POTENTIAL FOR USE OF KOCHIA PROSTRATA AND PERENNIAL GRASSES FOR USE IN RANGELAND REHABILITATION IN JORDAN

Derek W. Bailey[1], Raed Al Tabini[2], Howard Horton[3], James Libbin[1]*, Khalid Al-Khalidi[2], Ahmad Alqadi[2], Mohammad Al Oun[2], and Blair Waldron[3]

[1]College of Agriculture, Consumer and Environmental Sciences, New Mexico State University, Las Cruces, NM 88003 USA

[2]Badia Research and Development Center, Higher Council for Science & Technology, Amman, Jordan

[3]Forage and Range Research Lab, USDA-ARS, Logan, UT 84322 USA

Abstract

Six varieties of forage kochia [*Kochia prostrata* (L.) Shad.], three native shrubs, two introduced *Atriplex* shrub species native to cold deserts in the western United States and drought-tolerant perennial grass varieties were seeded and evaluated under arid rangeland conditions in Jordan. Varieties were seeded in December 2007 evaluated in August 2008 at two sites in arid rangeland areas of southern and northern Jordan. Precipitation was below normal with the southern site (Ghrain) receiving 110 mm and the northern site (Tal Rimah) receiving 58 mm. Plants were more abundant and taller ($P < 0.001$) at wetter Ghrain site than the drier Tal Rimah site. Only a few native and Atriplex shrubs emerged. Frequency measurement of forage kochia demonstrated that plants emerged and survived the summer in about half of each row. Abundance of KZ-6X, Octavny select and Sahro varieties of forage kochia were greater ($P < 0.05$) than the BC-118, Immigrant and Pustiny varieties. Height was similar ($P > 0.10$) among forage kochia varieties. Abundance and height of perennial grass varieties were similar ($P > 0.10$) when evaluated across both sites. However, the higher frequencies of Kazak Siberian wheatgrass (21 ± 3%) and Hycrest crested wheatgrass (20 ± 4%) at the drier Tal Rimah site suggested that these varieties might be superior toValivov Siberian wheatgrass (4 ± 3%) and Bozoiksky Russian wildrye (6 ± 4%) in very arid conditions. Based on this study, forage kochia appears to have great potential for establishing palatable perennial shrubs through direct seeding in arid rangeland conditions of Jordan, and except in extremely dry conditions arid-adapted perennial grass varieties may also be useful for direct seeding in rangeland restoration efforts.

Introduction

The Hashemite Kingdom of Jordan is primarily rangeland (about 90%) of which the majority is arid with less than 200 mm of annual precipitation. These rangelands support a range livestock industry that allows rural communities to maintain a valued and traditional way of life. In addition to livestock production Jordanian rangelands are the watersheds that receive rainfall and periodic snow, yield surface water and replenish groundwater.

A large proportion of the rangelands in Jordan has deteriorated and is in poor condition. Heavy stocking levels, continuous grazing near permanent water sources, plowing of land for dryland cultivation and drought are some of the reasons for the downward trend in rangeland condition in Jordan (Al-Tabini, 2001). Irrespective of the cause of the deterioration, responsibility of reversing this trend falls to rangeland users. A recent study by Al-Tabini et al. (2008) found that the combination of water harvesting and transplanting native shrubs resulted in a 7-fold increase in forage production (130 kg/ha to 950 kg/ha). Except in extreme drought conditions, estimated economic payback periods for these restoration activities were 4 to 9 years. Results from this study demonstrate the value of shrub establishment in rangeland restoration. However, transplanting shrubs is not practical for expansive rangelands because of the lack of available nursery stock, labor for planting and accessibility of equipment. Direct seeding of rangeland vegetation is less expensive, more rapid, and requires much less labor.

Forage kochia [*Kochia prostrata* (L.) Shad.] is a perennial polymorphic low-shrub that is native to areas from the Mediterranean Basin to Siberia (Shiskin 1936). Forage kochia is highly adapted to arid conditions and cold temperatures and has been used successfully in rangeland restoration in the western United States (Blauer et al., 1993; Harrison et al., 2000). Forage kochia can be direct seeded, and seeds do not need to be covered with soil (Harrison et al., 2000). Soil only needs to be slightly disturbed before seeding. In rangelands dominated with cheatgrass (*Bromus tectorum* L.) that burn frequently, forage kochia is one of the few plants that can be successfully seeded and used as bridge for establishing native species (Monaco et al., 2003).

Forage kochia is palatable and has been used by livestock in Kazakhstan and Uzbekistan and nearby areas during fall and winter for centuries (Waldron et al. 2005). Waldron et al. (2006) reported that forage kochia maintained a relatively high forage quality during the winter (8% to 12% crude protein). These authors also found that grazing cattle on forage kochia was $0.24·cow^{-1}·day^{-1} less expensive than feeding alfalfa hay in drylot pens.

The ability to readily establish with direct seeding, adaptability to arid conditions, relatively high nutritive quality and palatability makes forage kochia a potential candidate species for rangeland restoration in Jordan. The objective of this study was to compare and evaluate germination and initial establishment of six varieties of forage kochia, three native shrubs, two introduced *Atriplex* shrub species native to cold deserts in the western United States and drought-tolerant perennial grass varieties under arid rangeland conditions in Jordan.

Methods

The study was conducted at two sites, Ghrain and Tal Rimah. The Ghrain location is located southern Jorda, approximately 40 km southeast of Wadi Mousa. Tal Rimah is about located 70 km east of Al-Mafrak. Both sites were located on gentle terrain with nearly level slopes (< 1%).

At each site, replicate four 30 m x 30 m blocks were established within a 65 m x 65 m fenced location. Net wire was used for fencing to exclude livestock grazing. Within each block, six forage kochia varieties, four perennial grass varieties and five other shrub species were seeded (Table 1). Origin of the forage kochia varieties are described in Waldron et al. (2005). Each block was divided into 15 subplots, which were randomly allocated to the 15 varieties. Each subplot consisted of three 10-m rows located 6 m apart. Seeding was completed on 16 December 2007 in Tal Rimah and on 18 December 2007 in Ghrain. Forage kochia seeds were lightly covered with 2 to 3 mm of soil. Grass seeds and other shrubs were covered with 3 to 6 mm of soil. No attempt was made to incorporate water harvesting in the study.

During mid August 2008, frequency of the 15 varieties was measured in 30-cm diameter frames. Within each subplot the frame was placed at 90 equally distant locations along the three rows (30 frame placements per row). In addition, the height of the nearest plant (within 30 cm) was measured at 30 equally distant locations within a subplot (10 per row). Heights of plants measured within a subplot were averaged together.

Frequency and height data were analyzed using a statistical model that included site (Ghrain or Tal Rimah), forage type (forage kochia, perennial grass or other shrubs), and variety within forage type. The subplot was the experimental unit. The pdiff option of PROC MIXED was used for mean separation (SAS 1999).

Results and Discussion

Precipitation during the winter rainy season for Jordan (October through April) was below normal at both sites. No precipitation occurred before seeding, and after seeding Ghrain received 110 mm and Tal Rimah received 58 mm. These levels of precipitation are much less than levels of 130 to 500 mm that forage kochia and other perennial grass species has been evaluated and recommended for in the western United States (Waldron, 2004).

Table 1. Varieties of forage kochia, perennial grasses and other shrubs evaluated during the study.

Forage type	Variety	Scientific name
Forage kochia	BC 118	*Kochia prostrata* (L.) Scrad.
	Immigrant	
	KZ 6X	
	Octavny select	
	Pustiny	
	Sahro	
Perennial grass	Bozoisky Russian wildrye	*Psathyrostachys junceus* (Fisch.) Nevski
	Hycrest crested wheatgrass	*Agropyron desertorum* (Fisch. ex Link) Schult X *Agropyron cristatum* (L.) Gaertn.
	Kazak Siberian wheatgrass	*Agropyron fragile* (Roth) Candargy
	Vavilov Siberian wheatgrass	*Agropyron fragile* (Roth) Candargy
Other shrubs	Four-wing saltbush	*Atriplex canescens* (Pursh) Nutt.
	Shadscale	*Atriplex confertifolia* (Torr. & Frém.) S. Watson
	Native shrub	*Achillea fragrantissima* (Forssk) Sch. Bip
	Native shrub	*Atriplex halimus* L.
	Native shrub	*Salsola vermiculata* L.

The frequency of forages observed at Ghrain in August 2008 was higher ($P < 0.001$) than observed in Tal Rimah (Table 2). This is not surprising considering the higher level of precipitation that Ghrain received compared to Tal Rimah. The frequency of the other shrubs (native and *Atriplex*) was less (P < 0.01) than the forage kochia and perennial grasses. Only a few of these shrubs were observed during ocular observations in April and in frequency measurement recorded in August 2008. The quality of seeds of the native shrubs was not tested prior to seeding.

Table 2. Frequency of seeded forages at the Ghrain and Tal Rimah sites.

Item		Frequency (%)	SE[1]	*P*-value
Site	Ghrain	42.6	2.6	< 0.001
	Tal Rimah	16.2	2.6	
Forage types	Grass	47.5	3.5	<0.001
	Kochia	39.0	2.9	
	Other shrubs	1.8	3.1	
Grass species				> 0.10
Kazak Siberian wheatgrass		54.7	7.0	
Valivov Siberian wheatgrass		41.8		
Hycrest crested wheatgrass		51.8		
Bozoisky Russian wildrye		41.5		
Forage kochia				< 0.05
Immigrant		27.9	7.0	
Saharo		57.6		
BC 118		17.2		
Octavny		63.3		
Pustiny		20.6		
KZ 6X		47.2		
Other shrubs				> 0.10
4-wing saltbush		5.4	7.0	
Shadscale		0.0		
Atriplex halimus		3.3		
Salsola vermuclata		0.1		
Achillea fragrantissima		0.1		

[1] Standard error.

Frequency of KZ-6X, Octavny select, and Sahro forage kochia varieties were higher (*P* < 0.05) than the BC-118, Immigrant and Pustiny varieties (Table 2). The KZ-6X, Octavny select and Sahro varieties had similar (*P* > 0.10) frequencies, and the BC-118, Immigrant and Pustiny varieties had similar (*P* > 0.10) frequencies. At the wetter Ghrain site, frequencies of the KZ-6X, Octavny select and Sahro varieties were over 50%

indicating that plants were found in over half of each row, but the other varieties were found in less than half of each row. At the drier Tal Rimah site, the KZ-6X, Octavny select and Sahro varieties had frequencies between 40 and 50%. The ability for the KZ-6X, Octavny select and Sahro forage kochia varieties to emerge on about half of each row and survive over the summer with only 58 mm of precipitation suggests that forage kochia has the potential to be an extremely valuable species to use in rehabilitating the arid rangelands of Jordan.

Frequency did not differ ($P > 0.10$) among the perennial grass species when evaluated across sites (Table 2). At the drier Tal Rimah site, frequency of Kazak Siberian wheatgrass was 21 ± 3% and Hycrest crested wheatgrass was 20 ± 4%, while Valivov Siberian wheatgrass was 4 ± 3% and Bozoiksky Russian wildrye was 6 ± 4%. At wetter Ghrain site, frequencies of grasses were all greater than 75%. The lowest frequency was Bozoisky Russian wildrye (77 ± 7%) and the highest was Kazak Siberian wheatgrass (88 ± 7%). At Ghrain, perennial grasses emerged and survived the summer on over ¾ of the row, but at Tal Rimah only about 5% of each rows contained grasses for two varieties and about 1/5 of the row for the other two perennial grass varieties. Based on this study, Valivov Siberian wheatgrass and Hycrest crested wheatgrass appear to be good choices for seeding perennial grasses in very arid conditions.

The height of forage kochia was higher ($P < 0.001$) at Ghrain than at Tal Rimah (Table 3). Higher precipitation at Ghrain apparently allowed a greater abundance of plants to emerge (higher frequency) and allowed the plants that did emerge to grow taller. There were no differences ($P = 0.31$) in height among the six varieties of forage kochia. Many of the forage kochia plants at Tal Rimah were rosettes less than 1 cm tall. Forage kochia seedlings have the ability to persist in a very small rosette stage similar to the head of a thumb tack for 2 years of drought conditions without dying (Horton, 2004). If climatic conditions improve at Tal Rimah within the next two years, it is likely that most of these small forage kochia plants will survive.

Table 3. Height of seeded forage kochia varieties at the Ghrain and Tal Rimah sites.

Item		Height (cm)	SE[1]	*P*-value
Site	Ghrain	14.7	1.0	< 0.001
	Tal Rimah	0.9	1.0	
Kochia prostrata				0.31
Immigrant		7.4	1.7	
Saharo		8.2	1.7	
BC 118		7.2	1.8	
Octavny		10.6	1.7	
Pustiny		8.2	1.7	
KZ 6X		4.9	1.7	

[1] Standard error.

Heights of grasses at the wetter Ghrain site were higher ($P < 0.001$) than at the drier Tal Rimah (Table 4). No differences in height were observed among the perennial grass varieties ($P = 0.12$).

Table 4. Height of seeded grasses at the Ghrain and Tal Rimah sites.

Item		Height (cm)	SE[1]	*P*-value
Site	Ghrain	6.8	0.2	< 0.001
	Tal Rimah	3.4	0.3	
Grass species				0.12
Kazak Siberian wheatgrass		5.3	0.3	
Valivov Siberian wheatgrass		5.2		
Hycrest crested wheatgrass		5.5		
Bozoisky Russian wildrye		4.4		

[1] Standard error.

Management Implications

Forage kochia appears to be an excellent forage resource for restoring perennial vegetation in arid rangelands of Jordan. Forage kochia emerged and survived the summer in drought conditions (58 to 110 mm) that were drier than precipitation levels of 150 to 500 mm recommend by rangeland managers for this species in the western United States. Forage kochia can be broadcast seeded with minimal soil preparation, which will dramatically reduce restoration costs compared to transplanting nursery raised stock (Horton 2004). Perennial grass varieties evaluated in this study originated from Eurasia and were selected for arid and semi-arid conditions in the western United States. These grass varieties also have potential to be used in reseeding Jordanian rangelands, especially in areas receiving more than 100 mm of precipitation. Many of Jordanian rangelands are remote, and operation of machinery can be difficult because of rugged terrain or large rocks on the soil surface. Forage kochia and adapted perennial grass varieties may allow rangeland users to aerially or manually broadcast seeds to reestablish perennial vegetation. Forage kochia has also been used successively to act as a bridge for later establishment native vegetation. Further research is underway to examine long-term survival of forage kochia and perennial grass varieties, evaluate the potential of broadcast seeding on extensive rangelands and to determine efficacy of combining water harvesting with direct seeding

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