas Scientific; GE motor industrial system) to pass through a 1.0 mm screen. The forage quality analytical methods described by the Association of Official Analytical Chemists were used [10].

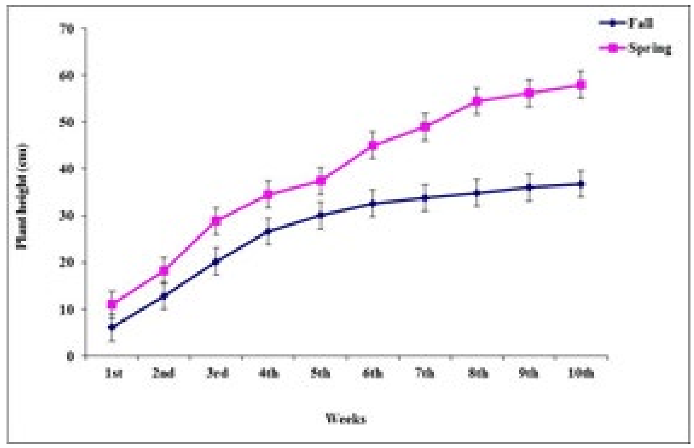
Statistical Analyses

All recorded data were subjected to statistical analysis using SAS (version 9.4) for comparisons across groups. Specially constructed graphs illustrate the logical manipulation of different treatment effects across the forage plant species.

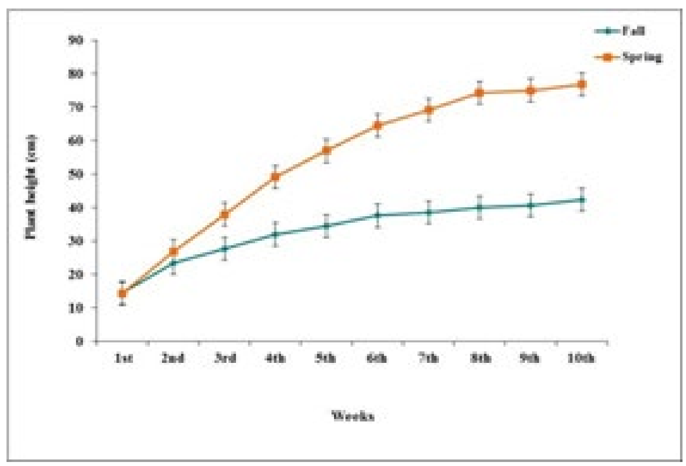
Results

Plant Height

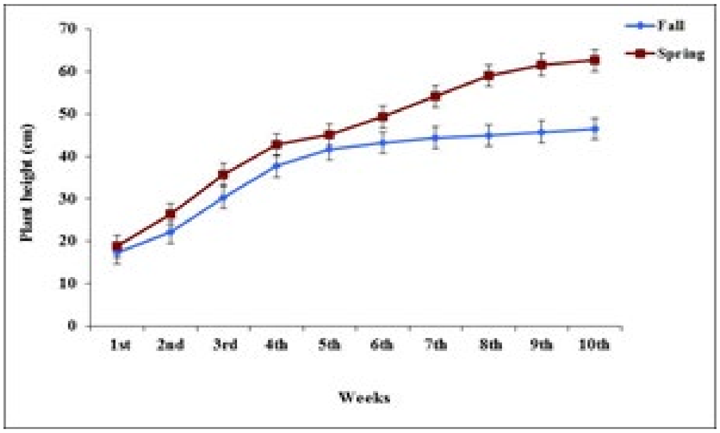
Considerable differences in plant height were observed between all forage species evaluated in this study [Figure 1].



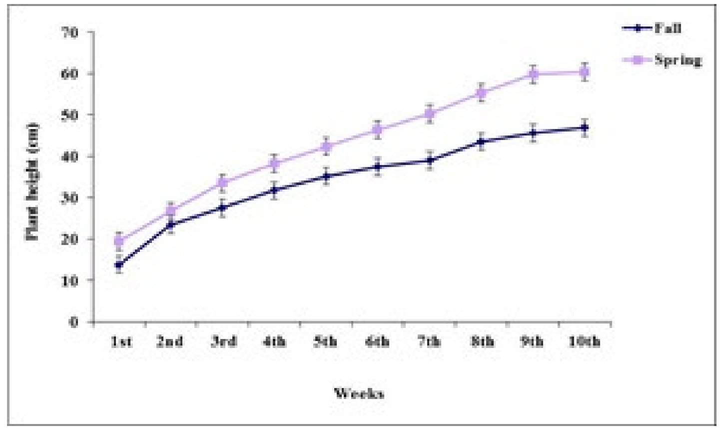
C. ciliaris



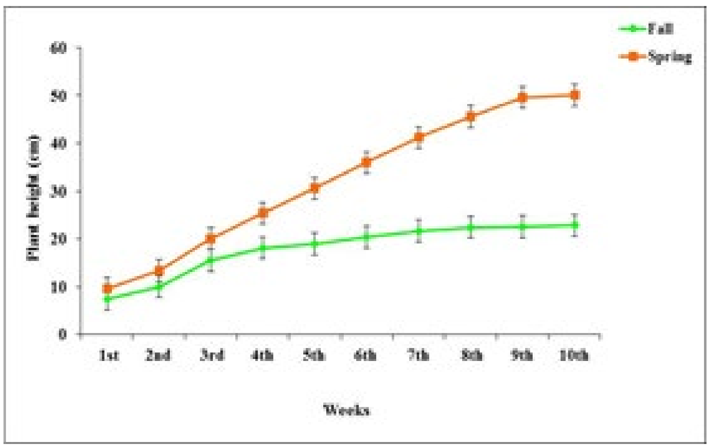
C. setigerus



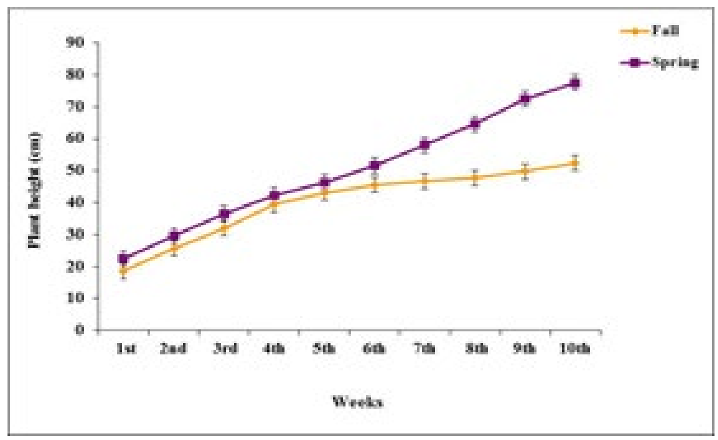
L. scindicus



P. divisum



P. turgidum



P. virgatum

Figure.1: Plant height measurement of the forage species recorded for the fall and spring planting treatment on a weekly basis. NB: Bars(I) represent standard errors of means (SEM) at 95% confidence intervals for comparisons by treatment within species; degrees of freedom (df) = 80.

Weekly plant-height measurements were recorded on *C. ciliaris, C. setigerus, L. scindicus, P. turgidum and P. divisum.* All varied in the fall and spring planting treatment under the irrigation system when compared to *P. virgatum*. Plant height increased significantly ($P<0.001$) (Table 1) over time in both planting seasons. The plant height was greater in spring as compared to that in fall planting across the entire study period across all species. However, significant difference in plant height between the two planting seasons occurred: after the 3rd week in *C. ciliaris*, *C. setigerus*, and *P. divisum*; after the 4th week in *P. turgidum*; and after the 6th week in *L. scindicus* and *P. virgatum*

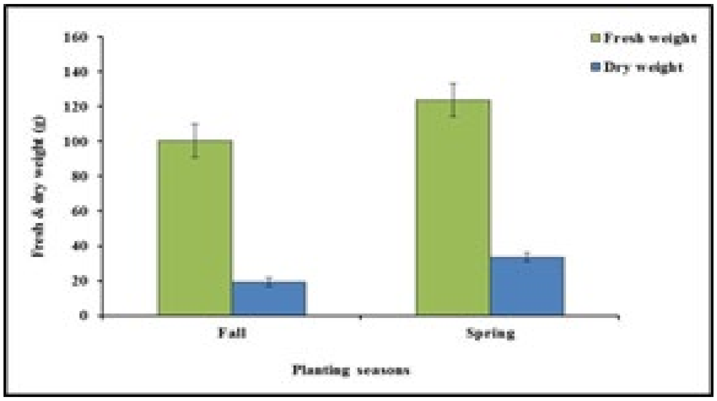
Table 1. Two way Analysis of Variance on effects of planting season and species on biomass yield and nutritive value of six forage species.

Variable	DF	F value	Pr>F
Plant Height Season	 1	 4.1**	 0.0491
Species	5	16.2***	<.0001
Season*Species	4	5.4***	0.0005
Fresh weight Season	 1	 6.5**	 0.0139
Species Season*Species	5 4	16.9*** 3.7***	<.0001 0.0070
Dry weight Season Species Season*Species	 1 5 4	 6.8** 12.7*** 3.4**	 0.0120 <.0001 0.0102
Ash Season Species Season*Species	 1 5 4	 11.0*** 26.1*** 17.3***	 0.0018 <.0001 <.0001
Fat Season Species Season*Species	 1 5 4	 3.6** 10.4*** 4.3***	 0.0639 <.0001 0.0025
Protein Season Species Season*Species	 1 5 4	 21.2*** 26.8*** 3.5***	 <.0001 <.0001 0.0085
NDF Season Species Season*Species	 1 5 4	 779.5*** 9.9*** 11.1***	 <.0001 <.0001 <.0001
ADF Season Species Season*Species	 1 5 4	 19.1*** 133.1*** 1.4ns	 <.0001 <.0001 0.2471

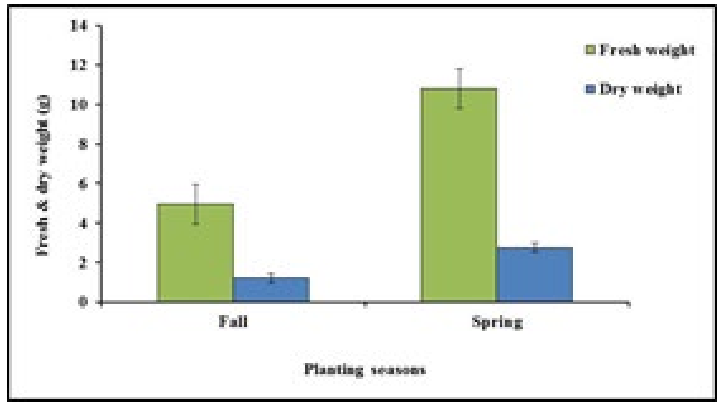
The plant height was greater in spring as compared to that in fall planting across the entire study period across all species. However, significant difference in plant height between the two planting seasons occurred: after the 3rd week in *C. ciliaris*, *C. setigerus*, and *P. divisum*; after the 4th week in *P. turgidum*; and after the 6th week in *L. scindicus* and *P. virgatum*. Plant height increase was much steep after 5 to 6 weeks of planting in all forage species in spring vs fall planting. The plant height at harvest for fall vs spring planting were: 37 vs 58, 42 vs 77, 47 vs 63, 23 vs 50, 47 vs 60, and 53 vs 78 cm for *C. ciliaris, C. setigerus, L. scindicus, P. turgidum, P. divisum, and P. virgatum,* receptively.

Plant Biomass

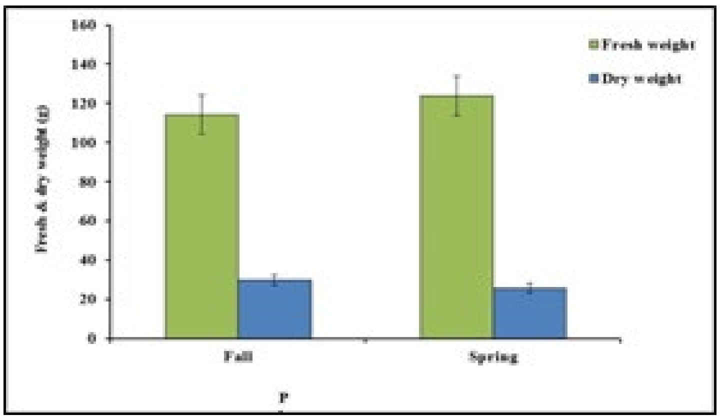
The differences in top growth, fresh and dry weight were observed between all forage species and planting seasons (i.e., fall versus spring) at the end of experiment [Figure 2].



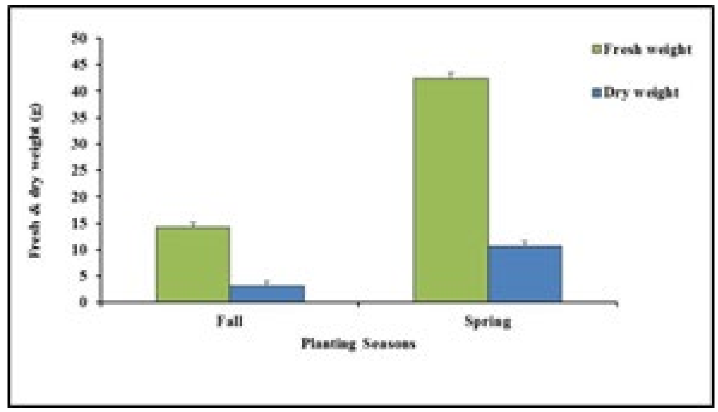
C. ciliaris (df) = 68



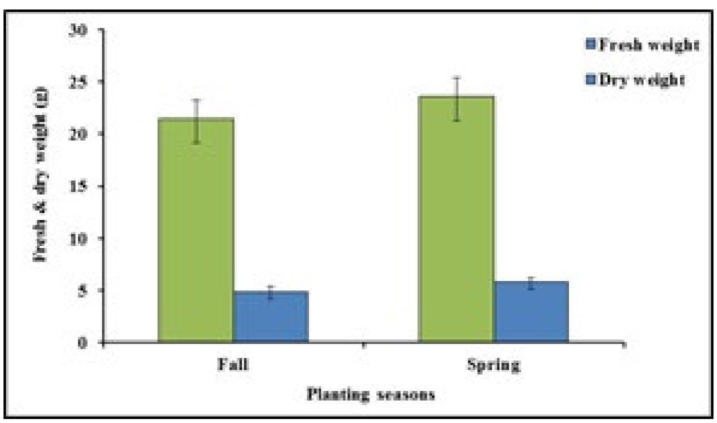
L. scindicus (df) = 53

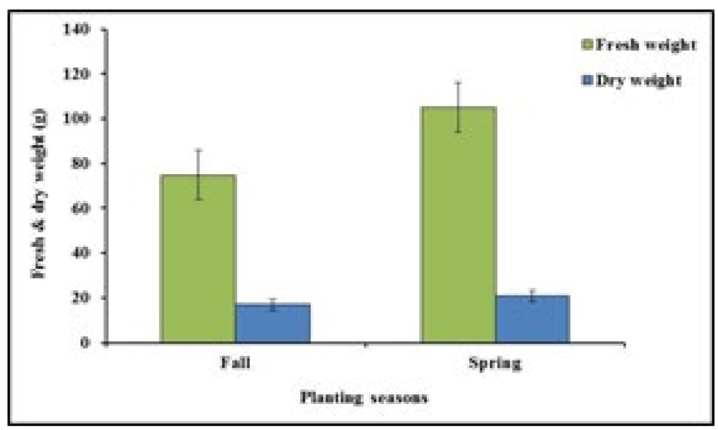


C. setigerus (df) = 53



P. divisum (df) = 53





P. virgatum (df) = 53

Figure 2: Fresh and dry biomass weights for the forage species in fall and spring planting. NB: Bars (I) represent standard errors of means (SEM) at 95% confidence intervals for comparisons by treatment within species; degrees of freedom (df) = 68, 53

Four out of six species with the exception of *C. setigerus* and *L. scindicus* tended to show increased fresh and dry weight under the spring planting season treatment, although differences were always significant (P<0.05) (Table 1). Nevertheless, the fresh and dry weight was lower in all of the forage species grown in the fall season treatment compared to the spring season treatment. The fresh and dry weight of *C. setigerus* showed no significant increase in both planting seasons, i.e., fall versus spring (Figure. 2). Slight differences in fresh weight occurred in the spring season planting than in the fall season planting, but the differences were not significant. The maximum mean values of the fresh and dry weight recorded in *C. setigerus* for the fall planting season were 114.2 and 29.76 g, respectively, and for the spring planting season, 123.9 and 25.64 g, respectively.

A similar trend of fresh and dry weight appeared in *L. scindicus*, and the differences were non-significant [Figure 2]. Top growth was reduced in *L. scindicus* under both planting seasons. The fresh weight recorded for the fall and spring planting was 21.46 vs 23.59 g, and the dry matter recorded was 4.88 vs 5.79 g, respectively.

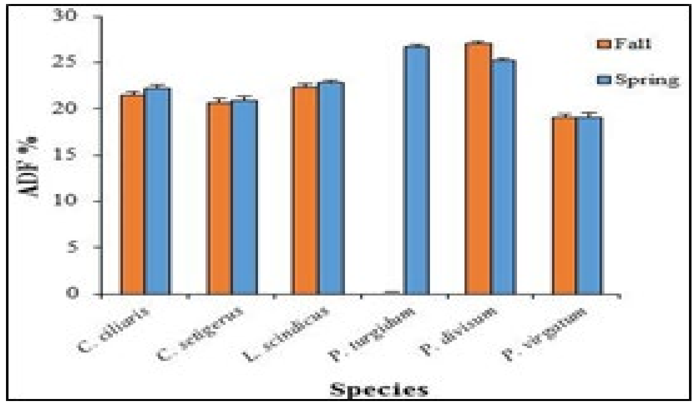
In case of *P. turgidum* the fresh and dry weight was significantly greater in the spring season planting compared to that in the fall season planting (P<0.001) (Table 1) (Figure. 2). However, analysis of the data showed that this species had a poorer fresh and dry weight for both planting seasons compared with the other forage species. The maximum mean values of the fresh and dry weight recorded in *P. turgidum* for the fall planting season were 4.97 and 1.24 g, respectively, and for the spring planting season, 10.81 and 2.76 g, respectively.

The fresh and dry weight of *P. divisum*, was significantly greater (P<0.001) (Table 1) in the spring season planting than that of the plants grown in the fall season planting (Figure. 2). The maximum mean values of the fresh and dry weight recorded in *P. divisum* for the fall planting season were 14.23 and 3.1 g, respectively, and for the spring planting season, 42.4 and 10.67 g, respectively.

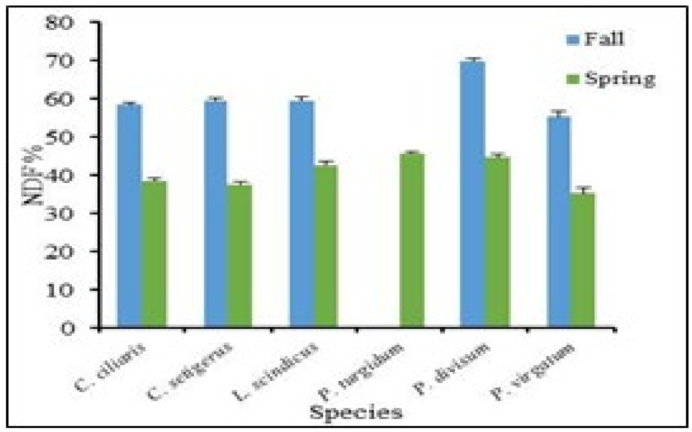
In *P. virgatum* only the fresh weight recorded significantly greater top growth during the spring season planting compared to the fall planting season with the maximum mean values of 104.9 and 74.8 g, respectively, (Figure. 2). The dry matter showed slight increase of 20.79 g in the spring planting season over the increase of 16.9 g in the fall planting season, but the difference was not significant.

Feeding Quality of Biomass

Native forage species varied in their nutritive values concentration when compared to *P. virgatum* in the fall and spring planting treatments. The laboratory analysis results of all the investigated forage species indicate that nutritive values increased significantly (P<0.001) (Table 1) under different growing seasons, i.e., fall versus spring (Figure 3-5).

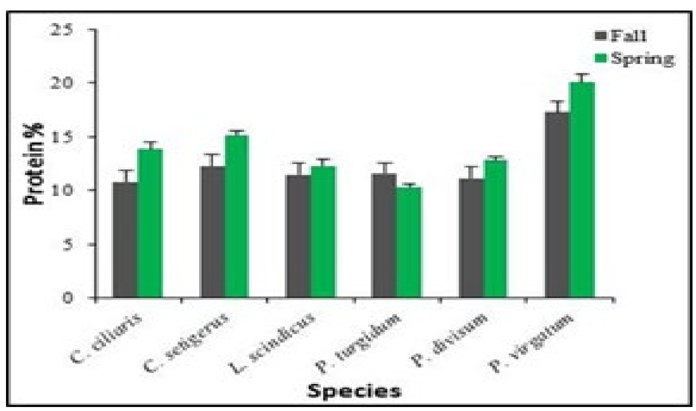


(A) ADF percentage

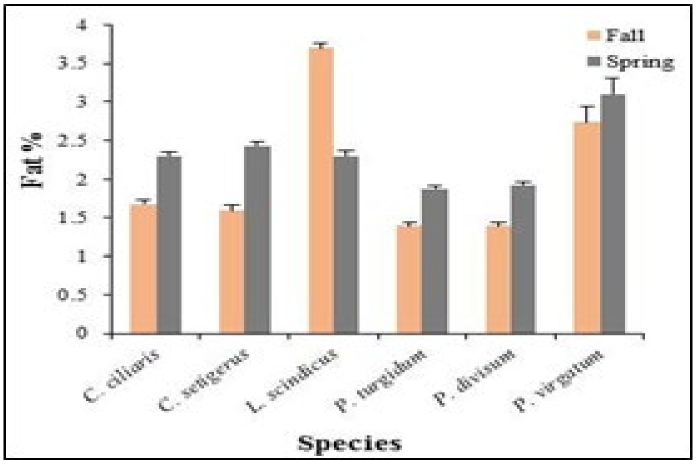


(B) NDF percentage

Figure 3: ADF (A) and NDF (B) percentage in biomass of all forage species in fall and spring planting. NB: Bars (I) represent standard errors of means (SEM) at 95% confidence intervals for comparisons by treatment within species; degrees of freedom (df) = 10.



(A) Protein percentage



(B) Fat percentage

Figure.4: Protein (A) and Fat (B) percentage in forage biomass of all species in fall and spring planting. NB: Bars (I) represent standard errors of means (SEM) at 95% confidence intervals for comparisons by treatment within species; degrees of freedom (df) = 10.

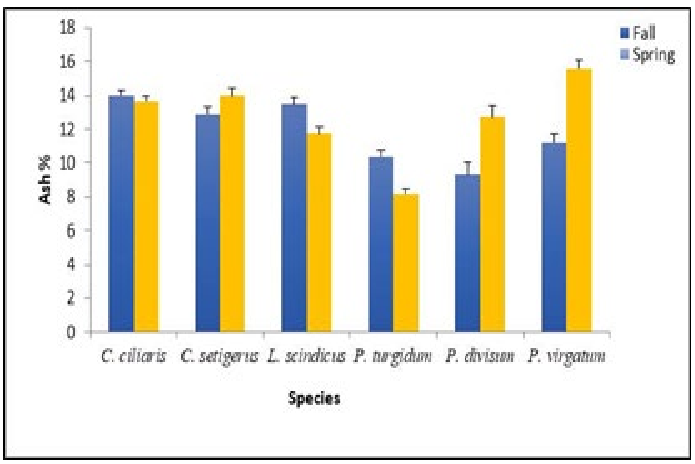


Figure. 5: Ash percentage of all forage species in fall and spring planting. NB: Bars (I) represent standard errors of means (SEM) at 95% confidence intervals for comparisons by treatment within species. d.f. = 10

NDF and ADF content

Data on nutritive value showed that the tested native forage species had significantly ($P<0.001$) (Table 1) higher content of NDF but not significantly so of ADF in the dry matter than *P. virgatum* in both planting seasons (Figure. 3 A and B). The maximum level of NDF and ADF content in the fall and spring planting treatments was observed in *L. scindicus*, *P. turgidum* and *P. divisum* compared to that in *P. virgatum*. In *C. setigerus* and *C. ciliaris* also, the NDF and ADF values were greater than *P. virgatum* in the fall planting treatment but in the spring planting treatment the NDF values were nearly similar to *P. virgatum* (not significant). The lowest values recorded for ADF and NDF was for *P. virgatum* with a mean value of 19.03% and 55.39%, respectively, recorded in the fall treatment and 19.07% and 35.4%, respectively, recorded for the spring treatment (Figure 3 A and B).

Proteins Content

The protein percentage value of the native forage species was significantly ($P<0.001$) (Table 1) lower than that of *P. virgatum* in both planting seasons (Figure. 4A). The maximum level of protein percentage 17.3% and 20.06% was observed in *P. virgatum* in the fall and spring planting treatments, respectively. In contrast, the minimum protein percentage detected in *P. turgidum* was 11.6% and 10.38% for the fall and spring planting seasons, respectively (Figure 4A). The protein percentage value of *C. ciliaris*, *C. setigerus*, *L. scindicus* and *P .divisum* were also considerably lower than that of *P. virgatum* in the fall and spring planting treatment but not as low as that of *P. turgidum*.

Fat Content

The fat content measured in the dry matter of all forage species investigated during the fall and spring planting seasons followed the trend of the protein data. With the exception of *L. scindicus* in the fall treatment, all native forage species showed substantially lower fat content compared to *P. virgatum* in both planting seasons (Figure 4B). *L. scindicus* recorded considerably higher fat percentage of 3.7% in the fall treatment than the other forage species including the control, but not so in the spring treatment (Figure 4B). Nevertheless, the fat content 2.7% and 3.1%, of *P. virgatum* was significantly ($P<0.001$) (Table 1) greater during the fall and spring treatment than that of the other tested forage species. In contrast, the lowest fat percentage 1.3% and 1.8% was noticed in *P. turgidum* for the fall and spring planting seasons, respectively (Figure 4B). The fat percentage value of *C. ciliaris*, *C. setigerus*, and *P. divisum* was also considerably lower than that of *P. virgatum* in the fall and spring planting treatment but not as low as that of *P. turgidum*.

Ash Content

The ash percentage value of the native forage species was not consistently lower than that of *P. virgatum* in fall planting seasons but significantly so in the spring planting season (Figure 5). The highest ash percentage of 15.6% was observed in *P. virgatum* in the spring planting, whereas in the fall planting season, *C. ciliaris* had significantly ($P<0.001$) (Table 1) greater ash content of 14.02%. In contrast, the minimum ash percentage of 10.38% and 8.2% was detected in *P. turgidum* for the fall and spring planting seasons, respectively (Figure 5). The ash percentage value of *C. setigerus*, *L. scindicus* and *P. divisum* were also considerably greater than that of *P. virgatum* in the fall planting treatment but not in the spring planting treatment.

Discussion

This research was conducted to identify the native desert perennial grass species as potential forage crops based on evaluation of nutritive value of the biomass as influenced by planting time. Five desert grass species from Kuwait were compared to *P. virgatum* to measure the effects of fall (early October) vs spring (early March) planting on the biomass yield and the nutritive value. In the spring (early March), the seedling establishment of all forage species was superior when planted in spring as compared to that when planted in fall, which in turn contributed to greater plant height and biomass production of the former as compared to that of the latter planting. Seedlings of all forage species planted in (early March) survived summer heat under supplemental irrigation. In contrast, fall planting (early October) did not result in good establishment and growth rate despite adequate irrigation, suggesting that these forage species are warm-season grasses. [11] Reported that maximum yield potential of warm-season forage crops are obtained in warm summer season with adequate soil moisture.

The biomass production of spring planted *C. ciliaris*, *C. setigerus*, *L. scindicus* and *P. divisum*, were comparable to that of *P. virgatum*. *C. ciliaris* and *C. setigerus* produced more leaves, had greater top growth and accumulated more dry matter as compared to that of the other forage species including *P. virgatum,* therefore, the former species would competitive during establishment. Spring planted *C. ciliaris* and *C. setigerus* produced greater dry matter yield, i.e. 33 and 26 g, respectively, compared to 21 g biomass of *P. virgatum*. *L. scindicus* and *P. divisum* developed greater number of tillers but their leaves were fewer than those for *P. virgatum.* Spring planted *L. scindicus* and *P. divisum* produced greater biomass as compared to that of *P. turgidum*. As per the results *C. ciliaris*, *C. setigerus*, *L. scindicus* and *P. divisum*, survived the summer stress and grew healthy when conditions improved, therefore, are well adapted for spring planting (early March) and can tolerate the desert environment. Accordingly, these forage species are suitable for their use for sustainable commercial forage production in arid region [7].

The above-mentioned forage species can be well established under warm conditions of 30 - 35oC. Temperature below 10°C at night is reported to slow the growth of warm season grasses [11]. To optimize yield under normal conditions, these native forage species need to be seeded in the spring (early March) to take advantage of spring moisture and moderate temperatures. [12] Reported that slight alteration in climatic conditions at the time of seeding could be a major factor in achieving successful seedling establishment and vigorous growth. Because of later maturity and tolerance to warmer temperatures, these forages remain green, continue to grow into the summer season and may have a better chance of producing a high forage yield [11]. As per the reports forage yields increases with advancing maturity in different species before the yield decreases during senescence [13]. Overall, these forage species can be harvested in early-mid June, September and early December just prior to cool temperatures of the winter weather conditions to achieve the maximum forage yield.

There were considerable variations in the nutritive values observed between all forage species [Figure 3-5]. Data on nutritive value showed that native forage species had significantly ($P<0.001$) higher content of total NDF than *P. virgatum* in both the planting seasons (Figure 3 A and B). Among all of these forage species, *L. scindicus*, *P. turgidum* and *P. divisum* had high levels of fiber compared to that for *P. virgatum* in both planting seasons. This could be due to the alterations in morphological growth and leaf: stem ratio between the forage species [14]. In fall planted *C. setigerus* and *C. ciliaris* the NDF and ADF values were greater than those in *P. virgatum*. This difference was not evident in spring planted treatment. [15] reported that forage quality decreased with rising maturity caused in growth reduction level and tillers overripe.

The NDF concentration in each forage species was greater when planted in fall as compared to that planted in spring season. Since these forage species are warm season grasses, it is likely that they developed and matured rapidly during the spring season, which decreased the NDF concentration. The NDF content is extremely important in generating a quantitative forage energy prediction [16]. The increased levels of NDF content accumulated by most of the native forages suggest that more digestible fiber is available and is more efficient to the animals in digesting the desert grasses, which can be a further advantage for using naturally adapted forage species [7]. A high NDF in the feed contributes to increased energy, enhanced performance and greater milk yield in animals [17]. This suggests that the use of these native desert forages as animal feeds can increase the sustainability of livestock production in Kuwait.

Planting season influenced the biomass protein content of all species. In both seasons, the protein content was highest in case of *P. virgatum* (Figure 4A). Across all forage species, except for *P. turgidum*, the protein content was greater in spring as compared to that of the fall planted biomass. As per the reports, the protein concentration of forage grasses may decline with season and harvesting date [13]. Fales et al., [18] reported that protein and energy contents of the feed are greater in spring and fall as compared to those in summer. These fluctuations in nutrient content are closely correlated with the growth cycle of the forages. Nevertheless, the protein concentration of all forage species increased as drought stress increased.

The fat percentage was lower in fall as compared to that in spring planted biomass across all the species except that in *L. scindicus* which showed the reverse trend. (Figure 4B). [13] also reported that planting season influences the rate of plant growth and in turn forage quality and nutrient composition.

The ash percentage was highest in spring planted *P. virgatum,* while it was lowest in spring planted *P. turgidum*. In fall planting, however, the biomass ash content was greater in *C. ciliaris*, *C. setigerus*, and *L. scindicus* as compared to that in rest of species. Changes in the chemical composition with age of warm season grasses are probably due to variations in their phytomorphology, particularly the leaf: stem ratio [19]. [20],stated that the dry matter yield, total fibre, nitrogen, and ash content of warm season grasses can be significantly affected by the maturity stages and soil fertility during development.

Conclusion

The tested native forage species have shown great promise under hyperarid environment of Kuwait to be included in the forage production system. This will provide year around supply of fodder in Kuwait and reduce the gap between fodder import and local production. Farmers may integrate these native forages in the dry matter production for more diversity and pliability in their farming systems.

Acknowledgement

The author wishes to acknowledge the Kuwait Foundation for the Advancement of Science (KFAS) for financial support of the project and the Kuwait Institute for Scientific Research (KISR) for providing facilities and kind support.

Disclosure statement

The authors declare that there are no conflicts of interest.

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