Forage Production of Sainfoin across an Irrigation Gradient

Michael D. Peel,* Kay H. Asay, Douglas A. Johnson, and Blair L. Waldron

ABSTRACT

Limited water and curtailed use of public lands for grazing has increased interest in intensively managed pastures in the western USA. Our objective was to evaluate forage production of sainfoin (*Onobrychis viciifolia* Scop.), a nonbloating legume, compared with alfalfa (*Medicago sativa* L.). Thirteen sainfoin cultivars and 'Deseret' alfalfa were evaluated at four water levels (WLs) and four harvests in 1998 and 1999 under a line-source irrigation system. Water levels (WL1, WL2, WL3, and WL4) received an average of 78.3, 65.8, 34.9, and 8.3 cm of water, respectively. Significant effects were found for cultivar, cultivar × WL, harvest date, and cultivar × harvest date. Annual production of sainfoin at WL1, WL2, WL3, and WL4 was 11.6, 11.4, 9.6, and 8.9 Mg ha^{-1}, respectively, whereas annual production of Deseret was 20.7, 18.5, 18.0, and 16.3 Mg ha^{-1}, respectively. Overall yield trends across WLs were linear for sainfoin and Deseret and were parallel (P = 0.55) with slopes of b = 0.042 and b = 0.054, respectively. Yield of sainfoin at Harvest 1 through 4 was 5.5, 2.1, 1.5, and 1.3 Mg ha^{-1}, respectively. Yield of Deseret from Harvest 1 through 4 was 5.9, 5.3, 4.7, and 2.4 Mg ha^{-1}, respectively. Yields of the two species at Harvest 1 did not differ. The flat linear trend across WLs verifies that both crops are tolerant to dry conditions. With its highest production potential during early growth, sainfoin is best suited for situations where early growth of a nonbloating legume is desired, but will not compete with alfalfa in total seasonal production.

Low precipitation and growing urbanization are placing increased demands on limited water supplies in the Intermountian Region of the western USA. This, coupled with federal land policies that curtail the use of public lands for livestock grazing, has led to increased interest in upgrading private pastures, primarily through intensive management that includes use of improved pasture species to increase forage production and quality. Rumbaugh et al. (1982) demonstrated that inclusion of a legume with crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult. and *A. cristatum* (L.) Gaertn.] increased the forage yield, protein concentration, and protein yield of the resulting forage in a semiarid pasture in Utah. In addition, regrowth of the crested wheatgrass was more rapid in legume/wheatgrass mixes vs. crested wheatgrass alone.

Sainfoin is a perennial forage legume adapted to the calcareous soils of the western USA and can be used as an irrigated or dryland pasture species or for harvested forage. Forage quality of sainfoin compares favorably with alfalfa (Carleton et al., 1968a). Jensen et al. (1968) reported that gains, feed consumption, feed efficiency, and digestibility were similar for beef cattle fed sainfoin or alfalfa hay. Parker and Moss (1981) also reported that sainfoin compared favorably to alfalfa in average daily gain of dairy heifers, but that lactating dairy cows fed sainfoin were slightly less productive than those fed alfalfa.

Sainfoin is desirable for grazing because it is a nonbloating legume (Cooper et al., 1966; Jones and Lyttleton, 1971). Grazing studies with sainfoin have demonstrated its value. Karnezos and Matches (1991) reported that spring lambs exhibited a 63% greater average daily gain when grazing sainfoin in a mixture with wheatgrass than when only wheatgrass was grazed. In addition, Karnezos et al. (1994) reported that the inclusion of sainfoin in a wheatgrass mixture increased lamb production by 23% ha^{-1} compared with wheatgrass alone.

Ditterline and Cooper (1975) reported that sainfoin is easily established because of its large seed size and seedling vigor. Uniform, firm seedbeds are important for good stand establishment, and recommended seeding rates for pure stands of sainfoin range from 29 to 38 kg ha^{-1}. When seeding in mixtures, sainfoin and grass should be planted in alternating rows (Cash et al., 1993). Similar to alfalfa, optimum seeding depth for sainfoin is 1 to 2 cm (Cash et al., 1993; Tesar and Marble, 1988). Unlike alfalfa, sainfoin seeds are born in single-seed pods. Seed can be planted with pods removed or intact; however, pod removal is generally advantageous. As the germinating seedling emerges from the pod, the radicle can be injured and infected by *Alternaria* and *Fusarium* spp. pathogens (Ditterline and Cooper, 1975). Additionally, the pods slow water imbibition and contain water-soluble inhibitors that slow germination (Carleton et al., 1968a). Seed must be inoculated with sainfoin-specific *Rhizobium* to ensure N fixation. Sainfoin is best adapted to slightly alkaline soils with a pH of 7.0 to 8.0 (Cash et al., 1993) compared with alfalfa, which is sensitive to acid soils and grows best at pH values of 6.5 to 7.0 (Lanyon and Griffith, 1988).

Sainfoin exhibits poor persistence under some management practices (Carleton et al., 1968a; Ditterline and Cooper, 1975; Mowery and Matches, 1991), which has been attributed to root and crown diseases, particularly under irrigation (Cash et al., 1993). Mowery and Matches (1991) also report the timing and degree of defoliation from grazing affect persistence. Even so, Cash et al. (1993) reported that stands of sainfoin in Montana have persisted for more than 20 yr.

Forage production of sainfoin is greatest from early season growth, regardless of available moisture (Carleton et al., 1968b; Hanna and Smoliak, 1968; Bolger and Matches, 1990). Carleton et al. (1968b) reported annual yields of 'Vernal' alfalfa of 10.24 Mg ha^{-1} compared with 'Eski' sainfoin at 8.52 Mg ha^{-1}, and in a separate

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677 S. Segoe Rd., Madison, WI 53711 USA

Abbreviations: WL, water level.

trial, 'Beaver' alfalfa yielded 12.39 Mg ha^{-1} compared with Eski at 13.56 Mg ha^{-1}. In a 3-yr irrigated trial, Ditterline and Cooper (1975) reported that 'Ladak65' alfalfa yielded 11.54 Mg ha^{-1} compared with Eski at 12.04 Mg ha^{-1}. Similarly, Hanna and Smoliak (1968) reported that yield of Beaver was 7.53 Mg ha^{-1} compared with 'Krasnodar' sainfoin at 6.77 Mg ha^{-1} with irrigation. Under dryland conditions, they found that yield of Beaver was 3.16 Mg ha^{-1} compared with Krasnodar at 2.69 Mg ha^{-1}. Literature concerning the effect of varying amounts of water on sainfoin yield is limited to a report by Bolger and Matches (1990). They used a line-source irrigation system in Texas to evaluate the water-use efficiency of sainfoin and alfalfa and reported sainfoin yields at 85% of alfalfa. They demonstrated that alfalfa had greater water-use efficiency than sainfoin when spring moisture was limited; however, under adequate spring moisture, water-use efficiency was similar for sainfoin and alfalfa.

We designed a study to evaluate the relative productivity and distribution of forage production of sainfoin cultivars compared with 'Deseret' alfalfa under a water application gradient. In our study, 13 sainfoin cultivars and Deseret alfalfa were evaluated for relative forage yield under four irrigation levels. The line-source irrigation system described by Hanks et al. (1976) was combined with a rainout shelter described by Upchurch et al. (1983) to generate a water application gradient unencumbered by seasonal variations in precipitation.

MATERIALS AND METHODS

The 13 sainfoin cultivars evaluated in our study included 'Espers', 'Dukoractushchii', 'Severo-Kavkazckii Dvuukosnii', 'Poltava 553', and 'Artemovsk' from the former Soviet Union; 'Rees "A"' from the United Kingdom; 'Italian' (PI 313064) from Italy; 'Premier' from Switzerland; 'Pola' from Turkey; 'Germanskij' from the Czech Republic; 'Sparta' from Romania; and 'Eski' and 'Remont' from Montana State University. A detailed description of each cultivar can be found on the USDA National Plant Germplasm web site (http://www.ars-grin.gov/npgs/acc/acc_queries.html; verified 14 Nov. 2003). Deseret alfalfa was included for comparison and was selected because it is adapted to the Intermountain Region of the western USA (Pedersen and Griffin, 1977). Deseret has a fall dormancy rating of five according to the Certified Alfalfa Seed Council (Anonymous, 1991). A single alfalfa cultivar was used because of space limitations and the need to test as many sainfoin cultivars as possible. Plants were started in 3.8- by 21-cm Ray Leach Cone-tainers (Stuewe and Sons, Corvallis, OR) in the greenhouse 18 February 1997, and seedlings were transplanted to the field on 15 and 16 May 1997. Before planting, seed of both species were inoculated with appropriate *Rhizobium* (Liphatech, Milwaukee, WI). During the first month of establishment, replacement plants were planted where mortality occurred. The experiment was conducted at the Utah State Agriculture Experiment Station Evans Research Farm, located 2 km south of Logan, UT (41°41′ N, 111°50′ W, 1350 m above sea level). Soil type at the site was a Nibley silty clay loam series (fine, mixed, active, mesic Aquic Argixerolls). The site is on a broad, well-drained low lake terrace and consists of a silty clay layer to a depth of 1.5 m. No water table has been detected during annual testing to a depth of 2.0 m.

The experimental design was a randomized complete block with a strip plot arrangement and four replications. Cultivars constituted individual plots and were established perpendicular to and on both sides of a line-source irrigation pipe. Plots consisted of three rows of 14 plants each. The first and last plants in each row were designated borders. A single border row of 'CDII' crested wheatgrass (*A. desertorum*) was planted between each entry in the study. All plants were planted on 30-cm centers. The design and permanent nature of the rainout shelter precluded mechanical planting typically used for alfalfa and sainfoin. Furthermore, a limited seed supply for most of the sainfoin cultivars limited testing to spaced plants. A uniform plant population and optimum use of limited sainfoin seed was ensured by use of spaced plants. Each WL within a cultivar consisted of three rows of three plants for a total of nine plants. Water levels were set up in strips across cultivars. Plots nearest to the sprinkler line, which received the most water, were designated as WL1, and those most distant from the sprinkler line were designated as WL4.

Plots were watered uniformly throughout 1997, the establishment year. In 1998 and 1999, water was applied as needed based on plant growth to maintain the water gradient. The water gradient was established to represent a range of water conditions from high irrigation to semiarid conditions. Amounts of irrigation water applied to WL1 through WL4, respectively, were 66.0, 58.9, 33.6, and 11.0 cm in 1998; and 90.6, 72.7, 36.2, 5.7 cm in 1999 for an average of 78.3, 65.8, 34.9, and 8.3 cm across the 2 yr of the study. The rainout shelter was manually closed during irrigation to eliminate the effects of wind. Because the precipitation sensor for the rainout shelter malfunctioned during the spring of 1998, the plots received some precipitation during that period. This was reflected in the higher amount of water received at WL4 and in a reduced water gradient between WL1 and WL4 in 1998. To counter the effect of this precipitation, no additional irrigation was applied to the plots before Harvest 1 in 1998, resulting in a lower water application in 1998 than 1999, except at WL4. The rainout shelter was locked open during the early part of each winter to obtain about 15 cm of snow cover to prevent excessive winter injury to the plants. This contributed about an additional 1.2 cm of water each season to all WLs. Fertilizer was applied uniformly once on 18 Dec. 1998 at the rate of 56 kg ha^{-1} each of N, P, and K. These nutrients were applied to ensure that they were not a limiting factor in obtaining maximum production at all WLs.

Harvest was targeted for 10% bloom of alfalfa; at this stage, flowering among sainfoin cultivars ranged from 20 to 75% at Harvests 1 through 3 for both years, and 0 to 25% at Harvest 4. Stage of flowering was based on a visual estimate. Maturity of Deseret plots was monitored to determine when to harvest, and every plot was visually rated for percentage bloom at harvest. The number of dead or missing plants also was determined for each plot before each harvest. Plots were harvested to a stubble height of 6 cm on 28 May, 7 July, 14 Aug., and 6 Oct. in 1998 and on 4 June, 14 July, 24 Aug., and 14 Oct. in 1999. The first frost occurred on 5 Oct. 1998 (−3°C) and on 27 Sept. 1999 (−7°C). Plots were harvested by hand, and forage was dried at 55°C until samples maintained a constant weight. Dry matter yield was determined on a subplot basis.

Data were analyzed across years, WLs, and harvest dates with the GLM procedure (SAS Institute, 1999) as a split plot in time (Steel and Torrie, 1980). Data were also analyzed within years, WLs, and harvest dates. Analysis of covariance was used to compare the overall yield slope between Deseret and sainfoin across WLs. Effects due to entry, WL, and year were considered fixed. Because of inherent design limitations with line-source sprinkler systems, irrigation treatments cannot be randomized; consequently, a valid error term is not

Table 1. Mean annual forage production of 13 sainfoin cultivars and Deseret alfalfa across four water levels in 1998 and 1999.

Cultivar	Water level 1	2	3	4	Mean production	Orthogonal trends† Linear	Quadratic	Cubic
	Mg ha^{-1}							
Deseret alfalfa	20.7	18.5	18.0	16.3	18.4	87.1*	1.2ns	11.7ns
Pola	16.7	14.1	13.1	9.5	13.4	92.0***	0.3ns	7.7ns
Sparta	13.9	12.5	12.2	11.5	12.5	80.7*	5.3ns	13.9ns
Remont	15.9	13.2	10.6	9.1	12.2	94.2***	4.7ns	1.2ns
Espers	12.8	13.1	9.4	9.4	11.2	83.9***	3.4ns	12.8ns
Germanskij	11.5	12.2	10.6	10.2	11.1	75.7*	1.5ns	22.8ns
Poltava	10.7	9.9	9.6	9.6	9.9	66.5ns	27.3ns	6.2ns
Eski	9.8	11.4	9.3	9.1	9.9	42.8*	4.6ns	52.8*
Severo-Kavkazckii Dvuukosnii	9.9	10.7	9.8	8.6	9.8	67.4ns	24.7ns	7.8ns
Italian	9.9	10.8	8.8	7.9	9.4	81.6*	2.8ns	15.5ns
Dukoractushchii	9.9	10.9	8.1	8.3	9.3	63.8*	1.2ns	35.0ns
Premier	10.3	11.0	7.2	7.4	9.0	76.1***	3.5ns	20.3*
Rees "A"	10.6	8.6	8.0	7.0	8.5	83.5*	4.8ns	11.7ns
Artemovsk	9.0	9.4	8.0	7.5	8.5	77.6*	<0.1ns	19.4ns
Mean of sainfoin	11.6	11.4	9.6	8.9	10.4	97.4***	0.5ns	2.0ns
LSD (0.05)	2.2	3.1	2.5	2.3	1.4			

* Significant at the 0.05 level of probability.
** Significant at the 0.01 level of probability.
*** Significant at the 0.001 level of probability.
† Percentage of irrigation level sums of squares due to orthogonal polynomial trends.

available to test the main effect of irrigation level (Hanks et al., 1980). Therefore, caution must be used in interpretation of WL main effects. Mean separations were made on the basis of the Fisher's protected LSD test at the 0.05 level of probability. Linear, quadratic, and cubic trends of forage yield across WL were determined for each cultivar using orthogonal polynomials with unequal intervals (Gomez and Gomez, 1984). Mean water amount at each WL was used in the computation of the coefficients.

RESULTS AND DISCUSSION

Comparison of Sainfoin with Deseret

Significant effects on dry matter yield were found for cultivars ($P < 0.001$), cultivar × WL ($P < 0.05$), harvest date ($P < 0.001$), and cultivar × harvest date ($P < 0.001$). The three-way interaction of cultivar × WL × harvest date was not significant. Average yield of sainfoin dropped 23.3% from WL1 to WL4 compared with Deseret alfalfa, which dropped 21.3% from WL1 to WL4 (Table 1). Yield of sainfoin was significantly lower than Deseret alfalfa at all WLs.

Only linear trends in yield were significant for Deseret (87.1% of sums of squares, $P = 0.03$) and sainfoin (97.4% of sums of squares, $P = 0.0001$) (Table 1). The linear trends in forage yield across WLs were parallel ($P = 0.55$) for sainfoin and Deseret with slopes of $b = 0.0421$ and $b = 0.0537$, respectively (Fig. 1). It is important to note that in this comparison, a single alfalfa cultivar is compared with 13 sainfoin cultivars. Another alfalfa cultivar might have responded differently. Previous comparisons of the direct effect of WL on production of sainfoin are limited to Bolger and Matches (1990); they used a line-source irrigation system without a rainout shelter. A major difference between our study and that of Bolger and Matches (1990) is that our lowest WL received only 25% of the lowest WL in their study. Bolger and Matches (1990) conducted their work in Lubbock, TX, which has about a 50-d longer growing season than our Utah site. Long-term average daily pan evaporation at Lubbock, TX, during June and July is 11.1 and 11.5 mm, respectively, compared with our Utah site, which averaged 6.0 and 7.7 mm per day during June and July, respectively, during the 2 yr of our study (Dugas and Ainsworth, 1983). Despite the longer growing season and greater evaporative demand for water at Lubbock, Bolger and Matches (1990) observed similar linear increases in forage production for both alfalfa and sainfoin with increasing levels of water application.

A comparison of yield trends across WLs within years showed that production decreased more because of water deficits in 1999 than in 1998. Average forage yield of both sainfoin and alfalfa in 1998 at WL2, WL3, and WL4 was 97, 90, and 90% of WL1, respectively. In 1999, average yield at WL2, WL3, and WL4 was 96, 75, and 61% of WL1, respectively. The change in trend between the 2 yr occurred largely at WL3 and WL4, and could be attributed to multiple factors. The carryover of soil moisture from the establishment year and a difference

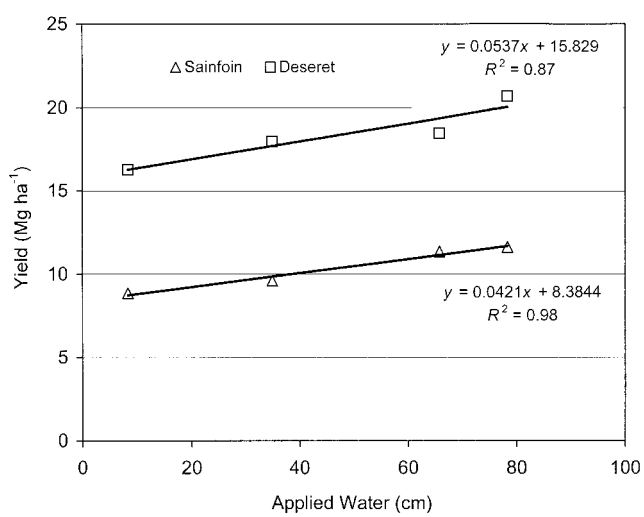

Fig. 1. Linear yield trends of 13 sainfoin cultivars and 'Deseret' alfalfa across water levels combined across 1998 and 1999. Lines are response to regression; actual yield is represented by triangles for sainfoin and squares for alfalfa.

in water application between the two years was probably responsible for the steeper gradient in forage yield in 1999 compared with 1998. In 1998, WL4 received 11.0 cm of moisture compared with 5.7 cm in 1999. A greater stand loss in 1999 compared with 1998 could have contributed to reduced production in 1999. After the fourth harvest, plant mortality for sainfoin averaged 5% in 1998 and 11% in 1999. No plant mortality occurred for Deseret in 1998, and was only 1% after the fourth harvest in 1999. An analysis of plant mortality indicated significant variation between years. However, no WL × cultivar interaction was observed, indicating that similar plant mortality occurred across all WLs.

The seasonal distribution of production and total production differed markedly between sainfoin and Deseret alfalfa. At Harvest 1, yields of sainfoin and alfalfa were not statistically different; however, the yield of alfalfa was higher than sainfoin at the three successive harvests, resulting in a significant production advantage for alfalfa (Fig. 2). Sainfoin produced 53.1, 20.4, 14.2, and 12.2% of its yearly production at Harvests 1 through 4, respectively. Alfalfa production was distributed more uniformly through the growing season with 32.2, 28.9, 25.6, and 13.3% of its yearly production at Harvests 1 through 4, respectively. A majority of total seasonal production from early growth was also reported for sainfoin by Carleton et al. (1968b), Hanna and Smoliak (1968), and Bolger and Matches (1990). Our observation that the early production of sainfoin is at least equal to alfalfa, but declined more rapidly than alfalfa, was also reported by Carleton et al. (1968b) and Hanna and Smoliak (1968).

The abundant early growth of sainfoin suggests it should be used in situations where the major focus is on grazed or harvested forage production early in the growing season or where limited early season water is available. While not the focus of this study, other factors to be considered include ease of establishment and persistence as compared with alfalfa. Ditterline and Cooper (1975) reported no failures in establishing sainfoin. However, persistence of sainfoin has often been reported as less than desirable (Carleton et al., 1968a; Ditterline and Cooper, 1975; Mowery and Matches, 1991).

A comparison of the combined effect of WL and harvest date on yield indicated that the seasonal distribution of forage production varied between sainfoin and alfalfa across WLs (Fig. 3). For sainfoin, yield reductions were greatest from Harvest 1 to 2, but also occurred between Harvests 2 and 3 for all WLs (Fig. 3a). The only reduction in yield of sainfoin between Harvests 3 and 4 occurred at the highest WL. However, yield of sainfoin was lower at WL4 than WL3 at Harvests 3 and 4. For alfalfa, the decline in yield at WL1, WL2, and WL3 from Harvests 1 through 3 was small compared with the decline between Harvests 3 and 4 (Fig. 3b). Yield at WL4 decreased more with each subsequent harvest than at the other WLs. The reduction in yield

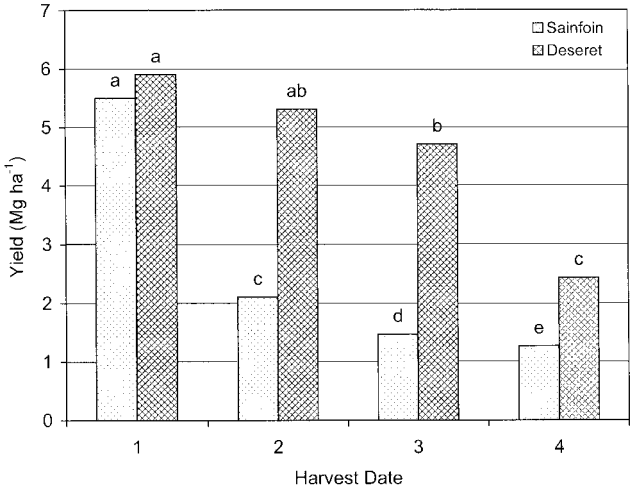

Fig. 2. Mean yields of 13 sainfoin cultivars and 'Deseret' alfalfa at four harvest dates combined across 1998 and 1999 and across water levels. Columns labeled with the same letter are not significantly different (P = 0.05).

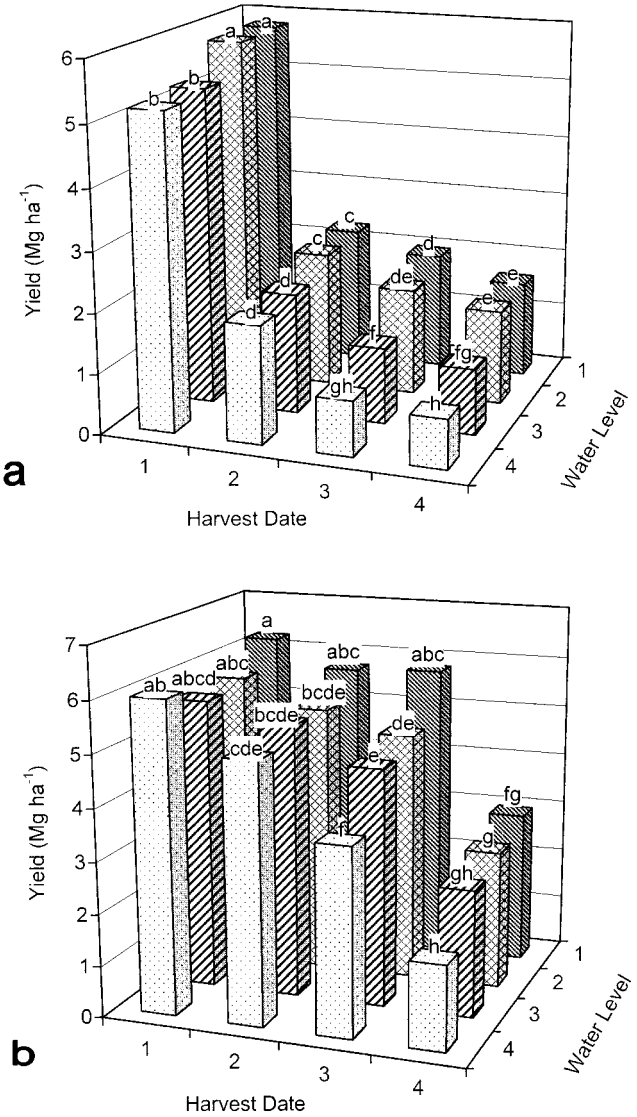

Fig. 3. Mean yields of (a) 13 sainfoin cultivars and (b) 'Deseret' alfalfa at four water levels (WL1 = highest) and four harvest dates (Harvest Date 1 = earliest) combined across 1998 and 1999. Columns labeled with the same letter are not significantly different (P = 0.05).

of alfalfa at Harvest 4 would be expected because the growth occurred during the cool, autumn period when an alfalfa cultivar with even an intermediate level of dormancy such as Deseret would tend to produce less regrowth.

Comparison of Sainfoin Cultivars

In an analysis of variance that included only the sainfoin cultivars, significant variation was detected for cultivar ($P \leq 0.001$), cultivar × WL ($P \leq 0.05$), and cultivar × harvest date ($P \leq 0.001$). The yield response to WL varied with cultivar and ranged from 9.0 to 16.7 Mg ha^{-1} at WL1 and from 7.0 to 11.5 Mg ha^{-1} at WL4 (Table 1). The cultivars with the highest overall yield showed the greatest yield increase in response to increasing WL. The yield of Pola, the top-yielding cultivar, dropped 43% from WL1 to WL4, whereas the average decrease in yield from WL1 to WL4 was 24% and the smallest decline was 7% for Eski, which yielded near the mean at all WLs. Those varieties with the least change in yield from WL1 to WL4 tended to have below-average yield across all WLs. An exception was Sparta, which had the second highest average yield, but only exhibited a yield reduction of 17% from WL1 to WL4.

The significant cultivar × WL interaction indicated a differential response of cultivars to changing WL. Changes in yield rank occurred between all WLs, but were most frequent between WL1 and WL2, where eight cultivars appeared to yield more at WL2 than WL1 (Table 1). Even though there were changes in rank among cultivars, they were small in magnitude. For example, the six cultivars with the highest average yield were similar in their yield rank at WL1 ($r = 0.94$), WL2 ($r = 0.81$), and WL3 ($r = 0.72$) to their overall yield rank, and had above-average yields at WL4. Similarly, those cultivars with yields below the mean at high WLs, while not having as large a change in yield from WL1 to WL4, tended to remain below the mean in yield at the low WLs.

Orthogonal trends were predominately linear among the sainfoin cultivars with only Eski and Premier having significant cubic trends (Table 1). The significant cubic trend for these two can be explained by a higher yield at WL2 than WL1, WL3, and WL4. This suggests a negative response to the excessive irrigation at WL1 by these cultivars that was not observed in others.

The significant cultivar × harvest date interaction reflects the changes in yield rank among cultivars across harvest dates. For example, Sparta ranked first in yield at Harvest 1, third at Harvest 2, and fourth at Harvest 3. Even though there were changes in yield rank, most sainfoin cultivars exhibited similar yield trends across harvest dates producing at least 50% of their total production at Harvest 1 (Table 2). The notable exception was Pola, which produced 43% of its total production at Harvest 1, compared with the overall mean of 53%. Pola ranked fourth in yield among sainfoin cultivars at Harvest 1, but ranked first at all other harvests and first in total production. Deseret had higher total yearly production than all sainfoin cultivars; however, at Harvest 1, Sparta yielded significantly higher than Deseret, and Pola, Remont, Espers, Germanskij, Poltava, Eski, and Severo-Kavkazckii Dvuukosnii yielded equal to Deseret (Table 2).

Table 2. Mean annual forage yield of 13 sainfoin cultivars and Deseret alfalfa at four harvest dates in 1998 and 1999 combined across four water levels.

Cultivar	Harvest date 1	2	3	4	Total mean production
	Mg ha^{-1}				
Deseret alfalfa	5.9	5.3	4.7	2.4	18.4
Pola	5.7	3.4	2.6	1.6	13.4
Sparta	6.9	2.5	1.7	1.4	12.5
Remont	6.0	2.7	2.1	1.3	12.2
Espers	5.6	2.5	1.8	1.2	11.2
Germanskij	5.7	2.4	1.7	1.4	11.1
Poltava	5.6	1.9	1.2	1.2	9.9
Eski	5.7	1.9	1.2	1.2	9.9
Severo-Kavkazckii Dvuukosnii	5.6	1.9	1.2	1.1	9.8
Italian	5.0	1.8	1.2	1.3	9.4
Dukoractushchii	5.1	2.1	1.2	1.0	9.3
Premier	5.1	1.7	1.0	1.2	9.0
Rees "A"	4.5	1.5	1.2	1.4	8.5
Artemovsk	5.0	1.3	1.0	1.2	8.5
Mean of sainfoin	5.5	2.1	1.5	1.3	10.4
LSD (0.05)	0.7	0.4	0.3	0.3	1.4

CONCLUSIONS

Forage yield responses for Deseret alfalfa and the 13 sainfoin cultivars evaluated in our study were parallel and declined linearly with decreasing water application under a line-source irrigation gradient system used in conjunction with a rainout shelter. The decline in forage production of sainfoin and Deseret alfalfa across varying WLs was relatively small, suggesting tolerance to dry conditions for both crops. When averaged across years and harvests, yields of Deseret alfalfa were significantly higher than those of sainfoin at all WLs. When averaged across WLs and years, sainfoin exhibited yields similar to Deseret alfalfa at the first harvest, but were significantly lower than Deseret at the three subsequent harvests. Consequently, sainfoin should be used in situations where the major focus is on grazed or harvested forage production early in the growing season. When forage production is desired throughout the growing season, alfalfa has a significant production advantage. The relative value of sainfoin's nonbloating characteristic and its reported lack of persistence in prolonged grazing situations vs. the greater production of alfalfa should also be considered. Sainfoin cultivars differed in their distribution of seasonal forage production; some cultivars might be better suited than others when forage production from sainfoin throughout the growing season is desired.

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REFERENCES

Anonymous. 1991. Alfalfa varieties. Certified Alfalfa Seed Council, Davis, CA.

Bolger, T.P., and A.G. Matches. 1990. Water-use efficiency and yield of sainfoin and alfalfa. Crop Sci. 30:143–148.

Carleton, A.E., C.S. Cooper, R.H. Delaney, A.L. Dubbs, and R.F. Eslick. 1968a. Growth and forage quality comparisons of sainfoin (*Onobrychis viciaefolis* Scop.) and alfalfa (*Medicago sativia* L.). Agron. J. 60:630–632.

Carleton, A.E., C.S. Cooper, C.W. Roath, and J.L. Krall. 1968b. Evaluation of sainfoin for irrigated hay in Montana. p. 44–48. *In* C.S. Cooper and A.E. Carleton (ed.) Sainfoin symposium. Bull. 627. Montana Agric. Exp. Stn., Bozeman, MT.

Cash, D., H. Bowman, and R.L. Ditterline. 1993. Sainfoin. Publ. (Montguide) MT9321. Montana Agric. Ext., Bozeman, MT.

Cooper, C.S., R.F. Elslick, and P.W. McDonald. 1966. Foam formation from extracts of 27 legume species in vitro. Crop Sci. 6:215–216.

Ditterline, R.L., and C.S. Cooper. 1975. Fifteen years with sainfoin. Bull. 681. Montana Agric. Exp. Stn., Bozeman, MT.

Dugas, W.A., and C.G. Ainsworth. 1983. Agroclimatic atlas of Texas. Part 6. Potential evapotranspiration. Misc. Pub. 1543. Texas Agric. Exp. Stn., College Station.

Gomez, K.A., and A.A. Gomez. 1984. Statistical procedures for agricultural research. 2nd ed. Wiley and Sons, New York.

Hanks, R.J., J. Keller, V.P. Rasmussen, and G.D. Wilson. 1976. Line source sprinkler for continuous variable irrigation crop production studies. Soil Sci. Soc. Am. J. 40:426–429.

Hanks, R.J., D.V. Sisson, R.L. Hurst, and K.G. Hubbard. 1980. Statistical analysis of results from irrigation experiments using the line source sprinkler system. Soil Sci. Soc. Am. J. 44:886–888.

Hanna, M.R., and S. Smoliak. 1968. Sainfoin yield evaluations in Canada. p. 38–43. *In* C.S. Cooper and A.E. Carleton (ed.) Sainfoin symposium. Bull. 627. Montana Agric. Exp. Stn., Bozeman, MT.

Jensen, R.H., C.R. Torell, A.L. Lesperance, and C.F. Speth. 1968. Evaluation of sainfoin and alfalfa with beef cattle. p. 97–99. *In* C.S. Cooper and A.E. Carleton (ed.) Sainfoin symposium. Bull. 627. Montana Agric. Exp. Stn., Bozeman, MT.

Jones, W.T., and J.L. Lyttleton. 1971. Bloat in cattle. A survey of legume forages that do and do not produce bloat. N. Z. J. Agric. Res. 14:101–107.

Karnezos, T.P., and A.G. Matches. 1991. Lamb production on wheatgrasses and wheatgrass-sainfoin mixtures. Agron. J. 83:278–286.

Karnezos, T.P., A.G. Matches, and C.P. Brown. 1994. Spring lamb production on alfalfa, sainfoin, wheatgrass pastures. Agron. J. 86: 497–502.

Lanyon, L.E., and W.K. Griffith. 1988. Nutrition and fertilizer use. p. 333–372. *In* A.A. Hanson et al. (ed.) Alfalfa and alfalfa improvement. Agron. Monograph 29. ASA, CSSA, and SSSA, Madison, WI.

Mowery, D.P., and A.G. Matches. 1991. Persistence of sainfoin under different grazing regimes. Agron. J. 83:714–716.

Parker, R.J., and B.R. Moss. 1981. Nutritional value of sainfoin hay compared with alfalfa hay. J. Dairy Sci. 64:206–210.

Pedersen, M.W., and G.D. Griffin. 1977. Registration of Deseret alfalfa. Crop Sci. 17:671.

Rumbaugh, M.D., D.A. Johnson, and G.A. Van Epps. 1982. Forage yield and quality in a Great Basin shrub, grass, and legume pasture experiment. J. Range Manage. 35:604–609.

SAS Institute. 1999. SAS/STAT user's guide. Ver. 8. SAS Inst., Cary, NC.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach. 2nd ed. McGraw-Hill, New York.

Tesar, M.B., and V.L. Marble. 1988. Alfalfa establishment. p. 303–332. *In* A.A. Hanson et al. (ed.) Alfalfa and alfalfa improvement. Agron. Monograph 29. ASA, CSSA, and SSSA, Madison, WI.

Upchurch, D.R., J.T. Ritchie, and M.A. Foale. 1983. Design of a large dual-structure rainout shelter. Agron. J. 75:845–848.