CHAPTER IV

GREENHOUSE STUDIES ON MEFLUIDIDE AND FLURPRIMIDOL TREATED KENTUCKY BLUEGRASS

Study A. Absorption of Mefluidide and Flurprimidol by Kentucky Bluegrass

Reason for Experimentation

Techniques on the application of growth regulators to turf has been a subject of much research (Aageson and Elkins, 1975). This is because of the inherent difficulty in applying a foliar absorbed growth regulator, such as maleic hydrazide, to achieve a uniformly suppressed turf. Because of this difficulty considerable effort has been devoted to the development of root-absorbed growth regulators.

Penetration of ^{14}C-mefluidide into Kentucky bluegrass plants occurs most readily at the basal leaf sheath or leaf axils. Translocation of radiolabeled material occurs within the leaf organ to which the chemical was applied with little translocation to the roots or other lear organs (Wills and McWhorter, 1970). Root absorbtion of mefluidide must also occur since Watschke (1974) found growth regulation of Kentucky bluegrass with granular formulations of mefluidide.

Flurprimidol has been described as a root-absorbed growth regulator (Wehner, 1980). Flurprimidol has also been shown to be absorbed by foliage of apple trees (pers. comm., L. D. Tukey, 1984).

Ancymidol, a flurprimidol-related compound inhibits gibberellin biosynthesis (Shive and Sisler, 1976). Biosynthesis of gibberellin occurs mainly in the above ground parts of plants but it can also occur below ground in the roots (Salisbury and Ross, 1978). Thus, the portion of the plant to which flurprimidol is applied could affect the source of gibberellin, e.g., from leaves and buds or roots. Further, gibberellin biosynthesis includes more than biosynthesis of GA_3. It could affect other GA's, e.g., GA_4 and GA_7 in apple. There are over 50 different forms of gibberellin in plants and fungi. In addition, some growth retardants are known to be mainly absorbed by certain tissues, e.g., paclobutrazol by roots and through xylem (Shearing and Batch, 1980).

In this study, the specific objective was to determine which avenues of absorption (roots, foliage, or both) are most effective for turfgrass growth regulation with mefluidide and flurprimidol.

Materials and Methods

In October 1982, 'Sydsport' Kentucky bluegrass seeds were sown into plastic containers filled with moist sand and the containers were placed in a greenhouse. Two weeks later, the seedlings were transplanted into plastic trays with 2.5 m^2 compartments filled with soil. The soil used throughout this study was a steam-sterilized Hagerstown silt loam (fine, mixed, mesic Hapludalf) that had an initial pH of 6.8, 62 ppm of Bray No. 1 extractable P, 0.43 meq/100 g of exchangeable K and a CEC of 13.7 meq/100 g. Plants were clipped weekly at 5 cm and fertilized monthly with a 10-13-17 (N-P-K basis) fertilizer containing soluble N.

After 5 months, the plants and soil in these trays were transferred into 10 cm diameter pots filled with soil. One day later, mefluidide (at a rate of 0.42 kg/ha) and flurprimidol (at a rate of 1.68 kg/ha) were applied in different methods of application as described by Shelley (1968) to determine which avenues of entry (root absorption, foliar absorption, or both) are most effective in reducing turfgrass growth. Four replications were used and the fourth group of plants were not treated and served as a check. All applications were made with an air pressure-venturi pickup atomizer sprayer powered by an electric pressure/vacuum pump. The spray rate was equivalent to 560 l/g.

To facilitate root absorption, soil applications were made by covering the grass foliage with a 50 ml glass beaker. The beaker was positioned flush with the soil surface and sprays were made on a whole pot basis. The glass surface was rinsed with a water spray to wash any chemical residues from the glass to the soil that was mulched with perlite.

To facilitate foliar absorption, foliar applications were made to plants in pots mulched with perlite. Immediately after application the contaminated perlite was removed by vacuum and new perlite was added. This reduced any soil contamination and permitted spray to fall only on the Kentucky bluegrass foliage.

To facilitate root and foliar absorption, soil + foliar applications were made to perlite mulched Kentucky bluegrass and the perlite was not removed. After 2 days, 1.25 cm of water was surface applied very slowly to the soil but not to the Kentucky bluegrass foliage.

Subsurface irrigation was then accomplished for 1 week by inserting plastic petri dishes filled with water underneath each pot. Following, this time, water was surface applied to both foliage and soil. Plants were not clipped for 5 weeks.

Canopy heights were made 4 weeks after applications. Five weeks after application, soil was washed from the plants and visual observations were made of shoot and rhizome growth. Data were analyzed in a randomized block design.

Results and Discussion

Canopy Height

Canopy height measurements showed that growth suppression of Kentucky bluegrass by mefluidide was not dependent upon the chemical absorption site (Table 27). Root, foliar, and root + foliar absorption of mefluidide caused equivalent growth suppression and little growth occurred following treatment.

Root and root + foliar absorption of flurprimidol resulted in only 1 cm of vertical shoot growth following treatment. Plant height of flurprimidol root and root + foliar treated grass was 70% less than that for the non-treated check. Foliar absorbed flurprimidol was less effective in reducing growth and plant height was decreased by only 60%. This effect may be attributed to the site of gibberellin biosynthesis. Gibberellin production in a turfgrass plant may be more important in roots than foliage. The site of production of a particular GA, e.g., GA_3, could also affect plant response to flurprimidol. This

Table 27. Effect of Absorption Sites of Mefluidide and Flurprimidol on the Canopy Height of Kentucky Bluegrass 4 Weeks After Treatment.

Treatment	Absorption Sites	Canopy Height cm
Non-treated Check	-	13.2
Mefluidide	roots	2.8 a*
	foliage	4.2 a
	roots + foliage	2.8 a
Flurprimidol	roots	3.7 b
	foliage	5.1 a
	roots + foliage	3.5 b

*Values within treatments with a letter in common do not significantly differ at the 5% level of probability using Duncan's Multiple Range Test.

could account for the greater growth regulation found with flurprimidol which was absorbed by roots or roots + foliage than that found with flurprimidol which was absorbed by foliage.

Visual Observations

Mefluidide inhibited tillering and leaf growth of Kentucky bluegrass for 4 weeks and visual density was poor in comparison with non-treated plants. After this time, tillers appeared from clusters of developing axillary buds on tillers and rhizomes. The development of these buds indicated that mefluidide had somehow disrupted apical dominance in the plant. Foliage on the plants, that existed at the time of treatment, was metallic green in color but new tillers were not discolored and appeared normal.

Flurprimidol stimulated tillering and Kentucky bluegrass appeared to have an abnormal bunch type growth habit. Leaf blades were shortened and dark green in color. Leaf sheaths were not clearly visible. Rhizomes of flurprimidol treated plants appeared normal.

Conclusions

The absorption sites needed for maximum growth regulation of Kentucky bluegrass with mefluidide and flurprimidol differ. Mefluidide causes equivalent growth suppression no matter if the chemical is absorbed by roots, foliage or roots + foliage. Flurprimidol is more effective if absorbed by roots or roots + foliage than if just absorbed by foliage. Flurprimidol needs to be root absorbed to be fully effective in reducing the growth of Kentucky bluegrass.

Mefluidide and flurprimidol produce visual changes in grass appearance. Mefluidide discolors the turf and temporarily inhibits tillering. Following inhibition, growth occurs from clusters of axillary buds on tillers and rhizomes. Flurprimidol stimulates basal tillering and leaf organs are shorter and appear dark green in color.

Study B. Effect of Mefluidide and Flurprimidol on the Root and Shoot Growth of Kentucky Bluegrass

Reason for Experimentation

Mefluidide was found by Nielsen and Wakefield (1974) to decrease the root growth of Jamestown red fescue and Fylking Kentucky bluegrass at 5 and 7 weeks after treatment. This treatment, however, increased the root growth of the 2 grasses by 9 weeks after treatment. Freeborg

and Daniel (1981) found mefluidide to reduce the root growth of Wabash Kentucky bluegrass in one experiment but not in another. Differences between these results were not explained. Another study, which did not include mefluidide, by Dernoeden and Wehner (1981) found flurprimidol to increase the root growth of Kentucky bluegrass when compared to a mowed check. Because these test results were inconclusive, the effects of mefluidide and flurprimidol on the root growth of Kentucky bluegrass needed to be studied in order to better understand plant response to these chemicals.

Watschke (1981) found Merion Kentucky bluegrass to be more injured by flurprimidol than Pennstar Kentucky bluegrass in a field experiment. Because of this observation, 2 Kentucky bluegrasses, 'Nugget and Sydsport, were used in this study. Nugget and Sydsport contrast each other in appearance and ecological adaptation. Nugget is a fine bladed Kentucky bluegrass from Alaska and is considered heat intolerant (Watschke et al., 1970). Sydsport is a coarse-bladed Kentucky bluegrass from Sweden and is considered heat tolerant (Wehner and Watschke, 1981).

The specific objective of this study was to determine the effect of mefluidide and flurprimidol on the root and shoot growth of Nugget and Sydsport Kentucky bluegrass.

Materials and Methods

In October 1982, Sydsport and Nugget bluegrass seeds were sown into plastic containers filled with moist sand and the containers were placed in a greenhouse. Two weeks later, seedlings were transplanted into plastic trays with 2.5 cm^2 compartments filled with soil. The

soil used throughout this study was a Hagerstown silt loam (fine, mixed, mesic Hapludalf) which had an initial pH of 6.8, 62 ppm of Bray No. 1 extractable P, 0.43 meq/100 g of exchangeable K and a CEC 13.7 meq/100 g. Plants were clipped weekly at 5 cm and fertilized monthly with a 10-13-17 (N-P-K basis) fertilizer containing soluble N.

After 5 months, wooden boxes with glass fronts, measuring 45.0 cm long and 6.2 cm wide were filled with steam-sterilized soil, sieved through a 2 mm sieve, according to the procedure of Downs (1967). Three Kentucky bluegrass plants (Nugget or Sydsport) were vegetatively established into each box and then either treated or not treated with flurprimidol at a rate of 1.68 kg/ha or mefluidide at 0.42 kg/ha. The materials were applied with an air pressure venturi-pickup atomizer sprayer that was powered by an electric pressure/vacuum pump and calibrated to deliver 560 l/ha. The boxes were inclined 30° forward to allow roots to grow inside the glass. Insulation board was used to cover the glass to eliminate light and cushion the glass against shock and breakage. Non-treated plants were either clipped or not clipped every week at 5 cm to provide a clipped and non-clipped check.

Following treatment, root elongation and proliferation was measured on the glass surface by using a grid made with Chart-pak® tape at 5 cm increments on the glass surface. Counts of active roots passing each grid level were taken 13, 21, 31, 38, 45, and 60 days after treatment. Active roots were determined by the procedure of Karnok and Kucharshi (1980). This involved illuminating the root zone with an ultraviolet light source (366 nm) inducing a flourescence of active tissue.

Thirteen and 21 days after treatment, tillers and number of leaves per tiller were counted per tiller. Leaf blade length and blade width at the collar region were also measured at this time. At 75 days after treatment, tillers and leaves per tiller were recounted and leaf blade length, sheath length and blade width were measured. Plants were then washed of soil and rhizomes counted and rhizome length and internodal distances measured. Roots were severed from foliage and both parts were measured and then weighed after drying at 70 C for 48 hours.

Results and Discussion

Root Growth

The 2 cultivars, Sydsport and Nugget, differed in their response to the 4 treatments in this study. Sydsport rooting differences did not occur until 38 days following treatment (Table 28). Nugget root growth was more sensitive than Sydsport and significant differences in root numbers occurred during the first 31 days following treatment (Table 29).

Nugget root numbers showed a post-treatment growth stimulation of roots 13 days after treatment (Table 29). Mefluidide-treated grass had 3 to 4 times as many roots at the 15 and 20 cm depth as compared to the other treatments. From 21 days after treatment until 60 days after treatment, root elongation and initiation was inhibited by mefluidide. Few roots were initiated by mefluidide-treated plants as evidenced by root numbers at 5 and 10 cm. At 45 and 60 days the lack of rooting became more obvious and root numbers at 45 days after treatment showed that mefluidide-treated Nugget had fewer roots. For

Table 28. Effect of Clipping and Applications of Mefluidide at 0.42 kg/ha and Flurprimidol 50W at 1.68 kg/ha on the Root Development of Sydsport Kentucky Bluegrass.

Dates	Treatment	Root Number at Various Depths (cm)						
		5	10	15	20	25	30	35
13 days	Unclipped Check	5.3 a*	7.6 a	3.0 a	0.3 a	0.0 a	0.0 a	0.0 a
	Clipped Check	4.6 a	6.3 a	2.3 a	0.0 a	0.0 a	0.0 a	0.0 a
	Mefluidide	4.6 a	10.6 a	5.6 a	2.0 a	0.3 a	0.0 a	0.0 a
	Flurprimidol	3.0 a	7.6 a	2.3 a	0.3 a	0.0 a	0.0 a	0.0 a
21 days	Unclipped Check	19.3 a	23.0 a	12.0 a	3.3 a	0.0 a	0.0 a	0.0 a
	Clipped Check	11.6 a	14.3 a	4.6 a	2.6 a	0.0 a	0.0 a	0.0 a
	Mefluidide	6.3 a	13.3 a	8.3 a	5.0 a	1.3 a	0.0 a	0.0 a
	Flurprimidol	15.6 a	14.0 a	5.6 a	0.6 a	0.0 a	0.0 a	0.0 a
31 days	Unclipped Check	23.6 a	28.6 a	20.6 a	15.6 a	7.6 a	3.0 a	1.0 a
	Clipped Check	19.6 a	21.0 a	15.3 a	7.6 a	5.0 a	1.6 a	0.3 a
	Mefluidide	6.0 a	11.0 a	8.0 a	6.0 a	2.3 a	0.0 a	0.0 a
	Flurprimidol	18.0 a	24.3 a	11.3 a	4.6 a	1.3 a	0.3 a	0.0 a
38 days	Unclipped Check	12.3 b	36.6 a	38.6 a	31.6 a	23.6 a	16.6 a	8.6 a
	Clipped Check	21.0 a	24.6 a	20.0 b	14.3 b	8.3 b	4.3 b	0.6 b
	Mefluidide	8.6 b	16.3 a	8.6 c	6.6 b	4.3 b	0.6 b	0.0 b
	Flurprimidol	22.3 a	31.6 a	24.3 b	14.6 b	10.0 b	1.6 b	0.6 b
45 days	Unclipped Check	18.6 ab	26.3 ab	35.0 a	28.3 a	30.0 a	21.6 a	10.0 a
	Clipped Check	29.0 a	29.3 ab	22.6 b	19.3 ab	12.0 b	10.3 b	8.0 a
	Mefluidide	6.6 b	16.0 b	11.3 c	7.0 b	3.6 b	0.3 c	0.3 a
	Flurprimidol	27.3 a	40.0 a	26.6 ab	22.3 ab	14.3 ab	5.0 bc	3.0 a
60 days	Unclipped Check	31.0 a	51.6 a	55.0 a	38.0 a	47.0 a	39.6 a	33.6 a
	Clipped Check	38.3 a	44.3 a	40.3 ab	36.0 a	30.3 a	26.3 b	22.3 ab
	Mefluidide	3.3 b	4.0 b	4.6 b	5.3 b	4.0 b	1.3 c	1.0 c
	Flurprimidol	30.3 a	39.3 a	25.6 b	26.6 a	24.0 a	20.0 b	15.6 c

*Values within dates in the same column with a letter in common do not differ significantly at the 5% level of probability using the Duncan's Multiple Range Test.

Table 29. Effect of Clipping and Applications of Mefluidide at 0.42 kg/ha and Flurprimidol 50W at 1.68 kg/ha on the Root Development of Nugget Kentucky Bluegrass.

Dates	Treatment	Root Number at Various Depths (cm)						
		5	10	15	20	25	30	35
13 days	Unclipped Check	6.3 a*	4.0 a	2.3 b	0.3 b	0.0 a	0.0 a	0.0 a
	Clipped Check	2.6 a	4.0 a	2.3 b	0.3 b	0.0 a	0.0 a	0.0 a
	Mefluidide	1.6 a	3.3 a	7.3 a	4.3 a	1.0 a	0.0 a	0.0 a
	Flurprimidol	2.3 a	4.3 a	1.6 b	0.0 b	0.0 a	0.0 a	0.0 a
21 days	Unclipped Check	12.0 a	17.6 a	11.0 a	5.3 a	0.6 a	0.3 a	0.0 a
	Clipped Check	10.3 a	10.6 a	5.6 a	3.6 a	1.3 a	0.6 a	0.0 a
	Mefluidide	0.0 b	3.6 a	6.3 a	4.0 a	1.6 a	0.3 a	0.0 a
	Flurprimidol	12.6 a	10.6 a	4.0 a	2.0 a	0.6 a	0.0 a	0.0 a
31 days	Unclipped Check	18.6 a	24.0 a	20.6 a	18.0 a	12.0 a	8.6 a	4.0 a
	Clipped	15.0 ab	15.3 a	12.3 ab	8.6 ab	2.6 a	2.6 a	1.3 a
	Mefluidide	1.0 c	4.6 a	5.0 b	4.0 b	2.6 a	1.0 a	1.0 a
	Flurprimidol	10.6 b	11.6 a	6.0 b	4.0 b	2.6 a	1.3 a	0.0 a
38 days	Unclipped Check	21.3 a	22.3 a	29.0 a	25.6 a	22.6 a	17.0 a	11.3 a
	Clipped Check	23.3 a	26.0 a	21.3 a	14.3 b	11.3 a	7.0 a	4.6 a
	Mefluidide	0.3 b	3.3 c	5.0 b	4.6 b	2.3 b	0.6 a	0.6 a
	Flurprimidol	17.3 a	16.3 b	11.6 b	7.3 b	5.6 b	4.3 a	1.3 a
45 days	Unclipped Check	27.0 a	30.3 a	34.3 a	30.3 a	27.3 a	21.3 a	11.3 a
	Clipped Check	21.3 ab	27.0 a	25.6 a	18.3 b	17.0 ab	13.0 a	9.3 a
	Mefluidide	0.0 c	4.0 b	3.0 c	3.6 c	2.0 b	0.3 a	0.0 a
	Flurprimidol	16.3 b	21.3 a	16.3 b	11.6 bc	12.6 ab	8.6 a	4.0 a
60 days	Unclipped Check	31.0 a	51.6 a	55.0 a	38.0 a	47.0 a	39.6 a	33.6 a
	Clipped Check	38.3 a	44.3 a	40.3 ab	36.6 a	30.3 a	26.3 b	22.3 ab
	Mefluidide	3.3 b	4.0 b	4.6 c	5.3 c	4.0 c	1.3 c	1.0 c
	Flurprimidol	30.3 a	39.3 a	25.6 b	26.6 b	24.0 b	20.0 b	15.6 b

*Values within dates in the same column with a letter in common do not significantly differ at the 5% level of probability using the Duncan's Multiple Range Test.

example, at 15 cm mefluidide treated turf had 91% fewer roots than the unclipped check, and 81% fewer roots than flurprimidol-treated grass. At 60 days following treatment, plants treated with mefluidide had a negligible amount of roots as compared to the other plants.

The number of roots of flurprimidol-treated Nugget Kentucky bluegrass at 15 and 20 cm were 70 and 77% lower than the unclipped check 31 days after treatment. A comparison of root number for flurprimidol-treated plants and the clipped check showed root growth also differed at 38 days after treatment. Flurprimidol-treated turf at this time had 37, 45 and 50% fewer roots than the clipped check at 10, 20 and 25 cm, respectively. Although root numbers at 60 days for Nugget were higher for the clipped and unclipped check, flurprimidol-treated plants differed significantly from the clipped check at 20 and 25 cm. At all depths, flurprimidol-treated plants had more roots than mefluidide treated plants.

Compared to the unclipped check, roots of clipped Nugget were decreased at 20 cm 38 days and 45 days after treatment. Also, root numbers of the clipped check were less than the unclipped check at 30 cm 60 days after treatment.

Sydsport root growth did not significantly differ until 38 days after treatment (Table 31). At this time, the unclipped check had more roots than the other treatments in the 15-35 cm depth. Clipping and flurprimidol-treatments caused fewer roots, but at no time did flurprimidol treated plants significantly differ from the clipped check. Mefluidide caused serious root inhibition with little change in root number after 21 days.

Tiller Growth

Significant changes in tiller numbers occurred during the course of this experiment. This was apparent within 13 days following growth regulator treatments (Table 30). The number of mefluidide-treated Sydsport tillers was significantly lower than that for flurprimidol-treated grass or the clipped check.

Final tiller number for both cultivars were considerably greater for flurprimidol-treated plants when compared to the unclipped check (Table 31). Flurprimidol-treated Nugget and Sydsport had a 130 and 147% greater tiller density, respectively. Mefluidide had an opposite impact, seriously inhibiting bluegrass tiller development. Much of the growth at this time was a result of shoot growth from rhizomes that began at 34 days after treatment. These shoots did not differ morphologically from the unclipped check.

Clipping of Sydsport caused a 49% increase in tillering over that of the unclipped check (Table 31). Clipping has been shown to increase tiller density in a number of turfgrass species (Beard, 1973).

Leaf Morphology and Color

Both mefluidide and flurprimidol caused modifications of leaf morphology (Table 30). Blade length of Sydsport was 56-61% shorter at 13 days after these treatment as compared to the non-clipped check. Nugget blades were 60% shorter when treated with mefluidide and 70% shorter when treated with flurprimidol. At 21 days, blade length of both cultivars was less with flurprimidol and mefluidide.

Table 30. Effect of Clipping, Mefluidide at 0.42 kg/ha and Flurprimidol at 1.68 kg/ha on the Shoot Morphology of 2 Kentucky Bluegrasses 13 and 21 Days After Application.

		13 Days				21 Days	
Cultivar	Treatment	Change in Tiller No. Count	Blade Length mm	Blade Width mm	Leaves per Tiller Count	Blade Length mm	Leaves per Tiller Count
Sydsport	Unclipped Check	4 ab*	106 a	3.3 a	3.7 a	139 a	4.1 b
	Clipped Check	10 a	50 b	2.9 ab	4.1 a	49 b	4.7 ab
	Mefluidide	- 4 b	41 b	2.1 b	3.0 a	44 b	3.4 c
	Flurprimidol	10 a	46 b	3.5 a	4.3 a	36 b	4.9 a
Nugget	Unclipped Check	6 a	137 a	2.9 a	4.0 a	164 a	4.4 a
	Clipped Check	7 a	60 b	2.1 a	4.4 a	51 b	4.5 a
	Mefluidide	- 3 a	55 bc	2.1 a	3.9 b	50 b	2.6 b
	Flurprimidol	3 a	40 c	2.8 a	3.9 a	37 b	5.1 a

*Values within grasses in the same column with a letter in common do not significantly differ at the 5% level of probability using Duncan's Multiple Range Test.

Table 31. Effect of Clipping, Mefluidide at 0.42 kg/ha and Flurprimidol at 1.68 kg/ha on the Shoot, Rhizome, and Root Growth of 2 Kentucky Bluegrasses.

			Leaf Blade			Leaf Sheath	Rhizome			Root		Foliage
Cultivar	Treatment	Change in Tiller No.	Length cm	Width mm	No. Per Tiller count	Length cm	Number count	Length cm	Internodal Distance cm	Length cm	Dry Weight g	Dry Weight g
Sydsport	Unclipped Check	90 c*	21.5 a	3.9 a	2.9 a	5.7 a	42 a	11.0 a	1.5 a	37.6 a	10.6 a	11.7 a
	Clipped Check	127 b	-	2.8 b	3.9 a	3.3 a	31 a	10.7 a	1.5 a	37.1 a	0.8 b	1.9 b
	Mefluidide	19 d	16.7 a	3.5 a	3.1 a	4.5 a	14 b	7.9 a	1.2 a	41.3 a	2.7 b	2.1 b
	Flurprimidol	223 a	6.1 b	4.0 a	4.1 a	2.0 b	8 b	6.8 b	1.0 a	35.3 a	1.5 b	5.1 b
Nugget	Unclipped Check	106 b	25.3 a	3.2 a	3.3 a	7.3 a	42 a	15.3 a	2.1 a	40.0 a	9.9 a	13.1 a
	Clipped Check	116 b	-	2.4 b	3.8 a	3.2 b	21 b	14.8 a	1.6 b	41.3 a	1.6 c	3.0 c
	Mefluidide	8 c	20.0 b	3.4 a	3.0 a	5.9 a	15 b	11.1 b	1.4 c	29.0 b	2.4 b	1.7 d
	Flurprimidol	254 a	5.6 c	3.7 a	3.6 a	2.0 b	10 b	9.7 b	1.2 d	36.0 a	1.3 d	4.4 b

*Values within dates in the same column with a letter in common do not differ significantly at the 5% level of probability using the Duncan's Multiple Range Test.

Leaf width and the numbers of leaf blades per tiller were affected by these treatments. At 13 days, mefluidide produced more narrow leaves on Sydsport and fewer leaves per tiller on Nugget. At 21 days, leaves per tiller were higher on flurprimidol-treated Sydsport than the unclipped check and both mefluidide-treated cultivars had fewer leaves per tiller.

Final bluegrass leaf blade measurements were 70-77% shorter on flurprimidol treated plants (Table 31). Leaf blade width, however, was not reduced, but actually tended to be wider. This effect on blade width contributed to improved visual density. Plants found in high populations often have narrower leaves, as in the case of the clipped check. But in this case, blades were more numerous and shorter and wider even though at the same time tiller density was increased. This suggested that flurprimidol produced cytokinin-like effects. Mefluidide's effect on leaf morphology at 75 days did not resemble its former suppressed condition.

Sheath length was less with flurprimidol and clipping for both cultivars of bluegrass. Sheath growth appeared to be more affected than blade length.

The color of leaf tissue was also affected by the growth regulators. Mefluidide caused leaf blades to be a metallic green color within 13 days after treatment. Leaves were brittle and not fully expanded. This discoloration and appearance was evident until new shoot growth developed from rhizomes at 34 days after treatment. Flurprimidol treated grass was dark green in color, and did not result

in undue discoloration. These plants took on the characteristic green associated with pyrimidine-methanol materials and color enhancement became apparent within 13 days after treatment.

Rhizomes

Rhizome number, length, and internodal distances were influenced by the 4 treatments. Nugget bluegrass rhizome growth was influenced more than Sydsport (Table 31). Rhizome number of Nugget was 50% lower when clipped, 64% lower when treated with mefluidide and 76% lower when treated with flurprimidol. Rhizome length of Nugget was more than 27% shorter when treated with either mefluidide or flurprimidol. Internodal distances were shorter in all treatments as compared to the unclipped check. Flurprimidol produced the greatest effect with a 57% reduction in length.

Rhizome number of Sydsport bluegrass was more than 65% less with mefluidide and flurprimidol. Only flurprimidol gave a significantly shorter rhizome length. Internodal distances of this cultivar were not affected by treatments, indicating a fewer number of nodes.

Rinal Root and Foliage Weight

Final root length measurements for mefluidide-treated Nugget were 27% shorter than the unclipped check (Table 31). Root weight for mefluidide-treated grass was also less than the unclipped check but exceeded the clipped check and flurprimidol treated grass. This related to an increase in rooting from new growth occurring after 34 days. Root weight of Sydsport was not significantly different from that for the

clipped check, mefluidide- or flurprimidol-treated grass. All, however, had considerably lower root weight than the unclipped check.

Final foliage weight was less with mefluidide and flurprimidol treatments. As in the case of the other measurements, Nugget seems to be more sensitive than Sydsport to treatments. For example, flurprimidol decreased leaf weight of Nugget by 66% and Sydsport by 56%.

Conclusions

Root growth of Nugget and Sydsport Kentucky bluegrass is reduced by mefluidide, flurprimidol or clipping. Mefluidide initially stimulates rooting of Nugget, but then seriously inhibits root growth of both cultivars. Flurprimidol is not as inhibitory to root growth as mefluidide. Sydsport, treated with flurprimidol, has rooting similar to a clipped plant, while Nugget, treated with flurprimidol, has fewer roots than a clipped plant. Root weight of both cultivars is decreased by mefluidide, flurprimidol and clipping.

Tiller and leaf growth is affected by growth regulators. Mefluidide thins tiller number of Sydsport and is inhibitory to tiller development of both cultivars for approximately 1 month. During this time, leaf blade length and number of leaves per tiller are less. Mefluidide also decreases blade width of Sydsport. Flurprimidol dramatically stimulates tiller production and reduces blade length of both cultivars. Leaf blade width and number of leaves per tiller of Sydsport are increased. Foliage weight is reduced by mefluidide, flurprimidol and clipping.

Nugget rhizome growth is more affected by mefluidide, flurprimidol, and clipping than Sydsport. Rhizome production of Nugget is reduced by these treatments. Both chemicals shorten rhizome length of Nugget. Sydsport rhizome production is decreased by flurprimidol and mefluidide. Unlike Nugget, only flurprimidol reduces Sydsport rhizome length and internodal distances are not affected. This indicates a fewer number of nodes.

Study C. Effect of Mefluidide and Flurprimidol on the Total Nonstructural Carbohydrates of Kentucky Bluegrass

Reason for Experimentation

Total nonstructural carbohydrates (TNC) of turfgrass have been shown to be affected by growth regulators. Watschke (1976) found TNC of field grown Pennstar and Fylking Kentucky bluegrass leaf tissue was increased by mefluidide, but this occurred only after leaf discoloration subsided. Nelson et al. (1977) in a greenhouse experiment discovered TNC in leaf tissue of tall fescue and bermudagrass was reduced by ancymidol. Kane and Smiley (1983) found TNC of greenhouse grown Merion and Fylking Kentucky bluegrass was not affected by flurprimidol but was increased by the pyrimidine-methanol fungicides fenarimol and nuarimol. Because these test results appeared inconsistent, additional research was conducted to better understand the effect of mefluidide and flurprimidol on Kentucky bluegrass. The specific objective of this study was to determine the effect of mefluidide and flurprimidol on the accumulation of TNC by Sydsport and Nugget Kentucky bluegrass.

Materials and Methods

In October 1982, 133 pure live seeds of Nugget and Sydsport Kentucky bluegrass were sown into 10 cm diameter pots filled with soil and the pots were placed in a greenhouse. The soil was a Hagerstown silt loam (fine, mixed, mesic Hapludalf) that had a pH of 6.4, 41 ppm of Bray No. 1 extractable P, 0.47 mq/100 g of exchangeable K, and a CEC of 14.2. Plants were fertilized bimonthly with a 20.0-4.3-8.2 (N-P-K basis) fertilizer containing soluble N at the equivalent rate of 49 kg N/ha. Plants were maintained at 2.5 cm by weekly clipping. Powdery mildew (Erysiphe graminis D.C.) was controlled during the winter months with Actidione TGF® (3-[2-(3,5-dimethyl-2-oxocyclohexyl)-2 hydroxyethyl]-glutarimide). Insect pests were controlled with diazinon (o,o-diethyl-o-isopropyl-4-methyl-6-pyrimidyl) phosphorothioate).

On 5 September 1983, the 2 Kentucky bluegrasses were treated or not treated in 3 replications with mefluidide 2S at a rate of 0.20 kg/ha or flurprimidol 50W at a rate of 1.1 kg/ha. (Low rates were used to prevent mefluidide phytotoxicity). Non-treated plants were either clipped weekly at 2.5 cm or left unclipped. At 2, 3, 4, and 5 weeks after application, canopy heights were measured and above ground plant parts (crown, leaf sheath, and leaf blade tissue) were collected from different pots for carbohydrate determination. Tissue was weighed, dried at 70 C, and reweighed. Samples were then ground in a UD cyclone mill. Total nonstructural carbohydrate (TNC) was extracted from the tissue for 1 hour with 0.01 N H_2SO_4 at 100 C (Smith et al., 1964). Carbohydrate was determined by a ferricyanide test for reducing sugar (Wolf and Ellmore, 1975).

Results and Discussion

Growth Regulation

Mefluidide had a greater effect on the growth of Sydsport than that of Nugget Kentucky bluegrass. Fresh shoot weight of Sydsport was decreased by 29-31% at 3, 4, and 5 weeks after application as compared to that for the unclipped check (Table 32). Mefluidide, however, only reduced fresh weight of Nugget by 14% at 3 weeks. Corresponding dry weights of Sydsport were reduced by mefluidide 16% to 36% at 3 to 5 weeks while treated Nugget showed a reduction at 4 weeks. These results concur with canopy heights. Mefluidide reduced canopy height of Sydsport 57% at 4 weeks, but had no effect on Nugget.

Flurprimidol also had a greater influence on the shoot growth of Sydsport than that of Nugget Kentucky bluegrass (Table 32). Fresh weight of flurprimidol-treated Sydsport averaged 23% less than that for the unclipped check at 3 to 5 weeks after treatment. Flurprimidol-treated Nugget fresh weight was reduced by only 10%. Dry weight of Sydsport was also significantly less during the 3 to 5 week period, while Nugget dry weight was reduced only at week 4.

Cultivar differences were not as obvious when canopy heights were compared. Canopy height of both cultivars was 50% lower than that for the unclipped check at 5 weeks after treatment. This result appeared inconsistent with the shoot weights obtained. Flurprimidol caused an increase in basal tillers, thus increasing shoot weight even though canopy height was reduced.

Table 32. Effect of Clipping, Mefluidide at 0.20 kg/ha, and Flurprimidol at 1.1 kg/ha on the Fresh Weight, Dry Weight, TNC and Canopy Height of 2 Kentucky Bluegrasses.

Cultivar	Treatment	Fresh Weight (g)				Dry Weight (g)				TNC (%)				Canopy Height (cm)			
		Weeks After Treatment				Weeks After Treatment				Weeks After Treatment				Weeks After Treatment			
		2	3	4	5	2	3	4	5	2	3	4	5	2	3	4	5
Sydsport	Unclipped Check	9.5 a*	8.8 a	8.9 a	10.9 a	3.0 a	3.1 a	3.0 a	3.0 a	7.9 a	13.2 a	15.6 a	18.1 a	4.5 a	6.8 a	8.3 a	9.0 a
	Clipped Check	8.2 a	7.3 b	7.4 bc	8.0 b	2.4 b	2.5 b	2.1 c	1.8 c	7.1 a	9.8 a	10.1 c	7.3 c	2.5 b	2.5 b	2.5 c	2.5 d
	Mefluidide	7.4 a	6.1 c	6.2 c	7.7 b	2.5 b	2.3 b	2.0 c	1.9 c	8.3 a	14.9 a	20.7 a	11.2 a	3.0 b	3.0 b	3.5 bc	6.0 b
	Flurprimidol 50W	8.3 a	5.9 c	7.7 ab	8.0 b	2.8 ab	2.5 b	2.5 b	2.6 b	9.0 a	16.1 a	15.8 b	16.1 a	4.0 a	4.0 ab	4.0 b	4.0 c
Nugget	Unclipped Check	8.0 a	6.8 a	8.1 a	9.4 a	2.8 a	3.0 a	3.4 a	3.0 a	8.4 a	9.2 a	12.5 a	11.6 a	4.4 a	7.8 a	10.2 a	11.0 a
	Clipped Check	6.3 b	5.1 c	6.6 b	6.8 b	2.3 a	2.3 a	2.5 a	2.2 b	8.4 a	5.9 a	9.1 a	8.3 a	2.5 b	2.5 c	2.5 c	2.5 c
	Mefluidide	8.0 a	5.8 bc	7.4 ab	9.6 a	2.8 a	2.6 a	2.6 b	2.6 ab	10.2 a	7.6 a	11.8 a	13.3 a	4.2 a	5.0 b	9.5 a	11.2 a
	Flurprimidol 50W	8.1 a	6.0 b	7.2 b	10.1 a	2.6 a	2.7 a	2.6 a	3.0 a	8.9 a	9.7 a	11.5 a	8.8 a	4.0 a	5.0 b	5.0 b	5.0 b

* Values within grasses in the same column with a letter in common do not significantly differ at the 5% level of probability using Duncan's Multiple Range Test.

TNC Analysis

TNC analysis also showed cultivar differences (Table 32). Sydsport TNC was significantly affected by mowing and mefluidide, while Nugget TNC was not. Clipped Sydsport Kentucky bluegrass had a significantly lower TNC than that for the unclipped check. The impact of clipping on reducing TNC of turfgrass is well documented (Beard, 1973). Mefluidide caused TNC to be 5% higher at 4 weeks and 6% lower at 5 weeks. The reduction of TNC of mefluidide can be explained by a utilization of accumulated TNC in the post-inhibition flush growth that occurred between week 4 and week 5. This stimulation is reflected by canopy height measurements. This concurs with Watschke (1976) who found a post inhibition flush growth on mefluidide treated Kentucky bluegrass. Neither cultivar showed TNC to be reduced by flurprimidol, and in fact flurprimidol treated Sydsport had a TNC level that exceeded the clipped check. This finding substantiates research by Kane and Smiley (1983), who also found flurprimidol did not reduce TNC of Merion and Fylking Kentucky bluegrass.

Conclusions

Mefluidide at 0.20 kg/ha reduces the fresh shoot weight, dry shoot weight, and canopy height of Sydsport Kentucky bluegrass more than that of Nugget Kentucky bluegrass. TNC of mefluidide-treated Sydsport accumulates TNC during the period of limited growth. This accumulated TNC is then used during a flush growth that occurs after growth inhibition effects of mefluidide have ended.

Flurprimidol at 1.1 kg/ha also affects the gorwth of Sydsport more that that of Nugget. Flurprimidol decreases the fresh shoot weight,

dry shoot weight and canopy height of both grasses but has a greater effect on Sydsport. Flurprimidol does not affect TNC accumulation because either photosynthate is used during growth suppression for the production of new tillers or photosynthesis is reduced.

Study D. Effect of Flurprimidol on the Photosynthesis of Kentucky Bluegrass

Reason for Experimentation

In the previous study, TNC was not accumulated by flurprimidol treated Kentucky bluegrass. Additional research was required to determine if this effect was due to reduced photosynthesis. Nelson et al. (1977) found ancymidol reduced the apparent photosynthesis of bermudagrass, but did not affect that for tall fescue. The specific objective of this study was to determine the effect of flurprimidol on the photosynthesis of Sydsport and Nugget Kentucky bluegrass.

Materials and Methods

Sydsport and Nugget Kentucky bluegrasses that were treated in the previous study were used. Photosynthetic measurements were made 8 weeks after flurprimidol applications on treated and unclipped Kentucky bluegrass. This was done by using an open CO_2 gas exchange system according to a modified procedure of Long (1982). Three replications of potted plants were placed inside a 30 cm high, 20 cm diameter cylindrical plexiglass chamber. The chamber was equipped with a fan and a coil of aluminum tubing that contained water circulated from a cooling tank.

Temperature inside the chamber was maintained at approximately 20 C. Incandescent flood lamps were suspended above the chamber, and emitted radiation was filtered through 10 cm of water. Photon flux density, adjusted with a rheostat, was 680 μE cm^{-2} s^{-1} at plant height. Leaf temperature was measured with a thermocouple positioned inside the canopy. A N_2, CO_2, and O_2 gas blend containing 0.03% CO_2 and 21% O_2 was made and passed into the chamber. CO_2 concentration was determined with a Beckman 865 Infrared Analyzer. Oxygen concentration was determined with a Beckman 755 Oxygen Analyzer. Gas was flowed out of the chamber into the sample cell of the Infrared Analyzer. The gas flow rate was 1650 cc/min. The difference in CO_2 between inlet and outlet gas streams was used to determine photosynthetic rate of the turfgrass. After this measurement, photosynthesis was again determined with a N_2, CO_2 and O_2 bas blend containing 0.03% CO_2 and 3% O_2. The difference between this measurement and the previous one was due to photorespiration. Dark and soil respiration were then determined by darkening the chamber and flowing a N_2, CO_2 and O_2 gas blend containing 0.03% CO_2 and 21% O_2 through the system. This value was used to adjust the photosynthetic measurements for dark and soil respiration. Plants were clipped and leaf tissue was dried at 70 C for 48 hours. Photosynthesis was determined on a dry leaf weight basis and data were analyzed in a randomized block design.

Results and Discussion

Although leaves were darker green, flurprimidol-treated Kentucky bluegrass did not have photosynthetic rates that differed from the

unclipped check (Table 33). Marcelle et al. (1973) also found CCC treated bean plants that had a darker green foliage not to have different photosynthetic rates than that for untreated plants. Nelson et al. (1977) determined ancymidol did not affect apparent photosynthesis of tall fescue.

Dry leaf weight of flurprimidol treated grass and the unclipped checks also did not differ even though canopy height was more than 50% shorter in flurprimidol-treated plants. Tiller density of flurprimidol-treated grass was observed to be greater than that for the unclipped check. These results infer the lack of accumulation of TNC by flurprimidol-treated plants is not because of reduced photosynthesis but rather because photosynthate is used for the production of tillers. Flurprimidol's stimulation of tiller production also occurred in Study B.

Conclusion

Flurprimidol reduces turfgrass growth without interfering with carbohydrate production. Photosynthate is continually used by treated plants for the production of tillers that are dwarfed in size.

Table 33. Photosynthesis in 21 and 3% O_2, Photorespiration, Canopy Height and Leaf Weight of Unclipped and Flurprimidol-Treated Sydsport and Nugget Kentucky Bluegrass.

Cultivar	Treatment	Gross Photosynthesis in 21% O_2	Gross Photosynthesis in 3% O_2	Photorespiration	Canopy Height	Leaf Weight
		----------mg CO_2/hr/g dry leaf----------			cm	g/pot
Sydsport	Unclipped Check	18.2*	23.9	5.7	9.4	2.7
	Flurprimidol	18.4	22.6	4.2	4.2	2.5
Nugget	Unclipped Check	21.6	26.8	5.2	10.6	2.3
	Flurprimidol	21.0	25.8	4.8	4.8	2.2

*Except for canopy height, means for each source of variation are not significantly different at the 0.05 level. Based on F-value determined by analysis of variance.