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Yield and quality of RS-2, a quackgrass × bluebunch wheatgrass hybrid

MARSHALL R. HAFERKAMP, DON C. ADAMS, MICHAEL M. BORMAN, ELAINE E. GRINGS AND PAT O. CURRIE

Haferkamp, Grings, and Currie (retired), USDA-ARS, Ft. Keogh Livestock and Range Research Laboratory, Miles City, Mont 59301; Adams, WCREC, University of Nebraska, North Platte 69101; Borman USDI-NBS, Oregon State University, Corvallis 97331.

Abstract

Understanding the effect of defoliation frequency and N fertilization on plant growth, forage yield, and quality of RS-2, a quackgrass [*Elytrigia repens* (L.) Nevski.] × bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh.) Love] hybrid, will help promote efficient use of this hybrid in livestock production systems. Plants were fertilized with 0, 112, or 224 kg N ha^{-1} in spring 1988 and 1989, or with a 112+112 kg N ha^{-1} split in spring and summer. One set of plants was unmowed or mowed to a 5-cm stubble height once in July or August in 1988 and another set was mowed initially in May, June, July, August, September, or October 1989 and monthly thereafter through October. Peak standing crop of unmowed plants was 3,470 kg ha^{-1} in 1988 and 5,850 kg ha^{-1} in 1989. In 1989 yields of fertilized plants exceeded those of unfertilized plants by 1,000 kg ha^{-1}. In 1988, crude protein exceeded 12% in unmowed forage and in 1989 varied from 20% in May to 8% in August. After fertilization, crude protein was increased by 2 to 4 percentage units in 1988 and by 2 percentage units in 1989, but fertilization had no effect on in vitro digestible organic matter. Regrowth contained more crude protein (15–22%) and digestible organic matter (29–40%) than unmowed forage. Sequential harvesting enhanced quality of regrowth, but standing crops did not exceed 350 kg ha^{-1}; except in June 1989. Sixty percent of the accumulated yield was harvested with the first mowing during May through August. Plots harvested initially in September and October were only harvested once. Our findings indicate an increase in forage yield potential and forage quality of RS-2 after harvesting and fertilizing the RS-2 hybrid.

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The RS-2 hybrid of quackgrass [*Elytrigia repens* (L.) Nevski] and bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh.) Love] was developed by the USDA-ARS Crops Research Laboratory, Logan, Ut. It is particularly noted for its productivity on slightly saline or alkaline semi-arid range sites. The plant is moderately rhizomatous and is an earlier generation of 'NewHy' (Asay et al. 1991). NewHy is adapted in temperate semi-arid rangelands which receive more than 330-mm precipitation.

RS-2 has persisted with irrigation since 1981 at Fort Keogh Livestock and Range Research Laboratory, Miles City, Mont. Currie et al. (1986) compared forage yield and quality of RS-2 to 'Prairieland' Altai wildrye (*Leymus angustus* [Trin.] Pilger), 'Vinall' Russian wildrye (*Psathyrostachys juncea* [Fisch.] Nevski), and 'Garrison' creeping foxtail (*Alopercurus arundinaceus* Poir.). RS-2 forage yield exceeded all other species and averaged 5,400 kg ha^{-1} in June or July. Forage quality of RS-2 was lower than all other species, when cut once in the growing season.

Yield and quality can be manipulated with mowing, grazing, or fertilization. Frequent quackgrass defoliation may inversely impact yield and delay maturity of subsequent cuttings, increase crude protein and in vitro digestible dry matter, and decrease neutral detergent fiber (Shaeffer et al. 1990). However, split-N application may enhance quackgrass forage quality (Schoper et al. 1979).

Our objective was to determine fertilization and mowing frequency effects on forage growth, yield, and quality of irrigated RS-2. This information will provide management options and efficiently integrate RS-2 use with native range.

Materials and Methods

Experiments were conducted on plots located in an RS-2 pasture at Miles City, Montana (46°22'30"N;36°50'00"W) in 1988 and 1989. The experiments in 1988 and 1989 were on separate places within the same pasture.

Location Description

Soil is a Havre loam, Ustic Torrifluvents, fine loamy, mixed (calcareous). No soil-N analyses were performed before the study, but residual N (NO_3) was determined in soil samples collected in the surface 30 cm of soil from each plot in fall 1989. During both years irrigation was used to supplement rainfall (Fig. 1A). Data in Fig. 1A represent on site precipitation and irrigation, as well as, precipitation received at a weather station located at Frank Wiley Field near Miles City (National Oceanic and Atmospheric Administration 1988-1989). Additional data are presented for the readers convenience to indicate growing conditions of the surrounding area before and after the study and during August 1988 when the study location received no moisture from precipitation or irrigation. Soil water was not determined in 1988, but was determined gravimetrically 12 times between 1 June and 6 Oct. 1989. Average monthly temperatures recorded at Frank Wiley Field were obtained from National Oceanic and Atmospheric Administration (1988–1989) (Fig. 1B). General plant development was defined by recording plant phenology.

Treatments

During 1988, 3 mowing treatments included an unmowed control and mowing to a 5-cm stubble height on either 11 July or 24 August. During 1989, 6 mowing treatments were imposed with initial mowings on 25 May, 28 June, 25 July, 23 August, 20 September, or 19 October 1989. Regrowth was mowed on each of the previously mowed plots on the remaining harvest dates. Exceptions included the plots mowed initially in September and October 1989 where regrowth was not mowed.

Ammonium nitrate was applied at 0, 112, and 224 kg N ha^{-1} on 5 June 1988 plus 2 applications of 112 kg N ha^{-1} on 5 June and 13 September 1988. Initial N application in 1989 was on 2 May with the second application in the split-N treatment on 1 August.

Measurements

Yield

Standing crop was harvested at 5-cm in three 30-by 60-cm quadrats per subplot on 29 June, 13 July, 28 July, 11 August, 24 August, 7 September, and 13 December 1988; and 25 May, 28 June, 5 and 25 July, 24 August, 20 September, and 19 October 1989. Samples were oven dried at 60°C for 48 hours and weighed. Carry-over effect of the 1989 mowing and fertilization treatments was estimated by measuring standing crop in 3 quadrats in each subplot in spring 1990 when RS-2 plants were 30 cm tall and inflorescences emerged.

Forage Quality

Representative forage samples were clipped at ground level from borders of plots on 20 and 29 June, 29 July, 24 August, 29 September, 26 October, 9 November, and 16 December 1988; and 25 May, 28 June, 25 July, 24 August, 20 September, and 19 October 1989, were dried for 48 hours at 60°C and weighed. Leaf blades and stems (which included leaf sheaths) were then separated and weighed to determine leaf:stem ratios and forage quality.

Samples were ground through a 1-mm screen and analyzed for total nitrogen (organic matter basis) with a Technicon[1] Auto

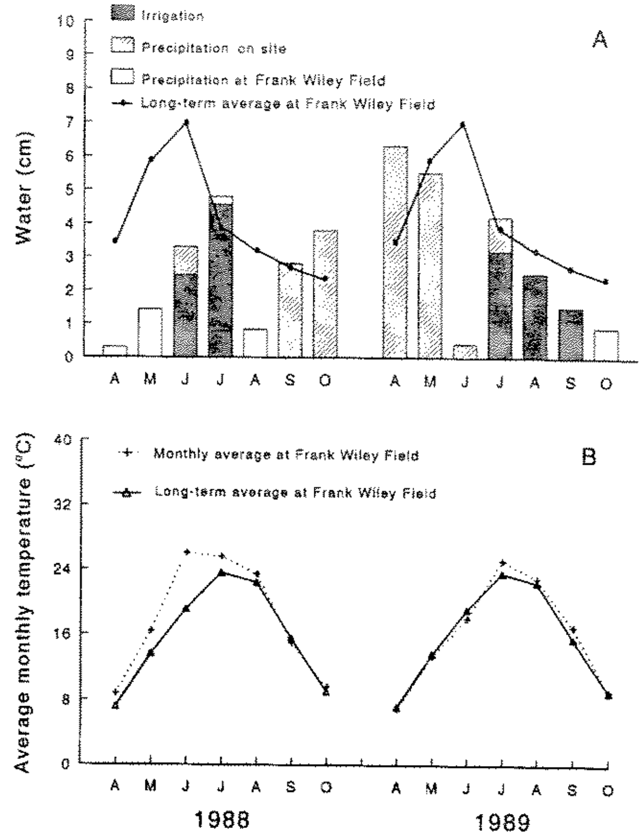

Fig. 1. (A) Precipitation and irrigation water received on the 2 research areas or in the general vicinity during May to October 1988 and 1989. Long-term averages denoted by solid line. (B) Average monthly (1988 and 1989) and long-term temperatures for Frank Wiley Field.

Analyzer (Technicon Industrial Systems 1977). Data are presented as crude protein (N * 6.25). In vitro digestible organic matter was determined using a modified Tilley and Terry (1963) technique (White et al. 1981).

Experimental Design and Statistical Analyses

Treatments were imposed in a randomized-complete-block design with a split-plot arrangement of treatments with 4 replications. Whole plots (14 by 14 m) were mowing dates, and subplots (3.5 by 14 m) were fertilization treatments. Regression analyses were used to determine relationships between standing crop, sample dates, and fertilization rates (0, 112, and 224 kg N ha^{-1}) for 1988 and 1989 unmowed controls and plots mowed on 11 July 1988. Differences were reported as significant at $P \leq 0.05$.

Main effects and interactions of mowing date, N fertilization, and plant part on crude protein and digestibility were evaluated with analysis of variance. In each instance, 2 analyses were required: 1) compared mowing effects (1988-unmowed control, 11 July mowing, and 24 August mowing; 1989-first, second, and third harvests) and N fertilization (1988-0, 112 and 224 kg N ha^{-1}; 1989–0, 112, 224 and 112+112 kg N ha^{-1}) within common sample

[1]Trade names and company names are included for the benefit of the reader, and imply no endorsement or preferential treatment of the product by USDA.

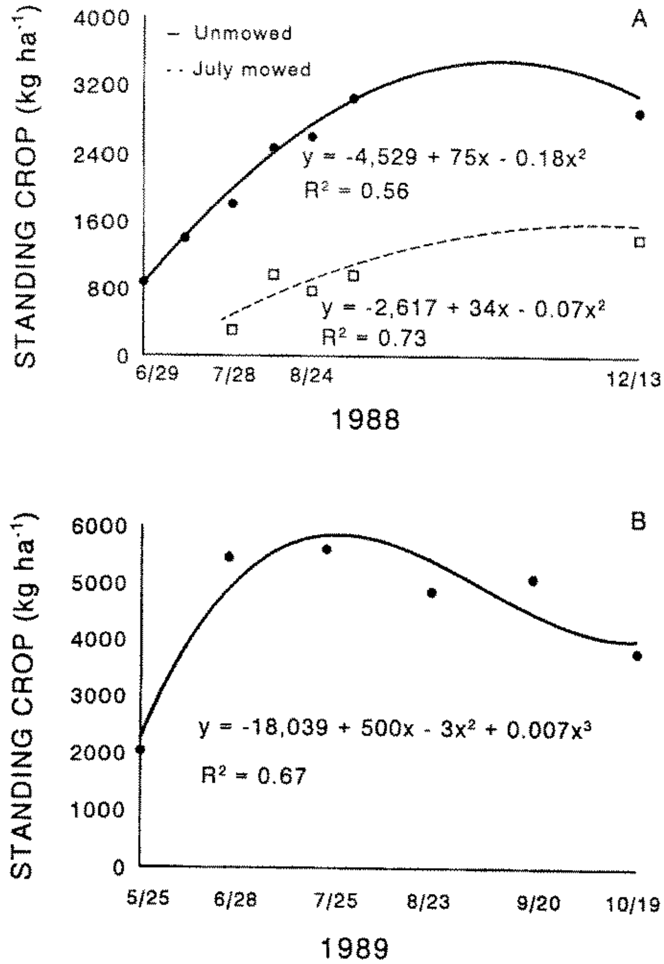

Fig. 2. Actual and predicted standing crop of unmowed and July mowed RS-2 stands in 1988, X = day of year beginning with 29 June 1988 as day 90, and actual and predicted standing crops of unmowed RS-2 stands in 1989, X = day of year beginning with 5 May 1989 as day 65.

dates, and 2) compared the effects of sample date within each mowing and N fertilization treatment. Two analyses were necessary since sampling dates were not the same for all mowing regimes. Analysis of variance was also used to determine significance of main effects and interactions of mowing sequence and N fertilization on forage regrowth and accumulated yields in 1989 and of standing crop in spring 1990. All tests were conducted with the appropriate error term required for a split-split-plot design, or with pooled residual error when the separate error terms were not significant ($P \geq 0.10$) (Petersen 1985). If there was a significant F-test, differences were reported as significant at $P \leq 0.05$, and means were separated by $FLSD_{0.05}$.

Results

Environment and Plant Development

Irrigation began later than usual for the dry spring of 1988 due to flood damage that occurred in August 1987 (Fig. 1A). Irrigation water was not applied after July 1988 because of equipment break-down and September rains. In 1989, irrigation began in July after above average precipitation in May and June and continued through September. Soil water in the 0- to 30-cm depth ranged between 18.6 and 8.0 g kg^{-1} the amount held at -0.03 MPa and -1.5 MPa during the sample period from 1 June to 6 October 1989. Water in the 30- to 60-cm and 60- to 90-cm depths was generally greater than 18.6 g kg^{-1} the amount held at -0.03 MPa. Average temperatures during April, May, June, July, August, September, and October were higher in 1988 than in 1989, and 1988 temperatures were higher than the long-term average in all months except September (Fig. 1B). These environmental differences between the 2 years contributed to year differences in plant phenological development and plant response to mowing and fertilization.

During 1988, plants developed slowly and remained vegetative for most of the growing season. Leaf:stem ratios ranged from 4.5 to 1.4 and remained relatively constant (Table 1). During 1989, plants were in the 4-to 5-leaf vegetative stage in late May, anthesis in June, and dough stage in late August. Leaf:stem ratios declined from 1 in May to less than 1 as plants matured (Table 1). Leaf:stem ratios increased to 26.1 following mowing in July 1988 and then decreased to 4.3 in November (Table 1). Leaf:stem ratios averaged 1.0 or less prior to mowing in 1989 and increased 2 to 3 fold in regrowth of plants mowed initially in May and 13 to 30 fold for plants mowed initially in June, July, or August (Table 1).

Table 1. Means ± 1 standard error for leaf:stem ratios of RS-2 plants growing on experimental mowing and fertilizer plots at Fort Keogh during 1988 and 1989.

	Mowing	
Date (1988)	Unmowed Control	July Mowed
	leaf:stem	
29 Jun.	1.4±0.08	
29 Jul.	3.2±0.35	26.1±9.82
24 Aug.	2.6±0.33	13.6±3.39
29 Sep.	4.5±0.54	25.3±3.36
26 Oct.	2.0±0.26	5.8±1.44
09 Nov.	2.0±0.15	4.3±0.46
16 Dec.	2.6±0.10	5.3±0.42

Date	Mowing					
(1989)	May	Jun.	Jul.	Aug.	Sep.	Oct.
			leaf:stem			
May	1.0±0.06	3.0±0.26	2.5±0.32	3.7±0.14	3.0±0.22	
Jun.		0.3±0.02	10.5±1.01	6.1±0.39	3.3±0.13	
Jul.			0.2±0.01	9.5±0.94	4.1±0.22	
Aug.				0.2±0.02	2.9±0.38	
Sep.					0.4±0.03	
Oct.						0.4±0.02

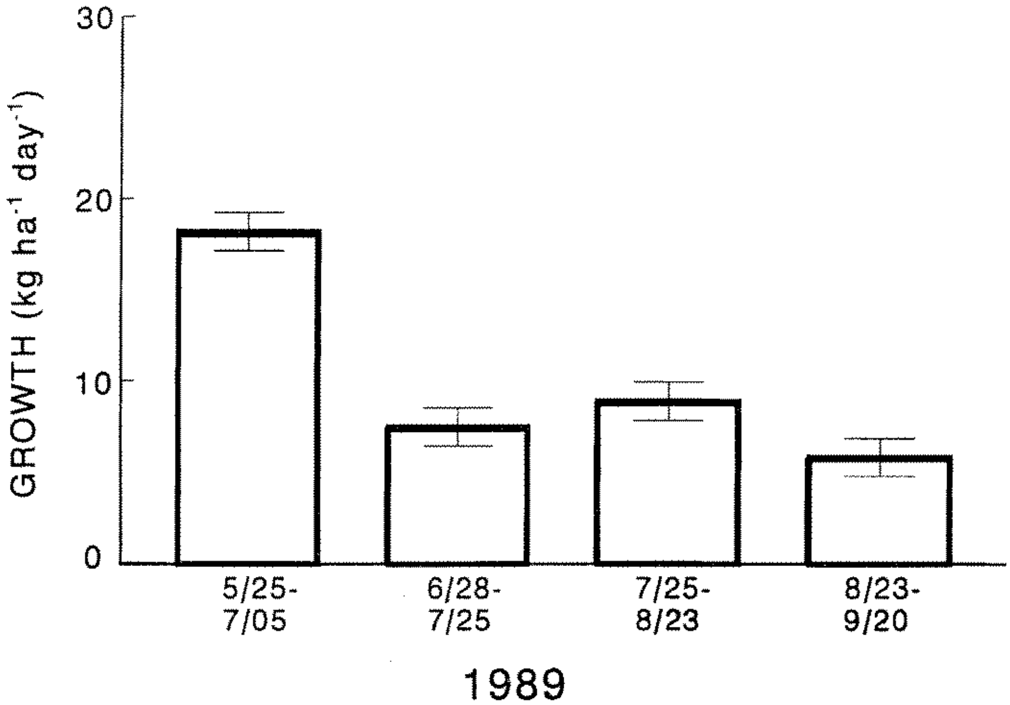

Fig. 3. Means and ± 1 standard error for initial rate of growth of RS-2 plants mowed initially in May, June, July or August 1989.

Forage Yield

Unmowed

Standing crop of unmowed plants peaked at 3,740 kg ha^{-1} during 1988 and 5,850 kg ha^{-1} in 1989 (Fig. 2). Regression analyses showed standing crop of unmowed forage was not significantly related to N fertilization at 0, 112, or 224 kg N ha^{-1} in 1988 or 1989 (data not shown). Analysis of variance, however, showed standing crops were increased 1,000 kg ha^{-1} by N (112, 224, and 112+112 kg N ha^{-1}) in 1989 but not in 1988.

Mowed

Prior to mowing on 11 July 1988 standing crop averaged 1,400 kg ha^{-1}, and regrowth averaged 1,400 kg ha^{-1} by December 1988 (Fig. 2A). In 1989, initial regrowth was greatest for plants mowed in May 1989 (Table 2, Fig. 3), but second period regrowth was similar for plants mowed initially in May, June, and July (Table 2). Regrowth was less for plants mowed later in the growing season. Prior to mowing on 24 August 1988 standing crop averaged 2,500 kg ha^{-1}, and regrowth averaged 300 kg ha^{-1} by December. In August 1989, standing crop averaged 4,858 kg ha^{-1}, and mowed plants regrew only 164 kg ha^{-1} by September (Table 2). Plants mowed initially in September or October produced standing crops averaging 5,093 and 3,784 kg ha^{-1}, but no measurable regrowth occurred between September and October. Nitrogen fertilization did not stimulate the growth of plants mowed in July 1988 (data not shown), but in 1989 initial and second period regrowth averaged 210 kg ha^{-1} without N fertilization and was significantly increased to 342 kg ha^{-1} with 224 and 112 + 112 kg N ha^{-1}.

Timing of mowing affected both regrowth and accumulated yields in 1989. Accumulated forage yields were greatest when plants were initially mowed in June and July, intermediate when mowing occurred after July (Table 2), and least when plants were mowed initially in May and October. Nitrogen fertilization increased accumulated forage yield 990 kg ha^{-1} when averaged across all N levels.

1990

Mowing in 1989 did not affect standing crops during spring 1990. Application of 112 and 224 kg N ha^{-1} increased standing crops by 23% and 51%. Residual soil NO_3 was 2, 12, 30, and 48 mg kg^{-1} for the 0, 112, 112 + 112, and 224 kg N ha^{-1} fertilization treatments, respectively. Yellow sweet clover [*Melilotus officinalis* (L.) Lam.] growing with RS-2 produced 380 kg ha^{-1} without N fertilizer, 129 kg ha^{-1} with 224 kg N ha^{-1}, and 217 kg ha^{-1} with 112+112 kg N ha^{-1}.

Forage Quality

Crude Protein

Crude protein of unmowed forage remained greater than 12% all year in 1988 (Fig. 4A) and greater than 10% in 1989 (Fig. 5A). Crude protein averaged 20% in May 1989, but the concentration declined to 13.5% by June and remained between 10.4 and 11.7% for the remainder of the year (Fig. 5A). Mowing stimulated regrowth, and crude protein of regrowth exceeded that of unmowed forage or older regrowth produced from earlier mowings in both 1988 (Fig. 4A) and 1989 (Fig. 5A). Regrowth produced during the same time period in July and August 1989 contained more crude protein after the initial than the second mowing (Fig. 5A). Crude protein was greater in leaves than stems of unmowed forage and regrowth in both 1988 (Fig. 4C and 4E) and 1989 (Fig. 5C and 5E).

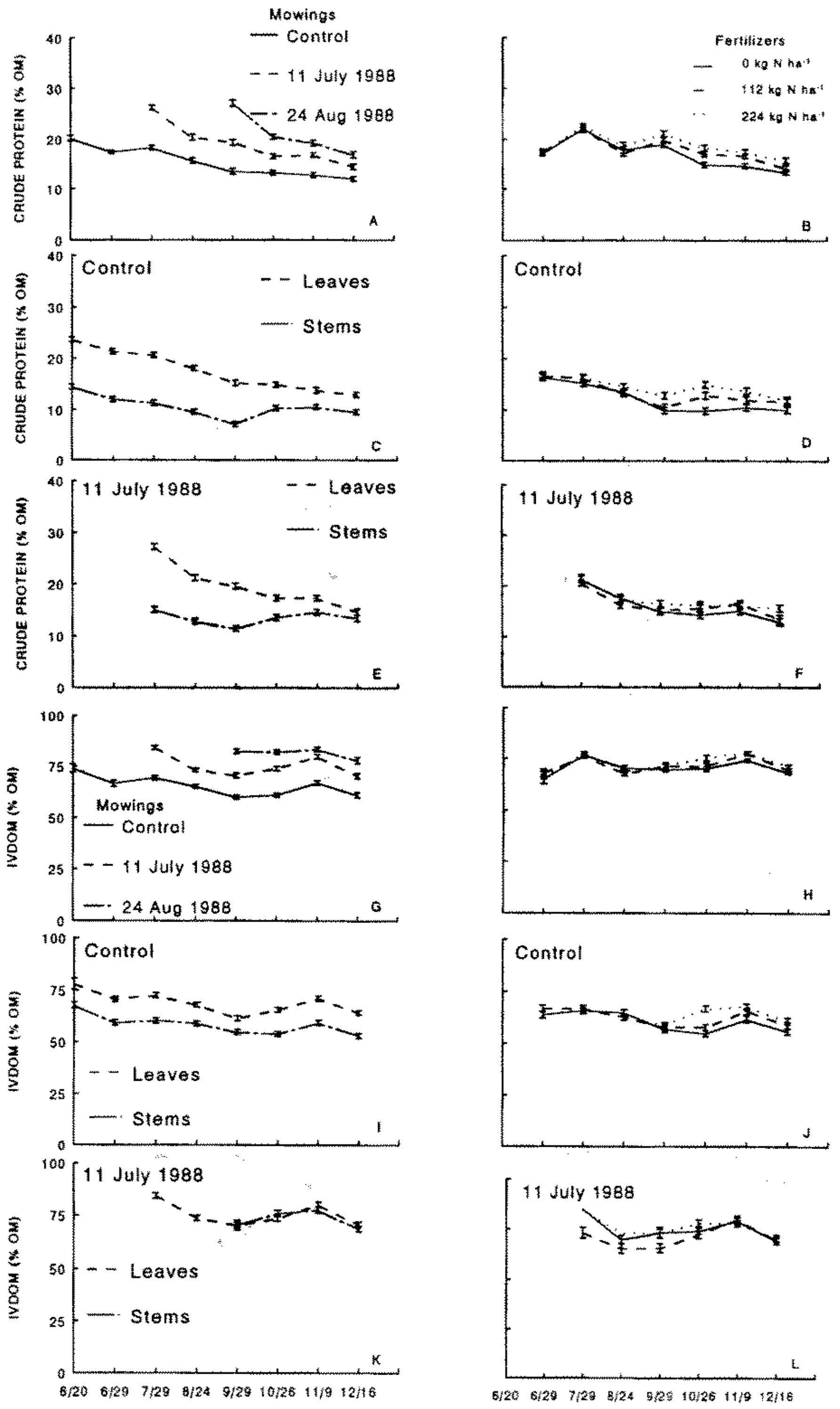

Fig. 4. Means and ± 1 standard error for crude protein (A and B) and in vitro digestible organic matter (G and H) concentration in RS-2 herbage collected from unmowed control plots, those mowed initially in July or August and fertilized with 3 rates of N in 1988. Crude protein (C, D, E, and F) and in vitro digestible organic matter (I, J, K, and L) concentrations of RS-2 leaves and stems collected from unmowed control plots, those mowed initially in July and fertilized with 3 rates of N in 1988.

Crude protein increased after N fertilization in unmowed forage in 1988, and the significant although small increase was most noticeable during October and November (Fig. 4B). Application of 224 kg N ha^{-1} increased crude protein in unmowed leaves and

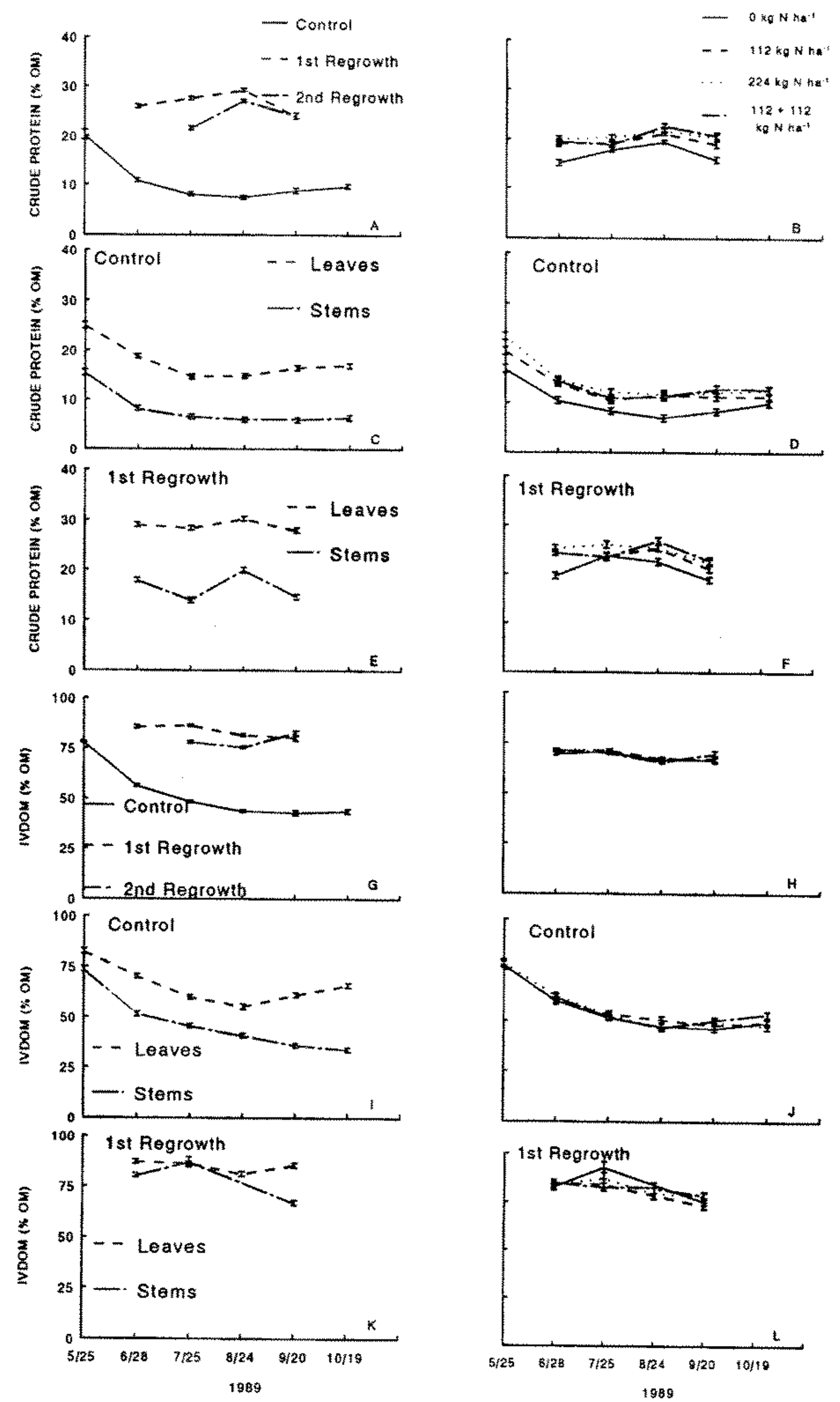

Fig. 5. Means and ± 1 standard error for crude protein (A and B) and in vitro digestible organic matter (G and H) concentration in RS-2 herbage collected from unmowed control plots and following the first (first regrowth) and second harvest (second regrowth) and all fertilized with 4 N treatments in 1989. Crude protein (C, D, E, and F) and in vitro digestible organic matter (I, J, K, and L) concentrations of RS-2 leaves and stems collected from unmowed control plots and following the first harvest (first regrowth) and all fertilized with 4 rates of N in 1989.

stems from September through December 1988 (Fig. 4D). Fertilization did not, however, affect crude protein in regrowth leaves and stems after July (Fig. 4F). During 1989, N fertilization consistently increased crude protein in leaves, stems, and forage by 3 to 6 percentage units (Fig. 5B, 5D, and 5F) in unmowed and regrowth samples. Consistent differences were, however, not detected between the 112, 224, and 112+112 kg N ha^{-1} treatments.

In vitro Digestible Organic Matter

Regrowth digestibility was greater than that of unmowed forage and greater for leaves than stems of unmowed forage during both 1988 and 1989 (Fig. 4G, 4I, 5G, and 5I). Differences in digestibility between leaves and stems of regrowth were not as consistent in unmowed forage (Fig. 4K and 5K). Nitrogen fertilization significantly increased in vitro digestible organic matter a small percentage in unmowed forage in 1988, and this increase occurred during October and November (Fig. 4J). During 1989, N fertilization had little effect on digestibility of unmowed forage or regrowth after the initial harvest (Fig. 5H, 5J, and 5L), but increased digestibility 7 percentage units in September regrowth produced after the second harvest (data not shown). Digestibility of unmowed forage was 76%.

Discussion

Although irrigated, the quantity of water applied did not appear adequate for optimum plant growth in 1988, and the amount was often less than the amount usually received as rain in the area (Fig. 1A). Standing crop of unmowed controls in 1989 ranged from 6 to 1.5 times greater than those produced in 1988 on similar dates in July. Lack of precipitation and elevated temperatures in spring 1988 were undoubtedly the dominant factors reducing forage yields that year. Once established RS-2 plants persist in relatively dry environmental conditions similar to those in 1988.

Although standing crops were larger in June and July 1989 than July 1988, considerably more regrowth was produced after the first harvest in 1988 than 1989. Probable causes for this variation between years include: 1) plants were vegetative in 1988 compared with reproductive in 1989, 2) considerably less forage was removed with the initial harvest in 1988 compared with 1989, and 3) total available water was less in June and July 1989 than 1988. However, a complete explanation for this variation in forage regrowth is difficult because it is difficult to separate the impact of plant phenological stage, environmental conditions (temperature and water), and time of mowing with potential regrowth.

During June, crude protein of the RS-2 hybrid was generally greater than 9%, or the level required for a 500-kg cow consuming 2 kg forage per 100 kg body weight, and an average milking ability during 90 to 120 day postpartum (NRC 1984) but was less than 9% from late July through late September 1989. When less than 9% the majority of the crude protein was available since acid detergent insoluble nitrogen averaged less than 2% (Haferkamp et al. 1993). Crude protein was consistently greater than 9% in regrowth from June through September, but there was often less than 300 kg ha^{-1} available forage.

Both mowing and N fertilization increased crude protein, but the increase due to fertilization was usually less than 3 percentage units. The importance of fertilizer may be minimal, since non-fertilized plants contained more than 13% crude protein averaged across mowing treatments in both 1988 and 1989. When forage from the unmowed controls in 1988 and 1989 is compared, it is apparent that forage and leaf quality were greater in 1988 than in 1989, particularly in July and August. This finding was not totally unexpected since the hot-dry conditions during 1988 limited forage yields and delayed plant phenological development.

High quality RS-2 forage in 1988, spring 1989, and in all regrowth contained a large amount of leaves (Table 1). Murray (1984) reported a high percentage of leaves in RS-2 forage. Perez-Trejo et al. (1979) reported regrowth produced from July to September (43% of accumulated yield) was mostly high-quality vegetative material.

Management Implications

The RS-2 hybrid produced high quality forage during spring and early summer and following mowing. Intermediate sized yields (>5,000 kg ha^{-1}) and good regrowth (> 500 kg ha^{-1}) were produced by plants mowed in early and mid-summer 1989. Although repeated mowings produced higher quality forage, environmental conditions were not always conducive for rapid regrowth. Thus, forage managers must set management objectives and then choose harvest dates and N fertilization treatments. Additional research will be needed to define the most efficient system for forage production with this hybrid. This study indicates large amounts, 6,000 kg ha^{-1}, of high quality forage can be harvested from pastures of RS-2 in the Northern Great Plains when managed by harvesting in mid-summer, resting, and then mowing or grazing again in fall or early winter. This is particularly true where the irrigation water supply is inadequate to provide consistent soil water levels throughout the growing season. However, the lack of a complete explanation for variation in

Table 2. Standing crops and accumulated yields for the 6 mowing treatments applied to RS-2 in 1989 at Fort Keogh.

	Mowing						
Date	May	Jun.	Jul.	Aug.	Sep.	Oct.	Accumulated
	kg ha^{-1}						
May	2,026[1]	567[2]	284[3]	297	222		3,396c[4]
Jun.		5,450	202	315	293		6,260a
Jul.			5,597	258	328		6,183a
Aug.				4,858	164		5,022b
Sep.					5,093		5,093b
Oct.						3,784	3,784c

[1]Values appearing on the diagonal represent the unmowed control.
[2]The second value in each row is the growth produced during the first regrowth period.
[3]The third value in each row is the growth produced during the second regrowth period.
[4]Means followed by similar letters are not significantly different $P \geq 0.05$.

regrowth prevents us from making management recommendations at this time.

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