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The Effect of Various Plant Growth Regulators on Rough Turf at Coles County Airport

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THE EFFECT OF VARIOUS PLANT GROWTH REGULATORS

ON ROUGH TURF AT COLES COUNTY AIRPORT

(TITLE)

BY

JAY C. A. HARNACK

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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1991

YEAR

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
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Abstract

A field test was conducted to determine the effectiveness of various concentrations of selected plant growth regulators. All PGR's were applied at various rates and combinations on rough turf at Coles County Airport, Charleston, Illinois.

The dominant grasses in the test site were bluegrass (*Poa pratensis* Huds.) and fescue (*Poa pratensis* L.).

The plant growth regulators were evaluated at regular intervals for the reduction of biomass, reduction of height, seedhead suppression, and color relative to control.

One third ounce per acre Escort in combination with 4 ounces per acre Embark was the most effective in reducing biomass accumulation followed by 1/4 ounce per acre Oust.

Subjective visual studies were performed to determine the amount of height reduction. One third ounce Escort with 1/4 pint Embark was the most effective followed by 1/4 ounce per acre Oust. One third ounce Escort with 1/4 pint Embark was also the most effective at reducing the production of seedheads followed by 1/4 ounce per acre Escort. One third ounce Escort with 1/4 pint Embark was the only treatment to display a significant injury in the form of discoloration during one sampling period.

Introduction

A plant growth regulator can be defined as a compound which alters plant growth and development (21). In this study , the effects of PGR's were investigated on rough turf at the Coles County Airport, Charleston, Ill.

Plant growth regulators offer a potential method of reducing mowing and labor expenses in the turfgrass industry. PGR's may be applied to specific turfgrasses in commercial, public, and agricultural premises where turfgrass care is labor intensive. Such areas include airports, utility and highway right-of-ways, cemeteries, golf courses, and roadsides. Besides reductions in maintenance cost, PGR's offer other benefits such as a means of fossil fuel conservation by reducing the amount of petroleum fuels consumed normally used during mowing, and a reduction of soil moisture consumption by PGR treated plants displaying a supressed metabolism. As much as 80% additional water is available to PGR treated grass throughout the season, thereby reducing watering costs (23). Also, Turfgrass that has been treated with PGR's often display a deeper green color. This greening effect is attributed to the increased availability of water, the accumulation of dark green and purple pigments by chemically stressed plants (3), and an increased number of chloroplasts per cell (21). Seedhead suppression is often observed after PGR application. As a result weeds may be controlled and turf height remains reduced.

Plant growth regulators are applied in the spring, after at least 80% greenup of turf. Recommended equipment for application to turfgrass are conventional power spray equipment fitted with a spray boom, off center nozzles, or handgun (22). Surfactants may be added to improve leaf coverage, reduce surface tension, increase the permeability of the cuticle, aid stomatal penetration, and reduce the polarity of regions on the leaf, all of which increase leaf absorption (26).

Although they provide many benefits, plant growth regulators are not a mowing substitute. Applications to mixed stands may result in non-uniform or irregular appearances due to the varying effectiveness of PGR's on different species. The applications of fungicides may be necessary in areas of high disease frequency, as a result of the slow growth rate. Improper application may also result in discoloration or uneven stands.

Literature Review

Escort and Oust herbicides are sulfonylurea compounds consisting of metsulfuron methyl and sulfometuron methyl respectively (Table 1). Both compounds are known to inhibit cell division and growth. Sulfonylureas are absorbed by the foliage and roots of both sensitive and resistant species and rapidly translocated throughout the plant. Inhibition takes place in growing tips of both roots and shoots of sensitive species by inhibiting the enzyme acetolactate synthase. This enzyme is required to produce valine and isoleucine, two amino acids essential for protein synthesis, and therefore growth (12, 15, and 16). Sensitivity is determined by a species ability to metabolize these products. Sensitive plants show little or no metabolism, while resistant plants can metabolize the product rapidly (12 and 15). Sulfonylureas are absorbed by the foliage and roots of both sensitive and resistant species, and are rapidly translocated throughout the plant (12).

When applied to soil, the movement of Escort is dependant on the amount of organic matter present and soil pH. Once combined with water, metsulfuron methyl and sulfometuron methyl exist in an equilibrium mixture of undissociated and ionized forms. The pH of the soil determines the greatest concentration of either form, i.e. as the pH of the soil become alkaline the ionized form becomes more prevalent. Both forms can bind to soil, although binding by the undissociated form occurs more readily (16).

The loss of biological activity after application of a plant growth regulator occurs in one of four ways: 1) removal of the product from the root zone by the plant, 2) chemical hydrolysis, 3) photolysis, and 4) microbial degradation. Chemical hydrolysis and microbial degradation are the most significant processes by which sulfonylureas are removed from the soil. Photolysis removes very little product from the soil. At a temperature of 45 C and a pH of 6, the half-life of Escort and Oust were determined in the laboratory to be 28 and 2 days respectively, but the half-life ranges from 4-6 weeks under seasonal growing conditions (12 and 16).

Event is a combination of two imidazolinone compounds, imazapyr and imazethapyr (Table 1). Imidazolinones regulate plant growth in a wide variety of species including annuals, perennials, grasses, and broadleaved weeds (28), and is recommended at 8 to 10 ounces per acre for the control of tall fescues, perennial ryegrass, bluegrass, and bahaigrasses (2). Imidazolinones retard plant growth by reducing levels of the branched-chain aliphatic amino acids isoleucine, leucine, and valine through the inhibition of acetohydroxyacid synthase, an enzyme that is required for their production. Inhibition of these enzymes causes a disruption of protein synthesis which then interferes with DNA synthesis and cell growth (3). Imidazolinones are readily absorbed throughout the roots, the primary site of uptake, by a process called ion trapping which is the mechanism by which the product is absorbed. The imidazolinones are converted to weak acids in the soil and under this condition a lipophilic undissociated form can diffuse across the cell membrane. It has been estimated however, that dependant upon the pH of the soil, only 10% of the imidazolinones available will be present in the undissociated form. After entering the root, the acid ionizes and becomes much less lipophilic allowing it to accumulate (26).

The 90% of the remaining product is removed by chemical hydrolysis, photodecomposition, and microbial degradation. Imidazolinones are very stable in normal soil pH ranges and have a half life in excess of six months. Under dry conditions, imidazolinones are very stable under ultraviolet light. Once in solution these compounds will degrade quickly, however UV light can only penetrate a few millimeters into the soil not allowing products below this depth to decompose. The principal form of breakdown appears to be microbial degradation. Field dissipation studies have shown that imidazolinone removal is optimum under warm, moist conditions (26).

Embark consists of a diethanolamine salt of mefluidie. Mefluidie controls growth of grasses, trees, groundcovers, various ornamentals, and is also widely used in synergistic combinations with other herbicides and plant growth regulators (22). The selectivity of mefluidie is at present unknown, although it affects cell division and stem elongation. It is absorbed by foliage and is systematic, but is usually confined to the leaf on which it was applied. Little or no translocation to the roots has been noted (22).

Embark, which has a half life in soil of less than one week, is readily broken down after application by chemical hydrolysis and microbial action (22).

Table 1. Product components

ESCORT

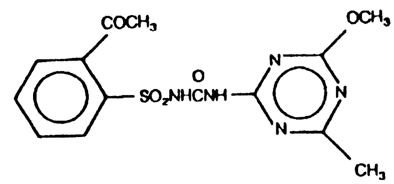
Components	Metsulfuron Methyl
Chemical family	Sulfonylurea
Molecular formula	$C_{14}H_{15}N_5O_6S$
Structural formula	
CA name	Methyl 2-[[[[(4-methyl-oxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]-amino]sulfonyl benzoate
Molecular weight	381.4
Melting point	158° C
Solubility	9.5 mg/ml @ pH 6.7
Physical state	Solid, white to pale yellow color, faint ester-like odor
Partition coefficient	NA
Ionization constant	pKa = 3.3
pH	4.6 in water as a solution of 0.27 mg/ml (25° C)
EPA registration #	352-439

Table 1. (cont.)

OUST

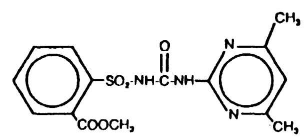
Component	Sulfometuron methyl
Chemical family	Sulfonyl urea
Molecular formula	$C_{15}H_{16}N_4O_5S$
Structural formula	
CA name	Methyl 2-[(4,6-dimethyl-2-pyrimidynl) amino]carbonyl]amino]sulfonyl]benzoate
Molecular weight	364.39
Melting point	203 - 205° C
Solubility	5.5 in water as a solution of 10 ppm @ 25° C
Physical state	Solid, off-white, dry flowable, odorless
Partition coefficient	NA
Ionization constant	pKa = 5.3
pH	7 in water as a solution of 70 ppm @ 25° C
EPA registration #	352-401

Table 1. (cont.)

EVENT

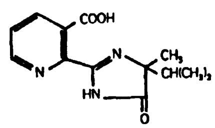
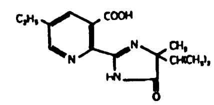
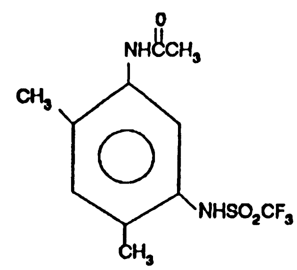
Components	Imazapyr	Imazethapyr
Chemical family	Imidazolinone	Imidazolinone
Molecular formula	$C_{13}H_{15}N_3O_3$	$C_{15}H_{19}N_3O_3$
Structural formula		
CA name	[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboylic acid	2-[4,5-dihydro-4-methyl-4-(1-methylethyl0-5-oxo-1H-imidazol-2-yl]-5-ethyl -3-pyridinecarboxlyic acid
Molecular weight	361.3	289.3
Melting point	160 - 173° C	169 - 173° C
Solubility	1 - 1.5% in water at 25° C	0.14 g/100 ml in water at 25° C
Physical state	White to tan powder, slight acetic acid odor	Off-white to tan powder with a slight pungent odor
Partition coefficient	1.3 @ 22° C	31 @ pH 7 (25° C)
Ionization constant	NA	NA
pH	3.0 - 3.5 @ a 1% solution in water @ 25° C	3.0 as a 0.14% solution in water @ 21° C
EPA registration #	241-273 (noncrop use)	NA

Table 1. (cont.)

EMBARK

Component	Dethanolamine salt of mefluidide
Chemical family	Mefluidide
Molecular formula	$C_{11}H_{13}F_3N_2O_3S$
Structural formula	
CA name	N-[2,4-dimethyl-5[[(trifluoromethyl) sulfonyl]amino]phenyl]acetamide
Molecular weight	310.3
Melting point	183 - 185° C
Solubility	0.18 mg/ml @ 23° C
Physical state	White, crystalline solid, odorless
Partition coefficient	NA
Ionization constant	NA
pH	7.5 - 8.5
EPA registration #	2217-759

Methods

All test plots were set up at the Coles County Airport, 5 miles west of Charleston, Illinois and 2.5 miles east of Mattoon, Illinois on U.S. Route 16. There were 24 plots, 8 in each of three repetitions. The plots were 30 feet by 6 feet with a two foot zone between adjacent plots and a twelve foot border around the test plot area. The content of each repetition and the letter assigned to each treatment is contained in Table 2. To conserve space, each treatment shall be identified by a corresponding letter.

Before the plots were staked, the test area was cut to a uniform height of two inches on November, 30 1988 to insure an equal base from which to measure growth.

Event, Oust, Escort, and Embark were applied in various concentrations and given treatment letters A - G (Table 2). All application were made on April 28, 1989 using a carbon dioxide pressurized hand held sprayer.

Prior to the first harvest, each individual plot was divided into subplots of 6' x 15', and two subplots of 6' x 7.5'. The 6' x 15' subplot was not mowed after the initial application of the PGR's. One 6' x 7.5' subplot was mowed once to two inches after PGR application. These two sets of subplots were used for subjective observations of weed composition, color, seedhead suppression, and turf height, and biomass sampling. A one way analysis of variance was used to determine the significance of results obtained from biomass sampling. The Kruskal-Wallis test was used to identify signifigance of the ranked data obtained during a single sampling date in the subjective evaluations, and a LSD (Least Significant Difference) test was used to compare the control mean to each other group mean.

Table 2. Coles County Airport Project
Plant Growth Regulator Application

Rep 1

1) 1/4 oz. Escort
2) 1/2 oz. Escort
3) 14 oz. Event
4) 10 oz. Event
5) 1/3 oz. Escort & 4 oz. Embark
6) Control
7) 1/4 oz. Oust
8) 12 oz. Event

Rep 2

1) 1/3 oz. Escort & 4 oz. Embark
2) 1/4 oz. Escort
3) 14 oz. Event
4) 10 oz. Event
5) 12 oz. Event
6) 1/2 oz. Event
7) 1/4 oz. Oust
8) Control

Rep 3

1) 1/4 oz. Escort
2) 14 oz. Event
3) 12 oz. Event
4) 1/3 oz. Escort & 4 oz. Embark
5) 10 oz. Event
6) Control
7) 1/2 oz. Escort
8) 1/4 oz. Oust

Table 2. (cont.)

Treatment Labels
1/4 oz./A Escort = **Treatment A**
1/2 oz./A Escort = **Treatment B**
10 oz./A Event = **Treatment C**
12 oz./A Event = **Treatment D**
14 oz./A Event = **Treatment E**
1/4 oz./A Oust = **Treatment F**
1/3 oz./A Escort & 4 oz. Embark = **Treatment G**

Table 3. Chronological order of methods used in the study of plant growth regulators at Coles County Airport, Illinois.

November 30, 1989:	Test area was mowed to a two inch height and test plots were staked out.
April 28, 1989:	Application of Plant growth regulators. Soil conditions moist (no mud), overcast sky, 86% humidity, winds from NW at 10-12 mph, air temperature 84 degrees F, Seedheads present were minimal.
May 14, 1989:	Plots were subdivided into subplots. One subplot per plot for weight studies, and two subplots for subjective visual studies. The subplot for weight studies (6' x 7.5) and one subplot for visual studies (6' x 7.5) were cut to two inches. The other subplot (6' x 15') was left uncut.
June 8, 1989:	Weight samples were collected for plots where PGR's were applied and for control subplots.
June 17, 1989:	Visual studies of color, seedhead suppression, weed control, and turf height conducted.
June 23, 1989:	Weight samples were collected for plots where PGR's were applied and for control subplots.
July 6, 1989:	Visual studies of color, seedhead suppression, weed control, and turf height conducted.
July 12, 1989:	Weight samples were collected for plots where PGR's were applied and for control subplots.
July 28, 1989:	Visual studies of color, seedhead suppression, weed control, and turf height conducted.
August 1, 1989:	Weight samples were collected for plots where PGR's were applied and for control subplots.

August 19, 1989: Visual studies of color, seedhead suppression, weed control, and turf height conducted.

September 2, 1989: Visual studies of color, seedhead suppression, weed control, and turf height conducted.

September 12, 1989: Weight samples were collected for plots where PGR's were applied and for control subplots.

Table 4. Sample calculations

Event

I. Ratio:

A. 10 oz./A
B. 12 oz./A
C. 14 oz./A

* applied at 30 gpa (gallons per acre) at 3 mph

II.

A. $$GPM=\frac{GPAxMPHxwidth}{5940}=\frac{30x3x20''}{5940}=0.303$$

GPM = gallons per minute
width = inches between nozzles
0.303 units = gpm/nozzle
5940 = nozzle reference number

B. Nozzle 8003 at 40 psi = 0.30 gpm

C. Boom pressure = 40 psi

D. 0.303 gpm = 1146.9 ml/min/nozzle
(1 gallon = 3785 ml)

E. Plot size

1. $$\frac{6'x30'}{43{,}560sq.ft./A}=0.00413A$$

* enough was mixed for application to four plots

2. 0.00413 x 4 = 0.01652 A in 4 plots

F. 10 oz./A x 0.01652 A = 0.1652 oz./0.01652 A
12 oz./A x 0.01652 A = 0.1982 oz./0.01652 A
14 oz./A x 0.01652 A = 0.2313 oz./0.01652 A

G. 29.6 ml/oz. x 0.1652 oz. = 4.89 ml at 10 oz./A
29.6 ml/oz. x 0.1982 oz. = 5.87 ml at 12 oz./A
29.6 ml/oz. x 0.2313 oz. = 6.85 ml at 14 oz./A

H. Volume of mixture for four plots

1. 30 GPA x 0.01652 A = 0.4956 gallons
2. 0.4956 gal. x 128 oz./gal x 29.6 ml/oz = 1878 ml

I. Application of Event

1. 10 oz./A = 4.89 ml in total volume of 1878 ml
2. 12 oz./A = 5.87 ml in total volume of 1878 ml
3. 14 oz./A = 6.85 ml in total volume of 1878 ml

Oust

A. - E. Same as above

F. 0.25 oz./A x 0.01652 A = 0.00413 oz./0.01652 A

G. 29.6 g/oz. x 0.00413 oz. = 0.122 g at 0.25 oz./A

H. Same as above

I. Application of Oust

0.25 oz./A = 0.122 g in total volume of 1878 ml

Escort

A. - E. Same as above

F. 0.25 oz./A x 0.01652 A = 0.00413 oz./0.01652 A
0.50 oz./A x 0.01652 A = 0.00826 oz./0.01652 A

G. 29.6 g/oz. x 0.00413 oz. = 0.122 g at 0.25 oz./A
29.6 g/oz. x 0.00826 oz. = 0.244 g at 0.50 oz./A

H. Same as above

I. Application of Escort

0.25 oz./A = 0.122 g in a total volume of 1878 ml
0.33 oz./A = 0.161 g in a total volume of 1878 ml
0.50 oz./A = 0.244 g in a total volume of 1878 ml

Escort with Embark

A. - E. Same as above

F. 0.33 oz./A x 0.01652 A = 0.00545 oz./0.01652 A
4.0 oz./A x 0.01652 A = 0.0661 oz./0.01652 A

G. 29.6 g/oz. x 0.00545 oz. = 0.161 g at 0.33 oz./A
29.6 ml/oz. x 0.0661 oz. = 1.96 ml at 4 oz./A

H. Same as above

I. Application of Escort with Embark

0.33 oz./A = 0.161 g in a total volume of 1878 ml
4.0 oz./A = 1.96 ml in a total volume of 1878 ml

Results

The average weight in grams, and the percent reduction from control of samples collected from the test plots are listed in Table 5. On sample date 6/8, 41 days after application, all PGR's showed some growth reduction . Treatment F was the most effective for sampling date 6/8 with a 52.8% reduction. Treatment G was the most effective for sampling dates 6/23 and 7/12 at 89.4% and 42.5% respectively. Treatment B was the most effective for sampling dates 8/1 and 9/12 with reductions of 24.3% and 22.8% respectively. Figure 4 illustrates the results of sample date 6/8. Treatment F was the most effective at this sampling date, showing a reduction of 52.8%. At this time, treatments C, F, and G showed statistically significant reduction of growth. All significance in the remainder of this document refers to statistical significance.

Two weeks later, all PGR's except treatment D, had shown increased growth regulation. Treatment G was the most effective with a 89.5% reduction from control. All treatments except D displayed significant reduction of biomass from control. Figure 2 illustrates the results of sample date 6/23/89.

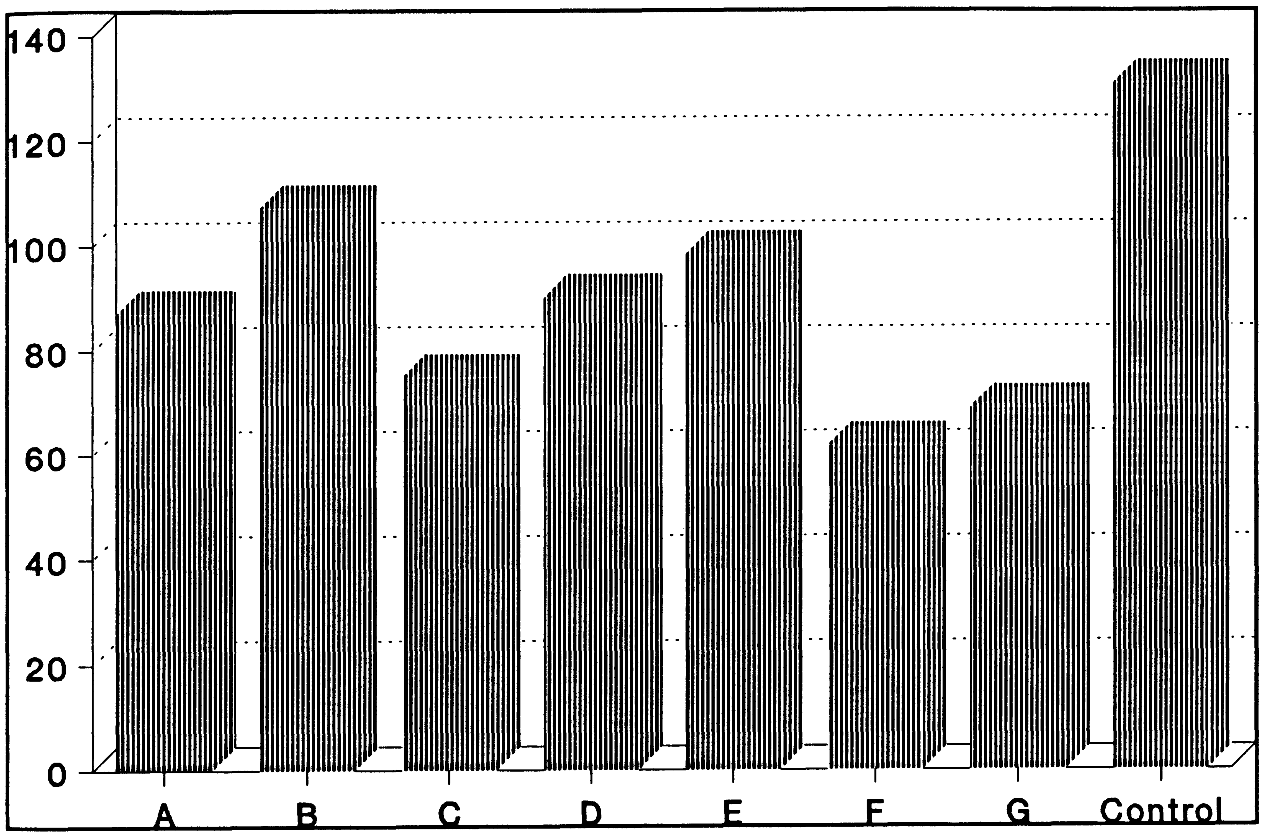
Sample date 7/12 marked a significant decrease in growth regulation of all PGR's. The percent reduction for all samples was decreased by at least 50% in all cases. Figure 3 illustrates the results of sample date 7/12/89. Treatment G continued to be the most effective, decreasing growth 42.5%. During this time period, only treatment G significantly reduced growth.

Results recorded on sample date 8/1 showed improvement for treatments A, B, C, and F. Treatments D, E, and G displayed decreases in the amount of biomass reduction. Treatment B was the most effective for this sampling date with a 24.3 % reduction of biomass from control. No treatments exhibited statistically significant growth reduction at this time. Figure 4 illustrates the results of sampling period 8/1.

Table 5. The average weight, in grams, and percent reduction from control of grass cuttings collected from rough turf at Coles County Airport. The turf was treated with selected plant growth regulators. The turf was cut to two inches for a 6' x 7.5' area of the sample plot.

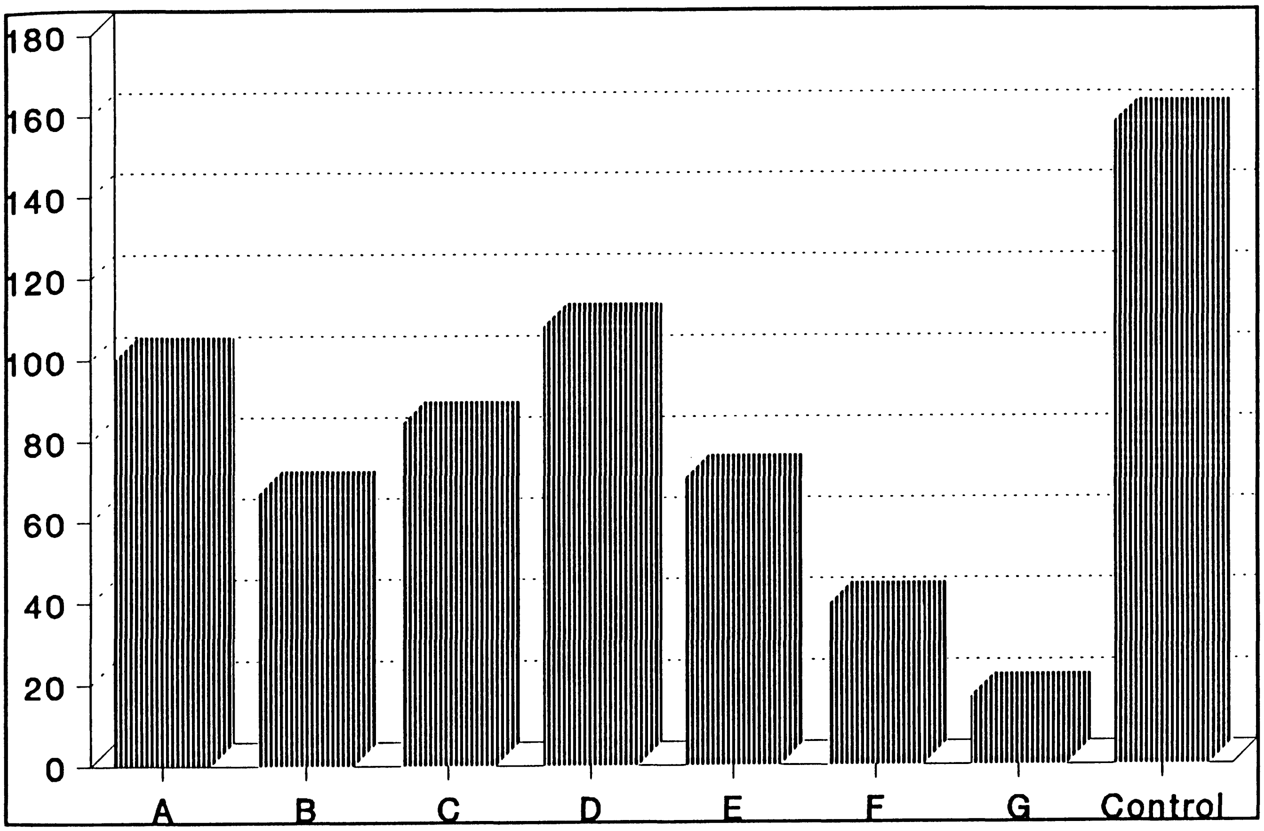
Average weight in grams of sample and percent reduction from control by date collected	6/8		6/23		7/12		8/1		9/12		
Product	g	% red	g	% red	g	% red	g	% red	g	% red	Avg
1/4 oz. Escort	261.35	33.3	300.32	36.7	358.96	2.5	389.70	24.0	1061.96	21.8	24
1/2 oz. Escort	321.27	18.1	200.62	57.7	327.93	11.0	388.55	24.3	1048.61	22.8	27
10 oz. Event	224.54	42.7	252.00	46.9	339.5	7.8	424.55	17.2	1289.9	5.0	24
12 oz. Event	270.37	31.0	324.14	31.7	348.31	5.4	512.15	0.2	1152.1	15.2	17
14 oz. Event	294.84	24.8	212.12	55.3	278.40	24.4	480.62	6.3	1271.7	6.4	23
1/4 oz. Oust	184.87	52.8	116.70	75.4	294.45	20.0	407.2	20.6	1192.6	12.2	36
1/3 oz. Escort with 4 oz. Embark	206.53	47.3	50.07	89.4	211.59	42.5	400.81	21.9	1184.35	12.8	43
Control	392.10	-	474.37	-	368.29	-	513.06	-	1358.2	-	-

Figure 1. The average weight, in grams, of grass cuttings from rough turf at Coles County Airport. The turf was cut to two inches for a 6 foot by 7.5 foot area of the sample plots. Samples were collected on 6/8/89.



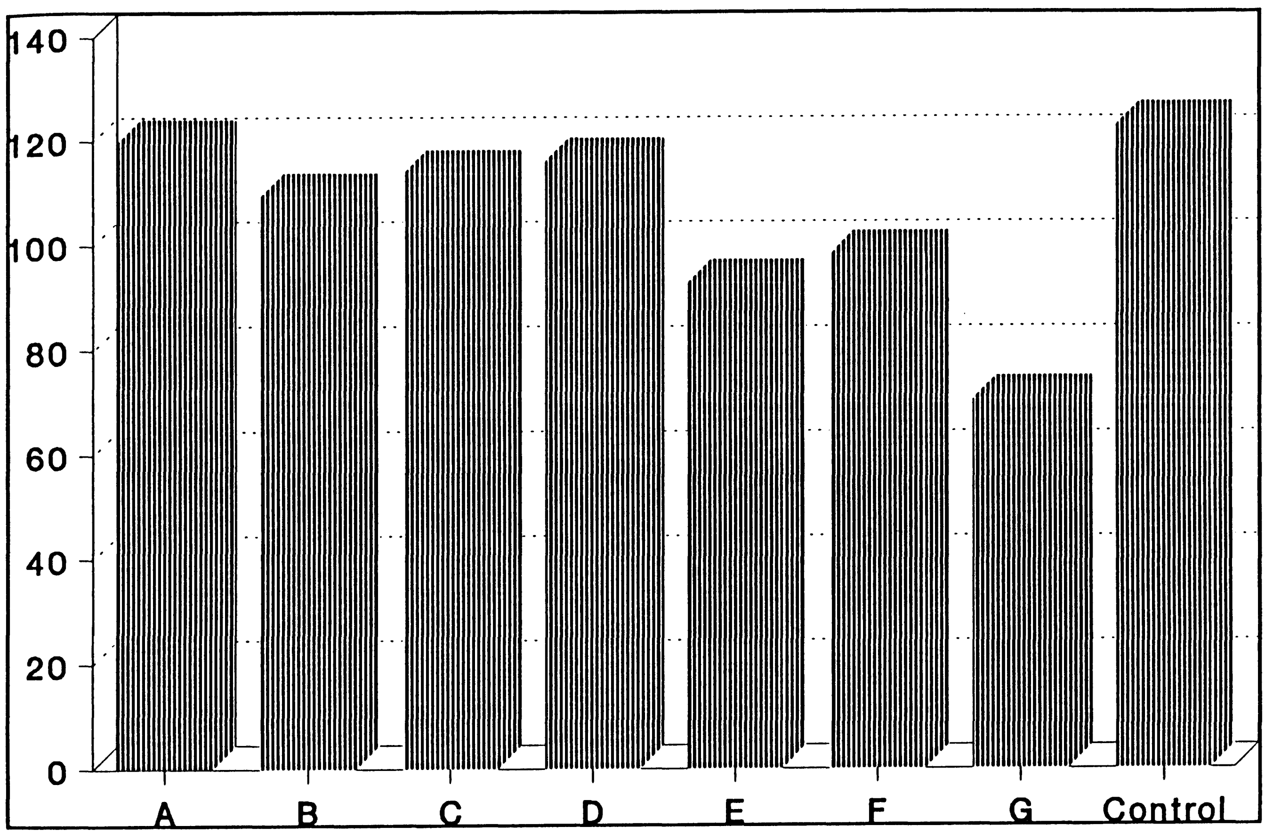
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 2. The average weight, in grams, of grass cuttings from rough turf at Coles County Airport. The turf was cut to two inches for a 6 foot by 7.5 foot area of the sample plots. Samples were collected on 6/23/89.



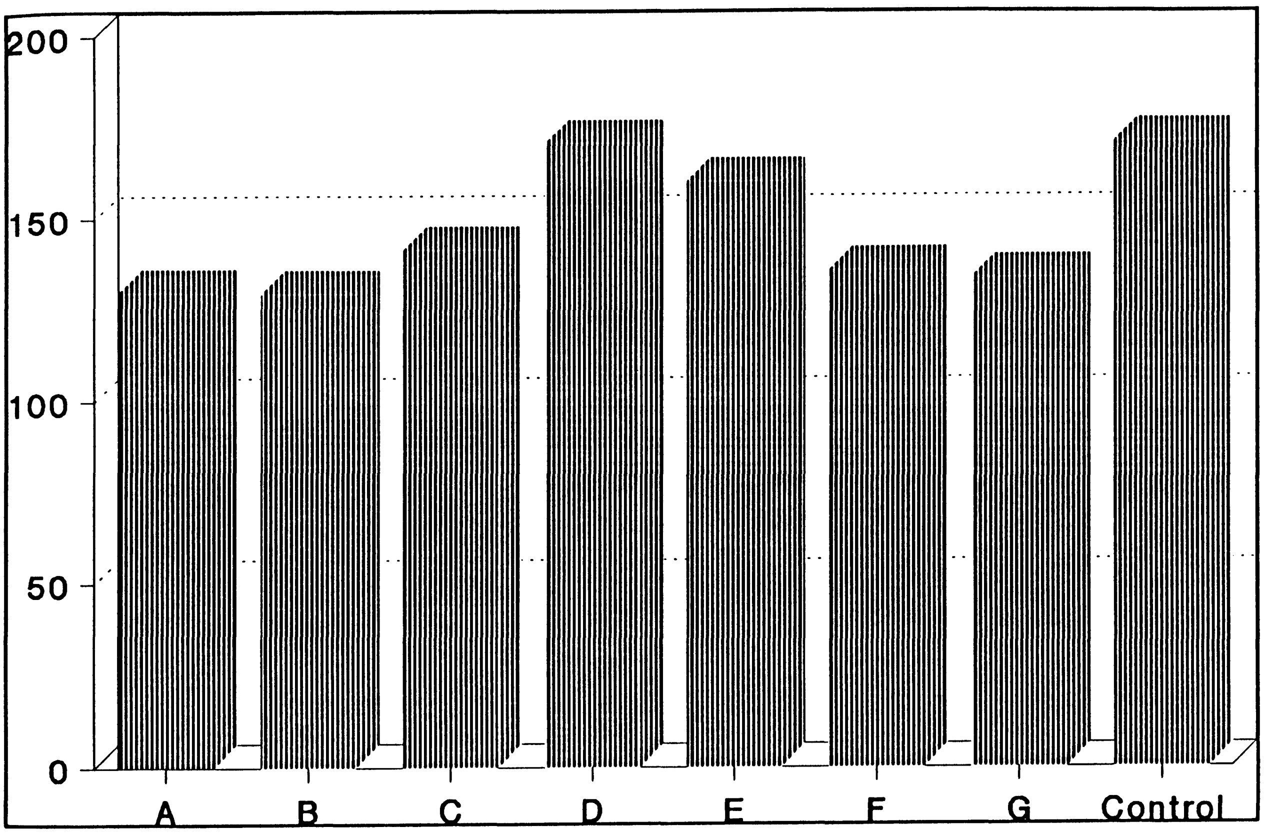
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 3. The average weight, in grams, of grass cuttings from rough turf at Coles County Airport. The turf was cut to two inches for a 6 foot by 7.5 foot area of the sample plots. Samples were collected on 7/12/89.



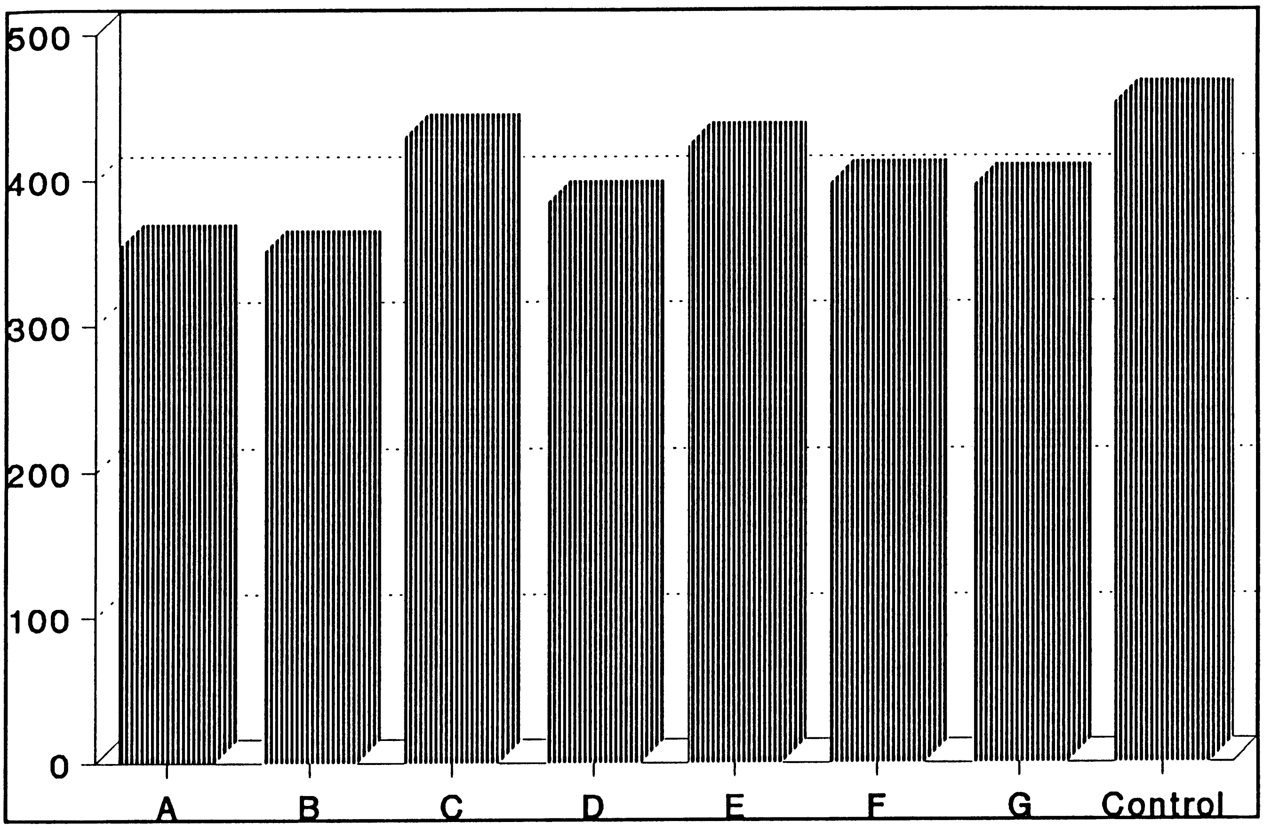
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 4. The average weight, in grams, of grass cuttings from rough turf at Coles County Airport. The turf was cut to two inches for a 6 foot by 7.5 foot area of the sample plots. Samples were collected on 8/1/89.



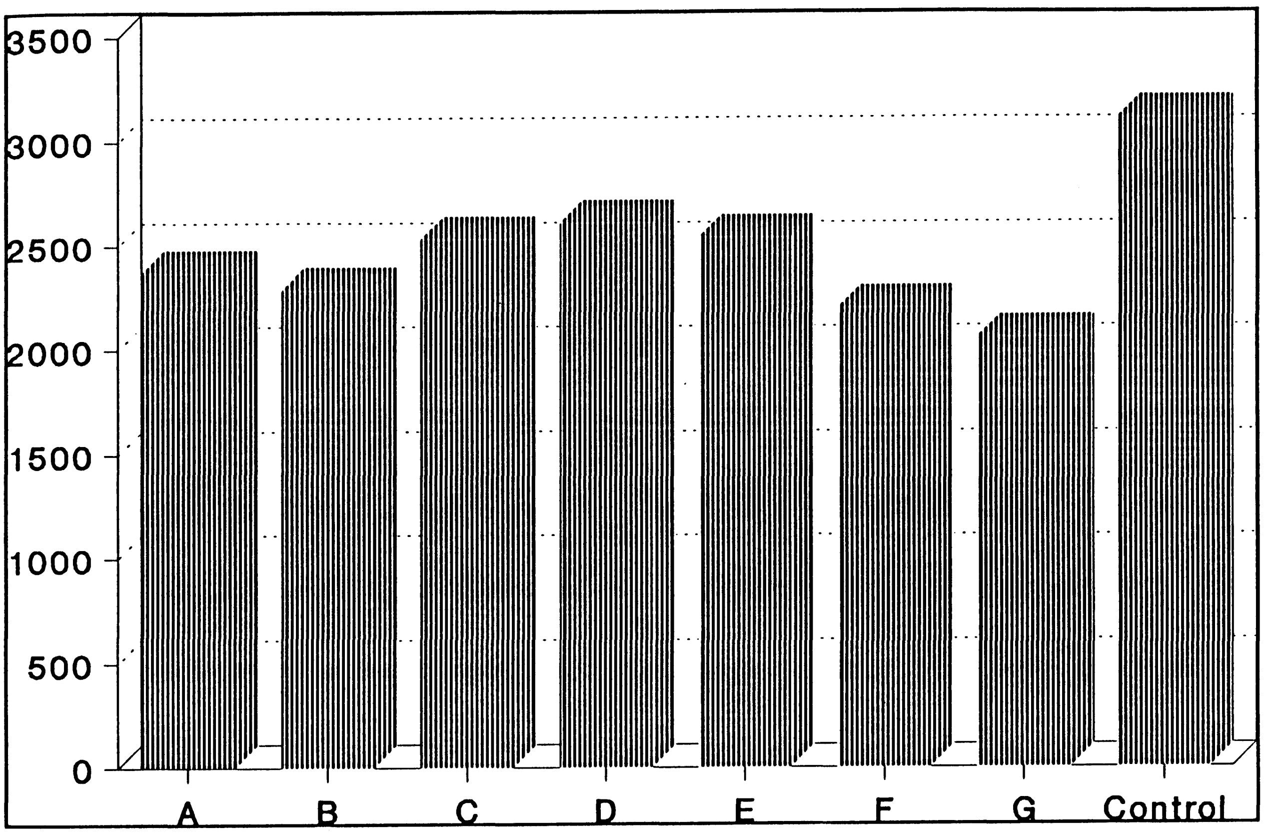
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 5. The average weight, in grams, of grass cuttings from rough turf at Coles County Airport. The turf was cut to two inches for a 6 foot by 7.5 foot area of the sample plots. Samples were collected on 9/12/89.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 6. The average weight, in grams, of grass cuttings collected from rough turf Coles County Airport. The turf was cut to two inches for a 6 foot by 7.5 foot area of the sample plots. Data for all sample dates.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

On sample date 9/12, 138 days after application, all PGR's exhibited less than 25% growth suppression. The fluctuations in percent reduction for all PGR's were, with one exception, small. Treatment B was the most effective with a 23% growth reduction from control. Treatment F was also effective with a reduction of 22%. All other PGR's reduced growth at less than 20%. No treatments, at this time, exhibited a significant reduction of growth. Figure 5 illustrates the results of sample date 9/12/89. Due to the large sample weights, the length of time between the previous sample date, and the total time from application, the researcher is not confident that the data obtained may clearly represent the PGR activity during the final sampling period.

The totals from each individual harvest were added to determine total biomass reduction for the entire sampling period. All PGR's resulted in average reductions of greater than 15%. Figure 6 indicates the results for the total sampling period from 4/28/89 to 9/12/89. An average reduction of biomass of 43% by treatment G was the most effective. Treatment F was also very effective at a rate of 36%. Treatment D was the least effective of all PGR's examined at 17%.

Listed in Table 6 are the results of subjective visual studies on the reduction of height of the turf in subplots that were cut once to two inches after initial PGR application. Treatment G was the most effective on all sampling dates.

Figure 7 indicates the results of the sample date 6/17. At this point, all PGR's were effective, with the difference in percent reduction between the most and least effective less than 20%. Treatment G the most effective at 47% reduction. Only treatment G showed a significant reduction of height.

Two weeks later on sample date 7/6, treatment G most effective again at 53%. All treatments displayed significant height reduction. Figure 8 illustrates the results of sample date 7/6/89.

Figure 9 indicates the results of sampling date 7/28. Treatment G remained the most effective, increasing reduction to 63%. This was the most effective reduction of height for turf cut to two inches for any one sampling date. Significant reduction of turf height was demonstrated again by all treatments.

It was evident that at sampling date 8 /19, the effectiveness of all PGR's was beginning to decrease. All treatments experienced decreases in percent reduction of biomass. Treatment G decreased to 43% reduction. At this time, only treatment C failed to show a significant reduction of turf height. Figure 10 illustrates the results of sampling date 8/19.

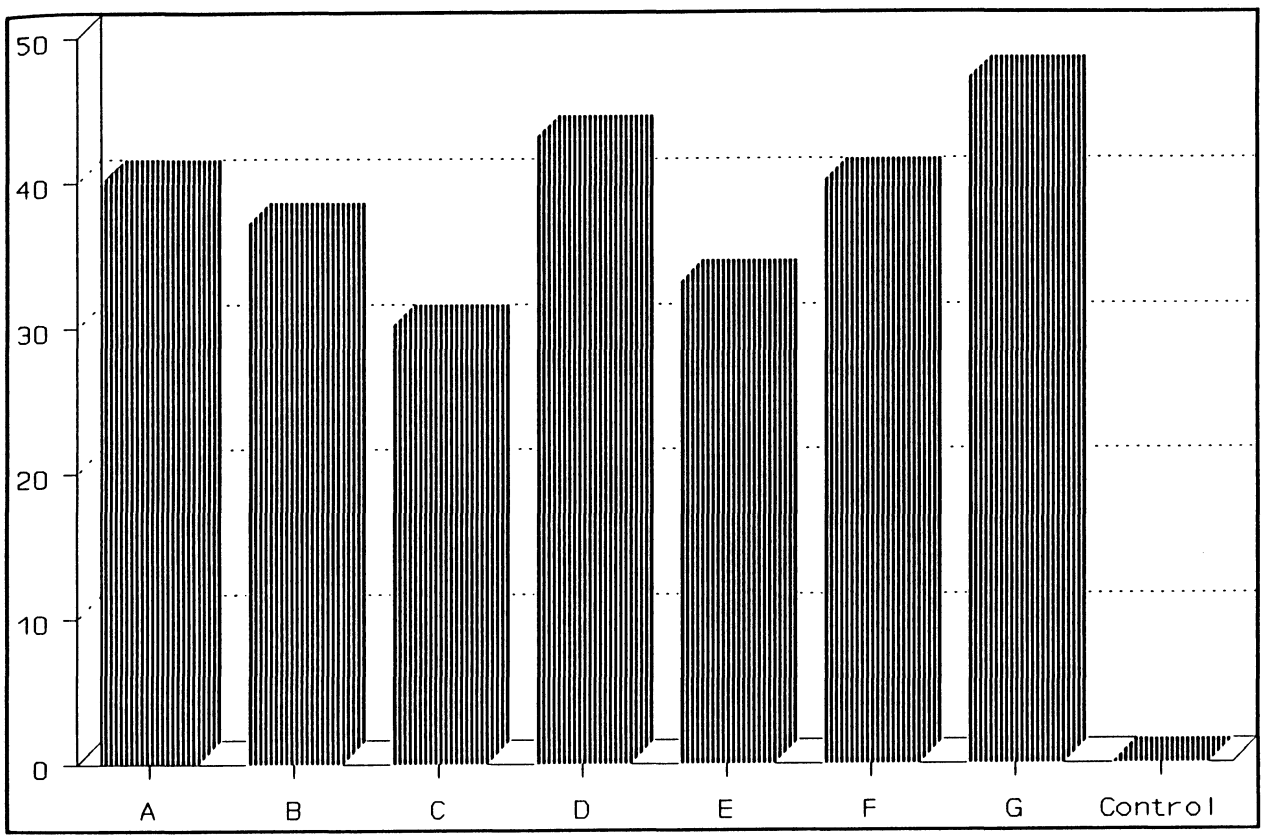
The last sample date for plots cut once was 9/2. It was clear at this time that the effectiveness of the PGR's was decreasing significantly. All products again exhibited decreases in the amount of height reduction as compared to control. Figure 11 illustrates the results from this sampling date. Treatment G decreased again but remained the most effective with a reduction of 27%. Only treatments G and E displayed a significant reduction of turf height for this sampling period.

Figure 12 indicates the average performances of the PGR's taken from the sub-plots that were cut to a height of two inches after product application for the entire sampling period. Treatment G was the most effective with an average height reduction of 47%. Treatment C was the least effective with an average reduction of 19%

Table 6. Visual study of the average percent reduction of height of cut rough turf at Coles Count Airport. The turf was treated with plant growth regulators. The test plots were mowed to two inches on May 14, 1989.

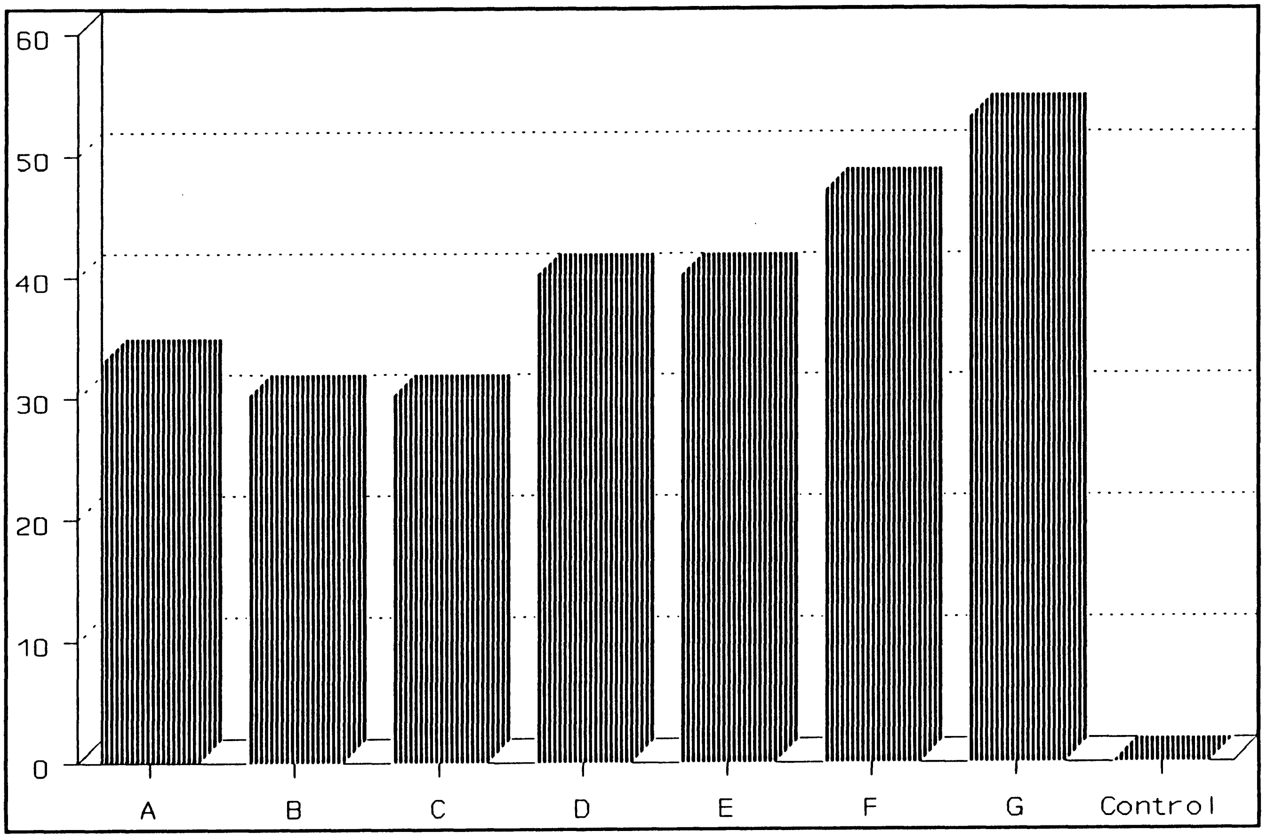
Products	6/17	7/6	7/28	8/19	9/12	Average
1/4 oz. Escort	40%	33%	47%	27%	13%	32.0%
1/2 oz. Escort	37%	30%	33%	23%	10%	26.6%
10 oz. Event	30%	30%	27%	10%	0%	19.4%
12 oz. Event	43%	40%	33%	20%	3%	28.0%
14 oz. Event	33%	40%	47%	33%	23%	35.2%
1/4 oz. Oust	40%	47%	47%	33%	20%	37.4%
1/3 oz. Escort w/ 1/4 pint Embark	47%	53%	63%	43%	27%	46.6%

Figure 7. Visual study of the average percent reduction in height of cut turf at Coles County Airport. The test plots wer mowed to two inches on May 14, 1989. Visual study of mowed area taken on 6/17/89.



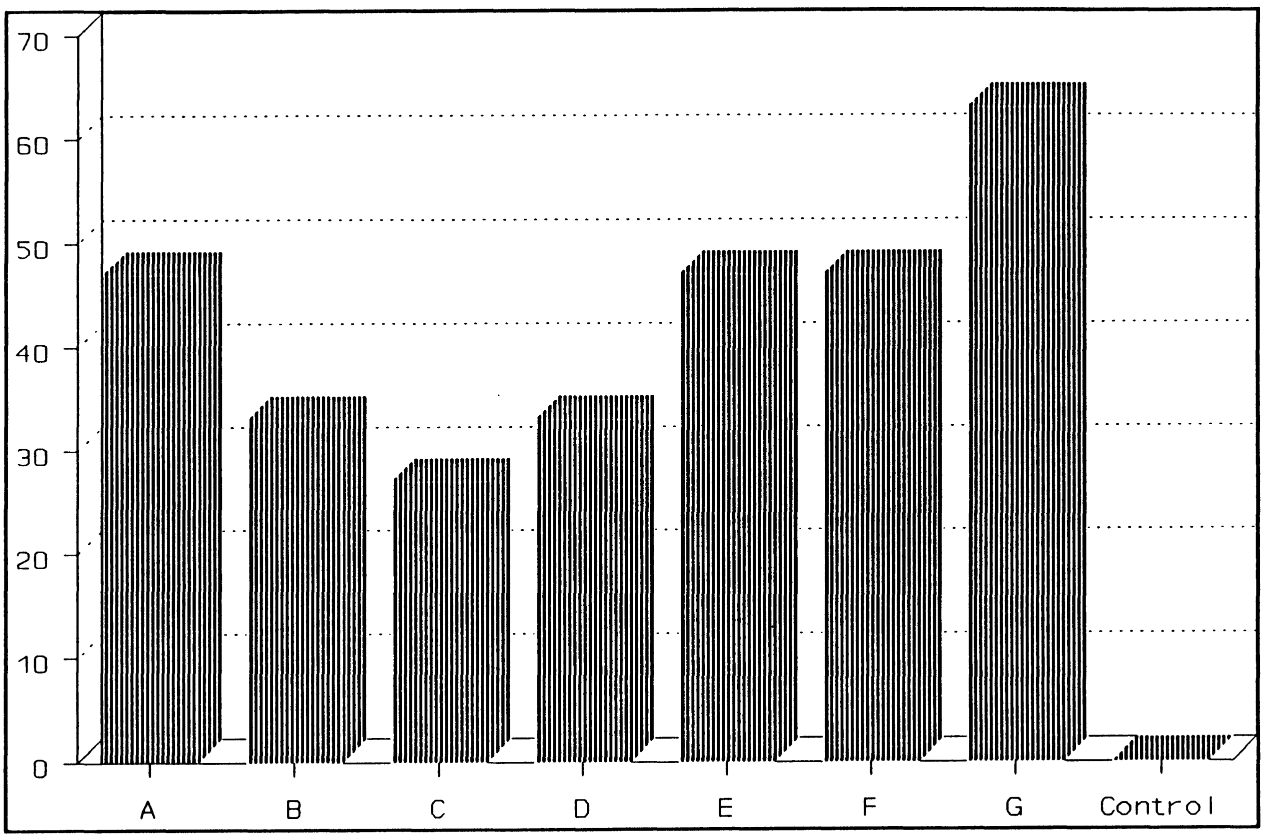
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 8. Visual study of the average percent reduction in height of cut turf at Coles County Airport. The test plots were mowed to two inches on May 14, 1989. Visual study of mowed area taken on 7/6/89.



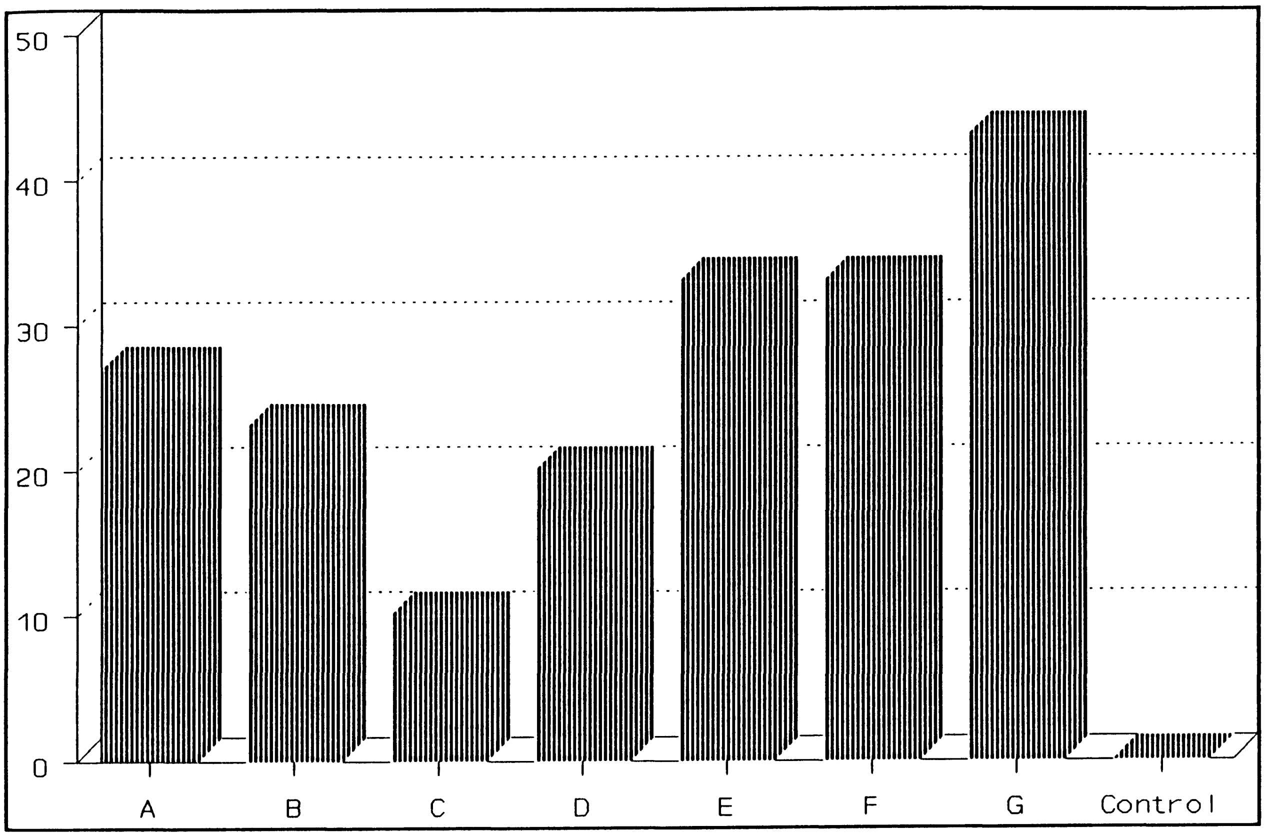
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 9. Visual study of the average percent reduction in height of cut turf at Coles County Airport. The test plots were mowed to two inches on May 14, 1989. Visual study of mowed area taken on 7/28/89.



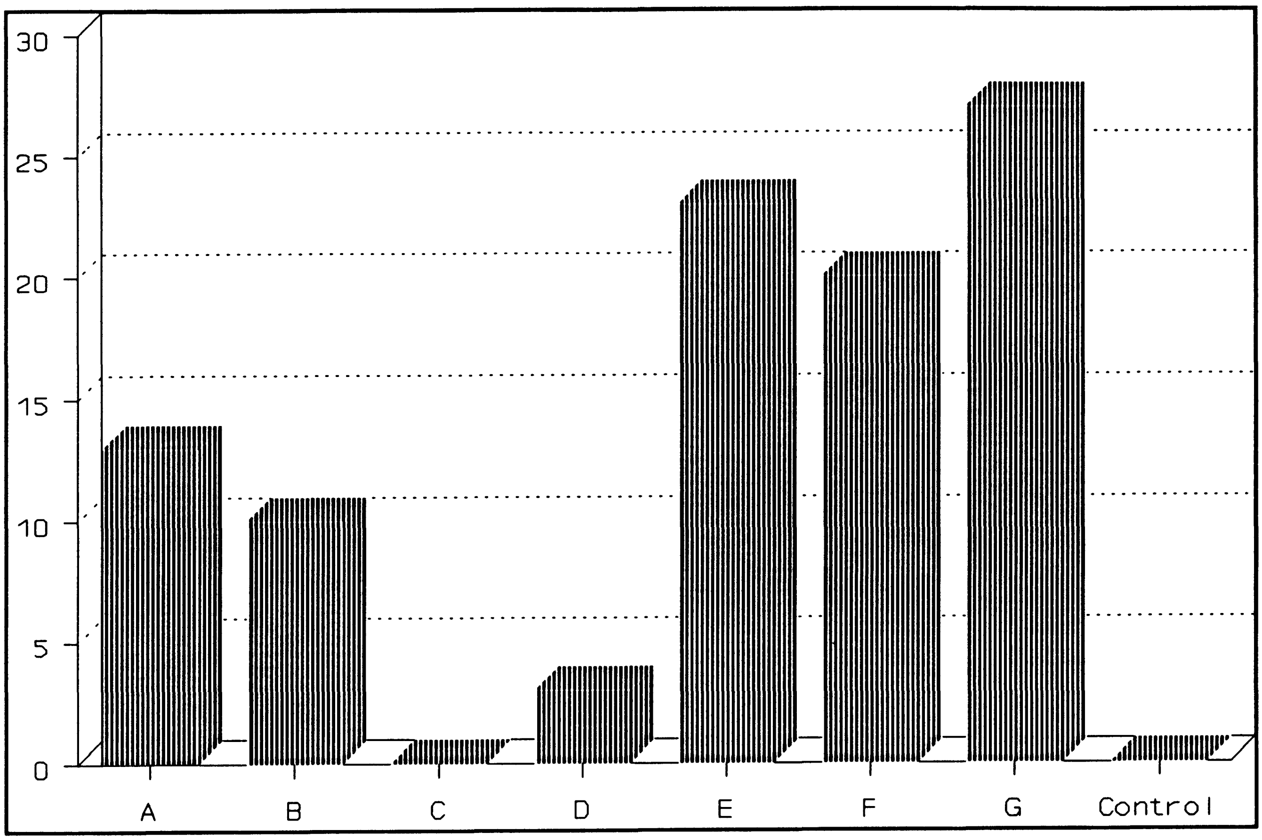
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 10. Visual study of the average percent reduction in height of cut turf at Coles County Airport. The test plots were mowed to two inches on May 14, 1989. Visual study of mowed area taken on 8/19/89.



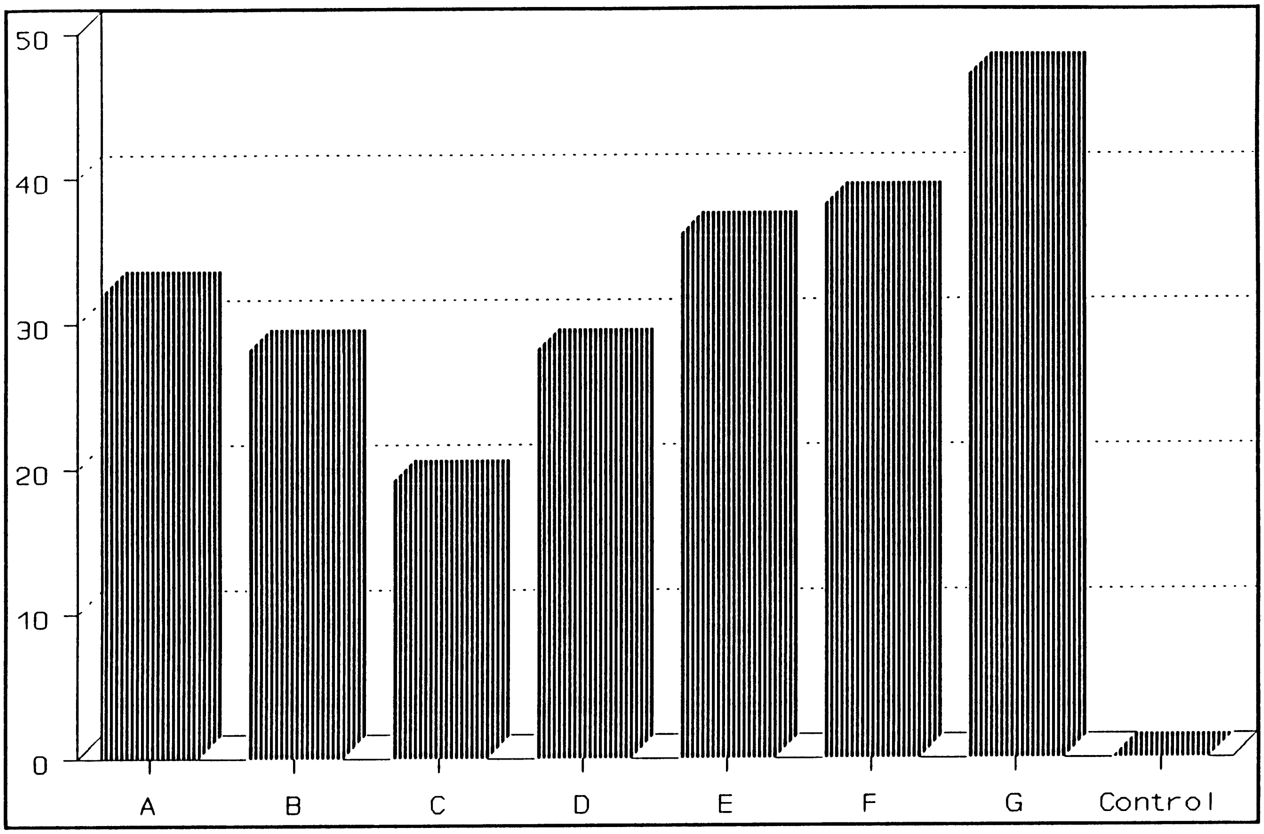
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 11. Visual study of the average percent reduction in height of cut turf at Coles County Airport. The test plots were mowed to two inches on May 14, 1989. Visual study of mowed area taken on 9/12/89.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 12. Visual study of the average percent reduction in height of cut turf at Coles County Airport. The test plots were mowed to two inches on May 14, 1989. Data for mowed subplots on all sample dates.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Subjective visual studies were also performed for the sub-plots that were not cut during the entire sampling period. The average percent reduction in height for each product is listed in Table 7. Treatment G was the most effective for sampling dates 7/6, 7/28, 8/19, and 9/2. Treatment D was the most effective for sampling date 6/17.

Figure 13 illustrates the results of sampling date 6/17. Treatment D showed the greatest reduction at 47%. All treatments except A, B, and F displayed a significant reduction of uncut turf height for this sampling period. Figure 14 illustrates the results of sampling date 7/6. Treatment G was the most effective at 43% reduction. Significant reductions in height of uncut turf were demonstrated by all of the treatments. Figure 15 illustrates the results of sampling date 7/28. Treatment G remained the most effective, increasing reduction to 57%, the highest rate of any sampling date. Again, all treatments displayed significant reductions of growth of uncut turf.

By sampling date 8/19, PGR activity was decreasing. All treatments experienced decreases in average percent height reduction. Figure 16 illustrates the results of this sampling date. Treatment G continued to be the most effective with a reduction rate of 43%. Treatments A, E, F, and G showed a significant growth reduction of uncut turf.

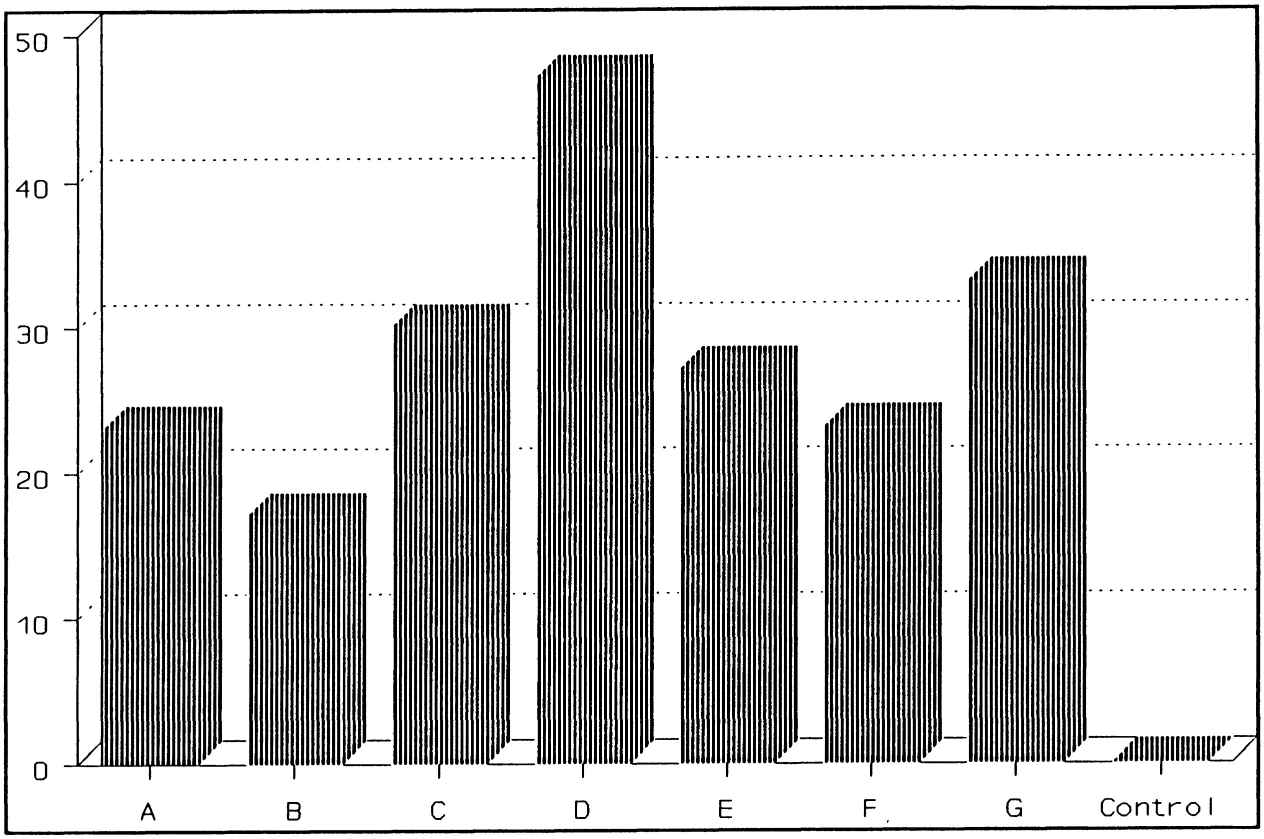
At sampling date 9/2, it was evident that PGR activity on the uncut turf was greatly reduced. Treatment G was the most effective concentration at a 20% reduction rate. No treatments displayed significant reduction of growth of uncut turf during this sampling period. Figure 17 illustrates the results of sampling date 9/2.

Figure 18 illustrates the average reduction of height of uncut turf for the entire sampling period. Treatment G was the most effective, reducing height by 39%. Treatments B and C were the least effective, reducing the height of uncut turf 17%.

Table 7. Visual study of the average percent reduction of height of uncut rough turf at Coles Count Airport. The turf was treated with plant growth regulators. Data from uncut turf.

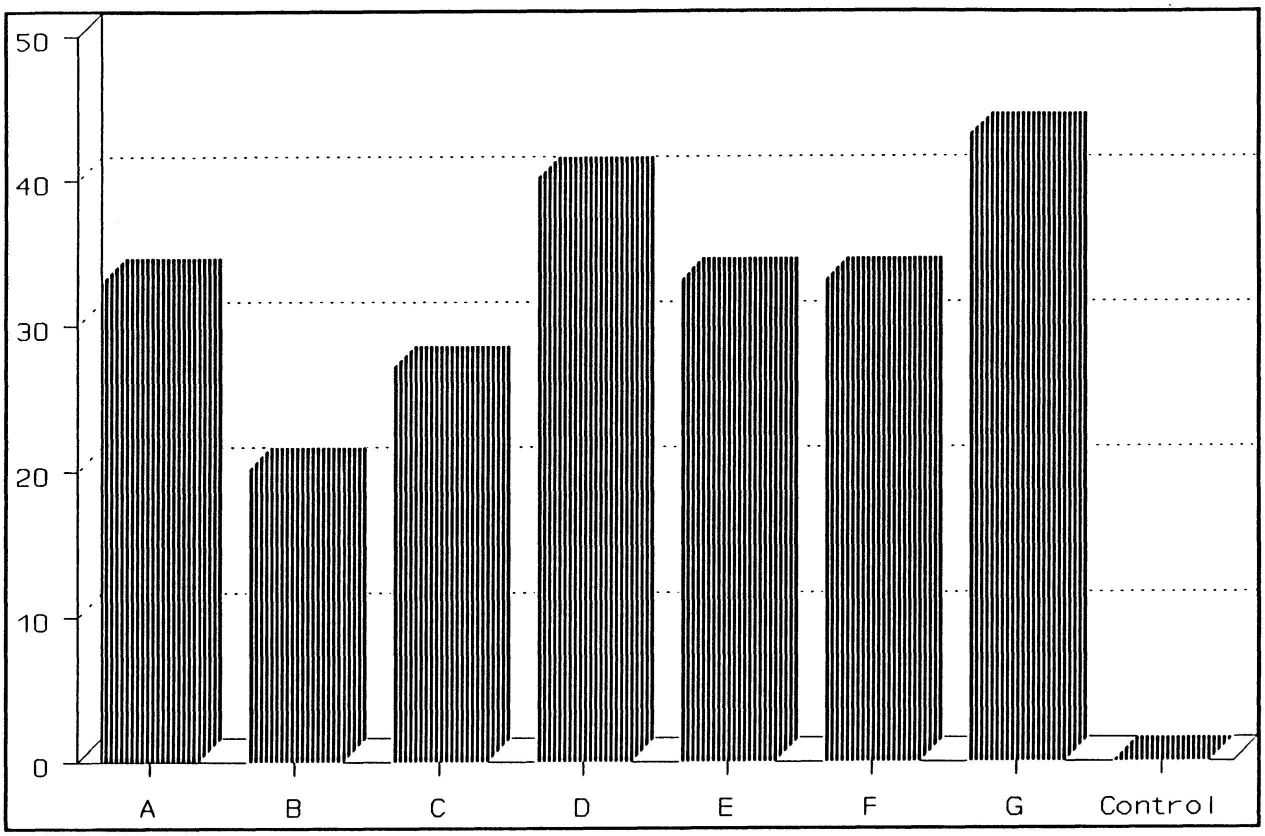
Products	6/17	7/6	7/28	8/19	9/12	Average
1/4 oz. Escort	23%	33%	43%	23%	3%	25.0%
1/2 oz. Escort	17%	20%	27%	20%	0%	16.8%
10 oz. Event	30%	27%	23%	7%	0%	17.4%
12 oz. Event	47%	40%	30%	20%	0%	27.4%
14 oz. Event	27%	33%	43%	33%	7%	28.6%
1/4 oz. Oust	23%	33%	50%	30%	3%	27.8%
1/3 oz. Escort w/ 1/4 pint Embark	33%	43%	57%	43%	20%	39.2%

Figure 13. Visual study of the average percent reduction in height of uncut turf at Coles County Airport. Data from uncut turf collected on 6/17/89



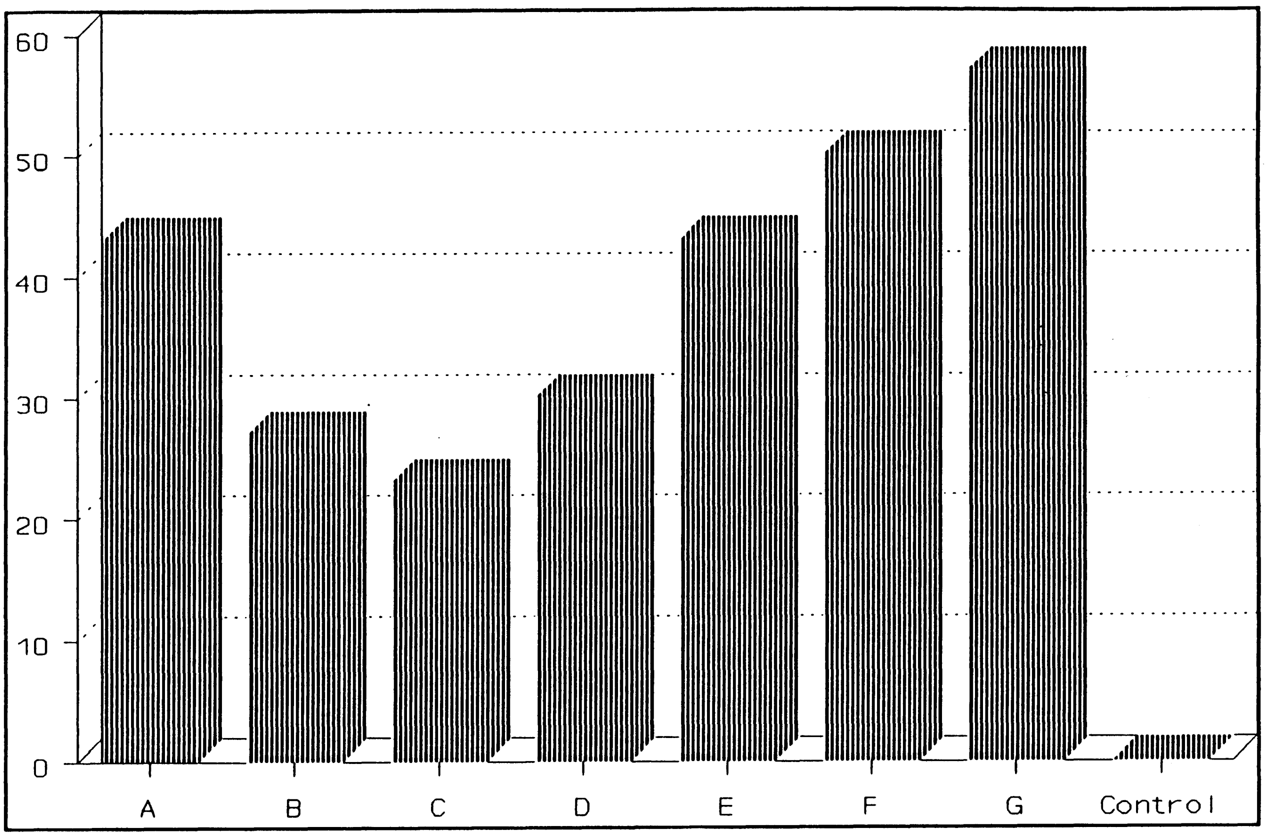
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 14. Visual study of the average percent reduction in height of uncut turf at Coles County Airport. Data from uncut turf collected on 7/6/89.



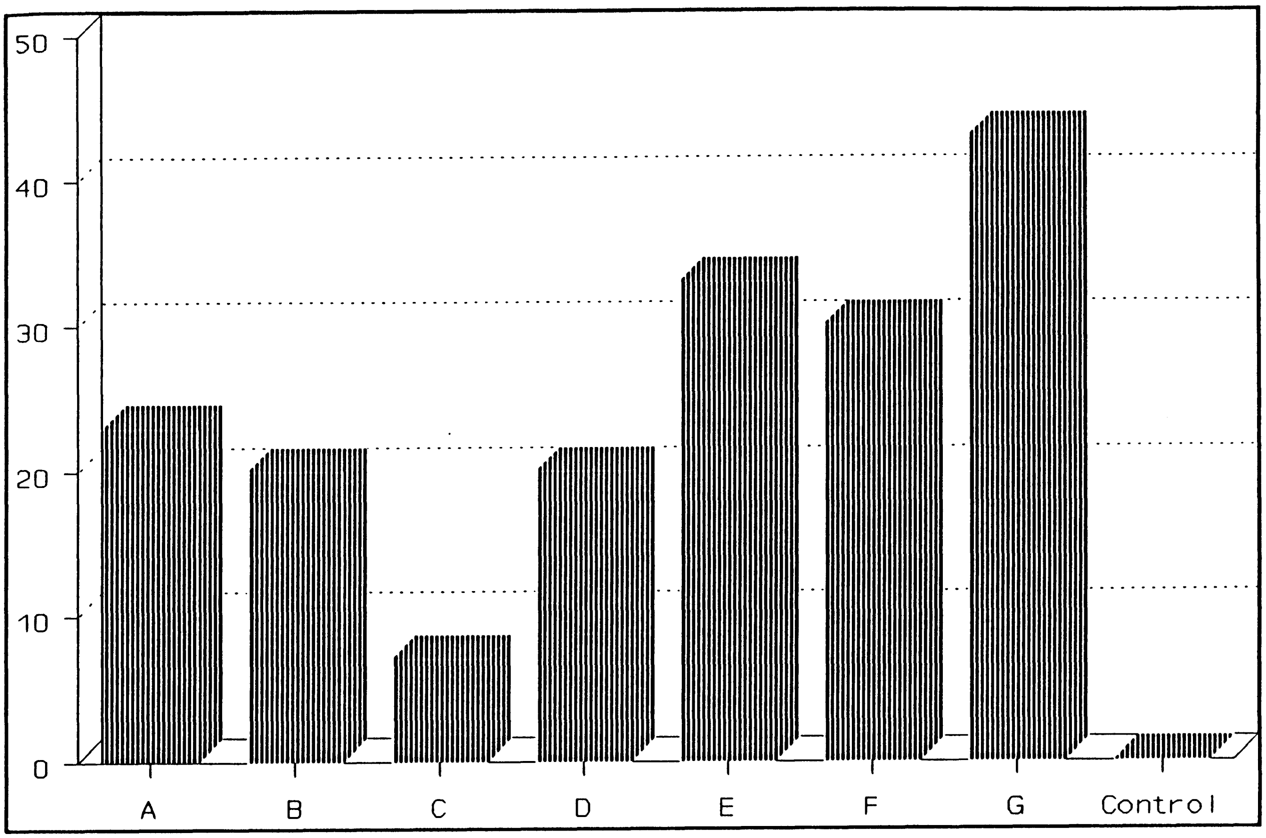
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 15. Visual study of the average percent reduction in height of uncut turf at Coles County Airport. Data from uncut turf collected on 7/28/89.



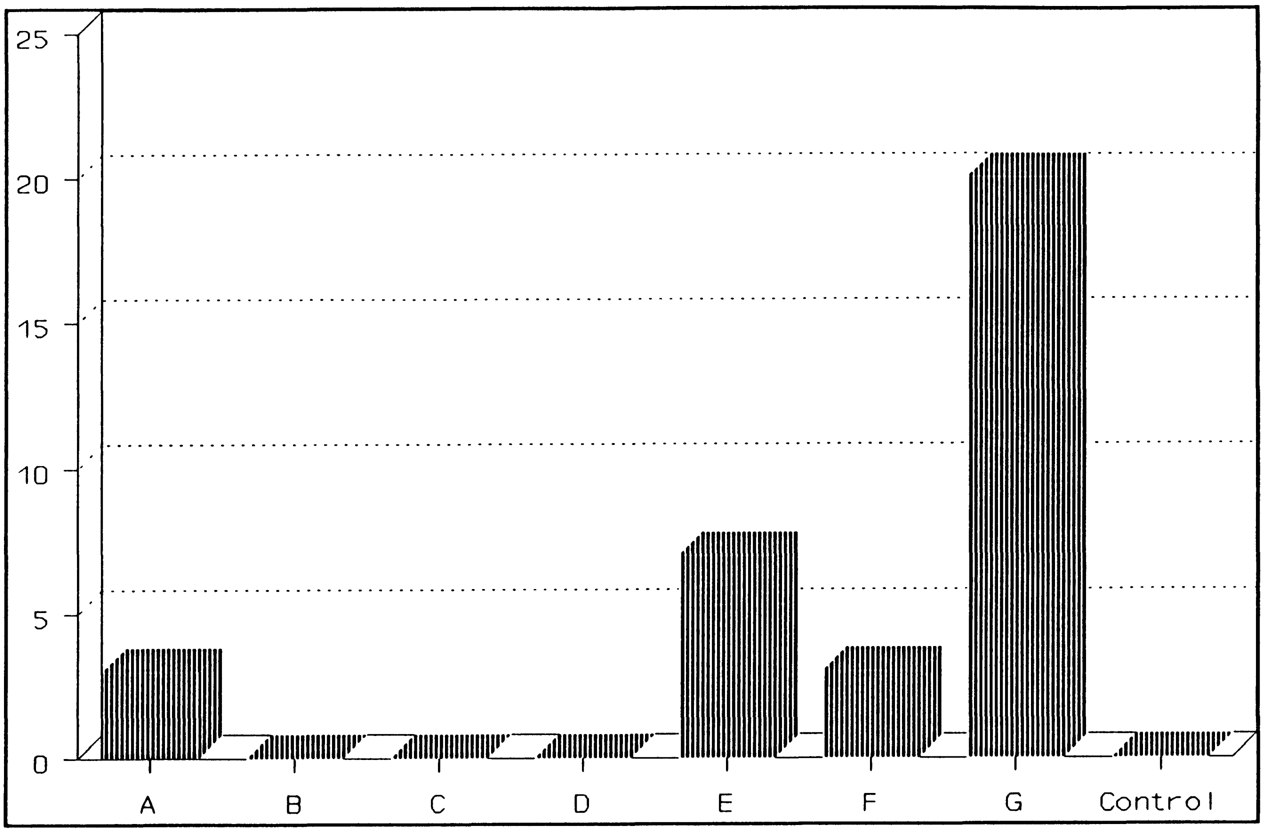
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 16. Visual study of the average percent reduction in height of uncut turf at Coles County Airport. Data from uncut turf collected on 8/19/88.



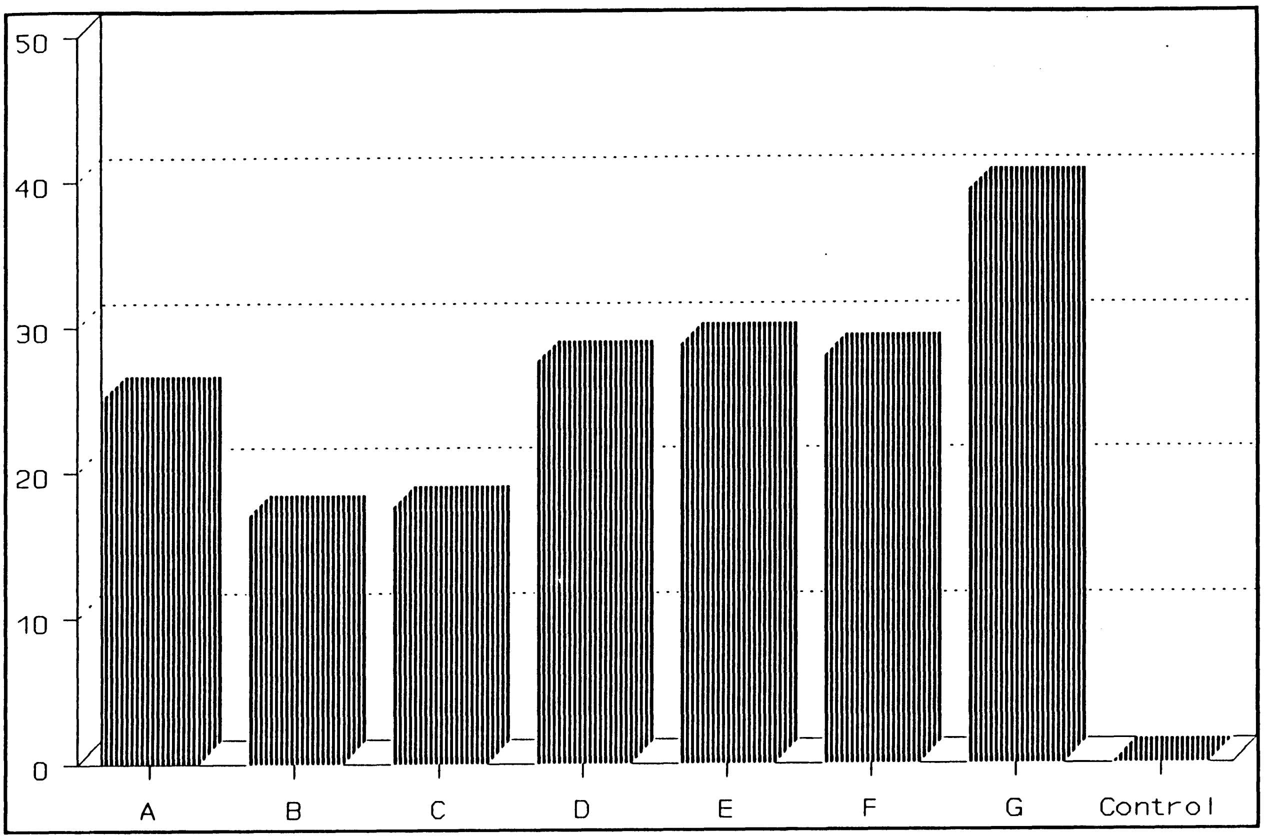
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 17. Visual study of the average percent reduction in height of uncut turf at Coles County Airport. Data from uncut turf collected on 9/12/1989.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 18. Visual study of the average percent reduction in height of uncut turf at Coles County Airport. Data from uncut turf for all sample dates.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Subjective visual studies were performed to determine the average percent reduction in seedhead production. The result are listed in Table 8. Treatments B and F were the most effective on sampling dates 6/17. Treatments G was the most effective on all other sampling dates.

Figure 19 illustrates the results of sampling date 6/17. Treatments B and F were the most effective with a reduction of seedhead production at 30%.

All treatments except E showed significant reduction of seedheads. On sampling date 7/6, treatment G was the most effective at 7/6 with a seedhead reduction rate of 37% All treatments exhibited significant reduction of seedhead suppression. Figure 20 indicates the results of sampling date 7/6.

On sampling date 7/28, PGR activity upon seedhead production increased. Figure 21 illustrates the results of this sampling date. Treatments G was again the most effective at reducing seedhead production at a rate of 47%. This was the most significant reduction of seedhead production for the entire sampling period. All treatments showed significant reduction of seedhead production for this sampliing period.

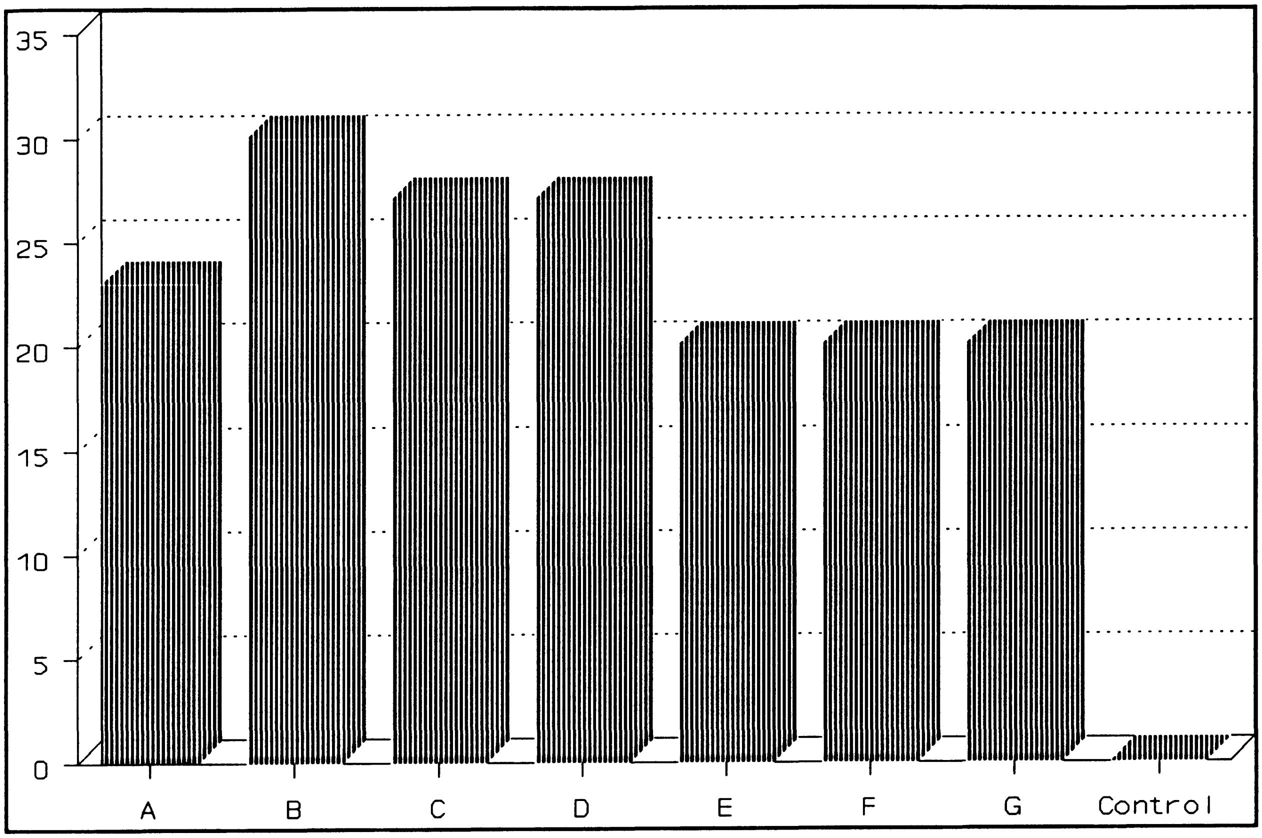
At sampling date 8/19, PGR activity on seedhead production was severely decreased. Treatment G was the most effective with a 27% reduction of seedhead production. Treatments B and G exhibited a significant suppression of seedhead production for this sampling date. Figure 22 indicates the results of sampling date 8/19.

On sampling date 9/2 very little suppression was observed. Figure 23 illustrates the results of this sampling date. Treatment G remained the most effective, reducing seedhead production 7%. No treatment displayed significant reduction of seedhead production for this sampling date. Figure 24 illustrates the average reduction of seedhead production for all treatments during the entire sampling period. Treatment G was the most effective, reducing seedhead production 28%. Treatment C was the least effective, reducing seedhead production 11%.

Table 8. Visual study of the average percent reduction in seedheads of rough turf at Coles County Airport. The turf was treated with plant growth regulators.

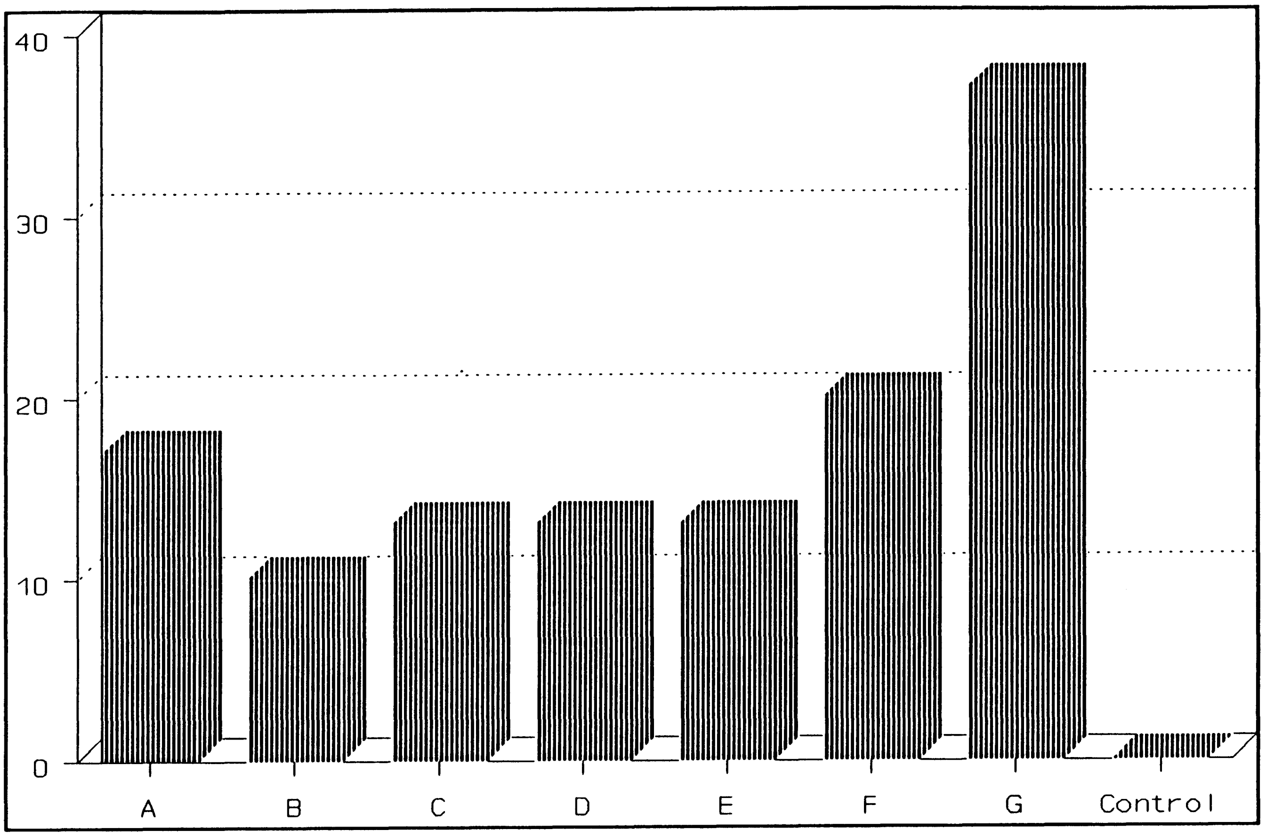
Product	6/17	7/6	7/28	8/19	9/12	Average
1/4 oz. Escort	23%	17%	23%	13%	0%	15.2%
1/2 oz. Escort	30%	10%	13%	7%	0%	12.0%
10 oz. Event	27%	13%	13%	3%	0%	11.2%
12 oz. Event	27%	13%	20%	3%	0%	12.6%
14 oz. Event	20%	13%	33%	23%	0%	17.8%
1/4 oz. Oust	30%	20%	30%	13%	3%	19.2%
1/3 oz. Escort w/ 1/4 pint Embark	20%	37%	47%	27%	7%	27.6%

Figure 19. Visual study of the average percent reduction of seedhead production for turf at Coles County Airport. Data collected on 6/17/1989.



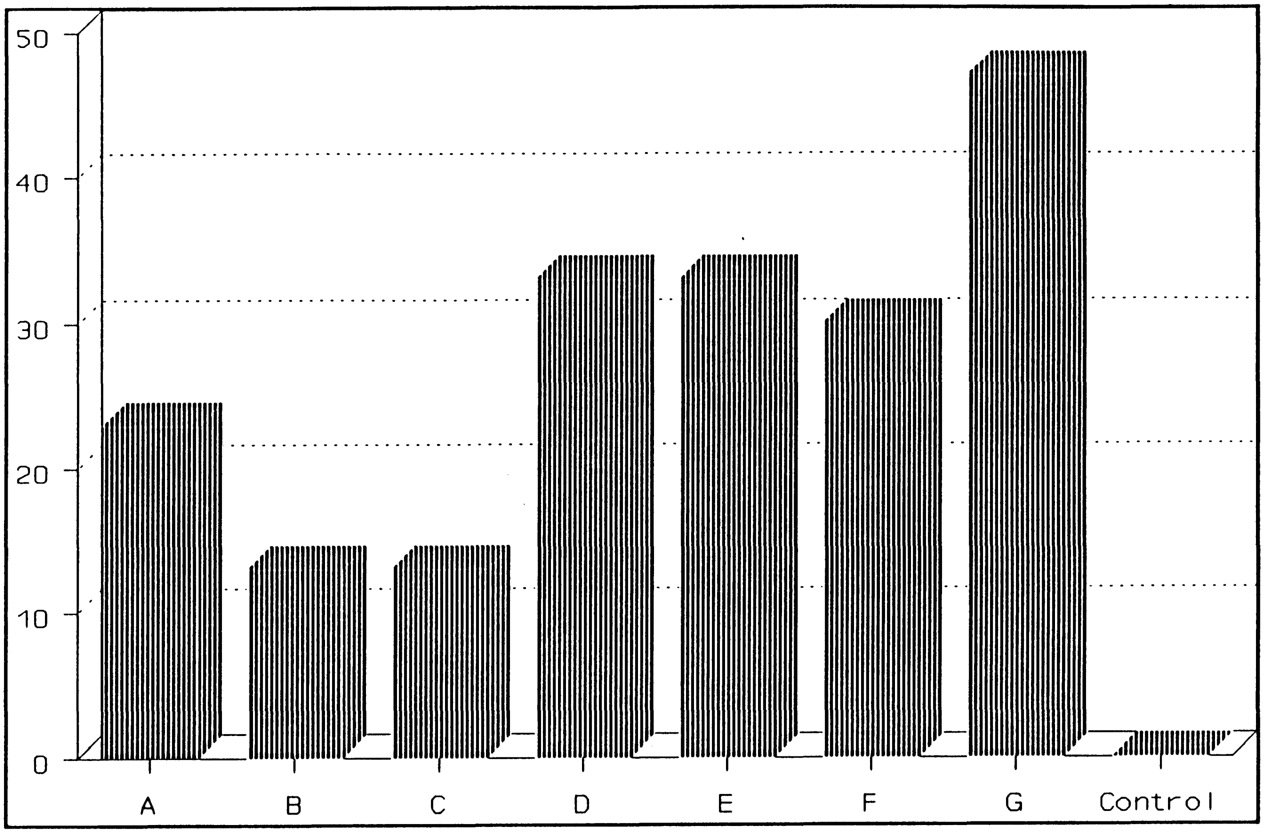
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 20. Visual study of the average percent reduction of seedhead production for turf at Coles County Airport. Data collected on 7/6/1989.



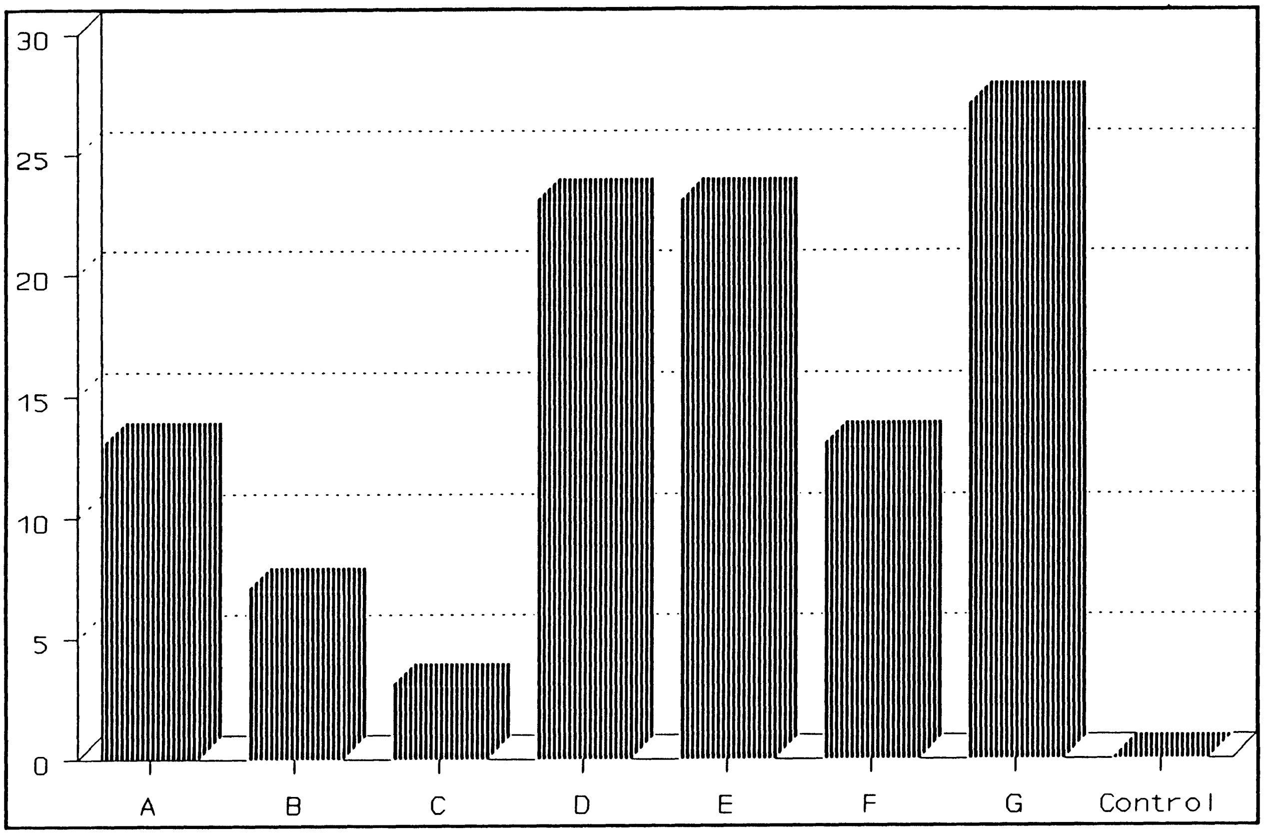
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 21. Visual study of the average percent reduction of seedhead production for turf at Coles County Airport. Data collected on 7/28/1989.



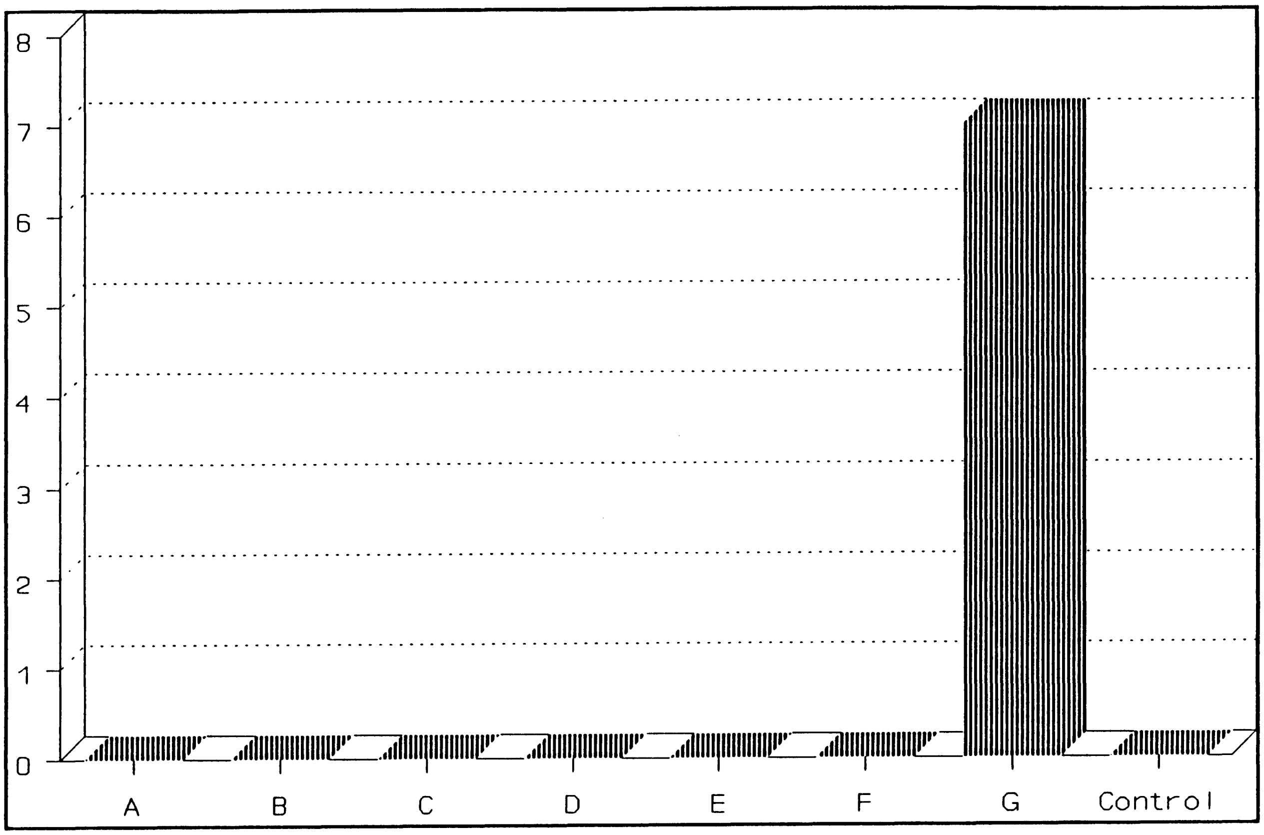
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 22. Visual study of the average percent reduction of seedhead production for turf at Coles County Airport. Data collected on 8/19/1989.



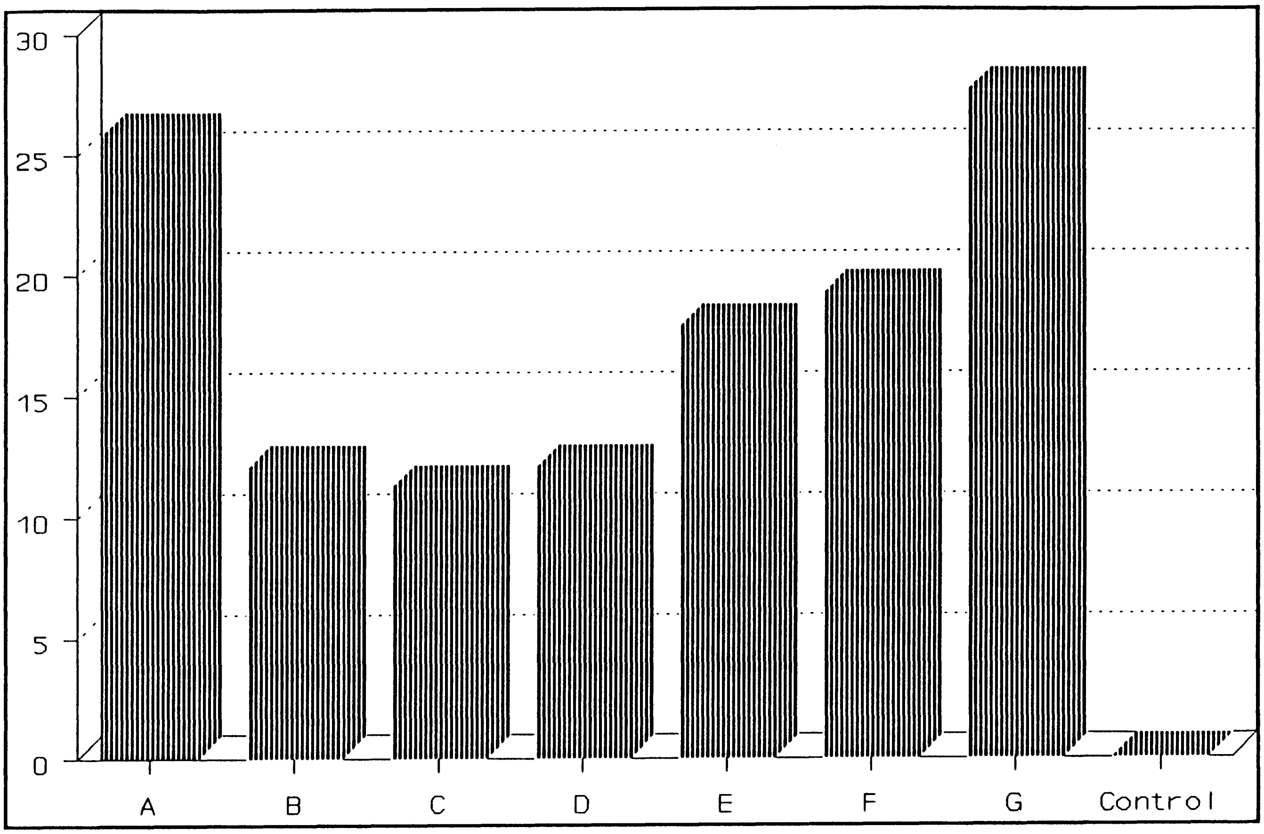
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 23. Visual study of the average percent reduction of seedhead production for turf at Coles County Airport. Data collected on 9/12/1989.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 24. Visual study of the average percent reduction of seedhead production for turf at Coles County Airport. Data collected for all sample dates.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 24 illustrates the average percent reduction of seedhead production for the entire sampling period. Treatment C was the most effective concentration with a reduction rate of 48%. Treatments D and E were at 31% and 25% respectively. Treatment B, at 39% reduction, was more effective than Treatment A at 26%. Treatments F and G were at 32% and 29% reduction rates.

The results of subjective visual studies done to determine the amount of turf injury caused by the treatments are listed in Table 9. The amount of turf injury was based on changes in turf color compared to control plots. Treatment G consistently demonstrated the highest rates of injury for all sampling dates. Figure 25 illustrates the results of sampling date 6/17 at which time no discoloration was noted.

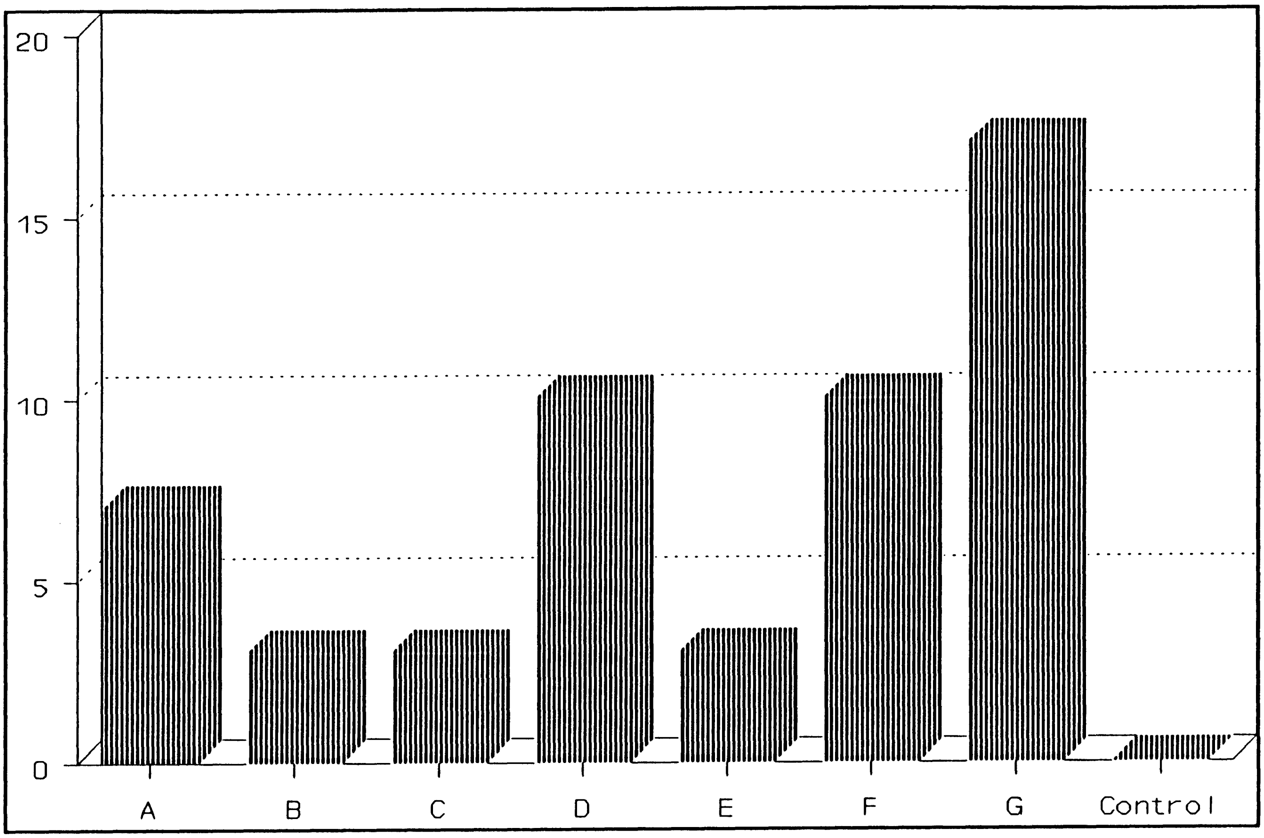
At sampling date 7/6, some discoloration was noted in all plots. Treatment G displayed significant damage for this sampling period. Figure 26 illustrates the results of sampling date 7/6. On sampling date 7/28, the discoloration had increased again for all plots and treatments A, E, F, and G displayed significant discoloration. Figure 27 illustrates the results of this sampling date. This is the only treatment to show a significant discoloration of more than one treatment for the entire sampling period. Figure 28 illustrates the results of sampling date 8/19. During this sampling period, treatment G was the single treatment to show significant discoloration.

At sampling date 9/2, all treatments showed no visible sign of injury in all plots. Figure 29 illustrates the results of sample date 9/2. Figure 30 illustrates the average discoloration for the entire sampling period.

Table 9. Visual study of the average percent reduction in turf color as a result of injury. The turf was treated with plant growth regulators. The test plots were divided into two areas; an area the turf was mowed to two inches and an area left uncut.

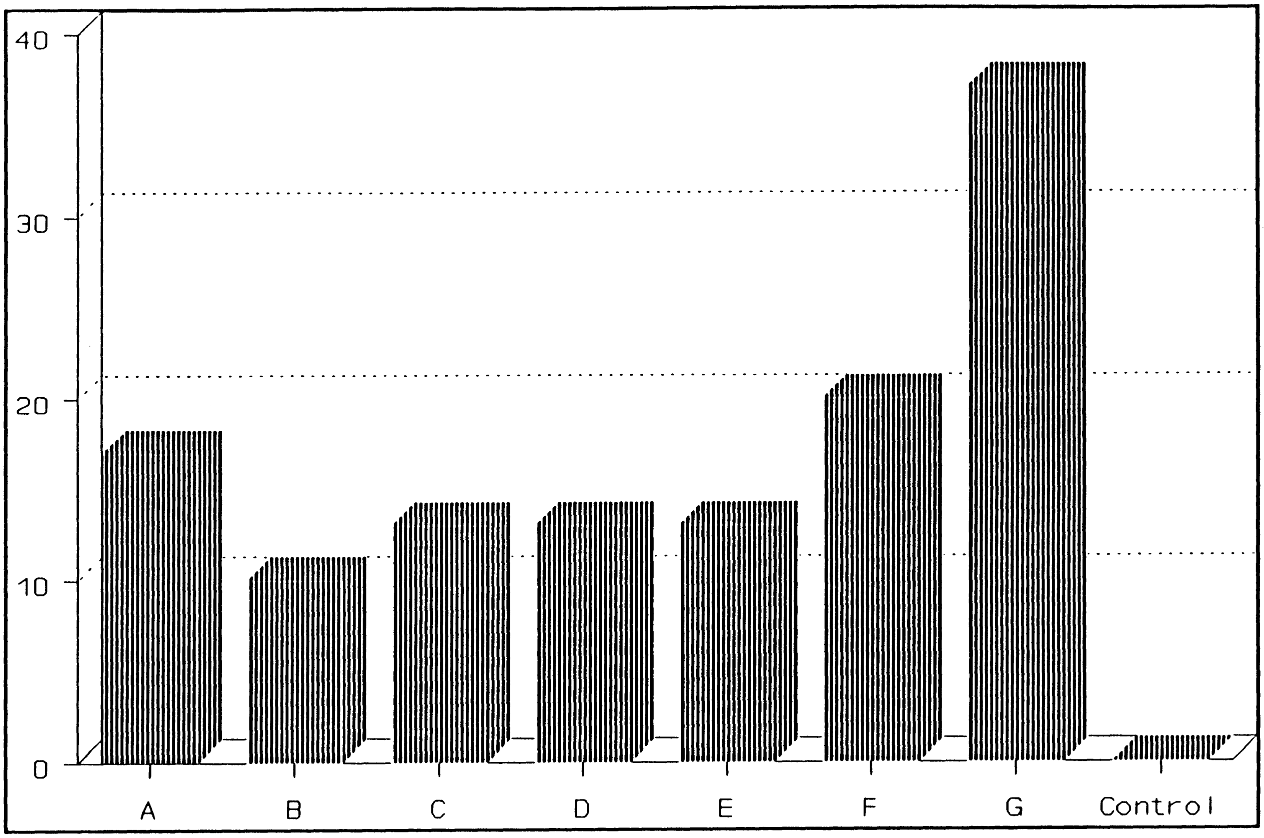
Products	6/17	7/6	7/28	8/19	9/12	Average
1/4 oz. Escort	7%	17%	23%	13%	0%	12.0%
1/2 oz. Escort	3%	10%	13%	7%	0%	6.6%
10 oz. Event	3%	13%	13%	3%	0%	6.4%
12 oz. Event	10%	13%	20%	3%	0%	9.2%
14 oz. Event	3%	13%	33%	23%	0%	14.4%
1/4 oz. Oust	10%	20%	30%	13%	3%	15.2%
1/3 oz. Escort w/ 1/4 pint Embark	17%	37%	47%	27%	7%	26.2%

Figure 25. Visual study of the average percent turf injury as exhibited by color change. The test plots were divided into two areas; an area mowed to two inches on May 14, 1988 and an area left uncut. Data collected on 6/17/1989.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 26. Visual study of the average percent turf injury as exhibited by color change. The test plots were divided into two area; an area mowed to two inches on May 14, 1989 and an area left uncut. Data collected on 7/6/1989.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 27. Visual study of the average percent turf injury as exhibited by color change. The test plots were divided into two areas; an area mowed to two inches on May 14, 1989 and an area left uncut. Data collected on 7/28/1989.

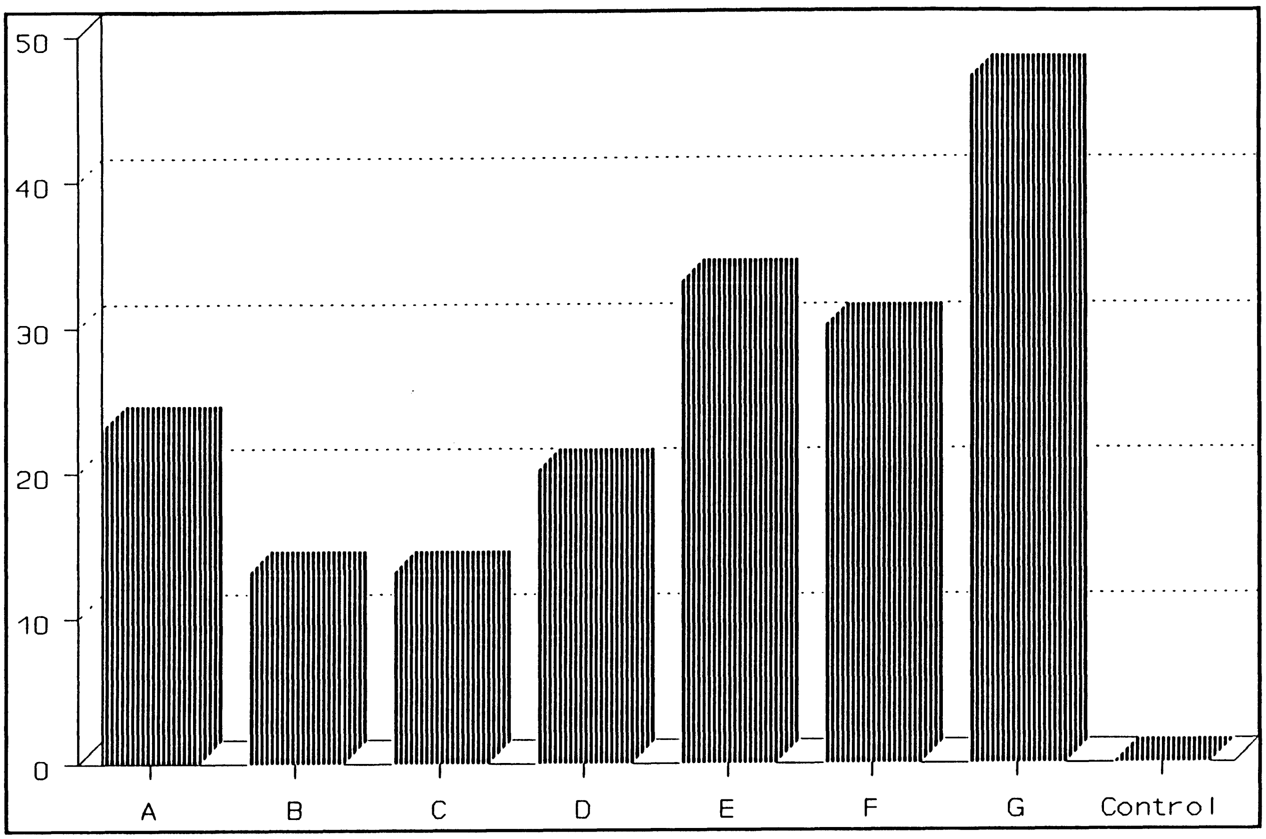
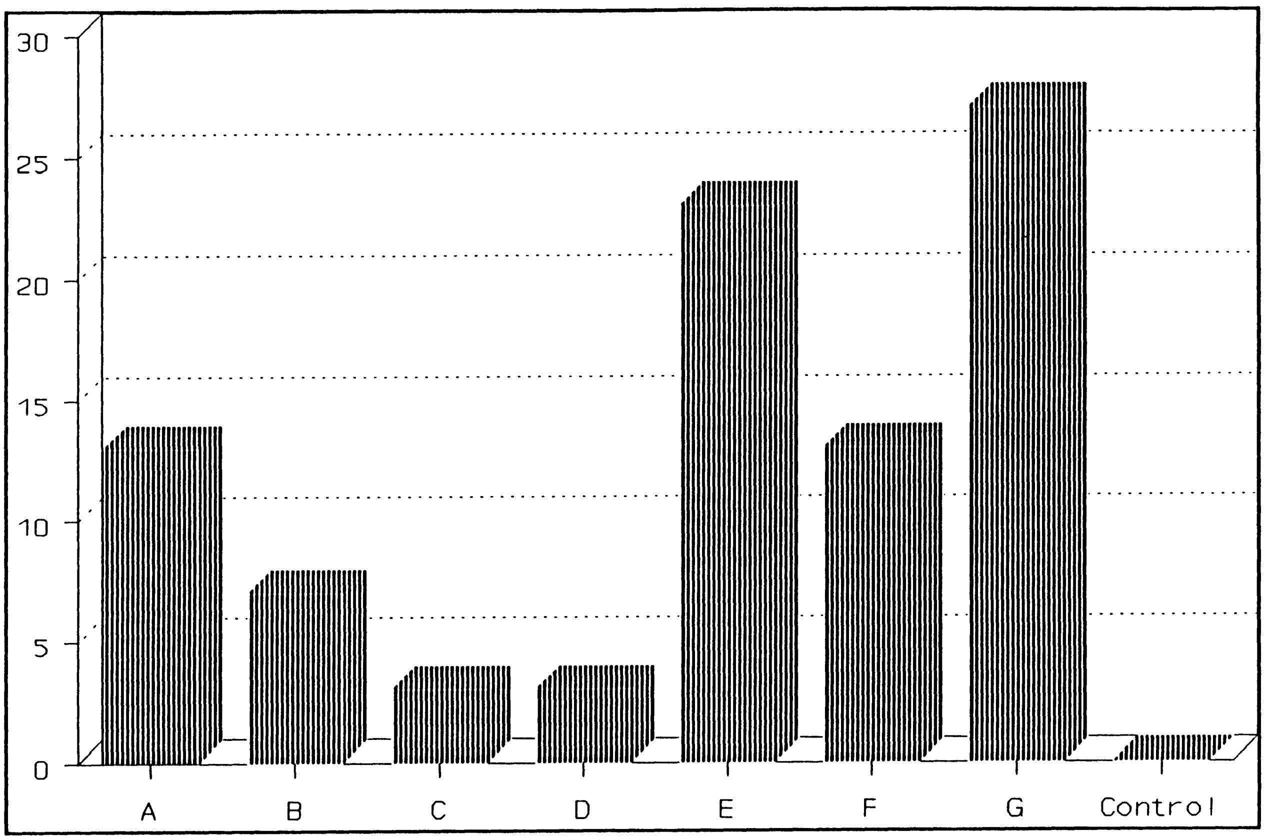


Figure 27

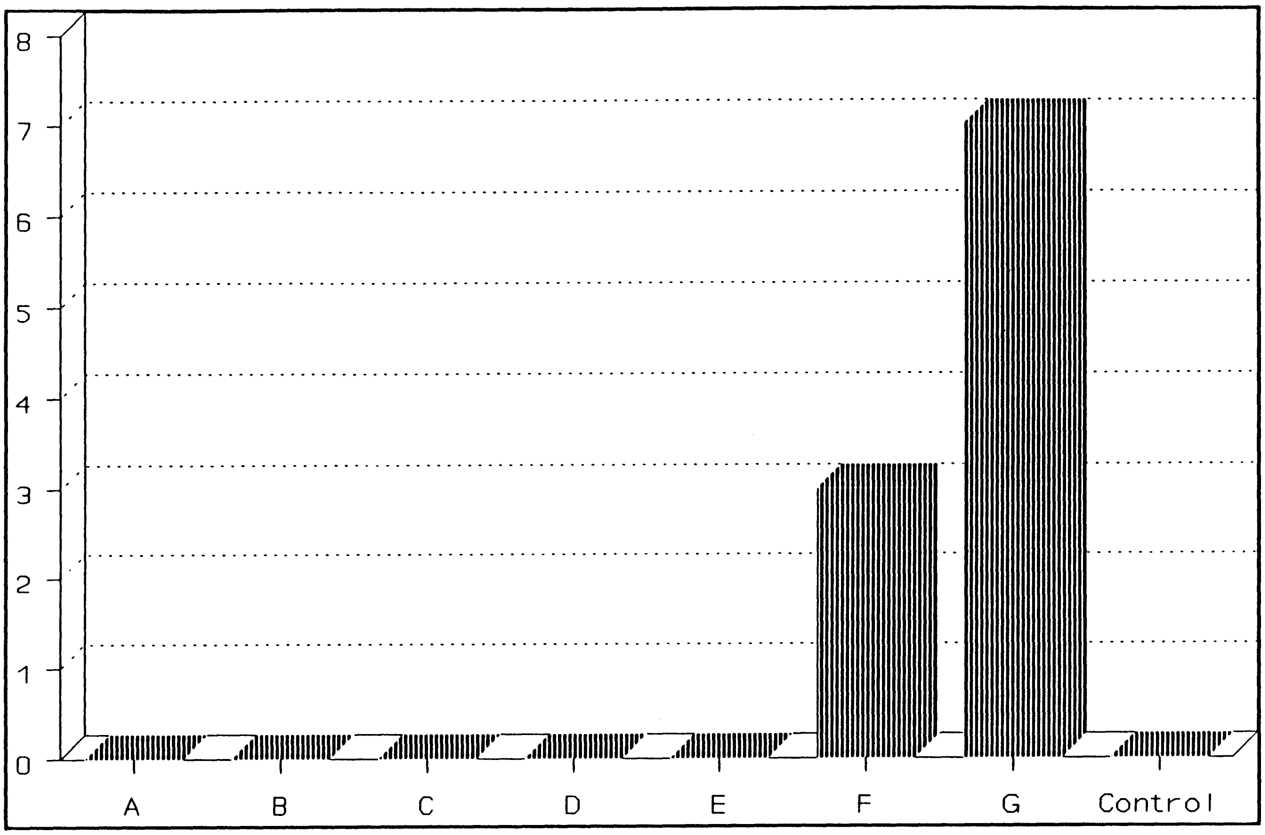
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 28. Visual study of the average percent turf injury as exhibited by color change. The test plots were divided into two areas; an area mowed to two inches on May 14, 1989 and an area left uncut. Data collected on 8/19/1989,



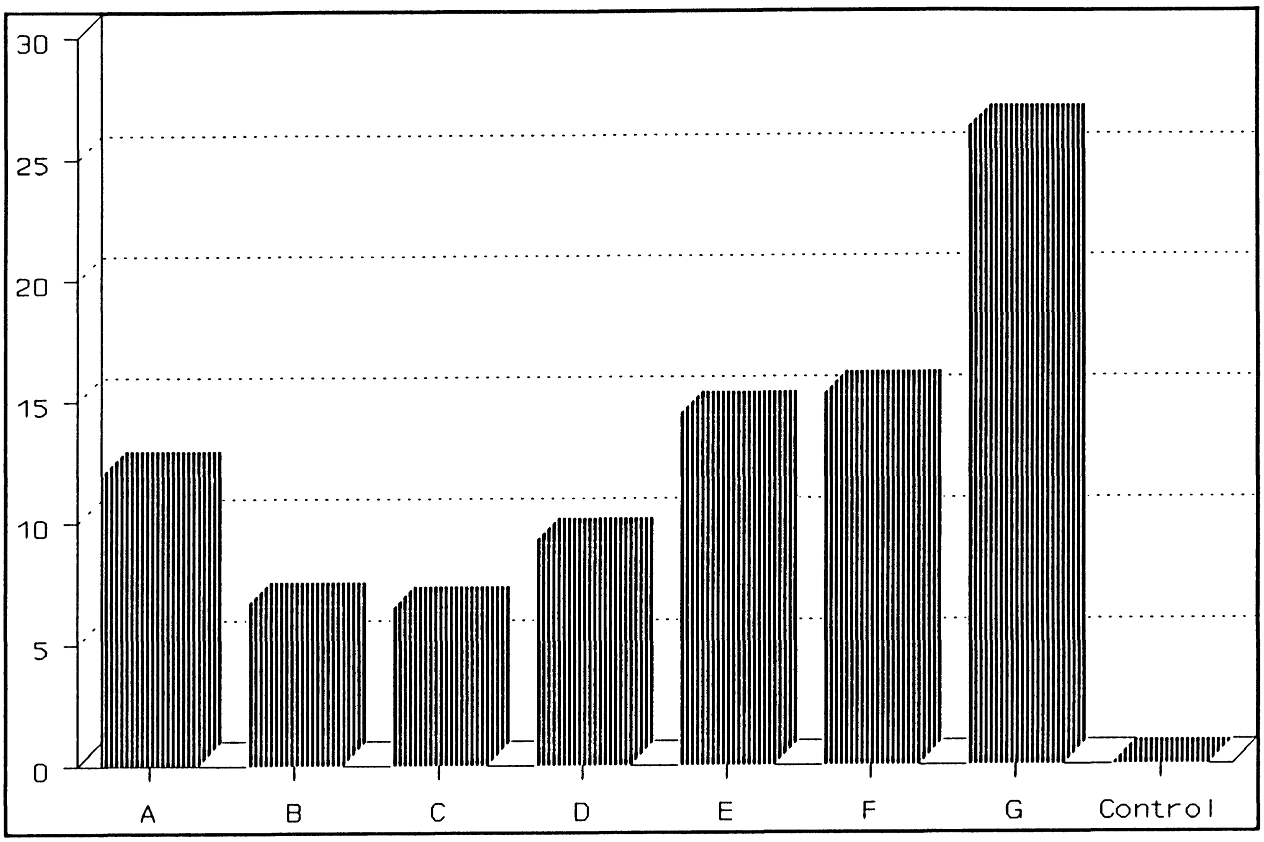
A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 29. Visual study of the average percent turf injury as exhibited by color change. The test plots were divided into two areas; an area mowed to two inches on May 14, 1989 and an area left uncut. Data collected 9/12/1989.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Figure 30. Visual study of the average percent turf injury as exhibited by color change. The test plots were divided into two areas; an area mowed to two inches on May 14, 1989 and an area left uncut. Date collected for all sample dates.



A = 1/4 oz. Escort
B = 1/2 oz. Escort
C = 10 oz. Event
D = 12 oz. Event
E = 14 oz. Event
F = 1/4 oz. Oust
G = 1/3 oz. Escort plus 1/4 pt. Embark

Summary

When considering both individual sampling dates and entire sampling periods, treatment G was consistently the most effective at reducing biomass and plant height. Treatment G was the most effective treatment for reducing biomass for every single sampling date and therefore the entire sampling period for the above mentioned parameters. This includes the height reduction of those sub-plots that were mowed and those not mowed.

Treatment B was the most effective and consistent treatment for reducing the production of seed heads. Treatment F was also very effective, but did not retain this effectiveness after the third sampling period. Treatment G was not as effective as treatment B, but it was as consistent.

Although treatment G performed extremely well, it displayed the highest rates of damage to the turf of any treatment for the entire sampling period, reducing at times the aesthetic value of the treatment below a level consistent with public use, i.e. golf courses, home, but possibly acceptable for commercial use, i.e. roadsides, ditches. Treatment F, while providing similar benefits in biomass reduction and plant height reduction, has a decreased rate of injury.

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