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Response of Russian brome, crested wheatgrass and tall wheatgrass to annual precipitation and grazing management in a semi-arid area

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Abstract

Three grass species, *Agropyron desertorum* (Agde) and *Agropyron elongatum* (Agel) and recently, *Bromus tomentellus* (Brto) are mainly used for range improvement as mixed seeding in semi-arid areas of Iran. Because there is little information about management of these grasses, this study was conducted at the Sisab Research Station in northern Iran to evaluate their responses to grazing management and annual precipitation. Four grazing management treatments were applied for three consecutive years, from 1999 to 2001: no grazing, and light (20-45% forage removal), moderate (45-65% forage removal) and heavy (65-80% forage removal) grazing by lambs and sheep. The fourth year was considered to be a rest from grazing. Data recorded up to fifth years from 1999-2003. The average herbage yield (HY) production across years of Agde (1357 kg/ha) and Agel (1250 kg/ha) was statistically similar, and higher than that of Brto (880 kg/ha). HY decreased with reduction in annual precipitation for all species, especially Agel. Plant number per unit area declined over the study period in all species. Three years of heavy grazing resulted in significant reduction in HY and/or plant number for Brto and Agde, but the rest year compensated for the negative effect of intensive grazing on dry matter production.

Keywords: Agropyron desertorum; Agropyron elongatum; Bromus tomentellus; herbage yield production; forage removal

1. Introduction

Crested wheatgrass and tall wheatgrass are widely used for range improvement in semi-arid areas of Iran. Recently, Russian brome has also shown promise for use in range improvement. Currently, the common practice in range improvement projects is to cultivate a mixed seeding of available range species from the lowlands to the highlands, and to manage uniformly in terms of grazing intensity and timing. We have observed that such this practice has resulted in poor success of range improvement projects and low durability of the cultivated species in semi-arid areas of North Khorasan, as well as in many other parts of Iran where rainfall is erratic, resulting in frequent dry and wet years.

The results of many experiments in other countries have indicated that species behave differently in response to the amount of precipitation and the intensity of grazing. For example, Richards and Caldwell (1985) reported that two grass species of *Agropyron desertorum* and *Agropyron spicatum* had different grazing tolerance under field conditions. Barker *et al.* (1994) found that five grass species showed dissimilar responses to water deficit. Holechek *et al.* (2003) have shown different responses of some key forage species to grazing intensity and annual precipitation over a 13-year period of grazing. However, no significant differences in plant species diversity, evenness, or richness were

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found between two areas in a semi-arid ecosystem with long-term grazing either during the wet season or year-round (Metzger *et al*. 2005). Tavakoli (1993) has reported that *Lolium perenne* had greater resistance to grazing intensity and lower resistance to drought relative to *Festuca arundinacea*, due to different morphological and physiological characteristics. Buwai and Trlica (1977) have also found different responses in several species subjected to different intensity and timing of grazing. Studies on *Agropyron elongatum* by Holechek et al (1989) in New Mexico and Kansas and by Gillen and Berg (2005) in Oklahoma got variable results in terms of plant performance due to different climatic conditions.

There is no previously published information about the responses of forage grass species to grazing management and variation in annual precipitation under climatic condition of Iran. Therefore, the purpose of this study was to determine how these species should best be used and managed in rangelands and pastures in the semi-arid ecosystems of this region.

2. Materials and methods

This study was performed at Sisab Research Station (SRS), where is located 35 km east of Bojnord in northeastern part of Iran. Altitude ranges within the site from 1300 to 1500 m above the sea level. A Climatology Station has been established in SRS in 1985. According to obtained data, the climate is semi-arid, with a cold winter and erratic rainfall throughout the wet season. Rainfall is highly variable between years. The long-term (17-year) average annual precipitation at this station is about 270 mm. Precipitation occurs mainly from October to June. The total annual precipitation during the experimental period is shown in Figure 1. Because the amount of rainfall ranged from 97 mm above to 75 mm below the long-term average rainfall, these years can be classified as normal (1999), drought (2000 and 2001) and wet (2002 and 2003) years.

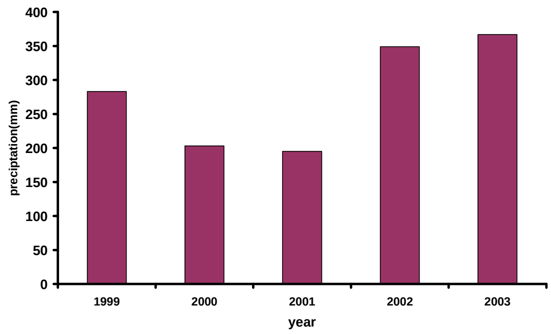

Fig. 1. Annual precipitation in Sisab Research Station during the experimental period

The growing season begins around the middle of March and completed through the end of November, if soil moisture be available. The soil texture is clay-loam with a pH of about 7.4. The Station encompasses a vast area of mountain range (more than 5 million ha) in North Khorasan, similar to areas in many other parts of Iran. Most of the key range species in North Khorasan are found within permanent range exclosures on the Station.

In this experiment, pure stands of two introduced grass species (crested wheatgrass *Agropyron desertorum*, hereinafter Agde, and tall wheatgrass *Agropyron elongatum*, hereinafter Agel) and one native species (Russian brome *Bromus tomentellus*, hereinafter Brto) were used to determine their responses to variable annual precipitation and different grazing management schemes. These species were cultivated by row seeding in 1995, and were grazed moderately by sheep until 1999. The current experiment started in 1999 and finished through 2003. Twelve paddocks (each 2000 square meters) were devoted to grazing application. Each paddock was divided into quarters, which were considered to be four inside replicates. Four grazing management treatments were applied for three consecutive years, from 1999 to 2001: no grazing (control), and light (20-45% forage removal), moderate (45-65% forage removal) and heavy (65-80% forage removal) grazing by lambs and sheep. The fourth year, 2002, was considered to be a rest period from grazing. Therefore, measurements were continued until 2003.

Grazing started in spring each year during the mid-vegetative stage of each species: from 20-25 April for Brto, from 6-10 May for Agde, and from 20-25 May for Agel paddocks. The pasture paddocks of each species were grazed by a herd of 60-80 lambs and sheep until the vegetation stands of each treatment visually reached the determined grazing levels. In some years, grazing was rotated in the paddocks if there was regrowth in the grazed areas. The following factors were measured during the experimental period.

a- The phenological stages of each species from beginning of growth to physiological seed maturity were recorded during the growing period in the control paddocks.

b- The herbage yield (HY) production of a two square meters per replicate (of four replicates) was determined by harvesting the grasses under the caged areas at the flowering stage. The harvested material was first dried in the shade, then oven dried for 48 hours at 80ºC and weighed to determine herbage yield as dry matter.

c- The number of individual plants per unit area was measured in 2000-2002 by counting the number of plants within an area 4 rows wide by 10 meters long in each replicate.

d: After anthesis, the number of tillers per plant was counted for 20 individual plants per species in 2000-2002. Tillers were separated into vegetative (Veg) and reproductive (Rep, flowering culms) classes.

To determine the effect of annual precipitation and grazing management on the herbage yield production and plant number of each species, the data from each of the five years were analyzed both separately and together by analysis of variance using the general linear model of SAS (SAS Institute Inc. 1991). The standard errors of the means (SEM) were used for comparison between treatments.

3. Results

A: Phenology

The time elapsed between the start of growth and physiological seed maturity, as well as the time of flowering of each species, is recorded in Table 1. The total lengths of the growing periods of these species were different, and varied between 110 and 168 days under the climatic conditions of SRS. *B. tomentellus* was the first to flower, and therefore reached the reproductive stage sooner than the other two grass species. *A. desertorum* was the second species to flower; *A. elongatum* needed a much longer time to reach the flowering stage.

Table 1. The lengths of vegetative and reproductive tillers in the studied grass species under the climatic conditions of Sisab Resaerch Station

Phenological stages Species	Vegetative	Reproductive	Total period (days)
Brto	March 5-May 21	May 22-June 22	110
Agde	March 9-June 9	June 10-July 21	132
Agel	March 10-July 5	July 6-August 16	168

Brto= *Bromus tomentellus* Agde= *Agropyron desertorum* Agel=*Agropyron elongatum*

B: Herbage yield production

The mean herbage yield of each species and grazing treatment across the five years of measurement, and also the mean HY of all species in each year, are shown in Table 2. The analysis of variance showed a significant (P<0.001) difference among species. *A. desertorum* and *A. elongatum* produced similar amounts of HY; both were significantly greater than the HY of *B. tomentellus* (Table 2). The mean HY values across all species under the different grazing treatments were not significantly different (P<0.844). However, the differences in mean HY production between species were highly significant (P<0.0001). The mean HY declined with reduction in annual rainfall (Table 2). The interaction between species and year was significant (P<0.0001), but the interactions between species and grazing and between year and grazing were not significant.

Table 2. The mean herbage yield (HY) production over five years of different grass species, the mean HY across species and years (Y) under different grazing treatments, and the mean HY across species in each year (Kg/ha).

Species	Brto	Agde	Agel	SEM	F
DM	900	1334	1236	35	***

Years	Y1	Y2	Y3	Y4	Y5	SEM	F
DM	1176	847	677	1425	1660	45	***

Treatments	C	L	M	H	SEM	F
DM	1181	1166	1147	1133	40	ns

* $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$ ns: not significant at $P \leq 0.05$

The yearly HY production of the three species under different grazing management treatments is shown in Table 3. In normal and wet years (the first, fourth and fifth years), HY of Agde and Agel was statistically similar and greater than that of Brto. In dry years (second and third years), however, Agde produced significantly greater HY than the other species (Table 3).

The herbage yield production of Russian brome after three years of grazing (i.e., in the fourth year of herbage harvesting) declined as the severity of grazing increased (Table 3). Crested wheatgrass also showed this reduction in HY under heavy grazing in the fourth year of the experiment, but no reduction was observed for tall wheatgrass under any grazing management treatment during the experimental period (Table 3). There were no significant interactions between species and grazing during the five years (Table 3).

C: Plant number

In general, the numbers of plants per hectare of the three grass species were reduced over time (Table 4). This reduction was most severe under treatment H in Brto and Agde, and under treatments M and H in Agel. The mean plant numbers per hectare of Brto (107,666), Agde (93,111) and Agel (54,745) were statistically different ($P<0.0001$), with SEM of 3745. Among the three grass species, Brto had the greatest number of plants per hectare and Agel had the smallest number of plants per hectare. No differences were observed among the mean plant numbers per hectare of species under the grazing treatments C (85,766), L (86,294), M (85,294) and H (83,338), with SEM of 4334. The interactions between species and grazing, between species and year, and between year and grazing were not significant.

D: Tiller number

The number of tillers per plant was different among species and years (Table 5). The number of tillers per plant was highest in crested wheatgrass and lowest in tall wheatgrass. All of the grasses responded to the severe drought year (2001) by reducing the number of tillers per plant, and also by reducing the proportion of reproductive to vegetative tillers. A dramatic change was observed in tall wheatgrass, in which plants failed to produce reproductive tillers during the drought years of 2000 and 2001. Crested wheatgrass produced a higher proportion of reproductive to vegetative tillers than that of the other two species.

4. Discussion and conclusion

Phenology can be defined as the timing of the developmental stages of aerial plant parts (vegetative and reproductive) is important to the survival, nutritional value of available forage and particulary relavant to vegetation management (Grime et al. 1988). Observations in the field indicate that *B. tomentellus* is one of the earliest species to produce a head. *A. desertorum* produces a head about 30 days later, and *A. elongatum* produces a head at least 57 days later, in early summer. These results have practical application for determining the timing of the start of grazing and of the removal of animals from rangelands or pastures. For example, if the aim is to provide animals with high quality food while ensuring that the plants can resist herbivory, Russian brome can be grazed sooner than the other species because of its earlier initiation of growth and attainment of flowering. The second species that can be grazed is crested wheatgrass, and the latest is tall wheatgrass. If these species are cultivated in pastures within a region, this makes it possible to increase the length of the grazing season in semi-arid areas. A short grazing period is one of the challenges of arid and semi-arid regions. Our experience in SRS shows that we can provide green forage for grazing animals for a longer time by cultivating species with different phonological stages as pasture-lands.

In arid and semi-arid rangelands repeated defoliation under natural water deficit conditions may have negative effect on stand longevity of grasses (Busso et al. 1989). During the drought years in SRS, Agde and Brto reduced their proportions of reproductive to vegetative tillers and Agel failed to complete its phenological stages. This means that in drought years Agel has little or no opportunity to produce seeds for regeneration. However it is not so important for perennial grasses such as grasses of this experiment in terms of regeneration because of these grasses have capacity for regeneration through vegetative organs, but in drought years plants may have less opportunity to store carbohydrate reserves that are used for revegetation of the plants in the following year. On the other hand, plants are more palatable in drought years because they have more vegetative tillers and leafier organs.

Table 3. HY production of three grass species under different grazing intensities during the five-year experiment

Species	Brto				Agde				Agel				SEM	F		
Grazing treatments	C	L	M	H	C	L	M	H	C	L	M	H		SP	gr	SpXGr
Y 1	707	636	848	923	1480	1120	1080	1302	1715	1380	1377	1542	151	***	ns	ns
Y 2	755	960	918	745	950	1142	878	957	758	562	863	676	97	***	ns	ns
Y 3	510	530	495	597	810	1027	945	910	530	660	490	625	62	***	*	ns
Y 4	1470	1140	970	728	1701	2206	2227	1513	1325	1292	1182	1346	169	***	*	ns
Y 5	1191	1261	1255	1372	1740	1522	1479	1696	2071	2062	2208	2063	237	***	ns	ns

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$
ns: not significant at $P \leq 0.05$

Table 4. Number of plants (in thousands per ha) of three grass species in the first and last years of the study under different grazing intensities

Species	Brto				Agde				Agel				SEM	F		
Grazing treatments	C	L	M	H	C	L	M	H	C	L	M	H		SP	gr	SPXAR
Year 1	105	120	128	135	119	115	109	110	72	68	76	77	11	***	ns	ns
Year 4	99	106	88	79	75	69	77	66	42	38	31	31	9	***	ns	ns

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$
ns: not significant at $P \leq 0.05$

Table 5. The average number of vegetative (Veg) and reproductive (Rep) tillers of individual plants during a drought year, a normal year and a wet year

Species	Brto		Agde		Agel	
Year	Veg	Rep	Veg	Rep	Veg	Rep
2000	50.7	34.9	40.9	55.8	62.8	0
2001	40.2	10.9	48.8	21.6	28.5	0.2
2002	39	25.2	17.4	68.4	26.7	29.8

Therefore, they may be grazed more severely due to the higher quality and lower quantity of available forage. Carbohydrate reserves are needed for regrowth when the plant is unable to support regrowth from photosynthesis (Caldwell 1984).

Water soluble carbohydrate concentration in the stubble of *Festuca arundinacea* reduced by increasing severity of defoliation (Tavakoli 1993) and by decreasing defoliation interval (Donaghy et al 2008). Bosso et al. (1989) reported that *Agropyron desertorum* and *Agropyron spicatum* suffered from repeated defoliation under drought conditions but water soluble carbohydrate replenished by increasing defoliation interval (Donaghy et al., 2008). However, we did not measure carbohydrate concentration in stem bases of plants in this experiment, but one of the causes of reducing forage production in Agde and Brto may be due to heavy grazing and drought. Retze et al. (2006) mentioned that protection for mountain ranges is especially needed during times of water stress. So, range managers should consider these factors in order to prevent the overgrazing of pastures or rangelands during drought years.

In this experiment herbage yield decreased with reduction in annual rainfall (Table 2). Yang et al. (2009) presented a direct relationship between amount of moisture availability and aboveground biomass in which confirmed our results.

The differences among species in herbage yield production and in ratio of reproductive to vegetative tillers show that the three species have different levels of sensitivity to drought. Malnowski et al. (2003) also reported different grazing response and drought tolerance for tall wheatgrass and crested wheatgrass. This sensitivity is greater in Agel than in the other species, due partly to its failure to complete its phenological stages in drought years. However, Agel has relatively greater potential than the other species in wet years (Table 4). These results suggest that Agel should be used in the higher mountains in North Khorasan, which receive more than 250 mm rainfall per year. Brto and Agde showed less variation in HY production than Agel under these erratic climatic conditions. This suggests that these species are more drought resistant than Agel, and can be used at lower elevations in semi-arid regions.

After three years of grazing, all species showed sensitivity to heavy grazing by reduction in herbage yield production or plant number per unit area or both. However, after one year of rest from grazing, all species had compensated for their reduction in herbage yield production under hard grazing. This shows the importance of a rest grazing period to the sustainability of plant production and for recovery after severe grazing, as has been reported by many other workers (e.g. Trlica *et al*., 1977; Buwai and Trlica 1977; Tavakoli 2002). These studies have indicated that most range plants need a change in grazing management and rest from grazing following severe defoliation. In our experiment, there were some differences in grazing resistance among the three species. Agel showed less sensitivity to grazing intensity than did the other species. Because this species was the last one to be grazed each year, it may lose this superiority if it is grazed sooner.

In conclusion, the results of this experiment show that the productivity of these species in a semi-arid area fluctuates in time with variability of rainfall. Grazing intensity also influences the productivity of some species over time. A combination of information on precipitation, grazing intensity and grazing response of key species is needed for sound management decisions. To avoid overgrazing of these species, firstly these grasses should be planted separately and secondly, animals should be removed from pastures sooner or reduced stoking rate in dry years. *A. elongatum* needs more than 250 mm annual precipitation for acceptable production and for sustainability. It is possible to lengthen the grazing season in marginal lands by establishing pastures of all three grasses. Grazing can start on *B. tomentellus* and finish on *A. elongatum*. Rest grazing is an important part of grazing management in range and pastures that encounter overgrazing in arid and semi-arid areas. Grazing to about 50% of available forage may guarantee plant survival and sustainability. Also, because of importance of precipitation on plant production in which obtained from this experiment and emphasized by other workers (e.g. Yang et al. 2009, Retzer et al. 2006), we recommend that range improvement by seeding combined with moisture conservation practices in semi- arid condition of Iran.

References

Barker, D.J., C.Y Sullivan, and L.E. Nosser, 1994. Water deficit effects on osmotic potential, cell wall elasticity and proloine in five forage grasses. Agronomy Journal 85: 102-105.

Busso, C.A., R.J. Muller, and J.H. Richards. 1989. Effect of drought and defoliation on bud viability in two caespitose grasses. Annal of Botany. 63:477-485.

Buwai, M. and M.J. Trlica, 1977. Multiple defoliation effects on herbage yield, vigor, and total nonstructural carbohydrates of five range species. Journal of Range Management, 30: 164-171.

Caldwell. M.M. 1984. Plant requirement for prudent grazing. In: Developing strategies for rangelands management. Westview Press, Bulder, Co. USA. pp. 117-152.

Donaghy, D.J., L.R. Turner and K.A. Adamczewski. 2008. Effect of defoliation on water soluble carbohydrate energy reserves, dry matter yield and herbage quality of tall fescue. Agronomy Journal. 100:122-127.

Gillen, R.L. and W.A. Berg. 2005. Response of perennial cool-season grasses to clipping in the southern plains. Agronomy Journals. 97:125-130.

Grime, J.P., J.G. Hodgson and R. Hunt. 1988. Comparative plant ecology. A functional approach to common British species. London. Unwin Hyman. 742p.

Holechek, J., D. Galt, J. Joseph, J. Navarro, G. Kumalo, F. Molinar and M. Thomas, 2003. Moderate and light cattle grazing effects on Chihuahuan desert rangelands. Journal of Range Management, 56: 133-139.

Holechek, J. L., R.E. Estell, C.B. Kuykendall, R. Valdez, M. cardenans, G. Nunez-Hernandez. 1989. Seeded wheatgrass yield and nutritive quality on New Mexico big sagebrush range. Journal of Range Management. 42:118-122.

Malinowski, D.P., A.A. Hopkins, W.E. Pinchak, J.W. Sij and R.J. Ansley. 2003. Productivity and survival of defoliated wheatgrass in the rolling plains of Texas. Agronomy Journal. 95:614-626.

Metzger, K.L., M.B. Coughenour, R.M. Reich and R.B. Boone, 2005. Effects of seasonal grazing on plant species diversity and vegetation structure in a semi-arid ecosystem. Journal of Arid Environments, 61: 147-160.

Retzer, V., K. Nadrowski and G. Miehe. 2006. Variation of precipitation and its effect on phytomass production and consumption by livestock and large wild herbivores along and altitudinal gradient during a drought, South Gobi, Mongolia. Journal of Arid Environments. 66: 135-150.

Richards, J.H. and and M.M. Caldwell. 1985. Soluble carbohydrates, concurrent photosynthesis and efficiency in regrowth following defoliation: a field study with *Agropyron* species. Journal of Applied Ecology. 22:907-920.

Tavakoli, H. 1993. Physiological and morphological responses of tall fescue and perennial ryegrass to defoliation. PhD. Thesis. Massey University. New Zealand.

Tavakoli, H., 2002. Rangeland production and composition under different grazing management. The Second National Range and Range Management Seminar in Iran. 128-133.

Trlica, M.J., M. Buwai, and J. W. Menke, 1977. Effect of rest following defoliation on the recovery of several range species. Journal of Range Management, 30: 21-27.

Yang, Y.H., J.Y. Fang, Y. D. Pan, and C.J. Ji. 2009. Aboveground biomass in Tibetan grasslands. Journal of Arid Environments, 73: 91-95.