Performance of warm-season turfgrasses in an area of Central Italy

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Abstract: Traditionally, in Italy, the C3 cool-season grasses have been the dominant species used for turfs, even though they do not appear to be the most suitable for the Mediterranean climate. However, recent limited water availability and the need to reduce energy inputs have placed drought tolerant warm-season turfgrasses under the spotlight. These species combine aesthetics with performance advantages in terms of water consumption, and with regard to the reduction of fertilizer and pesticides use. The present research was aimed to test the performance of warm-season turfgrass species (three cultivars of *Cynodon dactylon*, two cultivars of *Paspalum vaginatum* and two of *Zoysia japonica*) in a climatic transition zone in Tuscany, to evaluate their potential for use in this environment. The assessment of several parameters, which were estimated periodically, permitted performance evaluation of each species/cultivar, thereby enhancing the existing knowledge of these species and their potentiality in this environment. Results showed that the species with the best adaptation to the environment was *Cynodon dactylon*, which had higher performances compared to the other species. *Paspalum vaginatum* reported good quality in terms of color and density, but was damaged by low temperatures during winter. *Zoysia japonica* displayed a poor performance during the first year, but quality increased during the second year, yielding satisfactory results.

1. Introduction

Turfs and lawns are an important part of the landscape: they enhance its beauty (Geren *et al.*, 2009) and provide important ecological benefits (Beard, 1973; Linse *et al.*, 2001; Busey, 2003; Argenti and Ferrari, 2009) especially in areas modified by human intervention.

Recently, the need for larger spaces for individual, family environments and common areas for socialization has increased the concept that green spaces represent a higher standard of living in urban areas (Hull, 1990; Roberts, 1990). This awareness has increased interest in turf, as a surface capable of fulfilling technical, aesthetic and recreational goals, ensuring high quality standards, practicability and durability of the turf (Volterrani and Magni, 2007). In turn, this has led to the development of precise management practices (Gaetani *et al.*, 2013) through which to minimize the negative impact on the environment. The main problem connected to turfgrass is the amount of input necessary to obtain a high quality surface (Easton and Petrovic, 2005). The predominant challenge is the utilization of water for irrigation (Youngner *et al.*, 1981; Sevostianova and Leinauer, 2014). This aspect may reach critical levels especially in Mediterranean regions, characterized by low rainfall and hot summer temperatures. These climatic characteristics suggest the use of a low water rate and drought tolerant species such as warm-season turfgrasses (Marchione, 2008) that can provide high quality turf with suitable water consumption and low fertilizer and pesticide input (Turgeon, 2002; Schiavon *et al.*, 2013). The main objection to the use of these grasses is their lack of green color during the winter period, when they enter in dormancy and loose chlorophyll (Bernardini, 2007). This occurs especially in central Italy, an area characterized by high summer and cold winter temperatures, where cold tolerance and rapidity of recovery from winter dormancy are also important qualities (Magni *et al.*, 2014).

The objective of this investigation was to assess performance and adaptation, especially in relation to cold temperature, of three species (seven cultivars) of C4 warm-season turfgrass species and a cool-season grass as a comparison, in an internal area of the Tuscany Region.

2. Materials and Methods

The experimental site was located in a borderline area of Mediterranean climate in the centre of Tuscany, characterized by hot summer and low winter temperatures. The experimental trial started in the late spring of 2011 in Antria (Tuscany, central Italy) on natural soil, contain-

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ing 16.4% sand, 54.1% silt and 29.5% clay. The study was conducted over two growing seasons (2011 and 2012), starting after full establishment of the turf, up to the period of dormancy. Due to the presence of a meteorological station nearby, weather parameters were recorded in detail for the entire experimental period.

The species under comparison included *Cynodon dactylon* ('Black Jack', 'Casino Royale' and 'La Paloma'), *Paspalum vaginatum* ('Marina' and 'Sea Spray'), and *Zoysia japonica* ('Compadre' and 'Zenith') and a cool-season grass as control (*Lolium perenne* 'Kokomo'). The eight different accessions tested were replicated three times for a total of 24 plots (2x3 m with a surface area of 6 m^2) according to a complete randomized block design.

Sowing took place on the 10 June 2011. Seed rate was 25 g m^{-2}, as an average of the suggested dose for warm-season species (Panella *et al.*, 2000). Seeding was performed manually and followed by rolling. Cultural practices for the growing season included four or five applications of standard fertilizers (yearly total amount 318-85-81 kg ha^{-1} NPK). Irrigation was performed to restore 100% of crop evapotranspiration (ETc) and it was applied with a sprinkler system. Periodically, mowing was carried out with a mowing height of 30 mm performed by a rotary mower. A glyphosate treatment was performed during the dormancy period to reduce the presence of weeds (1 l ha^{-1}).

The following parameters were monitored during the trial and evaluated every two weeks (Pardini *et al.*, 2002; Reyneri and Bruno, 2008):

- *Aesthetic quality of the turf*: scores were visually assigned on a scale ranging from 1 to 9 (1= poorest quality, 9= highest quality) (Piano, 2005; Bigelow and Walker, 2008). Quality was also compared to additional parameters measured during the trial (color, ground cover and weeds) by multiple regression analysis to establish which aspects are the most related to quality;
- *Turf color*: scores were visually assigned on a scale ranging from 1 to 9 (1= light green, 9= dark green) (Bullitta *et al.*, 2005; Kir *et al.*, 2010);
- *Ground cover*: estimated visually as a percentage of soil cover;
- *Weed infestation*: estimated visually as percentage of soil cover.

All the data were grouped to obtain seasonal aggregation, where S1 was the first season of trials corresponding to summer 2011, S2 was autumn 2011, S3 spring 2012, S4 summer 2012 and S5 was the end of the study in autumn 2012.

The mean length of winter dormancy was estimated for each species, and plants were considered dormant when color scores means reached a value of 2.

Statistical analysis was carried out by means of ANOVA and Tukey test to discriminate differences among averages species values. Moreover, through multiple regression analysis, it was possible to evaluate which of the tested parameters (color, ground cover and presence of weeds) was strongly related to the quality on a global scale. All analysis were performed utilizing IBM SPSS Statistics software (release 20).

3. Results

Meteorological trends during experimental period

Both years were characterized by very hot and dry summer periods. In particular, 2011 was exceptionally dry until late autumn and had a total rainfall of 500 mm compared to the average of 800 mm (2002-2010). The highest recorded temperature occurred in August (38°C). During winter the coldest month was February 2012 with severe temperatures below 0°C (-9°C minimum recorded) and, even in full dormancy, warm-season grasses can be damage by the cold. Damage is also proportional to the duration of low temperatures. In 2012 there was a total rainfall of approximately 900 mm but it was concentrated at the end of the year. For this reason, during the summer, there was a severe water deficit replaced by irrigation. Spring was exceptionally warm, whereas the summer was one of the driest in recent decades.

Turf quality

Figure 1 shows the interaction between quality and season (S1= summer 2011, S5= autumn 2012) for the eight species or cultivars. The species that showed the best performance over time was *Cynodon dactylon*, with good values and a constant quality trend. All three cultivars belonging to this species performed well: in particular, 'Black Jack', obtained higher scores at the beginning of the trial. The highest value (7.1) was attained during summer 2012 (S4), even though the presence of thatch probably influenced the estimation. *Paspalum vaginatum*, after a good start and an improvement in autumn, proved to be the most sensitive species to low winter temperatures, having slower vegetative growth during the spring 2012 (S3) and the worst score, due to damage that occurred during winter. 'Sea Spray' showed better results in comparison to 'Marina'. *Zoysia japonica* performed badly during the year of establishment until the second growing season. Thereafter,

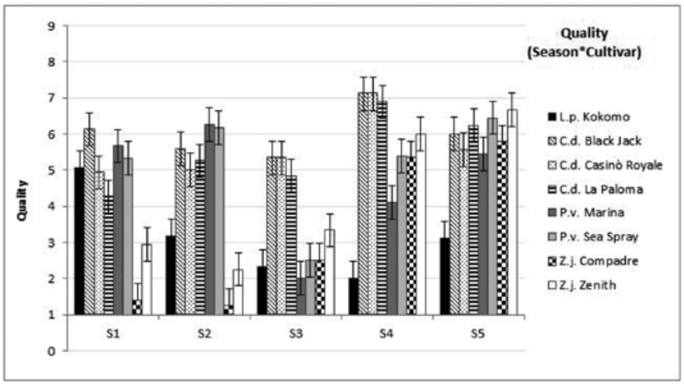

Fig. 1 - Global quality of the species/cultivars under investigation during the trial period (assessment with 1-9 scale). Bars = standard error. L.p. = Lolium perenne, C.d. = *Cynodon dactylon*, P.v. = Paspalum vaginatum, Z.j. = *Zoysia japonica*.

it gradually improved and gave very good scores at the end of the second year. 'Zenith' performed better than 'Compadre' on an overall scale. *Lolium perenne* was the most unsuitable species, showing a rapid initial establishment, after which the quality began to decrease from S2, attaining the worst score (2) in S4.

Color

The best performance regarding color was obtained with *Lolium perenne*: it was clearly superior with a darker and brighter color in each period (Fig. 2). Only *P. vaginatum*, in S3, showed equivalent scores and it resulted to be the species with the best color among the tested warm-season grasses. *Cynodon dactylon* gave unsatisfactory results, showing a decrease in quality in both years (in late summer and in the beginning of autumn), due to a rapid entrance into dormancy. Moreover, the light green color, typical of these seeded cultivars of *Cynodon* and the high production of thatch, influenced the scores. The trend of the two cultivars of *Zoysia japonica* appears to be very similar to that of *Cynodon*.

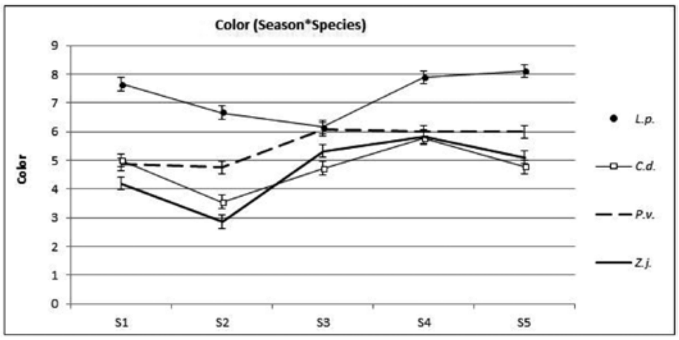

Fig. 2 - Average color of the species under investigation during the trial period (assessment with 1-9 scale). Bars = standard error. L.p. = Lolium perenne, C.d. = *Cynodon dactylon*, P.v. = Paspalum vaginatum, Z.j. = *Zoysia japonica*.

Ground cover and weed infestation

Table 1 shows the average ground cover values for each species during the different seasons of the trial. It is clear that the warm-season grasses increased the soil cover over time, while the percentage of *L. perenne* remained almost unchanged compared to the initial one (approximately 55-60%). *P. vaginatum*, due to the winter cold, had a poor cover percentage in the spring of the second year but it was able to regenerate an efficient soil cover thanks to its strong stolons, and this trend is evident for both cultivars. *C. dactylon* demonstrated good and constant soil coverage and it was more satisfactory than other species, whereas *Z. japonica* displayed the typical behavior of this species, attaining optimal values at the end of the growing season of the second year (S5).

As regards the presence of weeds (Table 1), infestation spread rapidly during the first year on *L. perenne* and *Z. japonica*. The high presence of weeds on *Lolium* is also due to the fact that this species is characterized by a bunch type

Table 1 - Average value (±SE) of ground cover and infestation of the tested cultivars over the 5 seasons

Species/ cultivar	Ground cover (%)				
	S1	S2	S3	S4	S5
Lp	59.0±7.5 a	58.3±2.1 bcd	58.3±4.6 ab	51.7±4.8 d	61.7±2.5 c
Cd1	73.7±5.2 ab	86.3±5.1 a	76.7±8.8 a	92.8±1.5 a	95.0±0.1 a
Cd2	63.7±5.8 ab	81.3±4.4 a	78.3±2.2 a	92.2±1.1 a	94.4±0.6 a
Cd3	57.0±5.6 ab	79.6±4.2 ab	73.3±3.6 a	92.2±1.1 a	93.9±1.1 a
Pv1	67.0±3.2 ab	78.3±2.1 ab	40.0±6.3 b	58.1±9.3 cd	83.3±5.9 b
Pv2	61.7±2.6 ab	76.7±6.9 ab	42.5±14.4 b	71.9±12.3 bc	88.9±5.3 ab
Zj1	24.7±2.4 c	40.8±3.4 d	52.5±6.3 b	78.9±1.5 ab	87.2±2.0 ab
Zj2	39.7±7.6 bc	56.3±6.3 cd	60.0±3.8 ab	83.3±2.5 ab	89.4±0.6 ab
Species/ cultivar	**Infestation (%)**				
	S1	S2	S3	S4	S5
Lp	4.0±2.3 ab	16.7±4.0 bc	30.0±5.8 c	23.3±4.4 b	30.6±4.0 b
Cd1	0.3±0.3 a	5.8±0.8 ab	8.3±2.2 a	6.7±1.0 a	16.1±2.9 ab
Cd2	1.7±0.9 a	10.8±1.1 abc	8.3±2.2 a	9.4±2.8 a	18.9±5.3 ab
Cd3	1.7±1.2 a	5.4±1.1 a	7.5±2.5 a	9.4±4.4 a	13.9±5.6 a
Pv1	1.3±0.9 a	3.3±1.1 a	19.2±5.8 bc	14.7±6.8 b	20.0±3.3 ab
Pv2	1.0±1.0 a	4.2±0.4 a	15.0±2.5 ab	12.5±2.7 ab	19.4±7.2 ab
Zj1	4.3±1.3 ab	17.9±4.2 c	19.2±4.4 bc	11.7±3.5 ab	18.9±4.5 ab
Zj2	8.7±1.3 b	19.6±1.8 c	23.3±2.2 bc	13.9±2.4 ab	9.4±0.6 a

Lp= *Lolium perenne* Kokomo, Cd1= *Cynodon dactylon* Black Jack, Cd2= *C. dactylon* Casinò Royale, Cd3= *C. dactylon* La Paloma, Pv1= *Paspalum vaginatum* Marina, Pv2= *P. vaginatum* Sea Spray, Zj1= *Zoysia japonica* Compadre, Zj2= *Z. japonica* Zenith.
Values in a column with the same letter are not significantly different (P<0.05) according to Tukey test.

habitus that makes it less competitive with opportunistic weed species in comparison to warm-season grasses. In addition, *Lolium*, after being stressed by the high summer temperatures, was also the only species not treated with glyphosate, taking into account its vegetative activity during the winter. For *Zoysia*, the infestation was easily attributable to a slow establishment that left plenty of space for the development of invasive species at the beginning of the trial. Nevertheless, for all the species, despite the winter control with glyphosate, a manual control against weeds in the second year was necessary. After these operations, the presence of weeds was shown to be reduced, thanks to the ability of these highly-competitive species to suppress weed growth.

Multiple regression analysis

This model permits the calculation of turf quality value (considered the dependent variable) through the other observed parameters. The model applied (a stepwise model) involves a mechanism of removal of the independent variables provided that they do not cause a decline in the power of the model. The elimination of the variables from the model is performed automatically by comparison with a threshold value of significance, which in this case was set to be equal to 0.05.

From the analysis the following formula was obtained:

Global quality= -1.447+0.067*cover-0, 050*weeds+0.443*color (R^2 = 0.884)

The parameters were ordered starting from the one most related to overall quality to the one with the lowest influence on the formula. No variable was removed from the model, demonstrating the importance of all investigated parameters in describing the aesthetic value of a turf. The presence of weeds, as expected, produced a negative value, as it was inversely related to the aesthetic appearance of the turf. The very high determination coefficient indicated the good correlation between the independent variables and the dependant variable (turf quality). This type of analysis could be used in future investigations to predict the overall performance of a turf.

Winter dormancy

Table 2 shows the dates at the beginning and the end of the growing season, and the length of vegetation and dormancy periods for the species during the trial years.

At the end of the first year of experimentation, dormancy took place in November for all the species, with differences of about two weeks between the earliest (*Zoysia*) and latest (*Paspalum*) entrance into dormancy.

The period of dormancy during winter 2011-2012 was particularly long for *Paspalum*, also because the growing season in the spring 2012 started at the end of April. *Cynodon* and *Zoysia* showed early vegetation activity at the end of March. The growing season for 2012 was longer for *Z. japonica* (236 days), due to its early vegetative growth and the entrance into dormancy in mid-November, which was exceeded only by *Paspalum vaginatum*. Nearly the same duration was found for *C. dactylon* (233 days), with greater precocity in vegetative growth, but with an earlier loss of green color than with other species. The shortest growing season, as expected, was found in *P. vaginatum* (208 days), despite its late entrance into dormancy.

The period of dormancy during winter 2012-2013 showed a substantial analogy to the previous year for *Zoysia* (137 days in 2011/2012 and 142 in 2012/2013) and *Paspalum* (151 days compared to 159) but a considerable lengthening for *Cynodon* (124 days compare to 160 in the second year). This behavior could be connected to the fact that mean and maximum spring temperatures in 2013 were lower compared with the previous year. This trend definitely affected the vegetative growth of the earliest species (*Cynodon*), highlighting the important role temperatures play in the vegetative activity of warm-season grasses.

4. Discussion and Conclusions

In this study, *Cynodon dactylon* emerged as the species with the best overall behavior and the best potential adaptation to the environment. It displayed good quality standards, rapid establishment, good overall appearance, high ground cover and a competitive behavior against weed

Table 2 - Dates of the beginning and the end of the growing season and length of vegetation and dormancy periods for the species during the years of trial

Species	Beginning	End	Vegetation (days)	Dormancy (days)
Cynodon dactylon		16/11/2011		124
Paspalum vaginatum		26/11/2011		151
Zoysia japonica		08/11/2011		137
Cynodon dactylon	20/03/2012	08/11/2012	233	
Paspalum vaginatum	26/04/2012	20/11/2012	208	
Zoysia japonica	25/03/2012	16/11/2012	236	
Cynodon dactylon	17/04/2013			160
Paspalum vaginatum	28/04/2013			159
Zoysia japonica	07/04/2013			142

infestation. The constancy of studied parameters along experimental trial are consistent with Volterrani *et al.* (1997). The worst performance concerned color of this species that probably resulted remarkably affected by presence of thatch, confirming the observations of Holm *et al.* (1991).

Paspalum vaginatum presented an overall satisfactory appearance. However, the species was highly susceptible to cold winters, in agreement with De Luca *et al.* (2008), and Tesi (2012) reported cold damages on *Paspalum* with temperature around -7°C. Anyway this species performed in a very good manner concerning other variables, as it displayed a dark green-blue color, as well as a good color retention during autumn, as reported previously by Volterrani *et al.* (1996) and Geren *et al.* (2009). Given that the stability of the turf was compromised, this behavior establishes a limit to the use of this species in areas that border the Mediterranean climate or with severe risks of low temperatures during winter.

Zoysia japonica exhibited a typical growing pattern, confirming that observed by Patton and Reicher (2007), and it showed very poor performance in the first year, slow development and not competitive attitude against weeds. Similar results regarding this species were found by Geren *et al.* (2009) in a comparative study among warm-season grasses in Turkey. On the other hand, starting from the beginning of the second year, a gradual increase in quality, color and coverage was observed, and the species achieved remarkable results at the end of second growing season, in agreement with Sladek *et al.*, (2011).

Through multiple regression analysis it was possible to evaluate which of the tested parameters influenced turf quality the most. The results showed that the ground cover and the presence of weeds are strongly related with the overall aesthetic quality.

The winter season revealed important differences in relation to the length of the period of dormancy among species. *P. vaginatum* had the longest period of dormancy (about 155 days as the average of the two years of experimentation). A delay in the vegetative activity in *Paspalum*, in comparison to other warm-season grasses, was also reported by other authors in different climatic areas (Duncan, 1996; Miele *et al.*, 2000; Volterrani *et al.*, 2001), as well as in both coastal and internal areas of Tuscany (Volterrani *et al.*, 2000; Pardini *et al.*, 2002) and in the province of Rome (Croce *et al.*, 2001). *C. dactylon* showed a rapid recovery from winter dormancy in warm springs, while a longer length of dormancy was observed during the cold spring 2013. *Z. japonica* remained dormant for approximately 140 days during both years of the experiment.

In general, in the interior zones of this study, the duration of dormancy was found to be longer than those verified by other experiments along the coastal areas of central Italy (Croce *et al.*, 2004). For this reason, in this environment, it is necessary to plan and analyze costs and benefits associated with the use of warm-season grasses. Where it is not possible to accept the absence of green color during winter, it is evident that the use of warm-season species can be extended to these areas only by adopting appropriate overseeding programs, but these interventions seem possible only in high standard turf such as those related to sport pitches.

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