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Effects of Aminocyclopyrachlor Plus Metsulfuron on Tall Fescue Yield, Forage Quality, and Ergot Alkaloid Concentration

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Most tall fescue in the United States is infected with a fungal endophyte which imparts certain advantages to the plant, such as drought tolerance, insect feeding deterrence, and enhanced mineral uptake. However, the endophyte also produces ergot alkaloids that are harmful to livestock and contribute to fescue toxicosis. Because the alkaloids are concentrated in seed and stems, a potential way to reduce the likelihood of fescue toxicosis is by suppressing seedhead formation with herbicides. Research was conducted from 2012 to 2014 using metsulfuron applied alone and in combination with other herbicides in spring to determine the growth response of tall fescue, effects on forage quality, and ergot alkaloid concentration. Clipping or metsulfuron applied alone or in combination with aminocyclopyrachlor or aminopyralid reduced seedhead density by 36 to 55% compared to the nontreated control. Treatments containing metsulfuron reduced spring harvest yield 35 to 61%, but no differences were observed in the summer or year-after harvests. The same treatments increased crude protein levels by 1.03 to 2.14% and reduced acid detergent fiber levels by 1.60 to 2.76% compared to the nontreated control at spring harvest. Treatments containing metsulfuron reduced ergot alkaloid concentration 26 to 34% at the spring harvest, but no differences were observed in summer-harvested forage. Results from this study indicate metsulfuron applied alone or in combination with aminocyclopyrachlor or aminopyralid can potentially reduce the severity of fescue toxicosis and improve forage quality.

Nomenclature: Aminocyclopyrachlor; aminopyralid; metsulfuron; tall fescue, *Schedonorus arundinaceus* (Schreb.) Dumort., nom. cons.
Key words: Fescue toxicosis, forage improvement, hay fields, nutritive value, pastures, seedhead suppression.

La mayoría del pasto *Schedonorus arundinaceus*, en los Estados Unidos, está infectado con un hongo endófito lo que le brinda ciertas ventajas a la planta, tales como tolerancia a la sequía, repelencia de insectos plaga, y una absorción de nutrientes mejorada. Sin embargo, el endófito también produce esclerocios con alkaloids que son dañinos para el ganado y contribuyen a la toxicosis con *S. arundinaceus*. Debido a que los alkaloids están concentrados en las semillas y los tallos, una forma potencial de reducir la probabilidad de la toxicosis con *S. arundinaceus* es el suprimir la formación de inflorescencias con herbicidas. Se realizó una investigación desde 2012 a 2014 usando metsulfuron aplicado solo y en combinación con otros herbicidas en la primavera para determinar la respuesta del crecimiento de *S. arundinaceus*, los efectos en la calidad del forraje, y la concentración de alkaloids de esclerocios. La poda o la aplicación de metsulfuron solo o en combinación con aminocyclopyrachlor o aminopyralid redujeron la densidad de inflorescencias en 36 a 55% al compararse con el testigo sin tratamiento. Los tratamientos que contenían metsulfuron redujeron los rendimientos de cosecha en la primavera 35 a 61%, pero no se observaron diferencias en la cosecha de verano o cosechas en años posteriores. Los mismos tratamientos aumentaron los niveles de proteína cruda de 1.03 a 2.14% y redujeron los niveles de fibra detergente ácida de 1.6 a 2.76% al compararse con el testigo sin tratamiento en la cosecha de primavera. Los tratamientos que contenían metsulfuron redujeron la concentración de alkaloids de esclerocios de 26 a 34% en la cosecha de primavera, pero no se observaron diferencias en la cosecha de forraje de verano. Los resultados de este estudio indican que metsulfuron aplicado solo o en combinación con aminocyclopyrachlor o aminopyralid pueden potencialmente reducir la severidad de la toxicosis con *S. arundinaceus* y mejorar la calidad del forraje.

Tall fescue is one of the most predominant cool-season perennial grasses, with 14 million ha grown in the United States (Buckner et al. 1979). Tall fescue pastures support approximately 8.5 million beef cows and 700,000 horses in the United States (Hoveland 1993). During the 1940s and 1950s, the

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Kentucky 31 (KY31) cultivar became prevalent throughout the southeastern United States, due to its dependability, adaptability to a wide range of soils, and ability to provide grazing mass over much of the year (Stuedemann and Hoveland 1988). The persistence of tall fescue in the humid transition zone is mainly due to the presence of a fungal endophyte [*Epichloë coenophiala* (Morgan-Jones & W. Gams) C. W. Bacon & Schardl, comb. nov., formerly *Neotyphodium coenophialum* (Morgan-Jones & W. Gams) Glenn, C. W. Bacon & Hanlin]. The symbiotic relationship imparts certain advantages to the plant such as drought tolerance (West et al. 1993), insect feeding deterrence (Funk et al. 1993; Johnson et al. 1985), and enhanced mineral uptake (Malinowski et al. 1998, 1999).

Despite the above characteristics and the fact that well-managed tall fescue has good quality indicators for crude protein, digestible dry matter, and mineral content (Bush and Buckner 1973), the grass has been associated with poor animal performance. Fescue toxicosis is an animal disorder that has common symptoms of intolerance to heat, rough hair coats, nervousness, reduced conception rates, and reduced average daily gain (ADG) (Stuedemann and Hoveland 1988). The malady costs American livestock producers between $600 million and $1 billion annually (Fribourg and Waller 2005; Roberts and Andrae 2010). The same endophyte that confers beneficial characteristics to tall fescue also produces ergot alkaloids that are toxic to livestock.

Several strategies have been employed to reduce the harmful effects of the endophyte. Renovation with endophyte-free or novel-endophyte tall fescue is an option in certain situations. However, endophyte-free tall fescue is less persistent than endophyte-infected tall fescue, especially in more southern regions or on rocky soils (Bransby et al. 1988; Read and Camp 1986; Roberts and Andrae 2010). Additionally, endophyte-free tall fescue stands can be readily contaminated with endophyte-infected volunteer tall fescue by seed remaining in the soil seed bank or by seed from nearby plants (Barker et al. 2005). Even replacement with novel-endophyte tall fescue might not be adopted due to complex renovation processes and high seed costs (Roberts and Andrae 2005).

When pasture renovation is not feasible, tall fescue production should include strategies related to alkaloid management, a concept that focuses on minimizing toxicity (Roberts and Andrae 2010). Ergot alkaloids are found with highest concentrations in tall fescue seedheads (Rottinghaus et al. 1991). Accordingly, ergot alkaloid concentrations in tall fescue pastures are high in late spring, when seedheads are present (Belesky et al. 1988; Rottinghaus et al. 1991). Compounding the problem of fescue toxicosis is the fact that tall fescue seedheads are often selectively grazed by cattle and horses (Aiken et al. 1993; Goff et al. 2012). In pasture systems, grazing management and mechanical clipping can be used to ensure animals consume mostly vegetative growth where the alkaloids are less abundant. Another alkaloid management strategy is suppressing seedhead formation with herbicides. Early research reported mefluidide applications suppressed tall fescue seedheads and improved forage quality (Glenn et al. 1980; Reynolds et al. 1993b; Turner et al. 1990). Other studies have shown that clethodim, haloxyfop, and sethoxydim also reduced seedhead density and improved forage quality (Reynolds et al. 1993a,b).

Recent research has focused on seedhead suppression with metsulfuron. The herbicide is an acetolactate synthase (ALS) inhibitor and provides control of several perennial broadleaf and brush species (Bradley et al. 2004; Derr 1989; Ferrell et al. 2009). In one study, metsulfuron at 6 and 8 g ai ha^{-1} reduced tall fescue seedhead density 38 to 77% and 47 to 81%, respectively (Moyer and Kelley 1995). Sather et al. (2013) reported metsulfuron-containing herbicides applied to vegetative tall fescue reduced seedhead density 14 to 61%. Researchers in Kentucky have also reported seedhead suppression with aminopyralid plus metsulfuron (Aiken et al. 2012; Goff et al. 2014). Although metsulfuron reduces tall fescue seedhead density, it also reduces forage yield (Moyer and Kelley 1995; Sather et al. 2013). As indicated by Aiken and Strickland (2013), research is needed to determine whether yield reductions can be attributed to a reduction in the presence of seedheads and stems or a direct negative effect on vegetative growth rates. Research is also needed to determine effects of different herbicides and rates on ergot alkaloids in fresh-harvested forage.

Aminocyclopyrachlor, hereafter abbreviated ACP, is a synthetic auxin herbicide that has been registered for use in noncropland and right-of-way

Table 1. Herbicide application and harvest dates in 2012 and 2013 field experiments in Tennessee.

Activity	First year		Second year	
	Alcoa	Crossville	Alcoa	Crossville
Herbicide application	March 19, 2012	March 21, 2012	April 3, 2013	April 9, 2013
Spring harvest	April 27, 2012	May 10, 2012	May 23, 2013	May 29, 2013
Summer harvest	June 21, 2012	July 3, 2012	August 20, 2013	August 22, 2013
Year-after harvest	May 16, 2013	May 29, 2013	May 13, 2014	May 27, 2014

applications (Anonymous 2014). One potential herbicide application to pastures is a combination of ACP plus metsulfuron. Previous research has been conducted to evaluate the efficacy of ACP plus metsulfuron on pasture weeds, but has not included impacts on other aspects of forage production. Therefore, the objective of this study was to determine the effects of metsulfuron applied alone and in combination with ACP or aminopyralid on tall fescue injury, seedhead density, total yield, leaf yield, forage nutritive values, and ergot alkaloid concentration.

Materials and Methods

Research was initiated in March 2012 and repeated in April 2013 at the East Tennessee Research and Education Center near Alcoa, TN (35.844°N, 83.965°W) and the Plateau Research and Education Center near Crossville, TN (36.014°N, 85.129°W). The predominant soil types at Alcoa sites were Decatur silty clay loam and Alcoa loam, whereas the predominant soil at Crossville was a Lily loam. The sites chosen were well-established KY31 tall fescue pastures with at least 85% endophyte infestation level as determined by microscopic analysis of tillers. Each site was mowed in winter prior to trial initiation to 15 cm stubble height. Individual treated plot size was 1.8 by 6.1 m with running checks 0.5 m wide on both sides of the plot. Plots were arranged in a randomized complete block design with four replications. Nitrogen was applied 2 wk after herbicide application at a rate of 67 kg ha^{-1}. Livestock were excluded for the duration of the experiment.

Herbicide treatments were ACP (DPX-MAT28 50SG Herbicide, DuPont, Wilmington, DE 19898) plus metsulfuron (Ally XP Herbicide, DuPont) at 47 + 7 and 78 + 12 g ai ha^{-1}, metsulfuron alone at 7 and 12 g ai ha^{-1}, aminopyralid plus metsulfuron (Chaparral Specialty Herbicide, Dow AgroSciences, Indianapolis, IN 46268) at 77 + 12 g ai ha^{-1}, and ACP plus 2,4-D (DPX-RRW97 Herbicide, DuPont) at 78 + 591 g ai ha^{-1}. Rates were based on anticipated use rates of ACP plus metsulfuron, where 47 + 7 and 78 + 12 g ha^{-1} correspond to 0.6× and 1× use rates, respectively. ACP plus 2,4-D was included as a comparison herbicide treatment that did not contain metsulfuron. At herbicide application, tall fescue was 15 cm in height and in the vegetative growth stage (Table 1). Early spring herbicide application coincided with recommended timing for control of several weeds, including musk thistle (*Carduus nutans* L.), buckhorn plantain (*Plantago lanceolata* L.), and buttercup species (*Ranunculus* spp.). Herbicides were applied with a CO_2 backpack sprayer and a four-nozzle boom calibrated to deliver 140 L ha^{-1} of spray solution which included nonionic surfactant at 0.25% v/v. A clipping treatment was included to compare chemical seedhead suppression with mechanical removal. Plots were clipped at the early boot stage of tall fescue, approximately 2 wk before harvest using a sicklebar mower. Clipping height was 25 ± 3 cm, which was ~ 3 cm above the leaf canopy, in order not to interfere with later yield measurements.

Tall fescue discoloration and stunting were visually evaluated at 2, 4, 8, 16, and 52 wk after treatment (WAT) on a 0 to 99% scale. Discoloration was based on yellowing, browning, and desiccation of tall fescue leaves, whereas stunting was based on plant height and vigor. Plots were harvested once in the spring and once in the summer to determine seedhead density, yield, forage quality, and total ergot alkaloid concentration. At each harvest time, two 0.09 m^2 sample areas in each plot were clipped using hand trimmers at a height of 12 ± 1 cm. The plant material was separated into tall fescue leaves, tall fescue stems (including seedheads), and other plant matter, then dried and weighed. Leaf blades that were attached to stems were removed at the collar. A 0.9-m-wide strip in the center of each plot was harvested using a Carter forage harvester (Carter Manufacturing. Co., Brookston, IN 47923) and weighed for fresh weight. The remaining study area was then harvested in the same manner, and biomass was removed to simulate a typical hay harvest. At approximately 2 mo and 6 mo after treatment (MAT), tall fescue tiller density was determined by counting tillers present in two 0.09 m^2 sample areas in each plot. The following spring, approximately 14 MAT, plots were harvested again to determine yield, forage quality, and tiller density.

Subsamples of harvested forage were placed in paper bags and dried in a forced air oven at 60 C for 72 h and moisture content determined. The dried subsamples were ground using a Wiley mill (Thomas Scientific, Swedesboro, NJ 08085) to pass a 2 mm screen and then ground using a cyclone mill (UDY Corporation, Fort Collins, CO 80524) to pass a 1 mm screen and stored in sealed bags at room temperature. Ground samples were scanned from 1,100 to 2,500 nm to determine log $reflectance^{-1}$ using a near-infrared reflectance spectroscopy (NIRS) instrument (FOSS 5000, FOSS NIRSystems, Inc., Laurel, MD 20723) while running WinISI II software (Infrasoft International LLC, State College, PA 16801). Forage quality constituents of crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin, calcium (Ca), magnesium (Mg), and relative forage quality (RFQ) were estimated using a mixed hay predictive equation (12MH50-2.eqa, NIRS Forage and Feed Testing Consortium, Hillsboro, WI) and are reported on a dry matter (DM) basis. Spectral data were subjected to principal component analysis and all predicted nutritive values for forage samples fit the supplied equations (H-statistics for all samples were < 3.0).

For ergot alkaloid determination, additional subsamples of fresh harvested forage were sealed in plastic bags and immediately stored in a dry ice cooler to prevent alkaloid degradation. Plastic bags were then frozen and stored at −21 C until processing. Samples were freeze-dried at −30 C for 14 d and then ground to 1 mm particle width as previously described. Total ergot alkaloid concentrations were determined according to the procedure described by Hill and Agee (1994) using a commercial ELISA test kit (Agrinostics Ltd., Watkinsville, GA 30677).

All data were subjected to ANOVA using PROC GLIMMIX (SAS Version 9.4, SAS Institute, Inc., Cary, NC 27513). Each site-year combination was considered an environment sampled at random, as suggested by Carmer et al. (1989) and Blouin et al. (2011). Treatment was considered a fixed effect, whereas environment and replication (nested within environment) were considered random effects. Tall fescue injury data were arc sin square-root transformed prior to analysis to improve normality, although nontransformed means are presented for clarity. Means from all data were separated using Fisher's protected LSD test at $P \leq 0.05$.

Results and Discussion

Tall Fescue Injury. Injury to tall fescue was observed with all treatments containing metsulfuron through the summer harvest (Table 2). At 2 WAT, treatments containing 12 g ha^{-1} metsulfuron resulted in higher discoloration and stunting compared to treatments containing 7 g ha^{-1} metsulfuron. By 4 WAT, stunting was 49 to 53% with treatments containing 12 g ha^{-1} metsulfuron. By 8 WAT, the highest stunting observed was 28%, indicating that tall fescue had partially recovered. Moyer and Kelley (1995) reported 58 to 75% tall fescue injury at 3 WAT with 8 g ha^{-1} metsulfuron, but Payne et al. (2010) observed 22% injury at 1 mo after treatment with 10 g ha^{-1} metsulfuron. Our results fall within the range of injury reported in these previous studies. At the summer harvest, tall fescue was nearly fully recovered, with maximum discoloration and stunting at 6 and 8%, respectively. Payne et al. (2010) also found that tall fescue had nearly recovered at 5 MAT, where injury was $< 5\%$ with 10 g ha^{-1} metsulfuron applied in the spring. At 1 yr after treatment (YAT), no discoloration or stunting was observed (data not shown). These results corroborate with those of Sather et al. (2013), who found no tall fescue height differences with the nontreated control at 1 YAT after spring applications of several metsulfuron-containing herbicides.

Seedhead Density. Clipping and metsulfuron applied alone or in combination with ACP or

Table 2. Discoloration and stunting of tall fescue in response to herbicide treatments across 4 site-yr in Tennessee.

Treatment[a,b]	Rate	2 WAT[b]		4 WAT		8 WAT		Summer harvest	
		Discoloration[c]	Stunting	Discoloration	Stunting	Discoloration	Stunting	Discoloration	Stunting
	g ha^{-1}	%							
ACP + MET	47 + 7	11 b	19 b	17 b	38 b	10 bc	18 b	3 b	6 ab
ACP + MET	78 + 12	16 a	27 a	23 a	49 a	9 c	24 a	4 ab	5 b
MET	7	12 b	21 b	18 b	37 b	7 c	14 c	4 ab	4 b
MET	12	15 a	28 a	26 a	53 a	15 a	28 a	5 ab	8 ab
APD + MET	77 + 12	16 a	29 a	23 a	50 a	13 ab	24 a	6 a	8 a
ACP + 2,4-D	78 + 591	0 c	0 c	0 c	0 c	0 d	0 d	0 c	0 c

[a] Herbicide treatments were applied with nonionic surfactant at 0.25% v/v.

[b] Abbreviations: ACP, aminocyclopyrachlor; MET, metsulfuron; APD, aminopyralid; WAT, weeks after treatment.

[c] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$. All data were arc sin transformed prior to analysis to improve normality. Nontransformed means are presented for clarity.

aminopyralid reduced tall fescue seedheads 36 to 55% compared to the nontreated control (Table 3). Although visual injury evaluations were different for treatments containing metsulfuron at 7 g ha^{-1} compared to 12 g ha^{-1}, seedhead reduction was similar among these treatments, indicating that treatments containing 7 g ha^{-1} metsulfuron might adequately reduce seedheads with less injury to tall fescue. Moyer and Kelley (1995) observed 47 to 81% seedhead reduction with 8 g ha^{-1} metsulfuron. Sather et al. (2013) reported 40 to 61% seedhead reduction with rates of metsulfuron ranging from 13 to 21 g ha^{-1} applied alone or in combination with aminopyralid at spring vegetative stage. In the same study, no differences were found within those treatments, also indicating that seedhead suppression can be achieved with lower rates of metsulfuron. Results from Kentucky studies have also shown aminopyralid plus metsulfuron reduces tall fescue seedheads (Aiken et al. 2012; Goff et al. 2014). Treatment with ACP plus 2,4-D resulted in higher seedhead density than the nontreated control. One reason for this observation might be due to reduced broadleaf weed competition in those plots, because development of grass tillers is hindered by shading (Smith and Whitelam 1997).

Table 3. Tall fescue seedhead density, yield, and total ergot alkaloid concentration at spring harvest in response to clipping and herbicide treatments across 4 site-yr in Tennessee.

Treatment[a]	Rate	Fescue Seedheads[b]	Total Biomass Yield	Fescue Leaves	Fescue Stems	Other	Alkaloid Concentration	Fescue Tillers
	g ha^{-1}	no. m^{-2}	kg ha^{-1}				μg kg^{-1}	no. m^{-2}
ACP + MET[c]	47 + 7	149 c	2526 bc	640 b	656 b	1522 ab	1,074 cd	753 c
ACP + MET	78 + 12	143 c	2010 c	568 b	603 b	1165 c	983 d	870 abc
MET	7	202 c	2671 b	724 b	996 b	1150 c	1,091 cd	794 bc
MET	12	158 c	2251 bc	575 b	578 b	1147 c	1,022 cd	878 abc
APD + MET	77 + 12	150 c	2180 bc	542 b	569 b	1309 abc	978 d	793 bc
ACP + 2,4-D	78 + 591	399 a	4275 a	1225 a	2171 a	1368 abc	1,771 a	1024 a
Clip	—	183 c	3785 a	1095 a	1020 b	1243 bc	1,298 bc	1004 a
Nontreated	—	317 b	4139 a	1090 a	1726 a	1591 a	1,484 b	936 ab

[a] Herbicide treatments were applied with nonionic surfactant at 0.25% v/v. Clipping treatment was applied 2 wk before first harvest.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$.

[c] Abbreviations: ACP, aminocyclopyrachlor; MET, metsulfuron; APD, aminopyralid.

Table 4. Yield and total ergot alkaloid concentration in tall fescue at summer harvest in response to clipping and herbicide treatments across 4 site-yr in Tennessee.

Treatment[a]	Rate	Total Biomass Yield[b]	Fescue Leaves	Alkaloid Concentration	Fescue Tillers
	$g\ ha^{-1}$	$kg\ ha^{-1}$		$\mu g\ kg^{-1}$	no. m^{-2}
ACP + MET[c]	47 + 7	1,869 a	1,513 a	828 a	763 a
ACP + MET	78 + 12	1,805 a	1,840 a	869 a	876 a
MET	7	2,027 a	1,570 a	760 a	845 a
MET	12	1,931 a	1,435 a	804 a	914 a
APD + MET	77 + 12	2,003 a	1,278 a	673 a	751 a
ACP + 2,4-D	78 + 591	1,773 a	1,856 a	713 a	869 a
Clip	—	1,836 a	1,500 a	768 a	896 a
Nontreated	—	1,650 a	1,411 a	701 a	755 a

[a] Herbicide treatments were applied with nonionic surfactant at 0.25% v/v. Clipping treatment was applied 2 wk before first harvest.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$.

[c] Abbreviations: ACP, aminocyclopyrachlor; MET, metsulfuron; APD, aminopyralid.

Tall Fescue Yield. Metsulfuron applied alone or in combination with ACP or aminopyralid reduced total biomass yield at spring harvest (Table 3). Yield reduction with treatments containing 7 g ha^{-1} metsulfuron was 35 to 39%, whereas reduction with treatments containing 12 g ha^{-1} metsulfuron was 46 to 51% from the nontreated control. In a previous study, metsulfuron applied alone at 4 to 8 g ha^{-1} reduced yield 31 to 60% (Moyer and Kelley 1995). Metsulfuron rates ranging from 13 to 21 g ha^{-1} applied alone or in combination with aminopyralid reduced tall fescue yield 43 to 63% (Sather et al. 2013).

Herbicide treatments containing metsulfuron reduced tall fescue stem yield 42 to 67%, but also reduced tall fescue leaf yield 34 to 50% from nontreated. The greatest reduction in yield of other species was 28%, following application of 77 + 12 g ha^{-1} aminopyralid plus metsulfuron. The majority of other plant species present was Kentucky bluegrass (*Poa pratensis* L.) and orchardgrass (*Dactylis glomerata* L.). Because tall fescue was injured with treatments containing metsulfuron, the proportion of other species was greater, most likely due to the greater tolerance of Kentucky bluegrass and orchardgrass to metsulfuron (Dernoeden 1990; Witt 2009). At 2 MAT, ACP plus metsulfuron at 47 + 7 g ha^{-1} reduced tall fescue tiller density 20% compared to the nontreated control. As indicated by the reductions in tall fescue leaf yield and tiller density, total biomass yield reduction at spring harvest can be attributed not to just seedhead suppression, but also reductions in tall fescue vegetative growth per unit area. Goff et al. (2014) observed reductions in tall fescue crowns and increased presence of orchardgrass and Kentucky bluegrass in response to aminopyralid plus metsulfuron applied in early spring.

Total biomass yields and tall fescue leaf yields in all treatments were the same at the summer harvest (Table 4). Similarity between yields provides further

Table 5. Yield and tiller density of tall fescue at year-after harvest in response to clipping and herbicide treatments across 4 site-yr in Tennessee.

Treatment[a]	Rate	Total Biomass Yield[b]	Fescue Tillers
	$g\ ha^{-1}$	$kg\ ha^{-1}$	no. m^{-2}
ACP + MET[c]	47 + 7	4,179 a	897 a
ACP + MET	78 + 12	4,274 a	875 a
MET	7	4,118 a	903 a
MET	12	4,211 a	861 a
APD + MET	77 + 12	3,902 a	780 a
ACP + 2,4-D	78 + 591	4,276 a	891 a
Clip	—	4,162 a	832 a
Nontreated	—	3,960 a	866 a

[a] Herbicide treatments were applied with nonionic surfactant at 0.25% v/v. Clipping treatment was applied 2 wk before first harvest.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$.

[c] Abbreviations: ACP, aminocyclopyrachlor; MET, metsulfuron; APD, aminopyralid.

Table 6. Tall fescue nutritive values at spring harvest in response to clipping and herbicide treatments across 4 site-yr in Tennessee.

Treatment[a]	Rate	CP[b,c]	ADF	NDF	Lignin	Ca	Mg	RFQ
	g ha^{-1}	%						—
ACP + MET[c]	47 + 7	14.23 bc	34.31 b	64.62 b	4.703 abc	0.216 bcd	0.204 bc	105.48 ab
ACP + MET	78 + 12	15.34 a	33.15 d	63.06 c	4.486 c	0.241 a	0.218 a	107.57 a
MET	7	14.52 bc	34.24 bc	64.23 bc	4.548 bc	0.236 ab	0.212 ab	105.30 ab
MET	12	14.90 ab	33.53 cd	63.53 bc	4.483 c	0.238 ab	0.215 ab	107.55 a
APD + MET	77 + 12	14.68 ab	33.85 bcd	64.18 bc	4.679 abc	0.229 abc	0.208 abc	105.67 ab
ACP + 2,4-D	78 + 591	13.21 d	36.29 a	66.71 a	4.937 a	0.201 d	0.195 c	99.03 c
Clip	—	13.89 c	35.52 a	66.17 a	4.807 ab	0.210 cd	0.208 abc	98.56 c
Nontreated	—	13.20 d	35.91 a	65.94 a	4.953 a	0.210 cd	0.197 c	102.21 bc

[a] Herbicide treatments were applied with nonionic surfactant at 0.25% v/v. Clipping treatment was applied 2 wk before first harvest.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq 0.05$.

[c] Abbreviations: CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; Ca, calcium; Mg, magnesium; RFQ, relative forage quality; ACP, aminocyclopyrachlor; MET, metsulfuron; APD, aminopyralid.

evidence that tall fescue receiving metsulfuron-containing treatments had recovered by the summer harvest. Additionally, tiller densities in all treatments were the same at 6 MAT. At the year-after harvest, yields and tiller densities in all treatments were the same, as well (Table 5). Sather et al. (2013) also reported no differences in fall and year-after tall fescue yields among metsulfuron-containing herbicides applied in the spring.

Forage Quality. At spring harvest, treatments containing metsulfuron resulted in CP content ranging from 14.23 to 15.34%, whereas CP content in nontreated forage was 13.20% (Table 6). Treatments containing metsulfuron reduced ADF and NDF of harvested forage. ACP plus metsulfuron at 78 + 12 g ha^{-1} and metsulfuron alone at 7 or 12 g ha^{-1} reduced lignin content compared to the nontreated control and ACP plus 2,4-D. NDF estimates the cell wall fraction, or total fiber content, and is used to predict forage intake by animals. ADF estimates the highly indigestible fraction of fiber and is used to predict forage digestibility. As grasses mature, cell walls become lignified and more indigestible than younger, vegetative forage. Additionally, stems have higher fiber and less CP than leaves. Treatments containing metsulfuron resulted in lower stem yields than nontreated forage; therefore, these treatments had greater CP and less fiber than nontreated forage. Moyer and Kelley (1995) found 8 g ha^{-1} metsulfuron increased CP content by as much as 34 g kg^{-1} over the nontreated control. Sather et al. (2013) found that metsulfuron at 13 g ha^{-1} applied alone or in combination with aminopyralid had CP contents of 8.2 and 9.1%, respectively, and were greater than the 6.5% CP found in nontreated forage. These studies also reported similar reductions in fiber content with metsulfuron-containing treatments.

Relative forage quality (RFQ) is an index of forage quality that takes into account CP, intake, and digestibility and predicts animal performance more accurately than relative feed value (Ball et al. 2001). ACP plus metsulfuron at 78 + 12 g ha^{-1} and metsulfuron alone at 12 g ha^{-1} improved RFQ compared to the nontreated control at spring harvest. All metsulfuron-containing treatments improved RFQ compared to ACP plus 2,4-D and clipping treatments. ACP plus metsulfuron at 78 + 12 g ha^{-1} and metsulfuron alone at 7 or 12 g ha^{-1} resulted in greater Ca and Mg content in compared to nontreated.

At summer harvest, CP, ADF, NDF, and RFQ were similar for all treatments (Table 7). By this time, tall fescue had recovered and leaf proportions were similar. Also, stem reductions at this time would not factor into forage quality improvements as with the spring harvest. At year after harvest, CP, ADF, NDF, and RFQ were similar for all treatments ($P > 0.32$, data not shown). Our results indicate that improvements to tall fescue forage quality after applications of metsulfuron-containing treatments are most apparent in the spring harvest.

Table 7. Tall fescue nutritive values at summer harvest in response to clipping and herbicide treatments across 4 site-yr in Tennessee.

Treatment[a]	Rate	CP[b,c]	ADF	NDF	RFQ
	g ha^{-1}	%			—
ACP + MET[c]	47 + 7	11.40 a	36.78 a	68.64 a	97.35 a
ACP + MET	78 + 12	11.40 a	36.46 a	68.36 a	97.87 a
MET	7	11.36 a	36.88 a	68.90 a	96.05 a
MET	12	11.24 a	36.58 a	68.52 a	97.72 a
APD + MET	77 + 12	11.04 a	37.42 a	69.90 a	93.45 a
ACP + 2,4-D	78 + 591	11.47 a	36.67 a	69.30 a	96.27 a
Clip	—	10.84 a	37.08 a	69.00 a	95.21 a
Nontreated	—	10.78 a	37.30 a	69.22 a	94.80 a

[a] Herbicide treatments were applied with nonionic surfactant at 0.25% v/v. Clipping treatment was applied 2 wk before first harvest.

[b] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD test at $P \leq < 0.05$.

[c] Abbreviations: CP, crude protein; ADF, acid detergent fiber; NDF, neutral detergent fiber; RFQ, relative forage quality; ACP, aminocyclopyrachlor; MET, metsulfuron; APD, aminopyralid.

Total Ergot Alkaloids. At spring harvest, treatments containing metsulfuron reduced ergot alkaloid concentration 26 to 34% from the nontreated control (Table 3), probably due to the reduction in seedheads, which have the greatest amount of ergot alkaloids compared to other tall fescue plant parts (Rottinghaus et al. 1991). Clipping did not change ergot alkaloids compared to nontreated. Although clipping reduced seedhead density, the clipped seedheads were still present in harvested forage and alkaloids might have only partially degraded by the time of the spring harvest. Additionally, the stems that remained below the clipping height could have contributed to greater alkaloid amounts. Aiken et al. (2012) found that stems had greater ergopeptine concentrations than leaf blades and sheaths. At summer harvest, ergot alkaloid concentrations were the same in all treatments (Table 4). This is likely due to tall fescue being in the vegetative stage of growth and little to no stems or seedheads present in harvested forage.

Metsulfuron applied alone or in combination with ACP or aminopyralid reduced seedhead density and total ergot alkaloid concentrations in spring-harvested tall fescue forage. Forage quality was also greater in all treatments containing metsulfuron due to the low proportion of stems. Animal performance might be improved by consumption of less toxic and more nutritive forage. However, treatments containing metsulfuron also injured tall fescue and reduced yield in the spring. Cattle stocking rate might need to be reduced in the spring due to limited forage availability with these treatments. By late summer, tall fescue had recovered, and forage yields and nutritive values were similar. Metsulfuron applied alone or in combination with ACP or aminopyralid can be utilized to reduce the severity of fescue toxicosis with no long-term effects on grass productivity.

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