Effects of close cutting on ground cover and quality of a polystand of Manilagrass and cool season turfgrasses

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Abstract

Warm season turfgrasses can be grown successfully in the transition zone, but dormancy occurs to some extent during the winter. Overseeding with cool-season turfgrasses is necessary if winter dormancy of warm season turfgrasses is not tolerated. The increasing availability of zoysiagrass cultivars has enabled this genus to be considered suitable for low-maintenance golf courses, especially for golf tees and golf fairways. On the other hand, zoysiagrasses have the most rigid leaves of all turfgrass species, followed by bermudagrasses and by the other warm season turf species. Thus, to have a high mowing quality, mowers working constantly on zoysiagrasses require more sharpening than mowers working on other grasses. Rotary mowers are not suitable for mowing at low heights and often result in scalping, while reel mowers perform optimal mowing at a short height (below 2.5 cm) but require accurate management and frequent sharpening. Autonomous mowers have proven to produce a superior turf quality compared with traditional walk-behind rotary mowers, but no autonomous mower has ever been tested at a low mowing height on an overseeded warm season turfgrass. Because of this, the trial was carried out to simulate a golf tee overseeded with cool season turfgrasses, with low input fertilisation rates and with one of the most difficult turf species to mow; i.e. Zoysia matrella (L.) Merr. The trial was carried out in San Piero a Grado (Pisa, Italy) from October 2016 to October 2018. After a two-year period the best turf quality was achieved with Festuca rubra L. ssp. cultivars among the overseeded species, especially during fall. In many cases turf quality increased after manila grass green up since the combination of both cool season and warm season species gave a higher quality to the turfgrass, due to the finer leaf texture and higher shoot density of some cool season species. Moreover, recovery of manila grass ground cover was satisfying. In conclusion, a polystand of manila grass and Festuca rubra ssp. could be suitable for golf tees with low-input management.

Introduction

The use of warm season turfgrass species in hot and transitional climatic zones can give numerous advantages over cool season turfgrass species, such as lower water needs, the possibility of irrigating with salty water or wastewater (Carrow and Duncan, 1988; Harivandi, 1991) and lower susceptibility to fungal diseases (Gullino et al., 2000). Considerable technical and environmental advantages could be gained, by a more widespread utilisation of warm season turfgrasses in the coastal regions of the Mediterranean Basin. This area falls in the turfgrass transition zone, where warm season turfgrasses can be grown successfully, but dormancy occurs to some extent during the cooler months (Volterrani et al., 1997). Where winter quiescence of warm season turfgrass is not tolerated for technical or aesthetic reasons, overseeding with cool season turfgrasses is necessary in order to remedy. This practice allows to create a temporary actively growing green cover, when the use of turf covers or turf painting are considered secondary remedies to warm season turfgrass winter dormancy (Volterrani et al., 2003). The increasing popularity and availability of zoysiagrass cultivars has enabled this genus to be considered suitable for sports turfs and golf courses (Magni et al., 2017; Patton et al., 2017). Zoysia ssp. have a good tolerance to moisture deficits and shade, produce limited vertical growth requiring minimal mowing, develop a dense mat of vertical and horizontal organs that limit weed invasion and have a short dormant period, making them potentially suitable for low-maintenance turfs (Whereley et al., 2011; Pompeiano et al., 2012; Pompeiano et al., 2014). Historically, zoysiagrass cultivars were developed for lawn use; however they have a high genetic variability, which results in several morphological differences...
(Anderson, 2000). Although the use of zoysiagrasses on putting greens in the United States is quite recent (Morris, 2016), the use of zoysiagrasses for golf greens, golf tees and golf fairways is encouraging (Engelke et al., 2002a, 2002b). The optimal mowing height for zoysiagrasses ranges from 0.3 to 0.4 cm (Patton et al., 2017), depending on species and cultivars. On the other hand, zoysiagrasses have the most rigid leaves of all turfgrass species, followed by bermudagrasses and by the other warm season turf species (Turgeon, 2012). High neutral detergent fiber content makes zoysiagrasses more difficult to mow (Lulli et al., 2012). Thus, to have a high mowing quality, mowers working constantly on zoysiagrasses require more sharpening than mowers working on other grasses (Bevard et al., 2005). Typically, turfgrass mowers are divided into three main groups: rotary mowers, reel mowers, and flail mowers. Rotary mowers cut the grass by hitting it with a revolving single blade and are most effective at mowing tall grass and mulching clippings. However, rotary mowers are not suitable for mowing at low heights and often result in scalping (Munshaw, 2018). Reel mowers instead cut the grass with a scissor-like action using a reel cylinder and a bed knife. Reel mowers perform optimal mowing at a short height (below 2.5 cm) and are suitable for tough-to-mow grasses such as zoysiagrass and bermudagrass (Munshaw, 2018). Reel mowers are, thus, usually chosen for golf courses and sports turfs. However, there is a kind of rotary mower that has proven to produce a superior turf quality compared with traditional walk-behind rotary mowers: autonomous mowers (Grossi et al., 2016; Pirchio et al., 2018b). Time and labour saving, no polluting gasses, preventing contact with allergens, energy saving and very low noise emissions are just some of the advantages of using autonomous mowers (Hicks and Hall, 2000; Ragonese and Marx, 2015). Modern autonomous mowers are battery powered and perform lawn mowing without requiring an operator. Unlike walk-behind rotary mowers, autonomous mowers are not designed to collect clippings. Autonomous mowers are, thus, usually programmed to operate every day to produce minimal amounts of small clippings. Through a process called grasscycling (or mulching) the small clippings can be easily integrated into the turfgrass without forming thatch (Bredé, 2000). The cutting system of autonomous mowers usually consists of a cutting disc with small pivoting blades (Honda, 2018; Husqvarna, 2018), or a single blade with three or four cutting edges (Robonom, 2018; Zucchetti Centro Sistemi Spa, 2018). Theoretically, autonomous mowers may reach a minimum of 2.0 cm mowing height. In a recent trial (Pirchio et al., 2018a), a prototype-autonomous mower cutting at a 1.2 cm mowing height has been tested on a manila grass turf. The authors suggest that the autonomous mower tested in the trial may be a valid alternative to reel mowers at low mowing heights. In scientific literature, no autonomous mower has ever been tested at a low mowing height on an overseeded warm season turfgrass. The trial was carried out to simulate a low-maintenance golf tee, overseeded with cool season turfgrasses, without any pesticide application and with one of the most hard to mow turfgrass species: Zoysia matrella (Turgeon, 2012). The aim of this trial was to compare the performance of different cool season turfgrasses in a polystand with manila grass for a year-round period of two years, mown as a golf tee at 1.0 cm (Czyzewski and McGraw, 2017) with a prototype-autonomous rotary mower, evaluating their persistence as ground cover, overall quality, turf colour and shoot density.

Materials and methods

The trial was carried out in the experimental station Rottaia of the Centre for Research on Turfgrass for Environment and Sports (CeRTES), Department of Agriculture Food and Environment, University of Pisa, located at S. Piero a Grado, Pisa (43°40’ N, 10° 19’ E, 6 m. a.s.l.), Italy, from October 2016 to October 2018. A mature stand of manila grass (Zoysia matrella cv Zeon), established on a silty loam soil (Calcaric Fluvisol, 28% sand, 55% silt and 17% clay) with a pH of 7.8 and 18 g kg⁻¹ organic matter, was scalped and aerated with a verticutter on October 2, 2016. A 5 mm silica-sand-top-dressing was carried out afterwards. On October 20, 2016, 11 different cool season turfgrasses and a dwarf white clover (Trifolium repens cv Microclover) were overseeded manually (Table 1) and arranged in a randomised block experimental design with 4 replications. Dwarf clover had been chosen as a control since it does not belong to the Poaceae family. Plots had a 1.5 m² (1.0×1.5 m) surface area. To improve seed germination, the entire trial area was covered with Edilfloor Thermodelt geotextile (30 g m⁻² specific weight) for 20 days after seeding and irrigated every day. At sowing date, 50 kg ha⁻¹ of N, 92 kg ha⁻¹ of P and 50 kg ha⁻¹ of K were distributed.

In 2017 (March, 9; August, 29) and 2018 (March, 6; August, 28), 50 kg ha⁻¹ of P, 100 kg ha⁻¹ of N and 50 kg ha⁻¹ of K were distributed at 7 h d⁻¹. Automatic mowing was performed with an autonomous mower (Honda mod. HRD 536 C; Honda France manufacturing; Ormes, France) set at 6.0 cm mowing height. Subsequent mowing was carried out once a week with a reel mower (McLane mod. 20-3.5 RP-7; McLane; Paramount, CA) and mowing height was gradually reduced to 1.0 cm. From February 13, 2017, automatic mowing was performed with an autonomous mower (Husqvarna mod. Automower 310; Husqvarna; Stockholm, Sweden) custom modified to cut from 0.5 to 2.5 cm. Mowing height was set at 1.0 cm and mowing time was set at 7 h d⁻¹.

Every month, from February 2017 to October 2018, the following parameters were visually assessed: i) Ground cover (%): as the percentage of ground covered by the overseeded species and by manila grass; ii) Weed cover (%): as the percentage of ground cov-

| Species                                      | Cultivar | Seed rates (g m⁻²) |
|----------------------------------------------|----------|--------------------|
| Agrostis stolonifera L.                      | L93      | 5                  |
| Festuca arundinacea Schreb.                  | Essential| 50                 |
| Festuca rubra L. ssp. commutata (Thuil.) Nyman | Greenmile| 25                 |
| Festuca rubra L. ssp. rubra Gaud.            | Heidrun  | 25                 |
| Festuca rubra L. ssp. trichophylla (Ducros ex Gaudin) K. Richt | Valdora | 25                 |
| Lolium multiflorum Lam.                      | Acella   | 50                 |
| Lolium perenne L.                            | Berlitz  | 50                 |
| Lolium perenne L.                            | Columbine| 50                 |
| Poa pratensis L.                             | Yvette   | 15                 |
| Poa supina Schard.                           | Supreme  | 15                 |
| Poa trivialis L.                             | Sabrena  | 15                 |
| Trifolium repens L.                          | Microclover| 20               |
ered by weeds; iii) Visual quality: (1 = poor; 9 = excellent), with 6 considered the minimum acceptable level (Morris and Shearman, 2018); iv) Colour: (1 = straw brown, 6 = light green and 9 = dark green), with 6 considered the minimum acceptable level (Morris and Shearman, 2018).

On May 25, 2017, and on May 16, 2018 one 50 cm² core sample per plot was collected and shoot density was determined by direct counting with data reported as number of shoots per square centimetre.

Statistical analysis was carried out with a COSTAT 6.400 software (CoHort Software, Monterey, CA, USA). All data were analysed by one-way ANOVA, and all pairwise Fisher’s least significant difference (LSD) test at the probability level of 0.05.

Results

Ground cover

During the first year Lolium entries showed a very high ground cover at the beginning of the trial (from 69% to 84%), but at the end of the summer their ground cover strongly decreased (Table 2), and no differences were found between Lolium perenne cultivars. Poa entries and Festuca arundinacea ground cover also strongly decreased during summer, while Agrostis stolonifera increased its ground cover throughout the summer (from 61% to 78%). Trifolium repens ground cover increased during all the first year (from 36% to 99%) (Table 2). After the spring green up Z. matrella ground cover ranged from 20% to 57%, filling up the empty spaces formerly covered by the cool season species. Zoysia matrella ground cover progressively increased during summer as most of the cool season species ground cover decreased except for T. repens, A. stolonifera, and Festuca rubra trichophylla. Trifolium repens did not allow Z. matrella to expand, as only 1% of Zoysia remained after the end of the summer (Table 2). At the beginning of the second year of the trial Lolium entries showed a ground cover ranging from 20% to 41% (Table 3), but at the end of the trial Lolium entries ground cover was close to 0%. Poa entries had a slightly higher ground cover at the beginning of the second year (ranging from 47% to 48%), but at the end of the trial ground cover was also close to 0% (Table 3).

Festuca arundinacea had a very low ground cover during all the second year, while the ground cover of Festuca rubra cultivars was very high at the beginning of the second year (ranging from 80% to 86%) and decreased during summer. Agrostis stolonifera ground cover also decreased during the summer (from 67% to 33%), showing major competition from manila grass. Trifolium repens ground cover was very high at the beginning of the second year but decreased at the end of the summer. After the green up Zoysia matrella ground cover ranged from 15% to 89% and progressively increased since all cool season species decreased their ground cover during summer (Table 3).

At the end of both years Trifolium repens had the highest ground cover, followed by Agrostis stolonifera and by Festuca rubra cultivars (Tables 2 and 3).

Visual quality

During the first year of the trial, turf quality of most cool season species increased from February to September, with the exception of Poa supina, Lolium multiflorum and Festuca arundinacea, since their ground cover was lower than 5%. At the beginning of the trial, only Lolium perenne cultivars and Festuca rubra cultivars had an acceptable quality. Trifolium repens had the lowest quality while Lolium perenne cultivars had the highest (Table 4). At the end of the first year Trifolium repens still had the lowest quality (6.1) while Festuca rubra cultivars and Poa trivialis had the highest quality (from 7.3 to 7.5). At the beginning of the second year of the trial only Festuca rubra cultivars had a good quality (Table 4). At the end of the trial Festuca rubra cultivars had the highest quality (from 7.3 to 7.6) while the lowest quality was achieved by Agrostis stolonifera with a score of 5.6.

Table 2. Cool season species and Zoysia matrella ground cover percentages during the first year of the trial (2017) on February 20, April 3, June 7 and September 2 (in each date total ground cover was 100%, i.e. no bare soil and no weeds).

| Species                  | Cultivar         | 20-Feb | 3-Apr | 7-Jun | 2-Sep |
|--------------------------|-----------------|--------|--------|--------|--------|
| Cool species (%)         | Z. matrella (%) | Cool species (%) | Z. matrella (%) | Cool species (%) | Z. matrella (%) | Cool species (%) | Z. matrella (%) |
| Agrostis stolonifera     | LS3             | 40     | 60     | 38     | 61     | 39     | 78     | 22       |
| Festuca arundinacea      | Essential       | 55     | 45     | 45     | 55     | 46     | 54     | 96       |
| Festuca rubra comnlatata | Greenmile       | 40     | 60     | 57     | 43     | 55     | 45     | 61       |
| Festuca rubra rubra      | Heidrun         | 35     | 65     | 61     | 39     | 58     | 42     | 52       |
| Festuca rubra trichophylla | Valdora      | 49     | 51     | 47     | 53     | 51     | 49     | 65       |
| Lolium multiflorum       | Ascella         | 69     | 31     | 43     | 57     | 10     | 90     | 0        |
| Lolium perenne           | Berlino        | 81     | 19     | 61     | 39     | 47     | 53     | 11       |
|                         | Columbine       | 84     | 16     | 72     | 28     | 52     | 48     | 17       |
| Poa pratensis            | Yvette          | 36     | 64     | 47     | 53     | 29     | 71     | 19       |
|                         | Supreme         | 30     | 70     | 44     | 56     | 39     | 61     | 4        |
| Poa trivialis            | Sahrena         | 55     | 45     | 80     | 20     | 7      | 93     | 32       |
| Trifolium repens         | Microclover     | 36     | 64     | 61     | 39     | 89     | 11     | 99       |
| LSD 0.05                 | 16               | 19     | 21     | 21     | 18     | 18     | 15     | 15       |

Means are significantly different at the 0.05 level of probability as determined by Fisher’s protected LSD. *Bormant (Zoysia matrella green up started on March 10).
(not acceptable value) and *Trifolium repens* with a score of 6.4 (acceptable according to the 1-9 scale). The quality of the other cool season species was not evaluated at the end of the trial since their ground cover was lower than 5% (Table 4).

**Colour**

At the beginning of the first year of the trial, the colour of most cool season species was acceptable with the exception of *Lolium multiflorum* (Table 5). At the end of the first year, the colour of all cool season species evaluated was acceptable. *Agrostis stolonifera* had the lowest colour score (6.0) and *Trifolium repens* had the highest (7.3). At the beginning of the second year, only *Trifolium repens* had a good colour (7.0), while the other cool season species ranged from 5.2 to 6.3 (Table 5). From February to April colour scores of most species decreased. *Agrostis stolonifera* had the lowest score (5.1) and *Poa pratensis* had the highest (6.3). At the end of the second year only *Agrostis stolonifera* had a non-acceptable colour, while *Festuca rubra* cultivars and *Trifolium repens* ranged from 6.0 to 7.1.

**Shoot density**

Shoot density during the first year varied from 5.5 to 12.9 shoots cm⁻² (Table 6). *L. multiflorum* and *F. arundinacea* had the lowest shoot density (5.5 and 6.4 shoots cm⁻², respectively) while *P. trivialis* and *F. rubra trichophylla* had the highest (12.9 and 12.3 shoots cm⁻², respectively). During the second year of the trial shoot density of all species was lower, ranging from 0.4 to 6.7 shoots cm⁻² (Table 6). Moreover, during the second year *L. multi-

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**Table 3. Cool season species and *Zoysia matrella* ground cover percentages during the second year of the trial (2018) on February 9, April 6, June 1 and October 3 (in each date total ground cover was 100%, i.e. no bare soil and no weeds).**

| Species | Cultivar | 9-Feb | 6-Apr | 1-Jun | 3-Oct |
|---------|----------|-------|-------|-------|-------|
|         | Cool species (%) | *Zoysia matrella* (%) | Cool species (%) | *Zoysia matrella* (%) | Cool species (%) | *Zoysia matrella* (%) |
| *Agrostis stolonifera* | L93 | 67 | 33 | 66 | 34 | 31 | 69 | 33 | 67 |
| *Festuca arundinacea* Essential | 10 | 90 | 11 | 89 | 3 | 97 | 5 | 95 |
| *Festuca rubra commutata* | Greenmile | 80 | 20 | 79 | 21 | 30 | 70 | 26 | 74 |
| *Festuca rubra rubra* | Heidrun | 80 | 20 | 79 | 21 | 30 | 70 | 26 | 74 |
| *Festuca rubra trichophylla* Valdora | 86 | 14 | 85 | 15 | 35 | 65 | 30 | 70 |
| *Lolium multiflorum* Accella | 20 | 80 | 20 | 80 | 5 | 95 | 0 | 100 |
| *Lolium perenne* Berliz | 35 | 65 | 35 | 65 | 8 | 92 | 3 | 97 |
| *Lolium perenne* Columbine | 41 | 59 | 41 | 59 | 10 | 90 | 3 | 97 |
| *Poa pratensis* Yvette | 47 | 53 | 45 | 55 | 16 | 84 | 3 | 97 |
| *Poa supina* Supreme | 48 | 52 | 40 | 60 | 11 | 89 | 3 | 97 |
| *Poa trivialis* Sabrena | 47 | 53 | 45 | 55 | 5 | 95 | 0 | 100 |
| *Trifolium repens* Microclover | 91 | 9 | 69 | 31 | 71 | 29 | 55 | 45 |
| LSD 0.05 | 19 | 20 | 21 | 21 | 11 | 11 | 14 | 14 |

Means are significantly different at the 0.05 level of probability as determined by Fisher’s protected LSD. *Dormant (*Zoysia matrella* green up started on March 7).

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**Table 4. Cool season species quality (1 = poor, 9 = excellent, 6 = minimum acceptable level) during the first year (2017) on February 20, April 6 and September 2 and during the second year (2018) on February 9, April 6 and October 3.**

| Species | Cultivar | 20-Feb | 2017 | 3-Apr | 2-Sep | 9-Feb | 2018 | 6-Apr | 3-Oct |
|---------|----------|--------|------|-------|-------|-------|------|-------|-------|
| *Agrostis stolonifera* | L93 | 5.5 | 6.3 | 7.0 | - | 5.4 | 5.4 | 5.6 |
| *Festuca arundinacea* Essential | 5.4 | 4.8 | - | - | 5.3 | 6.0 | - |
| *Festuca rubra commutata* | Greenmile | 6.2 | 6.3 | 7.3 | - | 7.0 | 6.8 | 7.6 |
| *Festuca rubra rubra* | Heidrun | 6.4 | 6.8 | 7.5 | - | 6.8 | 6.1 | 7.5 |
| *Festuca rubra trichophylla* Valdora | 6.4 | 6.6 | 7.4 | - | 6.8 | 6.4 | 7.5 |
| *Lolium multiflorum* Accella | 4.9 | 4.8 | - | - | 5.0 | 6.0 | - |
| *Lolium perenne* Berliz | 6.5 | 6.9 | 7.1 | - | 6.4 | 6.6 | - |
| *Lolium perenne* Columbine | 6.6 | 6.8 | 7.0 | - | 6.2 | 6.3 | - |
| *Poa pratensis* Yvette | 5.4 | 5.9 | 7.1 | - | 5.8 | 6.3 | - |
| *Poa supina* Supreme | 5.0 | 5.4 | - | - | 5.1 | 5.9 | - |
| *Poa trivialis* Sabrena | 5.9 | 6.5 | 7.4 | - | 5.0 | 5.5 | - |
| *Trifolium repens* Microclover | 3.8 | 4.5 | 6.1 | - | 6.0 | 6.0 | 6.4 |
| LSD 0.05 | 1.2 | 1.6 | 1.1 | 0.8 | 1.0 | 0.9 |

Means are significantly different at the 0.05 level of probability as determined by Fisher’s protected LSD. - = not evaluated (Ground cover less than 5%).

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florum and *F. arundinacea* had the lowest shoot density (0.4 and 0.6 shoots cm$^{-2}$, respectively), while the highest shoot density belonged to *F. rubra commutata* (6.7 shoots cm$^{-2}$), *A. stolonifera* (6.6 shoots cm$^{-2}$) and *F. rubra trichophylla* (6.6 shoots cm$^{-2}$).

### Weed cover

Weed cover percentage resulted lower than 1% during all the trial period (data not shown) probably due to the extreme competition exerted by manila grass against weeds.

### Discussion

Ground cover percentage of most turf species was lower during the second year of the trial. Moreover, during both years, ground cover percentage of most species decreased at the end of the summer. The trend of the ground cover of *Lolium multiflorum* was very similar to what Volterrani et al. (2004) had previously reported on bermudagrass. Starting at 69% ground cover at the beginning of the first year and at 20% ground cover at the beginning of the second year, at the end of the summer of both years *Lolium multiflorum* ground cover percentage was 0%. *Lolium perenne*, *L. multiflorum* and *P. supina* showed to suffer from the competition exerted by manila grass, although *L. perenne* and *L. multiflorum* are both often chosen to overseed bermudagrass (*Cynodon dactylon*) turfs (Serensits et al., 2011; Aldahir et al., 2015). *Festuca rubra* sp. cultivars showed to be more persistent in the polystand with manila grass. *Festuca rubra* sp. cultivars also showed a higher ground cover at the beginning of the second year compared to the other cool season species apart for *T. repens* and *A. stolonifera*. The species that was less affected by manila grass

| Species                | Cultivar | 20-Feb | 2017 3-Apr | 2-Sep | 9-Feb | 2018 6-Apr | 3-Oct |
|------------------------|----------|--------|------------|-------|-------|------------|-------|
| *Agrostis stolonifera* | L93      | 6.4    | 6.5        | 6.0   | 5.2   | 5.1        | 5.5   |
| *Festuca arundinacea*  | Essential| 6.3    | 6.6        | 6.6   | 6.0   | 6.0        | -     |
| *Festuca rubra commutata* | Greenmile | 6.6   | 6.8        | 6.7   | 6.2   | 5.8        | 6.7   |
| *Festuca rubra rubra*  | Heidrun  | 6.8    | 6.6        | 6.6   | 5.8   | 5.5        | 6.6   |
| *Festuca rubra trichophylla* | Valdora | 6.8   | 6.9        | 6.8   | 5.7   | 5.3        | 6.0   |
| *Lolium multiflorum*   | Assella  | 4.9    | 5.9        | -     | 6.0   | 6.0        | -     |
| *Lolium perenne*       | Berlioz  | 5.8    | 6.8        | 6.9   | 5.8   | 5.5        | -     |
| *Lolium perenne*       | Columbine| 6.1    | 6.6        | 6.8   | 5.7   | 5.8        | -     |
| *Poa pratensis*        | Yvette   | 6.9    | 6.8        | 6.9   | 6.3   | 6.3        | -     |
| *Poa supina*           | Supreme  | 6.5    | 6.6        | -     | 6.2   | 6.0        | -     |
| *Poa trivialis*        | Sabrena  | 6.8    | 7.0        | 6.8   | 6.0   | 6.0        | -     |
| *Trifolium repens*     | Microclover | 6.1  | 7.0        | 7.3   | 7.0   | 6.0        | 7.1   |

Means are significantly different at the 0.05 level of probability as determined by Fisher’s protected LSD. *Stalks.

| Species                | Cultivar | 23-May 2017 Shoot density (no. cm$^{-2}$) | 16-May 2018 Shoot density (no. cm$^{-2}$) |
|------------------------|----------|------------------------------------------|------------------------------------------|
| *Agrostis stolonifera* | L93      | 9.2                                      | 6.6                                      |
| *Festuca arundinacea*  | Essential| 6.4                                      | 0.6                                      |
| *Festuca rubra commutata* | Greenmile | 11.6                                    | 0.7                                      |
| *Festuca rubra rubra*  | Heidrun  | 10.9                                     | 6.0                                      |
| *Festuca rubra trichophylla* | Valdora | 12.3                                     | 6.6                                      |
| *Lolium multiflorum*   | Assella  | 5.5                                      | 0.4                                      |
| *Lolium perenne*       | Columbine| 9.2                                      | 2.4                                      |
| *Lolium perenne*       | Berlioz  | 11.4                                     | 3.2                                      |
| *Poa pratensis*        | Yvette   | 9.5                                      | 2.1                                      |
| *Poa supina*           | Supreme  | 10.7                                     | 2.1                                      |
| *Poa trivialis*        | Sabrena  | 12.9                                     | 3.0                                      |
| *Trifolium repens*     | Microclover | 6.0*                                     | 3.4*                                     |

Means are significantly different at the 0.05 level of probability as determined by Fisher’s protected LSD. *Stalks.
competition was the dwarf clover, especially at the end of the first year when its ground cover was 99%. Despite this, at the end of the second year manila grass reached 45% of ground cover. Dwarf clover proved to be too competitive even for manila grass, probably due to its high seed rate establishment (McCurdy et al., 2013) associated with the low fertilisation program adopted. Dwarf clover quality was initially quite low, however it increased and remained acceptable during the second year. The best quality was achieved by Festuca rubra sp. cultivars and Lolium perenne cultivars. Shoot density of all cool season species was higher at the end of the first year rather than at the end of the second year. This was probably due to the very strong competition offered by manila grass that progressively managed to expand to the cool season species. The very low shoot density of Lolium multiflorum and Festuca arundinacea at the end of the second year showed that these species did not adapt to withstand manila grass competition. Although other studies have shown poor summer recovery of zoysiagrass after overseeding (Razmjoo et al., 1996; Zhang et al., 2008), our results highlighted that after two years only dwarf clover caused an incomplete recovery of manila grass.

Conclusions

Overseeding has become a standard industry practice for golf courses and athletic fields receiving significant traffic during the winter season in the southern United States (Fontanier and Steinke, 2017). In order to have a low-input turf management, a polystand may be a more sustainable practice since overseeding is performed only at the beginning. In our study, after a two-year trial period, the best quality was achieved by Festuca rubra sp. cultivars. In many cases quality increased after manila grass green up because the combination of cool season and warm season species produced a finer leaf texture and a higher shoot density. Moreover, manila grass ground cover recovery was satisfying, even if during the first year it appeared quite slow, probably because of the severe scalping and the thick sand top-dressing. These encouraging results show that it’s possible to obtain a useful and sustainable intercropping between cool season turf species and manila grass for a two-year period. A polystand of manila grass with some cultivars of Festuca rubra ssp. could be suitable for a low-input management of a golf tee, looking forward to the reduction of chemical inputs allowed on turfs by the European regulations.

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