Volume 13, Issue 4, Page 141-147, 2024 https://doi.org/10.46810/tdfd.1540506 Research Article

BİNGÖL UNIVERSITY

Türk Doğa ve Fen Dergisi
Turkish Journal of Nature and Science
www.dergipark.gov.tr/tdfd

Color Response of Turfgrass Cultivars to Gibberellic Acid under Mediterranean Climate Conditions

Emre KARA[1*], Mustafa SÜRMEN[1], Türkan METİN[1] Bekir Sami GÜNGÖR[1]

[1] Aydın Adnan Menderes University, Faculty of Agriculture, Department of Field Crops, Aydın, Türkiye
Emre KARA ORCID No: 0000-0002-5535-8398
Mustafa SÜRMEN ORCID No: 0000-0001-9748-618X
Türkan METİN ORCID No: 0009-0000-0073-3990
Bekri Sami GÜNGÖR ORCID No: 0009-0005-6597-1937

**Corresponding author: emre.kara@adu.edu.tr*

(Received: 31.08.2024, Accepted: 30.10.2024, Online Publication: 30.12.2024)

Keywords
Color,
Turfgrass,
Plant growth regulator,
Turfgrass quality

Abstract: Plant growth regulators (PGRs) are broadly used in turfgrass management. Gibberellic acid is also applied in many plants due to its positive effects on plant growth and development. However, some studies have indicated that these applications may have a negative effect on color. The study aimed to find out the effect of different doses of gibberellic acid applications on visual quality in different turfgrass species. Gibberellic acid was applied as control, 0.05 and 0.1 kg ha^{-1}. Among the turfgrass species, twenty different cultivars of four different species were used as material in the experiment. Although studies have demonstrated that this plant growth regulator enhances stress tolerance, it has been observed to diminish color values (L, a*, b*). Visual quality is a crucial aspect of lawns. The study also revealed that grass varieties exhibited differential responses to gibberellic acid with respect to visual quality and color properties.

Akdeniz İkliminde Renk Bakımından Çim Çeşitlerinin Giberellik Aside Tepkisi

Anahtar Kelimeler
Renk,
Çim,
Bitki büyüme düzenleyicisi
Çim kalitesi

Öz: Bitki büyüme düzenleyicileri çim alan yönetiminde yaygın olarak kullanılmaktadır. Giberellik asit de bitki büyümesi ve gelişimi üzerindeki olumlu etkileri nedeniyle birçok bitkide uygulanmaktadır. Ancak, bazı çalışmalar bu uygulamaların renk üzerinde olumsuz bir etkiye sahip olabileceğini göstermiştir. Bu çalışma, farklı çim türlerinde farklı dozlarda giberellik asit uygulamalarının görsel ve renk kalitesi üzerindeki etkisini bulmayı amaçlamıştır. Giberellik asit kontrol, 0.05 ve 0.1 kg ha^{-1} olarak uygulanmıştır. Çim türleri arasında 4 farklı türün 20 farklı çeşidi denemede materyal olarak kullanılmıştır. Görsel kalite, görsel derecelendirme sistemi kullanılarak değerlendirilmiştir. Renk kalitesi spektrofotometre kullanılarak incelenmiştir. Genel olarak, giberellik asit kullanımının görsel kalite üzerinde olumsuz etkileri olduğu gözlenmiştir. Bu bitki büyüme düzenleyicisinin stres koşullarına karşı direnci artırdığını gösteren çalışmalar olmasına rağmen renk değerleri (L, a*, b*) açısından düşüşlere neden olduğu gözlenmiştir. Görsel kalite çim alanlar için çok önemlidir. Çalışma neticesinde ayrıca çim çeşitlerinin görsel kalite ve renk özellikleri bakımından giberellik aside farklı tepkiler verdiği gözlemlenmiştir.

1. INTRODUCTION

Turfgrass is a vital component of urban and suburban landscapes, offering functional, environmental, and aesthetic advantages. Studies have shown that turfgrasses play a role in reducing soil erosion, surface runoff, and safeguarding water quality [1]. Additionally, they aid in carbon sequestration, nutrient cycling, and maintaining water quality [2]. Turfgrass also helps mitigate the impacts of urban sprawl in rapidly urbanizing societies [3] and it is good for menthal health. The economic significance of the turfgrass industry is substantial, driven by factors such as property development, environmental benefits, and the aesthetic appeal of turfgrass in urban environments [4].

Turfgrass color is a critical aspect of turfgrass quality due to its aesthetic significance. Studies have emphasized the importance of turfgrass color in enhancing the visual quality of turfgrass [5]. The color of turfgrass is a key characteristic that significantly influences its overall quality and appeal to consumers [6]. Maintaining an intense green color in turfgrass is essential for improving its aesthetic value and increasing consumer acceptance [6]. Additionally, turfgrass color is commonly used as a primary indicator of its quality conditions [7].

The color of turfgrass is influenced by various factors such as fertilization, genetic characteristics, and environmental conditions. Nitrogen is crucial for maintaining turfgrass density and color, as well as enhancing its resistance and recovery from stress [8]. Studies have shown that the application of colorants can enhance turfgrass color and quality, especially during stressful and dormant periods [9,10]. Moreover, the genetic color of turfgrass cultivars plays a significant role in achieving the desired aesthetic value of turfgrass [11]. Furthermore, research has underscored the significance of color differentiation in turfgrass studies, as it has ramifications for a multitude of facets of turfgrass research, including the utilization of pesticides, fertilizers and cultivars. [12]. Digital image analysis is a valuable method for quantifying turfgrass color and evaluating turfgrass quality in research studies [13].

Gibberellic acid (GA) has been identified as a key regulator affecting various aspects of plant growth and development, including turfgrass. Gibberellin application resulted usually in the yellowing of grass leaves. This effect can be reduced by higher nitrogen fertilization. Gibberellic Acid is used in sports facilities to extend the period of exploitation from early spring to late autumn. Research has shown that GA application can enhance growth rates in turfgrass, potentially aiding in the recovery of injured areas by promoting growth in the surrounding turf [14]. Moreover, GA has been linked to regulating shoot elongation in higher plants, which is crucial for managing turfgrass effectively [15]. However, it is thought that it may have a negative effect on the color quality of grass. In this study conducted for this purpose, the effects of different doses of gibberellic acid on the color quality of twenty different grass species in the Mediterranean climate were examined.

2. MATERIAL AND METHOD

2.1. Study site

The field study was established at Aydın Adnan Menderes University (Aydın, Türkiye) Research and experimental fields (37º 45' 51" N, 27º 45' 32" E, 27 m altitude) as a split-plot experiment in randomized block design with three replications in 2023-2024. The soil in which the experiment was conducted had an alkaline, sandy-loamy texture, low organic matter content, and an adequate amount of mineral matter, based on samples taken before to the experiment (Table 1.).

Table 1. Soil traits of the experiment field (0-30 cm)

P ppm	K ppm	Ca ppm	Mg ppm	Na ppm	Fe ppm	pH	Total Salt (%)	Organic Matter (%)
19	903	2740	1164	46	8.32	8.16	0.0093	1.20

When the climate data taken during the turfgrass vegetation period in the area where the experiment was carried out were compared with the long-term means, it was observed that the experimental year was warmer and drier in terms of average temperatures. Especially high winter temperatures caused a faster growth in all turfgrass species (Table 2.).

Table 2. Some climate variables for the years 2023, 2024 and long-term mean*

	Mean Temperature (°C)		Total Precipitation (mm)	
Months	2023/24	LTM	2023/24	LTM
September	24.8	23.9	22.1	43.8
October	19.7	18.8	2.2	79.9
November	15.9	13.4	151.4	40.9
December	11.7	9.4	95.1	50.9
January	9.5	8.2	74.2	27.8
February	10.4	9.4	6.1	13.4
March	12.7	12.1	5	17.9
April	19.1	16.2	21.9	10.0
Total	15.4	13.9	378	573.7

LTM: Long term mean: 1985-2022.

2.2. Field management

A total of 20 cultivars of four different species were used in the experiment. These cultivars are generally the ones that can be evaluated in mixtures and used intensively in turfgrass areas. Information about the varieties is given in Table 3.

Table 3. Cultivars of the experiment

Lolium perenne L.	*Festuca arundinacea* L.	*Poa pratensis* L.	*Festuca rubra rubra*
Belida	Sergei	Zeptor	Kolossos
Sox Fan	Greenfront	Geisha	
Blackstone	Eye Candy		
Troya	Tomcat-1		
Monsieur	Brockton		
Stravinsky	Jaguar AG		
Spark	Meister		
Ankyra	Starlett		
Essence			

The experiment was conducted with three replications, with 75 grams of grass seed applied per square meter. Irrigation was performed on a daily basis until germination, utilizing an oscillating garden lawn irrigation nozzle that allowed for the precise control of its width. The first mowing process took place when the plants reached a height of 15 cm. The mowing operations were carried out with AL-KO HIGHLINE 46.5 P-A gasoline lawnmower from a height of 7-8 cm in order not to affect any kind of development. No herbicide was applied for weed control in the trial, and Fiskars® Stand-up Weed Puller (4-claw) was used to remove weeds. Turfgrasses were fertilized with mineral fertilizers at rates: 180 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1}, and 120 kg K_2O ha^{-1} before sowing. From March onwards, a fertilization rate of 50 kg N ha^{-1} was applied following each mowing, marking the onset of active growth. Gibberellic acids were applied in March 2024 at three rates (control, 0.05, 0.1 kg PGR ha^{-1}) with knapsack sprayer. Irrigation was done with sprinkler irrigation systems according to the water capacity of the field only when the plant needs it.

2.3. Measurements

The color parameters such as L* (Lightness), a* (Red to green), and b* (yellow to blue) of the samples were determined by using a colorimeter (Hunter lab, Color flex EZ model: 45º/0º). Then, the CIE L*a*b* values related to each sample were recorded separately. The chroma was assessed following the methodology outlined by Rezah et al. [16]. The Commission Internationale de l'Eclairage (CIE) Lab color system was used to compute color parameters in relation to the D65 illuminant standard. The projection of color components is represented by this CIELab system on the axes L, a, and b. Lightness is represented by the L value, which is 100 for white and 0 for black. The chromatic coordinates that are described by the values a and b are green-red and blue-yellow, respectively. A hue of green or blue is represented by a negative an or b, and a hue of red or yellow by a positive an or b, respectively. In accordance with the National Turfgrass Evaluation Program (NTEP) in the United States [17,18] turfgrass quality was measured on a scale of 1 to 9, with the lowest score indicating broad leaf, very poor appearance, and light green turfgrass, and the highest score indicating thin leaves, a very good appearance, and dark green turfgrass. Three turfgrass characteristics were assessed: leaf texture, overall appearance, and turfgrass color. Green canopy cover measured by Canopeo was maesured at after gibberellic acid application. Canopeo is a tool developed for measuring fractional green canopy cover in various vegetation types, including turfgrass. It utilizes color ratios of red to green (R/G) and blue to green (B/G) along with an excess green index to assess canopy cover [19]. Research has shown that Canopeo is effective in estimating green coverage of living turfgrasses, although additional calibration may be necessary for colorant-treated turfgrasses [20]. Measurements were carried out 30 days after the application of the treatments.

2.4. Statistical analysis

Statistical analyses were performed using R Studio (v4.1.2) [21]. The Shapiro–Wilk test was used to determine the distribution of normality. The relationships between the traits were analyzed at $p<0.01$ level of significance by using analysis of variance and LSD test in randomized completely block design as split plots.

3. RESULTS AND DISCUSSION

Turfgrass cultivars had significantly different color characteristics. However, they all had in common their response to gibberellic acid application doses. Yellowish and lighter leaves appeared as gibberellic acid application increased. For L* values, the interaction was significantly different. Higher gibberellic acid doses resulted in lighter leaves (L = 38.46). Among the cultivars, *Festuca arundinacea* cv. Greenfront had the lightest character (L= 42.39). However, the control treatment of this variety was also lightest. The darkest (L= 31.34) turfgrass cultivar was *Lolium perenne* cv. Blackstone. The stunning result was that the increase in gibberellic acid dose in this turfgrass cultivar did not increase the lighter properties of the turfgrass color much. Since the cultivars had their genetic characteristics, the changes in all of them were at different levels (Table 4.).

Table 4. Effect of gibberellic acid application on turfgrass color CIELab (L*) parameter.

	L*			
Cultivar/Doses	**Control**	**0.05 kg ha^{-1}**	**0.1 kg ha^{-1}**	**Mean****
Lp-Belida	38.90	39.98	42.95	40.61 c
Fa- Sergei	39.13	39.17	41.94	40.08 d
Pp-Zeptor	38.46	39.62	40.34	39.47 e
Fa-Greenfront	41.77	42.07	43.33	42.39 a
Fa-Eye Candy	29.10	34.81	35.94	33.28 k
Lp-Sox Fan	29.04	35.18	36.44	33.55 jk
Lp-Blackstone	30.81	31.46	31.76	31.34 m
Lp-Truva	30.12	31.90	34.40	32.14 l
Fa-Tomcat	32.24	32.13	36.32	33.56 jk
Lp-Monsieur	31.10	33.48	36.81	33.79 ıj
Fa-Brockton	34.66	37.90	37.98	36.84 h
Pp-Geisha	38.09	38.98	39.04	38.70 f
Lp-Stravinsky	38.17	41.32	41.73	40.40 cd
Frr-Kolossos	39.69	41.46	42.31	41.15 b
Lp-Spark	32.02	38.73	41.26	37.34 g
Fa-Jaguar AG	33.74	37.92	40.62	37.43 g
Fa-Meister	31.03	32.56	36.78	33.46 jk
Lp-Ankyra	31.88	33.60	34.72	33.40 jk
Fa-Starlett	32.73	33.55	35.94	34.07 ı
Lp-Essence	29.96	32.05	38.63	33.54 jk
Mean**	34.13 c	36.39 b	38.46 a	

cv:1.28 LSDcul: 0.43, LSDdoses: 0.17; **mean values with different letters are significantly different (*p < 0.01*).

In terms of a* mean values, significantly different characteristics were observed for both varieties and doses. Higher green (a*= -8.668) was observed with the increase in dose. However, the increase in green color does not show a characteristic alone. At the same time, b* averages should also be examined together. The increase in b* characteristic leads to an increase in the yellowish characteristic. The b* values, which we will explain after expressing the differences between grass varieties, also increased with the increase in gibberellic acid dose. Among the turfgrass cultivars, the highest green (a*=-9.317) was obtained with *Festuca arundinacea* cv. Brockton. The lowest was obtained with *Lolium perenne* cv. Spark and *Festuca arundinacea* cv. Sergei. As observed in Lightness values, the averages of this character also showed different results according to genetic differences (Table 5.).

Table 5. Effect of gibberellic acid application on turfgrass color CIELab (a*) parameter.

	a*			
Cultivar/Doses	**Control**	**0.05 kg ha^{-1}**	**0.1 kg ha^{-1}**	**Mean****
Lp-Belida	-8.256	-8.670	-8.760	-8.562 j
Fa- Sergei	-5.943	-7.603	-8.320	-7.288 a
Pp-Zeptor	-6.503	-9.513	-9.700	-8.572 j
Fa-Greenfront	-7.353	-8.690	-9.270	-8.437 j
Fa-Eye Candy	-6.673	-9.050	-9.350	-8.357 hj
Lp-Sox Fan	-6.960	-9.040	-9.666	-8.555 j
Lp-Blackstone	-7.280	-8.193	-8.706	-8.060 fg
Lp-Truva	-7.696	-7.893	-8.283	-7.957 eg
Fa-Tomcat	-7.473	-7.636	-9.403	-8.171 gı
Lp-Monsieur	-7.476	-7.686	-8.600	-7.921 eg
Fa-Brockton	-8.736	-9.553	-9.663	-9.317 l
Pp-Geisha	-8.626	-8.783	-9.153	-8.854 k
Lp-Stravinsky	-7.546	-7.636	-7.753	-7.645 bd
Frr-Kolossos	-8.026	-8.053	-8.263	-8.114 gh
Lp-Spark	-7.083	-7.290	-7.673	-7.348 a
Fa-Jaguar AG	-6.763	-7.920	-7.593	-7.425 ab
Fa-Meister	-7.390	-7.573	-8.226	-7.730 ce
Lp-Ankyra	-8.076	-8.266	-8.850	-8.397 ıj
Fa-Starlett	-6.720	-8.343	-8.453	-7.838 df
Lp-Essence	-7.183	-7.576	-7.683	-7.481 ac
Mean**	-7.388 a	-8.248 b	-8.668 c	

cv:3.52 LSDcul:0.266 LSDdoses:0.103; **mean values with different letters are significantly different (*p < 0.01*).

Significantly different traits were observed for the b* character in relation to the a* parameter. Likewise, the interaction was significant as in all traits. This character, in which yellowish was observed in a certain way, had higher values with the increase in dose. In this respect, the highest result (b*= 18.26) was obtained with 0.1 kg ha^{-1}. Although it was observed that *Poa pratensis* cv. Zeptor was the yellowest among the varieties (b*=24.68), when the control group was controlled, it was observed that this variety was more yellow than the other varieties before the plant growth regulator application. In this respect, the most striking yellowing was observed in *Festuca arundinacea* cv. Eye Candy. The variety average with the lowest yellow color pigment was *Lolium perenne* cv. Sox Fan, cv. Blackstone (Table 6.).

Table 6. Effect of gibberellic acid application on turfgrass color CIELab (b*) parameter.

	b*			
Cultivar/Doses	**Control**	**0.05 kg ha^{-1}**	**0.1 kg ha^{-1}**	**Mean****
Lp-Belida	17.78	18.80	19.03	18.53 d
Fa- Sergei	17.88	21.30	21.75	20.31 c
Pp-Zeptor	23.65	24.99	25.40	24.68 a
Fa-Greenfront	12.96	18.79	19.76	17.17 fg
Fa-Eye Candy	12.46	17.03	17.50	15.66 ı
Lp-Sox Fan	11.89	13.86	14.84	13.53 l
Lp-Blackstone	11.76	14.03	14.33	13.37 l
Lp-Truva	14.78	18.27	19.05	17.37 ef
Fa-Tomcat	13.55	14.81	22.41	16.92 g
Lp-Monsieur	13.41	13.94	17.02	14.79 jk
Fa-Brockton	21.57	23.39	23.68	22.88 c
Pp-Geisha	15.86	16.87	17.88	16.87 g
Lp-Stravinsky	14.04	15.13	15.53	14.90 j
Frr-Kolossos	16.41	16.75	17.10	16.75 g
Lp-Spark	14.04	14.37	14.87	14.43 k
Fa-Jaguar AG	14.88	15.57	16.41	15.62 ı
Fa-Meister	13.06	17.07	17.53	15.89 hı
Lp-Ankyra	16.76	17.87	18.34	17.66 e
Fa-Starlett	14.66	16.86	17.00	16.17 h
Lp-Essence	14.00	15.22	15.83	15.01 j
Mean**	15.27 c	17.24 b	18.26 a	

cv:2.64 LSDcul: 0.41 LSDdoses: 0.16; **mean values with different letters are significantly different ($p < 0.01$).

It was observed that gibberellic acid treatments caused statistical differences at the level of ($p < 0.01$) in terms of canopy cover and visual quality among turfgrass species. The changes observed in terms of color characteristics were in the same direction in terms of canopy cover and visual quality characters. It was determined that gibberellic acid treatments decreased the canopy cover as well as the color quality. Compared to the control treatment, all but three varieties were observed above 90% cover. *Lolium perenne* cv. Stravinsky was the cultivar that was observed to be more affected by canopy cover with gibberellic acid application. *Lolium perenne* cv. Essence was the least affected variety and had the highest average value (97.49%). The effect of gibberellic acid on visual quality was determined by visual rating. Decreases in visual quality were observed due to yellowish. The highest visual quality value was obtained from the control with 6.75. Although there were different visual values among the varieties, *Festuca arundinacea* cv. Starlett had a higher visual quality (6.33). The rapid decline in visual quality was observed with *Lolium perenne* cv. Truva (Table 7.).

Table 7. Effect of gibberellic acid application on turfgrass canopy cover and visual quality

	Canopeo (Canopy Cover%)**				Visual Quality(1-9)**			
Cultivar/Doses	**Control**	**0.05 kg ha^{-1}**	**0.1 kg ha^{-1}**	**Mean**	**Control**	**0.05 kg ha^{-1}**	**0.1 kg ha^{-1}**	**Mean**
Lp-Belida	92.70	87.66	87.37	89.24 f	6.00	4.33	3.33	4.55 hı
Fa- Sergei	98.37	95.69	94.68	96.24bc	6.33	5.33	4.00	5.22 dg
Pp-Zeptor	97.41	97.58	91.41	95.47cd	6.33	4.66	3.33	4.77 gı
Fa-Greenfront	90.37	87.25	86.52	88.05 f	5.66	5.00	4.00	4.88 fh
Fa-Eye Candy	98.69	92.51	92.16	94.45de	7.00	5.33	4.33	5.55 be
Lp-Sox Fan	98.40	95.44	92.22	95.35cd	6.66	6.00	5.00	5.88 ab
Lp-Blackstone	96.05	98.49	95.92	96.82ab	7.00	5.00	3.33	5.11 eg
Lp-Truva	86.48	79.81	77.53	81.27 ı	8.00	4.00	2.66	4.88 fh
Fa-Tomcat	95.14	87.76	83.98	88.96 f	7.00	5.33	3.00	5.11 eg
Lp-Monsieur	98.98	96.89	96.34	97.40ab	8.00	5.33	4.33	5.88 ab
Fa-Brockton	85.09	84.15	81.77	83.67 h	6.00	5.00	3.33	4.77 gı
Pp-Geisha	97.92	97.28	93.61	96.27ac	6.00	5.00	3.33	4.77 gı
Lp-Stravinsky	98.37	80.95	80.56	86.62 g	6.00	5.00	4.00	5.00 fh
Frr-Kolossos	97.47	95.03	90.90	94.47de	5.66	4.33	3.00	4.33 ı
Lp-Spark	95.99	95.66	92.36	94.67de	7.66	5.66	4.00	5.77 bc
Fa-Jaguar AG	97.70	97.22	87.02	93.98 e	6.33	6.00	4.66	5.66 bd
Fa-Meister	96.05	92.87	92.96	93.96 e	8.00	4.66	3.33	5.33 cf
Lp-Ankyra	94.54	89.43	80.67	88.21 f	7.00	5.00	2.66	4.88 fh
Fa-Starlett	87.19	80.89	77.03	81.70 ı	7.33	5.66	6.00	6.33 a
Lp-Essence	98.14	97.76	96.56	97.49 a	7.00	5.00	3.00	5.00 fh
Mean**	95.05 a	91.51 b	88.58 c		6.75 a	5.08 b	3.73 c	

cv:1.44 LSDcul: 1.23, LSDdoses:0.47, cv:10.74 LSDcul:0.52 LSDdoses:0.20 ; **mean values with different letters are significantly different ($p < 0.01$).

Gibberellic acid, a plant growth regulator, has been extensively studied for its effects on plant pigments. While gibberellic acid is known to positively influence various aspects of plant growth and development, such as stem elongation, germination, and flowering [22], there is evidence suggesting that it can have negative effects on plant coloration. Research has shown that gibberellic acid can alter the contents of pigments in plants. For instance, a study on the application of gibberellic acid on Asarum europaeum L. cut leaves found that gibberellic acid affects the biosynthesis of photosynthetic pigments [23]. Additionally, the application of gibberellic acid, along with other phytohormones, was found to increase pigment content in salinized wheat plants [24]. Gibberellic acid is reported to have very positive effects on tillering, growth and root characteristics in plants [25]. However, there is also striking information that gibberellic acid applications in particular yellowish turfgrass species [26]. In a study on this subject, the effect of different plant growth regulators on turfgrass species was examined. The results clearly indicated that gibberellic acid caused color loss in turfgrass species [17]. Despite its positive properties, this study aimed to examine the effects on color loss, canopy cover and visual quality in different turfgrass species. The fact that the studies on this subject are in different species and there are not enough studies on this subject has revealed the necessity of this study for turf areas where color quality is very important. It is also stated that the color loss problem that will occur in turf color and quality can be reduced by using higher nitrogen fertilizer [27].

4. CONCLUSION

Gibberellic acid (GA) is a plant growth regulator widely used in agriculture and turfgrass areas to enhance plant growth and development. GA promotes cell elongation and division, resulting in increased shoot growth and overall turf vigor. This can be particularly advantageous during the early growing season or in cool climates where turfgrass might otherwise be slow to green up. Additionally, the application of GA can improve the grass's stress tolerance. It aids in strengthening the turf against environmental stresses such as drought, salinity, and extreme temperatures, making it more resilient and maintaining its aesthetic appeal under challenging conditions. However, there are some considerations to keep in mind when using GA on turfgrass. Different turfgrass species respond differently to GA, so understanding the specific needs and responses of the turfgrass being managed is essential. At the same time, striking results were obtained in this study based on the potential that gibberellic acid applications may cause yellowing of turfgrass color and changes in visual quality for these and similar reasons. In the study conducted on different species varieties, the negative effects of gibberellic acid applications on canopy coverage, especially in the establishment year, were revealed. In terms of color values, decreases in green color quality were detected especially with increasing dose. Different responses were observed among species.

REFERENCES

[1] Philocles S, Torres A, Patton A, Watkins E. The adoption of low-input turfgrasses in the midwestern us: the case of fine fescues and tall fescue. Horticulturae. 2023;9(5):550.

[2] Bauer S, Lloyd D, Horgan B, Soldat D. Agronomic and physiological responses of cool-season turfgrass to fall-applied nitrogen. Crop Science. 2012;52(1):1-10.

[3] Brosnan JT, Chandra A, Gaussoin RE, Kowalewski A, Leinauer B, Rossi FS, et al. A justification for continued management of turfgrass during economic contraction. Agricultural & Env Letters. 2020;5(1).

[4] Haydu JJ, Hodges AW, Hall CR. Economic Impacts of the Turfgrass and Lawncare Industry in the United States. EDIS. 2006;(7).

[5] Salehi H, Khosh-Khui M. Turfgrass Monoculture, Cool-Cool, and Cool-Warm Season Seed Mixture Establishment and Growth Responses. HortSci. 2004;39(7):1732-5.

[6] Santos PLFd, Silva PST, Matos AMS, Alves ML, Nascimento MVLd, Castilho RMMd. Aesthetic and sensory quality of Emerald grass (Zoysia japonica) as a function of substrate cultivation and mineral fertilization. Ornam Hortic. 2020;26(3):381-9.

[7] Kazemi F, Golzarian MR, Rabbani Kheir Khah SM. Quality and Establishment of Some Water-Conserving Turfgrass Species for Sustainable Development and Some Ecosystem Services in Arid Urban Environments. Land. 2024 May 21;13(6):721.

[8] Baldwin CM, Brede AD. Quantifying Nitrogen Requirement for Creeping Bentgrass Putting-Green Cultivars. Agronomy Journal. 2012 Sep;104(5):1208-16.

[9] Shearman R, Wit L, Severmutlu S, Budak H, Gaussoin R. Colorant Effects on Dormant Buffalograss Turf Performance. horttech. 2005;15(2):244-6.

[10] Pinnix GD, McCauley RK, Miller GL. Air Temperature Effects on Turfgrass Colorant Transfer. Crop Forage & Turfgrass Mgmt. 2018;4(1):1-6.

[11] Serba DD, Hejl RW, Burayu W, Umeda K, Bushman BS, Williams CF. Pertinent Water-Saving Management Strategies for Sustainable Turfgrass in the Desert U.S. Southwest. Sustainability. 2022;14(19):12722.

[12] Berndt WL, Karcher DE, Richardson MD. Color-distance modeling improves differentiation of colors in digital images of hybrid bermudagrass. Crop Science. 2020;60(4):2138-48.

[13] Karcher DE, Richardson MD. Quantifying Turfgrass Color Using Digital Image Analysis. Crop Science. 2003;43(3):943-51.

[14] Barker WL, Beam JB, Askew SD. Effects of Rimsulfuron Lateral Relocation on Creeping Bentgrass (Agrostis stolonifera). Weed technol. 2005;19(3):647-52.

[15] Tan Z, Qian Y. Light Intensity Affects Gibberellic Acid Content in Kentucky Bluegrass. HortSci. 2003;38(1):113-6.
[16] Rezaei S, Ghobadian B, Ebadi M, Jangi F, Ghomi H. Effects of cold plasma on the color parameters of Hyssop (Hyssopus officinalis L.) using color imaging instrumentation and spectrophotometer. Color Research & Application. 2020;45(1):29-39.
[17] Głąb T, Szewczyk W, Gondek K. Response of Kentucky Bluegrass Turfgrass to Plant Growth Regulators. Agronomy. 2023;13(3):799.
[18] Whitman B, Iannone BV, Kruse JK, Unruh JB, Dale AG. Cultivar blends: A strategy for creating more resilient warm season turfgrass lawns. Urban Ecosyst. 2022;25(3):797-810.
[19] Patrignani A, Ochsner TE. Canopeo: A Powerful New Tool for Measuring Fractional Green Canopy Cover. Agronomy Journal. 2015;107(6):2312-20.
[20] Chhetri M, Fontanier C. Use of Canopeo for Estimating Green Coverage of Bermudagrass during Postdormancy Regrowth. hortte. 2021;31(6):817-9.
[21] R Core Team, R language and environment for statistical computing. R Foundation for Statistical. Computing, 2020.
[22] El-Sheikh MA, Rajaselvam J, Abdel-Salam EM, Vijayaraghavan P, Alatar AA, Devadhasan Biji G. Paecilomyces sp. ZB is a cell factory for the production of gibberellic acid using a cheap substrate in solid state fermentation. Saudi Journal of Biological Sciences. 2020;27(9):2431-8.
[23] Pogroszewska E, Joniec M, Rubinowska K, Najda A. Effect of pre-harvest application of gibberellic acid on the contents of pigments in cut leaves of Asarum europaeum L.. Acta Agrobot. 2014;67(2):77-84.
[24] Aldesuquy H. Synergistic effect of phytohormones on pigment and fine structure of chloroplasts in flag leaf of wheat plants irrigated by seawater. Egyptian Journal of Basic and Applied Sciences. 2015;2(4):310-7.
[25] Abdullah BS, Abdulrahman YA. Effect of different concentrations of gibberellic acid on seeds germination and growth in different turf grass genera. Kufa Jour. Agri. Sci. 2017;9(2):226-247.
[26] Christians NE, Patton AJ, Law QD. Fundamentals of Turfgrass Management. John Wiley & Sons: Hoboken, NJ, USA, p. 480, 2017.
[27] Matthew C, Hofmann WA, Osborne MA. Pasture response to gibberellins: A review and recommendations. New Zealand Journal of Agricultural Research. 2009;52(2):213-25.