Chemical Mowing of A Fairway Zoysiagrass Turf (Zoysia japonica Steud.) Using New Generation of PGRs

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식물생장조절제를 이용한 들잔디의 화학적 예초관리에 관한 연구

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국문초록

식물생장조절제(Plant Growth Regulators, PGRs)를 이용한 예초관리 방법이 들잔디 엽색 및 품질에 미치는 영향을 규명함으로 잔디 적응력 관점에서 적합한 PGR 종류 및 살포수준을 파악하고자 본 연구를 시작하였다.

실험은 들잔디 생육이 왕성한 시기인 6월(실험 I)과 7월(실험 II) 2회에 걸쳐 각각 다른 장소에서 실시하였다. 공시약제 처리구는 Type I PGR인 amidochlor 3 수준 및 mefluidide 3 수준과 Type II PGR인 trinexapac-ethyl 4 수준, 그리고 무처리구를 포함하여 전체 11 처리구였고, 실험구 배치는 난괴법 4 반복으로 하였다.

공시한 3종류 PGR 모두 잔디엽색 및 품질에 통계적으로 유의한 차이가 있었지만, PGR 종류 · 살포수준 및 생육상태에 따라 처리효과는 다르게 나타났다. 잔디엽색 및 품질은 PGR 살포후 경과기간에 따라 점진적으로 억제되는 경향이었다. 처리 1주후 잔디품질은 대조구에 비해 큰 차이가 없었지만, 2주에서 4주까지는 PGR 종류 및 살포수준에 따라 유의하게 감소하여 0.08 ml/m² 이상의 trinexapac-ethyl 처리구 및 1.20 ml/m² 이상의 mefluidide 처리구는 잔디품질이 적정수준 이하로 나타났다. 실험 I, II에서 PGR 살포수준이 증가할수록 잔디품질도 이에 따라 크게 감소하였다. 3종류 PGR중 amidochlor 처리구에서 잔디품질 감소가 가장 적게 나타난 반면, mefluidide 처리구에서는 가장 크게 나타났다. 처리 4주 부터 대부분 처리구에서 잔디품질이 적정수준 이상으로 회복되기 시작하였다.

본 실험을 통해 잔디관리 수준에서 저관리 잔디지역은 0.08 ml/m² 수준의 trinexapac-ethyl 처리구가 장기간 생장억제 관점에서 실용성과 경제성 측면에서 들잔디 관리에 효율적인 것으로 판단되었고, 고관리 잔디지역은

0.04～0.08 ml/m² 수준의 trinexapac-ethyl 처리구 및 0.60～1.20 ml/m² 수준의 amidochlor 처리구가 적합한 것으로 판단되었지만, 계절에 따라 PGR 효과정도가 다르게 나타났다. 따라서, 잔디 관리시 잔디의 생육상태, 예초절감 기간, 잔디품질의 기대수준 및 적용할 수 있는 관리수준에 따라 적합한 PGR 종류 선정과 함께 살포시기 및 살포량을 효율적으로 결정하는 것이 필요한 것으로 사료되었다.

Key Words : zoysiagrass, chemical mowing, plant growth regulators(PGRs), turfgrass quality, turfgrass color

I. INTRODUCTION

A goal of turfgrass management is to produce a dense sward with reduced shoot growth(Kaufmann, 1990; Watschke *et al*., 1992). Mowing achieves this outcome, but at some cost. Mowing involves the periodic removal of turfgrass shoots, which are detrimental to turf from a botanical point. However, it is the most basic practice of turfgrass cultures, and thus must be performed to maintain top growth and sustain ornamental turfs.

Golf course turf was originally mowed by grazing sheep and other domesticated animals. That changed with the invention of the mechanical mower by Edwin Budding in 1830(Beard, 1973). Over the ensuing decades, mechanical mowing has become a fundamental practice in maintaining a quality turf. Unlike other cultural practices, mowing is largely a reactive practice. Sometimes climate and terrain can prevent a turf manager from properly reacting to turf growth. But today's PGRs allow turf managers to proactively manage turf growth. Combined with a sound mowing, they can be a valuable tool for turfgrass management even during the difficult-to-mow times, such as a rainy season, as well as in dangerous-to-mow areas, such as rocky or rough terrain(Kim, 1998; Kim and Nam, 1996).

1. PGR Uses for Turfgrass Management

PGRs were introduced in the late 1940s for application to utility turfs to reduce their mowing requirements by inhibiting vertical shoot growth. PGRs are organic compounds that regulate growth and development when applied in small amounts(DiPaola, 1988). These chemicals modify plant growth by retarding the growth, by improving flowering or by controlling plant shape(BAA, 1994). PGRs have been slowly integrated into turfgrass management strategies. Turf managers have often used PGRs, without realizing it Some herbicides and fungicides affect turf growth through hormonal activity(Danneberger and Street, 1990). The chemicals 2,4-D and 2,4-D.P are auxin-type herbicides, stimulating excessive growth of broadleaf weeds at growing points. A non-selective herbicide, glyphosate('Roundup') also has a function of growth-regulating effects on bahiagrass(*Paspalum notatum* Flugge). Certain fungicides like benomyl('Tersan 1991'), triadimefon('Bayleton'), fenarimol('Rubigan') and propiconazole('Banner') are systemic, being absorbed and translocated, and work as a PGR.

Maleic hydrazide has been used extensively in low-maintenance areas such as highway and airport runway turf for vegetation control, but its negative effects limit use on higher quality turf. Most PGRs are not routinely used on highly visible, high-maintenance turf areas because of serious side effects, including turf quality loss, foliar discoloration, and stand thinning. However, the new generation of PGRs such as trinexapac-ethyl('Primo'), flurprimidol('Cutless'), amidochlor('Limit') and paclobutrazol('Scotts TGR') have been tested or used on medium- to high-maintenance turfs. These products tend to be less phytotoxic than their predecessors, but the effectiveness may vary because of differing application rates, frequencies, and timing, as well as variety of grass species and cultivar responses(Danneberger and Street, 1990; Fermanian, 1997; Kim and Kim, 1999; Watschke *et al.*, 1992). Therefore, investigation with newer PGRs is needed before extensive use.

2. Necessity of Alternative Mowing Practice in Korea

Chemical mowing with PGRs has a great potential in Korea because of their environmental compatibility and minimal input for sustainable turfgrass management. The very tough, stiff stems and leaves of Korean lawngrass(*Zoysia japonica* Steud.) create difficulties for normal mowing practice. Also, clipping management can take as long as mowing, and still leave turf managers with a disposal problem. In a rainy season, mechanical mowing is one of the hardest tasks of turfgrass management. Mower operation should be restricted to limited use during periods of high soil moisture content to minimize turf injury, especially on the fine-textured soils. Moreover, most of the new golf courses are built on rocky or rough terrain in mountainous areas. This means that turf managers will face an even tougher mowing challenge than before, even during the non-rainy seasons. Reasons to consider PGRs for turfgrass management strategies continue to grow with increasing cost of both hand and mechanical labor for vegetation control, and rising concern about environmentally compatible management, such as reducing landscape debris of clippings in landfills. Therefore, chemical mowing is expected to be a feasible alternative that may improve turf quality, reduce labor costs and grass clippings, and relieve soil compaction in difficult-to-mow circumstances.

The primary benefit will be to reduce mowing frequency in difficult or dangerous areas and amount of grass clippings through suppression of vertical shoot growth. It was reported that mowing requirements decreased by 50% with PGRs(Fermanian, 1997; Watschke and DiPaola, 1995). Kim and Kim(1999) concluded mowing frequency reduction by 30 to 60%. Decreased growth, however, is also related to turf quality loss and discoloration. Generally, the higher the application rates, the greater the suppression intensity of vertical growth and turf quality(Kim, 1998; Kim and Kim, 1996). Accordingly, the selection of PGRs and application rate should be determined to optimize turf quality and performance as well as to maximize vertical shoot growth suppression.

PGR effects on turfgrasses have been reported extensively(Breuninger, 1993; Breuninger and Watschke, 1989; Cooper *et al.*, 1987 and 1988; Dernoeden, 1984; Dudeck and Peacock, 1985; Fermanian, 1997; Gaul and Christians, 1988; Gaussoin and Branham, 1987 and 1989; Higgins *et al.*, 1987; Johnson and Carrow, 1989, 1991, 1993 and 1994; Kageyama *et al.*, 1989; Kim 1998; Kim and Kim, 1996 and 1999; Kim *et al.*, 1997; Kim and Nam, 1996; King *et al.*, 1997; Koski, 1997; Lowe *et al.*, 1999; Pennypacker *et al.*, 1981; Qian and Engelke, 1998). However, there is not much information on the responses of zoysiagrass to PGRs. Field studies with the new generation of PGRs are even more limited under domestic climate conditions, except for a few(Kim, 1998; Kim and Kim, 1999; Kim *et al.*, 1997). This study was initiated to evaluate the influence of chemical mowing with newer PGRs on the turf quality and color of zoysiagrass and to determine a desirable PGR and its optimum application rate in terms of turf performance.

II. MATERIALS AND METHODS

Zoysiagrass color and quality were evaluated in field experiments treated with PGRs at the Turfgrass Research Facility, Samsung Everland Inc. in Gunpo, Kyounggi-Do. Experiments I and II were done at different sites and times in 1995. The experiments were conducted on zoysiagrass turf from June to September in 1995. The turf was established by sodding.

Chemical mowing treatments for Experiment I were made on June 22 at the early stage of vigorous growth of zoysiagrass. In Experiment II, we applied PGRs on July 18 at the middle stage of vigorous growth to double-check the results of Experiment I. PGRs in the study were amidochlor('Limit', Monsanto Company, St. Louis, MO, USA), mefluidide('Embark', PBI Gordon Corporation, Kansas City, KS, USA), and trinexapac-ethyl('Primo', Novartis, Greensboro, NC, USA). The experiments were comprised of 11 treatments: an untreated control(no growth regulator application), four rates of trinexapac-ethyl, 0.02('Primo' LL), 0.04('Primo' L), 0.08('Primo' M) and 0.16 mℓ/m² ('Primo' H), three rates of amidochlor, 0.30('Limit' L), 0.60('Limit' M) and 1.20 mℓ/m² ('Limit' H), and three rates of mefluidide, 0.60('Embark' L), 1.20('Embark' M) and 2.40 mℓ/m²('Embark' H). The plots were treated within two days of mowing and PGRs applied by hand sprayers capable of accurate and uniform delivery. The sealed mix tank was vigorously shaken prior to application. The amount of delivery was based on 100 mℓ/m² for all treatments. The treatments were replicated four times in a randomized complete block design in both experiments. The plot size was 2 m x 2 m for Experiment I and 2 m x 1 m for Experiment II.

Cultural practices followed a fairway maintenance program for a well-managed zoysiagrass golf turf. Mowing was done at a 20 mm height of cut before PGR treatments. Research plots were fertilized as follows each year. The schedule for Nitrogen was 2.0 g/m² in April and May, 3.5 g/m² in June, July and August. Phosphorus was applied at 5.0 g/m² in September and K at 2.5 g/m² in May, June and July. Irrigation was applied as needed to avoid wilting. Fungicides and insecticides were applied curatively.

Turfgrass color and quality were evaluated to find the ideal PGR with less phytotoxic injury and discoloration, and determine its application rate for an acceptable turf performance. Evaluation was made on a weekly basis during the study. The study was terminated eight weeks after its initiation. Turfgrass color ratings were based on a 1 to 9 visual rating scale(Skogley and Sawyer, 1992), with 1 = straw brown and 9 = dark green. Turfgrass quality ratings were also based on 1 to 9 visual rating scale, with 1 = poorest and 9 = best quality. Data were analyzed as a randomized complete block design with analysis of variance, using the General Linear Model procedures and the Statistical Analysis System(SAS Institute, 1990). Means were separated using least significant differences at the

0.05 probability level(Steel and Torrie, 1980). Color and quality ratings were compared with those of the untreated control as a contrasting value, being 100% of no suppression in turfgrass color and quality.

III. RESULTS AND DISCUSSION

1. PGR Effects on Turfgrass Quality

Zoysiagrass quality was significantly influenced by PGRs. Deterioration of turfgrass quality appeared from 1 week after treatment(WAT) in both Experiments I and II, but treatment effects were variable with PGRs, application rates, and application timing. In Experiment I turf quality was not significantly affected in most of the trinexapac-ethyl-applied plots during the first week, as compared with the untreated plots(Figure 1). Mefluidide at high rate of 2.40 mℓ/m² caused a 10% quality reduction. However, amidochlor treatments at any rate from 0.30 to 1.20 mℓ/m² increased zoysiagrass quality, which was 10% higher than the control plot's rating.

In Experiment II turf quality responses were similar to those with Experiment I, but the quality suppression was a little greater(Figure 2). As observed in Experiment I, most amidochlor-applied plots produced higher quality than plots of other PGRs, exhibiting only an 8% reduction from the control quality ratings at the highest rate of 1.20 mℓ/m². Turfgrass quality reduction, however, was 20% at the highest rates of trinexapac-ethyl(0.16 mℓ/m²) and mefluidide(2.40 mℓ/m²). PGRs can be divided as Types I and II according to how they reduce growth(Kaufmann. 1986; Watschke. 1985). Amidochlor is a root-absorbed, Type I PGR. It doesn't inhibit growth until it reaches the roots where xylem can transport it elsewhere in the plant(Danneberger and Street, 1990; Turgeon, 1996; Watschke and DiPaola, 1995). This may allow some growth to occur following application. Therefore, turf quality suppression in the amidochlor-applied plots would be delayed, compared with plots of other PGRs. This result was supported by other investigations(Kim, 1998; Kim and Kim, 1999). In studies to determine PGR effects on the vertical growth of Korean lawngrass, they found the suppression intensity of the amidochlor-applied plots was half of other PGR-treated plots.

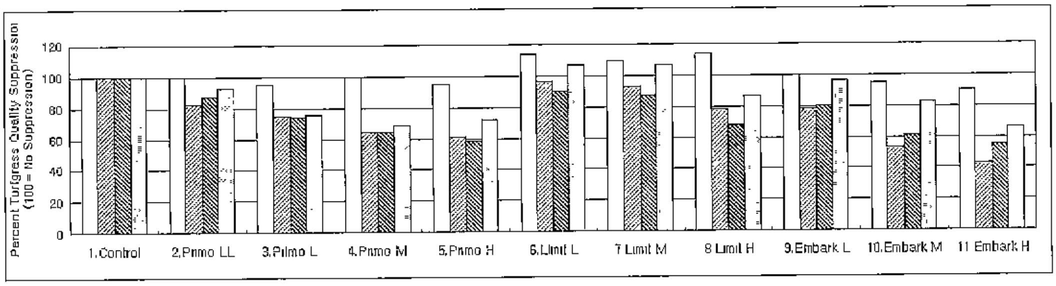

Figure 1. Influence of trenexapac-ethyl('Primo'), amidochlor('Limit'), and mefluidide ('Embark') treatments on turfgrass quality of a fairway zoysiagrass turf applied on June 22, 1995.

Legend: □: 1WAT; ▨: 2WAT, ▧: 4WAT, ■: 8WAT

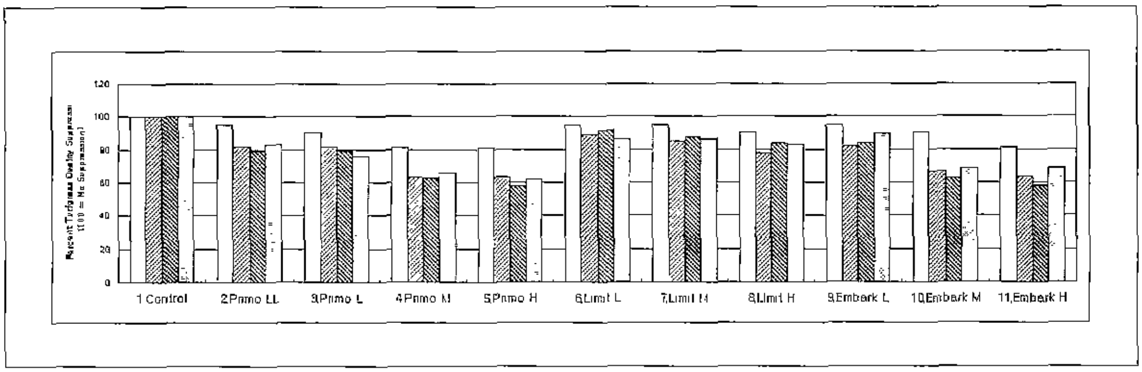

Figure 2 Influence of trenexapac-ethyl('Primo'), amidochlor('Limit'), and mefluidide ('Embark') treatments on turfgrass quality of a fairway zoysiagrass turf applied on July 18, 1995.

Legend: □: 1WAT; ▨: 2WAT, ▧: 4WAT; ■: 8WAT

Turfgrass quality was progressively suppressed over time after PGR application. In 2 WAT, quality differences were more evident between PGRs and their application rates. On plots treated with trinexapac-ethyl, the quality reduction was 18 to 40% relative to its rates of 0.02 to 0.16 mℓ/m^2 in both Experiments I and II(Figures 1 and 2). Amidochlor reduced quality by 21% at the highest application rate of 1.20 mℓ/m^2 in both experiments, while the quality reduction was lower than 7% in Experiment I and 14% in Experiment II at lower rates(0.30 and 0.60 mℓ/m^2). Mefluidide treatment, however, dramatically reduced quality as application rates increased. At the lowest rate of 0.60 mℓ/m^2, turf quality was approximately 20% lower than the control's ratings in both experiments. At the highest rate of 2.40 mℓ/m^2, quality was 58% lower in Experiment I and 38% lower in Experiment II, when compared with the untreated control. Mefluidide is a Type I inhibitor, but foliarly absorbed. It can rapidly stop cell division and differentiation in meristematic areas and thus inhibit growth and development(Kaufmann, 1986; Turgeon, 1996, Watschke, 1985). Therefore, turfgrass plants in the mefluidide-treated plots were considered to be immediate in responses, compared to those treated with other PGRs. Kim and Kim(1999) reported that growth suppression began to appear three or four days earlier in the mefluidide-treated plots than in the others.

In 4 WAT the quality responses were similar to the two-week ratings. The suppression intensity of turf quality generally increased with application rates and time after application in the study. The higher the application rate, the greater the quality reduction (Figures 1 and 2). Generally, with amidochlor application, turf quality reduction was less than that of the other PGR treatments. The quality reduction at the lowest rate of 0.30 mℓ/m^2 was 10% in both experiments, while 32% and 17% reductions were observed at the highest rate of 1.20 mℓ/m^2 in Experiments I and II, respectively(Figures 1 and 2). Trinexapac-ethyl application caused 14 to 41% reduction in Experiment I and 20 to 41% reduction in Experiment II compared to the control plot's ratings, as application rates increased. Mefluidide treatments suppressed the turf quality by 20 to 44% and by 18 to 41% in Experiments I and II, respectively, depending on rates.

In the study, a value of 30% or greater in quality suppression was considered unacceptable for turf quality. In this regard, turfgrass quality was rated acceptable for 1 WAT on all plots of PGRs tested(Figures 1 and 2). But 2 to 4 WAT, zoysiagràss turf quality significantly decreased depending on treatments. Applications of trinexapac-ethyl above 0.08 mℓ/㎡ and mefluidide above 1.20 mℓ/㎡ were unacceptable from a standpoint of turfgrass quality. However, amidochlor applied at any rate tested, trinexapac-ethyl at less than 0.08 mℓ/㎡, and mefluidide at 0.60 mℓ/㎡ all preserved acceptable turf quality.

After 4 WAT, turfgrass quality progressively began improving to acceptable levels in most of the plots treated with PGRs. In Experiment I, by 8 WAT, all plots produced acceptable turfgrass quality except mefluidide-treated ones receiving the highest rate of 2.40 mℓ/㎡, where the quality was rated at 64% of the control(Figure 1). At the two lower rates of mefluidide of 0.60 and 1.20 mℓ/㎡, the quality was 96% and 82%, respectively. On the trinexapac-ethyl-treated plots, turf quality increased to 92% at the lowest rate of 0.02 mℓ/㎡, and 72% at the highest rate of 0.16 mℓ/㎡(Figure 1). With amidochlor application, turf quality improved by 84% at the highest rate of 1.20 mℓ/㎡. At the two lower rates of 0.30 to 0.60 mℓ/㎡, however, the quality was approximately 7% higher than the control plot's ratings.

Similar responses were found in Experiment II, but the intensity of turf quality recovery was less, compared with that of Experiment I. In 8 WAT, trinexapac-ethyl-applied plots produced 82% of the control plot's ratings at 0.02 mℓ/㎡ and 77% at 0.04 mℓ/㎡(Figure 2). Unlike the data of Experiment I, however, turf quality was unacceptable at rate exceeding 0.04 mℓ/㎡. Amidochlor application produced better quality over the other PGRs, being around 85% of the control ratings at all rates. Mefluidide at the lowest rate of 0.60 mℓ/㎡ increased the quality to 90%, but turf quality at medium to high rates(1.20 to 2.40 mℓ/㎡) was not acceptable, which rated only 69% of the control plot's quality.

2. PGR Effects on Turfgrass Color

Significant treatment differences on zoysiagrass color were observed, but the period and intensity of discoloration varied with PGRs, application rates and application timing. In Experiment I treated on June 22, 1995, zoysiagrass discoloration did not occur during the first week, with the exception of the mefluidide-treated turf. Turfgrass color decreased by 5% in mefluidide-treated plots at all rates tested(Figure 3). As discussed earlier, the mefluidide application inhibited growth and development in immediate response(Kaufmann, 1986; Turgeon, 1996; Watschke, 1985), and thus was considered highly prone to deteriorate zoysiagrass color. Turf managers should be aware of the risk of foliar discoloration in the application of mefluidide on zoysiagrass turf.

PGR effects on zoysiagrass color were more evident in 2 WAT. Compared to the control plots, trinexapac-ethyl-treated plots produced color ratings of 96 to 88% as application rates increased from 0.02 to 0.16 mℓ/㎡(Figure 3). Amidochlor at the highest rate of 1.20 mℓ/㎡ caused an 8% color suppression, but only 4% at two lower rates(0.30 and 0.60 mℓ/㎡). Mefluidide reduced color ratings more with higher application rates. At the lowest rate of 0.60 mℓ/㎡, the rating of turf color was 4% lower than the control, but 20% lower at the highest rate of 2.40 mℓ/㎡.

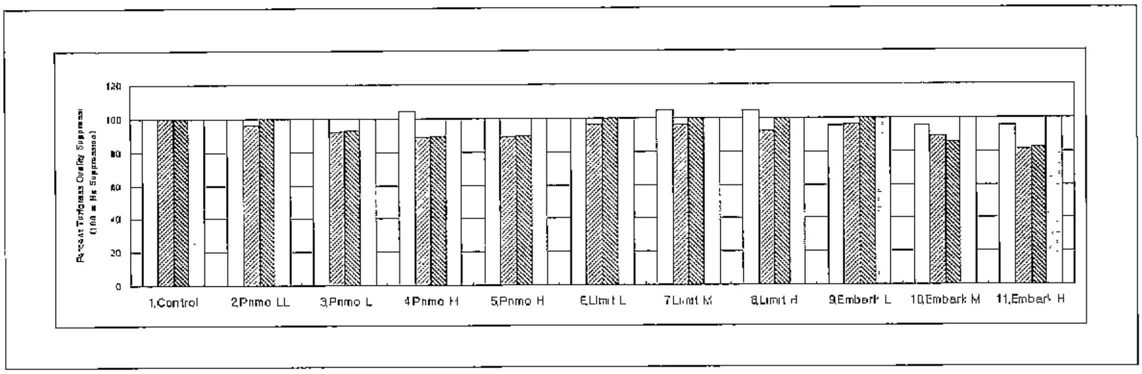

Figure 3. Influence of trenexapac-ethyl('Primo'), amidochlor('Limit'), and mefluidide('Embark') treatments on turfgrass color of a fairway zoysiagrass turf applied on June 22, 1995

Legend: □: 1WAT; ▨ 2WAT; ▧ 4WAT, ■: 8WAT

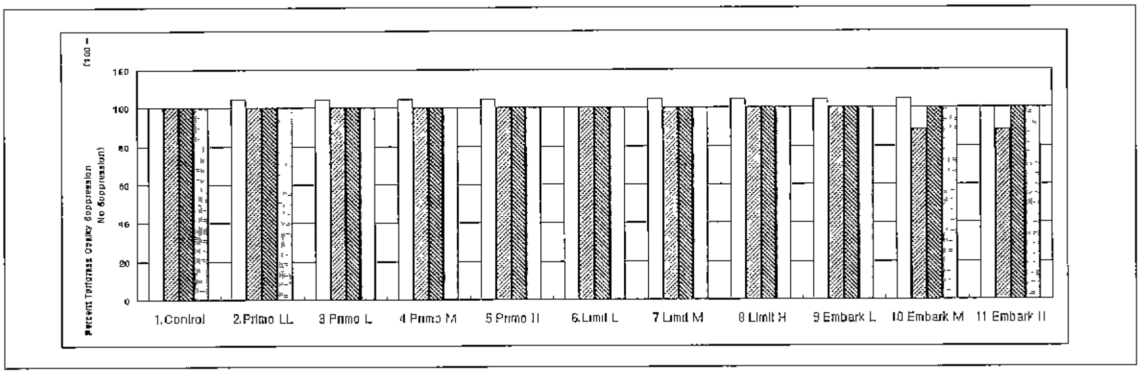

Figure 4. Influence of trenexapac-ethyl('Primo'), amidochlor('Limit'), and mefluidide('Embark') treatments on turfgrass color of a fairway zoysiagrass turf applied on July 18, 1995

Legend: □: 1WAT, ▨ 2WAT; ▧: 4WAT, ■: 8WAT

In 4 WAT, responses similar to the two-week ratings were observed, but they progressively increased(Figure 3). After 4 WAT, zoysiagrass color began to recover, but plots treated with mefluidide of 1.20 to 2.40 mℓ/m² produced significantly poorer turf color than the untreated turf until 5 WAT. However, differences were not found by 8 WAT among the treatments(Figure 3).

In Experiment II treated on July 18, 1995, discoloration was observed earlier than in Experiment I. In 2 WAT significant differences were found only with the mefluidide-treated plots exceeding the medium rate of 1.20 mℓ/m², being 11% suppression of the control plot's ratings(Figure 4). After 2 WAT, however, there were no significant differences in any plot treated with PGRs.

For all the PGRs tested, greater intensity of color suppression was observed in Experiment I than in Experiment II. We considered that seasonal variation of activity and effectiveness of PGRs occurred, depending upon circumstances. Several researchers(Danneberger and Street, 1990; Fermanian, 1997; Kim and Kim, 1999;

Watschke *et al.*, 1992) suggested that weather conditions influenced activity. Turf injury, ineffectiveness, or other unintended consequences may also result because of management and cultural practices such as fertility level, moisture availability, plant vigor, height and frequency of mowing and so on. Kim(1998) reported that seasonal variation of the effectiveness of PGRs was found in zoysiagrass turf. Zoysiagrass has an optimum growth temperature of 27 to 35°(Beard, 1973), and consequently can grow more vigorously in July than in June in Korea. Therefore, it was considered that seasonal variation of responses to PGRs was associated with difference in plant vigor according to season. These demonstrated zoysiagrass responses to PGRs might vary depending upon application timing. Turf quality loss and foliar discoloration are important factors to consider for turfgrass managers, who want to determine application rate and timing accurately. Kaufmann(1994) noted seasonal patterns of turfgrass growth must be considered in relation to proper application timing of PGRs. It was suggested the choice of PGR and its application rate be based on a defined period of mowing reduction(Kim and Kim, 1999). Climate is one of the important factors to consider for the PGR application. Thus, turf managers should determine application rate in relation with application timing.

IV. CONCLUSION

PGRs can be used effectively to make turfgrass management easier and less time consuming. Today's PGRs are an important tool for controlling turf foliar growth, but should be considered to optimize turf quality and performance, too. Zoysiagrass color and quality varied with PGRs, application rate, application timing, and time after treatment, especially after 1 WAT. Generally, the higher the application rate, the greater the suppression intensity of turf color and quality; but the inhibition period differed between PGRs. With optimum suppression of vertical growth, the intended level of turf performance must be considered, when integrating the use of PGRs for turfgrass management. In research by Kim and Kim(1999), vertical shoot growth was effectively suppressed for three to four weeks in the amidochlor-treated plots at 0.30 to 0.60 ㎖/㎡ and for eight weeks in plots of trinexapac-ethyl exceeding the rate of 0.08 ㎖/㎡ and with mefluidide at rates of 1.20 to 2.40 ㎖/㎡. However, this study showed that treatments of trinexapac-ethyl above 0.08 ㎖/㎡ and mefluidide above 1.20 ㎖/㎡ were considered to result in the unacceptable turf quality, while plots applied with amidochlor at any rate of 0.30 to 1.20 ㎖/㎡, trinexapac-ethyl at less than 0.08 ㎖/㎡, and mefluidide at 0.60 ㎖/㎡ produced acceptable turf quality.

Kaufmann(1994) concluded a crucial important step was to classify the turfs according to level of management when introducing PGRs to turfgrass cultural practice. On the low-maintenance turf such as zoysiagrass roughs, where mowing is infrequent and an expected turf quality is somewhat lower than other golf course areas, and other fringe turfs such as slopes and rocky or rough terrain that are difficult or hazardous to mow, we suggested that trinexapac-ethyl application at a medium rate of 0.08 ㎖/㎡ would be significantly and economically effective, among the products tested in regards to long-term growth suppression. On highly-maintained areas such as zoysiagrass tees and fairways, applications of trinexapac-ethyl at low to medium rates(0.04 to 0.08 $m\ell/m^2$) and amidochlor at medium to high rates (0.60 to 1.20 $m\ell/m^2$) would be a particularly effective tactic for turf managers who are trying to keep turf quality and performance as well as to reduce mowing frequency only for a short-term period. Mefluidide at all rates(0.60 to 2.40 $m\ell/m^2$), however, is not a good tactic for zoysiagrass management programs, because of extreme discoloration and significant reduction in turfgrass quality caused by chemical phytotoxicity.

Although a chemical approach will not completely replace mechanical mowing, it is potentially cost effective. Chemical mowing may be especially useful as an alternative, during periods of excessive rainfall, in areas with hazardous footing, given the increasing cost of both hand and mechanical labor for vegetation control, and increasing concern about environmentally compatible turfgrass management. This is especially true in Korea. Annual precipitation normally ranges from 1200 to 1500 mm(KMA, 1997), and more than half the rainfall occurs in late June through early August as described in Figure 5, because of the characteristics of the monsoon climate. Therefore, turf managers, used to cutting zoysia turfs every other day during this very vigorous stage of growth, have difficult-to-mow times in the rainy season and are almost unable to use mowers on tees, fairways, and roughs at the scheduled time, resulting in a poor quality of turf surface. Mower operation must be restricted during periods of high soil moisture content to minimize turf injury, especially in areas of fine-textured soils. Moreover, most of the new golf courses are built on rocky or rough terrain in mountainous areas. This means that turf managers will face a tougher mowing challenge than before, even during the non-rainy seasons.

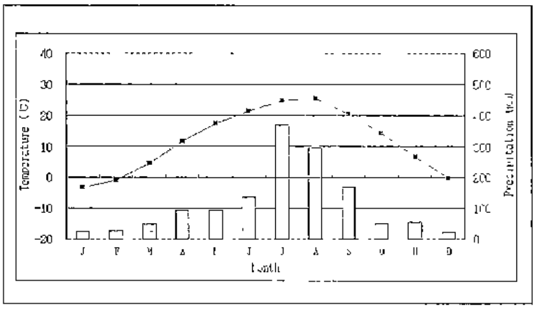

Figure 5. Mean monthly air temperature and precipitation in Seoul, Korea

Legend: ■: Precipitation, ▩: Mean Temp

Several researchers reported that PGRs could reduce mowing requirements by up to 50%(Fermanian, 1997; Watschke and DiPaola, 1995), or 60%(Kim et. al., 1997; Kim and Kim, 1999). However, an ideal PGR will reduce mowing requirements without phytotoxic injuries to turf color and quality. Accordingly, turf managers have to select an appropriate PGR and determine a proper rate and timing of application for turfgrass management, based on a defined period of mowing reduction, an intended level of turf performance, and a turfgrass culture intensity to employ. Kaufmann(1994) also suggested the intended use of the turf and the conditions at turfgrass site be concerns when considering the use of PGRs.

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