The European Journal of Plant Science and Biotechnology ©2008 Global Science Books

Adaptability of Bermudagrass Turf Varieties to a Mediterranean Environment

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ABSTRACT

The main agronomic interest in bermudagrass (*Cynodon dactylon* (L.) Pers.) in the last quarter of the 20th Century was in environments with harsh weather condition when the species was used as a turfgrass. Suitable varieties were mainly released in the USA and were well adapted to warm conditions of the USA bermudagrass belt, while information on their establishment and performance in Mediterranean sites was scant. An experiment on turf lawns using the most popular seed market bermudagrass varieties was established on a site with typical Mediterranean climate (Foggia, southern Italy). In July of 1999, the varieties were hand seeded in an experimental block design and evaluated across five years for qualitative, spring greenup and dormancy traits. The range of scores over the years was 7.9-8.4, 6-6.3 and 7.8-8.2, respectively for turf quality, colour and cover traits. A larger range of variation was observed in shoot density, in spring and summer assessment (21.6-29 and 21.2-30.4 stems 25 cm^{-2}, respectively). Results over seasons showed differences among cultivars for all qualitative characteristics. Spring score values were higher than those of other seasons for all traits. Autumn score was lower by 14.1%, 25.6% and 6.4% than the spring and summer season values, respectively for turf quality, colour and cover traits. All cultivars evaluated adapted well to the Mediterranean environment. When data was processed by a cluster method, a different adaptability among varieties to different seasons was shown. Varieties 'Jackpot' and 'Shangri-La' were in a group of best varieties in all seasons and for all qualitative traits.

Keywords: adaptability, seeded variety, turf quality warm season grass

INTRODUCTION

Bermudagrass is a warm season grass characterized with a four-carbon molecule as the first step in carbonate assimilation. This confers more efficient crop growth at high light intensity and temperatures than the C3 pathway (Brown 1988; Eastin and Sullivan 1988; Moss 1988). Plants of this species are characterized by stolons able to exploit the moisture of topsoil and preserve active physiological metabolism in a temperature range from 13 to 38°C. Outside of these limits, the plant becomes dormant and remains in that physiological stage until the temperature returns to the limit for plant development (Beard 1989; Zhang and Davies 1989; Beard and Sifers 1997; Huang *et al*. 1997a, 1997b; Huang and Fu 2001). The morphological and physiological peculiarity of bermudagrass plant contributed to its wide geographic diffusion around the world in tropical, sub-tropical and transitional zones (Harlan *et al*. 1970a, 1970b; Taliaferro *et al*. 1996).

Since the beginning of the 19th Century, bermudagrass was considered an important forage grass crop in the southern part of the USA (Burton and Hanna 1985). Later in the Century, the high agricultural incomes achieved by other crops [cotton (*Gossypium herbaceum* L.), corn (*Zea mays* L.) and peanut (*Arachis hypogea* L.)] led to the decline of bermudagrass cultivation. The reduced interest in the species for forage crop cultivation favoured the use of bermudagrass in establishing turf lawns for commercial sports grounds and the use of turfgrass mats to combat soil erosion in degraded environments (Burton and Hanna 1985). These new tasks for bermudagrass were supported by the USA government which funded breeding and agronomic programmes (NETP, National Turfgrass Evaluation Program) for developing and evaluating genotypes adapted to environments of the southern bermudagrass belt of the Mississippi State of USA (Alderson and Sharp 1994; Goatley *et al*. 1997). The landraces that carried alien germplasm from warm countries (Africa and Afghanistan) were the base germplasm used for developing turf varieties available in the seed today (Beard and Sifers 1998; Croce *et al*. 2001; Müller and Santoro 2001).

Despite these developments in the USA, bermudagrass was considered a dangerous weed of cultivated crops in the Mediterranean area. In view of the adaptability of bermudagrass to weather conditions, it now seems appropriate to evaluate the species for sowing sports green lawns during spring-autumn seasons. The warm season turf of bermudagrass, when grown in Mediterranean environments, presents more efficient physiological activity in spring-summer-autumn seasons and has lower management costs than cool season turfgrass (Kentucky bluegrass, *Poa pratensis* L.; tall fescue *Festuca arundinacea* Schreb.; perennial ryegrass, *Lolium perenne* L.; slender creeping red fescue, *Festuca rubra* spp. *tricophylla* Guaud. (Ricter); creeping red, *Festuca rubra* spp. *rubra* L.; chewing red, *Festuca rubra* spp. *commutata* Gaud.) (Eastin and Sullivan 1988; Croce *et al*. 2001; Miele *et al*. 2000; Volterrani *et al*. 2001; Martiniello and D'Andrea 2006). However, the lack of agronomic information on lawn management has limited the utilization of bermudagrass for public and private outdoor recreational and competitive sports turfgrass grounds in Mediterranean areas (Mitchell 1953; Baker and Jung 1968; Miele *et al*. 2000; Croce *et al*. 2001).

Because most bermudagrass varieties available on the international seed market were well adapted to the bermudagrass belt zone of America, knowledge on the adaptability of qualitative and performance characteristics of the varieties used for bermudagrass lawns in countries of Mediterranean climate remains essential for successful turf green establishment (Volterrani *et al*. 1977; Miele *et al*. 2000;

Received: 13 January, 2008. Accepted: 29 February, 2008.

Original Research Paper

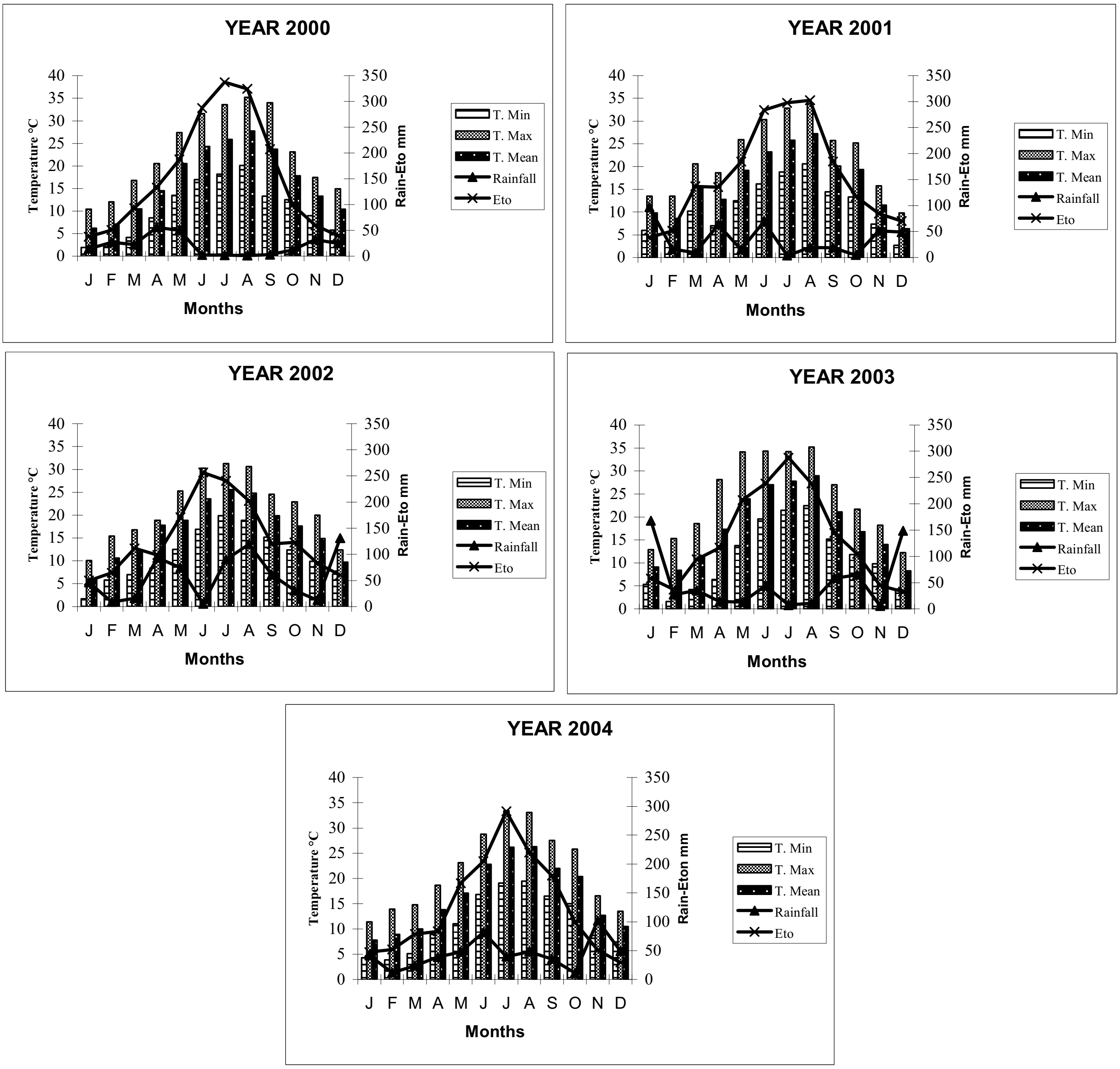

Fig. 1 Meteorological events during field evaluation. Climatic observation represents monthly mean (initial capital letter) across the year of experiment.

Croce *et al*. 2001; Volterrani *et al*. 2001).

The aims of this experiment were to evaluate agronomically the cultivars most widely used in worldwide turf lawns for performance and turf quality during the vegetative spring-summer-autumn period and for winter dormancy and greenup activity and to identify by a cluster method the varieties better adapted to Mediterranean climate in southern Italy.

MATERIALS AND METHODS

The experiment was established in July 1999 at the Forage Crops Institute of Foggia (15°13 E, 41°18 N and 76 m above sea level). The average values of monthly precipitation, mean temperatures and evaporation from a Class A water pan (Eto), verified across the years of evaluation, are reported in **Fig. 1**. The experiment was sown in a Chromic Vertisoil (FAO-ISRIC-ISSS 1998) characterised by the following soil properties: sand (2-0.02 mm) 471 g kg^{-1}; silt and clay (0.02-0.002 mm) 529 g kg^{-1}; pH (water) 8.2; cation exchange capacity 456 cmole g^{-1}; total nitrogen (Kjeldal) 1.3 g kg^{-1}; organic matter (Walkley-Black) 23 g kg^{-1}; available phosphorous 17 mg kg^{-1}; and exchangeable potassium 920 mg kg^{-1}.

Before seedbed preparation, the experimental field was equipped with a permanent irrigation system based on buried pipes with Rain-bird Mod. 5004's automatic disappearing rotary sprinklers. The seedbed was prepared at the end of June by ploughing to 35 cm depth with a mouldboard stubble of previous seed of common vetch (*Vicia sativa* L.). Fertiliser (30 kg ha^{-1} of N and 72 kg ha^{-1} P_2O_5) was applied before smoothing the soil with a field cultivator and tine harrow. Plots were 6 m^2 (2 m x 3 m) and arranged in a completely randomised block design with three replications. To avoid invasion of stolons, plots were separated in the long and short side by a 75 cm gap of bare soil. The plot size and alley adopted for establishing the experiment were uniformly used as by NTEP for evaluation trials of the National Bermudagrass Test in the United States and Canada (Gibeault and Aiuto 1999; Hall *et al.* 1999; Morris 2005).

In the first week of July, seeds of nine common bermudagrass varieties were hand sowed at a rate of 2.6 g m^{-2}. In this month the temperature (33-35°C) was, as suggested by Skerman and Riveros (1992), optimal for seed germination and seedling establishment and growth of tropical bermudagrass. The varieties used in the experiment, whose origin, year, selection breeding method and donor are given in **Table 1**, represent the most popular cultivars used for sowing turfgrass lawns around the world. Seed germinability of the varieties used in the experiments was over 95% at floating and visual test.

To avoid interaction between fertilisers and adaptability potential of the varieties, during the 5 years of evaluation all plots received an equal amount and type of fertilizer. Fertilizer applica-

Table 1 Bermudagrass cultivars, breeding method, origin, year and breeder releaser and seed seller.

Variety	Breeding method of release	Origin	Year of release	Breeder	Donor Company
Jackpot	Intercross from old Columbia River clones with those cold-tolerant of Washington State. Plants of two selected lines were pollinate and used for breeder seed production.	USA	1995	Jacklin Seed Company	Jacklin Seed Company Post Falls, Idaho, USA
Mirage	Phenotypic recurrent selection from breeding material derived by intercrossing six highly clones collected from germplasm of the southern and northern State of USA.	USA	1992	Oklahoma Agricul-tural Experimental Station	International Seeds Inc.
Mohawk	Synthetic variety of eight winter dormant and cold tolerant selected clones of cv. 'Vamont' with a repeated cycle of mass selection.	USA	1993	Virginia Turfagrass Research Centre in Arizona	Seeds West, Inc., Company, Arizona
Panama	Interpollination among clones selected by Pure Seed Testing from old turfs. Seed nursery harvest was the lot of the cultivar.	USA	1999	Burcley Research in California	Burenbrug
Pyramid	Intercrossing of Afghanistan self-compatible germplasm for introducing warm blood in the domestic turf grass industry adapted to bermudagrass belt. The cultivar was beaked from breeding material by mass selection.	USA	1996		International Seeds Inc. Company
Shangri-La	Intercrossing among Pure seed Testing from germplasm of Maryland landrace. Breeding germplasm was selected for mass selection for seed vigour and yield, turf quality and cold tolerance.	USA	1995	Pro Seeds of Oregon.	Pro Seeds Marketing, Inc. Company
Savannah	Synthetic cultivar developed among three clones of old cv. 'WA Savannah' crossed with clones of 'Dandridge' old turf.	USA	1997	Pure Seed Testing in Rossville, NC.	Seedland Marketing, Inc. Company
Sultan	Intercross among eight clones selected from old cvs. 'Common' and 'Guymon' turfs subjected to two cycle of phenotypic recurrent selection.	USA	1992	New Mexico Agricultural Experi-mental Station	Farmer Marketing Corporation, Seed West, Inc. Company
Sydney	Polycross among 7 Australian and USA domestic clones of phenotypic recurrent selection for seedling vigour and turf density characteristics.	USA	1996	New Mexico Agricultural Experi-mental Station	Seeds West, Inc. Company

Table 2 Clippings, water irrigations and total water applied by season and year in bermudagrass turf in a Mediterranean environment

Agronomic application	Year				
	2000	2001	2002	2003	2004
	N° clippings				
Spring	6	7	7	7	7
Summer	8	9	7	11	11
Autumn	4	4	4	6	4
Total clippings	18	20	18	24	22
	N° water irrigation				
Spring	10	11	9	15	9
Summer	22	19	18	18	18
Autumn	5	9	4	4	4
Total irrigations	37	39	31	37	31
	mm water applied				
Spring	210	231	189	315	189
Summer	462	399	378	378	378
Autumn	105	189	84	84	84
Total water applied	777	819	651	777	651

tion was made by hand. Nitrogen fertiliser was applied as ammonia nitrate (NO_3, 27 g kg^{-1}) at a rate of 50 kg ha^{-1} of nitrogen three times per year (beginning of March, June and October). Phosphorous (P_2O_5, 46 g kg^{-1} was applied as superphosphate at a rate of 40 kg ha^{-1} of P_2O_5 at the beginning of spring growth. In February the plots were aerated using self-propelled equipment with a hollow-core and 16 mm tines at 60 mm intervals. The resulting cores were removed by sweeping the plot. The amount of water distributed by the irrigation system took seasonal rainfall and Eto from the crop into account. To avoid drought stress during turfgrass growth, water was applied when the topsoil moisture content reached pF 4.0 (80-82% of water holding capacity). The volume of water and the number of waterings applied in the year of evaluation are reported in **Table 2**. During the experiment, dicotyledonous weed encroachment was controlled by appropriate herbicide treatment (Mondak 21 S at rate of 1.5 l ha^{-1}) while the monocotyledonous species were hand pulled.

The procedure of timing and record keeping of traits evaluated in the experiment was uniformized to protocols and guidelines used by NTEP, USA for evaluation in variety trials of bermudagrass turfgrass (Gibeault and Aiuto 1999; Hall *et al.* 1999; Morris 2005). The following traits were assessed on each plot during the five years of evaluation since 2000.

Turf quality. This trait was recorded at monthly intervals from April to November. Establishment, density, texture and uniformity of the turf were visually estimated based on a 1 to 9 scale, where 1 = dormant and 9 = highest quality of ideal turf;

Turf colour. This rating assessed the ability of the variety to hold colour over the period April to November. The rating was on a scale from 1 to 9, where 1 = brown stem and 9 = a dark green coloured stem;

Live ground cover. Living ground cover scores were based on the surface area covered by the shoots. This trait was assessed using a visual estimate of living stems present in the plot. The rating was assigned a score on a scale of 1 to 9, where 1 indicated poor stands (bare soil) and 9 the maximum coverage density. The rating was determined once a month from April to November;

Dormancy. The timing of dormancy was assessed using the colour of shoots from the beginning of the winter vegetative stasis. The colour of stems was visually determined every day from the beginning of December until the colour of the plant was totally brown. At that time the variety was considered dormant. Dormancy was expressed as the number of days from the first of December until the vegetation was dormant;

Spring greenup. This rating measured the transition from winter dormancy to active spring growth. It was based on a visual estimate of plot colour. The trait was expressed as the number of days from the first of April to the day when the tillers in the plot reached normal growth and development (after middle April) and when the plot was completely green;

Density. Turf density was determined in two picks made when the stems of the varieties in the plots completed spring green up (May) and before dormancy (October) by counting the shoots present in a core of 25 cm^{-2} harvested with a homemade circular cutter. After counting the shoots, the core was returned to the plot to plug the turf hole;

Thatch. The thickness of the spongy organic above the soil carpet was determined in the same sample used for counting shoot density. Measurements of thatch were expressed in mm of the organic layer over the soil, following application of the pressure of 40 g cm^{-2} on the thatch surface.

Table 3 Mean squares and significance of turf bermudagrass traits over years of evaluation in a Mediterranean environment.

Source of variation	df	Turf quality [a]			Turf colour [b]			Turf cover [c]		
		Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
Year (Y)	4	3.4**	3.3**	2.3**	5.8**	5.5**	5.1**	2.3**	2.8**	21.3**
Variety (V)	8	0.7**	0.4*	1.1**	0.6 *	0.7 *	0.5*	1.1**	0.5 *	1.3**
Interaction										
Y×V	32	0.2 ns		0.3 ns	0.2 ns	0.2 ns	0.4 ns	0.3 ns	0.7**	0.6*
Pooled error	75	0.3	0.2	0.4	0.3	0.4	0.3	0.4	0.3	0.4

Source of variation	df	Dormancy [d]	Spring greenup [e]	Shoot density [f]		Thatch [g]	
				Spring	Autumn	Spring	Autumn
Year (Y)	4	1.7**	142.6**	1096.8**	1105.4**	3.1**	1.2**
Variety (V)	8	0.21ns	62.8 ns	134.3**	145.8**	0.6 ns	1.2*
Interaction							
Y×V	32	0.07 ns	47.1 ns	36.0 ns	62.8**	0.4 ns	0.3 ns
Pooled error	75	0.3	56.3	20.7	22.9	0.4	0.5

*and **, Significant at the 0.05 and 0.01 probability levels, respectively. ns= not significant
[a]=[b]=[c] Score values from 1 to 9
[d] days from first December
[e] days from first April
[f] Shoots 25 cm^{-2}
[g] mm

Plots were clipped when the turfgrass was 5 cm tall, with a riding triplex mover at a height of 3.5 cm recovering and discarding the clippings.

Prior to ANOVA analysis, data were subjected to Bartlett's test of homogeneity of variance. The traits for the months which presented a null hypothesis not significantly different to Bartlett's were grouped for further statistical analysis. Data of April, May and June in spring; July, August and September in summer; and October and November in autumn were not statistically significant following Bartlett's homogeneity test, thus they were considered as a mean of spring, summer and autumn seasons in the ANOVA analysis.

Statistical analysis was conducted by using PROC ANOVA procedure of SAS (SAS Institute1997). In the model, varieties were analysed according to a split-plot over time with the year of evaluation considered as the main plot. The repeated model has two error terms, one of which is used to test the main plot-factor (year) while the other (the residual term) for the sub-plot factor (variety) and the interaction (year × variety). ANOVA was performed considering varieties as a fixed factor and year as a random factor. Comparisons among varieties were made using the pooled error term (Steel and Torrie 1980).

To identify the variety with the highest adaptability to the environmental conditions, all the parameters recorded across the period of evaluation were analysed according to the Scott and Knott (1974) cluster analysis method for grouping means in the analysis of variance, as described by Gates and Bilbro (1978). The data of each trait over the period of evaluation were grouped according to the null distribution of λ. This statistic, as defined by Edwards and Cavalli-Sforza (1965), when applied to univariate means of data, is a random variable with Student's distribution. Calculation of λ partitions the mean varieties of parameters in groups, for which the inter-group and intra-group showed a maximum and minimum sum square variability, respectively. Analysis of data across the five study years identifies, on the basis of the likelihood ratio test (Gates and Bilbro 1978), two cluster groups. The means within each cluster group never overlap, had minimum mean square interactions and were not statistically significant while the means between clusters were significant at P≥0.05 level of probability.

RESULTS

Analysis of variance revealed significant year and variety effects for all traits (**Table 3**). Autumn presented a lower max temperature than other seasons and the mean square value for all qualitative traits was lower than those of spring and summer seasons (**Table 3**). Turf colour showed a lower mean square among seasons than turf quality and turf cover traits. A statistical significance was observed in the interaction of the year and variety (Y×V) in summer and autumn for turf cover. The only other trait for which the Y×V interaction reached statistical significance was shoot density in autumn.

Table 4 Bermudagrass average parameters over years of evaluation.

Turf trait	Year					Mean	LSD 0.05
	I	II	III	IV	V		
	Score values from 1 to 9						
Turf quality	8.3	7.9	8.4	8.1	7.8	8.1	0.1
Turf colour	6.2	6.1	6.0	6.1	6.3	6.2	0.1
Turf cover	8.1	7.8	8.1	8.2	7.9	8.0	0.1
	Days						
Dormancy	4.9	5.1	5.0	5.2	5.1	5.1	0.2
Spring greenup	4.8	5.0	4.9	5.1	4.8	4.9	0.2
	Shoot density (Shoots 25 cm^{-2})						
May	27.1	23.4	22.2	21.6	29.0	24.6	1.3
September	29.4	28.1	21.2	26.1	30.4	27.2	1.1
	Thatch (mm)						
May	3.0	3.5	3.4	3.7	3.9	3.5	0.3
September	4.8	5.2	4.9	5.0	4.7	4.9	0.2

The rating mean values over the years of evaluation for turf quality, turf colour and turf cover traits (**Table 4**), namely 0.9, 2.8 and 1.0 point, respectively, were discard from the values of the ideal score by evidencing a weather condition affect higher on turf colour than other traits. Furthermore, because the score values of turf quality, turf colour and turf cover traits of the varieties evaluated in the study, in all years were higher than the considered the minimum acceptable score values (6 or over 6 point of score values) by Hall *et al.* (1999) and Morris (2005), they may bee successful used for implanting turf bermudagrass sport field grounds in Mediterranean environments.

The effect of year across the period of evaluation ranged from 7.8 to 8.4, 6.0 to 6.3 and 7.8 to 8.2 respectively, for turf quality, colour and cover traits (**Table 4**). The thatch measurement displayed significant difference between years of evaluation with depth, across the seasons, ranging from 3.0 to 3.9 and from 4.7 to 5.2 mm, respectively for spring and summer observations.

The seasonal average across varieties over the years for turf quality and colour traits showed a higher rating in spring and summer, with respective mean scores 14.1% and 25.6%, than those observed in autumn (**Table 4**).

Autumn was the season which strongly affected turf colour rather than turf quality (**Table 5**). In this season, the colour ratings were lower (16.4%) than those of turf quality. The seasonal variability in varieties for cover was 42.9% and 33.3% lower than those for turf colour and turf quality, respectively. The mean rating of varieties for turf cover in summer was 3.4 and 9.2% wider than the values of spring and autumn, respectively. Winter dormancy and spring

Table 5 Seasonal variety mean values of parameters over 5 years of evaluation in Mediterranean environment.

Bermudagrass	Spring	Summer	Autumn		Spring	Summer	Autumn		Spring	Summer	Autumn	
variety	Turf quality [a]			LSD 0.05	Turf colour [b]			SD 0.05	Turf cover [c]			LSD 0.05
Jackpot	8.5	8.8	7.5	0.6	8.3	8.5	6.2	0.8	8.8	9.0	8.3	0.4
Mirage	8.1	8.6	7.4	0.6	8.2	8.1	6.1	0.8	8.2	8.3	7.6	0.4
Mohawk	8.3	8.5	7.2	0.6	8.1	8.2	6.1	0.8	8.0	8.7	8.0	0.5
Panama	8.6	8.5	7.0	0.7	8.2	8.1	5.9	0.8	8.6	8.7	8.0	0.4
Pyramid	8.7	8.3	7.1	0.7	8.3	8.1	6.0	0.8	8.6	8.6	7.7	0.5
Shangri-La	8.4	8.9	8.0	0.5	8.5	8.7	6.5	0.8	8.4	8.7	8.4	0.3
Savannah	8.4	8.5	7.5	0.5	8.4	8.3	6.0	0.8	8.4	8.6	7.9	0.4
Sultan	7.9	8.5	7.0	0.6	8.1	8.2	5.9	0.8	8.4	8.7	7.8	0.5
Sydney	8.3	8.4	7.1	0.6	8.0	8.0	5.8	0.8	8.6	8.7	8.4	0.3
Mean	8.4	8.6	7.3	8.1	8.2	8.2	6.1	7.5	8.4	8.7	8.0	8.4
LSD 0.05	0.4	0.3	0.4		0.3	0.3	0.3		0.4	0.3	0.4	
(variety × season)	0.6				0.7				0.4			

[a]=[b]=[c] Score values from 1 to 9

Table 6 Seasonal variety mean values of parameters over 5 years of evaluation in Mediterranean environment.

Variety	Dormancy [a]	Spring greenup [b]	Shoot density [c] Spring	Shoot density [c] Autumn	LSD 0.05	Thatch [d] Spring	Thatch [d] Autumn	LSD 0.05
Jackpot	5.2	4.5	22.7	22.3	ns	3.4	4.7	0.8
Mirage	5.0	4.9	22.4	27.8	2.2	3.7	5.1	0.9
Mohawk	5.2	5.2	23.4	28.1	1.9	3.5	4.7	0.8
Panama	5.1	5.0	31.2	32.0	ns	3.6	4.9	0.8
Pyramid	5.1	5.0	21.6	26.1	2.0	3.3	5.5	0.9
Shangri-La	5.1	4.9	26.5	30.0	2.2	3.6	5.1	0.8
Savannah	5.4	4.7	25.8	30.6	2.2	3.8	5.1	0.8
Sultan	5.2	5.1	24.9	25.3	ns	3.4	4.7	0.8
Sydney	5.0	5.2	22.7	22.3	ns	3.3	4.6	0.8
Mean	5.1	4.9	24.6	27.2	1.3	3.5	4.9	
LSD 0.05	0.2	0.3	1.2	2.1		0.3	0.4	

ns= not significant

[a] Days from first December

[b] Days from first April

[c] Stems 25 cm^{-2}

[d] mm

greenup performances showed a modest variability among varieties (**Table 6**). The varieties ‘Jackpot’, ‘Mohawk’, ‘Savannah’ and ‘Sultan’ had later times for the beginning of winter stasis while ‘Jackpot’ and ‘Savannah’ had an earlier spring greenup than other varieties. Shoot density in spring was 9.6% lower than those recorded in autumn. ‘Panama’ was the variety with a higher number of shoots in spring and autumn (21.1 and 15.0%, respectively) than the mean of other varieties. The variability among varieties for depth of thatch across the seasons (8.6% lower in spring than in autumn) showed a different morphological development of the varieties in summer rather than in spring and autumn (**Table 6**).

Analysis of all data was processed according to the Scott and Knott (1974) cluster method identified for each season, and varieties were characterized to have a minimized year × season mean square interaction with meteorological events during the period of evaluation. The number of varieties included in the selected group for the turfgrass traits was dependent on the season of growth (**Table 7**). Spring was the season which presented most varieties in the selected group for all traits than other seasons. The number of varieties belonging to the selected spring group were 4 for both turf quality and colour and 3 for turf cover. The means of the varieties belonging to the selected group for turf quality, colour and cover in spring were 4.7, 3.6 and 4.7% higher than those of the discarded ones, respectively. By contrast, the number of varieties in the selected group for summer and autumn was reduced: 2 varieties in summer (turf quality and turf colour) and 2 in autumn (turf colour and turf cover). The selected group for winter stasis and spring greenup included one (‘Jackpot’) and two varieties (‘Shangri-La’ and ‘Savannah’), respectively (**Table 7**).

Table 7 Average seasonal values of turf parameters in bermudagrass homogeneous groups identified according to the Scott and Knott (1974) method.

Bermudagrass variety	Season		
	Spring [a]	Summer [a]	Autumn [a]
	Turf quality		
Jackpot	8.5	8.8	8.0
Panama	8.6		
Pyramid	8.7		
Shangri-La		8.9	
Savannah	8.4		
Mean selected group	8.6	8.9	8.0
Mean discarded group	8.2	8.5	7.5
	Turf colour		
Shangri-La	8.5	8.7	6.5
Savannah	8.4		
Pyramid	8.3		
Jackpot	8.2	8.5	6.2
Mean selected group	8.4	8.6	6.4
Mean discarded group	6.6	6.7	5.4
	Turf cover		
Jackpot	8.8	8.9	8.3
Panama	8.5		
Sydney	8.6		8.4
Mean selected group	8.5	8.9	8.4
Mean discarded group	8.1	8.1	7.9
	Dormancy [b]		
Savannah	5.1		
Mean selected group	5.1		
Mean discarded group	5.3		
	Spring greenup [c]		
Jackpot			4.5
Savannah			4.7
Mean selected group			4.6
Mean discarded group			5.3

[a] Scale of evaluation: 1 to 9 score

[b] days from first December

[c] days from first April

DISCUSSION

The performance of varieties used in the study exceeded those of advanced and most popular seeded bermudagrass cultivars evaluated at NTEP of the National Bermudagrass Test of the USA (Gibeaut and Autio 1999; Hall *et al.* 1999; Morris 2005). The differences between results of scale values of similar trait reported by Philley *et al.* (1999) in seeded turf bermudagrass cultivars in the four years of evaluations (1995-1998) at Mississippi State University, presented point value scores of the spring greenup, turf quality and cover characteristics, respectively 0.6 lower and 2.4 and 2.0 higher than the scores recorded in **Table 4** of the experiment.

Hall *et al.* (1999) and Morris (2005), following the evaluation of the NTEP bermudagrass test program concluded that a variety with a rating value of trait turf quality, turf colour and turf cover with score ≥6 is considered acceptable for use in a sports field ground or golf course fairway (**Table 5**). One should always bear in mind, though, that the traits of turfgrass are based on a turf evaluator's judgement, and that the score on turf colour trait is assessed only after greenup (specific phenological stage of plant development). The mean value of the score recorded at Foggia (Hall *et al.* 1999) and USA (Morris 2005) was 8.3 and 7.3, respectively for common varieties in experimental fields ('Jackpot', 'Mirage', 'Panama', 'Pyramid', 'Savannah' and 'Shangri-La'). Furthermore, the rating recorded at Foggia was always over a range of 0.3 to 1.0 more than those of the USA (Hall *et al.* 1999). However, the high score values of the three traits recorded in the experiments established at Foggia were evidence that the environmental conditions of the Mediterranean environment were more favourable to the establishment and growth of the same varieties. I conclude, after considering the ratings of quality traits of plant performance in winter, spring, summer and autumn as reported in **Table 5**, that the varieties evaluated may be retained well adapted to Mediterranean climates and may be useful base genetic material for developing improved bermudagrass in this environment for multiple purposes (sports fields, private and public gardens and mats for ecological proposes).

According to studies made on genetic variability by Caetano-anollés (1998), Yerramsetty *et al.* (2005) and Anderson and Wu (2007) using DNA amplification fingerprinting techniques on seeded bermudagrass varieties developed over the past two decades, a narrow genetic basis of diversity across varieties for turfgrass quality and performance characteristics was found. Genetic studies made by Kneebone (1966), Baltensperger *et al.* (1993) and Yerramsetty *et al.* (2005) on the progenitor used in the initial seed industry programme naturalized germplasm from the region along the Colorado river of Arizona and California. A study on genetic relationships by Zhang *et al.* (1999) and Yerramsetty *et al.* (2005) showed the most popular varieties to be very closely related to each other. Furthermore, Caetano-anollés (1998) and Yerramsetty *et al.* (2005) in a study carried out on DNA analysis, reported that the initial low diversity among parental lines may be further reduced by mechanical mixing of seed production fields leading to genetic contamination.

The values for all qualitative parameters observed in spring and summer seasons were favoured by environmental conditions which promote better development of the plants for turf quality, colour and cover traits in all varieties (**Table 5**). These results were in agreement with those obtained by Huang *et al.* (1997a, 1997b) under controlled growth conditions. The authors noted that in their experiments established in a greenhouse and based on four C4 plants (bermudagrass, centipedegrass (*Eremochloa ophiuroides* ([Munro] Hack.), seashore paspalum (*Paspalum vaginatum* Swartz), and zoysiagrass (*Zoysia japonica* Willd.) grown under two soil drying and four rewatering conditions that rewatering after a spate of dry conditions did not influence shoot and root development of bermudagrass. Thus the environmental conditions during the period of vegetative growth of turfgrass (**Fig. 1**) favoured the development of plants with high turf quality, colour and cover traits in all varieties. By contrast, the reduced rating of autumn values for the turf quality and colour traits may be due to the lack of the environmental conditions (reduction of photoperiod and soil and air temperatures) which interfered with the physiological process of plant development (Batten *et al.* 1981; Di Paola *et al.* 1982; Daget 1985; Sinclair *et al.* 2003). The weather factor which most influenced the turf quality of bermudagrass, in agreement with Sinclair *et al.* (2004), was the reduction of photoperiod of daylength which occurred in the autumn months. This assumption was supported by experiments made by Sinclair *et al.* (2004) on four warm-season grasses (bahiagrass (*Paspalum notatum* Flugge), bermudagrass, florakirk bermudagrass (*Cynodon dactilon* var. *elegans*) and florona stargrass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*) grown under field conditions during two seasons of short daylength under a gradient of photosynthetic photon flux density (0.1 to 30 μmol m^{-2} s^{-1}) on plant development. The results of Sinclair *et al.* (2004) experiments clearly showed that physiological processes in plant development were activated after photosynthetic photon flux density was light saturated. Thus, under the limit of light saturation in autumn months, bermudagrass plants have reduced physiological processes during development and turf quality in autumn (**Table 5**).

In the beginning of December as air temperature fell below 10°C all varieties lost their green colour and the plants remained yellow-brown and dormant until April when the soil temperature reached 18°C. This is in agreement with the results reported by DiPaola *et al.* (1982) and Sifers *et al.* (1985), The variability observed among varieties for dormancy and greenup traits was very small. However, the varieties 'Jackpot' and 'Savannah' differed from other species for early spring greenup and late dormancy, respectively (**Table 6**). In agreement with the results of Sifers *et al.* (1985), the min temperature of the winter months (**Fig. 1**) did not apparently injure the physiological activity of the roots system during winter vegetative stasis as shoot numbers and the rating values for turf cover and quality traits in spring were maintained well from year to year.

The mean square variability among seasons in turf qualitative parameters was related to the sensitivity of the trait to climatic parameters. Turf colour presented wider susceptibility across the seasons to climatic conditions than other qualitative characteristics. Turf colour was influenced by light rather than temperature and consequently the trait presented lower mean square variation among season than turf quality and turf cover trait while plant development was influenced mainly by temperature and Eto during the seasons (**Fig. 1**).

The low variability existing for cover in the spring and summer seasons reflected the adaptability of all varieties to the weather conditions experienced during these seasons while the decrease of cover score observed in autumn was a consequence of reduced light and temperature on plant development (**Table 5**).

The reduction of the scores for turf colour in autumn was a consequence of the effects of low seasonal temperatures on green chlorophyll pigments which result in a reduction of photosynthetic activity of the leaves (Moss 1988). The number of varieties in the different cluster groups was related to the magnitude of the variety × season interaction effect. The higher thatch values of summer were apparently a direct reflection of the higher plant development that occurred in this season rather than in others.

The varieties differently adapted to the environmental condition of the year. Among varieties, 'Pyramid' in spring and 'Shangri-La' in summer and autumn were well adapted for turf quality while 'Jackpot' and 'Shangri-La' were well established for cover in all seasons. The variability among varieties for winter dormancy and spring greenup and number of shoot in spring performances, as effect of low variety × environmental interaction, showed a different adaptation to the weather condition of the site. However, the reduction in shoot number in spring (9.6% lower than those of autumn) may be attributed to some stolons buds still being dormant at the time of shoot assessment in spring (**Table 6**).

The variation in number of varieties in the selected group among seasons (wider in spring a lower in summer and autumn) was a consequences of increase of the variety x environmental interaction effect caused by harsh weather conditions (high temperature and reduced rainfall) occurred in the seasons (**Table 7** and **Fig. 1**). Furthermore, the large number of varieties included in the cluster groups of spring parameters, may be due to favourable weather condition for plant development and to the lack of damage of the root system during winter stasis. Because the varieties 'Jackpot', 'Shangri-La' and 'Savannah' were present in the selected cluster group for turf quality traits in all seasons and 'Jackpot' and 'Savannah' in the group of dormancy and spring greenup traits, they may be considered better adapted to cope with the environmental condition of the seasons in the Mediterranean environment.

In conclusion, all the bermudagrass varieties studied were well adapted, demonstrated by turf quality, colour and cover traits in spring, summer and autumn seasons in the Mediterranean climate of the experiment. Furthermore, the results indicate that the inputs required for good turfgrass are less than with alternative species. When the results from this experiment are compared with work of Martiniello and D'Andrea (2006) for cool season turfgrass species (Kentucky bluegrass, tall fescue, perennial ryegrass, chewing, creeping and slender creeping red fescue) with bermudagrass, the number of clippings was reduced by 46.6%, the number of water applications by 38.6% and the total amount water by 36.9%. Considering the values of the turf traits in spring season, winter soil temperature did not damage the morphological organs and the nutritive reserve compounds stored in the root system during winter stasis. On the basis of the variety × environmental interaction, the Scott and Knott (1974) cluster method analysis singled out varieties with the genetic potentiality ('Jackpot', 'Savannah' and 'Shangri-La') to be able to establish bermudagrass lawns with better turf quality and performance during spring, summer and autumn periods in the Mediterranean environment.

CONCLUSIONS AND PERSPECTIVES

The establishment of turfgrass lawns for sports fields, public and home gardens and mats for landscaping in Mediterranean basin environments have constantly been increasing over the last decades. A survey carried out by the Italian National Olympic Committee on lawns used for sports grounds (golf courses, rugby, baseball, softball and football fields) has been increasing annually at a rate of about 3.2% in Italy (Martiniello 2005). However, instead of the ecological, agronomic and economic advantages of bermudagrass lawns, the new green surfaces in areas of Mediterranean zones (UNESCO-FAO 1963) are still being planted with cool season grasses. Several authors agreed on the wider adaptability of available bermudagraas varieties to Mediterranean environments (Volterrani *et al*. 1997; Mieli *et al*. 2000; Croce *et al*. 2001) over other turfgrasses that included cool and warm season grasses. Despite the potential interest of the scientific community in bermudagrass turfgrass rather than cool season grass, the diffusion of lawns made using warm season grasses in Mediterranean environments remains scant. The fail to use bermudagrass in implanting new lawns in Mediterranean environments has been due to a lack of agronomic facilities, specific knowledge and skilled operators able to take care of green surfaces made with bermudagrass.

However, the enhancement of bermudagrass turf in a Mediterranean environment requires an institution similar to that in the USA, the NTEP, which is designed to develop and coordinate uniform trials of bermudagrass to determine the adaptation, performance and characteristics of the cultivars evaluated.

The results of this study make several varieties selected from subtropical and transition zones of the US ('Cheyenne', 'Guymon', 'Jackpot', 'Mirage', 'Mohawk', 'Numex Sahara', 'Panama', 'Primavera', 'Princes', 'Pyramid', 'Savannah', 'Shangri-La', 'Sultan', 'Sydney' and 'Sonesta') available for use, having adapted well in experimental trials established under Mediterranean environments. The varieties used could be the most commonly used for implanting bermudagrass lawns in Mediterranean environments and could also be used as base genetic material for improving local germplasm and for the turfgrass industry for seed production. Moreover, seed availability of adapted bermudagrass varieties in Mediterranean environments represents a perspective for establishing bermudagrass lawns in golf courses and landscaping in Mediterranean countries such as Portugal, Spain, Italy, Greece, Israel, and North African countries.

ACKNOWLEDGEMENTS

Research was funded by the special project "Inerbimenti e tappeti erbosi per la valorizzazione agricola, ricreativa e sportiva del territorio" of the Ministry of Agricultural and Forestry Policy. Paper No. 160. The author thanks the technician Egisto D'Andrea for the assistance given in carrying out the agronomic assessment of the traits in the field experiment.

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