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Response of *Paspalum vaginatum* Turfgrass Grown under Shade Conditions to Paclobutrazol and Trinexapac-Ethyl as Plant Growth Retardants (PGRs)

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Abstract: This study was conducted at the Experimental Nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University during the two successive seasons of 2009/2010 and 2010/2011. This work aimed to investigate the response of paspalum (*Paspalum vaginatum*, Swartz cv. Salam) grown under different shade levels to foliar application of different concentrations of paclobutrazol and trinexapac-ethyl (TE). The turfgrass was covered with shade cloth of different light permeability levels providing shading levels of 42%, 63% and 70% of natural light. In addition, full sunlight (unshade) was used as a control. Plants grown under different shade levels treatments were sprayed monthly with either paclobutrazol (at 750 or 1500 ppm) or TE (at 200 or 400 ppm). Control plants were sprayed with tap water.It can be concluded that *Paspalum vaginatum* plants can be grown under shade level up to 42% with no significant reduction in growth. However, if shade level exceeds 42% (up to 70%) paclobutrazol at 1500 ppm or TE at 400 ppm can be used monthly as a foliar application to overcome the adverse effects of shade.

Key words: *Paspalum vaginatum* · Shade level · Trinexapac-ethyl (TE) · Paclobutrazol

INTRODUCTION

Seashore paspalum (*Paspalum vaginatum*, Swartz) is used as a turfgrass. Seashore paspalum is adapted to tropical and warm subtropical climates. It forms a dense, fine-textured turf of dark green color. It can be used for utility lawns and sport turfs including golf course greens [1]. The shade caused by trees, shrubs, buildings… etc seriously affects the quality and growth habit of turfgrass surfaces [2]. With increased shade, morphological changes was observed in different turfgrass species such as reduction in root density, quantity of clippings, root mass, lawn density and degree of coverage. Meanwhile, shoot vertical growth increased under shade [3, 4]. Furthermore, Physiological changes such as a reduction in chlorophyll and carotenoids contents as well as carbohydrate reserves have been observed in different grasses species responding to light reduction [5, 6].

Trinexapac-ethyl (TE) and paclobutrazol are used as plant growth retardants for high maintenance in turfgrass management to suppress shoot growth and inflorescences to reduce clipping production, mowing frequency and improving aesthetics [1]. TE is foliarly absorbed and acts by blocking the 3ß-hydoxylase enzyme that converts GA20 to GA late in the gibberellin biosynthesis pathway [7]. Pessarakli [8] stated that TE application increases leaf tissue levels of the cytokinin zeatin riboside. Cytokinins are known to strongly delay senescence via a number of mechanisms. In this respect, Stier [9] on Kentucky bluegrass (*Poa Pratensis*) and Supina bluegrass (*Poa Supina*); Tegg and Lane [10] on five cool-season turf species, Ervin [11] on Meyer zoysiagrass (*Zoysiaja ponica*); Goss *et al.* [12] on creeping bentgrass (*Agrostis stolonifera*) ; Tegg and Lane [13] on cool and warm-season turfgrasses species and Baldwin and Haibo [14] on Champion bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) reported that application of TE to turfgrasses during their exposure to shade stress reduced excessive vertical growth and clipping production but increased turf quality, coverage percentage, turf density, chlorophyll content and carbohydrate content. Also, Qian *et al.* [15] as well as Qian and Engelke [16] on zoysiagrass (*Zoysia matrella*) hybrid Diamond reported that application of TE enhanced root strength and root biomass during their exposure to shade conditions.

On the other hand, paclobutrazol is primarily absorbed through roots and acts early in the gibberellin biosynthesis pathway by blocking the enzyme entkaurene oxidase that converts ent-kaurene to ent-kaurenoic acid

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Table 1: Physical and chemical characteristics of the soil used for growing *Paspalum vaginatum* during 2009/2010 and 2010/2011 seasons

Physical characteristics

Coarse sand (%)	Fine sand (%)	Silt(%)	Clay(%)	Soil texture	Field capacity (% V)
6.40	12.70	10.30	70.60	Clay	67.30

Chemical characteristics

					Available macro-nutrients (ppm)		
CaCO3 (%)	Organic matter (%)	pH	EC(dS/m)	CEC (meq/100 g)	N	P	K
1.70	2.13	7.12	1.67	39.40	93.35	20.25	71.85

[7]. Paclobutrazol is used to decrease mowing frequency of turfgrasses. However, very limited data are available regarding the use of paclobutrazol on turfgrasses under shade stress.

The aim of this study was to improve the tolerance and quality of *Paspalum vaginatum*, Swartz grown under shading conditions by using trinexapac-ethyl (TE) and paclobutrazol as plant growth regulators (PGRs).

MATERIALS AND METHODS

This study was carried out in the Experimental Nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt during the two successive seasons of 2009/2010 and 2010/2011. The objective of the study was to investigate the response of seashore paspalum (*Paspalum vaginatum*, Swartz) grown under shade conditions to foliar application of trinexapac-ethyl (TE) and paclobutrazol.

Eighty beds (0.5 m x 0.5 m) were well prepared by incorporating the compost into the soil to depth of 12-15 cm, at the rate of 2 m^3/100 m^2. Round-Up, a non-selective weed killer was applied prior to planting at the rate of 1 liter/feddan to eliminate all vegetation. The physical and chemical characteristics of the experimental soil are shown in Table 1.

On February 1st (in both the first and second seasons), sods of seashore paspalum (*Paspalum vaginatum*, Swartz cv. Salam) were obtained from a private turf nursery then divided into 0.5 m x 0.5 m and planted in the prepared beds (plots). On March 1st the turfgrass was mowed then covered with three different levels of shade cloth (black saran of different light permeability levels). The shade levels were 40%, 60% and 73% shade. In addition, full sunlight (unshade) was used as a control. Shade cloth was fixed to a metal structure at height of 70 cm above the turfgrass surface to maintain proper airflow and data collection, the sides of each sod was also covered by shade cloth to prevent lateral sunlight penetration. To quantify relative shade levels, the light intensities under full light and shade levels were measured in midday through the experiment (beginning from 1 March till 30February in both seasons) using luxmeter (Digital lutron lux-101 lux meter) posited at 20 cm above soil surface and the monthly mean light intensity was calculated (Fig. 1). The average light intensities (in klux) were 72.01 for unshaded control plots, 41.73 under 40% shade cloth, 26.85 under 60% shade cloth and 21.64 under 73% shade cloth. These values correspond to 0% shade, 42%, 63% and 70% shade, respectively and these shade levels were used to designate the shade levels in this study as described by Qian and Engelke [16]. So, the incoming light intensities to turfgrass were100% (full sun), 58% and 37% and 30% light, respectively.

In both seasons, plants grown under different shade levels treatments were sprayed monthly (from 1March2009 and 2010 till 1 February, 2010 and 2011 in the first and second seasons, respectively) after mowing with either paclobutrazol [PAC100%, (±) - (R*,R*)-beta-((4-chlorophenyl)methyl)-alpha-(1,1-dimethylethyl)-1H-1,2,4,-triazole-1-ethanol] purchased from Tecknogreen company, Egypt at 750 or 1500 ppm or trinexapac-ethyl [TE 97%, 4-cyclopropyl-á-hydroxyl-methylene-3, 5-dioxocyclohexanecarboxylic acid ethyl ester $(C_{13}H_{16}O_5)$] purchased from Hebei Kaidi Agrochemical Enterprises Group, China at 200 or 400 ppm. In addition, control plants continued to be sprayed with tap water.

Starting from March 1st till October15th, the planting beds were irrigated daily at the rate of 6 liters/m^2, then the irrigation rate was reduced to 5 liters /m^2 three times a week till March 1st of the following year (the termination of the experiment). All the turfgrass beds received chemical NPK fertilization prepared by mixing 345.79 g ammonium nitrate (33.5 % N), 373.68 g calcium superphosphate (15.5% P_2O_5), 120.67 g potassium sulphate (48% K_2O) and 318.26 g sand as an inert component, giving 1158.4 g of the NPK mixture (with a formula of 10-5-5 and a ratio of 2:1:1). The mixture was applied monthly at the rate of 28.96 g/m^2 as recommended by Hussein and Mansour [17] on *Paspalum vaginatum.*

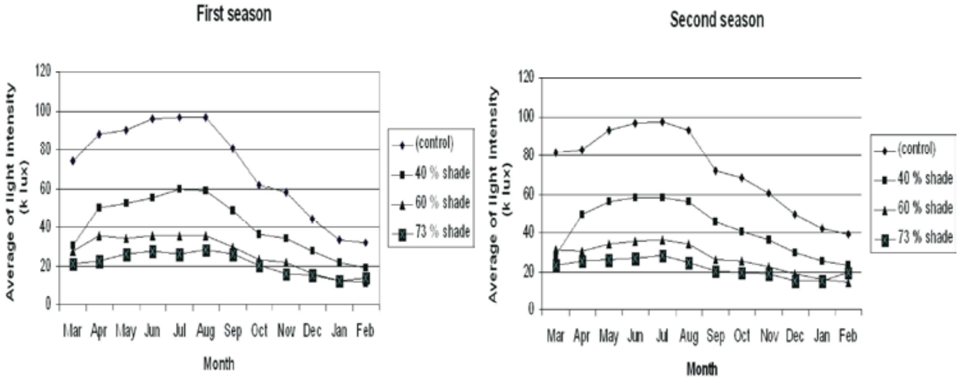

Fig.1: Average light intensity during the first season 2009/2010 and second season 2010/2011

The layout of the experiment was a split-plot design with 20 treatments (4 shading levels including the control x 5 plant growth retardants concentrations including the control) with 4 blocks (replicates), each consisting of 20 beds (1 bed /treatment). Shade levels were assigned to the main plots, while plant growth retardants treatments (PGR_S) were assigned to the sub-plots and were assigned randomly under each shade level.

On 1 and 15 March till the termination of the experiment (in both the first and second seasons) the turfgrass was mowed biweekly using scissors to a height of 3 cm. The average sward heights (cm) before mowing, as well as the average fresh and dry weights of the clippings (g/m2) after mowing were recorded throughout each growing season. At the end of each growing season, the coverage percentage [18], turf density (number of tillers/100 cm^2, recorded using a 10 cm x 10 cm wooden frame) as well as fresh and dry weights of underground parts (g/m^2) were recorded.

At the end of each season, fresh clipping samples were chemically analyzed to determine their total chlorophylls (a + b) and carotenoids contents (mg/g fresh matter) [19]. Also, the total carbohydrates content (% of dry matter) was determined in dried clipping samples using the method recommended by Dubois *et al*. [20]. Other dried clipping samples were digested to extract nutrients [21] and the extract was analyzed to determine its contents of nitrogen [22], phosphorus [23] and potassium [24].

Data collected for vegetative growth characteristics and chemical constituents were subjected to an analysis of variance as a factorial experiment in split plot design and the means were compared using the "Least Significant Difference (LSD)" test at the 0.05 level [25]. The coverage percentage data was subjected to arcsine transformation and the transformed data were statistically analyzed.

RESULTS AND DISCUSSION

Vegetative Growth Characteristics of *Paspalum Vaginatum*

Coverage Percentage: Data presented in Table 2 showed that in both seasons, raising the shade levels caused steady significant reduction in the coverage percentage compared to growing plants under full sun (control). These results are in agreement with the findings of Miller *et al*. [26] on Floradwarf and Tifdwarf bermudagrasses [*Cynodon dactylon* (L.) Pers. X *C. transvaalensis* Burtt-Davy], Teresa and Sergio [27] on three cool season species (*Festuca rubra* L. *Poa trivialis* L and *Agrostis stolonifera* L. var. *palustris*) and Jeffrey [28] on various cultivars of zoysiagrass and bermudagrass.They reported that the coverage percentage of the different turfgrasseses was decreased as shade levels increased, compared to full sunlight. The reduction in the coverage percentage as a result of reducing light conditions was explained by Pessarakli [8] who stated that this may be due to insufficient carbohydrate contentwhich restricts root development and tillering which in turn reduce coverage percentage.

Concerning the effect of growth retardant treatments on coverage percentage regardless of the effect of shade levels, data in Table 2 indicated that in both seasons, the coverage percentage of turf was significantly increased (in most cases) as a result of application of growth retardants, compared to the untreated control plants. Trinexapac-ethyl was generally more effective than paclobutrazol for increasing coverage percentage of turf. Among the two concentrations of trinexapac-ethyl,the most effective one was the lowest concentration (200 ppm) which gave the highest mean values, whereas the lowest values were recorded with those of untreated control plants. A similar increase in coverage percentage of turf as a result of different growth retardant treatments

Table 2: Effect of shade levels and plant growth regulator treatments on coverage percentage, sward height before mowing (cm) and lawn density (number of tillers/100 cm2) of *Paspalum vaginatum* during the 2009/2010 and 2010/2011 seasons

	First season (2009/2010)					Second season (2010/2011)				
	Shade degrees (SD)					Shade degrees (SD)				
*Growth regulator treatments (GR)	Control	(42%)	(63%)	(70%)	Mean (GR)	Control	(42%)	(63%)	(70%)	Mean (GR)
Coverage percentage										
Control	100.0 a	93.8 b-f	89.8 ef	79.3 g	90.7 b	100.0 a	94.5 b-d	92.3 d-f	88.8 f	93.9 b
PAC 1	100.0 a	96.0 a-d	91.3 d-f	89.5 ef	94.2 a	100.0 a	94.8 b-d	94.3 b-d	93.3 c-e	95.6 ab
PAC 2	100.0 a	94.5 b-e	92.0 c-f	89.0 f	93.9 a	100.0 a	94.5 b-d	90.3 ef	91.3 d-f	94.0 b
TE 1	100.0 a	97.5 ab	96.8 a-c	91.3 d-f	96.4 a	100.0 a	98.0 ab	97.8 ab	93.8 c-e	97.4 a
TE 2	100.0 a	94.8 a-e	92.0 c-f	90.3 ef	94.3 a	100.0 a	96.3 a-c	94.8 b-d	91.0 d-f	95.5 ab
Mean (SD)	100.0 a	95.3 b	92.4 c	87.9 d	------	100.0 a	95.6 b	93.9 c	91.6 d	-----
In each season, within the column for growth retardants treatments means, the row for shade treatment means, or the means for combinations of the two factors, means sharing one or more letters are insignificantly different at the 5% level, according to the "Least Significant Difference" test.										
Sward height before mowing (cm)										
Control	7.05	7.40	8.43	9.10	7.99	6.28	7.68	8.38	10.40	8.18
PAC 1	5.05	6.50	6.48	9.08	6.78	6.08	6.08	7.18	9.58	7.23
PAC 2	4.98	5.80	6.40	8.08	6.31	5.65	6.17	6.76	8.80	6.84
TE 1	4.93	5.23	5.65	5.10	5.23	6.03	6.33	7.25	7.33	6.73
TE 2	4.20	4.25	4.40	4.60	4.36	5.10	5.48	5.33	5.73	5.41
Mean (SD)	5.24	5.84	6.27	7.19	-----	5.83	6.34	6.98	8.37	------
LSD (0.05)										
SD			1.02					0.32		
GR			0.99					0.80		
SD X GR			1.98					1.61		
Turf density (number of tillers/ 100 cm^2)										
Control	198.3	182.8	158.8	146.3	171.5	214.3	197.0	165.0	156.0	183.1
PAC 1	201.0	190.0	188.3	164.8	186.0	215.5	200.8	200.8	156.8	193.4
PAC 2	208.0	201.5	201.8	198.3	202.4	216.5	213.5	205.8	199.8	208.9
TE 1	208.3	204.8	197.3	197.8	202.0	206.8	219.0	199.8	191.5	204.3
TE 2	213.8	210.8	209.0	205.3	209.7	224.8	216.0	204.8	198.0	210.9
Mean (SD)	205.9	198.0	191.0	182.5	------	215.6	209.3	195.2	180.4	------
LSD (0.05)										
SD			18.7					30.6		
GR			23.5					31.4		
SD X GR			46.9					62.8		

* PAC 1 = paclobutrazo at 750 ppm/ month TE 1 = trinexapac-ethyl at 200 ppm/ month
PAC 2 = paclobutrazo at 1500 ppm / month TE 2 = trinexapac-ethyl at 400 ppm / month

was reported by Sakr [29] on seashore paspalum (*Paspalum vaginatum*, Swartz), James *et al*. [30] on Riviera bermudagrass (*Cynodon dactylon* L.) reported that coverage percentage was improved by trinexapac-ethyl and paclobutrazol applications.

Regarding the interaction between the effects of different levels of shade and growth retardants treatments, data recorded on the coverage percentage of *Paspalum vaginatum* plants showed that within each concentration of growth retardants, increasing shade level decreased coverage percentage steadily in most cases. Within each shade level, application of either paclobutrazol or trinexapac-ethyl at any concentration, in most cases, improved the coverage percentage as compared to the plants grown under the same shade level and did not receive growth retardant application. Similar results were reported by Goss *et al*. [12] and Edward [31] on creeping bentgrass (*Agrostis stolonifera*) that TE application improved the coverage percentage of turf grown under shade. In both seasons, plants grown under shade level of 42% as well as 63% and sprayed with TE at 200 ppm had coverage percentage that was insignificantly different from those of control plants.

Sward Height Before Mowing: Data presented in Table 2 revealed that in both seasons, sward height of *Paspalum vaginatum* increased gradually with raising the shade levels, as compared to plants grown under full sunlight (control). The steady increase in sward height as a result of raising the shade levels is similar to that reported by Qian *et al*. [15] on zoysiagrass (*Zoysia matrella*, L.) hybrid Diamond. In both seasons, the increase in sward height of turfgrass was statistically significant (in most cases) as a result of raising the shade levels to 42 or 63% and 70%, compared to the control. Only one exception to this general trend was recorded in the first season with plants shaded with the lowest level (42%) which gave an insignificant higher sward height than those of the control plants. The increase in sward height under shade conditions can be easily explained since shading stimulates the production of GA which enhances cell enlargement without a concomitant increase in cell-wall thickness, thus leading to an increase in plant height [32]. These results are in agreement with the findings of Qian and Engelke [33] on *Zoysia matrella*, Tegg and Lane [10] on five cool-season turf species and Tegg and Lane [13] on cool-season and warm-season turf species as they reported that the plant height of the turfgrasses was increased with increasing shade levels.

In both seasons, application of the two types of growth retardants at any level caused a significant reduction in sward height, compared to the untreated control plants which recorded the highest sward height. The reduction in sward height as a result of the growth retardant treatments can be explained by the role played by these synthetic chemicals in interfering with the synthesis of gibberellins. Paclobutrazol acts as an early GA biosynthesis inhibitor [7]. Similar decrease in sward height as a result of using growth retardant treatments was reported by Beasley [34] on Kentucky bluegrass (*Poa pratensis* L.) and McCullough *et al*. [35] on seashore paspalum (*Paspalum vaginatum*).

It is also clear from the data in Table 2 that trinexapac-ethyl was generally more effective than paclobutrazol for height control of *Paspalum vaginatum* plants. Among TE treatments, the most effective one was spraying the plants with the highest concentration (400 ppm TE) since giving the shortest plants (4.36 and 5.41 cm in the first and second seasons, respectively). With any of the two chemical types, raising the application rate resulted in a steady decrease in sward height. These results are in harmony with the results obtained by Sakr [29] on seashore paspalum (*Paspalum vaginatum*, Swartz) and Liya *et al*. [36] on red fescue (*Festuca rubra*, L.), they reported that raising the application rate of paclobutrazol or trinexapac-ethyl resulted in a steady decrease in sward height.

The data recorded on the sward height also showed that within each growth retardant concentration, in most cases, raising the level of shade increased sward height steadily. On the other hand, within each level of shade, raising the application rate of any of two chemical types decreased sward height steadily (in most cases) as compared to those of plants sprayed with water (control). In both seasons, plants grown under 42 and 63% shade and sprayed with paclobutrazol at concentration of 750 and 1500 ppm or trinexapac-ethyl at concentration of 200 ppm had a sward height values which were insignificantly different than those of control plants. The tallest swards were those of plants grown under 70% shade and sprayed with water, whereas the shortest swards were those of plants grown in full sunlight and sprayed with TE at 400 ppm.

Lawn Density (Number of Tillers / 100 cm ^{2}): Data presented in Table 2 revealed that in both seasons, raising the shade levels resulted in a steady reduction in the lawn density of *Paspalum vaginatum* plants, as compared to plants grown under full sunlight. In both seasons, raising the shade level from 42 to 63% insignificantly decreased turf density, whereas these decrease was statistically significant at highest level of shade (70%). The results of decreased turf density as a result of increased shade levels are similar with the findings of Wherley *et al*. [37] on two cultivars of tall fescue (*Festuca arundinacea*) and Teresa and Sergio [27] on *Festuca rubra* L. *Poa trivialis* L and *Agrostis stolonifera* L. var. *palustris*.

Data presented in Table 2 also indicated that in both seasons, spraying *Paspalum vaginatum* with either paclobutrazol or trinexapac-ethyl (TE) concentrations increased the number of tillers/100 cm^2, as compared to the untreated control plants. In the first season, most of growth retardant treatments caused a significant increase in turf density, except the application of the lowest rates of paclobutrazol (750 ppm) which gave insignificantly higher lawn density than the control. In the second season, application of any rate of the two chemical types insignificantly increased lawn density compared to control. It is also clear from the data in Table 2 that with any of the two types of growth retardant, raising the application rate resulted in steady increase in the number of tillers/100 cm^2 (tillering) as compared to the untreated control plants. The steady increase in lawn density as a result of raising TE application rate was similar to that obtained by Sakr [29] on seashore paspalum (*Paspalum vaginatum*, Swartz). The increase in lawn density as a

Table 3: Effect of shade levels and plant growth regulator treatments on fresh and dry weights (g/m2) of clippings and underground parts of *Paspalum vaginatum* during the 2009/2010 and 2010/2011 seasons

	First season (2009/2010)					Second season (2010/2011)				
	Shade degrees (SD)					Shade degrees (SD)				
Growth regulator treatments (GR)	Control	(42%)	(63%)	(70%)	Mean (GR)	Control	(42%)	(63%)	(70%)	Mean (GR)
					Fresh weight of clippings (g/m^2)					
Control	120.9	105.3	87.9	74.8	97.2	128.7	122.4	118.0	98.4	116.9
PAC 1	106.0	85.5	79.2	71.2	85.5	110.1	96.8	89.0	83.7	94.9
PAC 2	99.6	84.2	75.4	71.5	82.7	103.8	100.4	87.6	80.3	93.0
TE 1	88.4	75.0	75.0	72.2	77.6	102.9	88.0	87.4	87.2	91.4
TE 2	75.9	73.9	69.8	69.0	72.2	87.3	78.3	78.1	77.3	80.2
Mean (SD)	98.1	84.8	77.5	71.7	-----	106.6	97.2	92.0	85.4	------
LSD (0.05)										
SD			13.5					12.2		
GR			14.0					18.4		
SD X GR			28.1					36.7		
					Dry weight of clippings (g/m^2)					
Control	27.5	20.5	18.4	16.2	20.7	33.9	29.5	25.5	22.6	27.9
PAC 1	19.8	17.7	16.6	15.3	17.3	31.8	24.1	20.0	19.8	23.9
PAC 2	19.1	17.6	16.3	13.1	16.6	26.5	22.9	20.5	18.6	22.1
TE 1	16.8	14.4	13.2	12.5	14.2	24.7	22.7	15.9	15.9	19.8
TE 2	16.7	12.7	12.5	12.1	13.5	22.8	15.4	14.4	14.2	16.7
Mean (SD)	20.0	16.6	15.4	13.8	-----	27.9	22.9	19.3	18.2	------
LSD (0.05)										
SD			4.0					3.1		
GR			3.2					3.8		
SD X GR			6.4					7.5		
					Fresh weight of underground parts (g/m^2)					
Control	462.5	461.6	458.7	351.2	433.5	392.9	391.0	365.5	354.1	375.9
PAC 1	506.8	427.1	426.4	355.7	429.0	482.5	392.0	389.0	383.5	411.7
PAC 2	517.2	429.4	426.7	357.8	432.8	602.9	570.0	578.4	561.7	578.3
TE 1	464.9	431.1	428.7	378.2	425.7	419.6	411.1	382.6	375.0	397.0
TE 2	464.5	432.0	429.8	402.5	432.2	462.2	458.8	457.0	434.2	453.1
Mean (SD)	483.2	436.2	434.0	369.1	------	472.0	444.6	434.5	421.7	------
LSD (0.05)										
SD			52.0					40.6		
GR			54.1					55.1		
SD X GR			108.1					110.2		
					Dry weight of underground parts (g/m2)					
Control	115.8	115.7	111.4	95.1	109.5	116.9	111.6	110.0	87.3	106.4
PAC 1	116.8	108.2	97.7	96.3	104.7	132.1	120.5	116.5	112.8	120.5
PAC 2	118.0	108.9	105.9	98.7	107.9	135.4	126.7	125.1	123.5	127.7
TE 1	106.6	101.7	98.4	97.1	100.9	120.3	116.7	114.6	111.9	115.9
TE 2	112.7	107.3	103.2	97.6	105.2	129.1	123.9	125.9	113.5	123.1
Mean (SD)	114.0	108.3	103.3	97.0	-----	126.8	119.9	118.4	109.8	-----
LSD (0.05)										
SD			13.7					12.5		
GR			14.6					16.1		
SD X GR			29.3					32.1		

* PAC 1 = paclobutrazo at 750 ppm/ month TE 1 = trinexapac-ethyl at 200 ppm/ month

PAC 2 = paclobutrazo at 1500 ppm / month TE 2 = trinexapac-ethyl at 400 ppm / month result of using paclobutrazol or trinexapac-ethyl may be attributed to the role of these growth retardants in increasing leaf tissue levels of the cytokinin which enhance cell division involved in initiation and growth of new tillers from axillary meristems, consequently increasing turf density in turfgrasses [7, 8]. These results are in agreement with the findings of Wetzel and Dernoeden [38] and Ervin and Koski [39] on *Lolium perenne*, Fagerness *et al*. [40] on Tifway bermudagrass, Beasley [34]; Beasley and Branham [41] on Kentucky bluegrass (*Poa pratensis* L.) and Yan and Huang [42] on creeping bentgrass (*Agrostis stolonifera* L.), they found that application of paclobutrazol or trinexapac-ethyl increased lawn density of treated turfgrasses compared to untreated control.

As for the interaction between the effects of different levels of shade and growth retardant treatments, the data in Table 2 also showed that within each concentration of growth retardant, raising the level of shade decreased lawn density of *Paspalum vaginatum* plants steadily (in most cases). On the other hand, within each level of shade, increasing the application rate of any of paclobutrazol or trinexapac-ethyl resulted in steady increases in lawn density (in most cases), as compared to those of the plants sprayed with water (control). In both seasons, plants grown under shade level of 42%, 63% and 70% and sprayed with any concentration of paclobutrazol or trinexapac-ethyl had number of shoots that were insignificantly different than those of control plants. In both seasons, the highest lawn density were obtained from full sun plants sprayed with TE at 400 ppm, while the lowest mean values were produced from plants grown under shade level of 70% and sprayed with tap water.

Fresh and Dry Weights of Clippings (g/m^2): The results recorded in the two seasons (Table 3) showed that the fresh and dry weights of clippings of *Paspalum vaginatum* plants were decreased steadily as the level of shade raised from 42 to 63 and 70%, compared to control plants. Accordingly, the lowest mean values were obtained from plants grown under the highest level of shade (70%), while the control plants hade the heaviest weights. In most cases, the lowest level of shade (42%) insignificantly decreased the fresh and dry weights of clippings. The only exception to this trend was detected in the second season with plants shaded with level of 42% shade, which gave a dry weight of clippings that was significantly lighter than that recorded with the control plants. Higher levels of shade (63 or 70%) caused a significant decrease in the fresh and dry weights of clippings as compared to the control. Similar reduction in fresh and dry weights of clippings as a result of reduced light levels was obtained by Jiang *et al.* [43] on seashore paspalum and hybrid bermudagrass (*Cynodon dactylon* L.x *C. transvaalensis* Burtt Davy) cultivars and Teresa and Sergio [27] on three cool season species and Baldwin *et al*. [44] on warm-season turfgrass.

The data in Table 3 indicated that in general, spraying *Paspalum vaginatum* with any rate of paclobutrazol or trinexapac-ethyl caused a significant reduction in fresh and dry weights, as compared to untreated control plants. The only exception to this trend was recorded in the first season, with plants sprayed with paclobutrazol at 750 ppm giving an insignificantly lighter fresh weight of clippings than that recorded with control plants. Similar reduction in fresh and dry weights of clippings as a result of paclobutrazol or Trinexapac-ethyl treatments were obtained by Ervin and Changho [45] on Meyer zoysiagrass(*Zoysia japonica*), Beasley [34] on Kentucky bluegrass (*Poa pratensis* L.), Fagerness *et al*. [46] on Tifway bermudagrass and McCullough *et al*. [35] on seashore paspalum (*Paspalum vaginatum*).

Data presented in Table 3 showed that within each type of the tested growth retardants, raising the application rate resulted in a steady decrease in the recorded mean values. These results are in agreement with the findings of McCullough *et al*. [47] on 'TifEagle' bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) and Sakr [29] on seashore paspalum (*Paspalum vaginatum*). trinexapac-ethyl was generally more effective than paclobutrazol for decreasing the fresh and dry weights of clippings. Among TE treatments, the highest concentration (400 ppm) was the most effective one, which gave the lowest mean values, while the highest mean values were resulted from untreated control plants.

Regarding the interaction between the effects of the different levels of shade and growth retardant treatments the recorded data revealed that in most cases, fresh and dry weights of clippings were decreased steadily as a result of raising the level of shade and/or raising the application rate of any of paclobutrazol or trinexapac-ethyl, as compared to the control plants, which gave the heaviest fresh weight of clippings, whereas the lowest weights were recorded with plants grown under the highest level of shade (70%) and sprayed with the highest concentration of trinexapac-ethyl (400 ppm).

Fresh and Dry Weights of Underground Parts (g/m^2): Data presented in Table 3 revealed that, in both seasons, the fresh and dry weights of underground parts were decreased steadily as a result of increasing the levels of shade from 42 to 63 or 70%, compared with the plants grown under full sun light (control). Accordingly, plants grown under the highest level of shade (70%) had the lowest fresh and dry weights of underground parts, whereas the highest mean values were obtained from control plants. In both seasons, the reduction in fresh and dry weights of underground parts was statistically insignificant with the lower shade levels (42 or 63%), while the reduction was significant with the highest level of shade (70%) as compared to those of plants grown under full sunlight. The reduction in fresh and dry weights of underground parts, as a result of shade treatment was similar with findings of Koh *et al*. [4] on two cultivars of creeping bentgrass (*Agrostis stolonifera*), Wherley *et al*. [37] on two cultivars of tall fescue (*Festuca arundinacea*) and Baldwin *et al*. [44] on warm-season turfgrasses.

The effect of the growth retardant treatments on the fresh and dry weights of underground parts was differed from one season to the other. In the first season, fresh and dry weights of underground parts were generally decreased as a result of paclobutrazol or trinexapac-ethyl treatments. However, application of any rate of the tested growth retardant treatments had no significant effect on reducing fresh and dry weights of underground parts, compared to control. Similar reductions in plant fresh and dry weights as a result of growth retardant treatments have been reported by McCullough *et al*. [48] and McCullough *et al*. [47] on TifEagle bermudagrass [*Cynodon dactylon* (L.) Pers. X *C. transvaalensis* Burtt-Davy] and McCullough *et al*. [49] on Champion and TifEagle bermudagrass.

In the second season, application of any rate of paclobutrazol or trinexapac-ethyl increased the recorded mean values, compared to the untreated control plants. This increase was statistically insignificant with the application of the lowest concentrations of paclobutrazol (750 ppm) or trinexapac-ethyl (200 ppm) whereas, application of the highest concentrations of these two chemicals significantly increased the fresh and dry weights of underground parts as compared to the untreated plants (control). These results are in agreement with the findings of Baldwin *et al.* [50] and McCullough *et al*. [51, 52] on TifEagle and Champion bermudagrass (*Cynodondactylon* (L.) Pers. x *C. transvaalensis* Burtt-Davy).

In both seasons, with either one of the two chemical types, raising the application rate resulted in steady increase in the fresh and dry weights of underground parts, as compared to the untreated plants (control). These results are in agreement with the findings of Sakr [29] on seashore paspalum (*Paspalum vaginatum*, Swartz) who found that raising the application rate of trinexapac-ethyl increased the fresh and dry weights of underground parts steadily.

The data recorded on the fresh and dry weights of underground parts showed that within each growth retardant concentration, raising the level of shade decreased fresh and dry weights of underground parts steadily (in most cases). On the other hand, within each level of shade, raising the application rate of any of paclobutrazol or trinexapac-ethyl resulted in steady increases in fresh and dry weights of underground parts, as compared to those of the plants sprayed with water (control). In the first seasons, the plants grown under any of the tested three levels of shade and sprayed with any concentration of paclobutrazol or trinexapac had insignificantly lighter fresh and dry weights than those of control plants. In the second season, plants grown under three shade levels (42%, 63% and 70) and sprayed with paclobutrazol at 750 ppm or the two concentration of trinexapac-ethyl (200 or 400 ppm) had fresh and dry weights of underground parts that were insignificantly different than those of control plants. In both seasons, the heaviest fresh and dry weights of underground parts were recorded with plants grown in full sun and sprayed with the highest concentration of paclobutrazol (1500 ppm), whereas the lowest weights were recorded with plants grown under 70% shade and sprayed with water.

Chemical Constituents of *Paspalum Vaginatum*

Total Chlorophylls and Carotenoids Contents: Results of chemical analysis of fresh clippings of *paspalum vaginatum* (Table 4) showed that the synthesis and accumulation of pigments was considerably affected by the shade levels treatments. In both seasons, total chlorophylls (a+b) and carotenoids concentration in clippings were decreased steadily as a result of raising shade levels. In most cases, raising shade levels from 42 to 63 or 73% significantly reduced the recorded mean values as a compared to those recorded with plants grown under full sunlight. The Only one exception to this general trend was detected in the first season with plants grown under shade level of 42%, which gave insignificantly lower carotenoids concentration than the control. Similar reductions in the total chlorophylls and carotenoids contents as a result of reduced light levels have been recorded by Edward [31] on creeping bentgrass (*Agrostis stolonifera*), Baldwin *et al.* [44] on warm-season turfgrass and Jeffrey [28] on various cultivars of zoysiagrass and bermudagrass.

Table 4: Effect of shade levels and plant growth regulator treatments on total chlorophylls (a + b), carotenoids contents and total carbohydrates concentration in clippings of *Paspalum vaginatum* during the 2009/2010 and 2010/2011 seasons

Growth regulator treatments (GR)	First season (2009/2010)					Second season (2010/2011)				
	Shade degrees (SD)					Shade degrees (SD)				
	Control	(42%)	(63%)	(70%)	Mean (GR)	Control	(42%)	(63%)	(70%)	Mean (GR)
Total chlorophylls (a+ b) content (mg/g fresh matter)										
Control	1.88	1.66	1.61	1.31	1.61	1.80	1.56	1.43	1.19	1.49
PAC 1	2.13	2.04	1.87	1.84	1.97	2.01	1.81	1.60	1.34	1.69
PAC 2	2.19	2.19	2.05	1.98	2.10	2.42	2.26	2.08	1.65	2.10
TE 1	2.42	2.15	2.05	1.87	2.12	2.81	2.09	1.95	1.82	2.17
TE 2	2.46	2.19	2.15	2.07	2.22	2.89	2.34	2.29	2.09	2.40
Mean (SD)	2.22	2.05	1.95	1.81	-----	2.38	2.01	1.87	1.62	-----
LSD (0.05)										
SD			0.12					0.16		
GR			0.17					0.17		
SD X GR			0.34					0.34		
Carotenoids content (mg/g fresh matter)										
Control	0.58	0.52	0.52	0.41	0.51	0.69	0.65	0.57	0.53	0.61
PAC 1	0.68	0.63	0.52	0.53	0.59	0.81	0.65	0.64	0.67	0.69
PAC 2	0.77	0.77	0.54	0.79	0.72	0.88	0.83	0.84	0.73	0.82
TE 1	0.82	0.79	0.78	0.67	0.77	1.04	0.83	0.77	0.61	0.81
TE 2	0.86	0.85	0.79	0.68	0.80	1.08	0.88	0.84	0.78	0.89
Mean (SD)	0.74	0.71	0.63	0.62	-----	0.90	0.76	0.73	0.66	-----
LSD (0.05)										
SD			0.04					0.04		
GR			0.05					0.09		
SD X GR			0.11					0.17		
Total carbohydrates (% of dry matter)										
Control	21.0	19.5	17.1	16.5	18.5	24.1	21.5	21.0	18.0	21.1
PAC 1	23.4	22.0	19.8	18.8	21.0	24.3	23.8	23.8	23.0	23.7
PAC 2	26.5	24.6	24.2	23.4	24.7	28.4	25.0	24.7	22.7	25.2
TE 1	25.5	25.4	23.1	21.1	23.8	25.8	24.8	26.0	24.0	25.1
TE 2	29.2	27.3	27.0	24.0	26.9	29.4	29.1	28.1	26.6	28.3
Mean (SD)	25.1	23.8	22.2	20.8	-----	26.4	24.8	24.7	22.9	-----
LSD (0.05)										
SD			1.6					1.6		
GR			1.9					1.2		
SD X GR			3.8					2.4		

* PAC 1 = paclobutrazo at 750 ppm/ month TE 1 = trinexapac-ethyl at 200 ppm/ month
PAC 2 = paclobutrazo at 1500 ppm / month TE 2 = trinexapac-ethyl at 400 ppm / month

These reductions in the total chlorophylls content as a result of reduced light levels was explained by Pessarakli [8] who stated that, leaves developing under low irradiance had fewer cells and chloroplasts, therefore chlorophylls is less in shade than full sun. Low light levels also causes a dispersal of chloroplast grana [37] and reduction or loss of the palisade layer, which in turn effect on chlorophylls concentration and light absorption [53].

Data presented in Table 4 also showed that chemical growth retardant treatments were very beneficial in terms of increasing the total chlorophylls and carotenoids content in clippings of *paspalum vagintum* plants. In most cases, application of any rate of the two types of growth retardant (paclobutrazol or trinexapac-ethyl) significantly increased the recorded mean values, as compared to untreated control plants. The only one exception to this general trend was recorded in the second season with plants that were sprayed with paclobutrazol at the concentration of 750 ppm, which gave insignificantly higher carotenoids content than that of untreated control plants. Similar increases in the content of total chlorophylls content as a result of paclobutrazol or trinexapac-ethyl treatments have been reported by

McCann and Huang [54] on creeping bentgrass (*Agrostis stolonifera*), Liya *et al*. [36] on red fescue (*Festuca rubra* L.), Yan and Huang [42], on creeping bentgrass (*Agrostis stolonifera* L.).

With any of the tested growth retardant treatments, raising the application rate caused a steady increase in total chlorophylls and carotenoids content as compared to control. This is in agreement with finding of Sakr [29] on seashore paspalum (*Paspalum vaginatum*). When the two chemical types of growth retardants were applied at the different concentrations, TE treatments appeared to be more effective than paclobutrazol for increasing the content of total chlorophylls and carotenoids in clippings of plants. However, monthly application of the highest rate of TE (400 ppm) gave the highest values compared to control plants.

The data recorded on total chlorophylls (a+b) and carotenoids content also indicated that within each concentration of paclobutrazol or trinexapac-ethyl, total chlorophylls and carotenoids contents were decreased steadily as a result of raising the level of shade (in most cases). On the other hand, within each level of shade, raising the application rate of any of growth retardants resulted in steady increase in total chlorophylls content, as compared to those of plants sprayed with tap water (control). In most cases, in both seasons, plants grown under shade levels of 42% 63 and 70% and sprayed with any concentration of paclobutrazol or trinexapac-ethyl had total chlorophylls content in clippings that were insignificantly different than those of control plants. In both seasons, the highest mean values were obtained from plants grown under full sunlight and sprayed with trinexapac-ethyl at the concentration of 400 ppm, whereas, the lowest mean values were obtained from plants grown under the shade level of 70% and sprayed with tap water.

Total Carbohydrates (% of Dry Matter): The data presented in Table 4 revealed that total carbohydrates percentage in dry clippings of *paspalum vaginatum* plants was generally affected by the different levels of shade. In both seasons, the mean total carbohydrates concentration was decreased gradually as a result of increasing the level of shade. The steady results in the recorded mean values are similar to those reported by Qian and Engelke [55] on zoysiagrass [*Zoysia mmrella* (L.) Merr.] hybrid Diamond. Generally, the differences in the total carbohydrates concentrations of plants grown under the levels of 42%, 63% or 70% shade were statistically significant, compared to plants grown under full sunlight. The only exception to this general trend was detected in the first season with plants grown under the lowest shade level (42%) which had insignificantly lower total carbohydrates content than the control. The results for decreasing total carbohydrates as a result shade treatments are in agreement with the findings of Jiang *et al.* [6] on Sea Isle 1 seashore paspalum (*Paspalum vaginatum*) and bermudagrass (*Cynodon dactylon*. x *Cynodon transvaalensis*) hybrid TifSport, Edward [31] on creeping bentgrass (*Agrostis stolonifera*) and Baldwin *et al*. [44] on warm-season turfgrass.

This reduction in the total carbohydrates percentage as a result of plants grown under shade conditions was explained by Jiang *et al*. [56] who reported that the reduced shoot density as a result of light reduction may be adversely affected canopy physiological status such as photosynthesis which in turn leading to limited carbohydrate synthesis.

Data tabulated in Table 4 also showed that the different growth retardant treatments had a makeable effect on the accumulation of total carbohydrates concentrations in clippings of *paspalum vaginatum* plants. In both seasons, the values recorded were significantly higher in plants receiving any of the different chemical growth retardant treatments, compared to the control. Similar increases in the carbohydrates concentration as a result of growth retardant treatments have been reported by Ervin and Zhang [57] on Kentucky bluegrass (*Poa pratensis* L.), creeping bentgrass (*Agrostis stolonifera* L.).

With any of the two chemical types, raising the application rate resulted in a steady increase in total carbohydrates concentrations. in both seasons, the most effective treatment was the highest rate of trinexapac-ethyl (400 ppm) followed by the highest rate of paclobutrazol (1500 ppm), since giving higher mean values than those recorded with the control. The steady increase in the concentration of total carbohydrates in clippings as a result of raising the application rate is similar to that reported by Sakr [29] on seashore paspalum (*Paspalum vaginatum*, Swartz).

Regarding the interaction between the effects of different levels of shade and growth retardant treatments, the data in Table 4 showed that within each concentration of the two types of growth retardants, raising the level of shade decreased total carbohydrates percentage in clippings steadily (in most cases). On the other hand, within each level of shade, raising the application rate of any of paclobutrazol or trinexapac-ethyl increased total carbohydrates percentage steadily, as compared to that recorded in plants sprayed with water. In both seasons,

Table 5: Effect of shade levels and plant growth regulator treatments on N, P and K concentrations (% of dry matter) in clippings of *Paspalum vaginatum* during the 2009/2010 and 2010/2011 seasons

Growth regulator treatments (GR)	First season (2009/2010)					Second season (2010/2011)				
	Shade degrees (SD)					Shade degrees (SD)				
	Control	(42%)	(63%)	(70%)	Mean (GR)	Control	(42%)	(63%)	(70%)	Mean (GR)
					N (% dry matter)					
Control	1.62	1.30	1.40	1.22	1.38	1.92	1.91	1.86	1.66	1.83
PAC 1	1.81	1.68	1.61	1.52	1.65	1.99	1.99	1.82	1.81	1.90
PAC 2	2.02	1.92	1.85	1.83	1.90	2.20	2.07	1.91	1.89	2.02
TE 1	2.06	1.83	1.83	1.77	1.87	2.30	2.24	1.99	1.72	2.06
TE 2	2.04	1.94	1.90	1.91	1.95	2.07	2.05	1.99	1.89	2.00
Mean (SD)	1.91	1.73	1.72	1.65	----	2.10	2.05	1.91	1.79	----
LSD (0.05)										
SD			0.14					0.28		
GR			0.19					0.34		
SD X GR			0.39					0.69		
					P (% dry matter)					
Control	0.18	0.16	0.16	0.10	0.15	0.17	0.16	0.13	0.09	0.14
PAC 1	0.21	0.21	0.19	0.18	0.20	0.19	0.12	0.15	0.14	0.15
PAC 2	0.22	0.21	0.20	0.21	0.21	0.20	0.18	0.16	0.18	0.18
TE 1	0.22	0.20	0.19	0.19	0.20	0.17	0.19	0.16	0.17	0.17
TE 2	0.29	0.24	0.23	0.21	0.24	0.24	0.22	0.22	0.19	0.22
Mean (SD)	0.22	0.20	0.19	0.18	------	0.20	0.17	0.16	0.15	------
LSD (0.05)										
SD			0.01					0.01		
GR			0.01					0.02		
SD X GR			0.02					0.04		
					K (% of dry matter)					
Control	1.68	1.50	1.42	1.33	1.48	1.79	1.59	1.37	1.26	1.50
PAC 1	1.90	1.87	1.60	1.62	1.75	1.81	1.80	1.55	1.74	1.72
PAC 2	1.94	1.84	1.80	1.74	1.83	1.99	1.80	1.65	1.60	1.76
TE 1	1.81	1.72	1.55	1.50	1.64	1.80	1.62	1.38	1.49	1.57
TE 2	1.91	1.80	1.71	1.54	1.74	1.97	1.95	1.85	1.55	1.83
Mean (SD)	1.85	1.74	1.62	1.55	-----	1.87	1.75	1.56	1.53	-----
LSD (0.05)										
SD			0.16					0.30		
GR			0.21					0.22		
SD X GR			0.42					0.45		

plants grown under the three shade levels and treated with paclobutrazol at concentrations of 750 or1500 ppm as well as plants grown under shade levels of 63 and 70% and treated with trinexapac-ethyl at 200 ppm hade total carbohydrates percentage in clippings which were insignificantly different than those of control plants. In both seasons, the highest mean values were obtained from plants grown under full sunlight and sprayed with the highest concentration of trinexapac-ethyl (400 ppm), whereas the lowest mean values were produced by plants grown under the shade level of 70 % and sprayed with tap water.

N, P and K % of Dry matter in Clippings: As shown in Table 5, the recorded data indicated that the concentration of N, P and K% in dried clippings of *Paspalum vaginatum* plants were decreased steadily with raising the levels of shade, compared to that recorded with control plants. Accordingly, the lowest concentration of N, P and K% were obtained from the clippings of plants grown under the highest level of shade (70%), whereas the highest concentrations of the three nutrients were recorded in the clippings of control plants. In most cases, increasing the levels of shade from 42 to 63% or 73% significantly decreased the concentration of

N, P and K%, with the exceptions of plans shaded with the lower shade levels of 42 or 63% (in the second season), which had insignificantly lower N % in dried clippings than the control plants, as well as the lowest shade level (42%) insignificantly decreased the K%, compared with the control plants.

The data also in Table 5 showed that the uptake and accumulation of N, P and K% were enhanced by using the different growth retardant treatments. In most cases, plants sprayed with any rate of paclobutrazol or trinexapac-ethyl had the concentrations of the three nutrients that were significantly higher than those recorded with the control. However, the increases in the N% in plants receiving the different concentrations of paclobutrazol or trinexapac-ethyl (in the second season) were generally insignificant. Similar increases in the N, P and K % as a result of growth retardant treatments have been reported by Mansour [58] on *Peperomia obtusifolia,* Gowda and Gowda [59]on *Jasminum sambac*, Haggag [60] on chrysanthemum, Easwaran *et al.* [61] on *Celosia cristata* and El-Sallami [62] on poinsettia.

In most cases, with any of the two chemical types of growth retardant, raising the application rate resulted in a steady increase in N, P and K percentage in dried clippings**.** This steady increase in the percentage of P as a result of raising the application rate is similar to that reported by Sakr [29] on seashore paspalum (*Paspalum vaginatum*, Swartz) and Othman [63] on *Helianthus annuus*. The most effective growth retardant treatment for increasing the nutrients in clippings was the highest paclobutrazol concentration (1500 ppm) and the highest trinexapac-ethyl concentration (400 ppm)**.**

The data recorded on N, P and K % showed that within each concentration of the tested growth retardants raising the level of shade resulted in steady decreases in N, P and K % in clippings (in most cases). On the other hand, in most cases, within each shade level, raising the application rate of any of paclobutrazol or trinexapac-ethyl increased N, P and K % steadily, as compared to the values recorded in plants sprayed with water. In both seasons, plants grown under the three tested shade levels (42%, 63% or73%) and sprayed with the different concentrations of paclobutrazol or trinexapac-ethyl hade N and K % in clippings that were insignificantly different than those recorded with the control plants.

It can be concluded that *Paspalum vaginatum* plants can be grown under shade up to 42% with no significant reduction in growth. However, if shade level exceeds to 42% (up to 70%) TE at concentration of 200 and 400 ppm and/or paclobutrazol at concentration of 750 and 1500 ppm can be used monthly as a foliar spray to overcome the adverse effects of shade.

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