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Impacts of seeding rates of different *Lolium* species on winter overseeding of seashore paspalum in Mediterranean regions: turf quality and suitability for football pitches

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Highlights

- *At different seeding rates in both the autumn and spring, we observed uniform transitions between Lolium species and seashore paspalum warm-season turfgrass.*
- *Tetraploid perennial ryegrass cv. Tetragreen and diploid perennial ryegrass cv. Sun generally performed better than the others for overseeding on seashore paspalum.*
- *75 and 100 g m^{-2} overseeding rates appeared to be the most suitable for optimal turf quality and football playing traits.*
- *The ball/surface and player/surface traits' values of overseeding applications on seashore paspalum were within acceptable limits.*
- *Winter overseeding of seashore paspalum turfgrass improved the visual appearance and suitability for use in football pitches in Mediterranean ecological conditions.*

Abstract

Overseeding is an essential management practice for turf cultivation in winter. Warm-season turfgrasses must be overseeded with cool-season turfgrass in the fall to provide green colour and maintain suitable playing surfaces by preventing wear on the dormant warm-season turfgrass throughout the winter months. The cool-season turfgrass species selected for overseeding affect the success or failure of the process in different ways via interaction with environmental conditions. A 2-year research study was conducted at the experimental areas of the Field Crops Department, Agriculture Faculty, Ege University in Izmir/Turkey during 2016-2018. The objectives of the study were to evaluate the overseeding performances of seashore paspalum cv. Sea Spray with different ryegrass (*Lolium*) species (diploid perennial ryegrass cv. Sun, tetraploid perennial ryegrass cv. Tetragreen, annual ryegrass cv. Axcella, intermediate ryegrass cv. TransAm), and determine the most suitable seeding rates (50, 75, 100 g m^{-2}) for the Mediterranean climate. In the study, the evaluation of turf performance traits such as color, visual turf quality, cover, fall and spring transition was conducted in both years. Additionally, some football playing quality traits, including ball rebound, force reduction, and vertical deformation were measured during the research periods. According to the results, tetraploid perennial ryegrass cv. Tetragreen and diploid perennial ryegrass cv. Sun generally performed better than the others. Concerning the overseeding rate, 75 or 100 g m^{-2} applications are recommended as the most suitable for obtaining good turfgrass quality and football playability.

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Introduction

Turf quality for football pitches is evaluated from several perspectives. For instance, the pitch appearance, *i.e.,* visual turf quality, is essential for those viewing the match in person or on television (Puhalla *et al.*, 2020). According to the Union of European Football Associations (UEFA) guidelines, every pitch should have an excellent visual appearance for the viewers. In addition, it should be level, smooth, and safe for the players, allowing for optimal play (UEFA, 2018). A pitch that does not meet these criteria is an obstacle to optimal performance for the players (Wesson, 2019). Football involves unique physical movements such as rapid start-stops, frequent and sudden changes in direction during the game (Yakich, 2022). For these reasons, the players' safety, performances, and the ball's response directly depend on the hardness, evenness, and homogeneity of the surface of the pitch (Miller, 2004). Turfgrasses affect the playing quality of matches by influencing the ball's roll/rebound or players' bounce and locomotor movements. They also reduce the risk of injury by cushioning impacts. Therefore, the selection of turfgrass species and associated scientific management practices are essential to maintain the quality of the game (Mathew *et al.*, 2021).

The selection of turfgrasses is a significant factor influencing pitch quality because their features vary between species (FIFA, 2010). In addition, this selection is sometimes tricky because some cool-season turfgrass species adapt poorly to summer conditions (high temperatures or low water availability), and drought or heat stress causes a severe decline in pitch quality (Barton and Colmer, 2006). For this reason, warm-season turfgrass species are preferred for football pitches between latitudes 43N and 43S, including some famous, high-capacity stadiums (Lulli *et al.*, 2014). The widespread use of these turfgrass species lies in their great adaptability to wide pH, salinity ranges (Marcum, 1999), high temperature and drought tolerance (Croce *et al.*, 2004), pest resistance, and a high colonization, recuperative ability due to strong indeterminate stolons and/or rhizomes (Turgeon, 2011) and wear tolerance (Brosnan and Deputy, 2009). In these warm areas, bermudagrass is widely used on sports grounds. In addition, certain seashore paspalum (*Paspalum vaginatum* Swartz) cultivars such as Sea Spray, Sea Dwarf, and Sea Isle are suitable for use on athletic fields in place of the hybrid bermudagrass species (Duncan and Carrow, 2000; Brosnan and Deputy, 2009). However, warm-season turfgrasses must be overseeded with cool-season turfgrass in the fall to provide green colour and maintain suitable playing surfaces by preventing wear on the dormant warm-season turfgrass throughout the winter months (Watschke and Schmidt, 1992; Horgan and Yelverton, 2001).

The cool-season turfgrass selected for overseeding largely determines the success or failure of the process. There are some transitional phases to consider when selecting a cool-season turfgrass for overseeding: specifically, ease of fall establishment of the overseeded grass and ease of spring transition back to warm-season turfgrass (Johnson, 1975). The ideal overseeding would be a rapid establishment, high-quality turfgrass, and a smooth transition back to the warm-season turfgrass species (Mazur and Rice, 1999). Each cool-season turfgrass species has positive and negative attributes that affect its overseeding performance (Stier *et al.*, 2020). Ryegrass (*Lolium spp.*) species are the most popular for overseeding purposes (Turgeon, 2011; Fontanier and Steinke, 2017). However, there are some differences in management and turf quality even when using different varieties of the same species (Christians *et al.*, 2016). In addition, overseeding rates play a significant role in the establishment and spring transition (Nelson *et al.*, 2005; Severmutlu *et al.*, 2005).

Overseeding success depends on factors such as selecting cool-season turfgrass varieties compatible with existing turfgrasses, adequate seedbed preparation, optimum timing, suitable seeding rate, post-planting maintenance, and proper handling of the spring transition (Kopec and Umeda, 2015; McCarty, 2018). Since turfgrasses show different growth characteristics in different regions or climatic conditions, these factors should be considered and determined separately for each location. For this reason, the objectives of present study were to evaluate the overseeding performances of seashore paspalum with different *Lolium* species (diploid perennial ryegrass *L. perenne* cv. Sun, tetraploid perennial ryegrass *L. perenne* cv. Tetragreen, annual ryegrass *L. multiflorum* cv. Axcella and intermediate ryegrass *L. perenne* x *L. multiflorum* - *L. hybridum* cv. TransAm) and determine the most suitable overseeding rates (50, 75 and 100 g m^{-2}) for the Mediterranean climate.

Materials and Methods

Site description

The trial was carried out on mature (over four-years-old) and healthy seashore paspalum cv. Sea Spray warm-season turfgrass at the experimental areas of the Field Crops Department, Agriculture Faculty, Ege University in Izmir/Turkey (Latitude 38°27'N and Longitude 27°13'E with an altitude of 26 m above sea level) during the two successive overseeding seasons of 2016/2017 and 2017/2018.

The meteorological data of Izmir Province were obtained from the Turkish State Meteorological Service database (Anonymous, 2022). Monthly mean air temperatures and total precipitations for the study period and long-term (30 years) are presented in Table 1. The experimental area is in the Mediterranean zone of Turkey, with temperate-rainy winters and hot-dry summers. A typical Mediterranean climate was observed during the two successive experimental years. Soil samples from the experimental area were analyzed using standard AOAC methods (AOAC, 2016). The soil at the site was a loamy sand (previously prepared for turf experiments) in texture with the following characteristics: pH 7.8, total $CaCO_3$ 2.450 mg kg^{-1}, total nitrogen 0.22 g kg^{-1}, organic matter 2.439 g kg^{-1}, available phosphorus 2.39 mg kg^{-1} and exchangeable potassium 127 mg kg^{-1}.

Experimental design and treatments

The warm-season turfgrass seashore paspalum (*Paspalum vaginatum* Swartz) cv. Sea Spray was used as plant material. Overseeding treatments were arranged in a split-plot design with three replications. The four species of ryegrass (diploid perennial ryegrass "*L. perenne"* cv. Sun, tetraploid perennial ryegrass "*L. perenne"* cv. Tetragreen, annual ryegrass "*L. multiflorum"* cv. Axcella and intermediate ryegrass "*L. perenne* x *L. multiflorum* - *L. hybridum*" cv. TransAm) were main plots, and three different overseeding rates (50, 75 and 100 g m^{-2}) were subplots. Each subplot sizes were 0.75×2.0 m. The same subplots were used for each treatment during the two successive experimental years.

No seedbed preparation was performed prior to overseeding. Before overseeding applications, the warm-season turfgrass was mown with a Masport 800 ST petrol lawn mower and then was verticutted in two directions to remove excess organic debris (thatch) from the soil-turfgrass interface. All plots were overseeded by hand at the set rates on 15 October in both experimental years. Immediately after overseeding, the plots were topdressed with washed sand at 1.8 kg m^{-2} to enhance the germination rate (Mazur and Rice, 1999). Prior to overseeding, primary fertilizer (Palm Organik; N-P-K: 12-12-12, natural humus 20%, Fe, Zn, Mn) was applied to the plots at a rate of 5 g m^{-2} N. The plots were mowed ten days after overseeding at 4.5 cm cutting height. After establishment, the turf height was maintained at approximately 3 cm for the duration of the study. During the first two weeks after overseeding, the plots were irrigated with potable water using an in-ground sprinkler system to maintain optimum germination/growth of ryegrass species for 10 minutes three times a day. Afterward, the plots were irrigated three times per week to prevent visual moisture stress in the winter and spring seasons (Grossi *et al.*, 2008; Brilman, 2009). After the ryegrass species completely covered the plots and before the beginning of spring growth, the plots were fertilized with a slow-release N source (Azolon Turf Master; N-P-K: 20-5-8, Mg 3%, S 11.5%) twice at a rate of 10 g m^{-2} N. Weeds in the plots were controlled by hand without any herbicide applications. Overseeding treatments were allowed to naturally transition each spring season without the use of chemical or cultural inputs. The plots were sprayed at 15-day intervals in the spring and summer months using various fungicides (Maxim XL 035 FS, Pomarsol Forte 80 WP, and Tachigaren 30 L). Thus, diseases caused by humidity and high temperatures were prevented. No insecticide applications were necessary or carried out throughout this study. The plots were mown regularly in the summer, and irrigation continued regularly, considering the soil moisture. In addition, slow-release fertilizer (Azolon Turf Master; N-P-K: 20-5-8, Mg 3%, S 11.5%) was applied at a rate of 5 g m^{-2} N in June, July, and August.

Data collection

The research was carried out from the date of overseeding application to the end of the spring and the beginning of the summer season. For this reason, the data collection was maintained in the middle of every month during the research periods (October-May), and means were obtained for each year.

The visual turf quality was determined quantitatively using the "FieldScout® GreenIndex+ Turf app and board" developed by Spectrum® Technologies, Inc. (Spectrum Technologies Inc., 2013). One of the ways to assess the health and quality of turf is by evaluating canopy greenness (Trenholm *et al.*, 1999; Bell *et al.*, 2002; Xiong *et al.*, 2007). The primary output of GreenIndex+ Turf is an index (dark green colour index: DGCI) that quantifies the greenness of the turf (Spectrum Technologies Inc., 2013), and there is a strong agreement between DGCI values and visual ratings (Karcher and Richardson, 2003). This is a low-cost method for objectively measuring turf quality and appearance, known as the visual rating (Xiang *et al*., 2017). It provides more precise and quantitative data, unlike traditional visual assessment based on researchers' ratings and requires no turf experience (Bell *et al.,* 2002). The visual turf quality data was determined in the morning to minimize environmental light noise. An iPad Air (Apple, A1474) with the FieldScout® GreenIndex+ Turf application was held approximately 100 cm above the turfgrass canopy, and four pictures of the turfgrass canopy per subplot were taken via the tablet's camera. Then, the application calculated the average visual turf quality with the help of the target board. The visual turf quality is based on a scale of 1 to 9, with 1=being poor and 9=being high-quality (Morris, 2002). A rating of 6 or higher is considered acceptable turf quality (Morris and Shearman, 1998).

The colour values were rated quantitatively using the "FieldScout® TCM 500 Turf Color Meter" developed by Spectrum® Technologies, Inc. based on a 1-9 scale (grass index) as used in NTEP Turfgrass Evaluation Guidelines (Morris and Shearman, 1998). The turf cover values were determined quantitatively by the "Canopeo App" developed by Oklahoma State University, and the data obtained were arranged on a scale of 1-9 (1=no plant or dormant turf, 9=full green coverage). Four measurements were taken within each subplot, and the average colour and turf cover values were obtained.

Ideal overseeding consists of three stages: rapidly establishing a high-quality turf surface with cool-season turfgrass in the fall, maintaining turf quality throughout the dormant period, and provision of a smooth transition back to warm-season turfgrass in the spring (Mazur and Rice, 1999; Turgeon, 2011). The fall and spring transition values were determined using the scoring method on a 1 to 9 scale (1=unacceptable, 5=minimally acceptable, 9=ideal transition) by the researchers.

The traits of football playing quality like ball rebound (cm), force reduction/shock absorption (%) and vertical deformation (mm) were measured on the plots in accordance with FIFA standard football playability tests (FIFA, 2005; Saunders *et al.*, 2011) using "The Club Set items (Club Ramp with Ball Rebound and The Fieldtester)" manufactured by Deltec Equipment BV, Netherlands. In determining the ball rebound trait, a football ball in accordance with the standards (FIFA approved, Adidas Tango Pasadena match ball, size 5, inflated to 0.9 bar, released from a height of 2 m) was used in the study. Four measurements were taken in each subplot in all football playability traits.

Table 1. Monthly mean air temperatures and total precipitations for the study period and long-term (30 years) in Izmir Province/Turkey.

Years		Months												
		1	2	3	4	5	6	7	8	9	10	11	12	X- Σ
Temperature (°C)														
2016	Min.	-2.8	2.2	3.1	9.4	11.5	15.3	21.1	20.8	13.6	10.5	3.8	-1.0	-
	Max.	21.3	27.0	25.8	30.7	33.3	39.7	38.6	37.9	35.2	29.5	27.3	16.5	-
	Avg.	8.1	13.9	13.3	19.0	20.7	27.5	29.3	28.9	24.7	19.5	14.3	8.3	19.0
2017	Min.	-2.6	-0.6	3.7	6.2	13.7	17.6	20.3	21.4	16.2	10.4	4.0	3.3	-
	Max.	17.4	19.9	24.8	30.0	32.8	39.8	41.3	39.2	38.5	29.1	23.8	21.0	-
	Avg.	6.7	10.8	13.4	16.4	21.5	26.3	29.0	28.6	24.5	18.5	13.5	11.8	18.4
2018	Min.	1.6	5.2	3.6	8.9	13.6	16.2	20.4	22.3	17.2	6.5	6.9	1.8	-
	Max.	17.1	20.0	23.7	30.7	34.1	38.1	37.9	38.7	34.3	27.6	25.8	18.1	-
	Avg.	9.4	12.4	15.8	19.1	23.8	26.2	28.8	29.0	25.4	19.5	15.4	9.3	19.5
LT	Min.	-6.4	-5.0	-3.1	0.6	7.0	10.0	16.1	15.2	10.0	5.3	-0.1	-4.0	-
	Max.	21.4	23.8	30.5	32.2	37.5	41.3	42.6	43.0	40.1	36.0	30.3	25.2	-
	Avg.	8.8	9.5	11.7	15.8	20.8	25.6	28.0	27.6	23.6	18.8	14.1	10.5	17.9
Precipitation (mm)														
2016	Total	232.2	85.1	122.0	28.4	37.1	2.8	0.0	0.4	8.6	0.5	114.8	20.2	652.1
2017	Total	283.7	45.0	122.7	20.3	45.7	3.3	0.0	0.1	0.0	61.3	62.0	110.7	754.8
2018	Total	97.5	131.6	51.6	3.9	21.9	12.7	0.0	0.8	4.5	42.5	76.9	112.0	555.9
LT	Total	121.0	101.9	74.3	47.0	29.3	8.3	2.0	2.2	15.7	44.3	95.0	144.1	685.1

LT, Long-term; Avg, average; Min, minimum; Max, maximum; X, mean; Σ: total.

Data analysis

Data were statistically analyzed using the PROC MIXED model with SAS/STAT software version 9.3 (SAS Institute, 2012) to determine significant treatment effects. Species, seeding rate, and year were fixed effects, whereas block was a random effect (SAS Institute, 2012). Before the analysis, variables were tested for the normality of data and based on those results, no data transformations were performed. According to the analysis of variance (ANOVA) results, data were combined over treatments and years, and the main effects were presented. Probabilities equal to or less than 0.05 were considered significant. If ANOVA indicated differences between treatment means, the least significant difference (LSD) test at P<0.05 was used for mean separation (Johnson and Bhattacharyya, 2019).

Results and Discussion

Colour

The turf colour findings are summarized in Table 2. Statistical analysis indicated significant differences in the species, seeding rates, and years (P<0.05). On the other hand, their interactions were found to be non-significant in the present study. The best turf colour values were obtained from tetraploid perennial ryegrass cv. Tetragreen and diploid perennial ryegrass cv. Sun plots (7.10 and 7.08 score, respectively), while the lowest colour value was recorded in annual ryegrass cv. Axcella (6.24 score). According to seeding rates, the rate of 100 g m^{-2} ranked best. The lowest colour values were recorded from the rate of 50 g m^{-2}. The turf colour values were significantly higher in the first year (6.94 scores) than in the second year (6.77 scores).

The colour is a desirable feature in turf areas for agronomic and physiological purposes (Kroon and Knops, 1990; Willems *et al.*, 1993). It is also a significant component of aesthetic quality (Karcher and Richardson, 2003). The development of warm-season turfgrass species slows when the air temperature decreases below 15°C and stops entirely if it is below 10°C (Duble, 1996; Stier *et al.*, 2020). This period is defined as winter dormancy, which is evident in the form of yellowing. With temperatures rising above 10°C, warm-season turfgrass species form green tissues again (Beard, 1973; Turgeon, 2011). The colour values were assigned monthly, from October to May, using a visual scale of 1-9 (1=straw, 9=darkest possible) and were separately calculated as the average of the overseeding periods in each research year. According to the scale of 1-9 score, the average colour values obtained from the measurements during both overseeding periods varied between 6.18 and 7.19 scores (data not shown). These colour value differences were primarily due to the different colour values of the *Lolium* species used in overseeding (Gómez de Barreda *et al.*, 2012). Plots overseeded with annual ryegrass cv. Axcella had a lighter green colour than the other *Lolium* species in winter and spring (data not presented). Other *Lolium* species achieved values close to each other in both research years. The present colour findings of perennial ryegrass were similar to the previous study conducted in Mediterranean ecological conditions (Salman, 2021). In addition, similar colour values were obtained in all seeding rates since *Lolium* species used in overseeding were allowed to grow at optimum growth and development temperatures due to their seeding in ideal climatic conditions. On the other hand, the significant differences in the second year regarding overseeding rates were obtained since the second year's temperature values (in December, especially) were higher than the first year. Seashore paspalum warm-season turfgrass entered the dormancy period when compared to the first year. Therefore, different com-

Table 2. Colour, visual turf quality, cover, fall and spring transition traits of overseeded *Sea Spray* seashore paspalum turfgrass with different ryegrass species.

Treatments	Colour (1-9 score)	Visual turf quality (1-9 score)	Cover (1-9 score)	Fall transition (1-9 score)	Spring transition (1-9 score)
Species (S)					
Annual ryegrass cv. Axcella	6.24^c	6.02^d	8.25^c	8.37^a	7.40^c
Diploid perennial ryegrass cv. Sun	7.08^a	8.52^b	8.43^b	7.93^c	8.73^a
Tetraploid perennial ryegrass cv. Tetragreen	7.10^a	8.68^a	8.55^a	8.05^b	8.60^b
Intermediate ryegrass cv. TransAm	7.02^b	8.38^c	8.50^a	8.08^b	8.57^b
Means	6.86	7.90	8.43	8.11	8.33
Seeding Rates (R)					
50 g m^{-2}	6.81^b	7.43^c	8.16^c	7.80^c	8.50^a
75 g m^{-2}	6.87^a	8.06^b	8.53^b	8.23^b	8.30^b
100 g m^{-2}	6.90^a	8.21^a	8.61^a	8.30^a	8.18^c
Means	6.86	7.90	8.43	8.11	8.33
Years (Y)					
1st Year	6.94^a	7.82^b	8.34^b	8.12	8.23^b
2nd Year	6.77^b	7.98^a	8.53^a	8.10	8.42^a
Means	6.86	7.90	8.43	8.11	8.33
ANOVA					
S	**	**	**	**	**
R	**	**	**	**	**
Y	**	**	**	ns	**
S × R	ns	*	**	ns	ns
S × Y	ns	**	ns	ns	**
R × Y	ns	ns	ns	**	*
S × R × Y	ns	ns	ns	ns	ns

*P<0.05; **P<0.01. [a,b,c]Means followed by different letters are significantly different (p<0.05) according to LSD's test. ANOVA, analysis of variance; ns, not significant. 1st Year: 2016-2017; 2nd Year: 2017-2018.

petition conditions emerged according to different overseeding rates of *Lolium* species. This situation affected the colour values and other traits in the following months.

Visual turf quality

The statistical results related to visual turf quality are given in Table 2. Statistical analysis showed significant differences between species, seeding rates, years, and SxR and SxY interactions, while RxY and triple interactions were found to be non-significant (P<0.05). The best visual turf quality values were determined from tetraploid perennial ryegrass cv. Tetragreen plots (8.68 scores). The lowest visual turf quality values were recorded from annual ryegrass cv. Axcella plots (6.02 scores) in the present study. Regarding seeding rates, the best scores were determined from the rate of 100 g m^{-2} overseeding applications (8.21 scores), while the lowest values were obtained from the rate of 50 g m^{-2} (7.43 scores). The second year's average visual turf quality value (7.98 scores) was higher than the first year's (7.82 scores).

According to the measurements performed with the FieldScout GreenIndex+ Turf app and board, all average visual turf quality values except annual ryegrass cv. Axcella in the first year were above the minimum acceptable level of 6.0 reported by Morris and Shearman (1998). Utilizing higher overseeding rates enhanced visual turf quality values of *Lolium* species. Intermediate ryegrass cv. TransAm demonstrated that it is similar to diploid perennial ryegrass cv. Sun in visual turf quality. The data also indicated that tetraploid perennial ryegrass cv. Tetragreen had the highest visual turf quality of *Lolium* species. A significant component of the turfgrass quality ratings is differences in turfgrass colour (Richardson *et al.*, 2007). Annual ryegrass tends to have a less desirable, lighter green colour than other overseeding species (Zhang *et al.*, 2008). As expected, the present research resulted in lower visual turf quality of annual ryegrass cv. Axcella (Gómez de Barreda and Rivero, 2008; Fontanier and Steinke, 2017).

Regarding the overseeding rate, visual turf quality tended to increase as the seeding rate increased. Researchers reported that higher seeding rates could improve turf quality and related traits similar to the present findings regarding similar cool-season turfgrass species (Minner *et al.*, 2008; Hoiberg *et al.*, 2009; Bornino *et al.*, 2010; Harper *et al.*, 2016). On the other hand, since the minimum acceptable visual turf quality values of all treatments were 6.0 and above, it is recommended to increase the overseeding rate considering the intended use of turf areas and especially the additional seed costs.

Cover

Our findings regarding turf cover are summarized in Table 2. Data showed significant differences in the species, seeding rates, years, and SxR interaction, whereas other interactions were non-significant (P<0.05). The best cover values were obtained from tetraploid perennial ryegrass cv. Tetragreen and intermediate ryegrass cv. TransAm plots (8.55 and 8.50 scores, respectively) in the research. In contrast, the lowest cover values were recorded from annual ryegrass cv. Axcella plots (8.25 scores). On the other hand, the 100 g m^{-2} seeding rate was ranked first with a score of 8.61. The lowest values were obtained from the rate of 50 g m^{-2} overseeding applications (8.16 scores). Regarding the year effect, the turf cover values of the second year (8.53 scores) were higher than the first year (8.34 scores).

Some cool-season turfgrass species can negatively affect turf quality during and after the transition to the warm-season turfgrass species because of their highly competitive ability in overseeding applications in spring and early summer (Foy, 1998). Overseeding applications on seashore paspalum, which emerged from dormancy with the warming of the weather in spring and is known to have the very high competitive ability, showed very successful results in the previous research (Duncan and Carrow, 2005; Demiroglu Topcu and Ozkan, 2016). In the present study, a homogeneous transition occurred between *Lolium* species which started to disappear with the spring transition, and seashore paspalum, which increased in the environment. Therefore, it was concluded that no gaps were formed in plots, and high coverage degrees were maintained during overseeding periods in all treatments. The tetraploid perennial ryegrass and intermediate ryegrass were the species that consistently produced the highest turfgrass coverage in the present study, identical to earlier research results that compared other ryegrass species and cultivars (Richardson, 2004). On the other hand, high levels of turfgrass density or turf cover reduce the risks of injury in sports fields (Chomiak *et al.*, 2000; Dest and Ebdon, 2011; Straw *et al.*, 2018). The present turf cover findings revealed that all overseeding treatments on seashore paspalum could contribute to the safety of players and football playability in the winter season.

Fall transition

The fall transition findings are summarized in Table 2. According to statistical analysis, SxR, SxY, and triple interactions and years were non-significant in the present study. In contrast, significant differences were found between species, seeding rates, and RxY interaction (P<0.05). The best fall transition values were obtained from annual ryegrass cv. Axcella plots (8.37 scores), while the lowest values were recorded from diploid perennial ryegrass cv. Sun plots (7.93 scores). According to seeding rates, the best fall transition values were determined from the rate of 100 m^{-2} overseeding applications (8.30 scores). On the other hand, the lowest values were obtained from the rate of 50 g m^{-2} overseeding applications (7.80 scores).

To achieve an effective and successful overseeding, an application should be imposed in the fall season when the competitive strength of the warm-season turfgrass species is comparatively limited, especially in fall. Only in this way an ideal fall transition occurs, in which the overseed cool-season turfgrass plants cover the area entirely and homogeneously as soon as possible (Beard, 1973; Beard, 2002). However, a very slow or delayed fall transition in the overseeding application areas prevents the growth and development of the cool-season turfgrass plants due to the competition with the warm-season turfgrass plants. This phenomenon causes these cool-season turfgrasses to enter the winter season without developing sufficiently. Additionally, the limited growth of plants can cause some adverse effects on cool-season turfgrass plants in winter. Among these disadvantages, a decrease in cover and colour values can reach severe levels (Foy, 1998; Longer, 2000; Askew, 2010). The annual ryegrass showed the highest fall transition values as it grows faster and produces more shoots (Rossini *et al.*, 2019). Therefore, it performed favorably and was superior to all other overseeding species. On the other hand, fall establishment time tends to decrease with higher seeding rates. For this reason, 100 gr m^{-2} overseeding applications had the highest scores in terms of fall transition traits.

Spring transition

The statistical results related to the spring transition are arranged in Table 2. The results of statistical analysis indicated significant differences between species, seeding rates, years, and SxY and RxY interactions, whereas SxR and triple interactions were non-significant (p-value < 0.05). Regarding the spring transition values in the present study, the best values were obtained from diploid perennial ryegrass cv. Sun plots (8.73 scores). The lowest values were recorded from annual ryegrass cv. Axcella plots (7.40 scores). In terms of seeding rates, the best scores were determined from the rate of 50 g m^{-2} overseeding applications (8.50 scores). On the other hand, the lowest values were obtained from the rate of 100 m^{-2} overseeding applications (8.18 scores). Moreover, the spring transition average value of the second year (8.42 scores) was found to be slightly higher than the first year (8.23 scores).

The highly competitive ability of cool-season turfgrass species in the spring and early summer periods can negatively affect turf quality during and after the transition to warm-season turfgrass (Foy, 1998). Therefore, the timing of the spring transition is crucial. A transition that occurs too quickly or too early can create gaps in the warm-season turfgrass cover, causing a visually poor appearance (Horgan and Yelverton, 2001). On the other hand, the fact that cool-season turfgrasses do not disappear from the area in the spring-summer causes the self-renewal period of warm-season turfgrasses to be limited in the summer months. Warm-season turfgrasses need an average of 100 days for adequate growth and development. Otherwise, they will weaken and disappear from the environment (Beard, 1973; Yelverton, 2005; Askew, 2010). On the other hand, to offset the poor late spring appearance of annual ryegrass alone, like the present results, mixtures containing annual and perennial ryegrass have been used to improve spring transition timing for winter overseeding (Chalmers and Singh, 2005). Our results are in agreement with previous literature.

Cool-season turfgrass species are often overseeded into warm-season turfgrass for aesthetics and functionality during winter. However, when the overseeded turfgrass persists beyond the spring, it becomes a weed (Serensits *et al.*, 2011). Therefore, seeding rates play a significant role in overseeding establishment and spring transition. Furthermore, with the higher overseeding rates, increased competition caused by the greater density of cool-season turfgrasses also tends to increase spring transition time (Gómez de Barreda, 2010; Christians *et al.*, 2016). The results of the present study were consistent with the research described above.

Ball rebound

The ball rebound findings are summarized in Table 3. Statistical analysis showed significant differences between species, seeding rates, and years, whereas their interactions were non-significant (P<0.05). The highest ball rebound values were determined from diploid perennial ryegrass cv. Sun plots (77.76 cm) in the present study. The lowest values were recorded from annual ryegrass cv. Axcella plots (69.16 cm). On the other hand, considering the seeding rates effects, the highest values were determined from the 100 g m^{-2} overseeding applications (75.92 cm). In comparison, the lowest values were obtained from the rate of 50 g m^{-2} overseeding applications (71.59 cm). Furthermore, the ball rebound values were significantly higher in the second year (74.63 cm) than in the first year (72.82 cm).

Different turfgrass species generate sports surfaces with different playing characteristics (Orchard *et al.*, 2005., Chivers, 2008; Lulli *et al.*, 2014). Therefore, some ball/surface and player/surface traits were investigated in the present research. As the ball rebound trait plays an essential role in footballers' possession of the ball during the game, it is desired to be within specific limit ranges. Baker and Canaway (1993) describe that these limits are determined under British conditions. The ball rebound feature is determined as a percentage (%) of the drop height of the ball in the British system. However, other European countries have accepted

Table 3. Some football playability traits of overseeded *Sea Spray* seashore paspalum turfgrass with different ryegrass species.

Treatments	Ball rebound (cm)	Force reduction (%)	Vertical deformation (mm)
Species (S)			
Annual ryegrass cv. Axcella	69.16^{d}	68.24^{a}	6.82^{a}
Diploid perennial ryegrass cv. Sun	77.76^{a}	65.22^{c}	6.12^{d}
Tetraploid perennial ryegrass cv. Tetragreen	72.66^{c}	66.63^{b}	6.19^{c}
Intermediate ryegrass cv. TransAm	75.32^{b}	66.51^{b}	6.25^{b}
Means	73.73	66.65	6.35
Seeding Rates (R)			
50 g m^{-2}	71.59^{c}	68.38^{a}	6.15^{c}
75 g m^{-2}	73.66^{b}	66.55^{b}	6.36^{b}
100 g m^{-2}	75.92^{a}	65.02^{c}	6.53^{a}
Means	73.73	66.65	6.35
Years (Y)			
1st Year	72.82^{b}	66.19^{b}	6.28^{b}
2nd Year	74.63^{a}	67.11^{a}	6.41^{a}
Means	73.73	66.65	6.35
ANOVA			
S	**	**	**
R	**	**	**
Y	**	**	**
S × R	ns	ns	ns
S × Y	ns	ns	ns
R × Y	ns	ns	ns
S × R × Y	ns	ns	ns

*P<0.05; **P<0.01. ^{a,b,c}Means followed by different letters are significantly different (p<0.05) according to LSD's test. ANOVA, analysis of variance; ns, not significant. 1st Year: 2016-2017; 2nd Year: 2017-2018.

different international borders under FIFA (2005). In FIFA standards, it is a more objective and easily measurable criterion since it is determined as the highest point (60-85 cm range for natural turf) the ball can rise after jumping. Factors such as rainfall or irrigation conditions, turf types or weakness of turf cover, and mowing heights are the most critical factors affecting the ball rebound (Canaway, 1984; Orchard, 2002; Grossi *et al.*, 2004; FIFA, 2009a; Saunders *et al.*, 2011; Avcioglu *et al.*, 2013; Kir *et al.*, 2014). For example, ball rebound values of 60-65 cm are measured in turf areas with sufficient soil moisture and strong-dense turf texture, while values of 80-85 cm are observed in less well-grown but acceptable turf conditions (Grossi *et al.*, 2004). According to diploid perennial ryegrass cv. Sun and intermediate ryegrass cv. TransAm, which have thinner shoots, lower ball rebound values were obtained from annual ryegrass cv. Axcella and tetraploid perennial ryegrass cv. Tetragreen plots because of their wider shoots, very dense and strong turf covers. In addition, the present results varied between the acceptable lower and upper limits (60-85 cm) of FIFA standards.

Force reduction

Our findings regarding force reduction values are summarized in Table 3. In this part of the study, all interactions were found to be non-significant (P<0.05). On the other hand, species, seeding rates, and year effects were significant. The highest force reduction values were obtained from annual ryegrass cv. Axcella plots (68.24%), whereas the lowest values were recorded from diploid perennial ryegrass cv. Sun plots (65.22%). According to seeding rates, the highest force reduction values were determined from the 50 g m^{-2} overseeding applications (68.38%). In addition, the lowest values were obtained from the rate of 100 g m^{-2} overseeding applications (65.02%). Moreover, the force reduction average value of the second year (67.11%) was found to be higher than the first year (66.19%).

Turfgrass species differ in their mechanical properties (Orchard *et al.*, 2013). As a result, some species may affect football players' safety, increasing the risk of injury (Orchard *et al.*, 2005). Force reduction trait is also referred to as the *shock absorption* of the turf surface. Shock absorption is defined as a measure of the ability of the turfgrass to absorb a part of the force on it, which is related to the hardness or softness of the turf (Rogers, 1988). Hard grounds can damage joints (ankle, hip, and spine) and cartilages in the human body and cause bruising in soft tissues or muscles (Saunders *et al.*, 2011; Baker and Canaway, 1993; Kir *et al.*, 2019). For this reason, the human body should also act as a spring on the surface it touches (Orchard, 2002). In effect, higher values (%) mean softer surfaces. Therefore, the force reduction value of turf is desired to be at the level of 60-70% in an optimal natural turf area. The acceptable lower limit of this value is reduced by up to 55% in relatively low-quality turf areas (Brosnan *et al.*, 2009).

The differences in force reduction values in turf surfaces can be caused by cover, texture, or turf quality features. A high turf density can also absorb the pressure forces to a great extent (Cockerham *et al.*, 1989; Cockerham *et al.*, 1998; Lulli *et al.*, 2004). In addition, there is a significant relationship between ground hardness and the game's speed. Faster speeds occur on hard grounds (Norton *et al.*, 2001; Otago *et al.*, 2007). The force reduction values are lower on hard surfaces such as strong turf density or wide leaf texture. Therefore, the ball rebound also occurs more. The present results related to force reduction were similar and inversely proportional to our ball rebound findings. This situation occured since the different *Lolium* species used in overseeding applications had significant morphological differences. On the other hand, the force reduction values tended to decrease due to the increased turf density as the overseeding rate increased. In addition, overseeding applications on seashore paspalum in the Mediterranean ecology were within acceptable limits (60-70%) for force reduction traits. The present findings were similar to previous studies of playing surface quality (ASTM, 2007; Baker *et al.*, 2007; Maxey *et al.*, 2022).

Vertical deformation

The statistical results related to vertical deformation are arranged in Table 3. The results found significant differences between species, seeding rates, and years, whereas their interactions were non-significant (P<0.05). The highest vertical deformation values were determined from annual ryegrass cv. Axcella plots (6.82 mm) and the lowest values were recorded from diploid perennial ryegrass cv. Sun plots (6.12 mm). Regarding seeding rates, the highest values were determined from the 100 g m^{-2} overseeding applications (6.53 mm). However, the lowest values were obtained from the 50 g m^{-2} overseeding applications (6.15 mm) in this study. On the other hand, the vertical deformation values were significantly higher in the first year (6.41 mm) than in the second year (6.28 mm).

An extremely deformed surface is unstable on football pitches and directly affects the footballers' running and playing style. They feel obligated to keep themself safe by shortening their steps and decreasing running speed. On the other hand, an unsafe movement environment occurs on the undeformed ground, which also disturbs the football player due to hardness and slippages (Orchard, 2002). Therefore, a vertical deformation that varies within certain limits is desired on football pitches. The 4-8 mm vertical deformation range is considered ideal for high-quality pitches in FIFA standards. The 9 mm vertical deformation is the upper limit on sports fields. In addition, the surfaces with deformation values of 10 mm and above are defined as extremely risky (indented-protruding=corrugated) (Baker and Canaway, 1993; FIFA, 2009b).

Ideal playing quality values are obtained in sports fields consisting of turfgrass types that can adapt to the ecology and form a good turf cover (Grossi *et al.*, 2004). According to the present findings, vertical deformation values were obtained between the FIFA standards' lower and upper limit values in all overseeding applications on seashore paspalum. The vertical deformation values varied due to the different features (especially the texture) of the *Lolium* species. The plots were not used as intensely as football pitches during the research periods. However, all overseeding applications performed on seashore paspalum formed stable surfaces in the Mediterranean climate.

Conclusions

The turf species used for overseeding should have attributes that can maintain plant density and colour traits during the winter season and gradually leave the area during the spring transition period with the increased air temperature. According to the results, tetraploid perennial ryegrass cv. Tetragreen and diploid perennial ryegrass cv. Sun generally performed better than the others for overseeding on seashore paspalum in terms of turf and playing quality traits. Concerning the overseeding rate, 75 and 100 g m^{-2} appeared to be the most suitable for obtaining a good turfgrass quality and football playability. This study demonstrated that winter overseeding application is useful on seashore paspalum for football pitches' turf quality and other playability traits in the

Mediterranean climate. However, long-term effects need to be observed and further specific research conducted concerning other cultivars of *Lolium* species or different turf management practices.

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