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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Seasonal Quality of Some Cool-Season Turfgrass Species in Cold Semi-Arid Climate

Bazı Serin İklim Çim Türlerinin Soğuk Yarı-Kurak İklimde Mevsimsel Kalitesi

Onur İLERİ[1*], Yasin ALTAY[2], Ali KOÇ[3]

Abstract

The study was carried out to determine winter hardiness, establishment speed, and seasonal variation in quality characteristics of some turf cultivars belonging to the common cool-season turf species in cold semi-arid climates. Nineteen different cultivars of perennial ryegrass, tall fescue, red fescue, Chewing's fescue, slender creeping red fescue, and Kentucky bluegrass were examined for six seasons in 2014-2016 years. The experiment was arranged in a randomized complete block design with three replications. The score-based measurements of turf texture, color, and general quality were taken in the middle of every season (2 summers, 2 springs, and 2 falls) for 2 years and the data were analyzed using non-parametric tests. Results showed that Stravinsky (perennial ryegrass) and Cardinal (red fescue) greatly lost their dark green color in autumn, while SR8600 (tall fescue) kept its satisfying green color. General quality decreased as the seasons proceeded, but Rosita (slender creeping red fescue) remained in high quality considering other red fescue species. Low adaptation ability was observed in Miracle and Evora cultivars of Kentucky bluegrass species due to their poor winter hardiness scores. These cultivars are also the slowest establishing among other cultivars. Results stated that Stravinsky, Esquire, Kokomo, Grandslam2 (perennial ryegrass), Maximal (red fescue), and Rosita (slender creeping red fescue) maintained high quality throughout summer and spring but decreased in autumn. However, Forte (tall fescue) and Evora (Kentucky bluegrass) presented better quality in autumn but the quality of Evora decreased in the next year. These cultivars should be used in a mixture to maintain high-quality turf through spring, summer, and autumn but Evora could require overseeding in some years. More and especially newly released cultivars should be tested to increase the turf quality of the mixtures.

Keywords: Cool-season, Cultivars, Seasonal variation, Turf quality, Turf species

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Öz

Bu çalışmada bazı yaygın serin iklim çim türlerine ait çeşitlerin yarı-kurak iklim koşulları altında kışa dayanıklılık tesis olma hızı ve çim kalitesi özelliklerinin mevsimsel değişimleri incelenmiştir. Çok yıllık çim, kamışsı yumak, kırmızı yumak, rizomlu kırmızı yumak, narin kırmızı yumak ve çayır salkımotu türlerine ait 19 farklı çeşit 2014-2016 yılları arasında incelenerek 6 mevsimde veri toplanmıştır. Deneme şansa bağlı tam bloklar deneme deseninde üç tekerrürlü olarak tasarlanmıştır. Çim tesisinde tekstür, renk ve genel kalite değerlerini belirlemek için skor temelli gözlemler her mevsimin (2 yaz, 2 güz, 2 bahar) ortasında yapılmıştır. Elde edilen skor verileri parametrik olmayan testler kullanılarak analiz edilmiştir. Bulgular tüm çeşitlere ait çim kalite özelliklerinin farklı mevsimsel değişim gösterdiğini ortaya koymuştur. Stravinsky (çok yıllık çim) ve Cardinal (kırmızı yumak) çeşitleri güz mevsiminde koyu yeşil renk özelliklerini büyük oranda kaybederlerken SR8600 (kamışsı yumak) çeşidi aynı mevsimde yeşil rengini korumuştur. Genel kalite yıl içerisinde bahardan güze doğru azalış eğilimde olurken Rosita çeşidi diğer kırmızı yumak çeşitlerine göre yüksek kaliteli tesis özelliğini korumuştur. Çayır salkımotu türüne ait Miracle ve Evora çeşitlerinin özellikle çok düşük kış dayanımı skorları nedeniyle yarı-kurak iklime adaptasyon yeteneklerinin çok düşük olduğu görülmüştür. Bu çeşitler aynı zamanda en yavaş tesis olmuşlardır. Stravinsky, Esquire, Kokomo, Grandslam2 (çok yıllık çim), Maximal (kırmızı yumak) ve Rosita (narin kırmızı yumak) çeşitleri bahar ve yaz mevsimi boyunca yüksek kaliteli tesis oluştururken güz ile birlikte görsel kalitede düşüşler tespit edilmiştir. Çayır salkım otu (*Poa pratensis*) türünün Forte ve Evora çeşitleri ise güz mevsiminde yüksek kalitede kalmışlardır ancak Evora çeşidinin kalitesi tesis sonrası 2. yılda düşüşe geçmiştir. Sonuçlar yıl boyu yüksek kalitede çim tesisi oluşturmak için bu çeşitlerin karışımlar halinde kullanılmasının daha uygun olduğunu göstermektedir. Evora çeşidi karışıma dahil edildiğinde 2. yıl üstten tohumlama yapılması gerekli görülmektedir. Karışımlarla tesis edilen çim alanların yarı-kurak iklimlerde yıl boyu yüksek kalitede tutulabilmesi için yeni tescil olan çeşitlerin de denenmesi faydalı olacaktır.

Anahtar Kelimeler: Çeşit, Çim kalitesi, Çim türleri, Mevsimsel değişim, Serin iklim

1. Introduction

The stress of daily life is challenging modern society in big cities and they are seeking greenness, especially turf areas, to blow off steam. These areas mostly consist of grasses and besides increasing the quality of human life (Russi et al., 2004; Ayanoglu and Orta, 2019), turf grasses are also fundamental for recreational areas, sports fields, landscapes, (Braun et al., 2021), and even for the conservation of soil from erosion (Ahn and Choi, 2013). Many other benefits were also stated by researchers as increasing the value of the property, providing aesthetics and cooling, mitigating runoff in urban, absorbing noise and pollutants, etc. (Stier et al., 2013; Monteiro, 2017; Balci and Orta, 2018). With the advancing civilization, turf areas are increasing in cities, and ensuring the high quality of these areas all year round is one of the most challenging issues for turf managers.

Maintaining high-quality turf is an issue where temperature significantly changes within a year like in temperate climates. In such areas, the seasons are generally distinct and the visual quality of turf grasses, especially color, may decline critically in response to a significant decrease or increase in temperature (Pinnix et al., 2018; Chen et al., 2021). Plant color is associated with chlorophyll content (Zhang et al., 2020) and high or low temperatures could cause dormancy in turf grasses, which leads to a decrement in leaf chlorophyll content (He and Huang, 2010). The turf quality of the species could seasonally change due to climatic variations, even among the cool-season species (Prokopiuk et al., 2019). Besides, Kir et al. (2010) indicated this seasonal variation in turf quality could differently occur among cultivars of the cool-season turf species. Therefore, turf performances of new cultivars could be investigated all year round.

Changing climate challenges all plants including turf species and thereby, the response of the species could change both spatially and temporally in the same ecology (Hatfield, 2017). Climatic variations triggered the release of new turf cultivars through increased breeding studies in the past decade, especially in countries like the USA, Canada, and the UK, where the turf industry advanced (Martiniello and D'Andrea, 2006; Meyer et al., 2017). There are plenty of turf species and cultivars in the market and the adaptation abilities of these species and cultivars should be tested under various environments because genotype × environment interaction significantly affects the turf quality (Russi et al., 2004; Gouveia et al., 2020). Turf managers prefer cultivars that are slowly growing, require low inputs, are tolerant of diseases, and are maintaining high quality (Hull et al., 1994; Christians et al., 2016). Cultivars belong to the cool-season species such as perennial ryegrass (PR), red fescue (RF), tall fescue (TF), and Kentucky bluegrass (KB) are highly preferred due to their high quality in Mediterranean countries (Martiniello and D'Andrea, 2006), North Europe (Sampoux et al., 2013), USA (Bonos and Huff, 2013), and in Turkey (Kir et al., 2010; Kara et al., 2020).

Turf quality is generally evaluated over visual parameters such as color and texture (Macolino et al., 2003; Bilgili and Acikgoz, 2011), but winter hardiness, density, and establishment speed are also important for the sustainability and functionality of these areas and they were included into turf measurements by researchers (Steinke and Stier, 2003; Hulke et al., 2007; Magni et al., 2014). Morris and Shearman (1998) revealed a rating-based method for the estimation of turf quality parameters and suggested the rating of color, density, texture, winter hardiness, etc., visually based on a 1-9 scale. This method is used by many researchers (Martiniello and D'Andrea, 2006; Sikorski et al., 2018; Prokopiuk et al., 2019; Ozkan and Kir, 2021) but analyzing these rating data is not proper by parametric tests because discrete data as in turf quality rates do not fulfill the assumptions of parametric tests as variance homogeneity and normal distribution of data. Therefore, it is suggested that nonparametric statistical tests can be useful to compare these data sets (Zar, 2013).

This study was conducted to determine the seasonal variation of turf quality in cold semi-arid climate conditions of Central Anatolia. Nineteen different cultivars belonging to the most common cool-season turf species were examined for two years and the data were analyzed using non-parametric tests.

2. Materials and Methods

2.1. Plant materials and study area

In the experiment, common cultivars of some cool-season turf grass species as perennial ryegrass (*Lolium perenne* L.) (PR), tall fescue (*Festuca arundinacea* Schreb.) (TF), red fescue (*Festuca rubra* ssp. *rubra*) (RF), slender creeping red fescue (*F. rubra* ssp. *trichophylla*) (SF), Chewing's fescue (*F. rubra* ssp. *commutata*) (CF), and Kentucky bluegrass (*Poa pratensis*) (KB) were used as plant turf materials. Cultivar names are given in *Table 1*.

Table 1. Cultivar names of the common turf grass species used in the experiment

Species	Cultivar	Species	Cultivar	Species	Cultivar
L. perenne	Stravinsky	*F. arundinacea*	SR8600	*F. rubra* ssp. *rubra*	Corail
	Esquire		Tomcat		Maximal
	Bizet-1		Avenger		Cardinal
	Kokomo		Forte	*F. rubra* ssp. *trichophylla*	Rosita
	Capri	*P. pratensis*	Miracle	*F. rubra* ssp. *commutata*	Maritza
	Grandslam2		Arrowhead		
	Monarch		Evora		

The study was carried out for two years from spring 2014 to spring 2016 in the experimental field of Eskisehir Osmangazi University, Faculty of Agriculture, which has an altitude of 795 m above sea level and was located within the borders of Eskisehir province, Türkiye. The long-term average (LTA) of precipitation is 352.4 mm for Eskisehir and it mostly falls as snow in winter due to temperature averages near or below zero (*Figure 1*). The cold semi-arid climate condition (BSk) prevails in the region according to the Koppen-Geiger classification method and the four seasons are distinct. Seasonal and long-term temperature averages are given in *Figure 1*. The soil of the experimental area has loamy characteristics with an 8.30 pH value, 0.49 dSm^{-1} EC, 3.02 % $CaCO3$, and 1.67% organic matter (Gozukara et al., 2022).

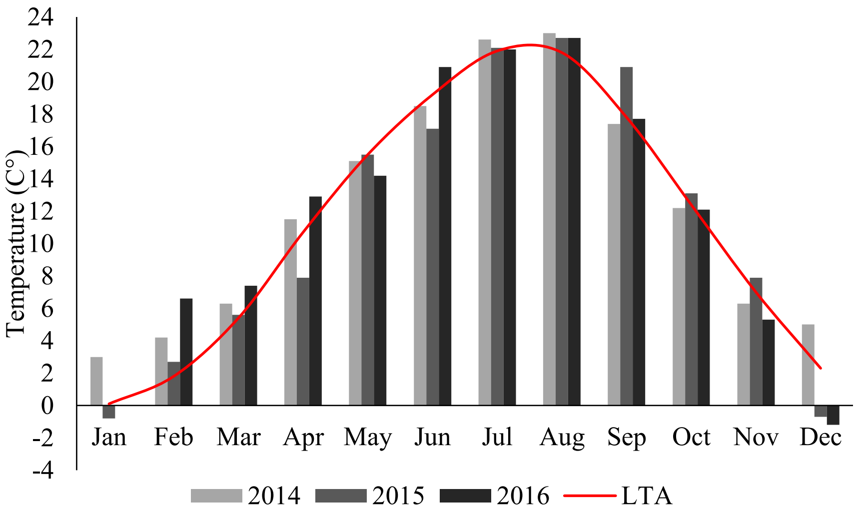

Figure 1. Seasonal variation of the temperature averages between the years 2014-2016 and LTA

2.2. Field studies and data collection

The seedbed was prepared by rotator and the soil was graded using the garden rake on 10 April 2014. Plots were prepared with the size of 2 x 2m ($4m^2$) and the experiment was arranged in a completely randomized block design with three replications. Cultivars of cool-season turf species were considered as treatment. Sowing was made into the plots by broadcast sowing on 11 April 2014 using the seeding rates of 25 g m^{-2} for KB and 40 g m^{-2} for the cultivars of the other species (Martiniello and D'Andrea, 2006). Nitrogen and P_2O_5 fertilizers were applied at the rates of 30 kg ha^{-1} and 72 kg ha^{-1} respectively while sowing (Martiniello and D'Andrea, 2006), and once turf was established, nitrogen fertilizer was applied in 6 rounds in a year (April, May, June, July, August, September) at the rate of 5 g m^{-2} (Bilgili and Acikgoz, 2007). After sowing, plots were covered at 1-2 cm thick of topsoil mixture containing 20% sieved-composted manure, 10% sand, and 70% silt loam soil and compressed using a lightweight roller to provide better establishment. Irrigation was applied by mini-sprinklers depending on the plant's requirements and with nearly 1-2 days intervals. Weeds were removed by hand. Plots were mowed from the height of 2-3 cm when they reached the height of 7-8 cm approximately (Demiroglu et al., 2010a).

Turf color, turf texture, general quality, and winter hardiness were assessed considering the 1-9 scale, and establishment speed was evaluated over coverage percent, which was suggested by the National Turf Evaluation

Program (NTEP) in the USA (Morris and Shearman, 1998). This program suggests the lowest rate (1) as very poor quality and the highest rate (9) as very good quality. Quality ratings were done visually on a seasonal basis (except winter) from the summer of 2014 to the spring of 2016 and every plot was rated in the middle of the seasons. Winter hardiness was rated in early spring by observing plant death and the cover rate was determined using a 1m transect, and a 75% cover rate was assumed as "established turf".

2.3. Statistical analyses

The study was designed in randomized plots design with three replications. The data were obtained using the visual rating method and they did not fulfill the assumptions of parametric tests as variance homogeneity and normal distribution ($P<0.05$). Therefore, data were analyzed using non-parametric tests in SPSS 18 software. Seasonal variation in turf quality parameters of the cool-season cultivars was analyzed by the Friedman test ($P<0.05$) because they are dependent, and the variations of winter hardiness and establishment speed among the cultivars were analyzed by Kruskal Wallis ($P<0.05$) test because the data are independent (Zar, 2013). Winter hardiness was analyzed considering two years and establishment speed was analyzed considering cultivars only. The means of the groups were compared using the Bonferroni-Dunn test ($P<0.05$).

3. Results and Discussion

3.1. Turf color

The turf color score of the cultivars varied between 4.65 – 5.67 and the seasonal variations were significant for Stravinsky and Esquire (PR), SR8600, Avenger, Forte (TF), Maximal, and Cardinal (RF), Rosita (SF), Miracle, Arrowhead, Evora (KB) (Table 2). Seasonal variation belonging to 8 out of 19 species was not statistically significant ($P<0.05$).

Turf color scores of PR and TF species were generally higher in spring 2015 and lower in summer seasons, but the fine fescue species (RF, SF, CF) presented the best turf color in summer 2015 (*Table 2*). KB species had the best results in autumn 2014 and spring 2015 but thereafter, significant decreases were observed (*Figure 2*). Turf color tended to decrease as the seasons advanced for all cultivars and the lowest color scores were recorded in the spring of 2016.

Turf grass species are well adapted to spring seasons in Mediterranean environments (Martiniello and D'Andrea, 2006). Well-adapted species present better color scores because turf color has a linear correlation with plant health and photosynthetic activity (Bell et al., 2002). Besides color is one of the most important visual parameters for both sports fields and recreational areas. In our study, PR and TF cultivars had a higher color score in spring, and Esquire and SR8600 cultivars showed good color performance (*Figure 2*). Bilgili and Acikgoz (2011) stated that cool-season turf mixtures had better color scores in spring, which was similar to our findings. However, the high color scores in spring greatly decreased in 2016, especially for Stravinsky and Esquire cultivars of perennial ryegrass (*Table 2*). This may be due to the stress caused by temperatures in 2016 (*Figure 1*) when the plants was growing rapidly. It is known that the response of the cultivars might be different even belong to the same species (Kir et al., 2010; Demiroglu et al., 2010b). There were different seasonal variations among the TF cultivars in terms of color but a slight decrement was observed for Avenger (*Figure 2*). Fine fescue species presented a higher seasonal variation in turf color and it was the lowest in autumn, especially in the first year (*Figure 2*). This might be due to the low adaptation of the species in the first year, but they presented better turf color in the autumn of 2015 (*Figure 2*). Wolski et al. (2021) stated fine fescue species; especially RF have better color scores in summer, which was similar to our findings (*Figure 2*). Arrowhead cultivar showed partly different seasonal variations in the second year considering other KB cultivars. Researchers stated different results for the seasonal variation of KB that indicate better color in autumn (Wolski et al., 2021), or in summer (Gul, 2015). Indeed this is due to ecological differences. In our study, cultivars of KB had the highest color score in the first year but in the second year, Miracle and Evora showed critical decreases (*Figure 2*). This might be due to their low adaptation abilities to cold semi-arid climate conditions.

Table 2. Turf color scores of the cultivars in different seasons

	Seasons							
Cultivars	**Summer14**	**Autumn14**	**Spring15**	**Summer15**	**Autumn15**	**Spring16**	**Mean**	**P**
Stravinsky	8.33a	2.33c	8.33a	5.00bc	3.00c	3.67c	5.11	**0.041**
Esquire	7.00ab	5.67c	8.33a	6.33bc	2.33d	3.67d	5.56	**0.021**
Bizet-1	5.67	6.67	5.67	5.67	3.67	4.33	5.28	0.205
Kokomo	7.00	5.00	7.00	5.00	3.00	6.33	5.56	0.216
Capri	4.33	6.33	5.00	5.00	3.67	4.33	4.78	0.294
Grandslam2	7.00	4.33	8.33	5.67	3.67	5.00	5.67	0.221
Monarch	4.33	7.33	7.00	5.67	2.33	4.33	5.17	0.061
SR8600	4.33b	6.33a	7.00a	1.67b	7.00a	2.33b	4.78	**0.019**
Tomcat	4.33	5.33	7.00	1.00	5.00	5.00	4.61	0.092
Avenger	5.33b	4.00bc	7.67a	1.00d	5.67bc	3.67c	4.56	**0.041**
Forte	5.67bc	4.33c	7.00ab	1.00d	7.67a	3.67c	4.89	**0.021**
Corail	3.67	3.33	6.33	7.67	5.00	6.33	5.39	0.154
Maximal	6.00b	1.67c	5.67b	9.00a	5.00b	5.67b	5.50	**0.035**
Cardinal	6.33b	1.00d	5.67bc	9.00a	6.33b	5.00bc	5.56	**0.024**
Rosita	5.33b	2.00d	5.00b	9.00a	4.33bc	5.00b	5.11	**0.028**
Maritza	6.00	3.33	5.67	7.00	5.67	5.00	5.45	0.259
Miracle	5.67bc	8.67a	7.67ab	4.33c	1.67d	1.00d	4.84	**0.010**
Arrowhead	6.67a	7.67a	7.67a	1.67c	3.00bc	5.00b	5.28	**0.029**
Evora	6.67bc	9.00a	7.67ab	4.33cd	1.67de	1.00e	5.06	**0.007**
Mean	5.77	4.96	6.83	5.00	4.19	4.23	5.16	

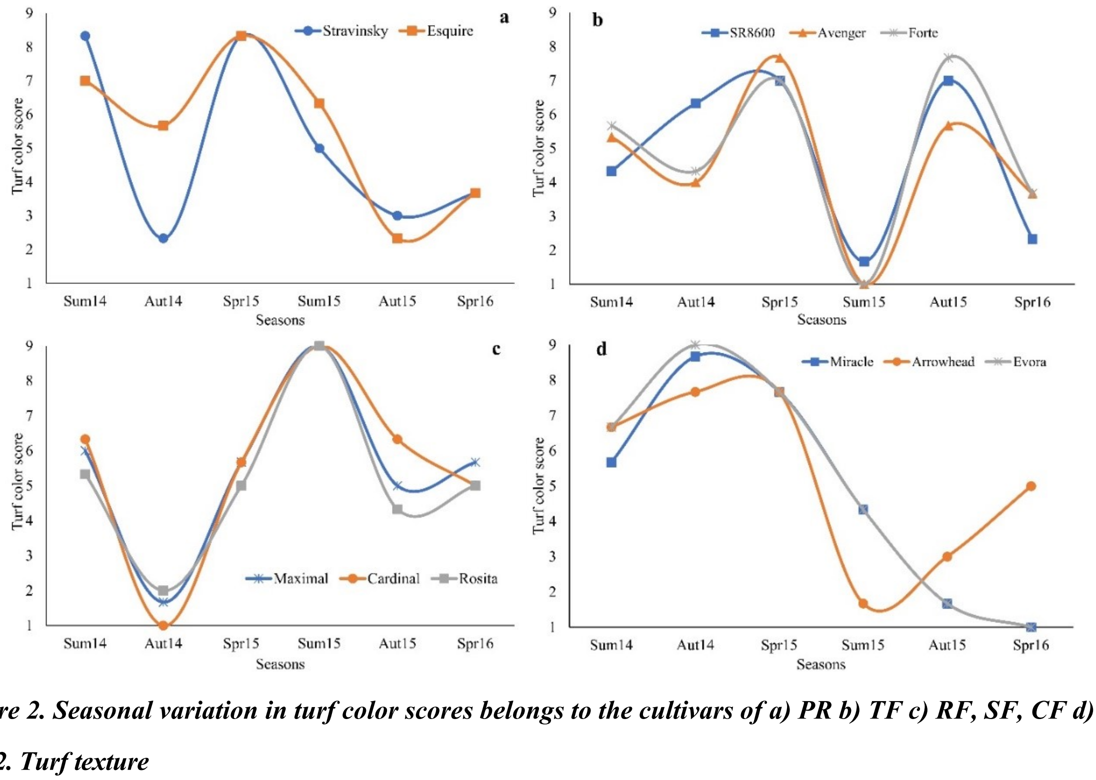

Figure 2. Seasonal variation in turf color scores belongs to the cultivars of a) PR b) TF c) RF, SF, CF d) KB

3.2. Turf texture

The mean texture score of the cultivars varied between 3.17 - 7.61 (*Table 3*). Only Stravinsky (PR), SR8600, and Forte (TF) had significant seasonal variation among them. The texture score of these cultivars was similarly higher in summer and lower in autumn but Stravinsky showed lesser variation than SR8600 and Forte (*Figure 3*).

Turf texture defines the overall width of the leaves and it is preferred to be between 1.5 – 3.00 mm for better visual quality (Beard, 1973; Salman et al., 2019). None of the cultivars used in this study had very coarse or very fine texture scores, considering the suggestions of NTEP for turf texture, where 1=very coarse and 9=very fine (*Table 3*). Texture differences are not only observed on a cultivar basis but a seasonal basis (Salman et al., 2011; Gul, 2015). In our study, texture scores of Stravinsky, SR8600, and Forte showed a significant seasonal variation. Turf grasses produce new leaf tissues after every mowing as long as the environmental conditions are favorable and the significant seasonal variation in texture score might be related to their rapid adaptation abilities to season-based changes in environmental conditions. However, lesser variation is preferred in green areas as observed in Stravinsky (*Figure 3*).

Table 3. Texture scores of the cultivars in different seasons

	Seasons							
Cultivars	**Summer14**	**Autumn14**	**Spring15**	**Summer15**	**Autumn15**	**Spring16**	**Mean**	**P**
Stravinsky	5.67b	3.00d	5.00bc	7.67a	4.33c	4.33c	5.00	**0.023**
Esquire	5.67	3.67	5.67	6.67	4.33	5.00	5.17	0.064
Bizet-1	3.67	3.67	7.00	3.67	5.00	5.00	4.67	0.075
Kokomo	5.00	3.67	5.67	6.33	5.00	4.33	5.00	0.288
Capri	3.00	3.67	5.67	6.33	5.67	4.33	4.78	0.203
Grandslam2	5.00	4.33	6.33	6.33	5.00	4.33	5.22	0.132
Monarch	3.67	5.00	7.00	6.33	7.00	6.33	5.89	0.352
SR8600	5.00b	1.00c	3.00bc	8.33a	1.00c	1.00c	3.22	**0.010**
Tomcat	3.00	1.00	4.33	7.67	2.33	2.33	3.44	0.087
Avenger	2.33	1.00	3.67	8.00	1.67	2.33	3.17	0.077
Forte	1.00d	1.00d	4.33ab	8.67a	1.00d	3.00bc	3.17	**0.017**
Corail	4.33	5.00	7.00	5.67	7.00	7.00	6.00	0.094
Maximal	5.67	6.33	7.67	4.67	7.00	8.33	6.61	0.065
Cardinal	7.00	6.33	7.67	6.00	7.00	7.00	6.83	0.887
Rosita	7.00	7.00	8.33	7.33	8.33	7.67	7.61	0.174
Maritza	6.33	7.00	8.33	7.00	7.00	7.67	7.22	0.459
Miracle	3.67	3.00	7.67	4.67	5.00	3.67	4.61	0.095
Arrowhead	2.33	4.33	4.33	6.00	3.00	1.00	3.50	0.061
Evora	3.67	3.67	7.00	5.00	5.00	4.33	4.78	0.230
Mean	4.37	3.88	6.09	6.44	4.82	4.68	5.04	

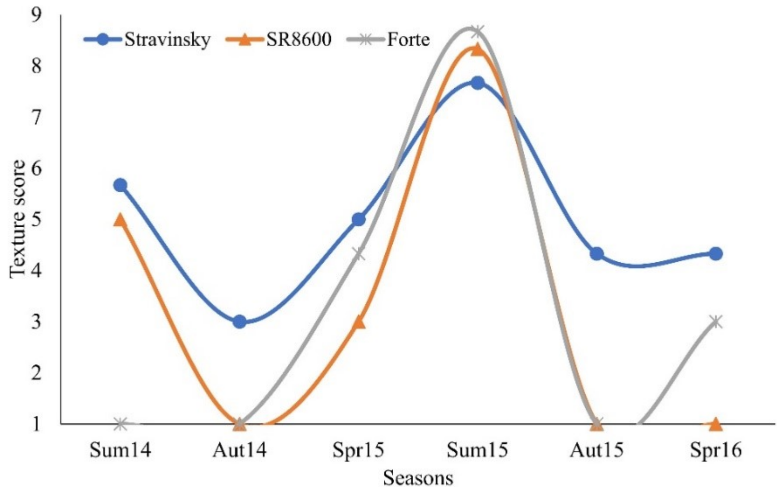

Figure 3. Seasonal variation in texture scores of Stravinsky, SR8600, and Forte

3.3. General turf quality

The general quality of the cultivars was determined as 4.98 in Eskisehir ecological conditions. Seasonal variation was significant (P≤0.05) for Stravinsky, Esquire, Kokomo, Grandslam2, Forte, Maximal, Rosita, Miracle, and Evora (*Table 4*). Cultivars of PR and KB showed a decreasing trend in general quality as the season advanced but the variation was irregular for fine fescue cultivars (*Figure 4*). The seasonal variation of the other ten cultivars was not statistically significant.

The general quality is information about the visual quality of turf grasses. It was defined as the composite of all visual quality parameters such as color uniformity, texture, etc. (Pooya et al., 2013; Salman et al., 2019). NTEP suggested a score-based evaluation using a 1-9 scale and the lowest score indicates very poor, while the highest score indicates the ideal quality (Beard, 1973; Pooya et al., 2013). The general quality of nine cultivars belonging to PR, TF, RF, SF, and KB species showed significant seasonal variation (*Table 4*). Cultivars of PR (Stravinsky, Esquire, Kokomo, Grandslam2) and fine fescue (Forte, Maxima, Rosita) had similar seasonal variation but the quality of Forte, Maxima, and Rosita significantly increased in autumn 2015 unlike the cultivars of PR and Rosita was the only cultivar, which reached to maximum score among the others (*Figure 4*). Researchers stated that cultivars have different quality scores in different seasons because of different adaptation abilities under changing climatic conditions (Kir et al., 2010; Salman et al., 2011; Wolski et al., 2021). Turf quality decreases down to the lowest score if turf species are not adapted to the environment (Demiroglu et al., 2010a). This might be the reason for the continuously decreasing turf quality of Miracle and Evora cultivars in our study. Therefore, these cultivars might be assumed as not adapted to cold semi-arid climates.

Table 4. General quality scores of the cultivars in different seasons

	Seasons							
Cultivars	**Summer14**	**Autumn14**	**Spring15**	**Summer15**	**Autumn15**	**Spring16**	**Mean**	**P**
Stravinsky	7.67a	3.33cd	5.00ab	4.33abc	5.00ab	1.67e	4.50	**0.047**
Esquire	8.67a	4.00b	7.67a	4.00b	3.67b	1.00c	4.84	**0.018**
Bizet-1	6.67	5.67	4.00	4.00	4.33	3.00	4.61	0.294
Kokomo	8.00a	5.00bc	7.00ab	3.33c	2.33cd	1.00d	4.44	**0.028**
Capri	7.00	6.33	6.33	5.33	3.00	2.33	5.05	0.078
Grandslam2	8.33a	4.00bc	7.67a	5.00b	5.67b	1.67c	5.39	**0.013**
Monarch	7.33	5.67	8.33	4.00	4.33	1.67	5.22	0.112
SR8600	6.33	4.67	4.33	5.67	6.33	2.33	4.94	0.195
Tomcat	6.67	6.00	5.00	5.67	5.00	3.67	5.34	0.116
Avenger	6.67	5.67	6.33	6.33	5.67	2.33	5.50	0.250
Forte	7.67a	3.33d	5.00c	6.00bc	6.33ab	3.00d	5.22	**0.016**
Corail	5.00	5.00	6.33	3.67	5.67	4.33	5.00	0.191
Maximal	5.67ab	2.33c	6.33ab	3.67c	7.00a	5.00b	5.00	**0.035**
Cardinal	7.33	2.67	7.00	3.67	5.67	5.00	5.22	0.253
Rosita	7.00b	2.00d	7.00b	6.00bc	9.00a	5.67c	6.11	**0.035**
Maritza	7.33	3.33	6.33	4.67	5.67	4.33	5.28	0.087
Miracle	5.67a	6.33a	5.00ab	4.33ab	2.33b	1.00b	4.11	**0.025**
Arrowhead	6.33	7.00	3.67	5.00	3.00	1.67	4.45	0.062
Evora	5.67b	7.33a	7.00a	3.00c	3.00c	1.00d	4.50	**0.016**
Mean	6.90	4.72	6.07	4.61	4.89	2.72	4.98	

3.4. Winter hardiness

Winter hardiness scores of the cultivars showed a significant variation ($P \leq 0.01$) and changed between 1.0 and 6.3. Corail, Maximal, and Cardinal had the highest scores but they were statistically in the same group with all cultivars except the cultivars that belong to KB species (*Table 5*). Miracle and Evora had the lowest winter hardiness scores.

Expression of winter hardiness is suggested by NTEP on a 1-9 scale, where 1 indicates 100% winter damage and 9 indicates 0% winter damage on the leaves. In our study, none of the cultivars had the highest winter hardiness score because a 0% winter injury of the leaves is almost impossible for turf grasses in environments, where winter seasons are cold and harsh (Hulke et al., 2007), as in Central Anatolia. However, the winter hardiness of some species, even cultivars, could show significant variations in different environments (Martiniello and D'Andrea, 2006; Varoglu et al., 2015; Alagoz and Turk, 2017). For example, Rimi and Macolino (2014) stated that overseeding an established turf using RF (cv. Corail) increased the winter hardiness of the turf. Corail is one of the cultivars, which had the best winter hardiness score in our study. Researchers generally stated high winter hardiness of KB (Aamlid et al., 2012; Zuk et al., 2012) but cultivars of KB, especially Miracle and Evora, had the lowest scores in our study (*Table 5*). This might indicate low adaptation of these cultivars to environments, where the winter is cold and harsh.

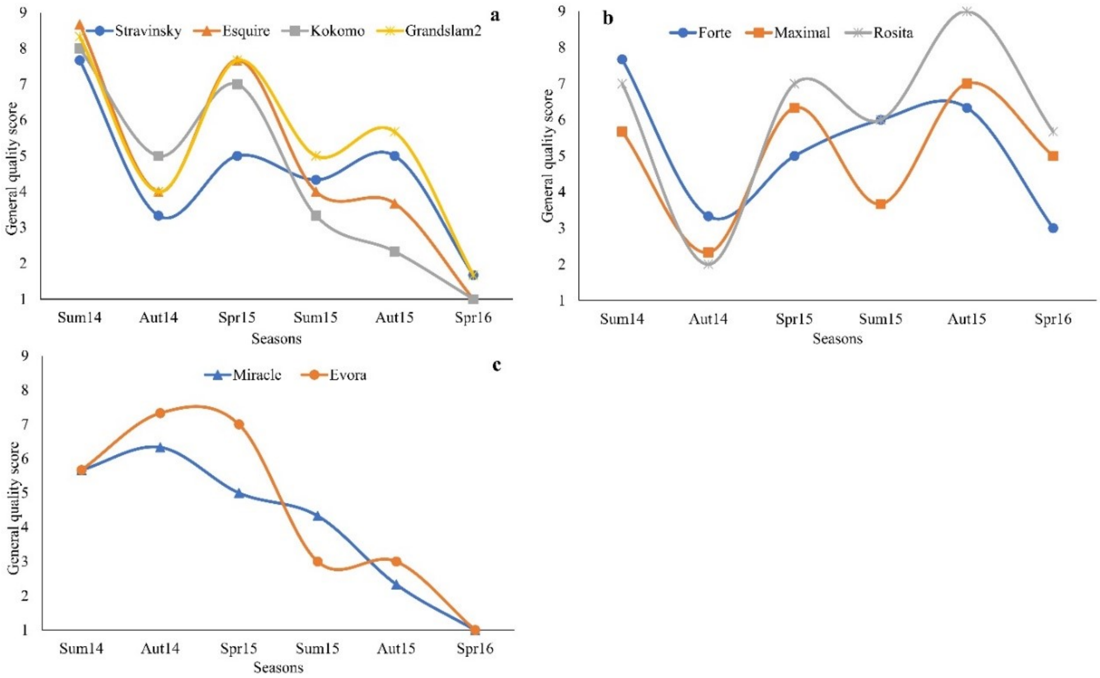

Figure 4. Seasonal variation in general quality scores belongs to the cultivars of a) PR b) TF, RF, SF c) KB

Table 5. Winter hardiness scores and establishment speed of the cultivars

Cultivars	Winter hardiness score	Establishment speed (days)
Stravinsky	4.7abc	32.0f
Esquire	3.7abc	24.7hi
Bizet-1	4.0abc	23.0ij
Kokomo	4.0abc	26.0h
Capri	3.0abc	20.3j
Grandslam2	4.3abc	26.3gh
Monarch	4.3abc	22.3ij
SR8600	5.0abc	45.3cd
Tomcat	6.0ab	40.3de
Avenger	5.3ab	31.7fg
Forte	5.3ab	34.0f
Corail	6.3a	39.7d
Maximal	6.3a	44.7d
Cardinal	6.3a	60.0a
Rosita	6.0ab	35.0ef
Maritza	5.3ab	41.0d
Miracle	2.0bc	54.7ab
Arrowhead	4.0b	53.0bc
Evora	1.0c	61.7a
Mean	4.6	37.6
P	**0.001**	**0.001**

3.5. Turf establishment speed

The mean establishment speed was 37.6 days and it significantly varied among the cultivars ($P \leq 0.01$) between 20.3 and 61.7 days (*Table 5*). The establishment speed of the cultivars belonging to PR species was higher, while it was the lowest for KB cultivars. Capri was the fastest established cultivar, while Evora was the slowest. However, Cardinal (RF) was also one of the slowest established cultivars (*Table 5*).

Results showed that species aligned as PR < TF < RF, SF, CF < KB in terms of the establishment speed. Other researchers also determined a similar variation of establishment speed among PR, TF, and KB (Valverde and Minner, 2007; Charif et al., 2021). However, significant cultivar-based variations were observed in our results. For example, Avenger and Forte cultivars of TF had similar establishment speeds to the cultivars of PR, but SR8600 and Tomcat were similar to the cultivars of fine fescue (*Table 5*). In addition, Cardinal significantly varied from other fine fescue cultivars in terms of establishment speed. This indicated that establishment speed could change significantly among the cultivars of the same turf species. Roche and Loch (2005) determined a significant variation among the cultivars of *Cynodon dactylon* in terms of establishment speed.

4. Conclusions

In conclusion, turf color and general quality of the cultivars did not vary significantly, but there were significant variations in texture. Cultivars of TF had lower texture scores than expected due to their rough structure. The results showed that seasonal variation of turf quality characteristics was significantly different among the most common cool-season turf species. PR and fine fescue species lost their visual quality, especially color in autumn just after the warm summer while KB remained high quality. Therefore, these species should be mixed to establish better-quality turf. However, it was observed that Miracle and Evora are not well adapted to cold semi-arid climates, due to their low winter hardiness. Therefore, the other cultivars of KB should be used in turf mixtures for these climatic conditions. Besides, KB was the slowest established species in our study, thus sowing date should be arranged considering the slow establishment speed of KB. Our results showed the seasonal variation in turf quality was not only varied species-based but also cultivar-based for the most common cool-season turf species. Therefore, other and newly released turf cultivars should be tested to ensure sustainable and high-quality turf year-round.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Ali Koc; Design: Ali Koc, Onur İleri; Data Collection or Processing: Onur İleri; Statistical Analyses: Yasin Altay; Literature Search: Onur İleri; Writing, Review and Editing: Ali Koc, Onur İleri.

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