# A Life-cycle approach to the control of Poa annua in bentgrass putting greens

John Neylan
Australian Golf Course
Superintendents Association

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**TU06003**

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**HAL PROJECT TU06003 (DECEMBER 2008)**
**LIFE-CYCLE APPROACH TO *POA ANNUA* CONTROL IN BENTGRASS PUTTING GREENS**


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**DECEMBER 2008**


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**PURPOSE OF THE REPORT**
This report details the research undertaken that has examined the most effective methods for the control/suppression of the weed species *Poa annua* through the strategic application of post and pre-emergent herbicides in combination with an effective seed head suppressant. The control methods employed coincide with the key periods of the *Poa annua* life cycle. That is;

- Seed head suppressant to suppress flowering and seed production. Applied prior to flower initiation.
- Pre-emergent herbicides to kill emerging seedlings. Applied in late summer through autumn.
- Post-emergent herbicides to control established plants. Applied in spring, summer and early autumn.

The research has also identified the different *Poa annua* ecotypes in the trial area prior to applying the treatments and investigated if the herbicide treatments resulted in any changes in the *Poa annua* population. The research has also determined whether there is a difference in the sensitivity between the various *Poa annua* ecotypes to different herbicides.


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**MEDIA SUMMARY**
**PROJECT TU06003**
**LIFE-CYCLE APPROACH TO *POA ANNUA* CONTROL IN BENTGRASS PUTTING GREENS**

*Poa annua* is a ubiquitous weed species in bentgrass putting greens and is difficult to control because of its many forms. The variations in form provide herbicide resistance and a high degree of regenerative potential.

This research project has examined the most effective methods for the control/suppression of the weed species *Poa annua* through the strategic application of post and pre-emergent herbicides in combination with an effective seed head suppressant. The control methods employed coincide with the key periods of the *Poa annua* life cycle. That is;

- Seed head suppressant to suppress flowering and seed production. Applied prior to flower initiation.
- Pre-emergent herbicides to kill emerging seedlings. Applied in late summer through autumn.
- Post-emergent herbicides to control established plants. Applied in spring, summer and early autumn.

The research has identified the different *Poa annua* ecotypes in the trial area prior to applying the treatments and investigated if the herbicide treatments resulted in any changes in the *Poa annua* population. Of the *Poa annua* plants collected, seven distinct types have been identified. The *Poa annua* population varied from; a very dense, compact, fine leafed plant that has very limited lateral spread and no seed heads to a more open plant, with coarse leaves and numerous stolons that exhibit strong lateral spread and large numbers of seed heads. These characteristics make *Poa annua* a very successful weed species as it can survive by different means and under a range of conditions.

In the field trials the most effective treatment has involved a combination treatment that targets each of the key stages of the life-cycle (i.e. vegetative, seedling and flowering stages). The use of paclobutrazol (post-emergent), ethephon (seed head inhibitor) and bensulide (pre-emergent) was the most effective treatment. The herbicide field trials demonstrated a shift in the *Poa annua* population to a higher proportion of the very dense, compact, fine leafed plants that are more herbicide tolerant.

Each of the seven *Poa annua* ecotypes were propagated in glasshouse trials to determine whether there is a difference in the sensitivity between the various *Poa annua* ecotypes to different herbicides. There were significant herbicide and *Poa annua* type interactions with the dense, fine leaf types having the greatest herbicide tolerance.

This research project has provided a good insight into the variations in the *Poa annua* population and their sensitivity to different herbicide treatments and therefore the likelihood of successfully controlling it.

The key take home messages from the research and the discussions with golf course superintendents are;

1. *Get together, share and learn.*
2. *Identify the predominant Poa annua types when formulating an appropriate control strategy.*
3. *Controlling Poa annua involves controlling the circumstances that favour its presence; high moisture, weak bentgrass and compacted soils.*
4. *There are many approaches to Poa annua control and a whole of course approach must be taken.*
5. *Know your chemicals and how and when they should be applied and understand where they fit into an integrated program.*
6. *Understand and communicate the possible consequences of a Poa annua control program.*

**TECHNICAL SUMMARY**
**PROJECT TU06003**
**LIFE-CYCLE APPROACH TO *POA ANNUA* CONTROL IN BENTGRASS PUTTING GREENS**

**Nature of the problem**

*Poa annua* is an unsown component of many sportsturf areas in temperate climates and has developed effective survival strategies that allow it to persist under a range of soil, moisture and nutritional regimes. *P. annua* will withstand close mowing and as the predominant species, forms a dense turf that can provide a high quality playing surface. However, *P.annua* has a lower tolerance than other turf species to stresses such as heat, drought and diseases and under summer stress will die out and leave dead, bare and unsightly patches in mixed swards.

Most treatment methods give variable results and repeated treatments are necessary to prevent the proportion of *P.annua* from increasing. The difficulty in achieving control is due to the large seed bank of *P.annua* and the potential for year round germination and rapid seedling growth. This gives *P.annua* a competitive advantage over other species in mixed swards where the *P.annua* can colonise bare areas left by mature *P. annua* plants that have died due to chemical applications or environmental stress.

*P. annua* dominated swards can consist of numerous ecotypes from true annuals through to those that are true perennials and this further complicates any control strategy. For any *P.annua* control program to be successful both pre and post emergent control is required.

**Methodology**

Effective herbicidal control of *P.annua* requires;

1. A good understanding of the *Poa annua* ecotypes to be controlled.

2. Taking a more strategic approach by targeting different stages of the life-cycle of *Poa annua* and varying the herbicide chemistry. The strategic life-cycle approach involves the use of;
    - Seed head suppressant to suppress flowering and seed production. Applied prior to flower initiation.
    - Pre-emergent herbicides to kill emerging seedlings. Applied in late summer through autumn.
    - Post-emergent herbicides to control established plants. Applied in spring, summer and early autumn.

This project has involved three main components;

1. Sampling *Poa annua* plants from the trial area both pre and post herbicide treatment, growing the plants to their mature size and then characterising them based on plant height, flower heads, stolons, density and leaf width.

2. Propagating the seven main *Poa annua* types identified and testing their sensitivity to three herbicides used in *Poa annua* control.

3. Undertaking field trials at three locations using a combination of pre and post emergent herbicides and a flower head inhibitor.

**Research findings**

This research identified seven distinct *Poa annua* types. The *Poa annua* population varied from; a very dense, compact, fine leafed plant that has very limited lateral spread and no seed heads to a more open plant, with coarse leaves and numerous stolons that exhibit strong lateral spread and large numbers of seed heads.

In the herbicide sensitivity trials there were significant herbicide and *Poa annua* type interactions with the dense, fine leaf types having the greatest herbicide tolerance.

In the field trials the most effective treatment involved a combination treatment that targeted each of the key stages of the life-cycle. The use of paclobutrazol (post-emergent), ethephon (seed head inhibitor) and bensulide (pre-emergent) was the most effective treatment. The herbicide field trials demonstrated a shift in the *Poa annua* population to a higher proportion of the very dense, compact, fine leafed plants that are more herbicide tolerant.

**Recommendations to industry**

As a result of this research the recommendations to industry are as follows;

**New greens:** *Poa annua* control must commence from early (within the first 6 months) in the life a bentgrass putting green. The first strategy is to introduce a pre-emergent herbicide such as bensulide to prevent the establishment of *Poa annua* seedlings.

**Established greens with a small *Poa annua* population (<10 – 15%):** In older (about 5 years) more established greens where there are established *Poa annua* plants (where the population is less than 10 - 20%), the control strategy will involve the use of a combination of; a pre-emergent herbicide, a seed head inhibitor such as ethephon and post-emergent herbicides such as endothal and paclobutrazol.

**Established greens with a moderate to high *Poa annua* population (>25%):** In old greens (usually greater than 10 years) where there are established *Poa annua* plants consisting of more than 25% of the population, it is recommended to determine the predominant *Poa annua* ecotypes before embarking on a herbicide program. This would involve randomly collecting plants (at least 50) from a typical green and growing them out to a mature plant and observing there characteristics and categorising them according to table 4 and appendix 2. Understanding the make up of the population will provide valuable information on what herbicide strategy to use and the likelihood of success.

**New technology and future work**

As part of these trials the data has been provided to two companies, Greenshed P/L and Campbell Chemicals P/L to assist in the registration of ethephon in Australia. Greenshed P/L achieved registration for ethephon as Intercept® 480SL Turf Growth Regulator in late March 2009, for the suppression of *Poa annua* seedheads.

This research identified seven distinct *Poa annua* types from one particular location. Research is required in the future to determine the diversity of *Poa annua* types from putting greens of different ages in different locations. This would assist in providing golf course superintendents broad categories of likely *Poa annua* types across different locations.

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**LIFE-CYCLE APPROACH TO *POA ANNUA* CONTROL IN BENTGRASS PUTTING GREENS**
**December 2008**

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## 1. INTRODUCTION

*Poa annua* is the most written and talked about weed affecting turf and has been at the forefront of the minds of turf managers since the 1920's (Zontek, 1987). Piper and Oakley (1921) described the value of *Poa annua* as a turf for putting greens and also commented that it would be very expensive to control and that such attempts would be hard to justify. The biology, physiology and control of *P. annua* have been researched more than any other turf problem and still there are no simple effective control strategies.

*Poa annua* is an unsown component of many sportsturf areas in temperate climates, however, it also occurs in environments ranging from the sub-Antarctic to the tropics. It is one of the five most widely distributed plants in the world (Fenner, 1985) having developed effective survival strategies that allow it to persist under a range of soil, moisture and nutritional regimes. *P. annua* will withstand close mowing and as the predominant species, forms a dense turf that can provide a high quality playing surface. However, *P.annua* has a lower tolerance than other turf species to stresses such as heat, drought and diseases (Peel, 1982) and under summer stress will die out and leave dead, bare and unsightly patches in mixed swards. Gibeault (1974) described both the desirable and undesirable turf forming characteristics of *Poa annua* and these are detailed in table 1.

In creeping bentgrass golf and bowling greens, *P.annua* is undesirable due to its upright growth compared to bentgrass which may affect the speed and direction of ball roll. The colour difference between the two species also detracts from the appearance of the surface. *Poa annua* flowers prolifically at very low cutting heights and this also disrupts the quality and appearance of the playing surface. The other problem that occurs in swards with a high proportion *P.annua* is that it dies out in late spring and summer leaving dead, bare and unsightly patches. Any effort to keep the *P.annua* alive gives it a competitive edge and allows it to spread further.

*P.annua* is treated by most turf managers as a weed to be eradicated. Most treatment methods give variable results and repeated treatments are necessary to prevent the proportion of *P.annua* from increasing. The difficulty in achieving control is due to the large seed bank of *P.annua* and the potential for year round germination and rapid seedling growth (Lush 1988). This gives *P.annua* a competitive advantage over other species in mixed swards where the *P.annua* can colonise bare areas left by mature *P. annua* plants that have died due to chemical applications or environmental stress. *P. annua* dominated swards can consist of numerous ecotypes from true annuals through to those that are true perennials and this further complicates any control strategy. For any *P.annua* control program to be successful both pre and post emergent control is required (Lush, 1990).

**Table 1: Turf characteristics of *Poa annua* (Gibeault, 1974)**

| Desirable turf characteristics | Undesirable turf characteristics |
|---|---|
| • Tolerates low mowing<br>• Tolerates moist soil conditions<br>• Dense and fine textured<br>• Tolerates compacted soils<br>• Moderate shade tolerance<br>• Moderate wear tolerance<br>• Re-establishes through self seeding | • High temperature susceptibility<br>• Low drought tolerance<br>• Susceptible to numerous diseases<br>• Unsightly flower heads |

### 1.1 *Poa annua* biotypes and life cycle

To develop an effective control strategy it is important to understand the characteristics of the plant and its life cycle. *P.annua* is a very diverse grass with potentially over 50 subspecies in a given turf area (Gibeault, 1974). *Poa annua* as a species is not strictly an annual and is represented by a continuum of types ranging from annual (*Poa annua* f. annua L.) to strongly perennial (*Poa annua* f. reptans [Hauskins] T. Koyama) forms (Johnson et.al. 1993). Gibeault (1974) and Breuninger (1993) described the main characteristics of the annual and perennial forms (see table 2).

In intensively maintained turf swards, with high levels of nutrition and irrigation, the perennial form dominates. Due to the prostrate and stoloniferous growth characteristics it has the ability to spread into thin or bare areas, potentially "swamping" the more desirable grass species particularly when conditions favour *P.annua*.

**Table 2: Growth characteristics of annual and perennial biotypes of *Poa annua* (from Gibeault, 1974 and Breuninger, 1993)**

| **Growth Characteristics** | **Annual Biotype *Poa annua* var. annua L.Timm** | **Perennial Biotype *Poa annua* var. reptans (Hauskins) Timm** |
|---|---|---|
| Life Cycle | Mostly annual but sometimes biennial | Perennial |
| Growth Habit | Erect, compact bunch type growth | Low growing, spreads by prostrate stolons and tillers |
| Flowers | Panicles are open with dense seed formation | Panicles are open with sparse to moderate seed formation |
| Tiller Number | Variable. Low in spring and high in Autumn | High. Produces secondary tillers, more stable in growth |
| Rooting | Few adventitious roots | Numerous adventitious roots |
| Heat Tolerance | Intolerant of summer in the transition zone | Tolerant of summer conditions in the transition zone |
| Seed Dormancy | Will germinate after dormancy of two or more months | Can germinate within 3 days of maturity on the plant |
| Growing Location | Occurs in golf course roughs, fairways and couchgrass greens and tees | Predominantly found on bentgrass greens. Also found on irrigated fairways and tees |

In a four year study on three golf greens, Cline et. al. (1993) identified four distinctly different phenotypes, including;

1. Prolific and continuous seed producers which are relatively coarse textured.
2. A group of dense, fine-textured plants that form distinct, relatively small clones. This group produces less seed and is resistant to invasion by bentgrass.
3. A group that exhibits more cold-temperature sensitivity.
4. A group of coarse, upright "curley" textured plants with a dark blue-green colour.

Hagley et.al. (2002) sampled putting greens on four golf courses representing different soils and ages of golf course and found that the difference in ecotypes was due to age. That is, the older the golf course the higher the proportion of the perennial type plants.

The true annual form of *P.annua* germinates from seed in late summer-early autumn, growing vegetatively in winter, seeds and produces flower in spring and then seneces in summer and dies. The perennial types can flower all year round with a major pulse in the late winter and spring (Lush, 1988). There is a major period of germination in the late summer-early autumn with some germination occurring in the spring.

Lush (1990) has suggested that the main germination period could be in the spring, following flowering and seed set. At this time there is some reduction in the number of tillers of *P.annua* which creates space for the new seedlings to grow. The perennial types survive throughout the year, however, there is a decline in the number of tillers during the summer (Cline et.al 1993) and then an increase in the autumn. The work of Lush (1988) indicates that the die back may be quite large, however, the continual germination and rapid seedling growth disguises what could be a significant death rate.

The main attribute of *P.annua* that gives it such a strong competitive ability is the large seed bank it establishes. Banks of seed up to 200,000 seeds /$m^2$ are common in *P.annua* turfs (Lush, 1990) with most of this seed germinating in spring or autumn. However, some seeds remain in the soil to form a long term reserve, with up to 20,000 seeds/$m^2$ in this bank. The germination of seeds in the long term bank is often stimulated by scarifying, coring or some other damage to the surface.

### 1.2 Control of *Poa annua*

The control of *P .annua* involves both chemical and cultural techniques that have been documented in numerous articles (Breuninger,1993, Zontek,1987 and Vargus, 1990) and include a variety of chemical treatments which have been used with varying success (table 3).

**Table 3: Pre and post emergent herbicides used in the control of *Poa annua***

| Post Emergent | Pre-emergent |
|---|---|
| Endothal | Ethofumesate |
| Ethofumesate | Bensulide |
| Paclobutrazol | Pendimethalin |
| Propyzamide (ws) | Oxadiazon |
| Atrazine (ws) | Propyzamide (ws) |
| Fenarimol | Dithiopyr |
| Simazine (ws) | |
| Glyphosate (ws) | |
| Tribunil | |
| Trifloxysulfuron (ws) | |
| Rimsulfuron (ws) | |

WS = warm season grasses only

The control of *P.annua* in warm season grasses using herbicides is significantly easier than controlling it in bentgrass golf greens. This is due in part to the efficacy of the chemicals, the increased herbicide tolerance of warm season grasses and the type of *P.annua* which is more likely to be of the true annual type particularly in fairway situations. It is also more difficult to control a cool-season grass species (*Poa annua*) in another cool-season grass species (*Agrostis* spp.).

The perennial types of *Poa annua* in greens are very difficult to kill and the response of many turf managers has been to increase the rates and frequency of herbicide application. The important ramifications of such a program are the development of strongly herbicide resistant strains of *P.annua* that are increasingly more difficult to kill.

Differential herbicide response on *P.annua* has been recorded for endothal (McMaugh, 1970) and atrazine (Ducruet and Gasquez, 1978). Gasquez and Darmency (1983) reported the presence of a new triazine resistant *P.annua* biotype which was distinguished by differences in the structure of the chloroplasts. The activity of the chloroplasts of resistant weeds could only be inhibited by rates of atrazine nearly 1000-fold higher than those required to inhibit susceptible chloroplasts. In field trials and on golf courses, this increase in atrazine resistance has been consistently observed. Neylan (1987) reported 83% control of *P.annua* with atrazine at 0.5 kg ai ha in year 1, with the denser, more prostrate type unaffected. However, in year 2 almost no control was obtained at rates less than 1.0 kg ai/lha. This result was due to the shift in the *P.annua* population from coarse, erect and open annual types to highly tillered, dense and finer perennial types. In some golf course situations atrazine is now ineffective after several years of regular use.

In recent years there has been strong field evidence that there is now a strain of *P.annua* resistant to propyzamide. This has occurred on sites where propyzamide has been used for several years and is cause for concern as this herbicide has been consistently the most effective and safest to use on couchgrass (*Cynodon* spp.).

Effective herbicidal control of *P.annua* in the future will require taking a more strategic approach by targeting different stages of the life-cycle of *Poa annua* and varying the herbicide chemistry. The strategic life-cycle approach involves the use of;

- Post emergent herbicides to control mature plants.
- Pre-emergent herbicides to reduce the numbers of new seedlings.
- Seed head inhibitors to reduce flower head production.

The use of maintenance practices that encourage the desirable species and give them a competitive advantage is essential. Maintaining a dense turf reduces the number of spaces in which *P.annua* seedlings can colonise and this often runs contrary to *P.annua* control programs involving low fertility that often results in an open turf. Several of the new bentgrass varieties have excellent density and provide fewer sites for *P.annua* invasion compared to older varieties such as ‘Penncross'. Turf subjected to high wear is a prime candidate for *P.annua* invasion and a balance must be achieved between ensuring adequate nutrition to give good turf recovery and the downside of stimulating the *P annua*. This is particularly a problem during the winter months when recovery is slow and *P.annua* is at its most competitive.

### 1.3 *Poa annua* control in creeping bentgrass (*Agrostis stolonifera*)

The control of *P.annua* in bentgrass putting and bowling greens has and will continue to be a challenge. There are various herbicide treatments, however, many are either ineffective or damage the desired species. Trials undertaken by Neylan et.al. (1997) demonstrated that paclobutrazol alone and in combination with the pre-emergent bensulide provided effective suppression of *P.annua*. Endothal in combination with bensulide provided significantly improved *P.annua* suppression compared to the endothal alone. Bensulide is an effective pre-emergent herbicide but it can cause a suppression in new root initiation (McMaugh,1970 and Neylan, et.al. 1997).

Kageyama et al. (1989) demonstrated that paclobutrazol was effective in suppressing *P.annua* in a creeping bentgrass sward while Johnson and Murphy (1995) concluded that paclobutrazol was not highly effective, however, properly timed multiple applications reduced *P.annua* sp. reptans ground coverage in creeping bentgrass.

Ethofumesate can provide good *P.annua* suppression (Adams, 1989 and Lewis and Dipaola 1989), however, multiple applications can result in a reduction in turf quality (Neylan, et.al. 1997).

Post-emergent control can be very difficult due to the different ecotypes of *Poa annua* that occur which have varying susceptibility to the available herbicides. Consequently, in an effort to achieve effective control it will often damage the bentgrass and disrupt the playing surface.

Once *Poa annua* is established in bentgrass it is very difficult to eradicate and it is preferred to prevent the germination of seeds and to prevent the flowering and seed set so as to reduce the seed bank.

The other challenge in achieving effective control/suppression is that repeated applications of the same herbicides will result in the selection of resistant plants. As herbicides become less effective there is a tendency to apply the herbicide at higher rates, which in turn confers stronger selection pressure. Anecdotal evidence suggests that there is a selection towards a more herbicide resistant perennial form of *Poa annua* and a study in Mississippi has isolated several triazine resistant ecotypes (Kelly, et.al. 1999). Once these resistant forms dominate the sward, further herbicide applications are generally ineffective and control can only be achieved through fumigation and reseeding with bentgrass.

There have been many *Poa annua* control trials undertaken over many years, however, none of these have taken a strategic or a multifaceted approach to control and suppression. Most trials have only examined 1 - 2 herbicides applied at different rates and generally concentrated on post-emergent control with some limited use of pre-emergent herbicides. Gelernter and Stowell (2001) described the use of the seed inhibitor ethephon, which can be used to suppress seed production and therefore reduce additions to the seed bank.

### 1.4 Trial objectives

The objectives of this project were;

i. To provide more effective control/suppression through the strategic application of post and pre-emergent herbicides in combination with an effective seed head suppressant that coincides with the key periods of the life cycle. That is;

- Seed head suppressant to suppress flowering and seed production. Applied prior to flower initiation.
- Pre-emergent herbicides to kill emerging seedlings. Applied in late summer through autumn.
- Post-emergent herbicides to control established plants. Applied in spring, summer and early autumn.

ii. To identify the number of *Poa annua* ecotypes in the trial area prior to applying the treatments and to determine if the treatments result in a change in the population.

iii. To determine whether there is a difference in the sensitivity to different herbicides used to control *Poa annua* between the different ecotypes.

## 2. MATERIALS AND METHODS

### 2.1 Identification of *Poa annua* ecotypes

At the Commonwealth GC site only, in order to identify the *Poa annua* ecotypes present, single plants were collected using a 9 mm diameter core sampler. The individual cores were established in a 100 mm pot and allowed to grow to their full size. Once the plants obtained their maximum size they were then characterised by morphological characteristics such as presence/absence of stolons, flower heads, height of mature plant and tiller number.

Prior to the treatments commencing, five *Poa annua* plants were collected at random from each individual plot with a total of 160 plants collected.

At the end of the trial period, 10 *Poa annua* plants were collected from each individual plot with a total of 320 plants collected.

The mature plants were assessed for the following characteristics;

- Maximum plant diameter
- Presence/absence of flower heads
- No. of flower heads
- No. stolons
- Plant density
- Visual leaf width

### 2.2 Herbicide control field studies

Field trials were undertaken at three sites to evaluate the effects of various herbicides and combinations of herbicides targeting the key periods of the life-cycle of *Poa annua*. The key periods of the life-cycle being;

i. Vegetative growth: autumn through to early summer. Use of post-emergent herbicides.

ii. Flowering: late winter through to late spring and autumn. Use of seed head inhibitor.

iii. Germination and seedling establishment: Use of pre-emergent herbicides.

**Trial sites:** The trials were undertaken at three sites on bentgrass putting greens with a *Poa annua* population of 10 – 25%. Each site was maintained as a putting green and accordingly was irrigated and fertilised as required to maintain a high quality putting surface and mown at least four times a week. The sites were;

| Site | Location | Description | Climate |
|---|---|---|---|
| Commonwealth GC | Oakleigh, VIC<br>$37^0$55'45.07"S<br>$145^0$05'11.37"E | Bentgrass nursery – sand profile<br>Grass: *Agrostis stolinfera* cv 'Penncross'<br>Mowing height: 3 mm<br>Irrigation: To prevent wilt<br>Pest control: as required<br>Renovation: annual – scarifying, hollow coring and topdressing | Mean annual rainfall: 714mm<br>Mean max. summer temperature: $25^0$C<br>Mean max. winter temperature: $14^0$C<br>Mean min. winter temperature: $6.5^0$C |
| Riversdale GC | Waverley, VIC<br>$37^0$52'16.82"S<br>$145^0$07'00.85"E | Bentgrass chipping green – sand profile<br>Grass: *Agrostis stolinfera* cv 'Penncross'<br>Mowing height: 3 mm<br>Irrigation: To prevent wilt<br>Pest control: as required<br>Renovation: annual – scarifying, hollow coring and topdressing | Mean annual rainfall: 865mm<br>Mean max. summer temperature: $25^0$C<br>Mean max. winter temperature: $13.5^0$C<br>Mean min. winter temperature: $6.0^0$C |
| Bonnie Doon GC | Pagewood, NSW<br>$33^0$56'14.60"S<br>$151^0$13'28.15"E | Bentgrass putting green – sand profile<br>Grass: *Agrostis stolinfera* cv 'Penncross'<br>Mowing height: 3 mm<br>Irrigation: To prevent wilt<br>Pest control: as required<br>Renovation: annual – scarifying, hollow coring and topdressing | Mean annual rainfall: 1085mm<br>Mean max. summer temperature: $26^0$C<br>Mean max. winter temperature: $17.0^0$C<br>Mean min. winter temperature: $7.8^0$C |

**2.2.1 Herbicide treatments at Commonwealth GC and Bonnie Doon GC:** The following herbicides were applied at both sites;

Pre-emergent
- Bensulide (B) as Exporsan™(a.i. 500 g/L) at 30L product/ha
- Dithiopyr (D) as Dimension™(a.i. 120 g/L) at 2L product/ha

Post-emergent
- Paclobutrazol (P) as Shortstop™ (a.i. 200 g/L)
  - P1 at 0.5 – 1.0L product/ha
  - P2 at 2L product/ha
- Endothal (En) as Poacheck™(a.i. 175 g/L) at 1.5L product/ha

Seed head suppressant
- Ethephon (Et) as Ethrel™(a.i. 480 g/L) at 8L product/ha

The treatments were applied using a calibrated gas powered, small plot sprayer and the application dates are detailed in appendix 1a and 1b.

The herbicide treatments and combinations applied were as follows;

| Treatment | Description |
|---|---|
| 1 | Monthly applications of Paclobutrazol (1L product/ha) |
| 2 | Autumn and spring applications of Paclobutrazol (2L product/ha)+ autumn applications of Dithiopyr (2L product/ha) |
| 3 | Autumn and spring applications of Paclobutrazol (2L product/ha)+ autumn applications of Bensulide (30L product/ha) |
| 4 | Autumn and spring applications of Paclobutrazol (2L product/ha)+ autumn applications of Dithiopyr (2L product/ha)with late autumn and spring applications of Ethephon (8L product/ha) |
| 5 | Autumn and spring applications of Paclobutrazol (2L product/ha) + autumn applications of Bensulide (30L product/ha) with late autumn and spring applications of Ethephon (8L product/ha) |
| 6 | Autumn and spring applications of Paclobutrazol (2L product/ha)+ autumn applications of Bensulide (30L product/ha) with late autumn and spring applications of Ethephon (8L product/ha) plus Endothal (1.5L product/ha) in January each year |
| 7 | Autumn and spring applications of Endothal (1.5L product/ha) |
| 8 | Untreated control |

### 2.2.2 Herbicide treatments at Riversdale GC

The herbicide treatments and combinations applied were as follows;

| Treatment | Description |
|---|---|
| 1 | Monthly applications of Paclobutrazol (1L product/ha) |
| 2 | Autumn and spring applications of Paclobutrazol (2.5L product/ha) |
| 3 | Monthly applications of Paclobutrazol (2.5L product/ha) + Ethephon (8L product/ha) |
| 4 | Monthly applications of Endothal (1.5L product/ha) |
| 5 | Weekly applications of Endothal (1.5L product/ha) – 3 applications |
| 6 | Monthly applications of Ethephon (8L product/ha) |
| 7 | Untreated control |

The treatments were applied using a calibrated gas powered, small plot sprayer and the application dates are detailed in appendix 1c.

**Trial layout and assessments:** The trials were set up as a randomized block design with four replicates and analysed using the Minitab statistical program. Each plot was 2 m x 1.5 m (3 $m^2$).

Assessments were undertaken as follows;

i. **% *Poa annua*:** The % of *Poa annua* was assessed visually and also using a one metre square grid with 100 squares. The grid was used initially where each square was assessed for the presence or the absence of a *Poa annua* plant. This method substantially overestimated the area infested with *Poa annua* and was discontinued as a method of assessment. Counts were undertaken prior to the treatments being applied and then every 3 months for the duration of the trial.

ii. **Turf quality:** The treatments were visually assessed monthly for turf quality using a 0 – 9 scale where 0 = very poor and 9 = excellent.

iii. **Turf density:** The treatments were visually assessed monthly for turf density using a 0 – 9 scale where 0 = no turf cover and 9 = very dense.

iv. **Presence of disease, insects and weeds:** The treatments were visually assessed monthly for the presence of disease, insect damage and weeds. Damage from disease and insects will be rated as a % of the plot area affected and weeds will be counted.

### 2.3 *Poa annua* ecotype tolerance to herbicides

There were 7 main ecotypes identified and each ecotype was propagated from an individual tiller from a single plant that was most representative of that ecotype to provide the replicates for the herbicide tolerance testing. The tillers were propagated in a 100 mm diameter pot and allowed to grow until it covered the surface area of the pot. There were 3 herbicide treatments and an untreated control.

The herbicides were;

- Endothal as Poacheck™(a.i. 175 g/L) at 1.5L product/ha
- Paclobutrazol as Shortstop™ (a.i. 200 g/L) at 2L product/ha
- Propizamide as Kerb™ (a.i. 500 g/L) at 2L product/ha

There were 4 replicates for each treatment (including an untreated control); there were 4 treatments x 4 replicates x 7 *Poa annua* ecotypes, giving 112 individual pots. The pots were allocated in a completely randomized designed.

The herbicide treatments were applied using a 1 L calibrated, pressurized sprayer. Each of the pots receiving that herbicide was arranged in a square pattern and the sprayer used to cover the area of pots using three passes to provide an even application.

The treatments were assessed daily for the amount of damage to the plant. They were visually assessed with 9 = no damage to 0 = all leaf tissue damaged.

The pots were initially treated and then assessed for 32 days. At 32 days a second herbicide treatment was made and the pots assessed for a further 21 days.

## 3. RESULTS

### 3.1 *Poa annua* ecotypes

#### 3.1.1 Pre-treatment *Poa annua* ecotypes

There were 160 plants collected and propagated prior to any herbicides being applied and the following key parameters were assessed;

- Plant height;
- Plant diameter;
- Presence of flowers;
- Number of flowers;
- Compactness and density.

There was a large amount of data collected and this is summarised in the following graphs (figures 1 – 5)

**Figure 1:** ***Poa annua*** **type**
**Maximum Plant Diameter (mm)**

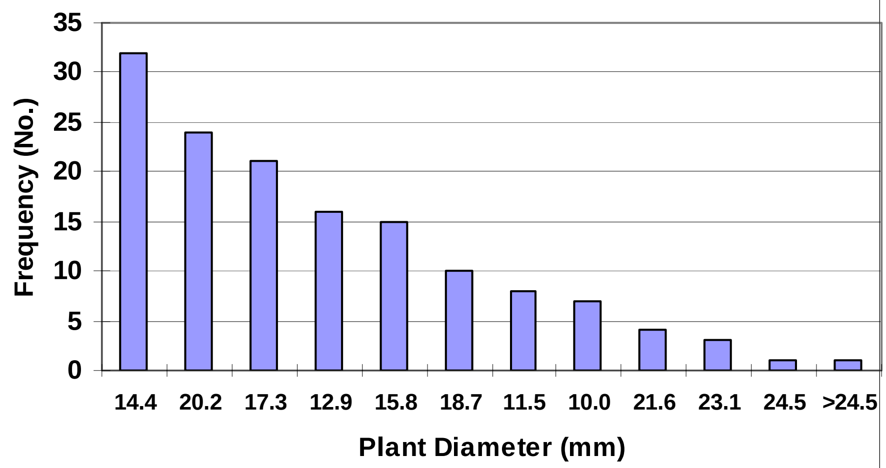
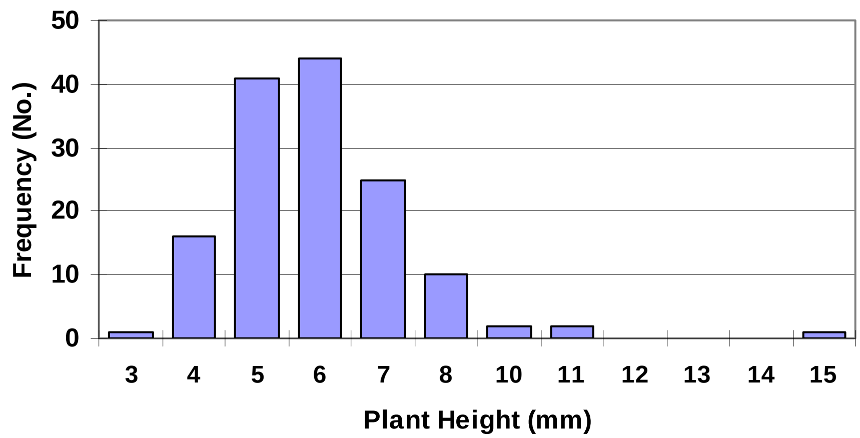
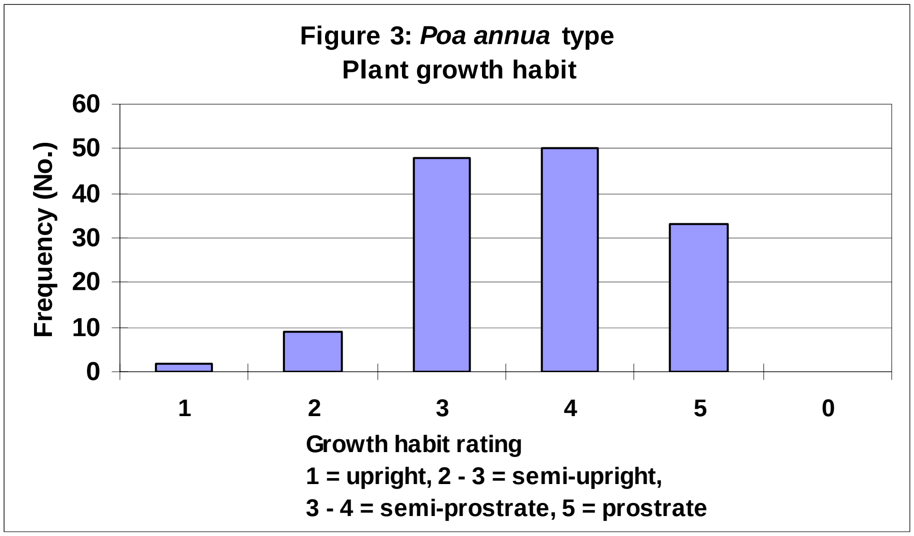
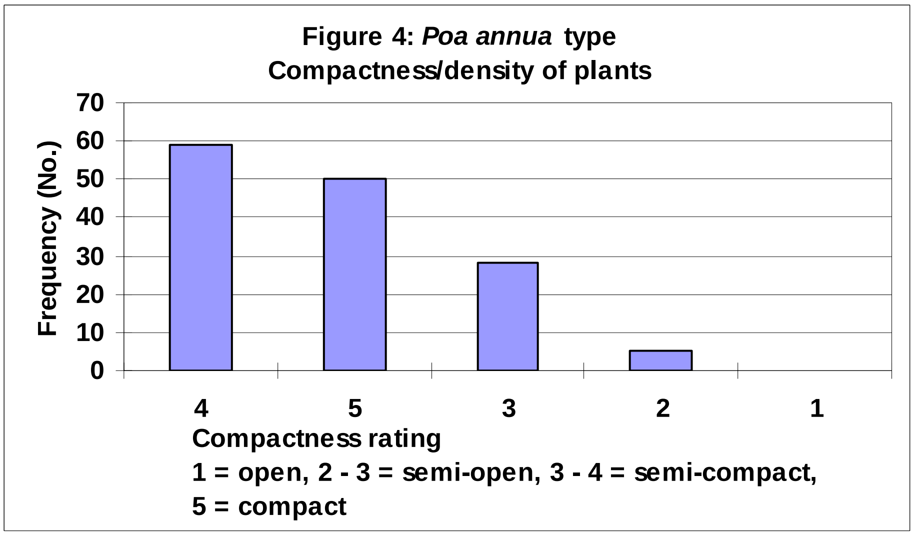
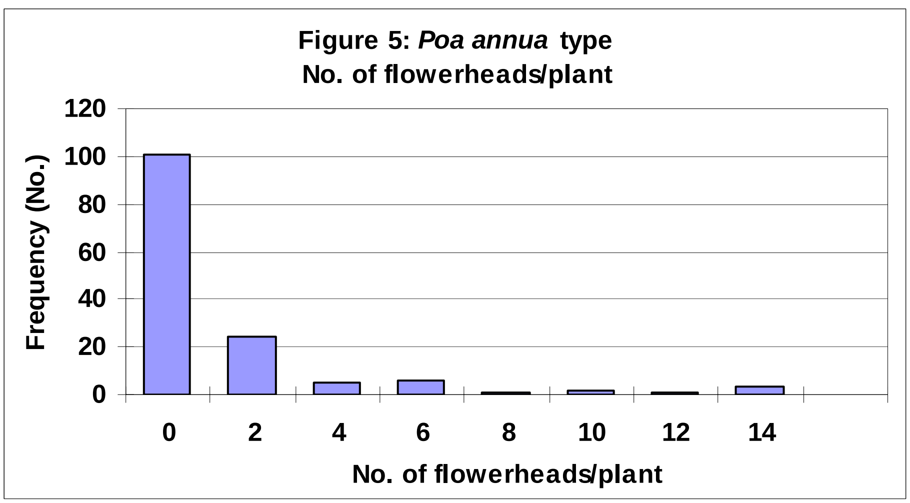



**Figure 2:** ***Poa annua*** **type**
**Maximum Plant Height (mm)**






In the collation of the data there were seven distinct *Poa annua* types identified (Table 4). The *Poa annua* population varies from a very dense, compact, fine leafed plant that has very limited lateral spread and no flower heads to a more open plant, with coarse leaves and numerous stolons that exhibit strong lateral spread and large numbers of flower heads.

Across the seven most prominent *Poa annua* types, maximum plant height for the population is normally distributed. Maximum plant height is related to type in that Type 1 and 2 plants are the shortest whereas Type 6 and 7 plants are the tallest.

Observations of the *Poa annua* types would indicate that there are variations from very dense types with little or no spread to large, coarse and aggressive space fillers. This variation provides an opportunity for *Poa annua* to colonise and persist in a variety of situations.

The majority of the *Poa annua* types are moderately dense to slightly open with coarse leaves and are strongly stoloniferous. However, there are two types with similar characteristics that are distinguished by the presence or absence of flower heads. They either have no or occasional flower heads or produce numerous flower heads which provides opportunity for *Poa annua* to colonise by spreading stolons or seed or both.

It has been noted that the categories described in table 4 hold true under ideal growing conditions, particularly as it relates to the presence of flower heads. When the plants are placed under heat or drought stress all *Poa annua* types will tend to produce at least a few flower heads.

**Table 4: Variation in *Poa annua* types collected from Commonwealth GC**

| Types | Description | % of population |
|---|---|---|
| Type 1 | Dense, tight, short plant with fine leaves and no flower heads. Short or no stolons. | 13 |
| Type 2 | Dense, tight, short plant with fine leaves and no flower heads. Medium stolon growth. | 14 |
| Type 3 | Dense, tight, short plant with fine leaves. Seed heads present. Medium stolon growth. | 6 |
| Type 4 | Dense, tight, short plant, “puffy growth” with coarse leaves. Some flower heads present. Medium stolon growth. | 3 |
| Type 5 | Moderately dense to slightly open, short plant with coarse leaves. No or occasional flower heads present. Strongly stoloniferous growth. | 24 |
| Type 6 | Moderately dense to slightly open, short plant with coarse leaves. Large number of flower heads present. Moderate stoloniferous growth. Plant die-back occurs following flowering. | 34 |
| Type 7 | Moderately dense to slightly open, short plant with coarse leaves. Large number of flower heads present. Strong stoloniferous growth. | 6 |
| Type 8 | Low density, open plant with long, broad leaves. Large number of flower heads present. Plant is very tall and spreading but produces no stolons. | |

### 3.1.2 Post-treatment *Poa annua* ecotypes

There were 320 plants collected and propagated following the field herbicide trials and the following key parameters were assessed;

- Plant height;

- Plant diameter;
- Presence of flowers;
- Number of flowers;
- Compactness and density.

In the collation of the data (table 5) there were eight distinct *Poa annua* types identified and were catagorised as detailed in table 4. The only difference compared to the pre-treatment *Poa annua* typing was the presence of a small number of annual plants identified in treatment 4.

There were significant differences in the *Poa annua* population for the various herbicide treatments/combinations and the results can be summarised as follows;

**Treatment 1:**
- There were significantly more type 2 plants compared to any other types.
- There was no significant difference in the percentage of the other plant types identified.

**Treatment 2:**
- There were significantly more type 1 plants compared to any other types.
- There was no significant difference in the percentage of the other plant types identified.

**Treatment 3:**
- There were significantly more type 1 plants compared to any other types.
- There was no significant difference in the percentage of the other plant types identified.

**Treatment 4:**
- There was no significant difference in the percentage of plant types identified.

**Treatment 5:**
- There were significantly more type 1 plants compared to any other types except for type 6 plants.
- There were significantly more type 6 plants compared to any other types except for type 2 plants.
- There was no significant difference in the percentage of the other plant types identified.

**Treatment 6:**
- There were significantly more type 1 plants compared to any other plant types.
- There was no significant difference in the percentage of the other plant types identified.

**Treatment 7:**
- There were significantly more type 1 plants compared to any other plant types.
- There was no significant difference in the percentage of the other plant types identified.

**Treatment 8 (control):**
- There were significantly more type 1 plants compared to any other plant types.
- There were significantly more type 6 plants compared to type 8 plants.
- There was no significant difference in the percentage of the other plant types identified.

**Comparison with pre-treatment population:** Compared to the pre-treatment population of *Poa annua* types there was a shift from the type 5 and 6 plants to type 1 and 2 plants. Over the period of the herbicide trials there was a substantial shift in the *Poa annua* population from the coarse leaf, more open and less dense plant types to the fine leaf, very dense and more herbicide resistant types.

The change in the population was also similar for the control, though there was a wider spread of types present compared to the herbicide treatments. The data suggests that herbicide applications will alter the make up of the *Poa annua* population with the very dense and more herbicide tolerant plants becoming the dominant types.

**Table 5: The % of different *Poa annua* ecotypes as affected by various herbicide treatments**

| *Poa annua* type | Herbicide treatments | | | | | | | | Pretreatment 2006 |
|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Control (T8) | |
| Type 1 | 18.5 | 56.5 | 57.0 | 38.8 | 49.0 | 47.3 | 63.8 | 44.3 | 13 |
| Type 2 | 50.8 | 5.0 | 11.8 | 0.0 | 10.5 | 13.0 | 18.0 | 15.5 | 14 |
| Type 3 | 2.5 | 13.8 | 11.0 | 10.3 | 2.5 | 0.0 | 0.0 | 2.8 | 6 |
| Type 4 | 0.0 | 0.0 | 0.0 | 10.5 | 0.0 | 0.0 | 0.0 | 2.8 | 3 |
| Type 5 | 2.5 | 5.5 | 8.8 | 11.0 | 0.0 | 8.0 | 5.8 | 5.5 | 24 |
| Type 6 | 12.3 | 11.0 | 5.5 | 13.8 | 33.0 | 18.3 | 10.0 | 18.5 | 34 |
| Type 7 | 13.5 | 8.5 | 6.0 | 13.8 | 5.0 | 13.3 | 2.5 | 10.3 | 6 |
| Type 8 | 0.0 | 0.0 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| **LSD** | **27.5** | **25.2** | **20.9** | **NS** | **23.1** | **25.0** | **22.1** | **18.1** | |

## 3.2 Field herbicide trials

### 3.2.1 Commonwealth Golf Club

**Visual % *Poa annua*:** The data was analysed using a two factor statistical analysis and the results are detailed in table 6. On six out of the eight assessment dates there was a significant difference in the visual percentage *Poa annua* population. The data can be summarised as follows;

**May 07:**

- All treatments had significantly less *Poa annua* compared to the untreated control.
- Treatments 2 and 5 had significantly less *Poa annua* compared to treatment 7.

**July 07:**

- Treatments 3, 4, 5 and 6 had significantly less *Poa annua* compared to the untreated control.
- Treatments 3, 5 and 6 had significantly less *Poa annua* compared to treatment 1.

**August 07:**

- Treatments 3, 4, 5 and 6 had significantly less *Poa annua* compared to the untreated control.
- Treatment 5 had significantly less *Poa annua* compared to treatment 7.

**October 07:**

- All treatments had significantly less *Poa annua* compared to the untreated control.
- Treatments 2, 3, 4, 5 and 6 had significantly less *Poa annua* compared to treatment 7.
- Treatments 3, 4, 5 and 6 had significantly less *Poa annua* compared to treatment 1.

**December 07:**

- All treatments had significantly less *Poa annua* compared to the untreated control.
- Treatments 3, 4, 5 and 6 had significantly less *Poa annua* compared to treatments 2 and 7.
- Treatments 3, 5 and 6 had significantly less *Poa annua* compared to treatment 1.

**March 08:**

- Treatments 2, 3, 4, 5 and 6 had significantly less *Poa annua* compared to treatments 7 and 8.

The results of these trials indicate that some form of chemical treatment will provide some form of *Poa annua* control as apposed to doing nothing. The combination treatments involving a post-emergent and a pre-emergent herbicide with or without the addition of the seed head inhibitor ethephon provided the best control. The autumn and spring applications of paclobutrazol at the 2 L/ha rate were more effective than the monthly applications at 1 L/ha.

**Table 6: Visual *Poa annua* assessment at Commonwealth Golf Club**

| TREATMENT | % *Poa annua* plants | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Dec-06 | Mar-07 | May-07 | Jul-07 | Aug-07 | Oct-07 | Dec-07 | Mar-08 |
| **T1** | 8.8 | 5.5 | 8.0 | 13.8 | 9.3 | 9.3 | 10.8 | 11.3 |
| **T2** | 8.8 | 5.0 | 5.5 | 13.0 | 9.8 | 5.8 | 12.3 | 8.8 |
| **T3** | 8.8 | 3.0 | 7.3 | 6.8 | 7.3 | 2.0 | 5.8 | 5.5 |
| **T4** | 6.3 | 3.5 | 8.5 | 9.3 | 8.5 | 3.3 | 7.0 | 7.5 |
| **T5** | 7.5 | 3.5 | 6.0 | 5.5 | 5.0 | 1.3 | 3.0 | 6.3 |
| **T6** | 6.3 | 2.3 | 8.5 | 6.5 | 6.5 | 2.3 | 4.3 | 5.5 |
| **T7** | 8.8 | 3.5 | 9.3 | 10.5 | 11.8 | 12.5 | 15.3 | 16.3 |
| **Control** | 10.0 | 5.0 | 16.3 | 15.5 | 15.5 | 19.3 | 25.0 | 16.3 |
| **P<0.05** | **ns** | **ns** | **3.2** | **5.1** | **6.6** | **5.5** | **4.5** | **6.9** |

**Visual turfgrass density and quality:** Turfgrass density was assessed and there was a significant difference on two of the assessment dates (table 7). At the October assessment treatments 4, 5 and 6 had a greater turf density compared to all other treatments. Treatment 3 had greater turf density compared to treatments 1, 7, and 8 and treatment 2 was greater than treatment 8.

At the December assessment treatments 5 and 6 had greater turf density compared to all other treatments except for treatment 3. Treatment 3 was significantly greater than treatment 8.

**Table 7: Visual turfgrass density at Commonwealth Golf Club**

| Treatment | Turgrass Density (0-9) | | | |
|---|---|---|---|---|
| | Jan-07 | Mar-07 | Oct-07 | Dec-07 |
| **T1** | 6.5 | 7.0 | 6.4 | 6.5 |
| **T2** | 6.8 | 6.8 | 6.9 | 6.6 |
| **T3** | 6.8 | 7.0 | 7.1 | 7.0 |
| **T4** | 6.6 | 6.9 | 7.9 | 7.3 |
| **T5** | 6.9 | 6.6 | 7.9 | 7.5 |
| **T6** | 6.9 | 6.6 | 8.0 | 7.5 |
| **T7** | 6.4 | 6.8 | 6.0 | 6.6 |
| **T8 (Control)** | 6.5 | 6.9 | 6.3 | 6.3 |
| **LSD (P<0.05)** | **ns** | **ns** | **0.6** | **0.6** |

There was no significant difference in turfgrass quality on any of the assessment dates.

### 3.2.2 Bonnie Doon Golf Club

**Visual % *Poa annua*:** The data was analysed using a two factor statistical analysis and the results are detailed in table 8. On seven out of the ten assessment dates there was a significant difference in the visual percentage *Poa annua* population. The data can be summarised as follows;

**June 07:**

- Treatment 5 had significantly less *Poa annua* compared to treatments 1, 3, 4 and 7.

**July 07:**

- Treatment 1, 4, 5, 6 and 7 had significantly less *Poa annua* compared to the untreated control.

**December 07:**

- Treatment 5 had significantly less *Poa annua* compared to treatments 1, 2, 4 and the untreated control.
- Treatments 3, 6 and 7 had significantly less *Poa annua* compared to the untreated control.

**June 08:**

- Treatment 3 had significantly less *Poa annua* compared to all treatments except treatments 1 and 6.
- Treatment 6 had significantly less *Poa annua* compared to treatments 4 and 8.

- Treatments 1, 2, 5 and 7 had significantly less *Poa annua* compared to the untreated control.

**September 08:**

- Treatment 3, 5 and 6 had significantly less *Poa annua* compared to treatments 2, 7 and 8.
- Treatments 2, 4 and 7 had significantly less *Poa annua* compared to the untreated control.

**November 08:**

- Treatment 2, 3, 4, 5 and 6 had significantly less *Poa annua* compared to treatments 7 and 8.

**Table 8: Visual *Poa annua* assessment at Bonnie Doon Golf Club**

| TREATMENT | Visual assessment % *Poa annua* plants | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Jan-07 | Feb-07 | Mar-07 | Jun-07 | Jul-07 | Dec-07 | Mar-08 | Jun-08 | Sep-08 | Nov-08 |
| **T1** | 10.8 | 16.3 | 17.5 | 56.3 | 36.3 | 30.0 | 12.5 | 18.8 | 18.8 | 15.0 |
| **T2** | 10.8 | 17.5 | 16.3 | 53.8 | 41.3 | 32.5 | 15.0 | 25.0 | 25.0 | 12.5 |
| **T3** | 14.3 | 15.0 | 13.8 | 56.3 | 40.0 | 25.0 | 16.3 | 10.0 | 13.8 | 15.0 |
| **T4** | 13.8 | 12.5 | 15.0 | 58.8 | 33.8 | 30.0 | 17.5 | 28.8 | 17.5 | 10.0 |
| **T5** | 13.0 | 15.0 | 12.5 | 41.3 | 32.5 | 17.5 | 18.8 | 20.0 | 13.8 | 13.8 |
| **T6** | 11.5 | 13.8 | 13.8 | 43.8 | 30.0 | 21.3 | 18.8 | 16.3 | 11.3 | 12.5 |
| **T7** | 12.0 | 16.3 | 15.0 | 56.3 | 32.5 | 23.8 | 13.8 | 20.0 | 22.5 | 27.5 |
| **T8 (Control)** | 12.3 | 16.3 | 18.8 | 53.8 | 50.0 | 37.5 | 18.8 | 36.3 | 38.8 | 35.0 |
| **LSD (P<0.05)** | **ns** | **ns** | **ns** | **14.3** | **13.5** | **11.6** | **6.4** | **9.0** | **9.3** | **8.9** |

The results of these trials indicate that some form of chemical treatment will provide some form of *Poa annua* control as apposed to doing nothing. The combination treatments involving a post-emergent and a pre-emergent herbicide with or without the addition of the seed head inhibitor ethephon provided the best control. The autumn and spring applications of paclobutrazol at the 2 L/ha rate were more effective than the monthly applications at 1 L/ha.

**Visual % flower heads:** The data was analysed using a two factor statistical analysis and the results are detailed in table 9. On two out of the five assessment dates there was a significant difference in the visual percentage of *Poa annua* flower heads. The data can be summarised as follows;

**February 08:**

- Treatments 4, 5, 6 and 7 had significantly fewer flower heads than treatments 2, 3 and 8.
- Treatment 1 had significantly fewer flower heads than treatments 3 and 8.

**May 08:**

- Treatments 4, 5 and 6 had significantly fewer flower heads than treatments 1, 2, 7 and 8.
- Treatment 3 had significantly fewer flower heads than treatments 1, 2 and 8.
- Treatment 7 had significantly fewer flower heads than treatments Treatment 8.

**September 08:**

- Treatment 6 had significantly fewer flower heads than treatments 2, 7 and 8.
- Treatment 3 and 5 had significantly fewer flower heads than treatments 2 and 8.
- All treatments had significantly fewer flower heads than the control.

**October 08:**

- Treatment 6 had significantly fewer flower heads than treatments 1, 2, 3, 7 and 8.
- Treatment 4 had significantly fewer flower heads than all treatments except for 5 and 6.
- All treatments had significantly fewer flower heads than the control.

**November 08:**

- Treatments 3, 4, 5 and 6 had significantly fewer flower heads than treatments 1, 7 and 8.
- All treatments had significantly fewer flower heads than the control.

In these trials each of the treatments containing ethephon had the greatest effect on flower head reduction with treatment 6 appearing to provide the superior flower head control, most probably due to the addition of endothal in the program.

**Table 9: Visual assessment % flower heads at Bonnie Doon Golf Club**

| TREATMENT | Feb-08 | Mar-08 | May-08 | Sep-08 | Oct-08 | Nov-08 |
|---|---|---|---|---|---|---|
| **T1** | 1.5 | 0.5 | 3.25 | 18.8 | 14.0 | 7.0 |
| **T2** | 2.5 | 1 | 3.5 | 25.0 | 8.8 | 4.3 |
| **T3** | 3 | 0.25 | 1.5 | 13.8 | 8.3 | 3.5 |
| **T4** | 1 | 1 | 0.75 | 17.5 | 3.0 | 2.8 |
| **T5** | 1 | 0.75 | 0 | 13.8 | 5.5 | 2.8 |
| **T6** | 0.5 | 0.25 | 0 | 11.3 | 4.0 | 2.0 |
| **T7** | 1.25 | 0.25 | 2.5 | 22.5 | 8.8 | 6.3 |
| **T8 (Control)** | 2.75 | 1 | 4.5 | 38.8 | 13.0 | 7.0 |
| **LSD (P<0.05)** | **1.1** | **ns** | **1.7** | **9.3** | **3.5** | **2.5** |

### 3.2.3 Riversdale Golf Club

**Visual % *Poa annua*:** The data was analysed using a two factor statistical analysis and the results are detailed in table 10. On three out of the five assessment dates there was a significant difference in the visual percentage *Poa annua* population. The data can be summarised as follows;

**Table 10: Visual *Poa annua* assessment at Riversdale Golf Club**

| TREATMENT | 8/10/2008 | 24/10/2008 | 6/11/2008 | 19/11/2008 | 3/12/2008 |
|---|---|---|---|---|---|
| **T1** | 43.3 | 32.8 | 50.0 | 30.0 | 46.7 |
| **T2** | 50.0 | 25.5 | 40.0 | 43.3 | 23.3 |
| **T3** | 36.7 | 25.8 | 25.0 | 50.0 | 26.7 |
| **T4** | 46.7 | 23.5 | 43.3 | 46.7 | 50.0 |
| **T5** | 60.0 | 26.3 | 26.7 | 36.7 | 53.3 |
| **T6** | 30.0 | 34.0 | 33.3 | 41.7 | 56.7 |
| **T7 (Control)** | 50.0 | 41.8 | 50.0 | 38.3 | 50.0 |
| **LSD (P<0.05)** | **21.6** | **ns** | **21.6** | **ns** | **16.9** |

**8/10/08:**

- Treatment 3 and 6 had significantly less *Poa annua* compared to treatment 5.

**6/11/08:**

- Treatments 3 and 5 had significantly less *Poa annua* compared to treatment 7.

**3/12/08:**

- Treatments 2 and 3 had significantly less *Poa annua* compared to treatments 1, 4, 5, 6 and 7.

**% Change:**

- Treatment 2 had a significantly greater percentage reduction in the *Poa annua* population compared to treatments 1, 4, 6 and 7.
- Treatment 3 had a significantly greater percentage reduction in the *Poa annua* population compared to treatment 6.
- Treatment 6 had a significantly greater percentage <u>increase</u> in the *Poa annua* population compared to all other treatments.

Of the treatments trialled, paclobutrazol at 2.5 L/ha provided the greatest reduction in the *Poa annua* population.

**Visual % flower heads:** The data was analysed using a two factor statistical analysis and the results are detailed in table 11. On two out of the five assessment dates there was a significant difference in the visual percentage of *Poa annua* flower heads. The data can be summarised as follows;

**6/11/08:**

- Treatments 3, 4, 5 and 6 had significantly fewer flower heads than treatments 1, 2 and 7.
- Treatment 4 had significantly fewer flower heads than treatment 7.

**3/12/08:**

- Treatment 6 had significantly fewer flower heads than treatments 2, 3 and 5.
- Treatments 3 and 5 had significantly fewer flower heads than treatment 1.

The effects of the treatments were somewhat inconsistent, however, the treatments with the flower head inhibitor ethephon were the most effective in reducing the number of flower heads. Endothal also had some effect on inhibiting the flower head production.

**Table 11: Visual assessment % flower heads at Riversdale GC**

| TREATMENT | 8/10/08 | 24/10/08 | 6/11/08 | 19/11/08 | 3/12/08 |
|---|---|---|---|---|---|
| **T1** | 4.0 | 2.8 | 3.0 | 1.3 | 2.7 |
| **T2** | 3.3 | 2.0 | 2.7 | 1.7 | 1.3 |
| **T3** | 2.3 | 1.8 | 1.0 | 2.0 | 1.0 |
| **T4** | 3.0 | 2.5 | 2.0 | 3.7 | 2.0 |
| **T5** | 4.0 | 2.0 | 0.8 | 3.0 | 1.0 |
| **T6** | 2.3 | 2.3 | 1.0 | 2.7 | 0.2 |
| **T8 (Control)** | 4.0 | 4.0 | 3.3 | 1.7 | 2.3 |
| **LSD (P<0.05)** | **ns** | **ns** | **1.2** | **ns** | **1.3** |

**Visual turfgrass density and quality:** The data was analysed using a two factor statistical analysis and the results are detailed in table 12. On two out of the five assessment dates there was a significant difference in the visual turfgrass density. The data can be summarised as follows;

**6/11/08:**

- Treatments 5 had significantly greater density compared to all treatments except for treatment 6.

**3/12/08:**

- Treatment 6 had significantly greater density compared to treatments 1, 2, 4 and 8.

**Table 12: Visual turfgrass density at Riversdale GC**

| TREATMENT | 8/10/08 | 24/10/08 | 6/11/08 | 19/11/08 | 3/12/08 |
|---|---|---|---|---|---|
| **T1** | 6.0 | 5.0 | 6.0 | 6.0 | 6.0 |
| **T2** | 6.0 | 5.3 | 6.0 | 5.8 | 6.0 |
| **T3** | 6.2 | 5.5 | 6.2 | 5.8 | 6.2 |
| **T4** | 5.5 | 5.6 | 6.0 | 6.0 | 6.0 |
| **T5** | 5.8 | 5.8 | 6.5 | 5.7 | 6.3 |
| **T6** | 6.0 | 6.3 | 6.2 | 5.7 | 6.8 |
| **T8 (Control)** | 6.2 | 6.8 | 6.0 | 6.0 | 6.0 |
| **LSD (P<0.05)** | **ns** | **ns** | **0.4** | **ns** | **0.6** |

There was no significant difference in turfgrass quality on any of the assessment dates.

### 3.3 *Poa annua* ecotype tolerance to herbicides

The data was analysed using a two factor statistical analysis that analysed the cultivar effect, the herbicide effect and the cultivar x herbicide interaction (table 13). The results can be summarised as follows;

**Cultivar effect:** At 14 DAT the type 5 plants were the most sensitive to herbicide applications, particularly compared to types 1, 4, 6 and 7. The type 2 ecotype was also more sensitive to herbicides compared to types 6 and 7 whereas types 1, 3, 4, 6 and 7 were the least sensitive to all herbicides.

At 21 DAT, the type 5 ecotype continued to be the most sensitive to the herbicides while the type 1 ecotype was the least sensitive. At 34 DAT this trend continued.

**Herbicide effect:** At 14 DAT the endothal had the most significant affect across all ecotypes. With endothal being a contact, desiccant type herbicide it would be expected to see a relatively quick result. The propizamide and the paclobutrazol were no different compared to the control and this would be expected given that both are taken up by the roots and need to be translocated through the plant in order to kill it.

At 21 DAT the endothal and the propizamide had a significant affect compared to the control whereas the paclobutrazol had no effect. The results of the propizamide application confirms that time is required for the plant to take up the herbicide and for it to take effect.

Following the second herbicide application (7 DAT), both the endothal and the propizamide had an increased effect with significant damage compared to the control. This result indicates the importance of a second application to kill any regrowth.

At no time did the paclobutrazol have a significant effect compared to the control. Paclobutrazol is a growth retardant and not necessarily herbicidal in its activity. It therefore suppresses growth but does not necessarily kill the plant completely.

***Poa annua* ecotype x herbicide interaction:** At 14 DAT there was significant interaction between ecotype and herbicide for the paclobutrazol. The endothal had a significant interaction across all ecotypes.

At 21 DAT there were significant interactions for all ecotypes with the endothal and the propizamide.
In particular there were significant interactions for; the type 2 ecotype and paclobutrazol, type 5 ecotype and all herbicide treatments and type 7 with endothal.

With the second application of herbicides there were significant interactions between all ecotypes with endothal and propizamide, however, this was less so for paclobutrazol. There were significant interactions between the types 1and 4 ecotypes and paclobutrazol.

## 4. DISCUSSION

Over the period of this research project there has been a large amount of data collected and analysed. The understanding of the *Poa annua* life cycle and the variations in ecotypes and their sensitivity to different herbicides is complex. However, this work has provided a better understanding of the complexities of dealing with *Poa annua*, particularly as it relates to different *Poa annua* ecotypes and their sensitivities to herbicides and what management strategies will provide the best form of control.

### 4.1 Identification of *Poa annua* ecotypes

There were seven distinctly different *Poa annua* ecotypes identified in this research though there was some overlap between the types and it was difficult to place them precisely into one particular category. However, with at least 90% of the population it was possible to place them in a definite category.

The *Poa annua* population varied from a very dense, compact, fine leafed plant that has very limited lateral spread and no flower heads to a more open plant, with coarse leaves and numerous stolons that exhibit strong lateral spread and large numbers of flower heads. The dense types with little lateral spread are typical of the true perennial types (*Poa annua* var. reptans). There were very few plants identified as being true annual types, indicating that in this situation the *Poa annua* types were well adapted and moving towards the more true perennial types.

While the *Poa annua* types were mainly perennial in nature the variations in the types would indicate that the variation from; very dense types with little or no spread to large, coarse and aggressive space fillers and also prolific seed producers provides an opportunity for *Poa annua* to colonise and persist in a variety of situations.

**Table 13: The effects of 3 herbicides on 7 *Poa annua* ecotypes**

| Cultivar effect | 14 DAT1 | 21 DAT1 | 30 DAT1 | 34 DAT1 | 7 DAT2 |
|---|---|---|---|---|---|
| T1 | 8.4 | 7.6 | 7.1 | 7.0 | 4.5 |
| T2 | 7.9 | 6.6 | 5.7 | 5.4 | 4.1 |
| T3 | 8.3 | 6.1 | 4.7 | 4.4 | 3.0 |
| T4 | 8.5 | 6.4 | 5.1 | 4.8 | 3.4 |
| T5 | 7.7 | 5.4 | 3.8 | 3.6 | 2.8 |
| T6 | 8.7 | 7.2 | 6.4 | 5.9 | 4.7 |
| T7 | 8.6 | 7.2 | 6.1 | 5.1 | 2.7 |
| **LSD (<0.05)** | **0.7** | **1.3** | **1.5** | **1.8** | **2.0** |
| | | | | | |
| **Herbicide effect** | **14 DAT1** | **21 DAT1** | **30 DAT1** | **34 DAT1** | **7 DAT2** |
| Paclobutrazol | 8.3 | 7.0 | 6.8 | 6.5 | 5.5 |
| Propizamide | 8.5 | 5.7 | 3.0 | 2.1 | 0.4 |
| Endothal | 7.4 | 6.0 | 4.8 | 4.6 | 2.0 |
| Control | 9.0 | 7.9 | 7.5 | 7.5 | 6.5 |
| **LSD (<0.05)** | **0.8** | **1.6** | **1.9** | **2.2** | **2.4** |

| ***Poa annua* type x herbicide interaction** | **14 DAT1** | **21 DAT1** | **30 DAT1** | **34 DAT1** | **7 DAT2** |
|---|---|---|---|---|---|
| **T1** | | | | | |
| Paclobutrazol | 8.5 | 8.0 | 7.8 | 7.3 | 6.3 |
| Propizamide | 9.0 | 7.5 | 5.8 | 6.0 | 2.0 |
| Endothal | 7.0 | 6.0 | 5.8 | 5.8 | 1.8 |
| Control | 9.0 | 8.8 | 9.0 | 9.0 | 8.0 |
| **T2** | | | | | |
| Paclobutrazol | 7.0 | 6.5 | 7.3 | 7.3 | 6.3 |
| Propizamide | 8.5 | 5.5 | 2.8 | 1.5 | 0.0 |
| Endothal | 7.3 | 6.5 | 5.3 | 5.3 | 2.8 |
| Control | 9.0 | 7.8 | 7.5 | 7.8 | 7.5 |
| **T3** | | | | | |
| Paclobutrazol | 8.3 | 6.8 | 6.8 | 7.0 | 5.0 |
| Propizamide | 7.5 | 4.5 | 1.5 | 0.5 | 0.0 |
| Endothal | 8.3 | 5.8 | 4.0 | 3.8 | 1.8 |
| Control | 9.0 | 7.5 | 6.5 | 6.5 | 5.3 |
| **T4** | | | | | |
| Paclobutrazol | 9.0 | 7.3 | 6.8 | 3.8 | 5.3 |
| Propizamide | 8.3 | 5.0 | 2.3 | 1.0 | 0.3 |
| Endothal | 7.8 | 5.8 | 4.5 | 2.0 | 1.3 |
| Control | 9.0 | 7.8 | 7.0 | 7.8 | 6.8 |
| **T5** | | | | | |
| Paclobutrazol | 7.3 | 5.0 | 4.0 | 3.8 | 3.3 |
| Propizamide | 8.3 | 4.5 | 1.5 | 1.0 | 0.0 |
| Endothal | 6.3 | 3.8 | 2.0 | 2.0 | 1.3 |
| Control | 9.0 | 8.3 | 7.5 | 7.8 | 6.8 |
| **T6** | | | | | |
| Paclobutrazol | 9.0 | 8.3 | 8.0 | 8.0 | 8.3 |
| Propizamide | 8.8 | 6.0 | 3.3 | 2.0 | 0.3 |
| Endothal | 8.0 | 6.8 | 6.5 | 6.0 | 3.3 |
| Control | 9.0 | 7.8 | 7.8 | 7.5 | 7.0 |
| **T7** | | | | | |
| Paclobutrazol | 9.0 | 7.5 | 7.0 | 6.3 | 4.3 |

| | | | | | |
|---|---|---|---|---|---|
| Propizamide | 9.0 | 6.8 | 4.3 | 2.3 | 0.5 |
| Endothal | 7.5 | 7.3 | 5.8 | 4.8 | 1.8 |
| Control | 9.0 | 7.3 | 7.3 | 7.0 | 4.3 |
| **LSD (<0.05)** | **0.5** | **1.0** | **1.2** | **1.4** | **1.5** |

The majority of the *Poa annua* types (i.e. type 5 and 6) were moderately dense to slightly open with coarse leaves and strongly stoloniferous. While these two types have similar characteristics they are distinguished by the presence or absence of flower heads. They either have no or occasional flower heads (type 5) or produce numerous flower heads (type 6) which provides opportunity for *Poa annua* to colonise by spreading stolons or seed or both.

The herbicide control trials resulted in a substantial shift of the *Poa annua* population from predominantly type 5 and 6 plants to the more perennial and herbicide resistant type 1 and 2 plants. While the overall population of *Poa annua* plants was reduced by the combination of paclobutrazol, bensulide and ethephon, what plants remained were strongly perennial in nature.

Examining the population shift in all treatments there was a trend towards the type 1 and 2 plants irrespective of the treatments and this tends to reinforce the observation of others that the older the green is, the more perennial in nature the *Poa annua* population becomes.

The proportion of *Poa annua* types present will determine the success of the control program. If there is a high population (greater than 15%) of the type 1 and 2 plants then the chances of control with the available registered herbicides will be low.

### 4.2 Herbicide control field studies

The results of these trials indicate that some form of chemical treatment will provide some level of *Poa annua* control as opposed to doing nothing. The combination treatments involving a post-emergent and a pre-emergent herbicide with or without the addition of the seed head inhibitor ethephon provided the best control. The autumn and spring applications of paclobutrazol at the 2 L/ha rate were more effective than the monthly applications at 1 L/ha.

### 4.3 *Poa annua* ecotype tolerance to herbicides

The different *Poa annua* ecotypes have different levels of sensitivity to herbicides commonly used for the control of *Poa annua,* with the Type 1 plants being the most herbicide tolerant and the Type 5 plants being the most sensitive.

Paclobutrazol, which is widely used in the control of *Poa annua*, was the least effective in killing the different *Poa annua* ecotypes. This result is consistent with it being a growth retardant or growth suppressant and not necessarily herbicidal in activity where a complete kill could be expected.

Endothal was the most effective herbicide across all *Poa annua* ecotypes and has been used in the selective control of *Poa annua* in bentgrass for nearly 40 years.

### 4.4 New herbicide registrations

One of the objectives of these trials was to examine new herbicides and to provide data for new chemical registrations.

As part of these trials the data has been provided to two companies, Greenshed P/L and Campbell Chemicals P/L to assist in the registration of ethephon in Australia. Greenshed P/L achieved registration for ethephon as Intercept® 480SL Turf Growth Regulator in late March 2009 for the suppression of *Poa annua* seedheads.

## 5. TECHNOLOGY TRANSFER

Over the life of this project there has been an extensive extension program involving; seminars, conference presentations, field days and articles in conference proceedings and the Australian Turfgrass Management Journal.

The following is a list of activities and publications;

AGCSA Research update in: *Proceedings Australian Turfgrass Conference, Brisbane July 2006.*
AGCSA website update (www.agcsa.com.au) December 2006. *Poa annua* control trials.
NSW Golf Course Superintendents meeting, August 2007 – AGCSA Research Update.
AGCSA Research Update in: *Proceedings Australian Turfgrass Conference, Cairns, July 2007.*
AGCSA Research Update in: *Proceedings Australian Turfgrass Conference, Melbourne, July 2008.*
NSW Golf Course Superintendents newsletter – June 2008
AGCSA Research Update in: *Proceedings Australian Turfgrass Conference, Hobart, July 2009.*

Australian Turfgrass Management Journal – 2006 *AGCSATech Update: Poa annua control trials* ATM 8.4.
Australian Turfgrass Management Journal – 2007 *AGCSATech Update: Poa annua control trials* ATM 9.3.
Australian Turfgrass Management Journal – 2007 *AGCSATech Update:* AGCSA Research Trials ATM 9.5.
Australian Turfgrass Management Journal – 2008 *AGCSATech Update: Poa annua control trials* ATM 10.1.
Australian Turfgrass Management Journal – 2008 *AGCSATech Update: Poa annua control trials* ATM 11.1.
*Poa annua* control trials update in the *AGCSA Action* Newsletter – October 2007

Website: All articles on the trials are uploaded onto the website. New HAL/Research link created.

Seminar/field days undertaken at Riversdale GC and Bonnie Doon GC in late November 2007, with key Golf Course Superintendents to discuss field results and how the results relate to their own field experiences. There were 80 golf course superintendents in attendance.

Data has also been presented at the Bonville GC northern NSW field days and the South Australian Golf Course Superintendents meeting in June 2008.

A workshop was held at Avondale GC on the 14th December 2008 with a select group of golf course superintendents from, WA, VIC, NSW and SA to discus *Poa annua* management strategies. The results of the workshop were published in Australian Turfgrass Management Journal – 2008 *Poa annua* Forum ATM 11.2 (see appendix 3).

## 6. RECOMMENDATIONS

This research has identified seven different *Poa annua* types in the trial area varying from a very dense, compact, fine leafed plant that has very limited lateral spread and no flower heads to a more open plant, with coarse leaves and numerous stolons that exhibit strong lateral spread and large numbers of flower heads. The very dense perennial types are strongly resistant to invasion from bentgrass (*Agrostis* sp.) while the aggressive space fillers can quickly colonise any weak or bare areas in the turf sward. The high seed production types provide another means of colonisation by quickly germinating and establishing in any weak or bare areas.

The different *Poa annua* types have varying degrees of sensitivity to herbicides commonly used in the control of this weed species which provides the *Poa annua* population with an increased chance of survival irrespective of the environmental or maintenance stresses.

In relation to the control of *Poa annua* in a bentgrass turf the following recommendations are made;

### 6.1 New greens

*Poa annua* control must commence from early (within the first 6 months) in the life a bentgrass putting green. The first strategy is to introduce a pre-emergent herbicide such as bensulide to prevent the establishment of *Poa annua* seedlings.

### 6.2 Established greens with a small *Poa annua* population (<10 – 15%)

In older (about 5 years), more established greens, where there are established *Poa annua* plants (where the population is less than 10 - 20%), the control strategy will involve the use of a combination of; a pre-emergent herbicide, a seed head inhibitor such as ethephon and post-emergent herbicides such as endothal and paclobutrazol. While the *Poa annua* population is less than 10%, hand weeding is also considered to be a critical part of the program, particularly in the removal of the more perennial types.

A typical program would be;

**Late winter/spring:** 2 – 3 applications of endothal.
**Spring:**

- Ethephon applications to control flower heads.
- Hand weeding.

**Summer:** Application(s) of paclobutrazol (as required).
**Late summer/early autumn:** Application of pre-emergent.
**Winter:** Applications of paclobutrazol (as required).

### 6.3 Established greens with a moderate to high *Poa annua* population (>25%)

In old greens (usually greater than 10 years) where there are established *Poa annua* plants consisting of more than 25% of the population, it is recommended to determine the predominant *Poa annua* ecotypes before embarking on a herbicide program. This would involve randomly collecting plants (at least 50) from a typical green and growing them out to a mature plant and observing there characteristics. Once they have achieved their maximum height and width, categorise them according to table 4 and appendix 2. Understanding the make up of the population will provide valuable information on what herbicide strategy to use and the likelihood of success.

Where the population consists of more than 25% of the more herbicide resistant type 1 and 2 plants, consideration needs to be given to whether a herbicide control program will have any benefit.

### 6.4 New chemicals

The one turf registered chemical missing from the preferred strategy is ethephon and this research would strongly recommend that it is registered in Australia. During the period of the research, data was provided to two manufacturers/suppliers of turf protection chemicals to assist in the registration of ethephon. It was registered in March 2009.

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## Appendix 1a: Herbicide application dates at Bonnie Doon Golf Club

| Treatment | 4/1/07 | 5/2/07 | 14/3/07 | 20/4/07 | 15/5/07 | 22/6/07 | 19/7/07 | 24/8/07 | 20/9/07 | 16/10/07 | 22/11/07 | 19/12/07 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T 1** | | | | | | | | | | | | |
| Paclobutrazol | x | x | x | x | x | x | x | x | x | x | x | x |
| **T2** | | | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x | | |
| Dimension | | | x | x | | | | | | | | |
| **T3** | | | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x | | |
| Bensulide | | | x | x | | | | | | | | |
| **T4** | | | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x | | |
| Dimension | | | x | x | | | | | | | | |
| Ethephon | | | | x | | | | x | x | x | | |
| **T5** | | | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x | | |
| Bensulide | | | x | x | | | | | | | | |
| Ethephon | | | | x | | | | x | x | x | | |
| **T6** | | | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x | | |
| Bensulide | | | x | x | | | | | | | | |
| Ethephon | | | | x | | | | x | x | x | | |
| Endothal | | | | | | | | | | | | |
| **T7** | | | | | | | | | | | | |
| Endothal | | | x | x | | | | | x | x | | |

| Treatment | 23/1/08 | 18/2/08 | 20/3/08 | 28/4/08 | 22/5/08 | 22/6/08 | 24/7/08 | 26/8/08 | 25/9/08 | 23/10/08 |
|---|---|---|---|---|---|---|---|---|---|---|
| **T 1** | | | | | | | | | | |
| Paclobutrazol | x | x | x | x | x | x | x | x | x | x |
| **T2** | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x |
| Dimension | | | x | x | | | | | | |
| **T3** | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x |
| Bensulide | | | x | x | | | | | | |
| **T4** | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x |
| Dimension | | | x | x | | | | | | |
| Ethephon | | | x | x | | | | x | x | x |
| **T5** | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x |
| Bensulide | | | x | x | | | | | | |
| Ethephon | | | x | x | | | | x | x | x |
| **T6** | | | | | | | | | | |
| Paclobutrazol | | | x | x | | | | x | x | x |
| Bensulide | | | x | x | | | | | | |
| Ethephon | | | x | x | | | | x | x | x |
| Endothal | x | | | | | | | | | |
| **T7** | | | | | | | | | | |
| Endothal | | | x | x | | | | | x | x |

## Appendix 1b: Herbicide applications at Commonwealth Golf Club

| Treatment | 22/1/07 | 21/2/07 | 21/3/07 | 26/4/07 | 28/5/07 | 16/7/07 | 24/8/07 | 12/9/07 | 25/10/07 | 23/11/07 | 20/12/07 | 16/1/08 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **T 1** | | | | | | | | | | | | |
| Paclobutrazol | x | x | x | x | x | x | x | x | x | x | x | x |
| **T2** | | | | | | | | | | | | |
| Paclobutrazol | | x | x | x | | | x | x | x | | | |
| Dimension | | x | x | x | | | | | | | | |
| **T3** | | | | | | | | | | | | |
| Paclobutrazol | | x | x | x | | | x | x | x | | | |
| Bensulide | | x | x | x | | | | | | | | |
| **T4** | | | | | | | | | | | | |
| Paclobutrazol | | x | x | x | | | x | x | x | | | |
| Dimension | | x | x | x | | | | | | | | |
| Ethephon | | | x | x | | | x | x | x | | | |
| **T5** | | | | | | | | | | | | |
| Paclobutrazol | | x | x | x | | | x | x | x | | | |
| Bensulide | | x | x | x | | | | | | | | |
| Ethephon | | | x | x | | | x | x | x | | | |
| **T6** | | | | | | | | | | | | |
| Paclobutrazol | | x | x | x | | | x | x | x | | | |
| Bensulide | | x | x | x | | | | | | | | |
| Ethephon | | | x | x | | | x | x | x | | | |
| Endothal | | | | | | | | | | | | x |
| **T7** | | | | | | | | | | | | |
| Endothal | | x | x | x | | | | | | | | |

## Appendix 1c: Herbicide applications at Riversdale Golf Club

| Treatment | 8/10/08 | 15/10/08 | 22/10/08 | 8/11/08 |
|---|---|---|---|---|
| **T 1** | | | | |
| Paclobutrazol (1L product/ha) | x | | | x |
| **T2** | | | | |
| Paclobutrazol (2.5 L product/ha) | x | | | x |
| **T3** | | | | |
| Paclobutrazol (2.5 L product/ha) | x | | | x |
| Ethephon | x | | | x |
| **T4** | | | | |
| Monthly endothal | x | | | x |
| **T5** | | | | |
| Weekly endothal | x | x | x | |
| **T6** | | | | |
| Ethephon | x | | | x |

**Appendix 2: *Poa annua* types and descriptions**

The *Poa annua* types have been catagorised according to leaf fineness, density, plant height and width, degree of stoloniferous growth and presence of flower heads. The types are described in the following table as well as individual photographs of plants representing that particular type.

| **Types** | **Description** |
|---|---|
| Type 1 | Dense, tight, short plant with fine leaves and no flower heads. Short or no stolons. |
| Type 2 | Dense, tight, short plant with fine leaves and no flower heads. Medium stolon growth. |
| Type 3 | Dense, tight, short plant with fine leaves. Seed heads present. Medium stolon growth. |
| Type 4 | Dense, tight, short plant, "puffy growth" with coarse leaves. Some flower heads present. Medium stolon growth. |
| Type 5 | Moderately dense to slightly open, short plant with coarse leaves. No or occasional flower heads present. Strongly stoloniferous growth. |
| Type 6 | Moderately dense to slightly open, short plant with coarse leaves. Large number of flower heads present. Moderate stoloniferous growth. Plant die-back occurs following flowering. |
| Type 7 | Moderately dense to slightly open, short plant with coarse leaves. Large number of flower heads present. Strong stoloniferous growth. |
| Type 8 | Low density, open plant with long, broad leaves. Large number of flower heads present. Plant is very tall and spreading but produces no stolons. |


| | |
|---|---|
| Type 1 | Dense, tight, short plant with fine leaves and no seed heads. Short or no stolons. |


| | |
|---|---|
| Type 2 | Dense, tight, short plant with fine leaves and no seed heads. Medium stolon growth. |

| | |
|---|---|
| Type 3 | Dense, tight, short plant with fine leaves. Seed heads present. Medium stolon growth. |

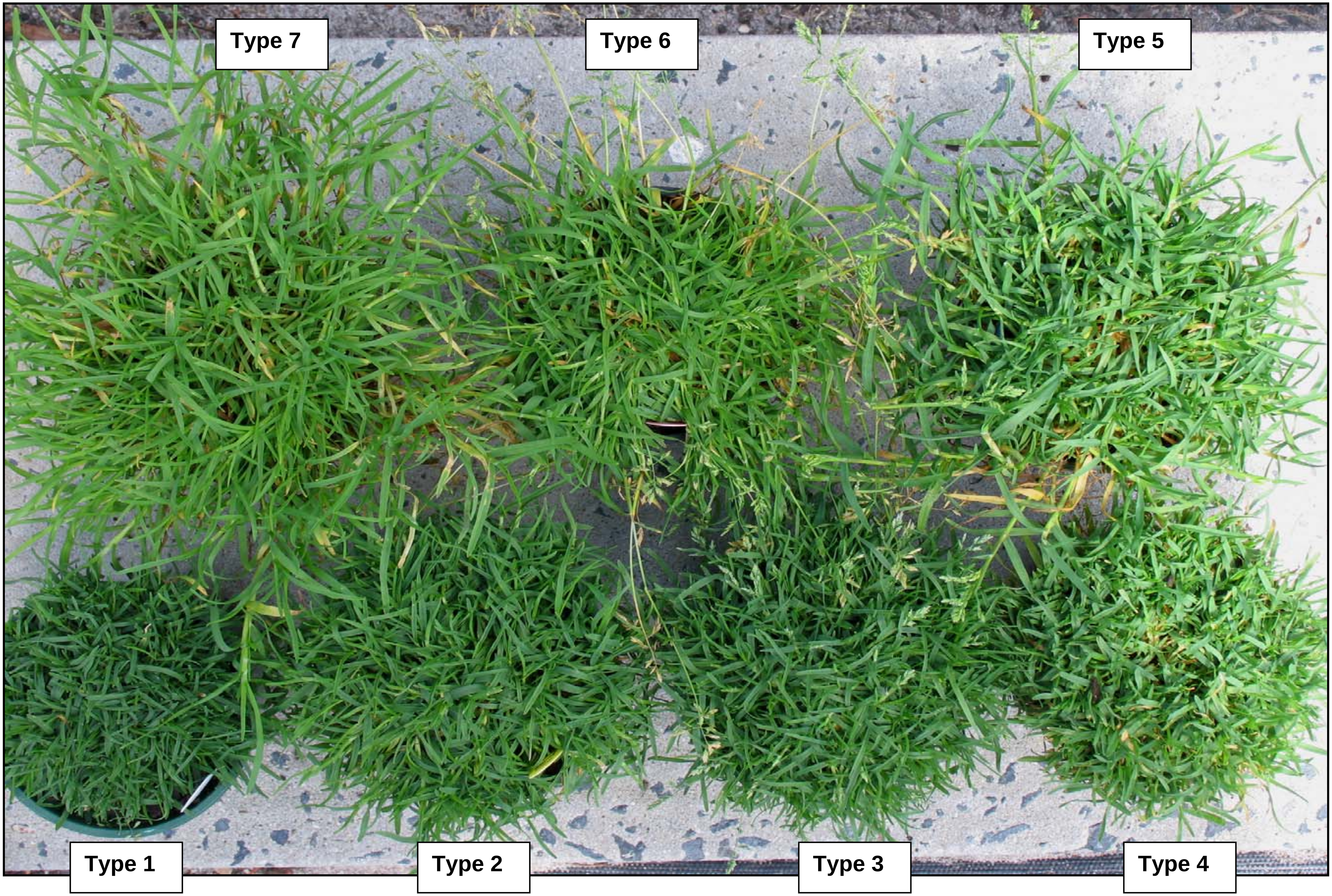
| | |
|---|---|
| Type 4 | Dense, tight, medium plant, "puffy growth" with coarse leaves. Some seed heads present. Medium stolon growth. |


| | |
|---|---|
| Type 5 | Moderately dense to slightly open, short plant with coarse leaves. No or occasional seed heads present. Strongly stoloniferous growth. |

| | |
|---|---|
| Type 6 | Moderately dense to slightly open, short plant with coarse leaves. Large number of seed heads present. Moderate to strong stoloniferous growth. Plant die-back occurs following flowering. |

| | |
|---|---|
| Type 7 | Moderately dense to slightly open, short plant with coarse leaves. Large number of seed heads present. Strong stoloniferous growth. |

| | |
|---|---|
| Type 8 | Low density, open plant with long, broad leaves. Large number of seed heads present. Plant is very tall and broad spreading. |




**All *Poa annua* types**

## APPENDIX 3: *POA ANNUA* CONTROL FORUM

**AGCSATECH UPDATE ATMJ 11.2**
**February 2009**

## INTRODUCTION

*Poa annua* is the most written and talked about weed affecting turf and has been at the forefront of the minds of turf managers since the 1920's (Zontek, 1987). Piper and Oakley (1921) described the value of *Poa annua* as a turf for putting greens and also commented that it would be very expensive to control and that such attempts would be hard to justify. The biology, physiology and control of *P. annua* have been researched more than any other turf problem and still there are no simple effective control strategies.

*P.annua* is treated by most turf managers as a weed to be eradicated. Most treatment methods give variable results and repeated treatments are necessary to prevent the proportion of *P.annua* from increasing. The difficulty in achieving control is due to the large seed bank of *P.annua* and the potential for year round germination and rapid seedling growth (Lush 1988). This gives *P.annua* a competitive advantage over other species in mixed swards where the *P.annua* can colonise bare areas left by mature *P. annua* plants that have died due to chemical applications or environmental stress. *P. annua* dominated swards can consist of numerous ecotypes from true annuals through to those that are true perennials and this further complicates any control strategy. For any *P.annua* control program to be successful both pre and post emergent control is required (Lush, 1990).

At a recent gathering of golf course superintendents the topic of the day was how to achieve "pure bentgrass" putting surfaces or how to keep *Poa annua* out. As part of the discussion forum a telephone hook up with world weed expert Dr. Fred Yelverton (North Carolina State University) also provided added expert opinion.

The superintendents came from far afield and represented a range of locations and climates, with each presenting how they combated the invasion of *Poa annua*. The aims of each superintendent were similar in that they were aiming to produce a high quality bentgrass putting surface year round while keeping the greens "Poa free". Easier said than done!!

With each of the 14 Superintendents presenting their programs it was interesting to note that while there were obvious similarities there was little repetition. This highlighted the fact that every set of circumstances is different and while the general principles remain similar, the specifics can be quite different.

So what was discussed and what can we as an industry take from it? The first and most important point is the value of getting together with your peers and sharing experiences. This involves not only sharing the successes but also the failures!

***Take home message No. 1: Get together, share and learn.***

The following information has been compiled from notes taken during the forum.

## *POA ANNUA* – THE WEED OR GREAT SURVIVOR?

The AGCSA has been undertaking extensive research trials over the past 3 years looking at the variations in *Poa annua* ecotypes and their sensitivity/resistance to various herbicides (ATMJ 11.1). Understanding the forms of *Poa annua* that you are dealing with provides an important insight into the likelihood of success or failure and what control strategy is going to be most effective.

All golf greens will have a number of different *Poa annua* ecotypes present at any one time where it exists anywhere from a true annual through to a true perennial with numerous types in between. The annual types germinate, grow, flower, set seed and die in a 12 month period. They are open upright plants that produce numerous seed heads and are prolific seed producers. The perennial types have a very high tiller density, produce a very dense turf and have very few seed heads. In the AGCSA's studies, seven *Poa annua* types were identified in the trial area and they tended towards being more perennial in nature but varied from very dense low seed head plants to aggressive spreading types with multiple seed heads.

When the individual plant types were subjected to applications of different herbicides, there were distinct differences in herbicide tolerance with the dense, perennial plants most tolerant to herbicides such as endothal and paclobutrazol. These studies also showed that while herbicide programs can be very effective in reducing the *Poa annua* population, it also has the potential to select out the more tolerant types which then over time will dominate the bentgrass turf.

It is this diversity in the *Poa annua* population and the ability to produce large amounts of seed (at any cutting height) that makes it so difficult to eradicate and why some control strategies meet with limited success.

***Take home message No. 2: Identify the predominant Poa annua types when formulating an appropriate control strategy.***

**TURF MANAGEMENT AND THE PRESENCE OF *POA ANNUA***

A recurring theme during the forum was that day to day maintenance activities have a profound effect on the presence of *Poa annua*.

The key factors discussed were;

i. **Water quality**: Many golf courses have to deal with water high in salts, sodium and bicarbonates which indirectly affect the *Poa annua* population. As the summer progresses, water quality places the bentgrass under stress and by late summer/early autumn the bentgrass can be weakened and lack density. This provides an opportunity for *Poa annua* to germinate and become established.

ii. **Renovations**: There is no doubt that hollow coring and scarifying in the cooler months can stimulate *Poa annua* germination and create spaces for seedlings to establish. As with all successful weed species, *Poa annua* is an opportunistic plant than can quickly establish itself in a small space devoid of competitors.

   Autumn renovations in particular are to be avoided and summer coring etc would appear to be more advantageous to the bentgrass and discourages the *Poa annua*.

   Some golf courses are avoiding annual renovations and this has to be balanced against thatch accumulation, soil compaction and the health of the bentgrass.

iii. **Irrigation**: Irrigation management was seen as an important tool in restricting the conditions suited to *Poa annua*. That is, deep infrequent irrigations that allow the surface to dry out are preferable to frequent, shallow irrigation. *Poa annua* and its shallow root system is favoured by keeping the top few millimetres regularly watered. The ability to achieve this is dependent on the bentgrass having a deep and healthy root system.

iv. **Traffic**: *Poa annua* needs an unoccupied space in which to germinate and grow. Any factor that reduces turf density will invariably favour *Poa annua* invasion. Traffic was identified as a key factor that favoured the presence of *Poa annua*. Greens with limited pin placements, poor traffic access (concentrated traffic) and small greens were most susceptible to *Poa annua* invasion.

v. **Greens design:** Golf Course Architects please note; greens that have poor <u>surface</u> drainage, e.g. gutters through the centre of greens, surface drainage towards the fronts of greens, the lack of multiple runoff areas and surface drainage into key pin areas will have a greater *Poa annua* population in these areas. Traffic access on and off greens and the size of greens also has a big influence on turf density and therefore the potential for *Poa annua* invasion.

vi. **Turf nutrition:** A very interesting aspect of the discussion was where turf nutrition fitted into the program. For many years there has often been a strategy of "starving" out the *Poa annua* by maintaining very low levels of fertility and in particular nitrogen. What became apparent was that it is not so much about the quantity of nitrogen applied but when. A key aspect to *Poa annua* control is to maintain the density of the bentgrass so that it can resist invasion during the autumn/winter periods of the year.

***Take home message 3: Controlling Poa annua involves controlling the circumstances that favour its presence; high moisture, weak bentgrass and compacted soils.***

**_POA ANNUA_ CONTROL PROGRAMS; WHAT'S BEEN WORKING**

There were several *Poa annua* control programs discussed and the following is a synopsis of what is considered to be working and can be used as a good starting point for the basis of a *Poa annua* control strategy. There are several key points that need to be considered if a successful control strategy is to be employed;

1. A "whole of golf course" approach needs to be taken to control all sources of *Poa annua* infestation. This requires controlling *Poa annua* in the fairways and roughs as well as the greens and greens surrounds.

2. Use pre-emergent herbicides on all areas outside of the green.

3. *Poa annua* control <u>must start early</u> in the life of the green.

4. The control of *Poa annua* will involve multiple strategies including; moisture control, herbicides, hand weeding and fertility management.

5. Maintain high turf density in the bentgrass going into winter.

6. Minimise coring and scarifying – particularly in autumn. Note that thatch control is still critical and other programs such as dusting and regular minityning (and dusting) during summer must be employed.

7. Healthy bentgrass turf = "success".

<u>Program 1</u>:

- Use of endothal in late winter/early spring when conditions are moist and overcast. About 3 applications (refer label recommendations).
- Use of paclobutrazol in spring/summer (refer label recommendations).
- Don't mow when spraying.
- Use air induction nozzles.
- Split the total volume of herbicide to be applied and make two passes across the green for best coverage of herbicide.
- Minimal fertility (low nitrogen) from autumn through to spring.
- Increase fertility during mid-spring through summer to grow bentgrass and in particular to increase turf density.

<u>Program 2:</u>

- Endothal June/July.
- Paclobutrazol every 6 weeks Aug through to May.
- Ethofumesate in March.
- Nitrogen at about 130 – 150kg N/ha/yr.

<u>Program 3</u>

- Using paclobutrazol and endothal for post-control with a strong emphasis on pre-emergents (eg. bensulide). Bensulide is used in a variety of programs from 4 applications at half rates from February onwards to 2 applications at full rates a month a part.

Additional activities

There were a number of additional points made that are worth considering as part of an overall *Poa annua* control strategy;

- High rates of iron sulphate at about 0.5 – 0.75 kg/100m$^2$.
- When using paclobutrazol it is important to get the follow up applications on before the effects of the previous application have worn off.
- Spot spraying of individual plants with endothal.
- Do not use the moss control chemical carfentrazone where bensulide has been used.

***Take home message 4: There are many approaches to Poa annua control and a whole of course approach must be taken.***

## HERBICIDE MODE OF ACTION

There are several herbicides used to control *Poa annua* and by having an understanding of their mode of action will assist in understanding where various herbicides fit into a program and how to get the best result from them.

For herbicides to be effective, they must enter the plant. Entrance may be influenced by factors, such as the shape or orientation of the leaf, roughness of the leaf surface, pubescence on the leaves, presence of wax, or the formulation of the herbicide. For example, it is difficult to obtain good coverage of plants with narrow upright leaves such as *Poa annua* since the herbicide bounces or runs off.

For herbicides applied to the foliage the main factors of concern are:
1. Efficiency of leaf retention
2. Cuticle penetration
3. Leaf absorption.

Once the herbicide is on the leaf it can be subjected to a number of forces:
1. It may be lost to the atmosphere due to volatilisation. This happens to Endothal.
2. The herbicide may dry to a crystalline form or concentrate to a viscous liquid.
3. It may penetrate the cuticle.

### Endothal
Endothal is classed as a phthalic acid and its exact mode of action is unknown. Endothal inhibits messenger RNA, and thus limits protein synthesis. It decreases the rate of respiration and lipid metabolism and interferes with normal cell division. with defoliation and brown desiccated tissue being typical symptoms. Endothal is a selective contact herbicide that is absorbed through leaves and roots and it is suggested that endothal can cause the death of plants by direct injury to root tissues subsequent to absorption.

### Bensulide
Bensulide is a Group E herbicide which works by inhibiting mitosis. Bensulide inhibits root growth and has an inhibitory effect on cell division. It is a soil applied pre-emergent herbicide that is adsorbed onto root surfaces with some also being absorbed by the root. A negligible amount, if any, is translocated upwards to the leaves. Research has shown that bensulide damages roots and root hairs in both cool and warm season grasses. It is classified as being strongly sorbed in soils although it does possess a tendency to leach to a greater depth than other pre-emergent herbicides, however, the amount of leaching is likely to be slight.

### Paclobutrazol
Paclobutrazol is a root absorbed Class B gibberellin biosynthesis inhibitor that inhibits gibberellin and sterol biosynthesis, and hence the rate of cell division. It is taken up into the xylem through the roots and translocated to growing sub-apical meristems where it produces more compact plants and enhances flowering and fruiting. Paclobutrazol inhibits gibberellin biosynthesis in the early stages of this pathway, which in turn prevents the synthesis of numerous gibberellins. Inhibition during the early stages of gibberellin biosynthesis can lead to

increased injury when environmentally-stressed turfgrasses are treated with paclobutrazol. Additionally, turfgrasses may exhibit various morphological responses such as the widening of creeping bentgrass leaf blades.

Because paclobutrazol is root absorbed, about 8 -10 mm of irrigation or rainfall is required within 24 hours of application to move the material into the turfgrass root zone. Once the paclobutrazol is watered in it attaches to soil carbon in the upper portion of the profile where the greatest congregation of *Poa annua* roots is likely to occur. Because healthy bentgrass roots are usually deeper than the *Poa annua* plants, the effects on the desirable species are less, which then gives it a competitive advantage over the *Poa annua*.

Paclobutrazol suppresses the growth of perennial biotypes of *Poa annua* in creeping bentgrass greens but does not necessarily kill the plant. Once the effects of the paclobutrazol wear off it is common to observe regrowth of the *Poa annua*.

**Ethofumesate**
Ethofumesate is a selective, systemic herbicide, absorbed by the emerging shoots (grasses) and roots (broad-leaved plants), with translocation to the foliage. It is not readily absorbed by leaves after the plant has generated a mature cuticle. Ethofumesate inhibits the growth of meristems, retards cellular division, and limits formation of a waxy cuticle.

**Pre-emergence herbicides**
Pre-emergence herbicides must be applied prior to weed seed germination and it is therefore important to understand the plant life-cycle and when germination is most likely to occur. The mode of action for most pre-emergence herbicides (e.g., bensulide, benefin, dithiopyr, oryzalin, pendimethalin, prodiamine) is the inhibition of certain phases of cell division during the seed germination process. As the weed seed germinates, the herbicide is absorbed by the root or shoots, cell division is blocked, growth is inhibited and eventually the immature seedling dies. Emerged weeds visible at the time of application are generally not controlled by pre-emergence herbicides. However, dithiopyr, ethofumesate, and pronamide are exceptions in that they can control the seedlings of some grassy weeds species.

***Take home message 5: Know your chemicals and how and when they should be applied and understand where they fit into an integrated program.***

## CONSEQUENCES OF *POA ANNUA* CONTROL

Whenever undertaking a weed control program there is always the consequences to consider and the factors that influence the success or failure of the program. The very premise of a weed control strategy is asking the question "what will be left once that weed is removed". Whether it is through herbicide applications, hand weeding or cultural techniques, there will be some changes to the playing surface, whether it is aesthetic change (e.g. colour), physical change (turf density, smoothness of surface etc.) or both. It is important that this is thought through and discussed with the golf club committee. It does not matter how well the consequences are explained, the reality often comes as a shock to the untrained. This is particularly the case where there is a relatively high proportion of *Poa annua* (e.g. greater than 15%). Even hand weeding a relatively small population of plants and the short term surface disruption can be disconcerting to golfers.

Another factor to consider is the influence of various chemicals that may be used. For example, paclobutrazol is a growth retardant and it will suppress the growth of the bentgrass and this can have ramifications during periods of heat stress and disease where recovery from injury can be retarded.

The condition of the root system of the bentgrass is also a factor that impacts on the use of various herbicides. In areas that experience high summer stress which damages the root system, care needs to be taken using herbicides in the early autumn that can further damage the root system and/or retard the growth of the bentgrass. In particular care needs to be taken with the use of the pre-emergent herbicides.

It may not be possible to start a *Poa annua* control program from day 1 and in many situations greens can have a significant *Poa annua* population present before a control program is implemented. If *Poa annua* control is considered to be feasible it is important to maintain the program. A common problem expressed was that various factors can disrupt the continuity of the program and this will upset the rate of success. Preparation for tournaments (often involving increased fertility and water), disease outbreaks and renovations can cause set backs in the program.

If an effective control program is to be implemented it needs to be "whole of course" and this needs to be explained to the Club, including the cost ramifications and how it will influence the outcome.

***Take home message 6: Understand and communicate the possible consequences of a Poa annua control program.***

**DR. YELVERTON'S COMMENTS**

Dr. Fred Yelverton has been to Australia on several occasions and is acknowledged as a world expert on weeds in turf. Dr. Yelverton joined the discussion and a Q and A session and he made several useful points in tackling *Poa annua*;

- In the USA about 80% of *Poa annua* germination occurs in the autumn in a 60 day window. The work of Dr. Mary Lush would indicate that in Australia the main flush of germination also occurs in the autumn with some germination occurring in the spring. However, the more perennial types can flower all year round with a major pulse in the late winter and spring.

- The pre-emergent herbicide bensulide is most effective if it is used from the early life of the green and is less effective once there is a well established *Poa annua* population.

- Dr. Yelverton has had experience with several new herbicide compounds. One of these is Bispyribac-sodium (Velocity™) which has been trialled in Australia. Dr. Yelverton indicated that it has had variable results in his trials.

- There are other new chemical compounds under trial including cumyluran and amicarbazol. Cumyluran takes about 12 months to have an effect on the *Poa annua* population and the amicarbazol provides good control, however, it does cause damage to the bentgrass depending on the time of the year and the cultivar (Penncross is more sensitive).

**AGCSA *POA ANNUA* CONTROL RESEARCH**

The AGCSA has been undertaking detailed research in using a life-cycle approach to the control of *Poa annua* using a combination of pre and post emergent herbicides, PGR and flower head inhibitors.

There have been a number of key findings from this research which are summarised as follows;

1. The *Poa annua* population is likely to vary from plants that are very dense, compact and fine leafed that have very limited lateral spread and no seed heads to a more open plant, with coarse leaves and numerous stolons that exhibit strong lateral spread and large numbers of seed heads.

2. The different *Poa annua* types respond differently to different herbicides used in its control.

3. Herbicide treatments appear to select out the tolerant types and the diversity of the population can move over time, potentially making it more difficult to achieve control.

4. The most effective program involved the use of pre and post control herbicides and a seed head inhibitor.

**CONCLUSIONS**

*Poa annua* is undoubtedly the greatest of weed species and is a true opportunist in that if you give it the slightest chance to invade a turf area it will. Its genetic diversity, ability to seed prolifically at low cutting heights and for the population dynamics to change with changing conditions makes it a formidable opponent.

The *Poa annua* forum did not reveal any new magic bullets but it did reinforce the basics;

1. Know your grasses.
2. Know your herbicides.
3. Know your site conditions.
4. Start your control program early in the life of the green.
5. For greatest success take a “whole of golf course approach”.
6. Use a combination of strategies; herbicides, nutrition, cultural etc.
7. Be consistent.
8. Understand the consequences of your strategy.
9. Communicate with your peers and your club.
10. Healthy, strong bentgrass equals optimum control.

*Please note: The Poa annua control strategies stated in the article are general in nature and are not meant to be implemented without careful thought and planning and taking into account local conditions..*