Growth regulators' effect on crested wheatgrass forage yield and quality

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Abstract

If crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] could be maintained in an immature growth stage, it would improve forage quality and thus extend the grazing season. In 1981 and 1982, plant growth regulators were applied to crested wheatgrass 0, 2, 4, and 6 weeks after first floral primordium initiation to determine which compound, date, and rate of application would maximize forage quality yet minimize reduction of forage yield when harvested at seed ripe stage. Mefluidide [N-(2,4-dimethyl-5-{[(trifluoromethyl)-sulfonyl]amino}phenyl)acetamide] at 4 rates [0.0, 0.28, 0.56, and 0.84 kg/ha active ingredient (a.i.)], maleic hydrazide (MH) (1,2-dihydro-3,6-pyridazinedione) at 4.5 kg/ha a.i., and MH (3.36 kg/ha a.i.) plus chlorflurenol (methyl-2-chloro-9-hydroxyfluorene-9-carboxylate) at 1.12 kg/ha a.i. were applied to crested wheatgrass growing on a Shambo loam (Typic Haploborolls) in northeast Montana. Application of MH or MH plus chlorflurenol generally gave a similar response in heading, forage yield, CP, and in vitro organic matter digestibility on a dry matter basis (IVDOMD) as did melfluidide at 0.56 kg/ha. Mefluidide (0.56 kg/ha) applied 2 weeks after first floral primordium initiation decreased heading 80 and 95%, decreased forage yield 20 and 30%, increased CP 1.7 and 2.3 percentage units, and increased IVDOMD 1.8 to 4.2 percentage units compared to untreated, depending upon year.

Key Words: *Agropyron desertorum*, heading, crude protein, in vitro digestibility, melfluidide, maleic hydrazide, chlorflurenol, floral primordium, growth stage, application rates

Crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] provides high quality forage during early spring, but forage quality (White and Wight 1981) and livestock weight gains decrease as the growing season progresses (Campbell 1961). If crested wheatgrass could be maintained in an immature growth stage, it would improve forage quality and thus extend the grazing season.

Haferkamp et al. (1987) found that application of melfluidide [N-(2,4-dimethyl-5-{[(trifluoromethyl)-sulfonyl]amino}phenyl) acetamide] to crested wheatgrass near floral differentiation increased crude protein (CP) 1.8 to 1.9 percentage units and in vitro digestible organic matter by 3.0 to 4.0 percentage units. However, this decreased forage production by 20 to 60% depending upon rate. The effect of timing of melfluidide application was not determined. Field and Whitford (1982) found that date of melfluidide application affected reductions in dry matter production of perennial ryegrass (*Lolium perenne* L.) depending upon plant growth stage. Other growth regulators such as maleic hydrazide (MH) (1,2-dihydro-3,6-pyridazinedione) and MH plus chlorflurenol (methyl-2-chloro-9-hydroxyfluorene-9-carboxylate) have effectively reduced heading of grasses along roadsides (Wakefield and Dore 1973), and may, therefore, be effective in increasing forage quality.

The study objective was to determine the effects of growth regulators [melfluidide (4 rates), MH, and MH plus chlorflurenol] and application date on heading, forage yield, CP, and in vitro digestibility of crested wheatgrass when harvested at seed ripe stage during early August.

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Materials and Methods

The study was conducted during 1981 and 1982 on a stand of standard crested wheatgrass seeded in the early 1960s. The study site was 25 km north of Sidney, Mont., at an elevation of 640 m (2,100 ft) on a silty range site. The soil is a Shambo loam (fine-loamy, mixed, Typic Haploborolls). A single application of ammonium nitrate was made in early December 1980 at 54 kg N/ha. Average annual precipitation is 350 mm, with 21% received from October through March, 44% from April through June, and 35% from July through September. Precipitation from October 1980 through May 1981 averaged 40% of normal each month, while June 1981 was twice normal. Precipitation from October through December 1981, January through March 1982, April through May, and June through September was 99, 232, 13, and 96% of normal, respectively. January and July long-term mean temperatures are −13 and 20° C, respectively, and the average frost-free period is 122 days.

Mefluidide (0.0, 0.28, 0.56, and 0.84 kg/ha of active ingredient [a.i.]), MH alone (4.5 kg/ha a.i.), and MH (3.36 kg/ha a.i.) plus chlorflurenol (1.12 kg/ha a.i.) were applied to a new set of plots on 3 dates in 1981 in a 3 × 6 factorial arrangement of treatments (plots 1.5 by 3 m) in 4 randomized complete blocks. Crested wheatgrass had not reached the early boot stage by the third application date so a fourth application was made on a set of plots adjacent to the first set. In 1982, the treatment area was expanded on the same site to include a 4 × 6 factorial arrangement of treatments. The first application of growth regulators each year was applied within the same week that the floral primordia were initiated as determined by weekly examination of nearby plants. Growth regulators were applied to a new set of plots every 2 weeks thereafter. The fourth application was made when crested wheatgrass was 1 and 20% headed in 1981 and 1982, respectively. Application dates were 7 April, 22 April, 4 May, and 18 May 1981; and 28 April, 12 May, 25 May, and 10 June 1982. Growth regulators were applied in water using 3 flat-fan nozzles (8004) mounted on a bicycle sprayer pressurized with CO_2 at 207 kPa (30 psi) moving at 3.2 km/hr (2 miles/hr) and delivering 469 and 425 L/ha during 1981 and 1982. Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) was applied in water on 7 May 1982 at 0.5 kg/ha a.i. with flat-fan nozzles (80015) delivering 210 L/ha to control yellow sweetclover (*Melilotus officinalis* Lam.) in the plots.

Crested wheatgrass seed heads were counted each year in 2 quadrats (0.5 by 0.63 m) within each plot when seed was ripe during early August. Forage was then harvested from a 1.0 by 2.0-m sample area to a 5-cm stubble height. Forage from the remainder of the plot was removed a few days later. Plant material was dried at 60° C and ground to pass a 1-mm screen before analysis. Nitrogen concentration was determined by the macro-Kjeldahl method and multiplied by 6.25 to estimate CP. In vitro organic matter digestibility on a dry matter basis (IVDOMD) was determined by a modification of the Tilley and Terry two-stage method (White et al. 1981).

Table 1. Probability of F test for linear, quadratic, and cubic interaction for 3 and 4 application dates in 1981 and 1982 with 4 rates of mefluidide (0, 0.28, 0.56, and 0.84 kg/ha) application on number of heads, forage yield, CP, and IVDOMD of crested wheatgrass grown near Sidney, Montana.

	Heads		Forage yield		CP		IVDOMD	
Interaction	81	82	81	82	81	82	81	82
Date × rate	<.01	.01	<.01	.06	<.01	<.01	.07	<.01
$D_l \times R_l$[1]	<.01	<.01	<.01	.85	<.01	.06	<.01	<.01
$D_l \times R_q$	.54	.20	.53	.47	.64	.68	.55	<.01
$D_l \times R_c$	.23	.96	.06	.88	.60	.80	.74	.31
$D_q \times R_l$	.04	.75	.14	<.01	<.01	<.01	.06	.64
$D_q \times R_q$	<.01	.09	.79	.10	.74	.86	.39	.60
$D_q \times R_c$	.03	.22	.90	.68	.23	.36	.80	.08
$D_c \times R_l$	—	.99	—	.05	—	.66	—	.18
$D_c \times R_q$	—	.03	—	.11	—	.21	—	<.01
$D_c \times R_c$	—	.28	—	.60	—	.04	—	.05

[1] $_l$ = linear, $_q$ = quadratic, $_c$ = cubic response

Precipitation was measured daily at the site from April through October in a standard 20-cm recording rain gauge. Precipitation data from November through March and daily air temperatures from February through June were obtained from an official weather station located at Sidney, Mont. Degree days (accumulated daily mean air temperature above 3° C threshold) accumulated from the first of February through June were calculated to determine if there was a difference between years when growth regulators were applied.

The data were first analyzed with a 3 date by 6 treatment and 4 × 6 factorial analysis of variance the first and second years, respectively, using a randomized complete block design to determine if different kinds of growth regulators had a significant effect on heading, forage yield, CP, and IVDOMD. The analysis showed a significant or highly significant date by treatment interaction for all variables measured. Since F test was significant, the least significant difference (LSD) test at 0.05% was used to determine: (1) if the response from application of 0.56 kg/ha of mefluidide differed from that of MH, and (2) if MH differed from that of MH plus chlorflurenol. The data from the fourth application in 1981 were analyzed separately since they were not included in the same blocks as the first 3 dates. All treatment differences reported are significant at the $P \leq 0.05$ probability level unless otherwise stated.

The response surface showing date and rate changes for mefluidide was determined using a 3 × 4 and 4 × 4 factorial analysis of variance the first and second years, respectively. The interaction treatment sum of squares was partitioned into linear, quadratic, and cubic components with orthogonal polynomials for all possible combinations of interactions of dates and rates (Table 1). Multiple regression was used to determine the coefficients for the appropriate terms in the interaction, e.g., date quadratic by rate cubic. Data from all 4 applications dates for both years were used to draw the 3-dimensional graphs to display the response surface. Adding data from the fourth application date in 1981 only slightly decreased the R^2 values and the response surface for the first 3 dates remained nearly the same.

Polynomial equations did not adequately represent the data when there was a significant interaction between date and rate even though R^2 values ranged from 0.77 to 0.97. The 3-dimensional graphs showed a response across application dates for the zero mefluidide rates when there should have been no response. Log and log-log transformations were tested but did not adequately represent the data between the zero and 0.28 kg rates.

Results and Discussion

Comparison of Chemicals

The licensed rates of MH (4.5 kg/ha a.i.) and MH (3.36 kg/ha) plus chlorflurenol (1.12 kg/ha) were used in this study to compare with various rates of mefluidide. The licensed rate of MH plus chlorflurenol was determined by extensive testing on various grass species in both the United States and Canada (Anderson 1970). With one exception, there was no significant difference between MH alone and MH plus chlorflurenol on heading, forage yield, CP, and IVDOMD of crested wheatgrass when applied on 4 application dates in 1981 and 1982 (Table 2). This exception was when MH plus chlorflurenol decreased forage yield more than MH alone on the first application date in 1981. Stich et al. (1978) also found that application of 5.6 kg/ha of MH decreased heading of red fescue (*Festuca rubra* L.) similar to application of 3.36 kg/ha of MH plus 1.12 kg/ha of chlorflurenol. However, Jagschitz et al. (1978) found that addition of chlorflurenol with MH was better than MH alone in reducing heading in Kentucky bluegrass (*Poa pratensis* L.) and about equal for the other 4 cool-season grasses.

There were some differences between application of mefluidide at 0.56 kg/ha and MH in 1981 and 1982 on heading, forage yield, CP, and IVDOMD of crested wheatgrass (Table 2). These differences were not consistent across all application dates and may have resulted from sampling error. For example, mefluidide decreased

Table 2. Effect of mefluidide (0.56 kg/ha) (MF), maleic hydrazide (4.5 kg/ha) (MH) and MH (3.36 kg/ha) plus chlorfluerenol (1.12 kg/ha) (MH+C) on number of heads, forage yield, CP, and IVDOMD of crested wheatgrass grown near Sidney, Montana during 1981 and 1982.

	Heads/m²			Forage, T/ha			CP, %			IVDOMD, %		
Appl. date	MF	MH	MH+C	MF	MH	MH+C	MF	MH	MH+C	MF	MH	MH+C
1981												
7 Apr.	168	363	288	1.78	1.82	1.50	6.6	6.9	6.6	56.4	56.0	54.7
22 Apr.	15	97	99	1.33	1.62	1.39	8.6	8.1	8.6	57.2	57.8	56.3
4 May	55	7	4	1.04	1.25	1.18	8.3	8.0	8.2	55.3	54.6	54.1
$LSD_{.05}$[1]		122			0.25			0.9			1.9	
18 May	372	107	55	1.27	1.26	1.32	7.4	7.4	7.7	53.3	51.4	52.6
$LSD_{.05}$		166			0.19			0.7			1.5	
1982												
28 Apr.	52	87	54	1.55	1.15	0.95	5.2	6.5	6.7	59.7	59.2	58.1
12 May	16	23	12	1.13	0.94	0.83	6.2	6.9	7.3	59.7	54.9	56.3
25 May	170	102	104	1.07	1.10	1.08	6.3	6.1	6.4	56.8	57.2	59.0
10 June	313	228	240	1.64	1.61	1.59	4.7	4.8	4.7	54.3	57.1	56.1
$LSD_{.05}$[1]		95			0.22			0.6			1.9	

[1]LSD of interaction

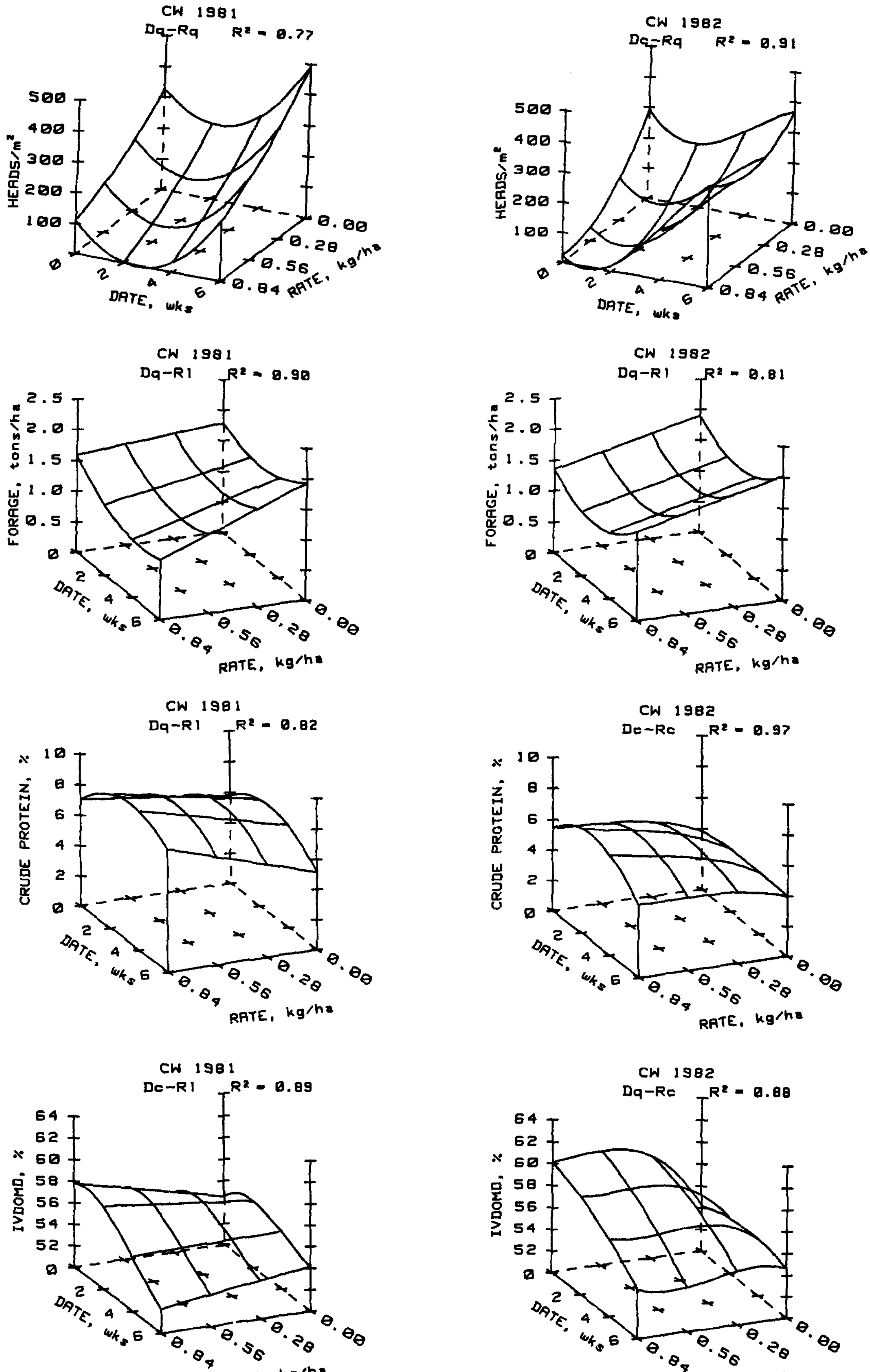

Fig. 1. *Effects of date (weeks after floral primordium initiation) and rate of mefluidide application on heads, forage yield, CP, and IVDOMD of crested wheatgrass grown near Sidney, Mont., during 1981 and 1982. The interaction terms used in plotting each response surface are listed on the graph, e.g., Dq-Rq, D=date, R=rate, l=linear, q=quadratic, and c=cubic.*

heading more than MH the first application date and less the last date in 1981 but no difference was noted the next year. Mefluidide reduced forage yield more than MH the second application date in 1981 but less than MH the first date in 1982. Mefluidide increased CP less than MH the first and second application dates in 1982 but not in 1981. Mefluidide also increased IVDOMD more than MH the last date in 1981 but less than MH the last date in 1982. Jagschitz et al. (1978) also found that mefluidide and MH were similar in reducing heading of 5 cool-season grasses. Stich et al. (1978) found that MH at 5.6 kg/ha was similar to 0.42 kg/ha of mefluidide in controlling heading of red fescue.

Date of Mefluidide Application

There was a significant date by rate interaction for mefluidide both years (Table 1). Application of mefluidide 2 to 4 weeks after floral primordium initiation in 1981 was most effective in reducing heading of crested wheatgrass but in 1982 it was most effective 2 weeks earlier (Fig. 1).

Why growth regulators were more effective reducing crested wheatgrass heading on the first application date in 1982 than in 1981 is unclear. Growth regulators were applied both years within the same week that the first floral primordium was initiated; at that time, leaf height was about 10 cm. Mefluidide was applied the first, second, third, and fourth application dates when 126, 229, 357, and 493 degree days had been accumulated the first year, and when 132, 237, 373, and 551 degree days had been accumulated the second year, respectively. Accumulated degree days were more nearly the same both years for the first 2 dates than the last 2 dates. The fourth application of mefluidide was made when crested wheatgrass was 1% and 20% headed the first and second years, respectively.

It does not appear that precipitation following application of growth regulators affected their effectiveness. During the first year, precipitation was received 5 (2 mm), 5 (2 mm), 4 (2 mm), and 5 (5 mm) days after application of growth regulators when applied 0, 2, 4, and 6 weeks after floral primordium initiation, respectively. During the second year, precipitation was received 10 (2 mm), 3 (13 mm), 2 (25 mm), and 17 (23 mm) days after application of growth regulators when applied 0, 2, 4, and 6 weeks after floral primordium initiation, respectively. The mefluidide label states that optimum results may not be obtained if precipitation occurs within 8 hr following application and this did not happen.

Others have found that date of mefluidide application on perennial ryegrass (Field and Whitford 1982), annual bluegrass [*Poa annua* var. *reptans* (Hauskins) Timm.] (Danneberger et al. 1987, Jagschitz 1985), tall fescue (*Festuca arundinacea* Schreb.) (Gerrish and Dougherty 1983), and foxtail barley (*Hordeum jubatum* L.) (White 1984) had a significant effect on head control. However, most researchers have applied mefluidide a few days after mowing of turf grasses (Hield et al. 1979), Field and Whitford 1980, Jackson et al. 1980) or on some calendar date with no measure of plant growth stage (Fales et al. 1976, Jagschitz et al. 1978, Robb et al. 1983, Glenn et al. 1987). However, White (1984) found that mefluidide was most effective in controlling heading of foxtail barley when applied near initiation of floral primordia. It appears from this study that mefluidide was most effective in reducing heading of crested wheatgrass when applied from 0 to 2 weeks after initiation of floral primordia. This would be 4 to 6 weeks before appearance of the seed heads. The optimum time for application of mefluidide to crested wheatgrass is less than that suggested on the mefluidide label. Label instructions state that maximum benefits can be attained by applying mefluidide at any time between uniform green up in the spring until 2 weeks before seed head appearance.

Mefluidide reduced August forage yield (Fig. 1) most when applied 2 to 6 weeks after floral primordium initiation in 1981 and 2 to 4 weeks after initiation in 1982. This was 2 weeks later than the most effective date for reducing heading. Mefluidide was most effective in increasing CP (Fig. 1) both years when applied 2 to 4 weeks after floral primordium initiation. In contrast mefluidide was most effective in increasing IVDOMD (Fig. 1) both years when applied 0 to 2 weeks after flora initiation.

Indices other than the initiation date of crested wheatgrass floral primordia could be used to determine when to apply mefluidide. For example, in both years Hood's phlox (*Phlox hoodii* Richardson) first flowered the same week that crested wheatgrass floral primordium was initiated. Common dandelion (*Taraxacum officinale* Weber) first flowered a week later.

Rate of Mefluidide Application

Mefluidide rates from 0 to 0.84 kg/ha decreased heads quadratically and forage yield linearly both years (Fig. 1). Mefluidide increased CP and IVDOMD linearly the first year but cubicly the second year (Fig. 1).

In 1982, application of only 0.28 kg/ha of mefluidide within 0 to 2 weeks after floral primordium initiation reduced crested wheatgrass seed heads by over 90% and increased forage quality. However, in 1981, a similar response required application of 0.56 kg/ha of mefluidide. Application of 0.56 kg/ha of mefluidide 2 weeks after floral primordium initiation decreased heading 80 and 95%, decreased forage yield 22 and 31%, increased CP 1.7 and 2.3 percentage units, and increased IVDOMD 1.8 and 4.2 percentage units in 1981 and 1982, respectively.

Morre and Tautvydas (1986) also found that application of successively higher rates of mefluidide to tall fescue caused a curvilinear decrease in heads. The response surface and magnitude of various rates of mefluidide on heading, forage yield, CP, and IVDOMD of crested wheatgrass was very similar to that reported by Haferkamp et al. (1987). They also found that heading, yield, and quality response varied from linear to curvilinear depending upon the year.

The effects of mefluidide might have been more consistent if a nonionic surfactant had been applied with it. Jackson et al. (1980) and Morre and Tautvydas (1986) found that application of a nonionic surfactant at 0.25 to 0.5% V/V with mefluidide enhanced its effectiveness, while Jagschitz et al. (1978) found no such effect. The mefluidide label originally prohibited additions of adjuvants such as surfactants, spreaders, stickers, etc. The label now states that nonionic surfactant be used at 0.25 to 0.5% volume/volume of tank mixture. If surfactant addition was as effective as reported by Morre and Tautvydas (1986), the 0.28 kg/ha mefluidide rate could have provided over 90% control of heading in 1981. This would reduce chemical cost by half.

Conclusions

Future research on improving forage quality with growth regulators should be concentrated on mefluidide. Mefluidide will be licensed for use on tall fescue in 1989, and this license may later be extended to crested wheatgrass. Maleic hydrazide or MH plus chlorflurenol will probably not be licensed for such use because of residue problems. The application of 4.5 kg/ha of MH had no consistent benefit over application of 0.56 kg/ha of mefluidide at 4 growth stages. Application of 3.36 kg/ha of MH plus 1.12 kg/ha of chlorflurenol at 4 growth stages had no beneficial effects on forage yield or quality in comparison with MH alone.

Mefluidide was more effective in decreasing heading and increasing CP and IVDOMD when applied 0 to 2 weeks after inititation of first floral primordium. The accumulation of degree days or initiation of first floral primordium can be used to determine when to apply mefluidide most effectively to crested wheatgrass. Application of 0.56 kg/ha of mefluidide 0 to 2 weeks after floral primordium initiation was the most effective treatment in reducing heading and increasing forage quality. Further research is needed to determine what date and rate mefluidide should be applied to crested wheatgrass to optimize beef gains per hectare. In order to increase beef gains per hectare mefluidide needs to be applied when it will maximize IVDOMD increases and minimize forage yield decreases.

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