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Response of Japanese Lawngrass (*Zoysia japonica*, Steud.) Grown in Sandy Soil to Some Soil Amendments and Fertilization Treatments

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Abstract: This study was conducted at a private turf nursery in El-Kassassin, Ismailia Governorate, during the two successive seasons of 2005 / 2006 and 2006 / 2007. This work aimed to investigate the response of Japanese lawngrass (*Zoysia japonica*, Steud.), grown in sandy soil, to some soil amendments and chemical fertilization treatments. During soil preparation, Kattameya and sewage sludge composts were added at the rate of 0.01 m^3 /m^2 of soil surface, whereas Agrosil was added at the rate of 120 g / m^2 of soil surface. After planting, the plants were fertilized with a conventional chemical NPK fertilizer (9 N - 5 P_2O_5 - 5 K_2O) at the rates of 33.3, 44.4 or 55.6 g fertilizer/m^2/month, or with the slow-release chemical commercial fertilizer "Haigrow" (18 N -10 P_2O_5-10 K_2O) at the rates of 50, 66.7 or 83.3 g fertilizer/m^2/3 months. In addition to the soil amendment and chemical fertilization treatments, plants of untreated plots (for both soil amendments and chemical fertilization) were used as controls. Results showed that soil amendments and chemical fertilization treatments increased the values recorded for the different growth parameters [plant height before mowing, lawn density (number of shoots/100 cm^2), fresh and dry weights of clippings and underground parts/m^2], as well as the contents of total chlorophylls, carotenoids, total carbohydrates, N, P, K, Ca, Mg, Fe, Mn, Zn and Cu in clippings, in most cases, comparing with the untreated plants. Among the three types of soil amendments, sewage sludge compost gave the highest values for plant height, number of shoots/100 cm^2, fresh and dry weights of clippings and underground parts/m^2, as well as the contents of total chlorophylls and carotenoids, N, P, K, Fe and Zn in the clippings, whereas Kattameya compost gave the highest contents of total carbohydrates, Mg, Mn and Cu in the clippings. Raising the fertilization rate of each chemical fertilizer resulted in steady increases in most values of the studied parameters. Data of nutrients′ indices pointed out that further studies should be conducted to investigate the response of plants to higher rates than those used for each chemical fertilizer. Conventional NPK fertilizer gave higher values for most of the vegetative growth and chemical characteristics, compared to slow-release fertilizer "Haigrow". Combining sewage sludge compost (0.01m^3/m^2) with the highest rate of conventional NPK fertilizer (55.6 g/m^2/month) resulted in the highest values for vegetative growth parameters as well as the contents of total chlorophylls, carotenoids, N, P, K, Fe and Zn in clippings. Also, combining the same soil amendment with the highest rate of Haigrow (83.3 g/m^2/3 momths) gave turf height, as well as fresh and dry weights of clippings with values which were insignificantly lower than those obtained by using the highest rate of the conventional NPK fertilizer. From the obtained results, it can be recommended that, for the best vegetative growth of *Zoysia japonica* turfgrass grown in sandy soil, the soil should be amended with sewage sludge compost (0.01 m^3 /m^2 of soil surface, added during soil preparation) and the plants should be supplied with 55.6 g/m^2/month of the conventional chemical fertilizer (9% N - 5% P_2O_5 - 5% K_2O).

Key words: *Zoysia japonica* · fertilization · soil amendments · slow release fertilizer

INTRODUCTION

During the last few years, large scale urban development has been taking place in Egypt, including the construction of new cities, residential compounds, as well as coastal touristic resorts and hotels. Such projects usually involve extensive landscape development (including large areas of turfgrasses), most of which takes

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place in desert areas, with poor sandy or rocky soils. Japanese lawngrass (*Zoysia japonica*, Steud.) is one of the most promising turfgrass species that can be used in the landscape of desert areas because it is quite tolerant to drought, heat and cold stress [1]. However, under such harsh growth conditions, it is necessary to ensure an adequate supply of nutrients to the turfgrass. In this respect Hussein and Mansour [2] on *Paspalum vaginatum*, Hussein and Mansour [3] on *Pennisetum clandestinum* and Hussein and Arafa [4] on *Paspalum vaginatum*, reported that conventional NPK fertilizers improved growth and quality of the turfgrasses.

Organic soil amendments, such as treated town refuse and sewage sludge compost, are often used to improve the chemical characteristics of the soil by increasing the supply of macro- and micro-nutrients and organic matter. They also improve the physical properties of sandy soil by increasing their water holding capacity. Soil amendments have shown considerable potential for use in the landscape for improving the impoverished soils [5]. Hussein and Mansour [2] reported that addition of sewage sludge compost or treated town refuse to the sandy soil during soil preparation improved growth and quality of seashore paspalum turfgrass (*Paspalum vaginatum*). Also, synthetic products such as Agrosil are sometimes used as soil amendments as mentioned by Kolb [6] on *Lonicera xylosteum*, Hussein [7] on *Cryptostegia grandiflora*, Mansour [8] on *Senna sulfurea* and Hussein [9] on *Senna occidentalis*.

Slow-release fertilizers also improved growth of turfgrasses and are safer to handle and labor-saving, compared to conventional NPK fertilizers (only 2-3 applications from the former instead of 4-12 from the latter). However, the price of slow-release fertilizers is higher than other fertilizers and they tend to promote thatch formation [10]. It was also suggested that the use of chemical slow-release fertilizers on turf produced high qualitative standards and at the same time reduce nitrogen leaching [11]. Floranid is one of the commercial slow-release fertilizers that have been tested and have showed promising results in controlling N leaching, compared to conventional fertilizer application [12-14]. Emarah [15] stated that the slow-release fertilizer Osmocote (16 N -10 P_2O_5-13 K_2O) improved vegetative growth characteristics of *Cynodon dactylon, C. transvaalensis* and Tifway (*C. dactylon x C. transvaalensis*). Also, Hussein and Mansour [2] on *Paspalum vaginatum*, found that although both Floranid Turf (20 N -5 P_2O_5-8 K_2O) and Floranid Master (16 N -5 P_2O_5 -10 K_2O) as slow release fertilizers improved turf growth and quality, the conventional NPK fertilizer was more effective, so they suggested that further studies should be conducted to investigate the effect of these two slow-release fertilizers when applied at concentrations higher than those tested (30, 50 and 70 g / m^2 every three months).

Plant analysis can be a useful tool for optimizing plant production by correcting plant nutrient deficiencies and imbalances as well as evaluating fertilizer requirements [16, 17]. The Diagnosis and Recommended Integrated System (DRIS) is a recent approach to interpreting plant-tissue analysis [18]. This methodology has received considerable attention since it was developed by Beaufils [19]. The DRIS system makes multiple comparisons between the levels of various plant nutrients and integrates these comparisons into a series of nutrient indices [16]. The DRIS index scale that results from those calculations is continuous and easy to understand [17]. This model is designed to determine if the nutrient contents of plants receiving fertilization treatments are excessive (positive indices), adequate (zero indices) or deficient (negative indices). Development of the DRIS for use with a plant involves compiling a database from which optimum ratios (mean and coefficient of variance) for all nutrient combinations are determined, called DRIS norms [20, 21]. Many investigators have successfully used DRIS on number of plants including fraser fir christmas [22], onions [23] and 'Valencia' sweet orange [24]. It was reported that the DRIS analysis provides the means for diagnosing nutrient imbalances and a potential basis for prescribing corrective amendments.

The present study was designed to investigate the effect of organic (kattameya and sewage sludge composts) and synthetic (Agrosil) soil amendments, as well as the effectiveness of different chemical fertilization treatments of conventional NPK fertilizers and Haigrow (a slow release fertilizer) on the vegetative growth and chemical composition of Japanese lawngrass (*Zoysia japonica*, Steud.) grown in sandy soil. This study aimed also to evaluate the effects of soil amendments on nutrients' indices (using Diagnosis and recommendation Integrated system, DRIS) under different chemical fertilization treatments, with the objective of diagnosing nutrient imbalance in plants.

MATERIALS AND METHODS

This study was conducted in a private turf nursery in El-Kassassin, Ismailia Governorate, during the two successive seasons of 2005/2006 and 2006/2007, with the

Table 1: Physical and chemical characteristics of the sandy soil used for growing *Zoysia japonica* during 2005/2006 and 2006/2007 seasons

Physical characteristics					
Clay (%)	Coarse sand (%)	Fine sand (%)	Silt (%)	Soil texture	Field capacity (% V)
2.8	38.5	52.4	6.3	Sandy	14.6

Chemical characteristics							
					Available macro - nutrients (ppm)		
pH	Organic matter (%)	$CaCO_3$ (%)	EC (dS/m) (1:2.5)	CEC (meq/100 g)	N	P	K
7.4	1.03	0.63	0.76	4.1	18.2	1.1	56.0

aim of investigating the response of Japanese lawngrass (*Zoysia japonica*, Steud.) to some soil amendments added during the preparation of the sandy soil, followed by the application of conventional NPK fertilizer or Haigrow as slow-release chemical fertilizer during the growing season. The effects of soil amendments on nutrients' indices (using Diagnosis and recommendation Integrated system, DRIS) were also evaluated under different fertilization treatments, with the objective of diagnosing nutrient imbalance in plant.

One hundred and twelve square of planting beds (1 m x 1 m) were prepared at the site of the experiment in a sandy soil, during February months of 2005 and 2006 years (in the first and second seasons, respectively).

Determination of the textural class of the soil, its calcium carbonate and organic matter%, its cation exchange capacity (CEC), as well as the chemical characteristics, such as soil reaction (pH) and electrical conductivity (EC), were carried out using the procedures outlined by the USDA [25]. The field capacity (%V), contents of available N and K were determined using the methods described by Page [26], while the content of available P was determined according to Watanabe and Olsen [27]. The physical and chemical characteristics of the soil are shown in Table 1.

Three soil amendments were used in this investigation: (1) Kattameya compost (treated town refuse, obtained from the Egyptian Company for Solid Waste Utilization, Cairo, Egypt), (2) Sewage sludge compost (obtained from Abou-Rawash station, Giza Governorate) and (3) Agrosil (a synthetic water-retaining soil amendment, manufactured by Compo, BASF, Germany, containing 2% N, 9.5% P and 38% silica). The density (g/cm^3), humidity (%) of the Kattameya and sewage sludge composts as well as macronutrients (N, P and K) and micronutrients (Fe, Zn, Mn and Cu) contents were determined according to Page [26]. In addition, organic matter% and electrical conductivity (EC, in a 1:10, agent: water extract)) were determined according to USDA [25]. The physical and chemical characteristics of the Kattameya and sewage sludge composts used in this study are shown in Table 2.

One quarter of the total number of planting beds was amended during preparation of the soil, using each of the three different types of soil amendments individually, 28 beds for each. The fourth quarter was left without soil amendment as control. The three soil amendments were incorporated into the soil to a depth of 15 cm. The Kattameya and sewage sludge composts as organic soil amendments were used at the rate of 0.01 m^3 /m^2 of soil surface for each, whereas Agrosil was used at the rate of 120 g / m^2 of soil surface. A non selective weed killer (Round-up) was used at a rate equivalent to 1 L / fed to eliminate the vegetation prior to planting.

On 1st March (in both seasons), plugs of Japanese lawngrass (*Zoysia japonica*, Steud.) were planted at a spacing of 10 cm x 10 cm (one square meter of sod gave enough plugs to plant about 5 m^2). Application of chemical fertilization treatments were initiated one month after planting (on 1st April of each season). The turfgrass was fertilized with three different rates of a conventional NPK fertilizer (9 N-5 P_2O_5 -5 K_2O), or with three different rates of Haigrow (18 N -10 P_2O_5 -10 K_2O) as a commercial slow-release fertilizer (obtained from Egyptian Group for Development, Giza, Egypt). Every 1000 g of the conventional NPK (9 N-5 P_2O_5 -5 K_2O) fertilizer were prepared by mixing 268.7 g ammonium nitrate fertilizer (33.5% N), 322.6 g calcium superphosphate fertilizer (15.5% P_2O_5), 104.2 g potassium sulphate fertilizer (48% K_2O) and 304.5 g sand as an inert component. Plants receiving conventional NPK fertilizer were treated with

Table 2: Physical and chemical characteristics of Kattameya and sewage sludge composts incorporated into the sandy soil before planting Japanese lawngrass (*Zoysia japonica* Steud.) during 2005/2006 and 2006/2007 seasons

Organic soil amendment	Physical characteristics		Chemical characteristics								
	Density (g/cm^3)	Humidity (%)	EC. (dS/m)	Organic matter (%)	N (%)	P (%)	K (%)	Fe (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)
Kattameya compost	0.45	25.0	2.21	29.5	1.2	0.45	0.82	791	211	111	97.5
Sewage sludge compost	0.51	9.0	1.62	46.4	4.8	0.21	0.46	640	291	65	45.9

monthly applications of this mixture, at three rates namely, 33.3, 44.4 or 55.6 g / m^2 of soil surface (providing the plants with 3 g N + 1.7 g P_2O_5 + 1.7 g K_2O, 4 g N + 2.2 g P_2O_5 + 2.2 g K_2O or 5 g N + 2.8 g P_2O_5 + 2.8 g K_2O /m^2, respectively). Haigrow (18 N -10 P_2O_5 -10 K_2O) was added every three months at three rates namely, 50, 66.7 or 83.3 g fertilizer / m^2 of soil surface. These rates of the slow-release fertilizer provided the plants with doses of N, P_2O_5 and K_2O equally to those provided by the conventional NPK fertilization treatments. In addition to the six chemical fertilization treatments, unfertilized plants were used as control.

The plants were irrigated daily from planting till 15th October (using a pop-up sprinkler system) at the rate of 7 L / m^2 of soil surface. Thereafter, they were irrigated every 2 days at the rate of 9 L / m^2 of soil surface till 15th January.

The layout of the experiment was a split-plot design, with the main plots in a randomized complete blocks design, with four blocks (replicates). The soil amendments (including the control) were assigned to the main plots, while the chemical fertilization treatments (including the control) were assigned to the sub-plots.

In both seasons, the turfgrass was mowed biweekly to a height of 3 cm starting on 15th April. The average plant height (cm) before mowing, as well as the average fresh and dry weights of the clippings (g/m^2) after mowing were recorded throughout each growing season. At the end of each growing season (on 15th January), lawn density (number of shoots / 100 cm^2) was recorded using a 10 cm x 10 cm wooden frame. Fresh and dry weights of underground parts (g / m^2) were also recorded.

At the end of both seasons, fresh clipping samples were chemically analyzed to determine total chlorophylls (a + b) and carotenoids contents (mg/g fresh matter) using the method described by Nornai [28]. Meanwhile the total carbohydrates content (% of dry matter) was determined in dried clipping samples, using the method recommended by Dubois *et al.* [29]. Also, dried clipping samples were digested to extract nutrients as described by Piper [30]. The extract was analyzed to determine contents of nitrogen (% of dry matter) as described by Pregl [31], phosphorus (% of dry matter) according to Jackson [32]. Potassium (% of dry matter), contents of Ca, Mg (mg/g dry matter), Fe, Mn, Zn and Cu (μg / g dry matter) were determined using a flame atomic absorption spectrophotometer (HGA-5000 graphite furnace) as recommended by Chapman and Pratt [33].

Data collected for vegetative growth characteristics were subjected to an analysis of variance and the means were compared using the "Least Significant Difference (LSD)" test at the 0.05 level according to Little and Hills [34].

Calculation of nutrients′ indices using DRIS: In the second season, the Diagnosis and Recommendation Integrated System (DRIS) was used to rank the importance of the various nutrients in limiting plant growth and to estimate the degree to which each of the limiting nutrients was deficient. The nutrients′ indices were calculated using ratios of all analyzed nutrients (N, P, K, Ca, Mg, Fe, Mn, Zn and Cu). The general formulas used to calculate nutrients′ indices were given by Walworth and Sumner [35], as follows:

$$AI = [+f(A/B) - f(A/C) + (A/D) \ldots +f(A/N)]/Z \quad (1)$$

Where A…N are nutrients, AI is the index for nutrient A and when A/B > a/b:

$$f(A/B) = \{[(A/B)/(a/b)]-1\} \times (1000/CV) \quad (2)$$

or, when A/B < a/b:

$$f(A/B) = \{1-[(a/b)/(A/B)]\} \times (1000/CV) \quad (3)$$

in which A/B is the observed ratio of two elements in the tissue, a/b is the norm for that ratio in a large population of high-growth plants, CV is the coefficient of variation associated with the norm and Z is the number of functions comprising the nutrient index.

RESULTS AND DISCUSSION

I-Vegetative growth characteristics:

1-Plant height before mowing: The results presented in Table 3 showed that in both seasons, the addition of soil amendments during soil preparation had a generally favourable effect on plant height before mowing of *Zoysia japonica* turfgrass, compared to the control. In both seasons, plants receiving any of the different types of soil amendments gave significantly taller plants than the control. Among the three types of soil amendments that were tested, sewage sludge compost gave the tallest plants, followed by Kattameya compost then Agrosil, with significant differences between each other in both growing seasons. Similar results were obtained by Hussein and Mansour [2] on *Paspalum vaginatum.*

Regarding the effect of chemical fertilizers on plant height before mowing, the results recorded in the

Table 3: Effect of soil amendments and chemical NPK fertilizers on plant height (cm) before mowing and lawn density (number of shoots/100 cm^2) of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

Chemical fertilizer treatments (CF)**	First season (2005/2006) Soil amendments (SA)* Control	KC	SS	A	Mean	Second season (2006/2007) Soil amendments (SA)* Control	KC	SS	A	Mean
Plant height before mowing (cm)										
Control	3.70	4.15	4.32	4.05	4.06	3.78	4.05	4.26	3.97	4.02
NPK_1	3.92	4.35	4.66	4.11	4.26	4.22	4.77	4.91	4.60	4.63
NPK_2	4.59	5.08	5.40	4.97	5.01	4.70	5.41	5.98	4.87	5.24
NPK_3	4.83	5.32	5.50	5.09	5.19	4.86	5.76	6.25	5.25	5.53
Ha_1	3.87	4.19	4.59	4.01	4.17	4.10	4.73	4.89	4.68	4.60
Ha_2	4.20	4.50	5.26	4.23	4.55	4.50	5.09	5.16	4.73	4.87
Ha_3	4.28	4.86	5.31	4.64	4.77	4.81	5.40	6.17	5.22	5.40
Means	4.20	4.64	5.00	4.44	----	4.42	5.03	5.37	4.76	----
LSD (0.05)										
SA	0.20					0.24				
CF	0.33					0.43				
SA X CF	0.44					0.57				
Lawn density (number of shoots/100 cm^2)										
Control	163.1	181.7	184.6	176.0	176.4	151.2	175.8	181.7	164.1	168.2
NPK_1	178.4	198.3	211.9	191.1	194.9	170.7	201.4	222.5	189.8	196.1
NPK_2	186.6	210.1	225.7	215.7	209.5	176.6	215.1	239.8	200.4	208.0
NPK_3	190.4	231.4	239.6	227.2	222.2	189.4	231.9	264.0	220.7	226.5
Ha_1	175.2	208.3	217.8	190.3	197.9	156.8	194.3	200.9	188.1	185.0
Ha_2	181.2	211.5	225.4	200.4	204.6	168.6	200.2	212.9	194.5	194.1
Ha_3	189.1	221.2	227.1	214.5	213.0	181.5	219.1	228.4	201.6	207.7
Means	180.6	208.9	218.9	202.2	----	170.7	205.4	221.5	194.2	----
LSD (0.05)										
SA	7.1					8.5				
CF	8.5					9.1				
SA X CF	10.4					10.6				

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

two seasons indicated that addition of any rate of the two types of fertilizers (conventional NPK fertilizers or Haigrow) increased plant height before mowing, compared to that of the control. Moreover, with any of the two types of fertilizer, raising the application rate resulted in a steady increase in plant height. A similar conclusion was reached by Hossni [36] on *Cynodon dactylon*, Emarah [15] on *C. dactylon*, *C. transvaalensis* and Tifway (*C. dactylon* x *C. transvaalensis*), Paswan and Machahary [37] on *Paspalum notatum* and Hussein and Mansour [2] on *Paspalum vaginatum*. In general, conventional NPK fertilization gave better results than Haigrow. The tallest plants in both seasons were those fertilized with the highest NPK rate (55.6 g / m^2 / month). In the first season, no significant difference was detected between the results of NPK_3 and NPK_2 treatments. Also, no significant difference was observed in the second season between the heights of plants supplied with NPK_3, NPK_2 or Ha_3 treatments.

Plant height was significantly affected by the interaction between the effects of soil amendments and chemical fertilizers. In both seasons, the lowest values were recorded for the control plants, whereas the combined treatment of sewage sludge compost and the highest rate of conventional NPK fertilization (NPK_3) gave the tallest plants, followed by values recorded with the combined treatment of sewage sludge compost and NPK_2 (in the first season) or Ha_3 (in the second season), with no significant difference between these values.

2-Lawn density (number of shoots / 100 cm^2): The results presented in Table (3) showed that in both seasons, the addition of the different soil amendments significantly increased the number of shoots/100 cm^2, compared to the control. Sewage sludge compost was the most effective soil amendment, resulting in the highest number of shoots/100 cm^2, followed by Kattameya compost, then Agrosil, with significant differences between the values obtained with the three soil amendments (except between Kattameya compost and Agrosil in the first season). These results are similar to those reported by Hussein and Mansour [2] on *Paspalum vaginatum*.

Chemical fertilization also significantly promoted the formation of shoots in *Zoysia japonica* plants. In both seasons, control plants had significantly fewer shoots / 100 cm^2 than those receiving the different chemical

Table 4: Effect of soil amendments and chemical NPK fertilizers on fresh and dry weights of clippings (g/m^2/2 weeks) of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

Chemical fertilizer treatments (CF)**	First season (2005/2006) Soil amendments (SA)*					Second season (2006/2007) Soil amendments (SA)*				
	Control	KC	SS	A	Mean	Control	KC	SS	A	Mean
Fresh weight of clippings (g/m^2/2 weeks)										
Control	18.2	21.4	25.0	19.6	21.1	14.3	21.2	25.3	17.6	19.6
NPK_1	22.6	33.6	40.4	28.8	31.4	17.4	25.2	31.0	23.0	24.2
NPK_2	29.0	37.2	48.0	30.2	36.1	26.4	35.2	40.8	35.0	34.4
NPK_3	30.4	46.2	49.8	41.4	42.0	28.0	47.2	47.0	40.2	40.6
Ha_1	21.0	29.2	32.6	23.8	26.7	16.6	28.6	31.0	20.6	24.2
Ha_2	24.6	38.4	42.0	28.8	33.5	20.6	32.8	43.0	26.4	30.7
Ha_3	30.0	39.4	46.2	37.6	38.3	26.4	39.2	45.0	31.0	35.4
Means	25.1	35.1	40.6	30.0	----	21.4	32.8	37.6	27.7	----
LSD (0.05)										
SA	4.6					3.8				
CF	6.2					6.6				
SA X CF	7.4					7.2				
Dry weight of clippings (g/m^2/2 weeks)										
Control	4.6	5.6	6.6	5.0	5.5	4.4	5.0	6.6	5.8	5.5
NPK_1	5.2	8.4	9.2	5.8	7.2	6.2	8.6	11.0	7.0	8.2
NPK_2	7.6	8.6	10.0	8.0	8.6	6.4	9.0	12.2	7.8	8.9
NPK_3	8.6	11.8	12.0	10.4	10.7	7.6	11.0	13.0	10.8	10.6
Ha_1	4.8	6.6	7.8	5.8	6.3	5.2	7.0	8.4	7.0	6.9
Ha_2	6.0	9.2	11.0	7.6	8.5	6.0	10.0	10.6	7.8	8.6
Ha_3	7.8	10.4	11.0	8.6	9.5	7.0	10.6	11.8	9.6	9.8
Means	6.4	8.7	9.7	7.3	----	6.1	8.7	10.5	8.0	----
LSD (0.05)										
SA	0.8					0.8				
CF	1.5					1.8				
SA X CF	2.1					1.9				

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

fertilization treatments. These results are similar to those reported by Beard *et al.* [38] on *Stenotaphrum secundatum*, Yeam *et al.* [39] on *Zoysia japonica* and Oral and Acikgoz [40] on a turfgrass mixture consisting of *Lolium perenne*, *Poa pratensis*, *Festuca rubra* var. *rubra* and *F. rubra* var. *commutata*. Data showed that raising the fertilization rate of each chemical fertilizer resulted in a steady increase in lawn density. Both fertilizers gave the best results when they were applied at the highest rate. In most cases, conventional NPK fertilization gave more shoots/100 cm^2 than Haigrow. The highest NPK rate gave a significantly higher number of shoots/100 cm^2, compared to any other chemical fertilization treatments. A similar conclusion was reported by Hussein and Mansour [2] on *Paspalum vaginatum*.

Regarding the effects of different combinations between soil amendments and chemical fertilizers, the highest number of shoots/100 cm^2, in both seasons, was obtained from plants grown in a soil amended with sewage sludge compost during soil preparation, followed by monthly NPK fertilization at the highest rate, with significant differences than most treatments.

3-Fresh and dry weights of clippings: The data recorded in the two seasons (Table 4) showed that both soil amendments and chemical fertilization had a considerable effect on the fresh and dry weights of *Zoysia japonica* clippings. Regarding the effect of soil amendments, the results recorded in both seasons showed that the addition of any type of soil amendments caused significant increases in the fresh and dry weights of clippings, compared to values recorded on control plants. In both seasons, significant differences in the fresh and dry weights of clippings were detected as a result of using the different soil amendments, with sewage sludge compost giving the highest values, followed by Kattameya compost, then Agrosil. However, no significant difference was obtained in the second season between the dry weight of clippings obtained in soil amended with Kattameya compost and that obtained in soil amended with Agrosil. Similar results were reported by Hussein and Mansour [2] on *Paspalum vaginatum*.

Chemical fertilization also resulted in promotion of vegetative growth of *Zoysia japonica* turfgrass in terms of the fresh and dry weights of clippings (Table 4). Raising the fertilization rate of each chemical fertilizer resulted in a steady increase in the values recorded. These results are in agreement with the findings of Kalmbacher and Martin [41] on *Paspalum atratum*, Paswan and Machahary [37] on *P. notatum* and Hussein and Mansour [2] on *P. vaginatum*. In most cases, the application of different rates of conventional NPK and Haigrow fertilization significantly increased the values recorded in both seasons, compared to the control. In general, when the two chemical fertilizers were applied at rates providing equivalent supplies nutrients the values recorded for fresh and dry weights of clippings were insignificantly higher with conventional NPK rates than with those of Haigrow (at the same order). The superior effect of conventional NPK fertilization on fresh and dry matter production, compared to that of slow-release fertilizer, is in agreement with the findings of Dressel *et al.* [42], who reported that readily soluble ammonium nitrate gave a higher dry matter production in lawn grasses than that obtained with other slow-release N forms. The highest conventional NPK application rate (55.6 g/m^2/month) gave the heaviest fresh and dry weights of clippings in both seasons, followed by Ha_3 (83.3 g/m^2/3 months), then NPK_2 (44.4 g/m^2/month), with mostly no significant difference between the values recorded with these three treatments. The favourable effect of NPK fertilization was reported by Hare *et al.* [43] on *Paspalum atratum*, Singh [44] on *Paspalum dilatatum*, *Pennisetum glaucum* x *Pennisetum purpureum* and *Brachiaria mutica* and Hussein and Mansour [2] on *Paspalum vaginatum*.

Regarding the interaction between the effects of soil amendments and chemical fertilizers, the data in Table 4 showed that in the first season, the highest fresh weight of clippings was obtained from plots amended with sewage sludge compost and supplied with NPK_3, followed by those receiving the same amendment (sewage sludge compost) and fertilized with NPK_2 or Ha_3, with no significant difference between their values. Also, plots amended with Kattameya compost and supplied with NPK_3 gave a fresh weight of clippings that was insignificantly lower than the previously mentioned highest fresh weight. In the second season, plots amended with Kattameya compost and supplied with NPK_3 gave the highest fresh weight of clippings, followed by plots amended with sewage sludge compost and receiving NPK_3, Ha_3, Ha_2 and NPK_2, with no significant difference between the recorded results. Also, plots amended with Agrosil and receiving NPK_3 gave a fresh weight of clippings that was insignificantly lower than the highest value recorded in the second season.

The data in Table 4 also showed that, in the first season, the highest dry weight of clippings was obtained from plots amended with sewage sludge compost and supplied with NPK_3, followed by plots receiving the same soil amendment, but supplied with Ha_3, Ha_2 and NPK_2 with no significant difference between their effects. Also, plots amended with Kattameya compost and receiving NPK_3 or Ha_3, as well as plots amended with Agrosil and receiving NPK_3 gave dry weights of clippings that were insignificantly differ than the highest dry weight previously mentioned. In the second season, plots amended with sewage sludge compost and receiving NPK_3 gave the highest dry weight of clippings followed by plots that received the same soil amendment and were supplied with NPK_2 or Ha_3, with no significant difference among the obtained values.

4-Fresh and dry weights of underground parts: The data presented in Table 5 showed that the fresh and dry weights of underground parts of plants were increased significantly, in both seasons, as a result of the addition of the tested soil amendments, compared to the control. In both seasons, the differences between the values recorded with the three types of soil amendments were significant, with sewage sludge compost giving the highest values, followed by Kattameya compost, whereas Agrosil was the least effective soil amendment. The generally favourable effects of sewage sludge compost and treated town refuse on underground parts are in agreement with the findings of Hussein and Mansour [2] on *Paspalum vaginatum*, who reported that incorporation of sewage sludge compost or treated town refuse in sandy soil during soil preparation increased the fresh and dry weights of underground parts of *Paspalum vaginatum*.

The growth of underground parts of *Zoysia japonica* turfgrass was also influenced by chemical fertilization. Regardless of types of fertilizer, raising the rate of chemical fertilization increased the fresh and dry weights of underground parts steadily, in both seasons. The promoting effect of raising fertilization rate on the fresh and dry weights of underground parts is in agreement with the findings of Singh [44] on *Paspalum dilatum*, *Pennisetum glaucum* x *Pennisetum purpureum* and *Brachiaria mutica*. In this respect, Sullivan *et al.* [45] mentioned that the nitrate uptake rate by Kentucky bluegrass (*Poa pratensis*) plants was significantly and positively correlated with the total biomass, length and area of underground organs. When equivalent doses of nutrients were supplied by the two types of chemical

Table 5: Effect of soil amendments and chemical NPK fertilizers on fresh and dry weights of underground parts (g/m^2) of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

Chemical fertilizer treatments (CF)**	First season (2005/2006) Soil amendments (SA)* Control	KC	SS	A	Mean	Second season (2006/2007) Soil amendments (SA)* Control	KC	SS	A	Mean
Fresh weight of underground parts (g/m^2)										
Control	251.1	280.0	310.1	275.3	279.1	192.6	240.1	263.4	215.1	227.8
NPK_1	300.4	400.3	425.7	340.5	366.7	215.0	270.5	306.3	228.7	255.1
NPK_2	337.7	415.9	513.1	380.4	411.8	261.6	323.8	338.2	286.8	302.6
NPK_3	345.5	463.4	562.3	457.9	457.3	277.3	340.2	380.5	332.2	332.6
Ha_1	271.8	310.2	440.6	324.4	336.8	208.6	256.4	283.4	231.3	244.9
Ha_2	300.9	370.6	444.5	362.5	369.6	222.2	280.1	326.2	265.7	273.6
Ha_3	326.8	436.1	467.9	401.0	408.0	245.9	309.7	354.3	271.9	295.5
Means	304.9	382.4	452.0	363.1	----	231.9	288.7	321.8	261.7	----
LSD (0.05)										
SA	11.1					11.4				
CF	14.4					13.2				
SA X CF	16.6					14.9				
Dry weight of underground parts (g/m^2)										
Control	100.3	108.7	128.9	102.0	110.0	76.3	100.4	103.0	88.0	91.9
NPK_1	113.0	144.5	172.9	131.7	140.5	87.0	115.0	126.4	106.2	108.7
NPK_2	142.5	157.7	180.7	143.2	156.0	115.3	135.0	152.6	121.2	131.0
NPK_3	154.9	189.5	227.8	167.9	185.0	121.7	158.0	190.4	138.1	152.1
Ha_1	109.3	141.9	186.8	125.7	140.9	88.8	111.1	124.1	100.2	106.1
Ha_2	117.2	146.6	189.6	135.2	147.2	97.8	125.5	142.3	101.8	116.9
Ha_3	135.1	180.4	203.9	165.1	171.1	110.3	130.8	167.7	115.7	131.1
Means	124.6	152.8	184.4	138.7	----	99.6	125.1	143.8	110.2	----
LSD (0.05)										
SA	9.3					6.8				
CF	11.3					8.5				
SA X CF	12.5					11.1				

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

fertilizers, conventional NPK fertilization gave heavier fresh and dry weights of underground parts than those of Haigrow fertilizer. These obtained results are in agreement with the findings of Hussein and Mansour [2] on *Paspalum vaginatum*, who reported that conventional NPK fertilization gave the heaviest fresh and dry weights of underground parts, followed by Floranid Master and Floranid Turf (slow-release fertilizers). The present data showed that the highest application rate of conventional NPK fertilization (55.6 g/m^2/month) gave the heaviest fresh and dry weights of underground parts of *Zoysia japonica* turfgrass, as compared with other treatments during both seasons.

The interaction between the effects of soil amendments and chemical fertilization also proved to be beneficial for the fresh and dry weights of underground parts of *Zoysia japonica* turfgrass. In both seasons, plots amended with sewage sludge compost and receiving monthly application of the highest conventional NPK rate gave significantly higher fresh and dry weights of underground parts than any other combined treatment of soil amendments and fertilization treatments.

II-Chemical composition:

1-Contents of pigments [total chlorophylls (a+b) and carotenoids]: The data presented in Table 6 showed that soil amendments had a favourable effect on the synthesis and accumulation of pigments in *Zoysia japonica* turfgrass. In both seasons, all plots amended with various soil amendments during soil preparation gave higher contents of total chlorophylls (a+b) and carotenoids in clippings, compared to the control. Among the three types of soil amendments, sewage sludge compost gave the highest contents of total chlorophylls and carotenoids, followed by Kattameya compost, whereas Agrosil was the least effective soil amendment in this respect. The present results are in agreement with the findings of Hussein and Mansour [2] who reported that addition of sewage sludge compost or treated town refuse as organic fertilizers during sandy soil preparation increased total chlorophylls and carotenoids in *Paspalum vaginatum* turfgrass. Also, Hussein [7] on *Cryptostegia grandiflora*, Mansour [8] on *Senna sulfurea* and Hussein [9] on *Senna occidentalis*, reported that the total chlorophylls in leaves of plants grown in a sandy soil

Table 6: Effect of soil amendments and chemical NPK fertilizers on total chlorophylls (a+b), caroteoids and total carbohydrates contents in clippings of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

	First season (2005/2006) Soil amendments (SA)*					Second season (2006/2007) Soil amendments (SA)*				
Chemical fertilizer treatments (CF)**	Control	KC	SS	A	Mean	Control	KC	SS	A	Mean
Total chlorophylls (a+b) content (mg/g fresh matter)										
Control	1.04	1.14	1.25	1.11	1.14	1.16	1.48	1.56	1.32	1.38
NPK_1	1.09	1.28	1.32	1.19	1.22	1.22	1.69	1.81	1.63	1.59
NPK_2	1.28	1.56	2.01	1.22	1.52	1.45	1.89	1.94	1.79	1.77
NPK_3	1.43	2.16	2.88	1.81	2.07	1.69	2.25	3.23	1.91	2.27
Ha_1	1.07	1.23	1.30	1.20	1.20	1.18	1.53	1.69	1.49	1.47
Ha_2	1.25	1.40	1.89	1.26	1.45	1.29	1.80	1.83	1.58	1.63
Ha_3	1.32	1.96	2.33	1.63	1.81	1.43	2.10	2.31	1.76	1.90
Means	1.21	1.53	1.85	1.35	----	1.35	1.82	2.05	1.64	----
Carotenoids content (mg/g fresh matter)										
Control	0.25	0.31	0.36	0.29	0.30	0.26	0.40	0.51	0.38	0.39
NPK_1	0.30	0.37	0.40	0.32	0.35	0.34	0.51	0.53	0.46	0.46
NPK_2	0.36	0.51	0.57	0.41	0.46	0.43	0.54	0.58	0.48	0.51
NPK_3	0.39	0.57	0.60	0.43	0.50	0.49	0.59	0.66	0.55	0.57
Ha_1	0.28	0.38	0.43	0.34	0.36	0.37	0.49	0.57	0.48	0.48
Ha_2	0.32	0.42	0.44	0.36	0.39	0.48	0.53	0.60	0.47	0.52
Ha_3	0.37	0.50	0.55	0.40	0.46	0.50	0.56	0.58	0.54	0.55
Means	0.32	0.44	0.48	0.36	----	0.41	0.52	0.58	0.48	----
Total carbohydrates content (% of dry matter)										
Control	12.1	15.8	13.5	12.4	13.5	11.5	13.6	12.8	12.5	12.6
NPK_1	13.3	18.9	17.6	15.1	16.2	13.3	15.9	15.4	14.7	14.8
NPK_2	13.8	19.8	18.4	16.6	17.2	15.3	19.9	19.6	17.3	18.0
NPK_3	14.1	19.9	18.8	16.9	17.4	15.8	20.8	19.8	17.9	18.6
Ha_1	12.3	15.8	14.7	13.4	14.1	12.1	13.9	13.5	13.4	13.2
Ha_2	13.1	17.7	15.8	15.6	15.6	13.5	15.8	14.9	14.4	14.7
Ha_3	14.3	18.9	16.5	15.9	16.4	13.8	16.9	15.7	14.9	15.3
Means	13.3	18.1	16.5	15.1	----	13.6	16.7	16.0	15.0	----

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

amended with Agrosil were higher than those found in leaves of plants grown in sand only or sand amended with taffla, but were still lower than those of plants grown in sandy soil amended with cattle manure, clay or sewage sludge compost.

Chemical fertilization was also very beneficial in terms of increasing the pigments content in *Zoysia japonica* clippings. In both seasons, the lowest contents of total chlorophylls and carotenoids were those of the controls. Application of the different rates of conventional NPK or slow-release fertilizers resulted in considerable increases in the contents of pigments, compared to the control. Within each type of fertilizer, raising the application rate resulted in a steady increase in the contents of pigments. The increase in the total chlorophylls content as a result of raising the fertilization rate is in agreement with the results reported by Dudeck [46] on *Stenotaphrum secundatum*, Paswan and Machahary [37] on bahiagrass (*Paspalum notatum*) and Hussein and Mansour [2] on *Paspalum vaginatum*. In most cases, when the two chemical fertilizers were applied at rates providing equivalent supplies of nutrients, conventional NPK fertilization was more effective than Haigrow for increasing the contents of total chlorophylls and carotenoids. However, monthly application of the highest rate of conventional NPK gave the highest contents of total chlorophylls and carotenoids in both seasons.

The favourable effect of soil amendments and chemical fertilization on the synthesis and accumulation of chlorophyll may be attributed to the availability of nitrogen supplied by soil amendments and chemical fertilizers, which is essential in the structure of porphyrin, found in such metabolically important compounds as chlorophyll. Also, nitrogen is needed for the synthesis of the protein molecules to which chlorophyll is bound, or in which it is embedded [47, 48].

Regarding the interaction between soil amendments and chemical fertilization, the data in Table 6 showed that in both seasons, combining sewage sludge compost with the highest NPK rate resulted in a higher content of total chlorophylls and carotenoids, compared to that obtained from any other combined treatment of soil amendments and chemical fertilization treatments.

2-Total carbohydrates: The content of total carbohydrates in *Zoysia japonica* clippings was generally increased as a result of addition of the different types of soil amendments during soil preparation, compared to the control (Table 6). In both seasons, Kattameya compost was the most effective soil amendment for increasing the content of total carbohydrates, followed by sewage sludge compost, whereas Agrosil was the least effective soil amendment in this respect.

The data in Table 6 also showed that chemical fertilization was also beneficial for the synthesis and accumulation of carbohydrates in the tissues of *Zoysia japonica* clippings. In both seasons, the values recorded were higher in plants receiving any of the different chemical fertilization treatments, compared to the control. Within each type of chemical fertilizer, raising the application rate increased the carbohydrates content steadily. Conventional NPK fertilization treatments were generally more effective treatments than Haigrow treatments for increasing the carbohydrates content. In both seasons, the highest values were obtained from plants fertilized with the highest NPK rate (55.6 g/m^2/month) followed by the medium NPK rate (44.4 g/m^2/month). The steady increase in the content of total carbohydrates as a result of raising the rate of NPK or slow-release fertilizer is similar to that reported by Emarah [15] on *Cynodon dactylon*, *C. transvaalensis* and Tifway (*C. dactylon* x *C. transvaalensis*) and Hussein and Mansour [2] on *Paspalum vaginatum*.

The favourable effect of the different chemical fertilization treatments on the content of total carbohydrates may be indirectly attributed to the increase in the content of total chlorophylls as a result of the treatments. As the synthesis of total chlorophylls was promoted, the rate of photosynthesis increased, leading to an increase in carbohydrate synthesis. Also, potassium can act as an activator of several enzymes involved in carbohydrate metabolism [47, 48]. Moreover, this promotion in the synthesis of total chlorophylls and total carbohydrates as a result of chemical fertilization may explain the increase in vegetative growth that was detected in plants receiving the different chemical fertilization treatments.

As a result of the interaction between the soil amendments and chemical fertilization treatments, the highest total carbohydrates content (in both seasons) was obtained from plots amended with Kattameya compost during soil preparation, followed by monthly applications of the highest NPK rate.

3- Contents of nutrients in clippings

a – Contents of N, P and K : The results recorded in the two seasons (Table 7) showed that the uptake and accumulation of N, P and K in *Zoysia japonica* clippings were enhanced by using soil amendments, since control plants had lower N, P and K contents comparing with those of plants grown in plots received soil amendments. Among the three soil amendments, sewage sludge compost gave the highest contents of N, P and K, thus, it appeared to be the most effective in promoting the uptake of nutrients, in both seasons. On the other hand, Agrosil was the least effective soil amendment for promoting nutrient uptake and accumulation. However, Agrosil gave lower contents of N, P and K compared to those obtained with sewage sludge compost or Kattameya compost, in both seasons.

As shown in Table 7 the contents of the three main nutrients (N, P and K) exibited a similar trend of response to the different chemical fertilization treatments. In both seasons, the lowest contents of the three nutrients were recorded in the clippings of control plants. Raising the fertilization rate resulted in steady increases in the contents of the three nutrients, regardless of the type of chemical fertilizer applied. The increase in the contents of nutrients in the tissues of clippings as a result of increasing fertilization rates can be easily explained, since raising NPK levels in the root medium led to more vegetative and root growth. This may be accompanied by more absorption of essential elements from the soil and their accumulation in plant tissues [49]. Similar increases in the N, P and K contents as a result of raising the fertilization rates have been reported by Goatley *et al.* [50] on "Tifgreen" bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) and Razmjoo *et al.* [51] on creeping bentgrass (*Agrostis palustris*). In both seasons, the highest contents of N, P and K were obtained from the clippings of plants fertilized with the highest rates of NPK (55.6 g/m^2/month). The conventional NPK fertilizer appeared to be more effective than Haigrow (a slow-release fertilizer) for increasing the contents of the three nutrients. These results are in agreement with the findings of Hummel and Waddington [52], they reported that N content was greater in clippings of *Poa pratensis* plants fertilized with water soluble N sources. Also, Emarah [15] on *Cynodon dactylon*, *C. transvaalensis* and Tifway (*C. dactylon* x *C. transvaalensis*) and Hussein and

Table 7: Effect of soil amendments and chemical NPK fertilizers on the contents of nitrogen, phosphorus and potassium in clippings of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

Chemical fertilizer treatments (CF)**	First season (2005/2006) Soil amendments (SA)*					Second season (2006/2007) Soil amendments (SA)*				
	Control	KC	SS	A	Mean	Control	KC	SS	A	Mean
Nitrogen content (% of dry matter)										
Control	1.01	1.12	1.22	1.16	1.13	1.30	1.59	1.70	1.56	1.54
NPK_1	1.15	1.34	1.58	1.26	1.33	1.58	1.89	2.08	1.74	1.82
NPK_2	1.35	1.62	1.70	1.40	1.52	1.63	1.94	2.25	2.11	1.98
NPK_3	1.35	1.69	1.88	1.74	1.67	1.79	2.35	2.65	2.22	2.25
Ha_1	1.11	1.25	1.36	1.21	1.23	1.41	1.79	1.84	1.65	1.67
Ha_2	1.20	1.40	1.60	1.32	1.38	1.68	2.11	2.20	1.83	1.96
Ha_3	1.25	1.52	1.69	1.60	1.52	1.76	2.21	2.33	1.86	2.04
Means	1.20	1.42	1.58	1.38	----	1.59	1.98	2.15	1.85	----
Phosphorus content (% of dry matter)										
Control	0.12	0.14	0.26	0.17	0.17	0.06	0.15	0.18	0.14	0.13
NPK_1	0.15	0.25	0.26	0.22	0.22	0.13	0.19	0.21	0.15	0.17
NPK_2	0.16	0.29	0.33	0.25	0.26	0.15	0.25	0.28	0.22	0.23
NPK_3	0.22	0.32	0.35	0.28	0.29	0.19	0.27	0.28	0.23	0.24
Ha_1	0.15	0.22	0.26	0.19	0.21	0.09	0.18	0.21	0.16	0.16
Ha_2	0.14	0.25	0.30	0.21	0.23	0.15	0.22	0.26	0.18	0.20
Ha_3	0.18	0.30	0.32	0.21	0.25	0.19	0.23	0.27	0.20	0.22
Means	0.16	0.25	0.30	0.22	----	0.14	0.21	0.24	0.18	----
Potassium content (% of dry matter)										
Control	1.01	1.37	1.46	1.22	1.27	1.22	1.46	1.59	1.30	1.39
NPK_1	1.12	1.38	1.49	1.30	1.32	1.26	1.58	1.65	1.66	1.54
NPK_2	1.29	1.83	1.99	1.62	1.68	1.40	1.80	1.92	1.73	1.71
NPK_3	1.43	1.90	2.15	1.69	1.79	1.52	1.98	2.09	1.79	1.85
Ha_1	1.15	1.30	1.45	1.28	1.30	1.35	1.53	1.73	1.41	1.51
Ha_2	1.23	1.52	1.83	1.45	1.51	1.38	1.79	1.95	1.55	1.67
Ha_3	1.30	1.76	2.00	1.84	1.73	1.48	1.83	2.03	1.69	1.76
Means	1.22	1.58	1.77	1.49	----	1.37	1.71	1.85	1.59	----

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

Mansour [2] on *Paspalum vaginatum*, reported that N, P and K contents were greater in clippings of plants fertilized with water soluble NPK sources than in plants fertilized with slow release fertilizers.

Regarding the interaction between the effects of soil amendments and chemical fertilization on the contents of N, P and K, the data in Table 7 showed that in both seasons, combining the addition of sewage sludge compost during soil preparation, with monthly application of the highest NPK rate resulted in the highest N, P and K contents compared with other treatments.

b – Contents of Ca, Mg, Fe, Mn, Zn and Cu: The results presented in Tables 8 and 9 showed that, in both seasons, the uptake and accumulation of Ca, Mg, Fe, Mn, Zn and Cu were enhanced in most cases by using soil amendments as compared to the control plants, which were grown in sand only. In both seasons, Agrosil gave the highest Ca content in *Zoysia japonica* clippings, whereas Kattameya compost gave the highest Mg, Mn and Cu contents. The highest Fe and Zn contents were recorded in plants grown in plots amended with sewage sludge compost.

The data in Tables 8 and 9 also showed that, in both seasons, the lowest contents of Ca, Mg, Fe and Mn, were recorded in the clippings of unfertilized control plants. In most cases, raising the chemical fertilization rate resulted in steady increases in the contents of the six nutrients, regardless of the type of chemical fertilizer applied. In both seasons, the highest contents of Ca, Mg, Fe, Mn and Cu were obtained from the clippings of plants fertilized with the highest Haigrow rate. Haigrow appeared to be more effective than the conventional NPK fertilizer for increasing the contents of Ca, Mg, Fe, Mn and Cu in clippings. In contrast, the conventional NPK fertilizer appeared to be more effective than Haigrow for increasing the contents of Zn. However, the highest contents of Zn were obtained in the clippings of plants fertilized with the highest rate of the conventional NPK fertilizer.

Table 8: Effect of soil amendments and chemical NPK fertilizers on the contents of calcium, magnesium and iron in clippings of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

Chemical fertilizer treatments (CF)**	First season (2005/2006) Soil amendments (SA)*					Second season (2006/2007) Soil amendments (SA)*				
	Control	KC	SS	A	Mean	Control	KC	SS	A	Mean
Calcium content (mg/g dry matter)										
Control	0.56	0.82	0.60	1.05	0.76	0.57	0.81	0.59	1.07	0.76
NPK_1	0.57	0.82	0.61	1.06	0.77	0.58	0.83	0.60	1.09	0.78
NPK_2	0.58	0.83	0.61	1.08	0.78	0.59	0.84	0.60	1.10	0.78
NPK_3	0.60	0.86	0.62	1.10	0.80	0.60	0.87	0.61	1.12	0.80
Ha_1	0.57	0.86	0.64	1.10	0.79	0.58	0.85	0.65	1.11	0.80
Ha_2	0.60	0.88	0.65	1.11	0.81	0.61	0.89	0.65	1.12	0.82
Ha_3	0.62	0.90	0.66	1.12	0.83	0.61	0.92	0.66	1.13	0.83
Means	0.59	0.85	0.63	1.09	----	0.59	0.86	0.62	1.11	----
Magnesium content (mg/g dry matter)										
Control	0.51	0.80	0.60	0.62	0.63	0.50	0.82	0.59	0.63	0.64
NPK_1	0.52	0.83	0.61	0.64	0.65	0.51	0.94	0.64	0.67	0.69
NPK_2	0.53	0.84	0.63	0.65	0.66	0.51	0.95	0.64	0.69	0.70
`NPK_3	0.53	0.86	0.64	0.66	0.67	0.53	0.97	0.64	0.69	0.71
Ha_1	0.54	0.84	0.66	0.69	0.68	0.55	0.83	0.65	0.73	0.69
Ha_2	0.56	0.85	0.68	0.70	0.70	0.56	0.83	0.65	0.74	0.70
Ha_3	0.57	0.85	0.68	0.72	0.71	0.56	0.84	0.66	0.76	0.71
Means	0.54	0.84	0.64	0.67	----	0.53	0.88	0.64	0.70	----
Iron content (µg/g dry matter)										
Control	120.4	149.9	230.3	152.1	163.2	125.6	160.5	245.3	140.3	167.9
NPK_1	128.3	153.2	246.7	157.3	171.4	137.2	164.1	259.1	151.2	177.9
NPK_2	137.6	156.1	251.3	162.2	176.8	149.3	166.2	260.3	151.9	181.9
NPK_3	149.1	159.2	260.0	165.7	183.5	161.5	169.3	275.2	152.3	189.6
Ha_1	153.5	168.3	253.4	164.2	184.9	150.3	179.1	263.7	163.2	189.1
Ha_2	155.2	170.5	258.1	167.0	187.7	152.7	183.2	269.2	169.1	193.6
Ha_3	169.4	175.0	261.3	170.7	194.1	153.8	187.5	273.1	175.2	197.4
Means	144.8	161.7	251.6	162.7	----	147.2	172.8	263.7	157.6	----

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

Regarding the interaction between the effects of soil amendments and fertilization treatments, the data in Tables 8 and 9 showed that in both seasons, plants grown in plots amended with Agrosil or Kattameya compost and supplied with the highest Haigrow rate gave the highest Ca and Cu contents (with using Agrosil and Kattameya compost, respectively). Plants grown in plots amended with Kattameya or sewage sludge composts and receiving the highest conventional NPK rate gave the highest Mg and Zn contents (with using Kattameya and sewage sludge composts, respectively). The highest Fe content was recorded in plants grown in plots amended with sewage sludge compost and fertilized using the highest Haigrow rate (in the first season) or using the highest conventional NPK rate (in the second season). The highest Mn content was recorded in plants grown in plots amended with Kattameya compost (in the first season) or sewage sludge compost (in the second season) and supplied with the highest rate of conventional NPK fertilization.

III. Results of the Diagnosis and Recommended Integrated System (DRIS): Regarding the effect of soil amendments and chemical fertilization treatments on nutrient indices, data presented in Table 10 showed that the values of N, P and K indices were negative; this means that the fertilization treatments were lower than the optimum rates. On the other hand, the values of Ca and Mg indices were positive; this means that the concentrations of theses two elements in *Zoysia japonica* plants were higher than the optimum concentrations contributing to a balance of nutrients. The values of Fe, Mn, Zn and Cu indices were zero, this means that the concentrations of these four elements in the plants were sufficient and the plants don't need any fertilizer applications of these trace elements.

Data presented in Table 10 showed that the lowest shortages in N, P and K were mostly recorded in plants grown in sandy soil amended with sewage sludge compost (since the highest indices were recorded in these plants), as compared to those of plants grown in sand

Table 9: Effect of soil amendments and chemical NPK fertilizers on the contents of manganese, zinc and copper in clippings of *Zoysia japonica* turfgrass during the two seasons of 2005/2006 and 2006/2007

Chemical fertilizer treatments (CF)**	First season (2005/2006) Soil amendments (SA)*					Second season (2006/2007) Soil amendments (SA)*				
	Control	KC	SS	A	Mean	Control	KC	SS	A	Mean
Manganese content (µg/g dry matter)										
Control	31.3	77.7	71.0	57.1	59.3	35.9	84.1	75.6	55.2	62.7
NPK_1	33.2	80.1	76.2	58.0	61.9	36.7	87.2	87.3	57.1	67.1
NPK_2	34.6	82.6	78.1	58.9	63.6	37.2	87.9	81.2	58.3	66.2
NPK_3	35.0	83.7	80.2	60.2	64.8	38.1	88.2	94.5	58.9	69.9
Ha_1	39.1	80.5	80.4	62.0	65.5	41.2	83.2	79.1	66.3	67.5
Ha_2	40.2	81.5	81.4	64.1	66.8	43.4	83.4	80.8	69.2	69.2
Ha_3	40.9	82.3	82.6	65.3	67.8	47.1	88.7	82.4	71.7	72.5
Means	36.3	81.2	78.6	60.8	----	39.9	86.1	83.0	62.4	----
Zinc content (µg/g dry matter)										
Control	19.9	20.2	35.0	21.2	24.1	22.4	26.1	32.6	28.4	27.4
NPK_1	24.0	25.3	37.1	27.6	28.5	34.6	27.3	40.1	28.6	32.7
NPK_2	26.3	26.4	37.1	28.3	29.5	36.7	28.4	41.9	28.9	34.0
NPK_3	29.3	27.7	39.2	29.8	31.5	39.1	28.9	42.3	29.1	34.9
Ha_1	22.4	25.3	36.8	26.0	27.6	25.3	26.9	36.3	27.9	29.1
Ha_2	27.3	26.5	37.2	27.3	29.6	27.1	27.0	37.5	28.4	30.0
Ha_3	28.2	27.4	38.4	30.4	31.1	28.4	27.1	37.9	28.5	30.5
Means	25.3	25.5	37.3	27.2	----	30.5	27.4	38.4	28.5	----
Copper content (µg/g dry matter)										
Control	4.4	4.8	2.9	3.8	4.0	4.5	4.7	3.1	3.7	4.0
NPK_1	4.8	4.8	3.0	3.8	4.1	5.1	4.8	3.3	3.8	4.3
NPK_2	4.9	4.9	3.1	3.9	4.2	5.3	4.8	3.6	3.8	4.4
NPK_3	5.0	5.0	3.1	4.0	4.3	5.5	5.0	3.9	3.9	4.6
Ha_1	4.6	5.0	3.3	3.5	4.1	4.6	5.1	4.2	3.7	4.4
Ha_2	4.7	5.1	3.5	3.6	4.2	4.6	5.3	4.2	3.7	4.5
Ha_3	4.7	5.3	3.8	3.7	4.4	4.8	5.5	4.5	3.8	4.7
Means	4.7	5.0	3.2	3.8	----	4.9	5.0	3.8	3.8	----

*KC = Kattameya compost, SS = Sewage sludge compost, A = Agrosil

only or sand amended with the other soil amendments, regardless of the effect of fertilization treatments. On the other hand, the lowest excessiveness in concentrations of Ca and Mg was recorded in plants grown in sandy soil amended with sewage sludge compost, since these plants had the lowest positive indices.

Data presented in Table 10 revealed, in general, the indices of N, P and K were increased with fertilization treatments, whereas the indices of Ca and Mg were decreased, regardless of type of the fertilizer, as compared to the control. In most cases, within each type of chemical fertilizer, raising the application rate increased N, P and K indices, whereas Ca and Mg indices were decreased. The highest N, P and K indices as well as the lowest Ca and Mg indices were mostly obtained from plants fertilized with the highest rate of conventional NPK fertilizer. This means that the highest conventional NPK rate resulted in the lowest shortage of N, P and K content as well as the lowest excessiveness in concentrations of Ca and Mg in plants received this fertilization rate.

Data presented in Table 10 showed that the highest indices of N, P and K (-50, -48 and -21, respectively), indicating the lowest shortage of these nutrients, were recorded in plants grown in sandy soil amended with sewage sludge compost and supplied with NPK_3, followed by those of plants grown in sandy soil amended with the same soil amendment and fertilized with Ha_3 (with indices of -71, -52 and -24, for N, P and K, respectively). This confirms the data presented in Table 7 which revealed that the highest N, P and K percentages were recorded in *Zoysia japonica* plants grown in sandy soil amended with sewage sludge compost and fertilized with NPK_3.

Also, the lowest positive indices of Ca and Mg (32 and 169, respectively), indicating the concentrations closest to the optimum, were recorded in plants grown in sandy soil amended with sewage sludge compost and fertilized with NPK_3, followed by that received NPK_2 (44 and 175, respectively).

As to the results of the Diagnosis and Recommended Integrated System (DRIS), it is suggested that further

Table 10: Effect of soil amendments and chemical NPK fertilizers on the N, P, K, Ca, Mg, Fe, Mn, Zn and Cu indices in clippings of *Zoysia japonica* turfgrass during the two second season (2006/2007)

Chemical fertilizer treatments (CF)**	Soil amendments (SA)*				Soil amendments (SA)*			
	Control	KC	SS	A	Control	KC	SS	A
	N -Index				P -Index			
Control	-109	-156	-162	-154	-427	-207	-146	-219
NPK_1	-96	-137	-76	-140	-159	-167	-90	-213
NPK_2	-93	-140	-72	-111	-129	-135	-60	-125
NPK_3	-85	-108	-50	-108	-90	-102	-48	-74
Ha_1	-113	-137	-101	-160	-277	-165	-93	-203
Ha_2	-95	-113	-77	-142	-141	-126	-62	-176
Ha_3	-92	-108	-71	-144	-94	-131	-52	-155
	K -Index				Ca -Index			
Control	-50	-67	-57	-73	+188	+147	+62	+253
NPK_1	-44	-62	-35	-58	+100	+48	+53	+229
NPK_2	-36	-51	-26	-52	+89	+98	+44	+178
NPK_3	-34	-46	-21	-52	+72	+89	+32	+159
Ha_1	-42	-59	-31	-72	+132	+137	+71	+238
Ha_2	-42	-57	-25	-64	+92	+119	+52	+215
Ha_3	-38	-48	-24	-56	+75	+116	+49	+202
	Mg -Index				Fe, Mn, Zn and Cu -Index			
Control	+342	+348	+248	+250	0	0	0	0
NPK_1	+216	+352	+209	+252	0	0	0	0
NPK_2	+196	+316	+175	+208	0	0	0	0
NPK_3	+178	+294	+169	+183	0	0	0	0
Ha_1	+293	+314	+218	+284	0	0	0	0
Ha_2	+220	+270	+187	+263	0	0	0	0
Ha_3	+194	+257	+184	+256	0	0	0	0

* KC = Kattameya compost SS = Sewage sludge compost A = Agrosil,
** NPK_1, NPK_2 and NPK_3 = NPK at 33.3, 44.4 and 55.6 g/m^2/month, respectively,
Ha_1, Ha_2 and Ha_3 = Haigrow at 50, 66.7 and 83.3 g/m^2/3 months, respectively

studies should be conducted to investigate the response of *Zoysia japonica* plants to higher rates of both chemical fertilizers (conventional NPK and Haigrow) than those used in the present study.

RECOMMENDATION

From the obtained results, it can be recommended that for the best vegetative growth of *Zoysia japonica* turfgrass grown in sandy soil, the soil should be amended with sewage sludge compost (at the rate of 0.01 m^3/m^2 of soil surface during soil preparation) and the plants should be supplied with 55.6 g/m^2/month of a conventional chemical NPK fertilizer, containing 9% N, 5% P_2O_5 and 5% K_2O.

REFERENCES

1. Turgeon, A.J., 2002. Turfgrass Management. Prentice Hall International, Ltd., New Jersey, USA, 6th Ed., pp: 84-86.
2. Hussein, M.M.M. and H.A. Mansour, 2001. Organic and chemical fertilization of seashore paspalum turfgrass in sandy soil. Al-Azhar J. Agric. Res., 34: 211- 234.
3. Hussein, M.M.M. and H.A. Mansour, 2003. Nitrogenous nutrition of kikuyu turfgrass using chemical and biofertilizers. J. Agric. Sci. Mansoura Univ., 28: 4943-4957.
4. Hussein, M.M.M. and Azza M.S. Arafa, 2007. Nitrogenous nutrition of paspalum turfgrass grown in sandy soil using chemical and biofertilizers. Annals of Agric. Sci., Moshtohor, 45: 337-351.
5. Smith, S.R., 1992. Sewage sludge and refuse composts as peat alternatives for conditioning impoverished soils: effects on the growth responses and mineral status of *Petunia grandiflora*. J. Hort. Sci., 67: 703-716.
6. Kolb, W., 1989. Help in establishment of shrubs. Deutscher Gartenbau, 43: 1282-1284.
7. Hussein, M.M.M., 2002. Growth of *Cryptostegia grandiflora* R. Br. in sandy soil as affected by fertilization and soil amendments. Proc. of the 2nd Cong. of Recent Tech. in Agric., Fac. Agric., Cairo Univ., 28-30 October, 2002. Bull. Fac. Agric., Cairo Univ., Special edition (2): 362- 378.
8. Mansour, H.A., 2002. Influence of soil amendments and NPK fertilization on the growth and chemical composition of *Senna sulfurea* plants grown in a sandy soil. Annals of Agric. Sci., Moshtohor, 40: 1779-1796.
9. Hussein, M.M.M., 2003. Growth of *Senna occidentalis* (L.) Link in sandy soil as affected by fertilization and soil amendments. Bull. Fac. Agric., Cairo Univ., 54: 189-216.
10. Prun, H., 1981. Lawn fertilization with slow-release fertilizers. Rasen Grunflachen Begrunungen, 12: 96-104. (Hort. Abst., 52: 5597).
11. Volterrani, M., M. Gaetani, N. Grossi, G. Pardini, S. Miele and S. Magni, 1999. The use of organic fertilizers on turf. Dynamics of nitrogen uptake and losses. Rivista di Agronomia, 33: 34-39.
12. Vallejo, A., M.C. Cartagena, D. Rodriguez and J.A. Diez, 1993. Nitrogen availability of soluble and slow -release nitrogen fertilizers as assessed by electroultrafiltration. Fertilizer Research, 34: 121-126.

13. Diez, J.A., R. Roman, M.C. Cartagena, A. Vallejo, A. Bustos and R. Caballero, 1994. Controlling nitrate pollution of aquifers by using different nitrogenous controlled release fertilizers in maize crop. Agriculture, Ecosystems & Environment, 48: 49-56.
14. Diez, J.A., R. Roman, M.C. Cartagena, A. Vallejo, A. Bustos and R. Caballero, 1996. Control of nitrate pollution by application of controlled release fertilizer (CRF), compost and an optimized irrigation system. Fertilizer Research, 43: 191-195.
15. Emarah, M.M.H., 1998. Effect of chemical fertilization and mowing height on growth of some turfgrasses. Ph. D. Thesis, Fac. Agric., Cairo Univ., Egypt.
16. Walworth, J.L., M.E. Sumner, R.A. Isaac and C.O. Plank, 1986. Preliminary DRIS norms for alfalfa in the southeastern united states and a comparison with the Midwest norms. Agron. J., 78: 1046-1052.
17. Baldock, J.O. and E.E. Schulte, 1996. Plant analysis with standardized scores combines DRIS and sufficiency range approaches for corn. Agron. J., 88: 448-456.
18. Junior, R.A.R. and P.H. Monnerat, 2003. DRIS norms validation for sugarcane crop. Pesq. Agrope. Bras., 38: 379-385.
19. Beaufils, E.R., 1973. Diagnosis and Recommendation Integrated System (DRIS). Univ. Natal Soil Sci. Bull, 12: 130-136.
20. Snyder, G.H., C.A. Sanchez and J.S. Alrichs, 1989. DRIS evaluation of the nutrient status of Bahia and St. Augustine turfgrasses. Proc. Fla. Sate Hort. Soc., Gainesville, 102: 133-137.
21. Payne, G.G., J.E. Rechcigl and R.L. Stephenson, 1990. Development of dignosis and recommendation integrated system norms for bahiagrass. Agron. J., 82: 930-934.
22. Hockman, J.N., J.A. Burger and D.W.M. Smith, 1989. A DRIS application to fraser fir Christmas tree. Communication in Soil Sci. and Plant Analysis, 20: 305-318.
23. Caldwell, J.O.N., M.E. Sumner and C.S. Vavrina, 1994. Development and testing of preliminary foliar DRIS norms for onions. HortSci., 29: 1501-1504.
24. Filho, F.A.M. and J.C. Azevedo, 2003. DRIS norms for 'Valencia' sweet orange on three rootstocks. Pesq. Agropec. Bras, 38: 85-93.
25. USDA, 2004. Soil Survey Laboratory Methods Manual. Rebecca Burt, Editor. Soil Survey Investigations Report. No. 42, Version 4, November 2004.
26. Page, A.L., 1982. Methods of Soil Analysis. Agronomy Inc., Soil Sci. Soc., Publisher, Madison, Wisconsin, USA, pp: 229, 351-352, 421-422 & 649.
27. Watanabe, F.S. and S.R. Olsen, 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. Soil Sci. Soc. Amer. Proc., 29: 677-678.
28. Nornai, R., 1982. Formula for determination of total chlorophylls pigments extracted with N.N. dimethyl formamide. Plant Physiol., 69: 1371-1381.
29. Dubois, M., F. Smith, K. A. Gilles, J. K. Hamilton and P.A. Rebers, 1956. Colorimetric method for determination of sugars and related substances. Annal Chem., 28: 350-356.
30. Piper, C.S., 1947. Soil and Plant Analysis. Univ. of Adelaide, Adelaide, Australia, pp: 258-275.
31. Pregl, P., 1945. Quantitative Organic Microanalysis. Churchill Publishing Co., London, 4th Ed., pp: 78-82.
32. Jackson, M.L., 1967. Soil Chemical Analysis. Prentice Hall, India, pp: 144-197.
33. Chapman, H.D. and P.F. Pratt, 1961. Methods of Soil, Plants and Water Analysis. Univ. of California, Division of Agricultural Sciences, pp: 60-69.
34. Little, T.M. and F.J. Hills, 1978. Agricultural Experimentation – Design and Analysis. John Wiley & Sons, Inc., New York, USA, pp: 61-63.
35. Walworth, J.L. and M.E. Sumner, 1987. The diagnosis and recommendation integrated system (DRIS). Adv. Soil Sci., 6: 149-188.
36. Hossni, Y.A., 1993. Effect of soil media, chemical fertilization and salinity on growth and chemical composition of bermudagrass (*Cynodon dactylon*, L.). Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.
37. Paswan, L. and R.K. Machahary, 2000. Effect of nitrogen on bahiagrass. J. Orn. Hort., 3: 87-90.
38. Beard, J.B., A. Almodares and R.L. Duble, 1978. Nitrogen fertilization studies on St. Augustine grass plus the relationship to thatch and its control. Tex. Turf. Res., 29-33. (Hort. Abst., 49: 2759).
39. Yeam, D.Y., Y.K. Joo and K.Y. Huh, 1987. Effect of fertilizer application on seed production in zoysiagrass (*Zoysia japonica* Steud). J. Kor. Soc. Hort. Sci., 28: 165-172. (Hort. Abst., 58: 6044).
40. Oral, N. and E. Acikgoz, 2001. Effects of nitrogen application timing on growth and quality of a turfgrass mixture. J. Plant Nutrition, 24: 101-109.
41. Kalmbacher, R.S. and F.G. Martin, 1999. Effect of N rate and time of application on atra paspalum. Tropical Grasslands, 33: 214-221.

42. Dressel, J., W. Weigelt and R. Hahndel, 1998. N-effect and leaching of various nitrogen fertilizers applied to lawn grass in a lysimeter experiment. Rasen Turf Gazon, 29: 4-7.
43. Hare, M.D., W. Suriyajantratong, P. Tatsapong, C. Kaewkunya, K. Wongpichet and K.Thummasaeng, 1999. Effect of nitrogen on production of *Paspalum atratum* on seasonally wet soils in north-east Thailand. Tropical Grasslands, 33: 207-213.
44. Singh, K.A., 1999. Effect of nitrogen levels on yield, root biomass distribution, nitrogen recovery by forage grasses and changes in soil properties of acid soil. Indian J. Agric. Sci., 69: 551-554.
45. Sullivan, W.M., J. ZhongChun and R.J. Hull, 2000. Root morphology and its relationship with nitrate uptake in Kentucky bluegrass. Crop Science, 40: 765-772.
46. Dudeck, A.E., 1991. Influence of planting method, fertility program, cultivar and soil type on St. Augustine grass. Proc. Fl. State Hort. Soc., 103: 355-360. (Hort. Abst., 64: 5570).
47. Devlin, R. M., 1975. Plant Physiology. Affiliated East-West Press Pvt. Ltd., New Delhi, India, 3rd Ed., pp: 217-234, 268-277 & 358-361.
48. Taiz, L. and E. Zeiger, 1998. Plant Physiology. Sinauer Associates, Inc., Publishers, Sunderland, Massachusetts, USA, 3rd Ed., pp: 67-76 and 114-115.
49. Jain, V.K., 1983. Fundamentals of Plant Physiology. S. Chand and Company, Ltd., Ram Nagar, New Delhi, 3rd Ed. pp: 72-87.
50. Goatley, J.M., V. Maddox, D.J. Lang and K.K. Crouse, 1994. "Tifgreen" bermudagrass response to late-season application of nitrogen and potassium. Agron. J., 86: 7-10.
51. Razmjoo, K., T. Imada, J. Suguira and S. Kaneko, 1996. Effect of nitrogen rates and mowing heights on color, density, uniformity and chemical composition of creeping bentgrass cultivars in winter. J. Plant Nutr., 19: 1499-1509. (Hort. Abst. 67: 7180).
52. Hummel, N.W. and D.V. Waddington, 1981. Evaluation of slow-release nitrogen sources on baron kentucky bluegrass. J. Amer. Soil Sci. Soc., 45: 966-970. (Hort. Abst., 52: 4070).