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STUDIES ON THE FERTILIZATION AND IRRIGATION OF TURFGRASSES: I- EFFECT OF NPK AND Fe FERTILIZATION ON THE VEGETATIVE GROWTH AND CHEMICAL COMPOSITION OF *Paspalum vaginatum* TURFGRASS

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ABSTRACT

This study was carried out at the nursery of 'Dream Land Golf Course' during the two successive seasons of 2000/2001 and 2001/2002, with the aim of investigating the effect of NPK and Fe fertilization on the vegetative growth and chemical composition of *Paspalum vaginatum* turfgrass. Different rates (0, 7.5, 12.5, and 17.5 g/m^2) of a soluble commercial NPK fertilizer (Kristalon, 19% N – 19% P_2O_5 – 19% K_2O) were applied as a top dressing, followed by irrigation, while Fe was supplied at concentrations of 0, 100, 200 or 300 ppm, using a commercial chelated Fe (EDTA) product. In both seasons, the NPK and Fe treatments were repeated every 2 weeks from 1st July 2000 and 2001 (in the first and second seasons, respectively) to 30th January 2001 and 2002 (in the two seasons, respectively).

In most cases, increasing NPK or Fe rates resulted in steady increases in the values recorded for the different vegetative growth characteristics (plant height of the turf before mowing, fresh and dry weights of clippings/week, fresh and dry weights of underground parts). Accordingly, application of the highest NPK and Fe rates (17.5 g/m^2 and 300 ppm, respectively) every two weeks gave the highest values for these characteristics in most months of the two seasons. In most cases, raising NPK or Fe rates also caused steady increases in the leaf pigments (chlorophyll a, b and carotenoids) contents, the total carbohydrates contents in the clippings and underground parts, as well as the contents of nutrients (N, P, K and Fe) in the clippings. Moreover, raising the NPK fertilization rate increased the contents of N, P and K in the underground parts, giving the highest values at the highest NPK fertilization rate (17.5 g/m^2), whereas the highest Fe content was obtained with the lowest NPK rate (7.5 g/m^2). The N, P, K and Fe contents in underground parts were increased steadily by raising the Fe fertilization rate up to the highest level (300 ppm).

From the above results, it can be recommended that *Paspalum vaginatum* turfgrass should be supplied every 2 weeks with NPK fertilization at the rate of 17.5 g/m^2, using the water-soluble fertilizer Kristalon (19% N – 19% P_2O_5 – 19% K_2O). Also, the plants should be sprayed every two weeks with a chelated Fe foliar fertilizer at the concentration of 300 ppm. It is also recommended that further investigations should be conducted to determine if the turfgrass will respond favourably to higher NPK and Fe fertilization rates.

INTRODUCTION

Turfgrasses have special growth habits that are different than those of all other plants; the grass plants are crowded together and compete with each other, along with neighbouring trees and shrubs, for water and nutrients. Moreover, turfgrasses that are used in planting lawns live and grow under unnatural conditions, since they are mowed regularly, which is highly irregular in nature, and their clippings (including the leaves responsible for manufacturing food through photosynthesis) are often removed. Because of this competition and the unnatural demands placed on lawns, supplying them with adequate fertilization is necessary for sustaining healthy growth. When properly fertilized, a lawn maintains good colour, density and vigour, and does not easily succumb to insects, weeds or diseases. When underfertilized, the lawn is not only less attractive, but also is considerably more susceptible to environmental stress and damage.

The promotion of growth and quality of turfgrasses as a result of supplying them with sufficient macro-nutrients (mainly N, in addition to P and K) has been reported by several researchers working with a variety of species [Christians *et al.* (1981) on *Agrostis palustris*; Mehnert and Mädel (1982) on *Poa pratensis, Festuca rubra commutata* and *Agrostis tenuis*; Yeam *et al.* (1987) on Zoysia grass; Hossni (1993) on *Cynodon dactylon*; Rajesh *et al.* (1993) on *Zoysia matrella*; Soliman (1997) on two species of ryegrass; Emarah (1998) on bermudagrass (*Cynodon dactylon* L.), *C. transvaalensis* Davy. and Tifway; Jiang *et al.* (2000) on *Festuca arundinacea* cv. Pixie; Trenholm *et al.* (2001) on *Paspalum vaginatum*; Oral and Acikgoz (2001) on a turf grass mixture; Surour (2001) on *Cynodon dactylon*; and Sartain (2002) on Tifway bermudagrass].

In addition to the favourable effects of fertilization on growth, it has been shown that N fertilization can be used to increase wear tolerance [Trenholm *et al.* (2001) on *Paspalum vaginatum*], and to break the summer dormancy of cold season species [Jiang *et al.* (2000) on *Festuca arundinacea* cv. Pixie].

The use of Fe (a micro-nutrient) in fertilization of turfgrasses has also been found to promote growth of turfgrasses [Xu and Mancino (2001) on creeping bentgrass and annual bluegrass], and to improve turfgrass colour [Daigger (1972) on Kentucky blue grass; and Yust *et al.* (1984) on *Poa pratensis*].

This study was conducted with the aim of determining the effect of different chemical NPK and Fe fertilization treatments on the vegetative growth and chemical composition of *Paspalum vaginatum* turfgrass. This species was selected because of its popularity and ability to grow under Egyptian conditions, especially in new cities and coastal resorts, where irrigation water often contains relatively high salinity levels. The information provided by this study may help in optimizing the fertilization programs used for providing turfgrasses with their nutritional requirements.

MATERIALS AND METHODS

This study was carried out at the nursery of 'Dream Land Golf Course' during the two successive seasons of 2000/2001 and 2001/2002, with the aim of investigating the effect of NPK and Fe fertilization treatments on the vegetative growth and chemical composition of *Paspalum vaginatum* turfgrass.

The surface layer of the soil of the experimental area was excavated to a depth of 20-25 cm and replaced by a new sandy soil. The physical and chemical characteristics of the sandy soil were determined at the Soil Department, Faculty of Agriculture, Cairo University, and are shown in Table (A). A sprinkler irrigation system was then installed, and was adjusted to provide the plants with 10 l/m^2/day. Soil leveling was then carried out, and the experimental area was divided into square beds (1 m X 1 m), with a distance of 50 cm between beds. The replicates were also separated from each other by a distance of 1.5 m.

Table (A): The physical and chemical characteristics of the sandy soil used for planting the turfgrasses in the 2000/2001 and 2001/2002 seasons.

pH	EC (dS/m)	Soluble Cations (meq/l)				Soluble Anions (meq/l)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
7.1	0.42	1.8	1.2	1.5	0.18	-	2.2	1.25	1.23

On 20th April 2000 and 2001 (in the first and second seasons, respectively), sprigs of *Paspalum vaginatum* Sw. (Family: Poaceae) - purchased from the nursery of PICO company, El-Behaira Governorate - were planted in the prepared beds at a spacing of 10 X 10 cm. The sprigs were watered daily at the rate of 10 l/m^2 until the turfgrass became well established (70 days after planting).

On 1st July, 2000 and 2001, the fertilization treatments were initiated. The planting beds received different combinations of NPK fertilization and Fe spray treatments. The soluble commercial fertilizer Kristalon (19% N – 19% P_2O_5 – 19% K_2O) was used (at rates of 0, 7.5, 12.5, and 17.5 g/m^2) for supplying the plants with the different NPK fertilization treatments. The Kristalon treatments were applied as a top dressing, followed by irrigation. The above rates of Kristalon were mixed with a small quantity of sand to ensure uniformity of distribution of the fertilizer. The different Fe treatments were supplied by using a commercial chelated Fe product (EDTA, 14% Fe, manufactured and distributed by Agrico International Co., Giza). The Fe fertilizer was dissolved in water and applied to the turfgrass as a spray at concentrations of 0, 100, 200 or 300 ppm of Fe. The NPK and Fe treatments were repeated every 2 weeks for a period of 7 months (from 1st July 2000 and 2001 in the first and second seasons, respectively, to 30th January 2001 and 2002 in the two seasons, respectively).

The layout of the experiment was a split plot design, with the main plots arranged in a randomized complete blocks design. The main plots were assigned to the NPK treatments, while the sub-plots were assigned to the Fe treatments. The experiment included 16 treatments (4 NPK treatments X 4 Fe treatments) and 3 replicates.

Common cultural practices were used throughout the experiment (from 1st April till the termination of the experiment on 31st January 2001 and 2002 in the first and second seasons, respectively), including pest and weed control, and daily irrigation. The turfgrass was mowed weekly to a height of 1.5 cm (using a cylindrical mower) during the period from 1st July till 31st November, then the intervals between mowings were prolonged to two weeks during the months of December and January.

Data on vegetative growth were recorded every 2 weeks (i.e. twice/month), from 1st of July to 31st of January. The recorded data included average plant height immediately before mowing (cm), fresh weight of clippings (g/m^2/week) immediately after mowing, as well as dry weight of clippings (g/m^2/week). At the termination of each season, the fresh and dry weights (g/m^2) of underground parts were recorded after the turfgrass was dug out to a depth of 15 cm, and the growing medium was washed off. The dry weights of clippings and underground parts were recorded after oven-drying at 70° C until a constant weight was obtained (after approximately 72 hours).

Samples of fresh leaves were collected on 26th of September 2001 and 2002 (in the two seasons, respectively), and were chemically analyzed to determine their contents of chlorophyll a, b and carotenoids, using the procedure detailed by Saric *et al.* (1967). In addition, samples of clippings were dried, and their contents of total carbohydrates were determined using the method described by Herbert *et al.* (1971). Wet extraction of elements was performed on dry clippings using the method recommended by Piper (1947), and the extract was chemically analyzed to determine the contents of nitrogen (using the Nesslar method, as described by Kock and McMeeckin, 1924), phosphorus (using the hydroquinon sodium sulphite method, as described by Troug and Meyer, 1939), as well as potassium and iron (using a "Philips Atomic Absorption Spectrophotometer, model PU 9100X).

The data recorded on vegetative growth was subjected to statistical analysis of variance (ANOVA), and the calculated means were compared using the "Least Significant Difference, L.S.D." test at the 0.05 level, as recommended by Steel and Torrie (1980).

RESULTS AND DISCUSSION

1- Vegetative growth

a- Plant height

The data presented in Table (1) show that the different NPK treatments had a marked effect on the average plant height in the first season, compared to the unfertilized control plants. In most months of the first season, control plants were significantly shorter than those receiving the different fertilization treatments. The only exception to this general trend was observed in November, with control plants being insignificantly different in height (1.99 cm) than those fertilized with 7.5 g NPK/m^2 (with a height of 2.05 cm). In general, increasing the NPK rate resulted in a steady increase in plant height. Consequently, the highest NPK rate (17.5 g/m^2) gave the tallest plants throughout the first season. In most months of the first season (viz. in August, September, October, December and January) plants receiving this treatment were significantly taller than those receiving any other NPK treatment.

A generally similar trend was observed in the second season, where plant height was increased steadily with increasing the NPK rate. The only exception to this general trend was detected in December, with fertilization using NPK at 7.5 g/m^2 giving insignificantly taller plants than those fertilized with NPK at 12.5 g/m^2. As in the first season, the highest NPK rate (17.5 g/m^2) gave the tallest plants throughout the growing season, while the shortest plants were those receiving no NPK fertilization. However, in July of the second season, no significant difference was detected between the values recorded with the different NPK rates (including the control). Also, no significant difference was detected in November between the heights of plants fertilized with NPK rates of 7.5, 12.5 or 17.5 g/m^2

The increase in plant height as a result of the different NPK treatments is in agreement with the findings of Hossni (1993) on *Cynodon dactylon*, Emarah (1998) on *Cynodon dactylon*, *C. transvaalensis* and Tifway, Trenholm *et al.* (2001) on *Paspalum vaginatum* and Surour (2001) on *Cynodon dactylon*.

Regarding the effect of Fe concentration, the data in Table (1) show that the different Fe treatments also had a considerable effect on plant height in both seasons. In all months of the first season, unfertilized control plants were shorter than those sprayed with the different Fe concentrations. Moreover, raising the Fe concentration caused a steady increase in plant height in all months of the first season, except November. However, the lowest Fe concentration (100 ppm) gave plants that were insignificantly taller than the control (in most months), whereas higher Fe concentrations (200 or 300 ppm) increased plant height significantly, compared to the control. Fe at the concentration of 300 ppm gave the tallest plants in the months of July, August, September, October, December and January, while the tallest plants in November were those sprayed with Fe at 200 ppm. The favourable effect of Fe spray treatments on plant height was also observed in the second season, with unsprayed plants being shorter in the months of July, August, September, October, December and January than those receiving the different Fe treatments. However, the Fe treatments showed no significant effect on plant height in November, with control plants being insignificantly taller than plants sprayed with the different Fe concentrations.

The data in Table (1) also show that the interaction between the NPK and Fe treatments was insignificant in all months of the two seasons. In most cases, the tallest plants were those fertilized with the highest NPK rate and sprayed with the highest Fe concentration.

b- Fresh and dry weights of clippings

The data recorded in the two seasons show that the NPK fertilization treatments had a significant effect on the fresh and dry weights of Paspalum vaginatum clippings (Tables 2 and 3). In all months of the two seasons, plants receiving no NPK fertilization gave the lowest fresh and dry weights of clippings. In most cases, increasing the NPK rate resulted in a steady increase in the recorded values. One exception to this general trend was detected in December of the second season, with the increase in clippings dry weight as a result of raising NPK being unsteady, since the dry weight of clippings was insignificantly reduced when NPK rate was increased from 7.5 g/m^2 to 12.5 g/m^2. In both seasons, the highest fresh and dry weights of clippings were those of plants supplied with the highest NPK rate (17.5 gm/m^2). In most months of the two seasons, this treatment gave significantly heavier fresh and dry clippings than any other NPK rate. The increase in the fresh and dry weights of clippings as a result of NPK fertilization is in agreement with results obtained by Mehnert and Mädel (1982) on Poa pratensis, Festuca rubra and Agrostis tenuis, Yeam *et al.* (1987) on Zoysiagrass, Hossni (1993) on Cynodon dactylon, Soliman (1997) on two species of rayegrass, Emarah (1998) on Cynodon dactylon, C. transvaalensis and Tifway, and Surour (2001) on Cynodon dactylon.

Table (1): Effect of NPK and Fe fertilization treatments on plant height (cm) of *Paspalum vaginatum* in the 2000/2001 and 2001/2002 seasons.

NPK fertilization rates (A)	Plant height (cm)																																		
	July					August					September					October					November					December					January				
	Fe concentration (B) (ppm)					Fe concentration (B) (ppm)					Fe concentration (B) (ppm)					Fe concentration (B) (ppm)					Fe concentration (B) (ppm)					Fe concentration (B) (ppm)					Fe concentration (B) (ppm)				
	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M
First season (2000/2001)																																			
Control	3.67	3.87	[illegible]	4.43	**4.03**	2.42	2.47	2.55	2.50	**2.48**	2.32	2.42	2.47	2.53	**2.43**	1.99	2.03	2.13	2.22	**2.09**	1.75	1.78	1.82	2.62	**1.99**	1.53	1.53	1.63	1.70	**1.60**	1.50	1.53	1.57	1.60	**1.55**
7.5 g/m²	4.30	4.43	4.63	5.00	**4.59**	3.12	3.18	3.28	3.33	**3.23**	2.92	2.93	3.02	3.05	**2.97**	2.03	2.10	2.16	2.58	**2.22**	1.93	2.05	2.12	2.12	**2.05**	1.73	1.73	1.80	1.87	**1.78**	1.63	1.67	1.70	1.70	**1.68**
12.5 g/m²	4.62	4.65	4.90	5.32	**4.87**	3.30	3.35	3.37	3.43	**3.36**	3.27	3.38	3.38	3.47	**3.38**	2.43	2.49	2.57	2.61	**2.53**	2.25	2.28	2.33	2.40	**2.32**	1.80	1.83	1.87	[illegible]	**1.85**	1.77	1.90	1.97	2.03	**1.89**
17.5 g/m²	4.75	4.98	5.08	5.47	**5.07**	3.82	3.97	4.08	4.10	**3.99**	3.55	3.60	3.70	3.83	**3.67**	2.73	2.84	2.87	2.93	**2.84**	2.43	2.47	2.53	2.60	**2.51**	2.27	2.33	2.40	2.47	**2.37**	2.17	2.20	2.27	2.33	**2.24**
Means	4.33	4.47	4.69	5.05	—	3.16	3.24	3.32	3.34	—	3.01	3.08	3.14	3.22	—	2.30	2.37	2.43	2.59	—	2.09	2.15	2.50	2.43	—	1.83	1.86	1.93	[illegible]	—	1.77	1.80	1.88	1.92	—
L.S.D. (0.05)																																			
A	0.51					0.11					0.09					0.17					0.30					0.04					0.09				
B	0.22					0.05					N.S.					0.13					N.S.					0.04					0.07				
A X B	N.S.					N.S.					N.S.					N.S.					N.S.					N.S.					N.S.				
Second season (2001/2002)																																			
Control	4.83	5.33	5.50	5.67	**5.33**	2.17	2.23	2.27	2.30	**2.24**	2.33	2.38	2.45	2.52	**2.42**	2.03	2.00	2.12	2.19	**2.10**	1.72	1.75	1.80	1.87	**1.78**	1.53	1.58	1.61	1.75	**1.62**	1.53	1.57	1.63	1.67	**1.60**
7.5 g/m²	5.03	5.50	5.73	5.97	**5.56**	3.00	3.17	3.23	3.27	**3.17**	2.77	2.88	2.96	3.03	**2.91**	2.34	2.40	2.54	2.60	**2.48**	2.83	1.98	2.05	2.10	**2.24**	1.83	1.97	1.87	1.90	**1.89**	1.70	1.77	1.80	1.77	**1.76**
12.5 g/m²	5.13	5.56	5.83	6.03	**5.64**	3.27	3.37	3.40	3.50	**3.38**	3.27	3.35	3.42	3.45	**3.37**	2.73	2.80	2.87	2.93	**2.83**	2.20	2.25	2.32	2.35	**2.28**	1.80	1.87	1.85	2.00	**1.88**	1.80	1.87	1.90	1.87	**1.86**
17.5 g/m²	5.43	5.83	6.00	6.50	**5.94**	3.73	3.77	3.83	3.97	**3.83**	3.67	3.70	3.75	3.87	**3.75**	3.03	3.08	3.13	3.25	**3.13**	2.40	2.47	2.52	2.57	**2.49**	2.10	2.17	2.23	2.40	**2.23**	2.13	2.20	2.23	2.30	**2.22**
Means	5.11	5.56	5.77	6.04	—	3.04	3.13	3.18	3.26	—	3.01	3.08	3.15	3.22	—	2.53	2.60	2.67	2.74	—	2.29	2.11	2.17	2.22	—	1.82	1.90	1.89	2.01	—	1.79	1.85	1.89	1.90	—
L.S.D. (0.05)																																			
A	N.S.					0.14					0.54					0.04					0.40					0.09					0.04				
B	0.13					0.05					0.06					0.05					N.S					0.07					0.04				
A X B	N.S.					N.S.					N.S.					[illegible]					N.S.					N.S.					N.S.				

Table (2): Effect of NPK and Fe fertilization treatments on the fresh weight (g/m^2/week) of *Paspalum vaginatum* clippings in the 2000/2001 and 2001/2002 seasons.

Fresh weight of clippings (g/m^2/week)

NPK fertilization rates (A)	July – Fe concentration (B) (ppm)					August – Fe concentration (B) (ppm)				
	0	100	200	300	M	0	100	200	300	M
First season (2000/2001)										
Control	32.51	36.59	45.26	52.21	41.64	26.47	29.60	34.95	37.71	32.19
7.5 g/m^2	35.40	43.30	50.48	57.00	46.55	29.59	34.71	39.66	49.14	38.28
12.5 g/m^2	41.57	50.27	57.05	68.79	54.42	34.48	39.53	51.04	59.35	46.09
17.5 g/m^2	51.20	61.68	73.31	82.26	67.11	47.97	53.25	61.35	67.61	57.54
Means	40.17	47.96	56.53	65.06	—	34.63	39.27	46.75	53.45	—
L.S.D. (0.05) A	[illegible]					1.86				
B	3.01					2.21				
A X B	N.S.					4.42				
Second season (2001/2002)										
Control	39.06	46.89	53.60	54.86	48.60	16.31	21.60	28.37	36.99	25.56
7.5 g/m^2	52.42	52.99	55.64	53.06	54.78	16.60	23.46	30.73	43.55	29.89
12.5 g/m^2	54.81	57.66	59.61	62.98	58.77	46.26	56.95	64.58	62.79	57.82
17.5 g/m^2	57.06	60.01	61.93	64.81	60.90	49.10	60.40	65.33	72.41	61.81
Means	50.84	54.39	57.69	60.13	—	32.29	40.61	47.51	53.67	—
L.S.D. (0.05) A	3.47					8.94				
B	2.09					3.45				
A X B	4.18					N.S.				

NPK fertilization rates (A)	September – Fe concentration (B) (ppm)					October – Fe concentration (B) (ppm)				
	0	100	200	300	M	0	100	200	300	M
First season (2000/2001)										
Control	6.48	9.66	10.28	12.52	9.74	5.27	7.30	7.90	9.50	7.49
7.5 g/m^2	17.18	20.43	22.84	27.43	21.97	11.89	13.95	15.96	18.59	15.10
12.5 g/m^2	21.81	25.62	30.28	37.50	28.80	14.79	17.66	20.64	24.98	19.52
17.5 g/m^2	37.00	40.35	48.44	55.11	45.23	23.97	26.78	31.88	35.84	29.61
Means	20.62	24.02	27.96	33.14	—	13.98	16.42	19.09	22.23	—
L.S.D. (0.05) A	7.49					4.57				
B	1.82					1.13				
A X B	3.64					2.27				
Second season (2001/2002)										
Control	8.36	14.31	15.83	19.44	14.54	6.39	8.82	10.43	13.12	9.63
7.5 g/m^2	13.54	15.32	19.14	22.72	17.68	8.59	10.68	12.84	15.27	11.85
12.5 g/m^2	24.08	24.81	27.37	30.87	26.78	14.63	15.59	17.44	19.76	16.85
17.5 g/m^2	27.23	38.34	41.27	48.01	38.76	17.81	22.79	25.48	29.78	23.77
Means	18.35	23.25	25.90	30.26	—	11.61	14.47	16.55	19.48	—
L.S.D. (0.05) A	7.73					4.66				
B	1.99					1.13				
A X B	3.99					2.27				

NPK fertilization rates (A)	November – Fe concentration (B) (ppm)					December – Fe concentration (B) (ppm)				
	0	100	200	300	M	0	100	200	300	M
First season (2000/2001)										
Control	3.89	4.75	5.48	5.88	5.00	2.93	3.47	3.80	3.90	3.53
7.5 g/m^2	5.27	6.16	6.98	8.38	6.69	3.30	3.97	4.73	5.45	4.36
12.5 g/m^2	6.26	8.78	9.79	11.59	9.11	3.44	4.12	5.27	6.10	4.73
17.5 g/m^2	8.09	11.63	12.77	13.87	11.59	4.63	6.70	7.77	10.47	7.39
Means	5.88	7.83	8.76	9.98	—	3.58	4.56	5.39	6.48	—
L.S.D. (0.05) A	2.10					0.43				
B	0.79					0.44				
A X B	1.58					0.88				
Second season (2001/2002)										
Control	3.18	3.97	4.80	6.12	4.39	2.50	2.80	3.27	3.77	3.08
7.5 g/m^2	3.65	4.71	5.93	7.15	5.36	3.20	3.60	3.73	4.33	3.72
12.5 g/m^2	5.18	6.36	7.51	8.66	6.93	3.58	3.71	3.80	4.15	3.81
17.5 g/m^2	6.78	7.72	10.36	11.56	9.11	4.10	4.37	4.80	5.43	4.68
Means	4.70	5.69	7.20	8.37	—	3.34	3.62	3.90	4.42	—
L.S.D. (0.05) A	0.89					0.51				
B	0.53					0.28				
A X B	N.S.					N.S.				

NPK fertilization rates (A)	January – Fe concentration (B) (ppm)				
	0	100	200	300	M
First season (2000/2001)					
Control	2.13	3.30	2.55	2.79	3.50
7.5 g/m^2	3.00	2.96	3.59	4.07	4.01
12.5 g/m^2	3.76	4.16	4.45	5.70	4.51
17.5 g/m^2	5.13	6.63	7.46	8.40	5.24
Means	3.44	3.48	4.52	6.91	—
L.S.D. (0.05) A	1.20				
B	0.11				
A X B	0.70				
Second season (2001/2002)					
Control	1.15	1.18	1.26	1.45	1.26
7.5 g/m^2	2.25	2.30	2.38	2.45	2.34
12.5 g/m^2	2.32	2.40	2.44	3.58	2.69
17.5 g/m^2	2.90	3.50	3.64	3.78	3.46
Means	2.16	2.35	2.43	2.81	—
L.S.D. (0.05) A	0.18				
B	0.13				
A X B	0.27				

Table (3): Effect of NPK and Fe fertilization treatments on the dry weight (g/m^2/week) of *Paspalum vaginatum* clippings in the 2000/2001 and 2001/2002 seasons.

Dry weight of clippings (g/m^2/week)

NPK fertilization rates (A)	July: Fe concentration (B) (ppm)					August: Fe concentration (B) (ppm)					September: Fe concentration (B) (ppm)					October: Fe concentration (B) (ppm)				
	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M
First season (2000/2001)																				
Control	17.50	19.67	23.30	29.24	22.21	14.38	17.72	20.45	22.37	18.80	3.87	5.62	6.04	6.85	5.55	3.05	4.99	6.52	6.79	5.34
7.5 g/m^2	19.58	22.55	27.64	33.36	26.96	16.58	21.33	24.17	26.58	22.01	9.44	10.92	13.38	15.32	12.26	5.23	6.97	7.52	9.06	7.19
12.5 g/m^2	23.49	28.82	31.31	38.25	31.09	17.96	20.21	29.53	33.40	27.12	11.78	14.30	17.25	21.10	16.10	7.64	8.69	9.85	12.01	8.55
17.5 g/m^2	28.26	36.94	44.31	50.11	37.74	26.61	28.79	34.33	38.69	30.26	18.78	21.53	26.12	31.09	24.38	9.25	13.36	14.42	16.85	13.47
Means	22.43	25.78	30.43	39.96	—	18.73	22.16	25.27	32.16	—	10.92	13.09	15.70	18.59	—	6.29	8.50	9.57	11.18	—
L.S.D. (0.05) A						3.82					3.92					2.23				
B	2.00					2.11					1.14					0.59				
A X B	4.01					N.S.					2.29					1.18				
Second season (2001/2002)																				
Control	20.09	25.94	27.86	30.83	26.18	10.10	11.25	13.43	19.49	13.82	4.20	7.13	10.06	9.68	7.77	3.28	5.20	5.57	6.29	5.07
7.5 g/m^2	28.86	29.35	29.96	36.48	35.36	10.69	12.15	17.37	23.67	15.42	8.21	10.82	11.68	14.68	11.35	6.93	8.29	9.28	11.29	8.95
12.5 g/m^2	29.08	33.69	32.43	35.77	32.24	26.19	30.53	34.04	34.55	31.33	12.37	12.73	13.69	15.44	14.20	9.03	10.55	12.30	14.14	11.46
17.5 g/m^2	29.83	31.83	36.34	39.12	34.28	28.41	33.22	37.88	43.37	35.72	14.91	20.69	22.44	25.19	20.81	12.68	15.03	17.50	20.16	16.34
Means	26.97	29.70	31.64	35.55	—	18.85	21.79	25.68	29.77	—	9.92	12.84	14.97	16.99	—	7.98	9.74	11.11	12.97	—
L.S.D. (0.05) A	3.63					4.34					2.85					2.33				
B	1.79					2.15					1.12					0.56				
A X B	N.S.					N.S.					2.25					1.14				

NPK fertilization rates (A)	November: Fe concentration (B) (ppm)					December: Fe concentration (B) (ppm)					January: Fe concentration (B) (ppm)				
	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M
First season (2000/2001)															
Control	2.41	2.90	3.33	3.93	3.15	1.62	1.96	2.13	2.21	1.98	1.17	1.31	1.47	1.74	1.41
7.5 g/m^2	3.30	3.85	4.72	5.47	4.34	1.93	2.25	2.87	3.18	2.56	1.86	2.13	2.21	2.61	2.20
12.5 g/m^2	3.83	5.00	5.81	6.72	5.34	2.04	2.18	2.96	3.35	2.68	2.33	2.73	3.09	4.14	3.07
17.5 g/m^2	4.78	6.73	7.75	8.76	7.00	2.78	3.78	4.39	6.14	4.27	3.31	3.60	4.29	4.79	4.00
Means	3.58	4.62	5.40	6.22	—	2.09	2.54	3.08	3.77	—	2.17	2.44	2.76	3.32	—
L.S.D. (0.05) A	0.68					0.32					0.76				
B	0.30					0.25					0.23				
A X B	0.60					0.51					0.47				
Second season (2001/2002)															
Control	1.90	2.31	2.98	3.44	2.66	1.38	1.52	1.84	1.95	1.67	0.56	0.62	0.76	0.84	0.70
7.5 g/m^2	2.12	3.05	3.29	4.04	3.12	1.70	1.96	2.08	2.45	2.05	1.23	1.42	1.51	1.68	1.49
12.5 g/m^2	2.91	3.99	2.28	4.45	3.91	2.04	1.89	1.96	2.29	1.99	1.29	1.45	1.66	2.03	1.61
17.5 g/m^2	3.52	4.68	5.72	7.71	5.41	2.11	2.28	2.69	3.13	2.55	1.47	1.72	1.95	2.19	1.83
Means	2.61	3.51	4.07	4.90	—	1.76	1.91	2.14	2.45	—	1.16	1.28	1.47	1.70	—
L.S.D. (0.05) A	0.81					0.22					0.14				
B	0.32					0.09					0.07				
A X B	0.65					0.17					0.15				

Regarding the effect of the Fe spray treatments, the data in Tables (2 and 3) show that in all months of the two seasons, the Fe treatments caused a general increase in the fresh and dry weights of clippings. In most months of the first season, increasing the Fe concentration resulted in steady increases in the fresh and dry weights of clippings. The generally favourable effect of Fe was particularly clear at the highest Fe concentration (300 ppm) which gave the highest values in all months, compared to those obtained with lower Fe concentrations. A similar trend was obtained in the second season, with the different Fe treatments causing significant increases in the fresh and dry weights of clippings in all months of the season. As in the first season, the highest values recorded in all months of the second season were obtained from plants sprayed with Fe at 300 ppm, whereas the lowest values in all months were obtained from plants receiving no Fe treatment. These results are in agreement with those obtained by Xu and Mancino (2001) on creeping bentgrass and annual bluegrass.

Regarding the interaction between NPK and Fe treatments, the results recorded in the two seasons (Tables 2 and 3) show that this interaction was significant in most months (especially in the first season). The heaviest fresh and dry weights in all months were obtained from plants receiving NPK fertilization at 17.5 g/m^2, combined with Fe spray treatment at the highest concentration (300 ppm), whereas the lowest values were obtained from plants receiving no NPK or Fe treatments.

c- Fresh and dry weights of underground parts

The results presented in Table (4) show that the effect of NPK fertilization on the dry weight of underground parts in *Paspalum vaginatum* was significant. In general, NPK fertilization increased the fresh and dry weights of underground parts. In both seasons, the lowest fresh and dry weights of underground parts were those obtained from plants receiving no NPK fertilization (control), whereas plants receiving any NPK rate gave significantly higher values than the control. Moreover, raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 increased the fresh and dry weights of underground parts steadily, with the highest NPK rate (17.5 g/m^2) giving the highest values in both seasons. These results are in agreement with those obtained by Yeam *et al.* (1987) on Zoysiagrass, and Soliman (1997) on two species of ryegrass.

The data in Table (4) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave significantly higher values for the fresh and dry weights of underground parts, compared to those of untreated plants. In both seasons, raising the Fe concentration from 0 to 100, 200 or 300 ppm caused steady and significant increases in the recorded values. Accordingly, the most effective Fe treatment for increasing the fresh and dry weights of underground parts was spraying the turfgrass with Fe at the highest concentration (300 ppm), which gave significantly higher values than any other Fe concentration.

Regarding the interaction between the effects of NPK and Fe treatments on the fresh and dry weights of underground parts, the data in Table (4) show that this interaction was insignificant in the two seasons. In both seasons, the lowest fresh and dry weights of underground parts were obtained from plants receiving no NPK or Fe fertilization, whereas the highest values were obtained from plants treated with NPK at 17.5 g/m^2, and Fe at 300 ppm.

Table (4): Effect of NPK and Fe fertilization treatments on the fresh and dry weights (g/m^2) of the underground parts of *Paspalum vaginatum* turfgrasses during the 2000/2001 and 2001/2002 seasons.

NPK fertilization rates (A)	First season (2000/2001)				
	Fe concentration (B) (ppm)				
	0	100	200	300	Mean
	Fresh weight of underground parts (g/m^2)				
Control	2914.3	3162.7	3374.0	3701.3	**3288.1**
7.5 g/m^2	3497.7	3728.7	3884.0	4138.0	**3812.1**
12.5 g/m^2	3549.8	3760.7	4099.7	4283.0	**3923.3**
17.5 g/m^2	3679.0	3973.3	4202.7	4407.3	**4065.6**
Means	**3410.2**	**3656.4**	**3890.1**	**4132.4**	—
L.S.D. (0.05)					
A	**169.6**				
B	**89.92**				
A X B	**N.S.**				
	Dry weight of underground parts (g/m2)				
Control	732.1	804.0	840.2	948.7	**831.2**
7.5 g/m^2	874.6	922.3	979.3	1044.6	**955.2**
12.5 g/m^2	897.6	943.4	1028.3	1064.1	**983.4**
17.5 g/m^2	923.0	996.7	1047.3	1105.1	**1018.0**
Means	**856.8**	**916.6**	**973.8**	**1040.6**	—
L.S.D. (0.05)					
A	**50.13**				
B	**24.81**				
A X B	**N.S.**				
	Second season (2001/2002)				
	Fe concentration (B) (ppm)				
Control	3205.7	3478.8	3644.8	4071.5	**3600.2**
7.5 g/m^2	3814.1	4068.2	4250.2	4485.1	**4154.4**
12.5 g/m^2	3838.4	4103.4	4509.5	4677.9	**4282.3**
17.5 g/m^2	4146.7	4337.3	4622.8	4814.5	**4480.3**
Means	**3751.2**	**3996.9**	**4256.8**	**4512.2**	—
L.S.D. (0.05)					
A	**133.8**				
B	**111.0**				
A X B	**N.S.**				
	Dry weight of underground parts (g/m2)				
Control	811.4	883.0	921.3	1021.3	**909.3**
7.5 g/m^2	960.5	1023.8	1069.7	1124.8	**1044.7**
12.5 g/m^2	963.1	1042.5	1137.7	1179.4	**1080.7**
17.5 g/m^2	1033.8	1112.3	1159.2	1236.9	**1135.6**
Means	**942.2**	**1015.4**	**1071.9**	**1140.6**	—
L.S.D. (0.05)					
A	**36.62**				
B	**32.6**				
A X B	**N.S.**				

The favourable effect of the NPK fertilization treatments on the studied vegetative growth characteristics (compared to the control) can be explained by the important roles played by N, P and K in the different physiological processes within the plant, which in turn affect plant growth. Also, nitrogen is present in the structure of protein molecules, while phosphorus is an essential constituent of nucleic acids and phospholipids, and potassium is essential as an activator for enzymes involved in the synthesis of certain peptide bonds (Devlin, 1975).

2- Effect on Chemical Composition

a- Leaf pigments (chlorophyll "a", chlorophyll "b" and carotenoids) content

The results recorded in the two seasons (Table 5) show that NPK fertilization had a generally favourable effect on the synthesis and accumulation of pigments (chlorophylls "a" and "b", and carotenoids) in *Paspalum vaginatum* leaves. In both seasons, the lowest values were obtained from the leaves of plants receiving no NPK fertilization (control). Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the contents of the different leaf pigments, with the highest NPK rate (17.5 g/m^2) giving the highest values in both seasons. These results are in agreement with those obtained by Christians *et al.* (1981) on *Agrostis palustris,* Hossni (1993) on *Cynodon dactylon*, Emarah (1998) on bermudagrass and Tifway, Jiang *et al.* (2000) on tall fescue, and Oral and Acikgoz (2001) on a turfgrass mixture.

The data presented in Table (5) also show that spraying *Paspalum vaginatum* with the different tested Fe concentrations gave higher contents of leaf pigments (chlorophylls "a" and "b", and carotenoids) than those obtained in unfertilized plants. Moreover, the effectiveness of Fe in promoting the synthesis of leaf pigments was increased by raising the Fe concentration. Accordingly, the most effective Fe treatment for increasing the pigments content was the application of 300 ppm, which gave the highest mean values, compared to those obtained in plants sprayed with any other Fe concentration. These results are in agreement with those obtained by Daigger (1972) on Kentucky bluegrass, Yust *et al.* (1984) on *Poa pratensis*, and Xu and Mancino (2001) on creeping bentgrass and annual bluegrass.

Considerable differences were also detected between the contents of pigments in plants receiving different combinations of NPK and Fe fertilization treatments. In both seasons, the lowest contents of the different leaf pigments (chlorophylls "a" and "b", and carotenoids) were obtained from plants receiving no NPK or Fe fertilization, whereas the highest values were obtained from plants treated with NPK at 17.5 g/m^2, and sprayed with Fe at 300 ppm.

b- Total carbohydrates content in clippings and underground parts

The results recorded in the two seasons (Table 6) show that the NPK fertilization treatments had a marked effect on the content of total carbohydrates in the clippings and underground parts of *Paspalum vaginatum*. In both seasons, plants receiving no NPK fertilization (control) had the lowest total carbohydrates contents. Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the recorded values. Accordingly, the highest content of total carbohydrates was obtained in the clippings and underground parts of plants fertilized with the highest NPK rate (17.5 g/m^2). The favourable effect of NPK fertilization on the synthesis and accumulation of total carbohydrates may be attributed to the increase in the leaf contents of leaf pigments, which resulted in active photosynthesis and an increase in the production of carbohydrates. These results are in agreement with the findings of

Hossni (1993) on *Cynodon dactylon*, Saleh (1993) on ryegrass, Goatley *et al.* (1994) on bermudagrass, and Emarah (1998) on bermudagrass and Tifway.

Table (5): Effect of NPK and Fe fertilization treatments on the contents (mg/g fresh matter) of pigments (chlorophyll a, b and carotenoids) in *Paspalum vaginatum* leaves in the 2000/2001 and 2001/2002 seasons.

NPK fertilization rates	Leaf pigments content (mg/g fresh matter) Chlorophyll "a" Fe concentration (ppm)				
	0	100	200	300	Means
	First season (2000/2001)				
Control	1.12	2.51	3.03	3.63	2.57
7.5 g/m^2	1.61	2.91	3.60	3.81	2.98
12.5 g/m^2	2.64	3.37	3.84	4.12	3.49
17.5 g/m^2	2.96	3.94	4.01	4.27	3.79
Means	2.08	3.18	3.62	3.96	—
	Chlorophyll "b"				
	Fe concentration (ppm)				
Control	1.05	1.51	1.61	2.75	1.73
7.5 g/m^2	1.10	1.54	1.77	2.76	1.79
12.5 g/m^2	1.26	1.62	2.16	3.03	2.02
17.5 g/m^2	1.49	1.98	2.74	3.10	2.33
Means	1.23	1.66	2.07	2.91	—
	Carotenoids				
	Fe concentration (ppm)				
Control	0.99	1.06	1.47	1.53	1.26
7.5 g/m^2	1.01	1.43	1.62	1.83	1.47
12.5 g/m^2	1.36	1.50	1.74	2.15	1.69
17.5 g/m^2	1.51	1.59	1.89	2.19	1.80
Means	1.22	1.40	1.68	1.93	—
	Second season (2001/2002)				
	Chlorophyll "a"				
	Fe concentration (ppm)				
Control	1.15	2.57	3.12	3.71	2.64
7.5 g/m^2	1.63	2.87	3.69	3.77	2.99
12.5 g/m^2	2.71	3.42	3.78	4.10	3.50
17.5 g/m^2	2.85	3.61	4.13	4.33	3.73
Means	2.09	3.12	3.68	3.99	—
	Chlorophyll "b"				
	Fe concentration (ppm)				
Control	1.13	1.56	1.57	2.83	1.77
7.5 g/m^2	1.17	1.55	1.78	2.87	1.84
12.5 g/m^2	1.28	1.70	2.22	3.10	2.08
17.5 g/m^2	1.54	2.04	2.69	3.14	2.35
Means	1.28	1.71	2.06	2.99	—
	Carotenoids				
	Fe concentration (ppm)				
Control	1.04	1.14	1.49	1.62	1.31
7.5 g/m^2	1.17	1.46	1.59	1.91	1.53
12.5 g/m^2	1.42	1.47	1.77	2.21	1.71
17.5 g/m^2	1.58	1.63	1.93	2.27	1.83
Means	1.30	1.43	1.70	2.00	—

Spraying Fe at the different tested concentrations also had a considerable effect on the total carbohydrates content in the clippings and underground parts of *Paspalum vaginatum* (Table 6). In both seasons, the application of the Fe fertilization treatments gave higher values than those found in untreated plants. Moreover, the highest contents of total carbohydrates were found in the clippings and underground parts of plants sprayed with the highest Fe concentration (300 ppm).

Regarding the interaction between the effect of NPK and Fe treatment, it was found that considerable differences occurred between the contents of total carbohydrates in the clippings and underground parts of plants receiving different combinations of NPK and Fe treatments. In both seasons, the lowest contents of total carbohydrates were obtained from plants receiving no NPK or Fe treatments, whereas the highest values were found in plants treated with the highest levels of NPK and Fe (17.5 g/m^2 and 300 ppm, respectively).

Table (6): Effect of NPK and Fe fertilization treatments on the total carbohydrates content in clippings and undergound parts of *Paspalum vaginatum* in the 2000/2001 and 2001/2002 seasons.

NPK fertilization rates	First season (2000/2001) Fe concentration (ppm)				
	0	100	200	300	Means
Total carbohydrates content in clippings (% dry matter)					
Control	8.44	10.11	12.07	15.04	**11.42**
7.5 g/m^2	11.21	12.18	15.42	15.60	**13.60**
12.5 g/m^2	11.80	13.16	15.68	17.26	**14.47**
17.5 g/m^2	15.28	17.87	18.92	19.89	**17.99**
Means	**11.68**	**13.33**	**15.52**	**16.95**	—
Total carbohydrates content in underground parts (% dry matter)					
Control	21.38	24.90	34.07	35.19	**28.88**
7.5 g/m^2	30.44	33.45	34.47	41.95	**35.08**
12.5 g/m^2	34.79	38.32	38.94	47.93	**39.99**
17.5 g/m^2	37.48	39.84	40.61	48.45	**41.59**
Means	**31.02**	**34.13**	**37.02**	**43.38**	—
Second season (2001/2002) Fe concentration (ppm)					
Total carbohydrates content in clippings (% dry matter)					
Control	9.73	12.68	13.14	15.34	**12.72**
7.5 g/m^2	13.36	15.17	16.18	16.70	**15.35**
12.5 g/m^2	14.18	14.97	16.35	18.14	**15.91**
17.5 g/m^2	15.58	18.14	19.31	19.96	**18.25**
Means	**13.21**	**15.24**	**16.25**	**17.54**	—
Total carbohydrates content in underground parts (% dry matter)					
Control	25.18	26.74	31.96	34.87	**29.69**
7.5 g/m^2	31.51	33.17	35.54	38.79	**34.75**
12.5 g/m^2	35.19	38.83	40.39	43.59	**39.50**
17.5 g/m^2	40.36	41.92	46.37	49.19	**44.46**
Means	**33.06**	**35.16**	**38.56**	**41.61**	—

c- Nutrients content in clippings

- Nitrogen

The results recorded in the two seasons (Table 7) show that NPK fertilization had a considerable effect on the nitrogen percentage in the clippings of *Paspalum vaginatum*. In both seasons, plants receiving no NPK fertilization (control) had a lower nitrogen content in their clippings (with means of 2.320 and 2.990%, in the first and second seasons, respectively) than those receiving any of the different NPK treatments. Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the N content, with the highest NPK rate (17.5 g/m^2) giving the highest N percentage (3.510 and 3.860% in the first and second seasons, respectively). These results are in agreement with those obtained by Rajesh *et al.* (1993) on *Zoysia matrella*, Hossni (1993) on *Cynodon dactylon*, and Emarah (1998) on bermudagrass and Tifway.

The data in table (7) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave significantly higher nitrogen contents in the clippings than those found in untreated plants. The most effective Fe treatment for increasing the nitrogen percentages was the application of 300 ppm.

Regarding the interaction between the effect of NPK and Fe fertilization, the data in Table (7) show that significant differences occurred between the nitrogen contents in the clippings of plants receiving different combinations of NPK and Fe treatments. In both seasons, the lowest nitrogen contents were found in plants receiving no NPK or Fe fertilization, whereas the highest nitrogen contents were found in plants treated with NPK at 17.5 g/m^2, and Fe at 300 ppm.

- Phosphorus

The results recorded in the two seasons (Table 7) show that NPK fertilization had a considerable effect on the P content in the clippings of *Paspalum vaginatum*. In both seasons, the lowest P contents were obtained from plants receiving no NPK fertilization (control). Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the P content. Accordingly, the highest P contents were obtained from plants treated with NPK at 17.5 g/m^2. These results are in agreement with those obtained by Goatley *et al.* (1994) on bermudagrass, Abdalla (1996) on *Cynodon dactylon*, and Emarah (1998) on bermudagrass and Tifway.

The data in table (7) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave significantly higher P contents in the clippings than those found in untreated plants (0 ppm). The most effective Fe treatment for increasing the P content was the application of 200 ppm.

Regarding the interaction between the effect of NPK and Fe treatments, it was found that significant differences occurred between the P contents in the clippings of plants receiving different combinations of NPK and Fe. In both seasons, the lowest P contents were found in plants receiving no NPK or Fe fertilization. On the other hand, the highest P content in the first season (1.050 mg/g dry matter) was recorded in plants fertilized with NPK at 17.5 g/m^2 and Fe at 200 or 300 ppm, whereas the highest P content in the second season (1.060 mg/g dry matter) was found in plants treated with NPK at 17.5 g/m^2 and Fe at 200 ppm.

Table (7): Effect of NPK and Fe fertilization treatments on the N, P, K and Fe contents in clippings of *Paspalum vaginatum* in the 2000/2001 and 2001/2002 seasons.

NPK fertilization rates	Nutrient contents in clippings																			
	N content (% dry matter)					P content (mg/g dry matter)					K content (% dry matter)					Fe content (mg/g dry matter)				
	Fe concentration (ppm)					Fe concentration (ppm)					Fe concentration (ppm)					Fe concentration (ppm)				
	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M
	First season (2000/2001)																			
Control	2.160	2.190	2.350	2.580	**2.320**	0.680	0.730	0.850	0.780	**0.760**	2.360	2.550	3.400	3.520	**2.960**	0.140	0.165	0.217	0.225	**0.187**
7.5 g/m²	2.250	2.350	2.550	3.160	**2.580**	0.860	0.870	0.910	0.870	**0.880**	2.520	3.240	3.530	3.740	**3.260**	0.133	0.163	0.207	0.265	**0.192**
12.5 g/m²	2.840	2.960	3.170	3.720	**3.170**	0.940	0.980	0.990	0.950	**0.960**	3.210	3.400	3.650	3.950	**3.550**	0.137	0.150	0.223	0.260	**0.193**
17.5 g/m²	3.120	3.330	3.410	4.190	**3.510**	0.980	0.990	1.050	1.050	**1.020**	3.600	4.090	4.200	4.310	**4.050**	0.113	0.183	0.247	0.290	**0.208**
Means	**2.590**	**2.710**	**2.870**	**3.410**	—	**0.870**	**0.890**	**0.950**	**0.910**	—	**2.920**	**3.320**	**3.690**	**3.880**	—	**0.131**	**0.165**	**0.224**	**0.260**	—
	Second season (2001/2002)																			
Control	2.450	2.740	3.230	3.530	**2.990**	0.760	0.790	0.780	0.790	**0.780**	2.550	2.850	3.150	3.630	**3.050**	0.110	0.165	0.204	0.238	**0.179**
7.5 g/m²	2.650	2.960	3.550	4.450	**3.400**	0.820	0.850	0.880	0.870	**0.860**	3.050	3.260	3.630	3.860	**3.450**	0.173	0.198	0.227	0.232	**0.207**
12.5 g/m²	3.020	3.190	3.740	4.490	**3.610**	0.900	0.960	0.960	0.940	**0.940**	3.500	3.630	3.850	4.050	**3.760**	0.133	0.187	0.250	0.281	**0.213**
17.5 g/m²	3.140	3.630	4.160	4.520	**3.860**	0.950	0.990	1.060	1.050	**1.010**	3.810	3.950	4.350	4.570	**4.170**	0.130	0.189	0.214	0.216	**0.187**
Means	**2.820**	**3.130**	**3.670**	**4.250**	—	**0.860**	**0.900**	**0.920**	**0.910**	—	**3.230**	**3.420**	**3.750**	**4.030**	—	**0.137**	**0.185**	**0.224**	**0.242**	—

- Potassium

The results recorded in the two seasons (Table 7) show that NPK fertilization had a considerable effect on the K percentage in the clippings of *Paspalum vaginatum*. In general, the lowest K contents were obtained from plant receiving no NPK fertilization (control). Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the K content, with the highest K percentages being found in plants treated with NPK at 17.5 g/m^2. These results are in agreement with those obtained by Hossni (1993) on *Cynodon dactylon*, Goatley *et al.* (1994) on bermudagrass, Emarah (1998) on bermudagrass and Tifway, and Sartain (2002) on Tifway bermudagrass.

The data in table (7) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave significantly higher K contents in the clippings than those found in untreated plants. The most effective Fe treatment for increasing the K percentage was the application of 300 ppm.

Regarding the interaction between the effect of NPK and Fe treatment, it was found that significant differences occurred between the potassium contents in the clippings of plants receiving different combinations of NPK and Fe. In both seasons, the lowest K contents were found in plants receiving no NPK or Fe fertilization, whereas the highest K contents were found in plants fertilized with NPK at 17.5 g/m^2, and Fe at 300 ppm.

- Iron

The results recorded in the two seasons (Table 7) show that NPK fertilization had a marked effect on the Fe content in the clippings of *Paspalum vaginatum*. In general, the lowest Fe contents, were obtained from plant receiving no NPK fertilization (control). In the first season, raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the iron content. Thus, the highest Fe content in the first season (0.208 mg/g) was obtained from plants treated with NPK at 17.5 g/m^2. On the other hand, the highest value recorded in the second season (0.213 mg/g) was obtained from plants treated with NPK at 12.5 g/m^2.

The data in table (7) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave significantly higher Fe contents in the clippings than those found in untreated plants. The most effective Fe treatment for increasing the iron content was the application of 300 ppm, which gave the highest mean values in both seasons. These results are in agreement with those obtained by Xu and Mancino (2001) on creeping bentgrass and annual bluegraas.

Regarding the interaction between the effect of NPK and Fe treatment, it was found that significant differences occurred between the iron contents in the clippings of plants receiving different combinations of NPK and Fe. However, the recorded trend differed from one season to the other. In the first season, the lowest Fe contents (0.113 mg/g) was found in plants fertilized with the highest NPK rate (17.5 g/m^2) but with no Fe (0 ppm), whereas the highest value (0.290 mg/g) was found in plants treated with NPK at 17.5 g/m^2, and Fe at 300 ppm. In the second season, the lowest Fe contents (0.110 mg/g) was found in plants supplied with no NPK or Fe fertilization, whereas the highest value (0.281 mg/g) was found in plants treated with NPK at 12.5 g/m^2, and with Fe at 300 ppm.

d- Nutrients content in underground parts

- Nitrogen

The results recorded in the two seasons (Table 8) show that NPK fertilization had a considerable effect on the nitrogen percentage in the underground parts of *Paspalum vaginatum*. In general, the lowest nitrogen contents were obtained from plants receiving no NPK fertilization (control). Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the nitrogen content, with the highest NPK rate (17.5 g/m^2) giving the highest nitrogen contents.

The data in table (8) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave considerably higher nitrogen contents in the underground parts than those found in untreated plants. The most effective Fe treatment for increasing the nitrogen percentages was the application of 300 ppm.

Regarding the interaction between the effect of NPK and Fe treatments, it was found that considerable differences occurred between the nitrogen contents in the underground parts of plants receiving different combinations of NPK and Fe levels. In both season, the lowest nitrogen contents were found in plants receiving no NPK or Fe fertilization, whereas the highest nitrogen contents were found in plants treated with NPK at 17.5 g/m^2, and with Fe at 300 ppm.

- Phosphorus

The results presented in Table (8) show that NPK fertilization had a considerable effect on the P content in the underground parts of *Paspalum vaginatum*. In general, the lowest P contents were those obtained from plants receiving no NPK fertilization (control). Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the P content. Consequently, the highest P contents were obtained from plants fertilized with the highest NPK rate (17.5 g/m^2).

The data in table (8) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave significantly higher P contents in the underground parts, compared to those found in untreated plants. Moreover, the most effective Fe treatment for increasing the P contents was the application of 300 ppm.

Regarding the interaction between the effect of NPK and Fe treatment, it was found that marked differences occurred between the P contents in the underground parts of plants receiving different combinations of NPK and Fe. In both seasons, the lowest P were found in plants receiving no NPK or Fe fertilization. On the other hand the highest P content in the first season (1.190 mg/g) was recorded in plants treated with NPK at 17.5 g/m^2 and Fe at 100 ppm, whereas the highest P content in the second season (1.190 mg/g) was recorded in plants treated with NPK at 17.5 g/m^2 and Fe at 300 ppm.

- Potassium

The results in Table (8) show that NPK fertilization had a considerable effect on the K percentage in the underground parts of *Paspalum vaginatum*. In general, the lowest K contents were those obtained from plants receiving no NPK fertilization (control). Raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 resulted in a steady increase in the K content. Accordingly, the highest K contents were obtained from plants fertilized with NPK at 17.5 g/m^2.

The data in table (8) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave higher K contents in the underground parts, compared to those found in untreated plants. The most effective Fe treatment for increasing the K percentages was the application of 300 ppm.

Regarding the interaction between the effect of NPK and Fe treatments, it was clear that considerable differences occurred between the K contents in the underground parts of plants receiving different combinations of NPK and Fe treatments. In both seasons, the lowest K contents were found in plants receiving no NPK or Fe fertilization, whereas the highest K contents were found in plants treated with NPK at 17.5 g/m^2, and Fe at 300 ppm.

- Iron

The results recorded in the two seasons (Table 8) show that in general, *Paspalum vaginatum* plants which received no NPK fertilization had lower Fe contents in their underground parts, compared to plants receiving the different NPK fertilization treatments. However, raising the level of NPK fertilization from 0 to 7.5, 12.5 or 17.5 g/m^2 did not cause a steady increase in the iron content, since plants receiving NPK fertilization at 12.5 or 17.5 g/m^2 had lower Fe contents than those fertilized at the lowest rate (7.5 g/m^2), which gave the highest values in both seasons.

The data in table (8) also show that the application of any level of Fe fertilization to *Paspalum vaginatum* gave higher Fe contents in the underground parts than those found in untreated plants. The most effective Fe treatment for increasing the iron content was the application of 300 ppm.

Regarding the interaction between the effect of NPK and Fe treatments, it was found that in both seasons, the lowest Fe contents were found in the underground parts of plants fertilized with NPK at 7.5 g/m^2 and no Fe (0 ppm). On the other hand, the highest Fe contents were found in plants fertilized with NPK at 7.5 g/m^2 and Fe at 300 ppm.

Recommendation: From the above results, it can be recommended that *Paspalum vaginatum* turfgrass should be supplied every 2 weeks with NPK fertilization at the rate of 17.5 g/m^2, using the water-soluble fertilizer Kristalon (19% N – 19% P_2O_5 – 19% K_2O). Also, the plants should be sprayed every two weeks with a chelated Fe foliar fertilizer at the concentration of 300 ppm. These treatments gave the best results in terms of the different growth characteristics (plant height before mowing, fresh and dry weight of clippings, and fresh and dry weight of underground parts). Moreover, plants receiving these treatments had the highest contents of leaf pigments (chlorophyll a, b and carotenoids), as well as the best nutritional status (in terms of the contents of total carbohydrates, as well as the contentents of N, P, K and Fe in the clippings and underground parts). It is also recommended that further investigations should be conducted to determine if the turfgrass will respond favourably to higher NPK and Fe fertilization rates.

Table (8): Effect of NPK and Fe fertilization treatments on the N, P, K and Fe contents in underground parts of *Paspalum vaginatum* in the 2000/2001 and 2001/2002 seasons.

NPK fertilization rates	Nutrient contents																			
	N content (% dry matter)					P content (mg/g dry matter)					K content (% dry matter)					Fe content (mg/g dry matter)				
	Fe concentration (ppm)					Fe concentration (ppm)					Fe concentration (ppm)					Fe concentration (ppm)				
	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M	0	100	200	300	M
	First season (2000/2001)																			
Control	2.160	2.350	2.450	3.430	**2.600**	0.610	0.610	0.680	0.710	**0.650**	2.420	2.720	3.000	3.380	**2.880**	0.190	0.197	0.240	0.283	**0.228**
7.5 g/m^2	2.550	2.740	3.680	3.720	**3.170**	0.860	0.860	0.800	0.850	**0.840**	3.070	3.720	3.810	3.970	**3.640**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12.5 g/m^2	3.330	3.700	3.800	4.780	**3.900**	0.990	0.980	1.050	0.980	**0.990**	3.440	4.010	4.640	4.650	**4.190**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17.5 g/m^2	3.510	3.820	4.070	5.080	**4.120**	1.050	1.190	1.130	1.160	**1.130**	4.010	4.540	4.750	4.860	**4.540**	0.187	0.260	0.260	0.275	**0.246**
Means	**2.890**	**3.150**	**3.500**	**4.250**	—	**0.880**	**0.910**	**0.910**	**0.920**	—	**3.240**	**3.750**	**4.050**	**4.220**	—	**0.194**	**0.225**	**0.266**	**0.281**	—
	Second season (2001/2002)																			
Control	2.140	2.650	3.140	3.530	**2.840**	0.630	0.640	0.670	0.690	**0.660**	2.510	2.650	3.050	3.350	**2.890**	0.197	0.210	0.239	0.296	**0.236**
7.5 g/m^2	2.630	2.990	3.610	3.940	**3.290**	0.810	0.820	0.840	0.840	**0.830**	3.320	3.750	3.910	4.350	**3.830**	0.193	0.263	0.291	0.317	**0.266**
12.5 g/m^2	3.350	3.620	4.190	4.680	**3.960**	0.990	0.990	1.000	1.000	**0.990**	3.650	4.410	4.530	4.750	**4.340**	0.238	0.250	0.268	0.268	**0.256**
17.5 g/m^2	3.510	4.020	4.580	5.170	**4.320**	1.150	1.160	1.140	1.190	**1.160**	4.430	4.550	4.820	4.900	**4.680**	0.219	0.249	0.271	0.288	**0.257**
Means	**3.990**	**3.320**	**3.880**	**4.330**	—	**0.900**	**0.900**	**0.910**	**0.930**	—	**3.480**	**3.840**	**4.080**	**4.340**	—	**0.212**	**0.243**	**0.267**	**0.292**	—

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دراسات على تسميد ورى نباتات المسطحات الخضراء
أولاً- تأثير التسميد بالعناصر الكبرى NPK والحديد على النموالخضرى والتركيب الكيماوى لنباتات البسبالم *Paspalum vaginatum*

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أجريت هذه الدراسة فى مشتل ملعب جولف دريم لاند خلال الموسمين المتتاليين ٢٠٠٠/٢٠٠١ و٢٠٠١/٢٠٠٢، بهدف بحث تأثير التسميد بالعناصر الكبرى (NPK) والحديد على النموالخضرى والتركيب الكيماوى لنباتات البسبالم (*Paspalum vaginatum*). هذا وقد أضيفت معدلات مختلفة (صفر، ٧,٥، ١٢,٥ و١٧,٥ جم/م^{٢}) من سماد NPK تجارى قابل للذوبان (كريستالون، يحتوى على ١٩% ن، ١٩% فو$_{٢}$أ$_{٥}$، و١٩% بو$_{٢}$أ) وذلك على سطح التربة، وتم الرى بعد التسميد ، فى حين أضيف الحديد رشا على الأوراق بتركيزات صفر، ١٠٠، ٢٠٠ أو٣٠٠ جزء فى المليون، وذلك بإستخدام منتج تجارى من الحديد المخلبى (EDTA). وفى كل من الموسمين تم تكرار معاملات الـ NPK والحديد كل أسبوعين إبتداء من أول يوليوحتى ٣٠ يناير.

وفى أغلب الحالات أدت زيادة معدلات الـ NPK أوالحديد إلى زيادة طردية فى القيم المسجلة لصفات النموالخضرى المختلفة (إرتفاع المسطح قبل القص، الأوزان الطازجة والجافة لناتج القص/أسبوع، الأوزان الطازجة والجافة للأجزاء الأرضية). وبالتالى فإن إضافة أعلى المعدلات من الـ NPK والحديد (١٧,٥ جم/ م^{٢} و٣٠٠ جزء فى المليون على التوالى) كل أسبوعين أعطت أعلى القيم لهذه الصفات فى أغلب الأشهر فى الموسمين. وفى أغلب الحالات ادى رفع معدلات الـ NPK أوالحديد أيضا إلى زيادة طردية فى محتوى الصبغات (كلوروفيل أ وب، والكاروتينويدات) فى الأوراق، ومحتوى الكربوهيدرات الكلية فى ناتج القص والأجزاء الأرضية، وأيضا محتوى العناصر الغذائية (نتروجين، فوسفور، بوتاسيوم، حديد) فى ناتج القص. كذلك

فإن رفع معدل التسميد بالعناصر الكبرى (NPK) أدى لزيادة محتوى النتروجين والفوسفور والبوتاسيوم فى الأجزاء الأرضية، حيث تم الحصول على أعلى القيم عند إستخدام أعلى معدل تسميد (١٧,٥ جم/م٢)، أما أعلى محتوى من الحديد فى الأجزاء الأرضية فتم الحصول عليه عند إضافة أقل معدل من الـ NPK (٧,٥ جم/م٢). هذا وقد زادت محتويات النتروجين والفوسفور والبوتاسيوم والحديد فى الأجزاء الأرضية طردياً بزيادة معدل التسميد بالحديد حتى أعلى تركيز (٣٠٠ جزء فى المليون).

من النتائج السابقة يمكن التوصية بتسميد المسطحات المنزرعة بنباتات البسبالم (*Paspalum vaginatum*) كل أسبوعين بالعناصر الكبرى NPK بمعدل ١٧,٥ جم/م٢ بإستخدام سماد كريستالون القابل للذوبان، وبرش النباتات كل أسبوعين بالحديد المخلبى بتركيز ٣٠٠ جزء فى المليون. كذلك يوصى بإجراء مزيد من البحث لتحديد مدى إستجابة المسطح لمعدلات تسميد NPK وحديد أعلى من تلك المستخدمة فى هذه الدراسة.