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Full Length Research Paper

Forage yield and survival of native range species under supplementary irrigation in Central Saudi Arabia

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The increase of livestock production in Saudi Arabia has resulted in a parallel increase in demand for forage production and hence greater exploitation of ground water for irrigation. The current trend of water conservation policies necessitates finding alternate sources of forages that consume less water than the traditional forage crops. The objective of this study was to evaluate the forage yield and survival of some range species under certain levels of supplementary irrigation. The evaluated species were *Atriplex halimus*, *Atriplex leucoclada, Farsetia aegyptia, Salsola villosa* and *Artemisia sieberi.* The supplementary irrigation treatments were: yearlong irrigation with an amount of 480 mm water, summer and fall irrigation (240 mm), summer irrigation (120 mm) and no supplementary irrigation. Results showed that supplementary irrigation of native range species during summer season increased yield by more than 3-fold over the rain-fed stand. This increase was associated by improvement in the plant survival. Of the five species evaluated, the two saltbushes *A. halimus and A. leucoclada* produced exceptionally high yield. This study suggested that there is a great potential for the use of native range species as efficient alternatives for the high water demanding traditional forages in arid regions.

Key words: Forage yield, range plants, supplementary irrigation.

INTRODUCTION

It is estimated that about 216,000 ha of agricultural lands in Saudi Arabia are currently cultivated with forage crops, producing nearly 326,000 tons per year (Ministry of Agriculture and Water, 2002). The main forage crops are alfalfa and rhodesgrass. The most important limitation to forage crop production is their high demand for the already scarce water resources. With incessant increase in demand for red meat, the demand for forage production will continue to increase. It is estimated that average national demand from alfalfa and rhodesgrass is over 2 million tons/ year (Alabdulkader et al., 2012). It is estimated that alfalfa requires 30,000 to 37,000 m^3 ha^{-1} $year^{-1}$ of irrigation water while rhodesgrass consumes nearly 17,000 to 24,000 m^3 ha^{-1} $year^{-1}$ of irrigation water depending on irrigation system used, climatic conditions and location (Al-Zaid et al., 1988).

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Demand for red meat is expected to increase steadily as indicated by the import figures of nearly 5 million live heads of sheep and the consumption of nearly so of locally raised sheep in 1999 (Ministry of Planning, 1999). Consequently, more demand for forage production and hence continuous demand for irrigation water is expected. The current government agricultural policy is geared towards reducing wheat and forage cultivation to conserve irrigation water. As a result, it is inferred that nearly 28,000 central pivots are now abandoned (Al-Qunaibet, 1994).

To utilize the abandoned central pivots, some farmers are beginning to cultivate native range browse species (Al-Hassan, 1997). Although this practice is new to the country, there are some studies demonstrating the potential use of native or introduced range shrub species for cultivation. Mirreh et al. (1995) reported that *Atriplex halimus* and *Atriplex leucoclada* have produced 6.6 ton ha^{-1} when irrigated with 400 mm $year^{-1}$ under central pivot. Al-Hassan et al. (1998) found that production of *A. halimus, Atriplex nummularia, Atriplex canescens* and

Atriplex lentiformis ranged from 0.43 to 2.4 kg plant $^{-1}$ year $^{-1}$ depending on water quality and irrigation system.

The objectives of this study were to: (1) evaluate the possibility for cultivating five range plants (*A. leucoclada, A. halimus, Farsetia aegyptia, Salsola villosa* and *Artemisia sieberi*) under different levels of supplementary irrigation, (2) evaluate seasonal yield distribution of the species and (3) evaluate species persistence under varying irrigation regime and sequential seasonal harvesting. All species under study are native to Saudi Arabia (Chaudhary, 1999) and have high to fairly good nutritive values (Abu-Zanat et al., 2003; Towhidi, 2007; Haddi et al., 2009). The two saltbushes; *A. halimus* and *A. leococlada* are amenable to inclusion into agro-sylvo-pastoral systems of production in arid lands (Le Houérou, 1992). *S. villosa* was the most important grazing shrub in northern rangelands of Saudi Arabia before overgrazing led to severe rangeland degradation (Chaudhary and Le Houerou, 2006). *F. aegyptia* and *A. sieberi* occur in several Middle Eastern countries but also decreased in abundance due to overgrazing (Brown and Al-Mazrooei, 2003; Bagheri et al., 2007).

MATERIALS AND METHODS

The study was conducted at the Agriculture Experimental Research Station, College of Food and Agricultural Sciences, King Saud University in Dirab (24° 42' N, 44° 46' E), 35 km south west of Riyadh. The soil is sandy loam and slightly alkaline (pH = 8.2, EC_e = 2.3 Mohs. cm^{-1}). The total amount of rainfall during the first and the second year of the experiment were 52.1 and 67.1 mm, respectively. The mean temperature was 26.2℃ in the first year and 27.0℃ in the second year. A sprinkler irrigation system consisting of four separate blocks was established and tested for uniformity of water distribution and for time required to deliver 20 mm (the amount of irrigation water at any one event).

The experiment was laid as a restricted split plot with four replicates. Each irrigation treatment (main plots) was fixed to one of the four blocks while species were randomly assigned in each replicate. Seeds of all species were collected from wild populations in the Northern region of Saudi Arabia and sown in a greenhouse. Seedlings of uniform appearance were transplanted to the field at the age of 8 months. Sixteen seedlings per experimental unit were planted at a distance of 1 m in all directions in two rows. Seedlings were irrigated every two-weeks with an amount of water equivalent to 20 mm for 15 months to attain plant establishment. Supplementary irrigation treatments were then imposed: 1) year-long irrigation (480 mm), 2) irrigation during fall and summer (240 mm), 3) irrigation during summer only (120 mm) and 4) non-irrigation treatment (rain-fed only).

Three months later, the current-year growth of leaves and twigs of all plants was cut by hand, but no growth measurements were taken. The amount of harvested material differed according to plant species, but generally, all harvested twigs and leaves were ≥ 3 mm. Leaf/stem ratio was determined but data were not included. The values were 0.70, 0.70, 0.20, 0.25, and 0.15 for *A. leucoclada, A. halimus, F.aegyptia, S. villosa* and *A. sieberi*, respectively.

Cutting continued every 3 months thereafter for the next two years to represent the cumulative seasonal dry matter production. Total fresh weight for each species was determined and a sample of 150 to 200 g was taken to determine dry matter content and other subsequent measurements. At each cutting time, persistence was also determined as the percentage of surviving individual plants. Data were subjected to the analysis of variance using SAS statistical package (SAS, 1988) and mean differences were tested using LSD $_{0.05}$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Dry matter percentage was not significantly affected by supplementary irrigation treatments but significant differences were observed in forage yield and plant survival among different irrigation treatments (Table 1). Averaged over the two years, seasons and species, supplementary irrigation treatments generally increased forage yield over the non-irrigated treatment (over 3-fold increase when irrigated during summer). However, differences were not significant among the three irrigation treatments (Table 1), suggesting that year-round supplementary irrigation or even during the period of fall and summer may not be feasible. This is in agreement with Powell et al. (1990) who found that yield of seeded perennial grasses was not different among first-year irrigation schedules. The general positive effects of supplementary irrigation are similar to those of other studies for different range plants (DePuit et al., 1982; Powell et al., 1990; Guevara et al., 2003). Generally, plant survival increased with increasing the amount of supplementary irrigation. Summer irrigation accounted for nearly 21% increase over rain-fed treatment indicating the importance of supplementary irrigation for maintaining a productive stand of shrubs during dry season. Similarly, Powell et al. (1990) found that certain irrigation rates were beneficial for seedling establishment and hence productivity of perennial grasses.

The measured attributes differed significantly among the four growing seasons (Table 1). The highest dry matter percentage was obtained during spring, while its lowest value was in fall (Table 1). Averages of forage yield varied from 208.8 kg/ha in summer to 491.1 kg/ha in winter. Survival percentage decreased as time progressed. It had the highest averages in winter (94.02%) and during the first year (99.38%). The percentage of both dry matter and survival showed highly significant values during the first year (Table 1).

The three measured attributes differed significantly among the five species (Table 1). *A. sieberi* had the highest dry matter percentage followed by *A. leucoclada* while *A. halimus* had the lowest dry matter percentage. These differences may reflect the inherited differences among the different species. Averaged over all other factors, *A. halimus* produced the highest forage yield (3 ton ha^{-1} year^{-1}) followed by *A. leucoclada* (2 ton ha^{-1} year^{-1}). However, there were no significant differences in forage yield between the other three species. In general, our results are comparable to those reported by others (Watson, 1990; Mirreh et al., 1995; Choukr-Allah, 1996; Al-Khateeb and Al-Gossibi, 2001; Abu-Zanat et al., 2004). With the exception of *A. leucoclada*, all species

Table 1. Mean values of dry matter, forage yield, and survival under different irrigation treatments within different seasons, years and five species.

Variable	Dry matter (%)	Forage yield (kg/ha)	Survival (%)
Irrigation			
Rain-fed only	48.6	2016	57.38
Summer (120 mm)	44.64	6976	78.32
Fall and Summer (240 mm)	43.07	7104	85.16
Year-round (480 mm)	42.83	6604	82.83
$LSD_{0.05}$	NS	1150.4	3.55
Seasons			
Winter	44.0	491.1	94.02
Spring	51.8	408.5	90.94
Summer	43.7	208.8	85.8
Fall	37.1	310.3	79.77
$LSD_{0.05}$	1.83	71.9	1.84
Years			
First year	47.68	1544.0	99.38
Second year	41.11	1301.6	75.85
$LSD_{0.05}$	1.05	NS	5.45
Species			
Atriplex leucoclada	49.10	7936	68.0
A. halimus	33.06	12480	95.9
Farsetia aegyptia	45.96	3088	93.5
Salsola villosa	42.48	2848	93.3
Artemisia sieberi	56.73	2016	85.9
$LSD_{0.05}$	2.47	1808	2.9

maintained relatively high survival (85.9 to 95.9%) suggesting a great potential for *A*. *leucoclada* as a forage resource.

The year and season had a significant interaction effect on both forage yield and plant survival (Table 2). Across seasons and within a year, forage yield was highest in winter of both years and lowest in fall and summer in the first and second year, respectively. Across years and within seasons, the forage yield was higher in the first year than in the second year except for fall where the reverse was observed. These differences could be attributed to the temporal and spatial variability of rainfall in the central region of Saudi Arabia (Alyamani and Sen, 1993). Plant survival was maintained at 100% for the first three seasons but decreased steadily thereafter (Table 2).

The averages of forage yield and plant survival were significantly affected by interaction of year and species (Table 3). Across years and within species, no specific trend was observed. However, forage yield of *A. leucoclada* was dramatically decreased in the second year, which could be probably due to the lower survival (Table 3).

The interaction between seasons and species showed significant effect on dry matter percentage, forage yield and plant survival (Table 4). Across species and within seasons, spring consistently had the highest dry matter percentage while other seasons did not demonstrate any specific trend. Across seasons and within species, no obvious trend was observed although apart from summer, *A. halimus* had consistently maintained the lowest dry matter percentage. These results are comparable to the findings of El-Shatnawi and Turuk (2002) for *A. halimus*. Within seasons, forage yield had no obvious trend. However, within species, *A*. *halimus* produced the highest forage yield except during summer and *A*. *sieberi* attained the lowest yield except during winter. As plant survival decreased with time, it was observed that within seasons and across species, winter had the highest survival, while fall had the lowest one. Within species and across seasons, the order of species survival from highest to lowest was as follows: *A. halimus, F. egyptia, S. villosa, A. sieberi* and *A. leucoclada* (Table 4).

The interaction between supplementary irrigation treatments and species had significant effect on both

Table 2. Effect of year and season on dry matter, forage yield and survival averaged over species and different levels of supplementary irrigation.

Year	Season	Dry matter (%)	Yield (kg.ha^{-1})	Survival (%)
First	Winter	45.9	581	100
	Spring	56.0	450	100
	Summer	46.1	256	100
	Fall	42.8	96	97.5
	LSD $_{0.05}$	2.5	96	1.0
Second	Winter	42.1	411	88.0
	Spring	47.8	367	81.9
	Summer	41.4	151	71.6
	Fall	33.1	373	61.0
	LSD $_{0.05}$	2.4	108	3.6
Average	Winter	44.0	491	94.0
	Spring	51.8	409	90.9
	Summer	43.7	209	85.8
	Fall	37.1	310	79.8
	LSD $_{0.05}$	1.8	72	1.8

Table 3. Dry matter, annual forage yield and survival of the five range species in the two years averaged over different irrigation treatments.

Year	Species	Dry matter (%)	Yield (kg. ha^{-1})	Survival (%)
First	*A. leucoclada*	49.3	3252	97.5
	A. halimus	39.4	2200	99.9
	F. aegyptia	50.3	732	99.1
	S. villosa	49.0	900	99.6
	A. sieberi	51.9	632	99.7
	LSD $_{0.05}$	2.8	107	1.1
Second	*A. leucoclada*	48.9	179	38.4
	A. halimus	33.1	4040	91.9
	F. aegyptia	46.0	812	87.8
	S. villosa	42.5	524	86.9
	A. sieberi	56.7	376	72.1
	LSD $_{0.05}$	2.5	120	4.0
Average	*A. leucoclada*	49.1	1984	68
	A. halimus	36.2	3120	95.9
	F. aegyptia	48.1	772	93.5
	S. villosa	45.7	712	93.3
	A. sieberi	54.3	504	85.9
	LSD $_{0.05}$	1.8	80.4	2.1

forage yield and plant survival. Across species, non-irrigated treatment generally had the lowest forage yield (Table 5). However, forage yield was not consistently parallel to the increase in supplementary irrigation (Table 5). Within species, the highest forage yield was produced by *A. halimus* followed by *A. leucoclada*. Across species and within irrigation treatments, non-irrigated treatment was characterized by the lowest plant survival. On the other hand, increasing the amount of supplementary irrigation was not constantly associated with increase in

Table 4. Dry matter, forage yield and survival of the five range species in different seasons of the year averaged over different irrigation treatments.

Species	Season	Dry matter (%)	Yield (kg. ha^{-1})	Survival (%)
A. leucoclada	Winter	44.5	522	82.5
	Spring	52.5	821	75.2
	Summer	49.0	507	64.1
	Fall	51.4	140	52.3
A. halimus	Winter	30.6	811	98.5
	Spring	44.0	961	97.5
	Summer	41.3	370	95.5
	Fall	29.3	980	92.2
F. aegyptia	Winter	45.9	360	97.5
	Spring	57.7	113	95.7
	Summer	39.7	30	92.5
	Fall	46.7	266	88.3
S. villosa	Winter	49.8	393	97.5
	Spring	50.0	100	95.3
	Summer	41.1	122	92.2
	Fall	42.5	98.5	88.1
A. sieberi	Winter	49.3	528	94.2
	Spring	55.8	59	91.0
	Summer	51.5	15	84.8
	Fall	34.3	70	77.7
	$LSD_{0.05}$	4.9	92	5.8

Table 5. Forage yield and survival of five shrub species in response to different irrigation treatments.

Species	Irrigation treatment	Yield (kg. ha^{-1})	Survival (%)
A. leucoclada	Rain-fed only	2288	59.6
	Summer (120 mm)	9440	68.5
	Fall and Summer (240 mm)	9520	88.7
	Year-round (480 mm)	10560	69.9
A. halimus	Rain-fed only	4320	85.2
	Summer (120 mm)	17600	98.6
	Fall and Summer (240 mm)	14880	99.8
	Year-round (480 mm)	13920	100.0
F. aegyptia	Rain-fed only	1152	85.2
	Summer (120 mm)	3328	97.3
	Fall and Summer (240 mm)	1120	98.7
	Year-round (480 mm)	1968	92.1
S. villosa	Rain-fed only	2240	84.9
	Summer (120 mm)	1696	92.4
	Fall and Summer (240 mm)	3600	98.2
	Year-round (480 mm)	3600	97.5

Table 5. Count'd.

A. sieberi	Rain-fed only	928	74.2
	Summer (120 mm)	2528	88.7
	Fall and Summer (240 mm)	1664	88.7
	Year-round (480 mm)	2976	96.1
	LSD $_{0.05}$	367	5.8

survival, as indicated by the high percentages under 240 mm supplementary irrigation (fall and summer irrigation), except for that of *A. sieberi*. Within species, *A. halimus* had the highest survival while *A. leucoclada* had the lowest.

In arid environments, water is the most limiting resource for forage production. Therefore, maximizing forage yield per unit of water used should be a priority. The present study indicated that supplementary irrigation of native range species during summer season increased yield by more than 3-fold over the rain-fed stand. This increase was partially contributed by improvement in the plant survival. Further supplementary irrigation during times other than summer would not likely be beneficial as evidenced from the non-significant differences among the supplementary irrigation treatments in terms of forage yield. Of the five species evaluated, the saltbush *A. halimus* produced exceptionally high yield. The study revealed that the examined range species would be alternative candidates for the high water demanding traditional forages. However, further work is needed to select a mixture of species that are well balanced in terms of high nutritive value and yield over the different seasons of the year in the arid regions.

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