Adaptive Strategies of Desert Grasses in Saudi Arabia

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Abstract

Adaptive strategies of dominant grasses in terms of stomatal resistance, rate of transpiration and photosynthesis, water potential of plants, and soil and water-use-efficiency were studied at 3 locations in the Kingdom. The locations chosen represented 3 different contrasting soil and climatic conditions of the regions. Results indicated that the desert plants have developed strategies to adjust stomatal behavior, rate of transpiration and water potential to cope with the harsh environment of the desert. The strategies involved appear to ensure survival of the species rather than high productivity.

Key Words: transpiration, photosynthesis, stomatal resistance, water potential, water-use-efficiency, protein, carbohydrates, drought tolerance

In Saudi Arabia, more than 70% of the land is considered rangelands covered with sand in one form or another. These rangelands have been the main sources of nutrition for different types of livestock.

The so-called desert ecosystem contains a multitude of plant species of grasses, forages, and shrubs which are under constant pressure by pastoral grazing and the environmental stresses. These plants have developed strategies both morphological and physiological to cope with the harsh environment of the desert (Mulrey and Rundel 1977, Noy-Meir 1973). Examples of morphological adaptation include leaf structure and orientation of leaves, leaf abscission, dormancy under adverse condition, and root-shoot ratio. Many desert plants operate on the C_4 photosynthetic pathway, which imparts drought resistance, efficient utilization of water and high light intensity under high temperatures. The physiological processes involved in the drought resistance or drought avoiding mechanisms usually include stomatal regulation, leaf water potential, transpiration, and photosynthesis adjustment. To what extent these processes are involved in adjusting to the harsh environment of the desert in Saudi Arabia have not been completely studied.

This study was undertaken to evaluate some of the physiological and nutritive characteristics of dominant grass species in 3 locations in the Kingdom.

Major objectives were (1) To evaluate the physiological performance of dominant desert grasses in terms of stomatal conductance, transpiration, water potential, and photosynthesis; (2) To determine the nutritional characteristics of these grasses; and (3) To use the information obtained through objectives 1 and 2 for seeking other species with similar characteristics for introduction and development in the Kingdom for livestock consumption.

Materials and Methods

Three locations representing contrasting soil and climatic conditions of the Kingdom were chosen in the central, eastern, and southwestern regions. Certain soil and climatic characteristics of the above regions are given in Figure 1 and in Tables 1 to 3 which indicate that the southwestern region is generally characterized by mild temperatures, low humidity, high precipitation and low salinity as compared to the central and eastern region. The eastern region with high summer temperatures is accompanied by high relative humidity, high salinity, and high water tables near the coastal areas. Study sites within each region were selected on the basis of visual observation of the diversity of plant species. Dominant species within each site were again determined by visual observation of the community and the population of each species within the community.

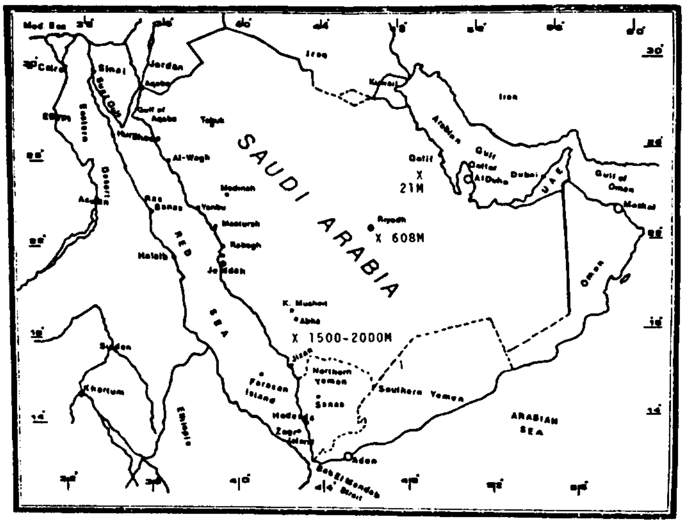

Fig. 1. *Map of the Kingdom of Saudi Arabia. X shows study sites.*

Table 1. Soil characteristics of study sites.

Region	EC	P	K	Organic Matter	Na	Ca	SO_4
	micromhos/cm	ppm	ppm	%	———	meq/1	———
Central	5.40	5.7	87	0.42	22	32.3	34.1
Eastern	5.25	5.1	75	0.53	13	11.2	13.1
South Western	2.2	4.5	214	0.77	23	30.2	41.3

Dominant species chosen for this study within each study site are shown in each table. Thermocouple psychrometers were installed near the root zone of at least 3 plants of each species to keep track of soil water potentials. Detailed data collections were started at different times at the 3 locations depending upon the occurrence of first event of rainfall at each site. Data were collected during the vegetative and flowering stage. Vegetative stage was defined as when tillers and leaves had fully developed; flowering stage was defined as when flowers were visible and anthesis and pollination had already taken place. Stomatal resistance of several leaves of the same plants was measured with a steady state porometer and averaged over all the plants of the same species. Similarly, rate of transpiration was measured on the same leaves used for stomatal resistance measurement using steady state porometers.

Water potential of several branches of the same plant was measured using a pressure bomb technique. At the same time, soil water tension was measured with a microvoltmeter and the thermocouple psychrometers. Photosynthesis of a few species was measured with a differential Beckman infrared gas analyzer, Model 865, using ambient CO_2 concentrations. Power to the

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Table 2. Average mean monthly and annual temperature of different regions of Saudia Arabia (10 years averages).

Region	Met. Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
		C°												
Southwestern	Taif Khamis-	14.8	16.2	19.4	21.9	24.9	28.3	27.9	28.1	27.1	22.5	18.5	15.3	22.0
	Mushait	13.7	15.2	17.0	18.9	21.3	24.2	23.2	23.2	22.5	18.9	16.2	13.6	17.8
	Abha	12.6	14.1	15.9	16.8	20.2	23.0	22.6	22.4	21.3	17.7	15.0	12.4	16.8
Central	Riyadh	13.8	16.2	20.3	25.2	31.0	34.5	34.7	34.8	32.1	26.6	20.5	14.9	24.1
	Qassim	12.2	14.8	19.5	23.6	29.2	32.9	33.9	33.7	31.6	25.7	19.5	14.1	21.5
Eastern	Dhahran	15.8	17.0	20.8	27.5	31.3	34.5	36.0	35.7	33.2	29.0	23.4	17.8	26.7

Table 3. Average mean monthly and annual rainfall of different regions of Saudi Arabia (10 years averages).

Region	Met. Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
		MM												
Southwestern	Taif Khamis-	9.3	5.7	19.8	29.8	34.8	4.5	1.5	6.3	5.2	6.0	26.8	6.5	156.2
	Mushait	8.1	16.8	52.9	34.2	34.7	7.3	23.0	18.1	7.5	0.4	18.1	21.6	242.0
	Abha	119.3	3.4	15.6	48.0	147.5	19.9	32.6	168.7	36.5	44.4	18.4	0.9	655.2
Central	Riyadh	18.9	4.5	29.4	36.3	16.5	0	1.0	0.1	0	0	3.9	7.7	119.3
	Qassim	19.4	8.7	21.7	25.1	8.5	0	0	0	0	1.0	21.1	18.6	125.0
Eastern	Dhahran	15.5	10.9	10.7	8.9	1.8	0	0	0	0	0	9.1	14.5	71.4

IRGA was supplied through a portable generator and a stabilizer.

Protein was determined by Kjeldahl N × 6.25. Kjeldahl N was determined on the aboveground parts of plants at vegetative and flowering stages. Similarly, total nonstructural carbohydrates (TNC) were determined on aboveground parts of plants according to the method described by Smith (1969).

Results and Discussion

Table 4 shows the water potentials of soil and different species from the 3 sites. In southwestern region 2 species namely *Eragrostis braunii* and *Hyperrhenia hirta* maintained higher water potential than the other species from the same site. *Panicum turgidum* and *Astenatherum fragilis* from the eastern region and *Panicum turgidum* from the central region maintained high water potentials (less negative) during the vegetative stage. Soil water potentials in the southwestern region were higher than in the central or the eastern region, but in all the locations it was beyond the sensitivity level of the thermocouple psychrometer. The water potentials of all the species at the 3 locations were lower (more negative) during the flowering stage than the vegetative stage. The same species that maintained high water potentials during vegetative stage also maintained high water potentials during flowering stage.

The decline in water potentials of aboveground parts of plants during flowering stage could be attributed to the depletion of soil water potentials as well as to the increased demand by the developing inflorescence. Most of these species, especially in the central and eastern regions, have a very short growing season. The vegetative stage is usually completed within 1 or 2 months following the event of rainfall. The flowering stage once initiated under favorable soil moisture conditions continues through a number of dry months. During this period most of the grain-bearing tillers slow down their vegetative growth and the developing inflorescence become the major sink for water and mineral resources.

The stomatal resistance and rate of transpiration of various grass species are given in Table 5. *Andropogon distachyus* and *Chrysopogon plumullosus* in the southwestern region, *Astenatherum fragilis* in the eastern and *Panicum turgidum* in the central region encountered higher stomatal resistance and correspondingly lower transpirational losses than the remaining species. Maintenance of high water potentials during periods of prolonged

Table 4. Water potentials of dominant grasses at vegetative and flowering stages.

Location	Species	Water Potential Vegetative	Water Potential Flowering	Soil Water Tension Vegetative	Soil Water Tension Flowering
		bars		bars	
Southwestern	*Andropogon distachyus*	−20	−25		
	Chrysopogon plumulosus	−18	−20	>−30	>−30
	Eragrostis braunii	−15	−20		
	Themeda triandra	−23	−25		
	Hyperrhenia hirta	−14	−16		
Eastern	*Panicum turgidum*	−16	−18		
	Astenatherum fragilis	−14	−17	>−50	>−50
	Stipagrostis plumosa	−32	−27		
Central	*Panicum turgidum*	−15	−17	>−50	>−50

Table 5. Stomatal resistance and transpiration of dominant grasses at vegetative and flowering stages.

Location	Species	Stomatal resistance Vegetative	Stomatal resistance Flowering	Transpiration Vegetative	Transpiration Flowering
		S/CM		mg/dm²/h	
Southwestern	*Andropogon distachyus*	10.5	18.7	2.4	0.8
	Chrysopogon plumulosus	8.7	15.8	3.5	1.2
	Eragrostis braunii	7.5	12.7	4.7	1.5
	Themeda triandra	6.5	10.7	5.8	1.7
	Hyperrhenia hirta	5.7	12.5	5.3	1.4
Eastern	*Panicum turgidum*	5.6	11.8	6.2	0.9
	Astenatherum fragilis	7.2	12.5	4.2	1.2
	Stipagrostis plumosa	5.3	11.3	4.8	1.8
Central	*Panicum turgidum*	8.3	15.8	2.8	1.1

dry season is one of the strategies developed by drought-avoiding plants to economize on the available water (Hsiao and Acevedo 1974, Bamberg et al. 1975, Stocker 1960, Teare et al. 1973).

Stomatal resistance of all the species was considerably greater during flowering stage than during vegetative stage and correspondingly the rate of transpiration was also lower than the vegetative stage. Plants adapted to the extreme environmental stresses adjust their stomatal conductance and water potential during rainless period to conserve water for the developng inflorescence. It was mentioned earlier that due to the prolonged seed development period, these plants utilize the water already present in the root-shoot system more efficiently. There is also the possibility of atmospheric moisture becoming available to these plants as a result of condensates at night when temperature are considerably lower than in the day time.

It is not clear from this study how stomatal adjustment is maintained to counteract the increasing atmospheric evaporative demand during the hotter parts of the day. Whether stomata close completely or partially and the degree of density of stomata have not been studied in these plants. However, a number of studies have shown stomatal regulation under drought or under high temperature and water stress conditions (Cowan 1977; Evenari et al. 1975; Frank and Barker 1976; Schulze et al. 1972, 1973).

Rate of photosynthesis of a few species studied (Table 6) was higher during vegetative stage than during flowering stage. At the same time, the water-use-efficiency was higher during flowering stage than the vegetative stage (Table 7). The higher photosynthetic rates could be attributed to the presence of more photosynthetic surface and more availability during the vegetative stage. Since the vegetative stage lasts for a few weeks, these plants, therefore, take advantage of the available water by increasing the rate of photosynthesis. At flowering stage, the higher water-use-efficiency again indicates the adaptive strategy of these plants economizing on the available water. Generally, these rates of photosynthesis are lower than those of other desert plant species (Bamberg et al. 1975, Ludlow and Wilson 1972, Berry 1975, Fischer and Turner 1978, Bjorkman et al. 1972). In fact, many desert plant species are there not for the purpose of increased productivity but merely for survival and these rates are adequate enough to maintain the perpetual survival and existence of their progenies.

Table 6. Photosynthesis of dominant grasses during vegetative and flowering stages.

Location	Species	Photosynthesis Vegetative	Photosynthesis Flowering
		$mgCO_2/dm^2/h$	
Eastern	*Panicum turgidum*	10.5	7.3
	Astenatherum fragilis	8.2	5.8
	Stipagrostis plumosa	7.8	4.5
Central	*Panicum turgidum*	11.8	8.7

Table 7. Ratio of transpiration/photosynthesis at vegetative and flowering stages.

Location	Species	Transpiration / Photosynthesis Vegetative	Transpiration / Photosynthesis Flowering
Eastern	*Panicum turgidum*	590	123
	Astenatherum fragilis	512	206
	Stipagrostis plumosa	615	400
Central	*Panicum turgidum*	237	126

In Table 8 are given the protein and carbohydrate contents of the aboveground parts of plants (flowers not included) during the vegetative and flowering stages. All the species were higher in both protein and carbohydrates during the vegetative and flowering stages. All the species were higher in both protein and carbohydrates during the vegetative stage than the flowering stage. *Panicum turgidum, Andropogon distachyus* and *Hyperrhenia hirta* exhibited higher protein content than the other species. The amounts of protein in these species is considerably higher than many desert grass species.

The decline in both protein and carbohydrates of leaves and stems during the flowering stage could be due to the translocation of these energy rich sources to the developing inflorescence. Total nonstructual carbohydrates at any time during the growth of these plants appear to be very low as compared to other species of the same taxonomic group.

TNC is a readily available source of energy and it appears that these are being used constantly by the plants and do not accumulate in any appreciable amounts in the aboveground parts or are translocated as reserves to the below-ground parts for use during stress or during regrowth. Data on the contents of below-ground parts are not available at the time of writing of this article.

These preliminary data on the physiological adaptation of desert grasses clearly indicate that these plants have developed strategies to cope with the adverse climatic conditions. Adjustment to the harsh environment is brought about by a particular parameter at different stages of development. The adaptive strategies such as stomatal regulation, leaf water potential, rate of photosynthesis etc., are adjusted according to the stress involved and the stage of maturity of the plants. How these changes are brought about and what are triggering mechanisms for signaling these changes are not known.

It is too soon to draw any definite conclusion about the real adaptive mechanisms of these plants. This preliminary data especially in the extreme arid environment are not enough to develop hypotheses describing the relationships between the state and the driving variables. However, study of this nature has not been

Table 8. Protein and carbohydrates of dominant grasses during vegetative and flowering stages.

Location	Species	Protein		Carbohydrates	
		Vegetative	Flowering	Vegetative	Flowering
		%		%	
Southwestern	*Andropogon distachyus*	7.8	5.7	6.5	4.8
	Chrysopogon plumulosus	6.5	4.8	5.8	4.2
	Eragrostis braunii	5.2	4.2	4.5	3.2
	Themeda triandra	4.8	3.2	6.7	4.7
	Hyperrhenia hirta	8.5	6.3	7.2	5.8
Eastern	*Panicum turgidum*	10.5	8.2	7.5	6.2
	Astenatherum fragilis	8.2	7.2	6.7	5.2
	Stipagrostis plumosa	6.8	5.5	5.2	4.3
Central	*Panicum turgidum*	9.7	7.2	7.3	5.8

reported anywhere on the desert grasses in Saudi Arabia. Thus it is considered important to indicate the trends in magnitude of the physiological parameters undergoing adjustment during the phenological stages under the harsh environment of the Kingdom.

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SRM Election Results

The Elections Committee Acting Chairman, Thane Johnson, along with several other Colorado Section members, counted the ballots for new officers on Monday, December 8, 1986, at the Society for Range Management headquarters. Elected officers are:

Second Vice-President—**Thomas E. Bedell**

Directors (1987-1989)—**Marilyn J. Samuel** and **Kenneth D. Sanders**

Directors Samuel and Sanders will replace retiring Directors Hunter and Whetzell in February 1987.

Ballots and tally sheets are retained in the Denver office for one year for review. Approximately 30% of the membership voted.