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Chemical Alteration in Wheat (*Triticum aestivum*) Shoot Induced by Mefluidide and Defoliation

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Abstract. Mefluidide [N-2(2,4-dimethyl-5-((trifluoromethyl)sulfonyl)amino)phenyl)acetamide] was applied to winter wheat (*Triticum aestivum*) to determine the alterations in shoot chemical composition and the value of the changes to a wheat-based forage system in field and controlled-environment chamber experiments. Mefluidide, applied at rates between 0.1 and 0.25 kg/ha during full tiller stage (Feekes stage 4), slowed down the rate of cellulose deposition in wheat shoot and reduced neutral-detergent fiber fractions. Mefluidide decreased the rate of nitrogen decline with advancing maturity of treated plants when compared to untreated ones. Mefluidide also reduced cellulose deposition and maintained high nitrogen contents in regrowth shoot tissues in addition to the effect produced by mechanical defoliation. Mefluidide, applied during jointing stage (stage 5), also retarded wheat maturation as the chemical maintained shoot chemical characteristics equivalent to those of earlier stages of development. Mefluidide did not alter significantly shoot chemical composition when applied at boot stage (stage 10), compared to untreated wheat. Based on the experimental results, mefluidide may be a management tool to alter timing of plant development. The delay in maturation and maintenance of vegetative quality longer into the spring attained with mefluidide may suggest a beneficial role of the chemical in a dual-purpose wheat production system that favors forage utilization.

Forage of small-grain crops has long been utilized as a high-quality source of feed for ruminant animals. Winter wheat (*Triticum aestivum*) is an integral

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component of forage-livestock production systems in an area of the Great Plains covering portions of Oklahoma, Texas, New Mexico, Colorado, and Kansas. Wheat is grazed during the winter months up to the onset of plant reproductive development in about mid-March in central Oklahoma. Animals are then removed from wheat fields, allowing floral initiation and grain production (Horn and Taliaferro 1977, Donnelly and McMurphy 1984). Thus in such a dual-purpose cropping system, the economic return from wheat includes both the values of the grain crop and animal products. However, at the time of animal removal from wheat fields, there is a forage deficit, as warm-season grass pasture production is not sufficiently high to support grazing (Horn and Taliaferro, 1977). Use of mefluidide during the spring has been suggested in order to delay heading and slow down shoot dry matter accumulation when the surplus growth cannot be utilized in a forage grazing system (Dao 1984, Schaffer and Marten 1986, Undersander 1986). Growth suppression and delay in plant development should also bring about the preservation of vegetative quality traits found in younger shoot tissues to be of value in a forage production setting. In addition, the effects of mefluidide, and of chemical growth retardants in general, should be distinguishable from the effects caused by defoliation, as defoliation results in regeneration of new and highly nutritious shoot tissues.

The objective of this study was to evaluate the role of mefluidide and chemical growth retardation of winter wheat in a dual-purpose cropping system. The effects of mefluidide on shoot chemical composition were determined, separated from those of mechanical defoliation, and assessed in the context of a forage-livestock-grain production system.

Materials and Methods

Field Experiments

Field plots (2.5 × 5.0 m) were established on Canadian fine sandy loam (Udic Haplustolls) and Bethany silt loam (Pachic Paleustolls) in 1983 and 1984, respectively. In October of each year, plots were seeded with Triumph 64, an early-maturity, tall, hard-red winter wheat cultivar at rate of 100 kg/ha. Between March and May of each growing season, mefluidide was applied at five rates ranging from 0 to 0.25 kg/ha with a backpack sprayer delivering 370 L/ha at 207 kPa. Mefluidide was applied at full tiller (Feekes stage 4), jointing (stage 5), and boot (stage 10) phenological stages (Large 1954) or on calendar dates of 3/30/83, 4/24/83, 5/4/83, 3/30/84, 4/27/84, and 5/8/84.

Duration and effects of mefluidide applied during full tiller stage on shoot chemical characteristics were determined in whole plant samples (0.5 × 0.5 m quadrats) obtained at approximately 2-week intervals. Upon collection, plants were separated into leaf and stem fractions and oven-dried at 65°C for 48 h. The dried materials were separately ground to pass a sieve with 1-mm openings prior to chemical analysis. Measurements of neutral- and acid-detergent fiber (NDF, ADF) contents, cellulose, lignin, nitrogen contents, and *in*

Table 1. Relationships between log-transform of 1/reflectance (1/R) at selected wavelengths and specific chemical constituents of wheat shoot.

Chemical constituent	Equation coefficient (b_i)	Wavelength (λ)	r^2
Neutral-detergent fiber	68.1		
	−1572.3	2432	0.93
	3930.0	1934	
	517.2	1904	
	1248.1	2102	
Acid-detergent fiber	9.7		
	−409.2	1906	0.94
	846.5	2486	
	−4664.6	2380	
	4602.6	1114	
Cellulose	15.9		
	−519.6	2178	0.95
	1784.3	2388	
	1139.7	2290	
	−645.2	2266	
Nitrogen	1.2		
	−197.6	1966	0.98
	−198.6	1162	
	−52.0	1928	
In vitro dry-matter disappearance	29.5		
	2607.4	1416	0.87
	1519.2	2276	
	−2046.3	1920	
	2761	2200	

Calibration equation: $\log (1/R) = b_0 + b_1\lambda_1 + \ldots + b_n\lambda_n$.

vitro dry-matter disappearance (IVDMD) were performed using near-infrared spectroscopy (Shenk et al, 1981) to assess the impact of mefluidide on plant chemical composition and advancing maturation. A total of 80 representative plant samples from both years, of varying growth stages and of all plant parts, were analyzed for fiber content (Goering and Van Soest, 1970), Kjeldahl nitrogen (AOAC 1975), and IVDMD according to a modified Tilley and Terry procedure (Monson et al. 1969). Least-squares multiple-regression technique was used to correlate chemical data to the log-transform of 1/reflectance (1/R) at selected wavelengths; the goodness of fit of the predictive relationships is presented in Table 1. All chemical data were then determined by using reflectance data and these regression equations.

Efficacy of mefluidide as influenced by plant growth stage was evaluated on samples collected from all plots on May 13, 1983, and May 21, 1984, or when wheat was in the milk stage (Feekes stage 10.2).

Field plots were established in a randomized complete block design with four replications. Analysis of variance, regression, and least significant difference (LSD) procedures were used to detect and separate treatment differences at the 0.05 level of probability.

Table 2. Time course effect of mefluidide on selected wheat shoot chemical constituents, when applied on March 30 of 1983 and 1984

Chemical constituent	Rate (kg/ha)	1983 4/15	1983 4/27	1983 5/13	1984 4/24	1984 5/08	1984 5/21
Neutral-detergent fiber (%)	0	47.3	52.5	60.0	51.4	59.3	63.1
	0.05	46.7	51.4	59.7	50.6	59.8	61.9
	0.1	45.3	50.2	56.9	49.3	58.2	60.7
	0.25	45.3	49.7	54.8	46.4	55.8	60.2
	LSD (5%)	1.8	1.8	2.1	2.1	1.3	1.6
Cellulose (%)	0	18.7	23.1	27.1	22.0	27.1	27.2
	0.05	18.6	22.9	26.5	21.9	27.6	27.1
	0.10	18.3	22.1	25.1	21.7	26.9	27.4
	0.25	17.1	20.5	24.0	18.3	25.4	27.2
	LSD (5%)	1.0	1.2	1.2	1.2	1.3	NS
Nitrogen (%)	0	2.52	2.11	1.60	1.54	1.24	1.22
	0.05	2.54	2.08	1.64	1.56	1.44	1.24
	0.1	2.54	2.25	1.92	1.70	1.43	1.20
	0.25	2.50	2.24	2.06	1.80	1.69	1.23
	LSD (5%)	NS	0.07	0.13	0.07	0.05	NS

Controlled-Environment Chamber Experiment

Bulk samples of Bethany soil were taken at the field site, air-dried, crushed, and passed through a sieve with 2-mm openings. Samples of 1.5 kg soil were placed in 25-cm ID plastic pots and seeded with 10 fungicide-treated kernels of Triumph 64. The pots were watered and arranged in controlled-environment chamber in a randomized complete block design with five replications. The chamber was maintained at 25°C day and 15°C night temperatures and a 16-h photoperiod. Three weeks after seeding, the pots were thinned to three plants of similar size. Mefluidide was applied at rates of 0, 0.1, and 0.25 kg/ha using a compressed-CO_2 sprayer at 187 L/ha 8 weeks after seeding. Two days after mefluidide application (day 61), half of the pots had wheat clipped to 2.5 cm above soil level. The same pots were defoliated again on days 74 and 89 after seeding. Dry weights and fiber and nitrogen analyses were performed as described previously.

Results and Discussion

The general pattern of chemical changes with maturation of the untreated plant was increased in cell wall material deposition based on observations of increased neutral-detergent fiber contents, particularly cellulose (Table 2), acid-detergent fiber, and lignin contents (data not shown). Neutral-detergent fiber analysis yielded an estimate of insoluble cell wall materials—i.e., cellulose, hemicellulose, lignin, and silica. The acid-detergent treatment extracted hemicellulose from wheat shoot samples in addition to cell constituents removed by a neutral-detergent solution. Shoot nitrogen content also declined with plant

Table 3. Effects of time of application and concentration (X) of mefluidide[a] on selected wheat shoot chemical characteristics, as measured on May 13, 1983 (Y1), and May 21, 1984 (Y2).

Chemical constituent	Growth[b] stage	Equation	r^2
Neutral-detergent fiber (%)	Full tiller	$Y1 = 59.9 - 29.6X + 37.1X^2$	0.79
		$Y2 = 61.4 - 1.4X$	0.11
	Jointing	$Y1 = 60.0 - 45.7X + 128.5X^2$	0.81
		$Y2 = 62.7 - 11.7X - 144.1X^2$	0.97
	Boot	$Y1 = 60.2 - 1.9X + 13.1X^2$	0.37
		$Y2 = 62.8 - 2.1X$	0.02
Cellulose (%)	Full tiller	$Y1 = 27.0 - 20.9X + 34.7X^2$	0.86
		$Y2 = 27.2 - 0.25X$	0.11
	Jointing	$Y1 = 26.7 - 15.3X + 35.9X^2$	0.51
		$Y2 = 27.1 - 0.64X - 52.7X^2$	0.89
	Boot	$Y1 = 27.1 + 0.21X$	<0.01
		$Y2 = 27.0 + 0.13X$	<0.01
Nitrogen (%)	Full tiller	$Y1 = 1.55 + 3.69X - 6.43X^2$	0.79
		$Y2 = 1.15 + 1.03X - 2.87X^2$	0.41
	Jointing	$Y1 = 1.52 + 1.14X - 2.932X^2$	0.34
		$Y2 = 1.17 + 0.78X$	0.44
	Boot	$Y1 = 1.61 - 0.17X$	0.09
		$Y2 = 1.19 - 0.16X$	0.04
In vitro dry-matter disappearance (%)	Full tiller	$Y1 = 61.78 + 18.27X - 48.44X^2$	0.53
		$Y2 = 64.10 - 13.01X - 7.38X^2$	0.85
	Jointing	$Y1 = 62.34 + 33.9X - 104.53X^2$	0.79
		$Y2 = 64.0 - 25.94X + 227.80X^2$	0.92
	Boot	$Y1 = 62.55 + 4.79X - 29.08X^2$	0.09
		$Y2 = 62.51 + 2.14X$	0.03

[a] Mefluidide rates: 0, 0.025, 0.05, 0.10, and 0.25 kg/ka.
[b] Date of application: full tiller, 3/30/83 and 3/30/84; jointing, 4/24/83 and 4/27/84; boot, 5/4/83 and 5/8/84.

age. The general loss of forage quality associated with advance in maturity has been observed in spring wheat, oats (*Avena sativa*), barley (*Hordeum vulgare*), and triticale (*Triticum durum* × *Secale cereale*) (Smith 1960, Cherney and Marten 1982a).

Mefluidide reduced shoot neutral-detergent fiber content at rates between 0.1 and 0.25 and at 0.25 kg/ha in 1983 and 1984, respectively (Table 2). The decline indicated soluble cell contents removed by the detergent made up a greater proportion of the treated wheat forage as opposed to cell wall materials. This suppressed neutral-detergent fiber deposition was accompanied by a reduction in shoot cellulose content throughout April and part of May of 1983 and on May 8 of 1984. The lower shoot fiber contents during that period were in fact equivalent to those of untreated wheat shoots at earlier dates, suggesting a delay in plant maturation. A slowdown in rate of decline of shoot nitrogen content, induced by mefluidide at rates between 0.1 and 0.25 kg/ha, further supports that observation (Table 2).

The data for mefluidide efficacy at later phenological stages are presented in Table 3. Mefluidide, applied during the jointing stage, can also effectively re-

Table 4. Effect of mechanical defoliation and mefluidide on cumulative wheat shoot growth 89 days after seeding.

Defoliation treatment	Application rate (kg/ha)	Shoot dry matter (g/pot)
None	0	3.48
	0.1	3.31
	0.25	3.19
Yes[a]	0	2.70
	0.1	2.66
	0.25	2.57
	LSD (5%)	0.19

[a] Defoliated on days 61, 74, and 89.

duce shoot NDF and cellulose, resulting in values equivalent to those found for the full tiller stage application. Reduction in cellulose deposition ranged from 7% to 13.8% of that of control plants for the 0.25 kg/ha rate. A high correlation was found between mefluidide rate and shoot fiber content. Similarly, plant nitrogen was maintained high relative to the mefluidide application rate. The chemical alteration in shoot quality is reflected in increased digestible matter (IVDMD) potentially recoverable by a grazing animal (Table 3). There was an apparent treatment-by-year interaction that could be attributed to differences in precipitation and temperature between the two growing seasons and to leaf rust in the spring of 1984. A precipitation deficit existed during May 1984, which could have shortened the length of the chemically induced delay in maturation. Plant response to mefluidide was attenuated in 1984, because in order to induce alterations in shoot chemical composition during jointing, as well as at other phenological stages, a rate of 0.25 kg/ha was required, whereas lower mefluidide rates were sufficient to produce an inhibitory effect on cell wall material deposition in 1983.

Mefluidide did not significantly alter shoot chemical composition and thus the progress of plant maturation when applied at Feekes stage 10 (Table 3). The efficacy of chemical growth retardant is growth stage–dependent and is reduced with advancing maturity of targeted tissues. This finding concurred with the lack of an effect of mefluidide on wheat morphology at the boot stage (Dao 1987). However, we had previously found that mefluidide decreased grain yield by reducing average kernel weight and kernel number per spike. Further studies may be needed to assess the relationship between carbon allocation during grain fill and late application of mefluidide.

In a forage-grazing setting, new growth of defoliated wheat exhibits desirable nutritional characteristics (Horn and Taliaferro 1977, Cherney and Marten 1982a,b). The high nutritional quality may even become problematic (Stewart et al. 1981). Such defoliation responses must be separated from those induced by mefluidide. Cumulative shoot dry matter accumulation was reduced by defoliation with the schedule imposed in these experiments (Table 4). It was postulated that the clipping frequency was high and reduced leaf area index as well as photosynthetic activity to suboptimal levels for sustained shoot growth.

Table 5. Effects of mefluidide on growth rate of uncut wheat between day 61 and day 89, and shoot regrowth rate of defoliated wheat between day 61–74 and day 74–89.

Defoliation treatment and growth period	Application (kg/ha)	Equation	r^2
Uncut day 61–89	0	$Y = -0.864 + 0.049X$	0.66
	0.1	$Y = -0.933 + 0.047X$	0.81
	0.25	$Y = -0.286 + 0.039X$	0.83
Clipped day 61–74	0	$Y = -1.839 + 0.030X$	0.98
	0.1	$Y = -1.849 + 0.030X$	0.98
	0.25	$Y = -1.417 + 0.023X$	0.93
Clipped day 74–89	0	$Y = -0.987 + 0.013X$	0.93
	0.1	$Y = -1.046 + 0.014X$	0.94
	0.25	$Y = -0.819 + 0.011X$	0.98

Table 6. *Tiller count/pot (Y) as a function of time (X) as affected by mefluidide and mechanical defoliation.*

Defoliation treatment	Mefluidide rate (kg/ha)	Equation	r^2
None	0	$Y = 0.444 \times 0.259X - 0.001X^2$	0.58
	0.1	$Y = 0.129 + 0.282X - 0.001X^2$	0.63
	0.25	$Y = 1.104 - 0.250X + 0.007X^2$	0.84
Yes[a]	0	$Y = -0.222 + 0.332X - 0.002X^2$	0.75
	0.1	$Y = -0.098 + 0.367X - 0.002X^2$	0.76
	0.25	$Y = 0.059 + 0.299X - 0.001X^2$	0.54

[a] Defoliated on days 61, 74, and 89.

Similar reduction in growth and vigor has been observed in western wheatgrass (*Agropyron smithii* Rybd.) and turfgrasses and has been associated with frequency and height of defoliation (Everson 1966, Krans and Beard 1985). In addition, mefluidide at 0.25 kg/ha reduced wheat dry matter accumulation by 10.9% in nondefoliated wheat and 4.8% for the biweekly defoliated plants. The phytomass suppression was in agreement with field results (Dao 1984).

Although the cumulative growth reduction was not apparently large, the rate of regrowth was significantly reduced in the first 2 weeks after initial defoliation and mefluidide at 0.25 kg/ha rate (Table 5). The suppressive effect may have worn off after the second cutting. Defoliation also increased wheat tiller density (Table 6) because of reduced apical dominance and stimulated development of lateral buds (Yeang and Hillman 1984). In addition to the defoliation effect, mefluidide further enhanced tillering. The increase was most noticeable at the 0.25 kg/ha rate in the nondefoliation treatment, where the demand for photoassimilate for regrowth is lower than that required in the defoliated treatment. Regrowth tissues had lower cellulose and higher nitrogen contents than unclipped tissues in control plants. Mefluidide further delayed forage cellulose deposition and nitrogen decline, as expected with the chemically induced development delay (Table 7).

Table 7. Effect of mefluidide and mechanical defoliation on selected chemical constituents of wheat shoot and regrowth tissues on days 61, 74, and 89.

Chemical constituent	Mefluidide rate (kg/ha)	Shoot (%)		Regrowth tissue (%)	
		day 61	day 89	day 61–74	day 74–89
Cellulose	0	24.8	31.5	28.0	26.8
	0.1	25.3	30.2	28.2	26.2
	0.25	25.5	29.1	27.5	25.6
	LSD (5%)	1.2	1.0	1.0	1.0
Nitrogen	0	1.38	0.98	2.98	3.22
	0.1	1.38	0.99	3.09	3.18
	0.25	1.38	0.93	3.25	3.31
	LSD (5%)	0.10	0.06	0.09	0.12

From the experimental findings, it appears that mefluidide may be a management tool to alter the timing of winter wheat development. The changes in forage chemical composition would be beneficial to a forage-grazing production system. A less mature forage, low in fiber and high in nitrogen contents, more digestible to a grazing animal, could be made available throughout the month of March and part of April, when anthesis would normally be in progress. Animal performance data indicated that an average weight gain of 0.84 kg/day of cattle on wheat during this period is attainable (Oltjen and Bolsen 1980). Although the loss in dry-matter production and the trade-off in grain yield potential (Dao 1987, Dunphy et al. 1982) must be weighed against the gain in quality, forage availability, during a time when it would normally be nonexistent and when animal grazing needs and marketable weight gains are critical, may outweigh the aforementioned shortcomings.

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